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Flightdeck Automation Problems: Perceptions and Reality

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INTRODUCTION

With the advent of advanced technology and the transfer of safety-critical functions away from human control, pilots, scientists, and aviation safety experts have expressed concerns about the safety of flightdeck automation. For example, Wiener [1] surveyed a group of pilots of advanced technology commercial transport aircraft and found significant concerns. Wise and his colleagues [2] found similar concerns among pilots of advanced technology corporate aircraft. Based on incident and accident data, Billings [3,4] cited problems with flightdeck automation and proposed a more human-centered approach to design and use, and Sarter and Woods [5,6] have sought to further investigate and verify concerns expressed by pilots and others in a series of simulator experiments exploring pilot interaction with automation.

Although much work is being done, to date there does not exist a comprehensive list of verified flightdeck automation human factors problems from which to coordinate projects and make the best use of limited research resources. The objectives of our research are to develop a comprehensive list of perceived flightdeck automation human factors problems and concerns in Phase 1, and to verify the perceived problems and concerns and prioritize them in Phase 2.

PHASE 1 METHODOLOGY

To obtain a comprehensive list of perceived problems and concerns, we used a very broad approach. We identified and collected 418 documents that we believed might contain citations of flightdeck automation problems and concerns. These documents included journal and proceedings papers, technical reports, articles from newspapers and aviation periodicals, training manuals, and personal communications. We found 1,635 citations in 150 of the documents analyzed.

From this literature and other sources, we identified aircraft accidents in which automation was a possible contributing factor. We obtained and reviewed 13 accident reports. We found 53 citations in the reports (each report had at least one citation) and recorded and classified them, as described above.

We obtained 591 Aviation Safety Reporting System (ASRS) reports about incidents involving advanced technology aircraft. In each report we examined the narrative section (in which the reporter describes the incident in his/her own words) for clear citations of, or very strong inferences about, automation factors that contributed to the incident. We found 368 citations in 246 reports.

We also surveyed automation experts. Participation invitations were sent to aviation and automation related news groups on the Internet, to selected individuals with demonstrated expertise in automation and flight safety, and to pilots. Along with basic demographic and flight experience questions, the questionnaire probed the respondent for flightdeck automation problems he/she knew about or concerns he/she had about flightdeck automation. We distributed 1,096 questionnaires and received back 128 from which we found 371 citations.

All this information has been captured in a relational database which will be made available at the end of the project. The database includes the specific problems and concerns raised, excerpts from the source for each citation, bibliographic information for each citation, and identification of any particular equipment cited.

PHASE 1 RESULTS

In total we identified 114 problems and concerns (P/Cs) from 2,427 citations from all sources. We organized the problems and concerns into one possible taxonomy, a summary of which is shown in Table 1. The taxonomy consists of three major categories of P/Cs: those having to do with the justification or reason for existence of automation, those having to do with the design of automation itself, and those having to do with the use of automation. Each category is divided into subcategories. The reader should bear in mind that the groups of P/Cs comprising the taxonomy and presented in Table 1 are expressions of concerns raised in the reviewed sources and are merely hypotheses until they are verified in Phase 2.

In Table 1, for each category we present the number of citations falling into that category and the percent of total citations that number represents. Because the taxonomy is hierarchical, higher level categories include citations from categories subordinate to them. Therefore, the numbers do not sum to the total number of citations and the percents do not sum to 100.

Note that these statistics must be interpreted with some caution. While our sources reflect a broad cross section of the aviation and human factors/psychology communities, we cannot claim with confidence that they are a representative sample. Therefore, these statistics should not be taken as an indication of the validity or importance of problems or concerns. It may be that a perceived problem with few or only a single citation may in fact be more dangerous than a perceived problem with many citations simply because it has not been well recognized.

PHASE 1 DISCUSSION

The Phase 1 results indicate a very broad set of problems and concerns about flightdeck automation, ranging from equipment reliability to how airlines require their pilots to use automation. They also reveal the depth of these concerns, ranging from pilots' views that equipment failures imperil their safety to the concerns of human factors scientists that manufacturer's flightdeck automation design philosophies do not adequately consider the pilot.

Although we included a wide variety of sources to compile the list of problems and concerns, the sample can in no sense be considered random. Therefore, as noted above, any statistics derived from the database relating to the relative proportion of citations of a particular P/C must be used with caution.

Table 1. Summary taxonomy of perceived flightdeck automation problems and concerns.

2,427 citations

Taxonomic categories	Number	Percent
J0: The justification of automation may be economy, not safety.	3	0.1%
J1: Automation may exist primarily due to commercial incentives.	3	0.1%
D0: Automation may be poorly designed.	1084	44.6%
D1: Automation function and logic may be poorly designed.	471	19.4%
D1.1: Automation may lack the functionality or performance desired by pilots.	91	3.7%
D1.2: Automation may fail to perform according to pilot expectations.	131	5.4%
D1.3: Automation may not control the aircraft the way pilots do.	3	0.1%
D1.4: Automation may be too complex.	73	3.0%
D1.5: Automation design may not be human-centered.	25	1.0%
D1.6: Automation may usurp pilot authority.	74	3.0%
D1.7: Automation protections which pilots rely upon can be lost.	1	<0.1%
D1.8: Automation may not be standardized.	51	2.1%
D1.9: Automation may be poorly integrated.	14	0.6%
D1.10: Automation documentation may be inadequate.	8	0.3%
D2: Pilot/automation interfaces may be poorly designed.	564	23.2%
D2.1: Automation controls may be poorly designed.	154	6.3%
D2.2: Automation displays may be poorly designed.	309	12.7%
D2.2.1: Automation may obscure its own mode (state) and behavior from pilots.	156	6.4%
D2.2.2: Automation may obscure situation information from pilots.	22	0.9%
D2.2.3: Automation may provide too much information.	31	1.3%
D3: Automation may not be compatible with the ATC system.	49	2.0%
D4: Cultural differences may not be considered in the design of automation.	1	<0.1%
U0: The use of automation may lead to problems.	1341	55.2%

Table 1 (continued). Summary taxonomy of perceived flightdeck automation problems and concerns.

2,427 citations

Taxonomic categories	Number	Percent
U1: The fact that automation is used may lead to problems.	568	23.4%
U1.1: The fact that automation is used may lead to problems for pilots.	547	22.5%
U1.1.1: Pilots may not perform as well when using automation.	1	<0.1%
U1.1.2: Pilots may have difficulty assuming control from automation.	12	0.5%
U1.1.3: Pilots may have difficulty recovering from automation failures.	16	0.7%
U1.1.4: Pilot roles may be different in automated aircraft.	74	3.0%
U1.1.5: Pilots may be out of the control loop when they use automation.	51	2.1%
U1.1.6: Pilots may place too much confidence in automation.	160	6.6%
U1.1.7: Pilots may abdicate responsibility to automation.	2	<0.1%
U1.1.8: Pilots may use automation when they should not.	61	2.5%
U1.1.9: Pilots may not place enough confidence in automation.	67	2.8%
U1.1.10: Pilots may not use automation when they should.	8	0.3%
U1.1.11: Pilots of automated aircraft may not acquire or maintain manual skills.	91	3.7%
U1.1.12: Pilots may lose automation skills if they do not regularly use automation.	2	<0.1%
U1.1.13: Pilots may experience more fatigue in automated aircraft.	2	<0.1%
U1.2: The fact that automation is used may lead to problems for airlines.	21	0.9%
U1.2.1: Airlines may not adequately involve pilots in equipment selection.	2	<0.1%
U1.2.2: Airline automation policies and procedures may be inadequate.	8	0.3%
U1.2.3: Airlines may assign two low-automation-time pilots to a crew.	11	0.5%
U2: The use of automation function and logic may lead to problems.	568	23.4%
U2.1: The use of automation function and logic may lead to problems for pilots.	419	17.3%
U2.1.1: Pilot workload may be increased by automation.	37	1.5%
U2.1.2: Pilot workload may not be optimized by automation.	46	1.9%
U2.1.3: Pilots may focus too much attention on automation.	198	8.2%
U2.1.4: Pilots may have difficulty with automation complexity.	122	5.0%
U2.1.4.1: Pilots may not understand automation adequately.	101	4.2%
U2.1.4.2: Pilots may have difficulty deciding how much automation to use.	4	0.2%
U2.1.4.3: Pilots may make mode selection errors.	17	0.7%
U2.1.5: Pilots may have difficulty transitioning between automated and conventional aircraft.	16	0.7%
U2.2: The use of automation function and logic may lead to problems for airlines.	149	6.1%
U2.2.1: Airlines may not provide adequate non-automated operations training.	13	0.5%
U2.2.2: Airlines may not provide adequate automation training.	107	4.4%
U2.2.3: Airlines may not keep automation databases up to date.	29	1.2%
U3: The use of pilot/automation interfaces may lead to problems.	205	8.4%
U3.1: Pilot situation awareness may be reduced by automation.	53	2.2%
U3.2: Pilots may have difficulty assessing automation failures.	60	2.5%
U3.3: Crew coordination may be more difficult in automated aircraft.	92	3.8%

PHASE 2 METHODOLOGY

Our objective for Phase 2 is to verify and prioritize the problems and concerns from Phase 1. The initial step in verification of the P/Cs was to survey 34 flightdeck automation experts (e.g. researchers at universities, manufacturers, avionics vendors, and NASA; airline pilots and training directors). The survey asked respondents to evaluate each of the P/Cs from Phase 1 indicating the degree to which they agreed that it is a problem, how critical to flight safety they believe it to be, and the type of information upon which they based their ratings. They were also given the option to mark "cannot address" on each P/C. Thirty surveys were returned and are currently being analyzed. Our initial survey results are presented here. In addition to the survey, we are evaluating the causal factors identified in accident reports, and data presented in available research reports, for evidence to verify the problems and concerns.

PHASE 2 RESULTS

The survey responses were analyzed individually for each P/C. The frequency distribution of the agreement ratings for each P/C was initially analyzed to determine whether at least 28 of the 30 respondents agreed that it did/did not represent a problem. After this review, 29 P/Cs were verified as problems (none were verified as not being problems). Next the frequency distributions of the agreement ratings were coded to indicate those responses which were based on the respondent's own data or their view of other data. Verification of each of the P/Cs proceeded taking the indicated data into account. If the general response distribution was skewed (either toward agreement or disagreement) and the data were supporting only the position of the skew, then the P/C was considered verified. Fifty of the P/Cs were verified as problems based on this review.

PHASE 2 DISCUSSION

The remaining 35 P/Cs are still in the process of verification. This process will consider all information provided by the survey respondents along with a review of the data suggested to be related to the P/C into consideration. Follow up communications with the survey respondents and other experts will also be used as necessary to understand the status of the knowledge about a particular P/C. Additionally, if no data are available to address a particular P/C, we will design and conduct experiments (including simulator experiments) to collect data for verification.

The criticality ratings provided by the survey respondents will then be used to make an initial prioritization of the final set of verified problems. This prioritization will be presented back to the survey respondents and other experts, including FAA flight standards and human factors personnel, for their feedback. A final prioritization of the verified P/Cs will be developed based on this feedback.

The survey results and verification process information are being coded in the relational database. For each problem this will include pointers to those studies and reports that include data or other information upon which it was verified. The products available at the end of this project will include a final report and the relational database.

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