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An Exploratory Study of Automation Errors in Part 91 Operations

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Introduction

As automation has become more accessible in a wider variety of aircraft, system operations have generally been enhanced (Gil, Kaber, Kaufmann, & Kim, 2012). However, automation-complacency related incidents, and more rarely accidents, do occur. For example, in September of 2017, a crew flying a Challenger CL600 reported that there was an altitude deviation upon disconnecting the autopilot. A summary provided by the crew indicated excessive automation dependency was a contributing factor in the incident (Aviation Safety Reporting System [ASRS], 2019). Relying too much on automation could deteriorate pilot skills and increase the risk of an aircraft accident (Parasuraman & Riley, 1997). Overreliance on automation has been an issue leading to pilot error (National Transportation Safety Board [NTSB], 2010, 2013, 2014). Most resent research has involved Part 121 operations (Brown, 2016; Martins, 2016; Brennan & Li, 2017). With the proliferation of automation in Part 91 operations, it is prudent for the aviation community to investigate the type of automation errors and outcomes. There might be different automation systems in Part 91 operations and the types of automations may be different from known Part 121 issues. Additionally, Part 91 pilots have different experience and training levels. For example, Part 91 can include recreational flyers, flight instructors, and students. Fortunately, National Aeronautics and Space Administration (NASA) maintains an open-access database for anyone to analyze.

The Aviation Safety Reporting System (ASRS) database compiles reports by pilots, flight crews, air traffic controllers, and various aviation professionals. The database allows anyone interested access to the reports. However, there are limitations to the database such as search criteria, filtering reports, and the nature of self-reporting. The reports are assumed to be accurate portrayals of the event. Benefits of the database include the ability to compile, categorize, and analyze “real-world” incidents (ASRS, 2019).

The purpose of the current study is to identify and categorize automation errors in Part 91 operations to assist the general aviation community in safety promotion efforts. Additionally, recommendations for practice will be outlined. In order to understand the magnitude of automation errors, a literature review has been conducted. Literature pertaining to flight automation, human-machine interface, and manual flying skills were examined to understand issues related to performance.

Literature Review

The Impact of Cockpit Automation on Pilot Performance in General Aviation Flight Operations

Gil et al. (2012) conducted a study to compare the effects of different forms of advanced cockpit automation for flight planning on pilot performance and workload. The study found out that using low-level automation, such as a Control Display Unit (CDU) which displays flight management information, led to significantly higher pilot workload and longer Time-to-Task Completion (TTC). Moreover, findings suggested that the control display unit mode of automation (CDU MOA) supported lower situational awareness than its advanced counterparts. Additionally, a more advanced system does not necessarily mean pilots will perform better in the cockpit or simulation. A pilot must know when the appropriate time to use the automation, prioritizing relevant information, understand monitoring behavior, and what to do when manual flying is required (Strauch, 2017; Billings, 2018).

Despite advanced automation training in aviation and safety programs, a high-level cockpit automation system can have significant negative effects on the individual operating these

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systems (Sheridan & Parasuraman, 2005). As technology advances, flight crews are prone to become more dependent on automation (Parasuraman, Sheridan, & Wickens, 2000).

Investigating Human-Automation Interaction Consequences on Pilots

A team of researchers conducted a study to understand the latent structure pilots used during evaluation of automation error scenarios (Durso et al., 2015). The authors used the human automation interface model to understand the clustering of human factor subsystems. Research findings showed it is the pilots' duty to decide when to engage and disengage aircraft automation, determine the proper scenario as to which piece of automation to use, and react to the constant amount of information that is provided by the automated system (Durso et al., 2015).

The authors argued that workload, awareness, and management were the three common constructs or subsystems that affected the way pilots interacted with cockpit automation (Durso et al., 2015). It was found that there was a structure and commonality in the way pilots in the study handled various automation scenarios (Durso et al., 2015). Simply put, pilots can be trained to understand the common consequences associated with the human-automation interaction. If automation errors occur, the pilot may have to fly the aircraft manually. Flying an aircraft manually, or without certain automation features, can be a challenge if manual flight skills are not practiced (Chialastri, 2012).

The Retention of Manual Flying Skills in an Automated Cockpit

Retention of manual flying skills is very important in an age where automated systems in the cockpit are commonplace. In 2014, researchers from NASA, San Jose State University, and University of California Santa Barbara published a study aimed at understanding how the prolonged use of cockpit automation effects manual flying skills of pilots (Casner, Geven, Recker, & Schooler, 2014). The study found that even though the pilots instrument scan and manual control skills were unimpaired, the cognitive tasks required for manual flight were significantly impacted (Casner et al., 2014). Furthermore, researchers found that cognitive errors were frequent, and that pilots made the same mistakes repeatedly. Regarding flying aircraft, cognitive skills degrade faster than psychomotor skills (Casner et al., 2014). Survey data collected from the study indicated pilots perceived recurrent training inadequate for retaining proficiency with manual flight skills (Casner et al., 2014).

Researchers investigating the human-automation relationship have emphasized the importance of keeping manual flight skills proficient (Casner et al., 2014). These past studies discuss the risks brought upon by automation as well as incidents to support their arguments. The findings can be linked, to an extent, to existing safety reports through the publicly accessible Aviation Safety Reporting System (ASRS) database.

Methodology

In this study, researchers utilized the ASRS database to gather narratives of automation-related incidents. The focus of this study was on automation errors in Part 91 operations. Incidents from the ASRS database were filtered out based on the following criteria and keywords:

- Date: January 1, 2007 to December 31, 2018
- Country: United States of America
- Operation: Part 91 Operations
- Text - “Automation”

For the purpose of this study, a range of eleven years was selected. This way, more reports could be identified so that results would be more conclusive. Part 91 operations were chosen as a keyword for this study. Additionally, the word "automation" was put into the text section of the search criteria, as a result, all incidents that had the word "automation" in the synopsis or narrative would appear in the search results. This broad criterion was selected to obtain as many reports as possible. Quotes will be included in the results to provide evidence of categories.

Results

The ASRS database yielded 161 reports that matched the search criteria. These reports were downloaded and shared among the three team for examination. Each team member categorized the reports. The researchers found it relatively easy to decipher the causes of the automation errors and the outcome of the error. A majority of the reports had the cause explicitly stated. A few of the reports required the researchers to discuss the report utilizing a consensus decision-making model. There were four main categories in which the automation-related errors were categorized. These categories included Automation Dependency, Automation Malfunction, Air Traffic Control, and Lack of Training/Familiarity. Out of the 161 total incidents, 73 of the incidents were caused by Automation Dependency, 34 of the incidents involved Automation Malfunction, 42 were due to Air Traffic Control, and 12 were Lack of Training/Familiarity with the automated systems. Figure 1 outlines the categories while Table 1 indicates the categories and causes.

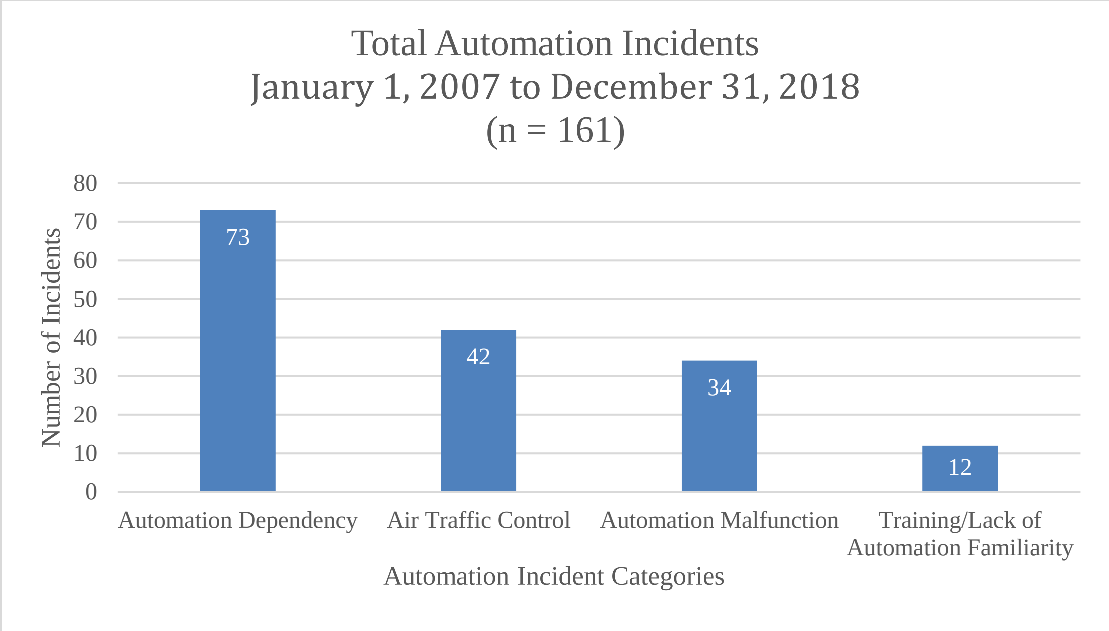

Figure 1. Total Automation Incidents ASRS Database.

Table 1

ASRS Database Incident Results

Incident Category	Number of Incidents	Causes
1. Automation Dependency	73	• Override Failure • Lack of Vigilance • Improper Automation Monitoring • Pilot Distraction
2. Automation Malfunction	34	• Flight Management System Error • Computer Miscalculations
3. Air Traffic Control	42	• Communicating Wrong Clearances
4. Lack of Training/Familiarity	12	• Organizational Issues • Pilot Performance
Total	161	

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For incidents placed in the Automation Dependency category, the causes for these incidents includes failure to override automation, altitude deviation error, lack of vigilance in the cockpit, improper automation monitoring, and pilot distraction. For incidents related to Automation Malfunction category, pilots reported flight management system errors and computer miscalculations. The incidents placed in the Air Traffic category typically were non pilot related incidents related to inaccurate clearances given by Air Traffic Control, and the last category is a lack of training/lack of familiarity with either the aircraft or automation. Since Automation Dependency had the most total incidents, a graph breaking down the various errors are shown in Figure 2.

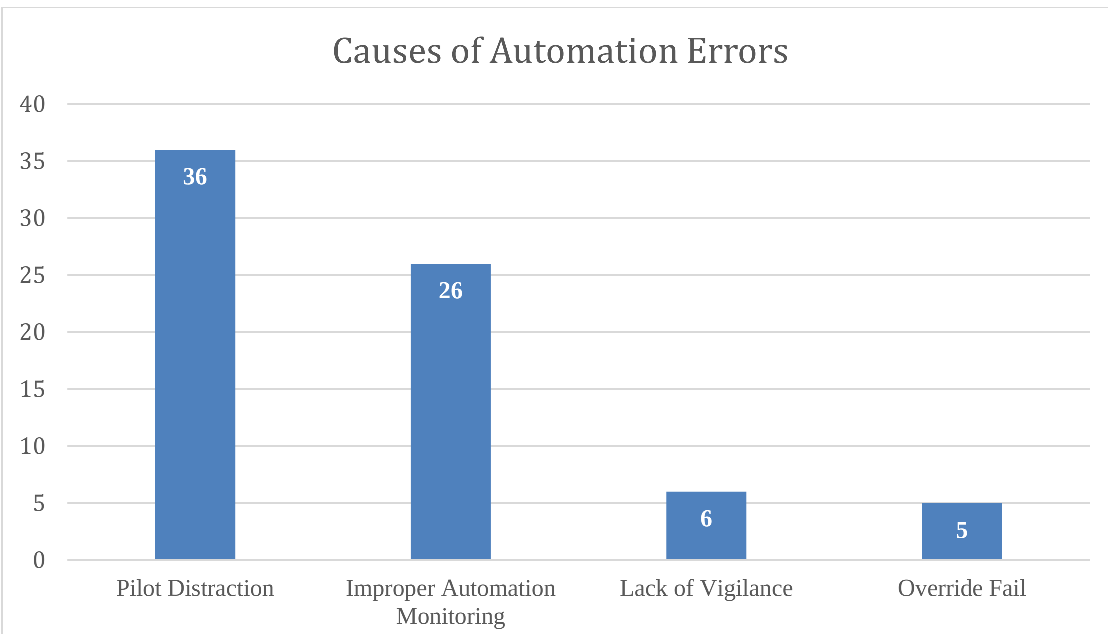

Figure 2. Automation Dependency Causes ASRS Database.

The following excerpts were from ASRS reports. The quotes were placed under the four categories of automation errors that were identified:

- Automation Dependency
    - *"First, I relied too much on automation, rather than taking over and flying the aircraft."*
    - *"I could have monitored the automation better and not be seen so Automation Dependent."*
    - *"However, I should have noticed that I was climbing and corrected the problem, a perfect example of too much dependence on automation."*
    - *"The automation worked as it was designed...to make the crossing restriction. I was unable to determine what had gone wrong."*
- Automation Malfunction
    - *"While flying the initial part of the arrival in mild turbulence and IMC, my autopilot failed. The failure resulted in a full and hard left bank."*
    - *"The aircraft GPS failed. Quickly followed by a complete failure in the Garmin 530. Approximately 3 minutes after this occurrence, the aircraft's PFD display showed a failure in all integrated equipment including attitude information, airspeed indicator, altimeter, heading indicator, and the integrated compass."*
    - *"Flight departed and while in cruise flight FL430, .90 Mach, and smooth air we experienced rudder control failure."*
- Air Traffic Control
    - *"Later, ATC asked us what we were navigating toward. He said we caught it in time but was curious because this happens on this departure a lot."*
    - *"Fort Worth Center Controller reported a problem with En Route Automation Modernization and an airspace violation relating to the problem."*
- Lack of Training/Familiarity
    - *"His pilot skills are good, but he has failed to get up to speed on the [aircraft] system, the automation, and adapt a crew concept in THIS airplane."*
    - *"The military pilots possibly need training to advise them about hazards associated with operating their transponders."*

Seventy-three (45%) of the automation incidents reported in Part 91 operations between January 1, 2007 and December 31, 2018 were due to the reliance on too much cockpit automation. Based on the findings from the study and the quotes given by pilots in the ASRS database, one can conclude that automation dependency is an issue among pilots in Part 91 operations.

Word Cloud

Word Clouds are an additional tool to visualize information. A study conducted by the University of Stuttgart, in Germany, has concluded that word clouds can provide a simple and effective way to visualize the frequency of words in reports or text documents (Lohmann, Heimerl, Bopp, Burch, & Ertl, 2015). The text is used often to visually unearth some information by looking at the frequency of the words or for aesthetic purposes (Lohmann et al., 2015). The authors point out that word clouds often serve as starting points for deeper analyses of information. Yet, the use of word clouds could be used to visually represent data in a way that is aesthetically appealing. Word Clouds are effective in communicating the most important words of a general text-document or report; therefore, one was created in regards to this study to show the most frequently-used words by pilots when reporting automation incidents to the ASRS database.

Figure 3 visually displays the most commonly seen words in the self-reported statements made by pilots in the ASRS database. The larger words indicate a higher frequency. Many words were used consistently in the ASRS reports suggesting that pilots are familiar with the same terminology in describing automation dependency.

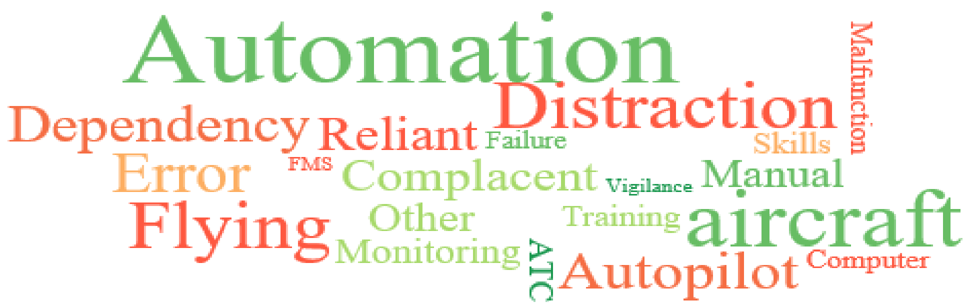

Figure 3. ASRS Database Word Cloud.

In Figure 3, the word cloud depicts words like automation, distraction, autopilot, dependency, complacent, and reliant as commonly seen words used throughout the selected ASRS reports. There were clearly more of these words, which indicate too much dependency on automation even in general aviation use. Other words like malfunction, error, and failure, which would indicate a problem with the automation, were not in many of the reports and only 34 total reports suggested automation problems. This suggests that the majority of automation issues are not primarily related to malfunctions but are instead more related to complacency among pilots when using automated systems in general aviation aircraft.

Discussion

Though the general aviation accident rate is steadily declining, it is important to investigate the causes of incidents (Federal Aviation Administration [FAA], 2018). Based on the results of the total number of automation incidents among general aviation operations, pilot dependency played a role in incidents gathered from the ASRS database. While it may not be a major factor in each case, the impact of pilot dependency is concerning. What is revealing is the fact that pilots know the effects of automation and how it can impact their own level of proficiency when hand-flying the aircraft. Nevertheless, the risks are still there, and attention towards safety promotion should be given.

Within the selected data set, pilots involved in automation-based incidents often stated unfamiliarity with the aircraft and or systems being operated. This can be troublesome during flight operations because if one error occurs it can lead to additional errors (Casner et al., 2014). Pilots tend to neglect cross-checking their instruments and leave it to automation to work for them. In regards to malfunctions of automation systems, the current study found that automation failures are reported less often. The findings from the ASRS reports suggest that dependency and lack of familiarity with the systems can cause more problems for pilots while flying.

Many general aviation aircraft have low-level automation compared to Part 121 counterparts, but utilized automation nonetheless. Low-level automation, such as the flight management system control display unit as one study showed, leads to higher workloads and supported lower situational awareness for pilots (Gil et al., 2012). It takes mental effort to program low-level automation in check, and an additional workload can put a strain on a pilot’s flying skills. Situational awareness is key to maintaining the safety of flight operations. Results indicated that pilots may have their situational awareness compromised while dealing with an automation error. Errors can increase workloads and create an additional distraction.

In regards to the ASRS database, it is assumed that the keywords and filters found all of the automation reports. However, the researchers believe that it is not always accurate. Some reports did not involve automation errors at all. The search did not always identify the targeted reports. It is recommended the filters be improved for improved accuracy. This could provide further evidence that the number of automation errors is much higher than known. Additional search filters would greatly improve the accuracy of the results. For example, the incidents are self-reported by pilots; therefore, there could be many incidents that are miscategorized or not reported at all.

In addition to improving the reliability of the data, adding criteria indicating the severity of the incidents would allow more investigation into the major incidents to determine the probable causes. Finally, an automated process to determine the frequency of automation errors, so that each reported error does not have to be counted manually, would be excellent in reducing time spent analyzing the ASRS reports. With these recommendations, the accuracy of the search results in the ASRS database will be greatly enhanced and there will be more detail in specific incidents which would allow for further investigation if needed.

Conclusion

Cockpit automation is a technology that has significantly helped the aviation industry in improving safety indicators (Chialastri, 2012). However, it also introduced new risks and problems (Scerbo, 2018). This research paper has provided various insights on pilots' dependence on automation, focusing on Part 91 operations. The findings showed areas for concern in automation dependency that may need to be addressed. The importance of learning to manually fly the aircraft must be emphasized from the base level of training for pilots. Automation is extremely useful when it is functioning and used properly. However, pilots should always be aware that technology can malfunction, and their stick and rudder skills must stay sharp to ensure the safety of each operation. Part of flight training fundamentals is the familiarity with all of the aircraft equipment. This allows for the proper use of the equipment at the right time. As pilots move on to more sophisticated equipment, they must always apply the fundamentals of flying the aircraft manually to avoid overreliance on automation technology.

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Previous studies and data reports from recent years have supported this research and exposed the vulnerability of pilots in Part 91 operations to automation dependency (Strauch, 2017; Billings, 2018). As aviation operation technology becomes more complex, so should the level of data reporting and analysis. A more defined database opens up opportunities for further research that can dig deeper into this topic and helps reduce the frequency of automation incidents and accidents.

As the general aviation accident rate decreases, it is important for stakeholders to continue to make progress with the reduction of accidents and incidents. Hopefully, with the findings from the ASRS database about the frequency of automation dependency among pilots in Part 91 operations, awareness of these issues may extend beyond pilots, but aviation schools around the country. Too much reliance on automation can lead to issues in the future; therefore, maintaining and continuing to sharpen manual flying skills is vital to ensuring maximum safety when operating an aircraft. Limitations of the study include using the ASRS database. The researchers assume all of the reports were accurate portrayals of the incidents. In regards to future research, a more detailed level of examination should occur. This includes utilizing inferential statistics to identify relationships and differences between the type of automation errors and type of deviation.

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