DLR Project NICo – Feasibility Study of an Alternate Airport Assistant for Pilots Deciding Where to Divert

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Abstract Recently, industry has worked on concepts for reducing active flight crew in cruise while one crew member is resting (extended Minimum Crew Operations, eMCO). The project Next generation Intelligent Cockpit (NICo) of the German Aerospace Centre (DLR) aimed to develop assistance systems in the context of single pilot operations (SiPO) to support and relieve pilots in phases of high workload. To assist pilots with considering options for an alternate airport in case of urgent diversions, DLR has designed an electronic flight bag (EFB) application that calculates in-flight and landing performance and provides a ranking of suitable airports. Four criteria comprising distance, fuel on arrival, stop margin and crosswind defined suitability. In a previous pilot survey, these criteria were identified as important when deciding where to divert.

The aims of a simulator study were to assess the functionalities of the EFB application and to gain pilot feedback on its usability and suggestions for further development. Focus was laid on investigating whether the equal weightings are consistent with the pilots' reasoning. Seven crews of two pilots with current or past Airbus A320 type rating performed a scenario in the DLR AVES full-motion A320 simulator. In this study, crews had to decide whether they would divert to an alternate airport when encountering a non-time-critical malfunction in adverse meteorological conditions. The pilots made use of the EFB application during their FORDEC process resting importance on its comprehensible ranking mechanism. In a preliminary analysis of results, it became evident that pilots rated the EFB application favourably and would consider using it in real operations when faced with the need to divert from the planned destination. Pilots experienced little workload throughout the scenario which shows that the EFB application is intuitive, helpful and lowers the workload in a potentially stressful situation.

Introduction

As global air traffic is forecast to grow significantly in the future and qualified aircrew is becoming scarce [1], concepts of reduced crew operations (RCO) have been investigated [2]. In recent times, the industry has been focussing on developing ideas to minimise the number of active crew members during cruise while one crew member is resting (extended Minimum Crew Operations, eMCO) [3]. Further reductions would lead to single pilot operations (SiPO) albeit neither concept is yet certified for EASA CS-25 aircraft. The project Next generation Intelligent Cockpit (NICo) of the German Aerospace Centre (DLR) aimed to develop assistance systems in the context of SiPO to support and

relieve pilots in phases of high workload [4]. These systems should not only be of use for SiPO but also for common multicrew operations.

Pilots are trained to adhere to the FORDEC or similar decision-making schemes. The mnemonic acronym FORDEC abbreviates the steps of collecting Facts, generating Options, analysing Risks and benefits, making a Decision, Executing it and Checking its adequacy over time [5]. According to recent expert interviews, pilots would welcome additional support, particularly with the FORDEC decision-making steps [6]. However, the experts emphasised that the final decision and its execution must remain the responsibility of the human crew or pilot, not an automated system.

DLR has created an electronic flight bag (EFB) application to support pilot's decision-making bearing in mind the FORDEC process. It should assist mainly with the categories Facts, Options, and Risks of FORDEC when exploring alternatives for a diversion. The application calculates and evaluates in-flight and landing performance to suggest suitable airports. The suitability of airports was determined by four key factors: distance, fuel on arrival, stop margin, and crosswind. Initially, these factors were given equal weight using the multi-criteria decision-making approach TOPSIS [7]. Findings from a previous pilot survey confirmed the importance of these criteria in determining where to divert [8]. The aims of the present study were thus to assess the feasibility of the EFB application and to get pilot feedback on its usability.

Methods

Fourteen pilots which hold or held an Air Transport Pilot Licence (ATPL) and were rated on the Airbus A320 were recruited to participate in the research study. The mean age of the participants was 49.36 (standard deviation, SD = 12.38) years. The average hours of flying experience were 14740 (SD = 10870). Seven pilots were first officers or captains, respectively. Categorised by their most recent operations, five pilots were flying long-range while nine were flying short-range flights.

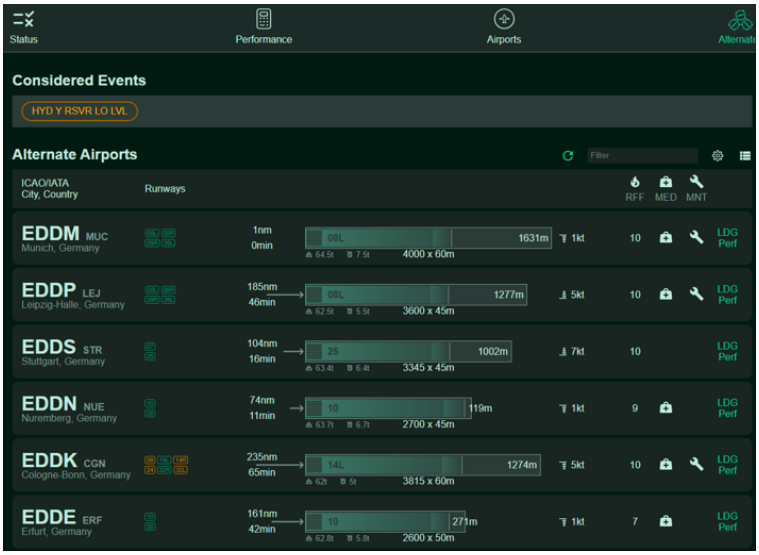

Fig. 1. *Alternates page*

For each experiment run, a crew of two pilots was seated in the Airbus A320 replica as part of the Air Vehicle Simulator (AVES) and was provided with the application under research on both EFB. After a familiarisation scenario, the main scenario flight was performed with both crew on the simulator flight deck. The pilots were free to choose who would be pilot flying (PF) and pilot monitoring (PM). Shortly after take-off upon retracting the slats and flaps, the crew would encounter a malfunction as the flaps would not fully retract but remained stuck between their 0 and 1 position. The effects of the failure

included higher fuel consumption because of increased drag, and longer distance required to land the aeroplane. Due to adverse weather conditions at several airports, the pilots needed to consider carefully where to divert.

The EFB app features four main pages, i.e. a status page, a performance page, an airports page and an alternates page. The most important page is the alternates page where a ranking of airports suitable for a diversion is provided (cf. Figure 1). Suitability is defined by the four aforementioned criteria comprising distance, fuel on arrival, stop margin and crosswind. These are weighted equally by default using the multi-criteria decision-making method TOPSIS. Pilots are able to modify the weightings relatively. The status page informs the pilots about the effects of a detected failure and its influence on the app's calculations, e.g. incresed fuel consumption. Also, considered Notices to Airmen (NOTAM) are shown. The other pages present the performance calculations for each runway of a selected airport and a list of airports with prevailing weather conditions.

The underlying calculations provide the distance and remaining flight time to each airport, as well as estimates of landing performance, i.e. required landing distances and speeds that are computed failure-dependant. In the given scenario, the flaps locked fault led to higher approach speeds and increased distances needed at landing. The system also considers any predicted crosswind and potentially higher fuel consumption. On the performance page, pilots can adapt input values like the runway condition and wind speed, or indicate the use of reverse thrust. Both pilots were provided the application on their respective EFB devices that were mounted to the side-wall panels of the flight deck. The EFB were not synchronised but allowed for individual use. The questionnaires employed in the research included one about demographics (i.e., age, gender, nationality, position, aircraft types, flight hours), one about the different features of the EFB app, one about ergonomics (i.e., situational awareness, trust, task sharing), and the NASA Task Load Index (NASA-TLX) [9].

During the scenario flight, data from the simulator as well as video and audio were recorded. The former included flight dynamics parameters, and aircraft system states, while the latter two comprised a view of the flight deck, screencasts from instruments, and communication between flight crew, simulated ATC, and researchers.

Results

The NASA-TLX questionnaire was administered upon concluding the experiment. Figure 2 shows the average weighted scores of twelve of the subjects across the dimensions mental demand (MD), physical demand (PD), temporal demand (TD), performance (PE), effort (EF), and frustration (FR), as well as the aggregate task load index (TLX). Two participants did not fill out the questionnaire and are thus not included in the results. On average, the pilots indicated a TLX of 7.41 which is fairly low an a scale from zero to 100. Partial scores of mental demand were the highest and those of frustration the lowest.

Valuable feedback on features and user interface of the application was received, including suggestions to increase button size, include a map, and provide a return button. All pilots indicated that the app's pages were intuitive to use. Many pilots affirmed that its features were useful.

Discussion

The research aimed to assess the feasibility of a newly developed EFB application that should support pilots' decision-making when considering options where to divert. The results revealed that pilots rated the app favourably and found its features useful, particularly the alternates ranking which is based on a multi-criteria decision-making method. Pilots rested importance on the comprehensibility of the ranking mechanism.

Pilots experienced low workload throughout the scenario and were on average little demanded nor frustrated. This supports the statement that the EFB app is not an additional burden on them. For a different scenario where pilots operated spacially separated and without the EFB app, Niedermeier *et al.* [4] reported that pilots felt rather overwhelmed and not able to deliver their full performance. Especially in such scenarios with high workload, the app could be of use.

The results need to be interpreted within the confines of the research. All participants volunteered, potentially leading to self-selection bias and the sample was relatively small (14 pilots). This limited number of participants does not allow any generalisation of the study results.

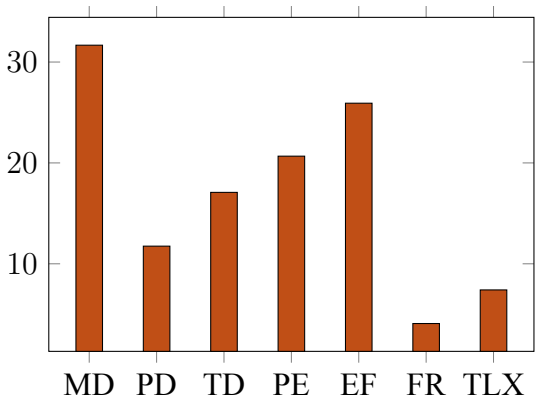

Fig. 2. *NASA-TLX average weighted scores*

Conclusion

Within the project NICo, an exploratory simulator study was performed to assess the feasibility of a newly-developed EFB app in a failure scenario. Although only seven crews took part in the experiments, interesting qualitative results based on questionnaires and crew comments were obtained. Crew comments showed the app's potential for use in commercial operations.

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