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A novel global operational concept in cockpits under peak workload situations

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ABSTRACT

The continual growth in air traffic demand, the emergence of new flight routes, and the increased congestion at major airports are some of the important incentives for developing novel solutions to deal with increased pilot workload and improve safety. This paper introduces a novel Global Operational Concept (GOC) for commercial aviation cockpits that is intended to support pilots during peak workload situations. This GOC applies to two-flight crew operations, intentional and unintentional flight-crew reduction and total flight-crew incapacitation, and comprises different solutions that cover all safety-related crew duties across all phases of flight and serves as an interface between technology and organisations. The GOC concept was developed under the Advanced Cockpit for Reduction of Stress and Workload (ACROSS) project, which was part of the European Commission's 7th Framework Programme (FP7) and investigated four solutions that will contribute to the reduction of pilot workload and stress by adapting cockpit applications and systems to challenging situations.

1. Introduction

The predicted overall growth in Air Traffic (The Roadmap, 2012; European Air Traffic Management Master Plan, 2009; Concept of Operations, 2007) on the one hand, and the strong demand for airlines efficiency (Lacabanne et al., 2012; Johnson et al., 2012) on the other, will increase the occurrence of events where the pilots' attention and actions will be subject to situations that are potentially more demanding than today's, especially during the take-off, climb, descent, approach and landing phases of the flight (Fadden et al., 2001; Harris, 2011; ICAO, 2004). Certain combinations of unpredictable situations (Aircraft Accident Report, 1995; Crew Incapacitation Enroute Jakarta to Sydney VH-OGN, 2008; All Engines-Out Landing Due to Fuel Exhaustion, 2001; DeJohn et al., 2004), such as difficult meteorological conditions, multiple system failures or cockpit crew incapacitation, can lead to peak workload conditions in which: the amount of information to process and actions to perform may exceed the amount of workload the crew can safely handle (Commercial Aircraft Information Security Concepts, 2005; Guidelines and Methods for Conducting the Safety Assessment, 1996; Guide for Conducting Risk Assessments, 2012; San Jose University, 1991). Notably, peak workload situations are an important precursor to accidents, thus, improving crew performance in peak workload conditions is a critical step for enhancing safety (Ecole Polytechnique de Montral, 1998; Arnrich et al., 2010; Blom et al., 2001; Breton and Rousseau, 2003; Selcon et al., 1991).

ACROSS, as part of the FP7, was not isolated nor does it provide a solution to all technical domains within the Transport programme. It was focused on reducing workload and stress in the cockpit under peak workload situations. The ACROSS project aims to develop pioneering solutions to reduce the pilots' peak workload (Cabon et al., 2002; Caldwell, 2005; Caldwell and Caldwell, 2003) and support them in dealing with difficult situations, thus enhancing safety and performance. In particular, ACROSS will work to develop, integrate and test new flight deck solutions so as to facilitate the management of peak workload (Carskadon and Dement, 1987) situations that can occur during a flight, and to reduce stress (Cohen et al., 1995) for pilots and thus improve safety for passengers by developing, integrating and testing new cockpit-based technologies (Bartley, 2001; Brire et al., 2001; Favre, 1994) that allow a reduced crew to operate safely in a limited number of well-defined conditions, such as when a crew member is on a planned rest period as part of fatigue prevention (DARPA, 2003; Dinges, 1995) or when one crew member is incapacitated.

Taking into account initial lessons on evaluations done on workload reduction and reduced crew operations (Ellis and Schnell, 2009; Elsey and Speyer, 1996; Endsley, 1988; Endsley and Garland, 2000; Endsley

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and Jones, 2000; ESSAI, 2000; Brookhuis et al., 1995), ACROSS will identify the main aspects to consider for future implementation of single-pilot operations.

2. ACROSS objectives

In order to better understand the ACROSS objectives presented below, it is important to explain how the objectives are linked to the current operational model under the point of view of the concept and regulations and how they were developed through the six ACROSS pillars presented in the next section.

Current concept: two pilots sharing information, complementing and cross-checking each other:

- One pilot flies the aircraft (pilot flying).
- The second pilot manages systems or provides support, such as by handling radio communications and trouble-shooting in the event of failures (pilot not-flying).
- The crewmembers cross-check each other's actions.

Current regulations: require that commercial airlines have at least two pilots aboard an aeroplane, including two in the cockpit:

- One of the pilots is allowed to leave the cockpit, but only for a short period of time and under certain conditions.
- In long-haul flights: one or more extra pilots are available to allow the other pilots to take an in-flight rest and to comply with the rules on flight-time limitations.

The main goal of ACROSS is to design systems that alleviate crew workload in current two-pilot operations in order to improve safety.

2.1. Objective 1: New cockpit solutions for peak workload situations

Today, pilots routinely fly in ever more demanding conditions (such as higher traffic densities, more demanding operational constraints and lower visibility conditions). Although operational technology has advanced to the point where some flight phases of modern aircraft are heavily automated, requiring relatively few actions by the crew, there remain instances where the workload may rise to the point where even within the two-pilot crew configuration, the flight crew comes under stress (such as during a complicated departure in high density airports, approach and arrival under unusual operating conditions).

The current level of automation and state-of-the-art operational equipment, in the context of existing and future operational environments, could be further improved to provide the flight crew with the support required to achieve the desired level of safety under peak crew workload conditions.

This will help when facing complex situations by providing tools that can help the crew in building a correct and timely mental picture of the situation with minimal effort (Weintraub et al., 1985). This is achieved through new avionics functionalities, cockpit displays, flight deck and air-ground communication solutions. The project aims to provide, for example:

- Increased automation in those conditions where this can contribute to increasing the safety level of the operation by relieving the flight crew from burdensome tasks for which the *human added value* is low while maintaining crew situational awareness and authority (Wickens et al., 2004).
- Improved human machine interaction. With the levels of automation in the cockpit constantly on the rise, the crew's tasks are increasingly focused on managing and overseeing the aircraft and its systems. This places increasing emphasis on the need for good synergy between the human pilot and the machine, effectively making the crew and the machine function as a single entity. This necessitates sound human-machine interfaces and interaction concepts (Wood and Howells, 2000; Salas et al., 2010).
- Improved support during abnormal conditions (failures, emergencies, etc.) to facilitate a correct and timely response by the flight crew without overloading them, thus mitigating the risk of pilot error (ICAO Document 9869, 2008; Boverie et al., 2002).

2.2. Objective 2: New cockpit solutions for reduced crew operations

Even if such incidents are rare, it happens occasionally that one of the pilots of a commercial flight is incapacitated, or even dies. In less dramatic situations, one pilot may not be able to perform needed actions due to illness or psychological issues (Boverie and Kortelainen, 2004; Boverie et al., 2005; Boverie and Giralt, 2008). It is therefore necessary for the remaining pilot(s) to manage the situation, likely under significant stress. In these cases, unplanned reduced crew situations will have to be managed.

Different situations will be addressed:

- Intentionally reduced crew in long-haul flights, for a limited period of time during cruise; the need is to support the remaining flight crew member in the cockpit while the other one is at rest, and to prevent fatigue by allowing him or her to rest efficiently.
- Partial flight crew incapacitation; ACROSS will analyse solutions to help the remaining pilot to safely complete the flight to the nearest suitable airport (assuming as a first step, that other parameters such as aircraft status and the external environment, are normal).
- Full flight-crew incapacitation, from cruise to landing until aircraft stops (no taxiing).

2.3. Objective 3: Identify open issues for possible single-pilot operations

This scenario could come closer to being implemented, leading to reduced costs for commercial aviation. Operators also require a vision on future possible reductions in the required number of crew members for air transport and business aircraft.

Single-pilot operations in all conditions are considered a long-term evolution that is not within the scope of ACROSS research and technology developments.

The ACROSS consortium considers single-pilot operations as a case study that stimulates innovation and facilitates the identification of solutions that could be used to improve the current safety level in situations of peak workload and reduced crew. Conversely, any solutions developed to manage peak workload and reduced crew situations may be considered for possible single pilot operations in the future.

3. The ACROSS pillars

The high-level objectives of ACROSS address crew issues from a human factors perspective (Washington University, 2000). This is also reflected in the structure of the project, which identifies six main pillars (see Fig. 1). The first four pillars focus on the four basic piloting tasks: aviate, navigate & manage mission, communicate and manage system. The remaining two pillars, crew monitoring and crew communication, focus on technologies which can help evaluate the crew's workload at any time as well as temporarily perform essential crew tasks and, in the most extreme cases, replace the crew under certain conditions.

Furthermore, the six ACROSS pillars were assessed/crosschecked with five Engineering System domains during the different stages of the project. For instance, early in the project some exercises driven by the aviation community and the ACROSS participants were conducted to draft the requirements that the systems allowing the crew to handle highly-stress scenarios should have, these requirements were classified in the ACROSS pillars (Aviate, Navigate, etc.) and distributed to the research teams. In the late stages of the project, once the systems were designed and prototyped, validation assessment were conducted (again