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# The future flight deck: Modelling dual, single and distributed crewing options

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ABSTRACT

It is argued that the barrier to single pilot operation is not the technology, but the failure to consider the whole socio-technical system. To better understand the socio-technical system we model alternative single pilot operations using Cognitive Work Analysis (CWA) and analyse those models using Social Network Analysis (SNA). Four potential models of single pilot operations were compared to existing two pilot operations. Using SOCA-CAT from CWA, we were able to identify the potential functional loading and interactions between networks of agents. The interactions formed the basis on the SNA. These analyses potentially form the basis for distributed system architecture for the operation of a future aircraft. The findings from the models suggest that distributed crewing option could be at least as resilient, in network architecture terms, as the current dual crewing operations.

## 1. Introduction

The trend in flight deck design over the past half century has been one of progressive ‘de-crewing’. Fifty years ago, it was not uncommon for there to be five crew on the flight deck of a civil airliner (two Pilots; Flight Engineer; Navigator and Radio Operator). Today, just two pilots, accomplish the same tasks once undertaken by five. Many functions are now wholly or partially automated. Consequently the role of the pilot has changed from one of being a ‘flyer’ to one of being a systems/flight deck manager.

Airline personnel costs vary between about 11% of operating costs to nearly 25%, depending upon aircraft type, sector length and how much activity is outsourced (RyanAir, 2009; easyJet, 2013). Crew costs for smaller commercial aircraft can be between 15% and 35% of the aircraft direct operating costs (Alcock, 2004). Annual accounts from a typical low-cost operator suggest that even for a larger airliner, the crew represent nearly 19% of operating costs (excluding fuel and propulsion – easyJet, 2013). The scope to make significant cost savings with the current common configuration for aircraft (cylindrical fuselage with wings, rudder and tail plane) is now limited. This configuration is approaching the end of its development potential. Alternative configurations such as the blended wing body concept which offer considerable structural and aerodynamic advantages, have met with limited enthusiasm from potential passengers. Problems of ensuring a safe and efficient means of passenger evacuation have also been identified (Galea et al., 2011). This configuration also needs a great deal of development in other areas (such as flight control systems and structural testing) before it will be suitable for service entry. Reducing the number of crew on the flight deck to just a single pilot will produced significant cost savings, especially in smaller commercial aircraft operated on shorter and ‘thinner’ (lower demand) routes.

Some manufacturers (e.g. Embraer) are already developing the technology for a single crew aircraft, as are avionics suppliers (e.g. Honeywell – see Keinrath et al., 2010). The approaches being adopted in these instances centre upon the development of sophisticated airborne technology to assist the pilot (e.g., Intelligent Knowledge-Based Systems and adaptive automation). This approach is also adopted in other research programmes looking at flight deck automation and crewing, for example the development of an Electronic Standby Pilot (ESP) as part of the Advanced Cockpit for the Reduction of Stress and Workload (ACROSS) project (see http://www.across-fp7.eu/). The medium term objectives of the ACROSS project are concerned with reducing the number of flight deck crew in the cruise phase in long-haul flights to permit crew to rest and help prevent fatigue. It is anticipated that the same technology will aid in the case of partial (or even full) flight crew incapacitation. The longer term objectives of the project are to form the basis for potential single crew operations.

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A similar approach has been adopted by other researchers in the past, particularly in the military domain, but with only mixed success (e.g. the COGnitive cockPIT – COGPIT programme – Bonner et al., 2000; Taylor et al., 2000; and the Cockpit Assistant Military Aircraft – CAMA programme - Schulte and Stütz, 2001; Stütz and Schulte, 2001). CASSY (the Cockpit ASsistant System) was a civil aircraft version of the latter developed by the same team (see Onken, 1994; Onken, 1997). The Cognitive Adaptive Man–Machine Interface (CAMMI) project (Keinrath et al., 2010) also makes use of extensive AI software in its approach to adaptive automation. A later requirements analysis for developing concepts for single pilot operations was also predicated upon the notion of incorporating extensive pilot automated assistance on the flight deck, particularly synthetic vision systems; data linking and direct voice input/output systems (Deutch and Pew, 2005). The main arguments for the use of two members of flight deck crew centre around issues concerned with pilot workload (specifically instances of workload peaks); the reduction of flight crew error and pilot incapacitation. Many of the assumptions are either questionable or are becoming out-dated as discussed in the following three paragraphs.

From the perspective of the person in command of any aircraft, there is a workload 'cost' associated with the management of crew on the flight deck. The requirement to coordinate crew, cooperate and communicate on the flight deck itself has workload associated with it. Doubling the number of crew does not half the workload. Furthermore, modern flight decks are already certificated so that they can be operated by a single-member of flight deck crew (see FAR/CS 25.1523). Automated flight deck systems have already considerably reduced pilot workload (Wiener and Curry, 1980; Harris, 2003).

While the second crew member may distribute the workload around the flight deck somewhat, it can be also be argued that they actually introduce an error mode. Poor CRM (Crew Resource Management) has been implicated as a contributory factor in nearly 23% of all fatal commercial jet aircraft accidents (CAA, 2008). The effectiveness of the second pilot as an 'error checker' is also questionable. Omission of action or inappropriate action was implicated in 39% of accidents and an incorrect application of procedures or a deliberate non-adherence to procedures was implicated in a further 13% (Civil Aviation Authority, 2008). Becoming 'low and slow' (a failure to cross monitor the flying pilot) was a factor in 12% of accidents. As a cross check on the position of the aircraft the PM's effectiveness would also seem to be questionable as a lack of positional awareness was identified as a causal factor in 27% of cases (Civil Aviation Authority, 2008). This is quite a crude analysis however. It is acknowledged that what these data do not show is in how many cases the second pilot trapped an error made by the other pilot and avoided an accident: this is unknown and unknowable. However, observational data obtained from routine flights reported that 47.2% of errors committed by Captains involved intentional non-compliance with Standard Operating Procedures (SOPs) or regulations: 38.5% were unintentional procedural non-compliance (Thomas, 2003). Thomas also reports that in observations of line operations crews did not demonstrate effective error detection, with more than half of all errors remaining undetected by one or both of the flight crew. As a result it can be argued that removing one of the pilots actually reduces the scope for accidents occurring as a result of miscommunication or mis-understanding between the pilots and that removing the PM does not double the workload on the flight deck.

Perhaps the greatest concern for the development of a single-crew aircraft is that associated with pilot death, incapacitation or impairment. However, such instances are very rare. A study of in-flight medical incapacitations in US airline pilots between 1993 and 1998, found only 39 instances of incapacitation and 11 instances of impairment (DeJohn et al., 2004). The rate of in-flight medical events (encompassing both types) was 0.058 per 100,000 flight hours. The probability that one of these events would *subsequently* result in an accident was calculated to be 0.04. DeJohn et al. (2004) observed that the safety of the flight was seriously impacted in only seven cases and resulted in two non-fatal accidents. A later study of UK commercial pilots by Evans and Radcliffe (2012) suggest that the annual in-flight incapacitation rate was 0.25%, however this study is seriously flawed in than it was not weighted by flight hour and the rate is expressed as a percentage of all UK registered pilots (irrespective of flight hours accumulated by each, per year).

It is argued that with the judicious use of existing equipment, there are no major reasons why a single pilot operated commercial aircraft is not feasible in the very near future using existing technology. Military aviation has flown complex, high performance single crew aircraft for many years and Unmanned Air Vehicles (UAVs) are now commonplace. UAV technology has matured and such aircraft are now regularly being used for national border and port security, homeland surveillance, scientific data collection and telecommunications services (Harris, 2007). Airworthiness standards for their design and operation in civil airspace are being developed on both sides of the Atlantic (e.g. UK Civil Aviation Authority, 2010 – *Unmanned Aircraft System Operations in UK Airspace – Guidance (CAP 722))*. Several UAVs are now the size of a small aircraft, with performance similar (or exceeding) that of a conventional aeroplane. It is worth noting that UAVs still have a designated 'Pilot in Command' International Civil Aviation Organisation Annex 2, 'Rules of the Air', states that the Responsibility of the pilot-in-command' of an aircraft shall, whether manipulating the controls or not, be responsible for the operation of the aircraft in accordance with the rules of the air, except that the pilot-in-command may depart from these rules in circumstances that render such departure absolutely necessary in the interests of safety'.

The greatest obstacle to the operation of civilian, single pilot, aircraft is not the technology *per se*. Rather, the barriers are: combining the ground and airborne technologies, designing the user interfaces and developing new concepts of operations to make such an aeroplane safe and useable in a wide range of normal and non-normal operating situations (when flown by a typical commercial pilot). That is to say that the Human Factors requirements are the prime driver in this case, not the technology. The concept evaluated in this paper is based upon an alternative design approach to that of utilising a large amount of on-board, complex, computing (e.g. that using agent-based software) first described by Harris (2007). The concept, uses a socio-technical systems-based design philosophy utilising a great deal of currently existing technology. In this case the control and crewing of the aircraft is distributed in real time across both the aircraft's flight deck and ground stations (see also: Stanton et al., 2014). The second pilot is not *replaced* by on-board Artificial Intelligence or Intelligent Knowledge-Based Systems, which would be both difficult to develop and challenging to certificate; they are merely *displaced*.

## 2. Design approach

The proposed approach regards a future single crew aircraft as just one part of a wider operating system, a radical change from the operation of current generation airliners. The initial high-level design architecture proposed for operating the Single Crew Aircraft consists of several discrete elements (Stanton et al., 2014):

- The aircraft itself (including pilot)
- Ground-based component including:
  - 'Second pilot' support station/office
  - Real-time engineering support
  - Navigation/flight planning support
- System 'Mirror'.