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Nick McDonnell
Trinity College Dublin, nmcdonal@tcd.ie

Alison Kay
Trinity College Dublin, Ireland, alison.kay@tcd.ie

Margaret Ryan
Trinity College Dublin, margaret.ryan@tcd.ie

See next page for additional authors

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Authors
Nick McDonnell, Alison Kay, Margaret Ryan, Rabea Morrison, and Rolf Zon

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Nick McDonald,[1], Alison Kay, Margaret Ryan[1], Rabea Morrison[1] and Rolf Zon[2]

[1] Centre for Innovative Human Systems, School of Psychology, Trinity College Dublin, Dublin 2, Ireland
{nmcdonld,alison.kay, Margaret.Ryan, ramorris}@tcd.ie

[2] NLR-Netherlands Aerospace Centre, Amsterdam, The Netherlands
{Rolf.Zon}@nlr.nl

This research provides a rich validated description of how crew manage workload for both two-pilot and reduced crew operations. It outlines flight operations modelling, operational narratives, requirements and scenarios validated with expert advisers from the EU-FP7 ACROSS Project. The crew are considered to be the managers of the operation who receive integrated technical support to help them manage flight operations across of three configurations i.e. 1) standard two-crew configuration, 2) reduced crew under normal operations 3) reduced-crew under non-normal operations developed within the FP7 EU-funded ACROSS (Advanced Cockpit for the Reduction Of Stress and Workload) project. ACROSS had three main objectives:

1. *New cockpit solutions for peak workload situations*. The ACROSS project to contribute to a cockpit environment that mitigates the impact of crew workload peaks in the flight deck and ensures that pilots have the opportunity to address all relevant issues in a timely and effective manner;
2. *New cockpit solutions for reduced–crew operations*. ACROSS to develop and integrate cockpit-based technologies that allow the remaining pilot to safely manage the flight.
3. *Identifying open issues for possible single pilot operations* ACROSS to identify aspects that currently prevent the reduction of the crew to a single pilot. (ACROSS, 2016)

Arguably, from a human factors point of view, two conditions need to be fulfilled for reduced crew operations in scheduled commercial aviation operations:

- The system needs to provide optimal support for the flight crew to ensure that one crew member can perform all functions adequately under all foreseeable circumstances, as far as reasonably practicable. This is an application of the distributed authority concept.

ACROSS (2016).ACROSS website. Accessed 20th March, 2016, http://www.across-fp7.eu/

- There needs to be adequate real time accountability to the wider system, to replace the mutual accountability of two crew, so that in the case of incapacity of the single crew member (either total incapacity or functional ineffectiveness), a timely and effective intervention is possible to save the aircraft. This is the accountable self-regulation concept. This is an application of the accountable self-regulation concept.

To achieve this, McDonald et al produced a human factors integration methdology and delivery of a crew-centric concept for management of the flight operation. Crew were put at the centre of the flight operations process. They were considered to me Managers of the Operation with ultimate authority on decision making.

Challenges faced in the ACROSS project such as 35+ partners spread throughout Europe, Multiple development, testing and evaluation sites, a variety of diverse technologies being developed in parallel made it evident that a traditional approach to human factors would not suffice. Also, feedback human factors integration workshops indicated that the classical workload models (e.g. [1]) were not comprehensive enough for our needs.

Modelling Workload and the Flight Operational Process - Workload is part of an overall operational context and cannot exist in isolation. It must be contextualized within the overall operation of the system. Decision making does not happen in a vacuum, thus the remainder of the system must be contextualized.

The crew play the key role in the use of the technologies to manage workload. The crew are responsible for managing the operation through the cognitive-behavioural cycle of: 1) Planning/Anticipating, 2) Monitoring, 3) Analysing, 4) Deciding 5) Acting 6) Checking, 7) Reviewing/Updating, 8) Reporting. The socio-technical system perspective extends the scope of inquiry beyond local 'here and now' interactions and liberates the focus from specific tasks by considering crew as managers of the overall process/system. The crew centric approach, taken complements procedural accounts that favour the 'here and now' and follow along a sequential timeline along the flight operations processes by introducing a systematic approach to inquire about crew functions that take the past and future into account in order to optimise the execution in the here and now. In ACROSS, the pilots were at the centre of flight operations and to get a full appreciation of workload in an applied operational context, the following global concept of workload was developed which encompassed three main types of cognitive workload management:

Proactive Workload Management: Managing workload using timelines and other schematisations. This enables anticipation, which in turn enables planning and allocating resources along the timeline. This enables crew to spread the anticipated workload better and also to be more prepared and more capable of absorbing unexpected spikes in workload.

Immediate Workload Management: In ACROSS immediate workload management is achieved through the use of automation, which reduces demand and together with enhanced decision support reduces crew workload in the here-and-now.

Reactive Workload Management: Managing workload by reacting to events/situations after they have happened. The main focus of reactive workload management in ACROSS is the Crew Monitoring System, which can detect pilot incapacitation and suggest mitigations.

This global workload concept was evaluated using Operational Narratives – validated via focus groups and on-line evaluation workshops with external expert advisory group (i.e. pilots, engineers, medics, risk analysts, legal experts, trainers, weather experts, psychologists).

In summary, the overall HF philosophy of ACROSS is built around an integrated concept that can demonstrate how the overall management of the operation and its dependencies is linked to and mediated by task performance of the crew and the role of automation as well as the functionality of the Human-Machine interface. Expressing the logic of the operational process as a whole, i.e. flying from A to B, as a sequence of critical points and associated dependencies allows one to transparently link a detailed assessment of task, crew and automation and HMI to the operational outcomes aspired to in ACROSS such as risk reduction in the flight operation. Because of this complexity the driving global workload concept should be clearly embedded in a rich understanding of operational reality. This involves a capability for 'System Design for Operations' [2]. The development of new technologies pushes us further to consider not just the transformation of human workload and operational roles at local level where new automation can enhance human functioning as well as supplanting it; it forces us to consider how relationships are transformed across the system and it puts clearly on the agenda the requirements for effective and accountable governance of the next generation of operational systems

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