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EDITORIAL

Neville A. Stanton, Wen-Chin Li & Don Harris. [*Ergonomics and Human Factors in Aviation*](#). Pages: 131-137.

ARTICLES

Neville A. Stanton, Katherine L. Plant, Kirsten M. A. Revell, Thomas G. C. Griffin, Scott Moffat & Maggie Stanton. *Distributed cognition in aviation operations: a gate-to-gate study with implications for distributed crewing*. Pages: 138-155.

The network analysis method, Event Analysis of Systemic Teamwork (EAST), was used to examine routine aviation operations from multiple perspectives from six key areas (i.e. Dispatch, ATC, ATM, Maintenance, Loading, and the Cockpit). Data was collected over a five-day observational field trial at an international air cargo operator. Researchers recorded the activities of agents operating within the six key areas over three outbound and two inbound flights. Three networks (i.e. social, information and task) were created for four key phases of flight: (i) pre-flight checks and engines start (ii) taxi, take-off and ascent, (iii) descent, landing and taxi, and (iv) park and shut down. The networks represent a 'work audit' of short-haul cargo operations, which enabled a detailed understanding of the interactions and connections within the current system. Implications for the future of distributed crewing concepts are discussed. **Practitioner Summary:** An analysis of the aviation system was undertaken using the amalgamated data from three outbound and two inbound flights. These analyses show the social, information and task interactions for cargo operations. This has been used to specify requirements for future distributed crewing options.

- **Keywords:** System of systems, distributed cognition, aviation, networks, EAST method

Kirsten M. A. Revell, Craig Allison, Rodney Sears & Neville A. Stanton. *Modelling distributed crewing in commercial aircraft with STAMP for a rapid decompression hazard*. Pages: 156-170.

Changes to crewing configurations in commercial airlines are likely as a means of reducing operating costs. To consider the safety implications for a distributed crewing configuration, system theoretic accident model and processes (STAMP) was applied to a rapid decompression hazard. High level control structures for current operations and distributed crewing are presented. The CONOPS generated by STAMP-STPA for distributed crewing, and design constraints associated with unsafe control actions (UCAs) are offered to progress in the route to certification for distributed crewing, and improve safety in current operations. Control loops between stakeholders were created using system-theoretic process analysis (STPA). The factors leading to the Helios 255 incident demonstrated the redundancy that a ground station could offer without the risk of hypoxia, during a decompression incident. STPA analysis also highlighted initial UCAs that could occur within the hypothetical distributed crewing configuration, prompting consideration of design constraints and new CONOPS for ground station design. **Practitioner Summary:** SPO in commercial aircraft is likely as a means to reduce costs. This paper makes a case for distributed crewing using STAMP-STPA. Comparing current operations with a distributed crewing configuration, the redundancy offered by a ground station is demonstrated. Design constraints and new CONOPs for distributed crewing, and current operations are proposed.

- **Keywords:** SPO, distributed crewing, STAMP, STPA, safety, rapid decompression

Lei Wang, Jingyi Zhang, Chuanting Dong, Hui Sun & Yong Ren. *A Method of Applying Flight Data to Evaluate Landing Operation Performance*. Pages: 171-180.

Pilots' operation has an important effect on flight safety and performance, particularly in the final landing stage when pilots need to deal with complicated operations. This study aims to determine the potential value of flight data and develop a method of evaluating a pilot's performance during landing phase based on flight quick access recorder (QAR) data from the perspective of risk assessment. First, a Landing Operation Performance Evaluation Model was developed based on risk evaluation principles. Three landing parameters, which are touchdown distance, touchdown vertical acceleration and touchdown pitch angle, were selected as indicators to evaluate the pilots' landing operation performance in this model. Second, the flight landing operation performance evaluation system (FLOPES) was set up based on the evaluation model. Test results showed that FLOPES can accomplish all calculation flow of operation performance evaluation. Finally, it concluded that this method is a more accurate and effective way for evaluating the landing operation performance of a flight. It could be as a practical tool for airlines to manage landing risk quantitatively and to provide a more practical support for improving training and design in aviation. **Practitioner summary:** This study aims to determine the potential value of flight data and to develop a method of evaluating pilot's landing operation performance from the risk evaluation perspective. Test results showed that this method is effective and could be as a practical tool for airlines to manage landing risk and improve training.

- **Keywords:** Flight data, flight operation, landing safety, performance evaluation

Don Harris & Wen-Chin Li. *Using Neural Networks to predict HFACS unsafe acts from the pre-conditions of unsafe acts*. Pages: 181-191.

Human Factors Analysis and Classification System (HFACS) is based upon Reason's organizational model of human error which suggests that there is a 'one to many'

mapping of condition tokens (HFACS level 2 psychological precursors) to unsafe act tokens (HFACS level 1 error and violations). Using accident data derived from 523 military aircraft accidents, the relationship between HFACS level 2 preconditions and level 1 unsafe acts was modelled using an artificial neural network (NN). This allowed an empirical model to be developed congruent with the underlying theory of HFACS. The NN solution produced an average overall classification rate of *ca.* 74% for all unsafe acts from information derived from their level 2 preconditions. However, the correct classification rate was superior for decision- and skill-based errors, than for perceptual errors and violations. **Practitioner Summary:** A model to predict unsafe acts (HFACS level 1) from their preconditions (HFACS level 2) was developed from the analysis of 523 military aircraft accidents using an artificial NN. The results could correctly predict approximately 74% of errors.

- **Keywords:** Human Factors Analysis and Classification System (HFACS), human error, Neural Networks, modelling, accident analysis

Brian Thoroman, Natassia Goode, Paul Salmon & Matthew Wooley. *What went right? An analysis of the protective factors in aviation near misses.* Pages: 192-203.

Learning from successful safety outcomes, or what went right, is an important emerging component of maintaining safe systems. Accordingly, there are increasing calls to study normal performance in near misses as a part of safety management activities. Despite this, there is limited guidance on how to accomplish this in practice. This article presents a study in which using Rasmussen's risk management framework to analyse 16 serious incidents from the aviation domain. The findings show that a network of protective factors prevents accidents with factors identified across the sociotechnical system. These protective networks share many properties with those identified in accidents. The article demonstrates that it is possible to identify these networks of protective factors from incident investigation reports. The theoretical implications of these results and future research opportunities are discussed. **Practitioner Statement:** The analysis of near misses is an important part of safety management activities. This article demonstrates that Rasmussen's risk management framework can be used to identify networks of protective factors which prevent accidents. Safety practitioners can use the framework described to discover and support the system-wide networks of protective factors.

- **Keywords:** Accident causation, Accident analysis, Accident prevention, Aviation, Incidents, Near miss, Systems thinking

Emmanuel Tsifetakis & Tom Kontogiannis. *Evaluating non-technical skills and mission essential competencies of pilots in military aviation environments.* Pages: 204-218.

To develop and validate a classification of non-technical skills (NTS) in military aviation, a study was conducted, using data from real operations of F16 aircraft formations. Phase 1 developed a NTS classification based on the literature review (e.g. NOTECHS) and a workshop with pilots. The Non-TECHnical-MILitary-Skills (NOTEMILS) scheme was tested in Phase 2 in a series of Principal Component Analysis with data from After-Action-Review sessions (i.e. 900 records from a wide range of operations). The NTS were found to make a good prediction of Mission Essential Components ($R^2 > 0.80$) above the effect of experience. Phase 3 undertook a reliability analysis where three raters assessed the NOTEMILS scheme with good results (i.e. all $r_{wg} > 0.80$). To look into the consistency of classifications, another test indicated that, at least, two out of three raters were in agreement in over 70% of the assessed flight segments. **Practitioner Summary:** A classification scheme of Non-Technical Skills (NTS) was developed and tested for reliability in military aviation operations. The NTS scheme is a valuable tool for assessing

individual and team skills of F-16 pilots in combat. It is noteworthy that the tool had a good capability of predicting Mission Essential Competencies.

- **Keywords:** Mission essential competencies, non-technical skills, behavioural markers, military aviation, NOTECHS, inter-rater reliability

Simon Ashley Bennett. *The training and practice of crew resource management: recommendations from an inductive in vivo study of the flight deck.* Pages: 219-232.

Crew resource management (CRM) is credited with saving 185 lives at Sioux City. While the theory behind CRM is well documented, there are few studies of how CRM manifests on the line. This inductive in vivo study had three objectives. First, to describe how CRM manifests. Secondly, to evaluate the efficacy of CRM vis-à-vis flight safety. Thirdly, to suggest improvements to the CRM training syllabus. The study produced five conclusions: First, CRM is durable under conditions of moderate strain. Secondly, crews embed and refine CRM through reflection and action. Thirdly, CRM facilitates and shapes social relations. Fourthly, mindlessness (Langer, 1989) undermines CRM. Finally, the interruption of flight-deck routines by third-parties poses a threat to flight-safety. The paper recommends multi-profession CRM training as a means of improving communication and co-ordination in and around aircraft. The study's limitations include a monocultural flight-deck: flights were operated by pilots with European backgrounds. Mindful of Hofstede's (1980), Engle's (2000) and Helmreich and Merritt's (2001) examination of the relationship between culture and performance, the author suggests the study be repeated with carriers that employ pilots from a variety of cultures.

Practitioner Summary: This *in vivo* study evaluates the efficacy of CRM vis-à-vis flight safety and supports a critique of the CRM syllabus. The author observed twenty sectors and attended a CRM training day. To improve safety and efficiency, it is recommended that airlines run multi-profession (inclusive) CRM training courses.

- **Keywords:** Crew resource management, ethnographic study, lived reality, praxis, training constituency

Evangelia Demerouti, Wouter Veldhuis, Claire Coombes & Rob Hunter. *Burnout among pilots: psychosocial factors related to happiness and performance at simulator training.* Pages: 233-245.

In this study among airline pilots, we aim to uncover the work characteristics (job demands and resources) and the outcomes (job crafting, happiness and simulator training performance) that are related to burnout for this occupational group. Using a large sample of airline pilots, we showed that 40% of the participating pilots experience high burnout. In line with Job Demands-Resources theory, job demands were detrimental for simulator training performance because they made pilots more exhausted and less able to craft their job, whereas job resources had a favourable effect because they reduced feelings of disengagement and increased job crafting. Moreover, burnout was negatively related to pilots' happiness with life. These findings highlight the importance of psychosocial factors and health for valuable outcomes for both pilots and airlines.

Practitioner Summary: Using an online survey among the members of a European pilots' professional association, we examined the relationship between psychosocial factors (work characteristics, burnout) and outcomes (simulator training performance, happiness). Forty per cent of the participating pilots experience high burnout. Job demands were detrimental, whereas job resources were favourable for simulator training performance/happiness. *Twitter text:* 40% of airline pilots experience burnout and psychosocial work factors and burnout relate to performance at pilots' simulator training.

- **Keywords:** Burnout, job crafting, job demands-resources theory, happiness, simulator training performance

Heikki Mansikka, Kai Virtanen & Don Harris. *Comparison of NASA-TLX scale, modified Cooper–Harper scale and mean inter-beat interval as measures of pilot mental workload during simulated flight tasks. Pages: 246-254.*

The sensitivity of NASA-TLX scale, modified Cooper–Harper (MCH) scale and the mean inter-beat interval (IBI) of successive heart beats, as measures of pilot mental workload (MWL), were evaluated in a flight training device (FTD). Operational F/A-18C pilots flew instrument approaches with varying task loads. Pilots' performance, subjective MWL ratings and IBI were measured. Based on the pilots' performance, three performance categories were formed; high-, medium- and low-performance. Values of the subjective rating scales and IBI were compared between categories. It was found that all measures were able to differentiate most task conditions and there was a strong, positive correlation between NASA-TLX and MCH scale. An explicit link between IBI, NASA-TLX, MCH and performance was demonstrated. While NASA-TLX, MCH and IBI have all been previously used to measure MWL, this study is the first one to investigate their association in a modern FTD, using a realistic flying mission and operational pilots. **Practitioner summary:** NASA-TLX scale, MCH scale and the IBI were evaluated in a flight training device. All measures were able to differentiate most task conditions and there was a positive correlation between NASA-TLX and MCH scale. An explicit link between IBI, NASA-TLX, MCH and performance was demonstrated.

- **Keywords:** Pilot mental workload, NASA-TLX scale, modified Cooper–Harper scale, inter-beat interval

Neville A. Stanton, Katherine L. Plant, Aaron P. Roberts & Craig K. Allison. *Use of Highways in the Sky and a virtual pad for landing Head Up Display symbology to enable improved helicopter pilots situation awareness and workload in degraded visual conditions. Pages: 255-267.*

Flight within degraded visual conditions is a great challenge to pilots of rotary-wing craft. Environmental cues typically used to guide interpretation of speed, location and approach can become obscured, forcing the pilots to rely on data available from in-cockpit instrumentation. To ease the task of flight during degraded visual conditions, pilots require easy access to flight critical information. The current study examined the effect of 'Highways in the Sky' symbology and a conformal virtual pad for landing presented using a Head Up Display (HUD) on pilots' workload and situation awareness for both clear and degraded conditions across a series of simulated rotary-wing approach and landings. Results suggest that access to the HUD lead to significant improvements to pilots' situation awareness, especially within degraded visual conditions. Importantly, access to the HUD facilitated pilot awareness in all conditions. Results are discussed in terms of future HUD development. **Practitioner Summary:** This paper explores the use of a novel Heads Up Display, to facilitate rotary-wing pilots' situation awareness and workload for simulated flights in both clear and degraded visual conditions. Results suggest that access to HUD facilitated pilots' situation awareness, especially when flying in degraded conditions.

- **Keywords:** Rotary-wing, head-up display, situation awareness, workload, Highways in the Sky

Daniel Martin & Jim Nixon. *Helicopter pilots' views of air traffic controller responsibilities: a mismatch. Pages: 268-276.*

Controllers and pilots must work together to ensure safe and efficient helicopter flight within the London control zone. Subjective ratings of pilot perception of controller responsibility for five key flight tasks were obtained from thirty helicopter pilots. Three

types of airspace were investigated. Results indicate that there is variation in pilot understanding of controller responsibility compared to the formal regulations that define controller responsibility. Significant differences in the perception of controller responsibility were found for the task of aircraft separation in class D airspace and along helicopter routes. Analysis of the patterns of response suggests that task type rather than the airspace type may be the key factor. Results are framed using the concept of a shared mental model. This research demonstrates that pilots flying in complex London airspace have an expectation of controller responsibility for certain flight tasks, in certain airspace types that is not supported by aviation regulation. **Practitioner Summary:** The responsibility for tasks during flight varies according to the flight rules used and airspace type. Helicopter pilots may attribute responsibility to controllers for tasks when controllers have no responsibility as defined by regulation. This variation between pilot perceptions of controller responsibility could affect safety within the London control zone.

- **Keywords:** Transportation safety, shared mental model, helicopter, air traffic controller

Álvaro Bustamante-Sánchez, Miguel Delgado-Terán & Vicente Javier Clemente-Suárez. *Psychophysiological response of different aircrew in normobaric hypoxia training*. Pages: 277-285.

Hypoxia remains the most important hazard in high altitude flights, but there is still a need for deeper analysis of the effect of hypoxia exposition in the psychophysiological and cognitive functions. The aim of this study was to study the effect of hypoxia training in cortical arousal, autonomic modulation, muscle strength and cognitive function. We analysed 23 male aircrew personnel of the Spanish Army and Air Force (10 Helicopter Pilots, 7 Transport Aircrew, 3 Transport Pilots and 3 F-18 Fighter Pilots) before, during and after a normobaric hypoxia exposition. Hypoxia produced an increase in perceived stress and effort, a higher Heart Rate and a decreased function of breath muscles. Working memory and pattern recognition were impaired after hypoxia exposition. Significant differences were found in cognitive tests performance among aircrew groups, suggesting differences on their previous training. These results can improve specific training for better preparation of pilots and aircrews for hypoxic threats. **Practitioner summary:** Distinct aircrew preparation produces a different hypoxia exposition effect on psychophysiological response and cognitive functions. Hypoxia produced an increase in Heart Rate, a decreased function of breath muscles, being more negatively affected in Transport Pilots. Cognition abilities were impaired after hypoxia exposition, independently of the aircrew group.

- **Keywords:** Hypoxia, aircrew, cognitive function, autonomic modulation, spirometry

Louise V. Coutts, Katherine L. Plant, Mark Smith, Luke Bolton, Katie J. Parnell, James Arnold & Neville A. Stanton. *Future technology on the flight deck: assessing the use of touchscreens in vibration environments*. Pages: 286-304.

Use of touchscreens in the flight deck has been steadily increasing, however, their usability may be severely impacted when turbulent conditions arise. Most previous research focusses on using touchscreens in static conditions; therefore, this study assessed touchscreen use whilst undergoing turbulent representative motion, generated using a 6-axis motion simulator. Touchscreens were tested in centre, side and overhead positions, to investigate how turbulence affected: (1) error rate, movement times and accuracy, (2) arm fatigue and discomfort. Two touchscreen technologies were compared: a 15" infra-red and a 17.3" projected capacitive touchscreen with force sensing capability. The potential of the force sensing capability to minimise unintentional

interactions was also investigated. Twenty-six participants undertook multi-direction tapping (ISO 9241; ISO 2010) and gesture tasks, under four vibration conditions (control, light chop, light turbulence and moderate turbulence). Error rate, movement time and workload increased and usability decreased significantly, with screen position and increasing turbulence level. **Practitioner Summary:** This study evaluated the use of infra-red and projected capacitive touchscreen technologies using multi-directional tapping and gesture tasks, whilst being subjected to different levels of turbulence representative motion. Performance degraded significantly with increasing turbulence level and touchscreen location. This has implications for future flight deck design.

- **Keywords:** Aviation, touchscreens, cockpit, turbulence, multi-directional tapping test

Peter Kearney, Wen-Chin Li, Chung-San Yu & Graham Braithwaite. *The impact of alerting designs on air traffic controller's eye movement patterns and situation awareness.* Pages: 305-318.

This research investigated controller's situation awareness by comparing COOPANS's acoustic alerts with newly designed semantic alerts. The results demonstrate that ATCOs' visual scan patterns had significant differences between acoustic and semantic designs. ATCOs established different eye movement patterns on fixations number, fixation duration and saccade velocity. Effective decision support systems require human-centered design with effective stimuli to direct ATCO's attention to critical events. It is necessary to provide ATCOs with specific alerting information to reflect the nature of the critical situation in order to minimise the side effects of startle and inattentive deafness. Consequently, the design of a semantic alert can significantly reduce ATCOs' response time, therefore providing valuable extra time in a time-limited situation to formulate and execute resolution strategies in critical air safety events. The findings of this research indicate that the context-specified design of semantic alerts could improve ATCO's situational awareness and significantly reduce response time in the event of Short Term Conflict Alert (STCA) activation which alerts to two aircraft having less than the required lateral or vertical separation. **Practitioner Summary:** Eye movements are closely linked with visual attention and can be analysed to explore shifting attention whilst performing monitoring tasks. This research has found that context-specific designed semantic alerts facilitated improved ATCO cognitive processing by integrating visual and auditory resources. Semantic designs have been demonstrated to be superior to acoustic design by directing the operator's attention more quickly to critical situations.

- **Keywords:** Air traffic management, alerting design, eye movement patterns, situation awareness, visual attention

Chiara P. Ryffel, Celine M. Muehlethaler, Sandro M. Huber & Achim Elfering. *Eye tracking as a debriefing tool in upset prevention and recovery training (UPRT) for general aviation pilots.* Pages: 319-329.

Upset prevention and recovery training (UPRT) is intended to improve the ability of pilots to recognize and avoid situations that can lead to airplane upsets and to improve their ability to recover control of an airplane that has exceeded the normal flight envelope. To this end, a set of different training contents – from theoretical knowledge of aerodynamics and human factors to practice-based flight training – is necessary. In order to support the debriefing with an objective feedback, and because visual scanning is a core competence, two studies on subjective evaluation of aviation pilots – one conducted in a flight simulator and the other one in-flight – focussed on the practical application of eye tracking as a debriefing tool in UPRT. From a practitioner's perspective, eye tracking appeared to be a useful method in terms of visualising instrument scanning techniques, supporting the instructor with objective debriefing material and fostering self-awareness in human processes. The discussion recommends adjusted UPRT instructor training and

further improvements to eye tracking hardware and software. **Practitioner Summary:** The article focuses on pilot evaluations of eye tracking as a debriefing tool in UPRT and the identification of critical elements in its use. Eye tracking is a promising debriefing tool for UPRT. The discussion points to desirable improvements of eye tracking hardware and software as well as adjustments to instructor training that are pertinent.

- **Keywords:** Aviation, debriefing, eye tracking, feedback tool, upset prevention, recovery training

Elizabeth L. Miller, Samuel M. Lapp & Matthew B. Parkinson. *The effects of seat width, load factor, and passenger demographics on airline passenger accommodation.* Pages: 330-341.

The objective of this work is to demonstrate a method for examining the competing effects of secular trends in body size, seat size and configuration, and the increased load factor of aeroplanes. The method uses statistical modelling and virtual fit testing to provide a flexible environment for exploring the impact of various parameters on passenger accommodation. A case study demonstrates the method by exploring the effect of seat width on the accommodation of US civilians (based on seated hip breadth). The case study demonstrates that recent trends of decreasing seat widths and increasing load factors lead to higher disaccommodation. Based on anthropometry and virtual fit, women are also shown to be disproportionately disaccommodated compared to men. **Practitioner summary:** Airlines are reducing seat width at the same time that individuals worldwide are getting larger. Flights are increasingly crowded, with load factor at a record high. This paper explores the effects of seat width on passenger accommodation under several scenarios involving load factor, demographics, and passenger seating allocation strategies.

- **Keywords:** Anthropometry, design for human variability, aviation, seating