

Multimodal detection of an electric aircraft propulsion system failure

Ahmed, Lamyeya; Bromfield, Mike

Document Version

Early version, also known as pre-print

Citation for published version (Harvard):

Ahmed, L & Bromfield, M 2024, Multimodal detection of an electric aircraft propulsion system failure. in *Contemporary Ergonomics & Human Factors 2024*. Chartered Institute of Ergonomics & Human Factors, pp. 400-402, Ergonomics & Human Factors 2024, Kenilworth, United Kingdom, 22/04/24.

[Link to publication on Research at Birmingham portal](#)

General rights

Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

- Users may freely distribute the URL that is used to identify this publication.
- Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
- User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
- Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy

While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Multimodal detection of an electric aircraft propulsion system failure

Lamyeya Ahmed¹, Michael A. Bromfield²

¹ Aerospace Engineering Master's Student, University of Birmingham and Corresponding Author, ² Associate Professor in Aerospace, University of Birmingham. CIEHF Member.

SUMMARY

The need for sustainable aviation has accelerated the development of electric aircraft and propulsion systems. These systems generate less noise when compared to conventional piston engines (Moshov & Toropylina, 2022) and in the event of a failure provide limited cues to the pilot. If pilots fail to recognise the situation and take prompt recovery action, powerplant failure is often followed by an aerodynamic stall and loss of control in flight (Smith & Bromfield, 2022). The aim of this research is to investigate the effects of multimodal presentation of the propulsion system status to improve pilot response times in the event of an electric propulsion systems failure. A human centred design approach was used to develop multimodal presentation of data using visual, auditory and visual/auditory feedback in combination. Simulated flights were conducted in a fixed-base flight simulator with control and experimental groups of student pilots (n=8). Results indicate that pilot response times are reduced when using a combination of visual/auditory presentation.

KEYWORDS

Electric Aircraft, Multimodal Presentation, Response Time, Workload, Propulsion System Usability

Introduction

Safety is paramount in aviation and the presentation of essential, contextual information for the management of an electric or hybrid aircraft's propulsion system is relatively new. The aim of this research is to investigate the effects of multimodal presentation of the propulsion system status to improve pilot response times in the event of an electric propulsion systems failure. The objectives of this research are to design multimodal presentation of essential data to enhance detection of engine failure, to reduce the workload of a pilot during emergencies and to determine the usability of different information presentations. This will inform future design of propulsion system monitoring and alerting systems for use in electric aircraft.

Methodology

Auditory presentation (A) was developed using a sound effects engine comprising a tone sine wave for sonification (Kramer, et al., 1999) with frequency proportional to the aircraft propulsion system revolutions per minute (RPM). A separate sound file, featuring a female voice aural alert annunciating "Engine failure" was created for engine failure events. The visual presentation (V) used a simulated Head Up Display (HUD), created using a game engine, and was positioned to the left of the pilot's forward field-of-view in the cockpit on the central visuals display of the simulator. A red warning cross ("X") with the caption "Engine Failure" was also presented during an engine failure. The multimodal presentation (VA) was the combination of the visual (V) and auditory (A) presentations, in addition to the conventional cockpit instrument displays (N). A fixed-base engineering flight simulator was used to simulate flights and propulsion system failures. Eight student pilots (mean age: 20.6, mean real aircraft flying hours: 11.5) were divided equally into control and experimental groups. A between-groups experimental mixed design was used with participants performing four simulated flight scenarios (normal take-off, normal approach, take-off with engine failure, glide approach (base

to finals with engine failure), with presentation (experimental group) or without presentation (control group). To avoid learning effects, the scenario sequence was pseudo-randomised and balanced for each group. Engine failure was also pseudo-randomised and manually triggered using the Flight Instructor/Operator Station at approximately 400 ft above ground level (AGL) for take-off and 750 ft AGL for the approach. Participants were instructed to press a button on the control yoke in the event of an engine failure, enabling response times to be captured. System usability was assessed using the System Usability Scale (Brooke, 1996) and workload using NASA-TLX (Hart & Staveland, 1988) after completion of each scenario.

Preliminary Results Analysis and Discussion

Preliminary results comparing Control vs Experimental Groups showed that, during take-off with engine failure, multimodal presentation (VA) response times were 1.27s faster than no presentation (N) response times. For the glide approach, multimodal presentation (VA) response times were 1.29s faster than no presentation (N). The multimodal (VA) results are consistent with previous research findings of Spence & Santangelo (Spence & Santangelo, 2007), where response times during high perceived load were improved using audio-visual cueing. Some participants commented that they used RPM sonification and the aural alert, as their primary source of information on system status. Some participants primarily used the appearance of the red cross as an indication of propulsion system failure. Visual presentation (V) ranked the highest for usability, however this may have been influenced by participants' preferred feedback styles (Chui, et al., 2020). SUS is normally used for the assessment of display design, using terminology more associated with displays and this may have also influenced feedback. During system failures, a minority of participants, were (task) fixated on establishing the appropriate glide speed and this delayed pressing the confirmation button or in one case forgetting to press the button at all.

Conclusions

Preliminary results with respect to response times for different presentation are encouraging. Subjective feedback regarding multimodal (VA) presentation was positive. Further analysis of the simulated flight data (including pilot control inputs) is needed to investigate response times more comprehensively. The experiment will be repeated with more participants, results consolidated and a full statistical analysis completed on all measures. This research will inform human-centred, future electric aircraft cockpit and HUD design. It has the potential to contribute to the prevention of loss of control in-flight accidents for electric/hybrid propulsion due to system failure.

References

- Brooke, J., 1996. SUS: A "quick and dirty" usability scale. In: Usability evaluation in industry. London: Taylor & Francis, p. 189–194.
- Chui, T. K., Molesworth, B. R. & Bromfield, M. A., 2020. Feedback and student learning: Matching learning and teaching style to improve student pilot performance. *The Int. Journal of Aerospace Psychology*, 31(2), pp. 71-86.
- Hart, S. & Staveland, L., 1988. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. *Advances in psychology*, Volume 52, pp. 139-183.
- Kramer, G. et al., 1999. Sonification Report: Status of the Field and Research Agenda. Prepared for the National Science Foundation by members of the International.
- Spence, C. & Santangelo, V., 2007. Multisensory Cues Capture Spatial Attention Regardless of Perceptual Load. *Journal of experimental psychology. Human perception and performance*, 33(6), pp. 1311-1321. doi: 10.1037/0096-1523.33.6.1311.
- Smith, J. & Bromfield, M.A., (2022) "General Aviation Loss of Control in Flight Accidents: Causal and Contributory Factors," *Journal of Air Transportation*, Vol. 30, No. 4 (2022), pp. 137-153 <https://doi.org/10.2514/1.D0286>