Review of UAV Loss of Control In-Flight

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Review of UAV Loss of Control In-Flight: Accidents and Incidents

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SUMMARY

Sixty Uncrewed Aerial Vehicle accident reports were analysed to identify possible causal and contributory factors leading to loss of control in flight and recovery actions where applicable. Manufacturing and design errors were dominant in 22 causal factors (34% of events) and 18 contributory factors (22% of events) (e.g. ingestion of precipitation). Recovery was not attempted in 35 (55%) events. The relationship between age, total hours experience, hours experience on type, recovery attempts and number of accidents increase with operator age or lack of experience was also analysed. As total experience increases the number of accidents and attempted recovery increases. All this information is presented in a framework adapted from the Accident Route Matrix to recognise loss of control in flight in future accidents and improve recovery response.

KEYWORDS

UAV, LOC-I, accident, Causal Factors, Contributory Factors

Introduction

Loss of control in flight (LOC-I) is the most frequent and significant cause of accidents for commercial and general aviation (IATA, 2019). LOC-I has been recently re-defined for both commercial (Bromfield & Landry, 2019) and general aviation (Smith & Bromfield, 2022) but no definition exists for UAVs. Despite accidents involving uncrewed aerial vehicles (UAVs) being 30 times higher than crewed aerial vehicles (McCarley et al), the causes of these accidents have not been previously investigated. The aim of this research is to identify the main causal and contributory factors leading to LOC-I for UAVs, considering human factors, automation levels and recovery methods to attempt to regain control. Sixty UK Air Accident Investigation Board civil aircraft accident and serious incident reports for UAVs within the UK, were analysed to help define LOC-I for UAVs and provide an illustrative framework for accident analysis and consistency in reporting.

Preliminary Analysis

Pre-conditions are operating conditions that do not alter before or during flight but may have an impact on commander's response in case of an upset. These include commander's age and experience and the type of operation. Each accident was thoroughly analysed to identify and categorise the main causal and contributory factors. The causal factors were identified as actions, omissions, events, conditions, or a combination thereof, that led to an accident or incident (McCarley et al., 2004). All other events after the primary causal event were considered as contributory factors. The accidents were categorised through a normalisation process based on their similarity and these categories were analysed using statistics. The main causal factors (34%) and contributory factors (22%) leading to LOC-I for UAVs were manufacturing failures. Issues related to human factors in UAVs were based on the interaction of the operator with the aircraft since they are not co-located (McCarley et al.,2004). To analyse the effect of human error on UAV operations, the main factors considered with respect to the number of accidents were: recovery methods attempted after LOC-I, the level of UAV automation, the operator's interface and reliance on autonomous features, the operator's age, total hours of experience/experience on type. Only three of the total number of accidents where recovery was attempted (45%) were successful. In 55% of accidents recovery was not attempted and this was due to insufficient time, the pilot losing sight of the UAV or not recognising LOC-I due to warning messages not being displayed. This infers pilot's inherent trust in automation and high reliance on 'fail-safe' functions and warning messages to recognise LOC-I.   Previous literature suggests that most human errors are caused by design inconsistencies of the ground control station (GCS) and failure in autonomous devices to predict or respond to all scenarios (Nilsson, 2011). The results of the accident analyses suggest that lower age groups (20-29 years) may rely more on automation during recovery. The largest reliance on 'return to home' and 'kill switch' functions was found for operators with less than 100 hours of experience. This may also be linked to lack of knowledge on how to use the equipment provided and/or low situation awareness. The results suggest that as experience on type increases, situation awareness and readiness of the pilot may also increase, helping to prevent LOC-I.

Proposed LOC-I Methodology for UAVs

LOC-I definitions and supporting frameworks for analysis of events have been devised for commercial aviation (Bromfield & Landry, 2019) and general aviation (Smith & Bromfield, 2022). However, for UAV LOC-I events, a considerably different operating environment, requires a more flexible, qualitative approach.   The Accident Route Matrix (NASEM, 1998) offers a more suitable 'hybrid' approach benefitting from the high-level fixed categories of Human Factors Analysis and Classification System (HFACS, 2014) in combination with the flexibility of AcciMap framework (Systems Thinking Lab, 2023). This approach has enabled the inclusion of all identified (and normalised) UAV accident causal and contributory factors. The use of a timeline in the ARM approach also allows these factors to be presented in a sequence of events leading to LOC-I, including operator's response, the main post-flight procedures, and recovery response whether successful or not (Figure 1).

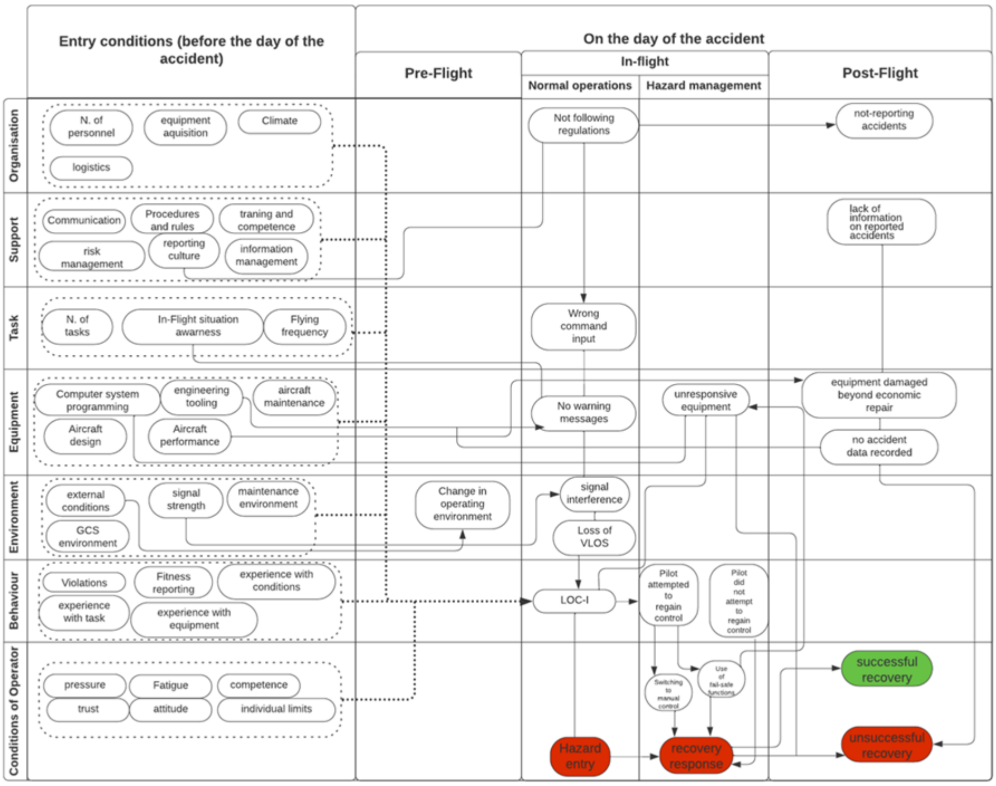

Figure 1: UAV LOC-I framework (adapted from ARM)

References

Bromfield, M. A. & Landry. S. J., (2019) "Loss of Control In Flight (LOC-I) – Time to Re-define?", (AIAA 2019-3612), 2019 Aviation Technology, Integration, and Operations Conference, Dallas, Texas, USA, 17-21 June 2019 https://doi.org/10.2514/6.2019-3612

HFACS Inc, (2014), The HFACS Framework, HFACS Incorporate, [retrieved 17 Feb 2023]. Available from: https://www.hfacs.com/hfacs-framework.html

IATA (2019), Loss of Control In-Flight Accident Analysis Report Edition 2019 Guidance Material and Best Practices. 2019.

McCarley, J.S. & Wickens, C.D., (2004), Human Factors Implications of UAVs in the National Airspace, Federal Aviation Administration.

NASEM (1998), Improving the Continued Airworthiness of Civil Aircraft: A Strategy for the FAA's Aircraft Certification Service. National Academies of Sciences, Engineering, and Medicine, Washington, DC: The National Academies Press. https://doi.org/10.17226/6265

Nilsson, S.J. (2011), Relationship between Recent Flight Experience and Pilot Error General Aviation Accidents, PhD Dissertation, Northcentral University, Prescott Valley, Arizona, USA, May 2011.

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

Systems Thinking Lab, AcciMap, [retrieve 17 Feb 2023]. Available from: https://systemsthinkinglab.com/accimap/

Weedon S., Cutler V & Revell S., (2014), A Trend Analysis of Human Factors Issues in UK Military Aviation, Royal Airforce Centre of Medicine, Bedfordshire, UK.