An electric aircraft accident case study – human factors analysis and lesson learned

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SUMMARY

An electrically powered aircraft was conducting flight tests, under experimental flight rules when power to the electrical motors was lost. The two-person crew took 9 seconds to identify the failed system and attempt recovery actions which were unsuccessful and the pilot landed in a field adjacent to the airport resulting in severe damage to the aircraft. HFACs was used to identify causal and contributory factors and highlight key learning points. The results informed changes to UK CAA experimental flight rules related to flight test organisation, use of system controls, positioning of displays and the availability of alerts and warnings.

KEYWORDS

Accident investigation, electric aircraft, human factors, regulation, flight test

Introduction – the accident

The electrically powered aircraft conducting flight tests under E Conditions (CAA, 2019) experienced a loss of power during an interruption of the power supply (AAIB, 2022). During this interruption the windmilling propeller generated a voltage high sufficient to lock out the power to the motors. The pilot and observer were unable to reset the system and restore electrical power and the pilot made a forced landing. The aim of this research is to identify possible/probable causal and contributory factors and highlight key learning points to inform future design, development and flight testing of electric or hybrid-electric aircraft.

Method

An in-depth review of the aircraft accident report (AAIB, 2022) was conducted using the Human Factors Analysis and Classification System (Wiegman & Shappell, 2002). HFACS is commonly used in aircraft accident investigation and the author has extended it to include social, economic or political factors (latent outside influences) and aircraft handling qualities and certification (active or latent preconditions for unsafe acts). Guidelines for the design and evaluation of flight deck displays and controls (FAA, 2016) and cockpit assessments (Qinetiq, 2015) were used to assess the cockpit environment. Regulation for the operation of aircraft under experimental conditions at the time of the accident was reviewed (CAA, 2019).

Results

An independent review of the accident report (AAIB, 2019) and the application of HFACS by the author yielded the following contributory factors within the extended HFACS framework.

Outside influences (latent)

The pressure to be ‘first to market’ and demonstrate flight with a zero-emission aircraft were likely to be present (social). The company received external grant funding and were committed to deliver on-time within the allocated budget. The flight test programme was delayed and this may have led to additional internal (unfunded) costs (economic/commercial pressures).

Organisational influences (latent)

Most specialist staff were from outside of the aviation industry. The competent person responsible for flight testing, lacked formal flight test education, training and experience. Flight test observer and flight test director lacked flight test education, training and experience (resource management). Staff were passionate and highly motivated working in a fast-paced and goal-oriented problem solving environment. Safety was not talked about as a key priority, essential in a flight testing environment (culture). There were few prescribed procedures and staff were given autonomy to develop practical workarounds or adaptions to solve problems and overcome constraints. There was a lack of independent risk assessment of the flight test programme and lack of post-flight debrief including 'lesson learned' (organisational process).

Unsafe supervision (latent)

The competent person responsible for flight testing was not actively engaged in flight test activities. The competent person did not enlist the help of other individuals with the appropriate knowledge, skills and experience for a project of this complexity (inadequate supervision). There was inappropriate test planning and organisation and lack of guidance on functional links between individuals in charge of flight test activity or how coordination was to be achieved. 'Plan to fly' and 'fly to plan' flight test principles were not followed (planned inappropriate operations). The propulsion system had failed on two previous flights however the risk assessment was not updated (failed to correct problem).

Preconditions for Unsafe Acts (active or latent)

Operational constraints at the airfield provided limited options for a forced landing. Poor design and positioning of the propulsion system management displays resulted in delays to identify/confirm situation. Blanking out of selected legacy instruments required adaption of pilot instrument scanning. A step to retard power lever in Aircraft Flight Manual (AFM) emergency procedures was missing. Propeller speed was controlled by rotary control fitted to side of power level quadrant (unconventional) (environmental factors/technological environment). There was a lack of Crew Resource Management/Threat & Error Management training in a flight test environment. The multi-crew flight test environment was treated as a single pilot operation with an observer (personnel factors/Crew Resource Management). The landing performance of the aircraft was not considered by the pilot. The aircraft was loaded above maximum take-off weight for the basic (unmodified) aircraft and 60 lb below the E-conditions limit. This meant that the aircraft was 'heavy' to fly resulting in degraded climb performance (condition of aircraft/handling qualities).

Unsafe Acts/Errors (active)

The pilot did not call for the emergency checklist. Multiple attempts were made to restart resulting in degraded flight path management. Flaps and landing gear lowered late (errors/decision errors). The aircraft deviated from heading on the downwind leg, deviated from height during base and finals then misjudged the forced landing (errors/skill-based). The lack of situation awareness during the propulsion system troubleshooting resulted in an overshoot of the runway (errors/perceptual).

Summary

‘First to market’ and commercial pressures led to workarounds and adaptions. Attention to safety and risk assessment were compromised due to lack of formal flight test education. The competent person was not an integral part of the flight test team (CRM). The design of the human-machine interface was sub-optimal for a high-risk test environment, resulting in reduced situation awareness for both pilot and observer. Procedural errors and delays led to deviation from the intended circuit pattern and approach profile.

Conclusions

This case study has highlighted the importance of an integrated approach to the application of human factors principles to design and development in a high risk, flight test environment where crew training and a systems thinking approach are essential for safe outcomes. Appropriate knowledgeable, skilled and experienced resources are essential to support technically challenging programmes. Regulatory oversight needs to be measured to keep pace with technological advancement but not stifle innovation. As a result of this analysis and recommendations made in the AAIB report (AAIB, 2022), changes to the E Conditions regulation were made with respect to the design of cockpit displays, controls, alert and warning systems (CAA, 2024).

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