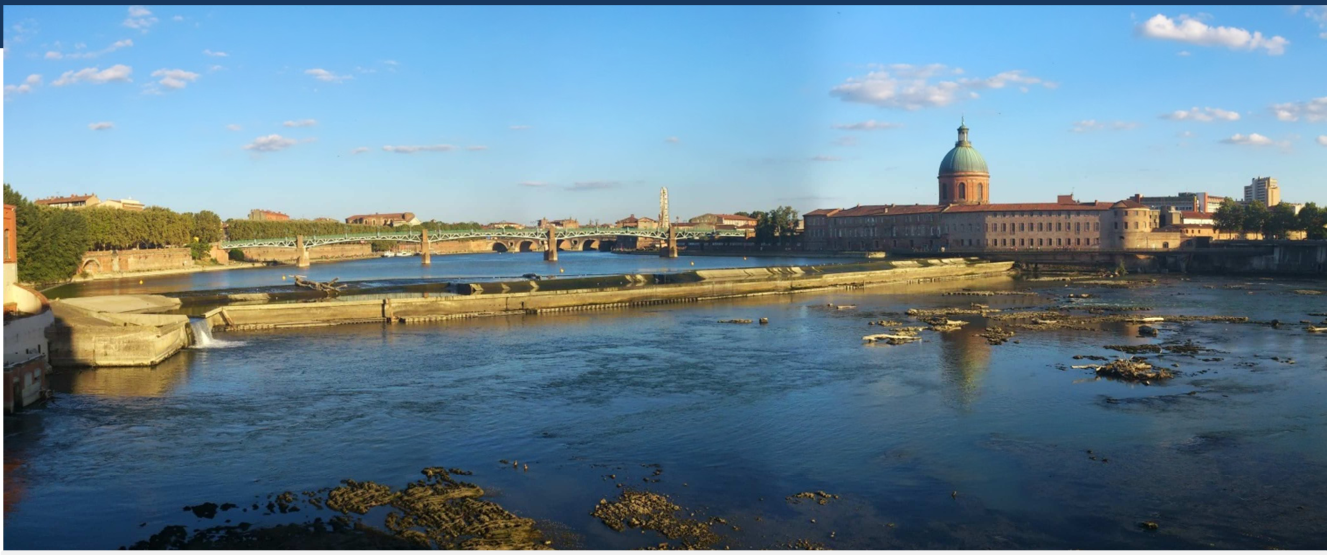

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Lessons learnt from Boeing 737 MAX accidents about human factor considerations in aircraft design and certification

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Content

Recently two newly certified Boeing 737-8 (MAX) (Lion Air flight JT610 and Ethiopian Airlines flight ET302) crashed within 4 months resulting in 346 fatalities. The causes of both accidents are similar: the unintended and repetitive activations of the Maneuvering Characteristics Augmentation System (MCAS), which resulted in repetitive aircraft nose down commands through horizontal stabilizer trim. The crews were not able to resolve the abnormal situation. Flight LNI043 just preceding the JT610 accident faced a similar situation resolved with major difficulties.

MCAS is a flight law, implemented in Flight Control Computers (FCC), introduced by Boeing in B737 type definition as part of the modification from NG to MAX and certified under FAA regulations, the resulting amended type certificate being validated by various other aviation authorities.

One common root cause to the 3 events is that pilot's FCC is fed with erroneous data from left angle of attack (AoA) sensor, thus triggering MCAS. This led to increased crew workload at low altitude with 3 simultaneous visual cockpit alerts and a physical alert (stick shaker); an expected alert (AOA DISAGREE) was not raised because of a design issue whose resolution was ongoing. During the 2 accident flights, crews were not able to correctly identify the aircraft situation and take related actions for continued safe flight. It required 3 minutes and 40 seconds to LNI043 crew to resolve the abnormal situation with the help of an additional crewmember.

Boeing's assumptions and evaluation methods used for safety assessment of the modified longitudinal control of B737 MAX apparently did not sufficiently consider cockpit effects (workload, situation awareness) of MCAS unintended activation and its possible causes (e.g. erroneous AoA), nor the resulting crew actions. They are based on engineering experience and regulatory requirements/guidance, complemented by interpretation in the context of successive aircraft modifications on B737 type.

Through analysis of official reports, our aim is to evaluate, with a safety improvement perspective, the following underlying human and human-machine interaction factors that may have contributed to those accidents.

- Cockpit situational awareness and pilot recognition of failures, in highly integrated aircraft systems: helping pilots to diagnose failures and prioritize its actions with quick reaction time and appropriate understanding of abnormal situation (application of CS/FAR25.1322);
- Assumptions about crew behavior during design and system safety analysis: complexity of full evaluation of abnormal scenarios based on regulatory guidance and previously validated assumptions, emphasized when modifying an existing safety-proven aircraft (consideration of human factors impacts and training as a related areas in application of 21A.101 - Change Product Rule)
- Decision taking for design choices: design decisions about MCAS could be seen as a "tunnel effect" with a focus on positive compliance demonstration to prescriptive requirements, and insufficient design-to-safety considerations possibly aided by low involvement of airworthiness engineers at appropriate levels;
- Maintenance human factors: as human decisions in maintenance significantly contributed to erroneous AoA value in JT610 accident, improvement of troubleshooting and repair to perform an evaluation of the airworthiness status of integrated aircraft system.

Keywords : Model-based architecture design, Task scheduling, Safety analysis