Workshop - Design of Dependable Systems – Fundamentals of Aircraft Safety
7th Scandinavian Conference on SYSTEM & SOFTWARE SAFETY, Stockholm, October 22-23, 2019

Design of Dependable Systems
Fundamentals of Aircraft Safety
Part 3

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Schedule

- 11:00-12:00 Part 3
  - Accident 2 – Ethiopia, 10th of March 2019
  - The aftermath from the accidents
    - JATR's final report to FAA
  - Boeings serious attempt to change the safety culture
  - Discussions

Accident 2 – Ethiopia - I

13th of March 2019

- 05:37:34 UTC, take-off clearance was issued
  - Flap settings 5 degrees
  - Stabilizer settings 5.6 units
  - Normal take-off
  - captain was the pilot flying

- 05:38:44, the left and right AoA deviated
  - Left AoA sensor first decreased then increased
  - Left AoA sensor saturated? To 74.5 degrees
  - Right AoA showed max 15.3 degrees

- Due to the high left AoA value, the left stick shaker activated and remained active the rest of the flight

Source: Aircraft Accident Investigation Preliminary Report
Ethiopian Airlines Group, B737-8 (MAX) Registered ET-AVJ
28 NM South East of Addis Ababa, Bole International Airport
March 10, 2019, Report No. AI-01/19

Accident 2 – Ethiopia - II

13th of March 2019

- 05:39:22, autopilot engaged
  - Flaps retracted
  - pitch trim position decreased to 4.6 units

- 05:39:50, captain asked first-officer to request to maintain runway heading (he knew they were in serious trouble)

- 05:39:55, autopilot disengaged

Source: Aircraft Accident Investigation Preliminary Report Ethiopian Airlines Group, B737-8 (MAX) Registered ET-AVJ 28 NM South East of Addis Ababa, Bole International Airport March 10, 2019, Report No. AI-01/19

Accident 2 – Ethiopia - III

13th of March 2019

- 05:39:57, captain asked first officer again to request to maintain runway heading plus that they had flight control problems

- 05:40:00, DFDR recorded automatic AND for 9 seconds
  - Pitch trim moved from 4.60 to 2.1 units
  - The aircraft stopped ascending and descended slightly

Source: Aircraft Accident Investigation Preliminary Report Ethiopian Airlines Group, B737-8 (MAX) Registered ET-AVJ 28 NM South East of Addis Ababa, Bole International Airport March 10, 2019, Report No. AI-01/19

Accident 2 – Ethiopia - IV

13th of March 2019

- 05:40:06, the column moved aft and positive climb was established

- 05:40:12, three seconds after the AND movement stopped, electric trim of stabilizer (ST) was recorded (ANU movement)
  - Pitch trim moved from 2.1 to 2.4 units
  - Pitch remained the same (backpressure on the column)

- 05:40:20, five seconds after the end of ANU stabilizer motion, a second instance of AND stabilizer trim occurred
  - Pitch trim moved to 0.4 units

Source: Aircraft Accident Investigation Preliminary Report
Ethiopian Airlines Group, B737-8 (MAX) Registered ET-AVJ
28 NM South East of Addis Ababa, Bole International Airport
March 10, 2019, Report No. AI-01/19

Accident 2 – Ethiopia - V

13th of March 2019

- 05:40:28, the DFDR records that the pilots perform manual electric trim in the ANU direction
  - Pitch trim reached 2.3 units

- 05:40:35, stab trim cut out was performed

- 05:40:41, approx. five seconds after the end of the ANU stabilizer movement, a third AND stabilizer movement occurred without motion on the stabilizer
  - Stab trim cut out switches were in cut off position

Source: Aircraft Accident Investigation Preliminary Report Ethiopian Airlines Group, B737-8 (MAX) Registered ET-AVJ 28 NM South East of Addis Ababa, Bole International Airport March 10, 2019, Report No. AI-01/19

Accident 2 – Ethiopia - VI

13th of March 2019

- 05:40:42 to 05:43:11, the stabilizer moves slowly in the AND direction
  - pitch trim 2.3 to 2.1 units at the same time both pilots both are trying to push back the control columns

- 05:41:32, left overspeed warning

- 05:41:46, the captain asked the first-officer if the trim is functional
  - The first officer replied that it is not working properly
  - The first officer tried to manually trim
  - The first officer told the captain it is not working

Source: Aircraft Accident Investigation Preliminary Report
Ethiopian Airlines Group, B737-8 (MAX) Registered ET-AVJ
28 NM South East of Addis Ababa, Bole International Airport
March 10, 2019, Report No. AI-01/19

Accident 2 – Ethiopia - VII

13th of March 2019

- 05:43:04, the captain asked the first officer to pitch up together and said pitch is not enough

- 05:43:11, two momentary manual electric trim inputs are recorded in the ANU direction
  - Stabilizer moves from 2.1 to 2.3 units

- Approx. five seconds after the last manual electric trim, an AND automatic trim condition occurred
  - Stabilizer moves from 2.3 to 1.0 unit in 5 s

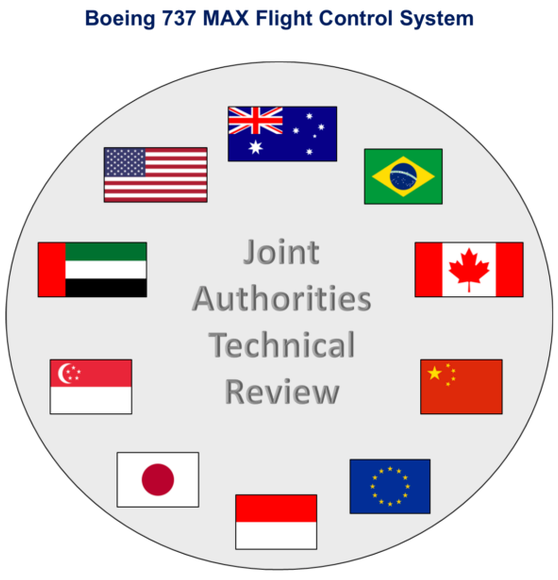
- Point of no return was reached
  - 40 degrees nose down
  - Left IAS recorded 458 kts
  - Right IAS recorded 500 kts

Source: Aircraft Accident Investigation Preliminary Report Ethiopian Airlines Group, B737-8 (MAX) Registered ET-AVJ 28 NM South East of Addis Ababa, Bole International Airport March 10, 2019, Report No. AI-01/19

Aftermath

- On June 1, 2019, FAA asked for a Joint Authorities Technical Review (JATR) on observations, findings and recommendations over FAA's aircraft certification process for the Boeing 737 MAX Flight Control System
  - The review spanned over the whole certification process
  - The idea was not to accelerate the MAX to service

- The JATR report was released on October 11, 2019
  - 12 recommendations



JATR Report -
Recommendation 1 (Page1 of 2)

- FAA should work with other civil aviation authorities to revise harmonized approach to the certification of changed products
  - Guidance documents should be revised to require a top-down approach whereby every change is evaluated from an integrated whole aircraft system perspective

JATR Report -
Recommendation 1 (Page 2 of 2)

- Changes to documentation should include the following key principles

"*A comprehensive integrated system-level analysis recognizing that in this complex interactive system,* ***every change could interact with other parts of the system***"

"The assessment of proposed design changes on existing systems at the aircraft level ***includes using development assurance principles, system safety principles, and validation & verification techniques****. The level of assessment should be proportional to the impact of the change at the aircraft level"*

"The consideration of training and qualification of flight and maintenance personnel, as well as detailed explicit procedures for the safe operation of the aircraft."

JATR Report -
Recommendation 2

"*JATR team members recommend that the* ***FAA update regulations and guidance that are out of date*** *and update certification procedures to ensure that the applied requirements, issue papers, means of compliance, and policies fully address the safety issues related to state-of-the-art designs employed on new projects*"

"*JATR team members also recommend that the FAA review its processes to ensure that* ***regulations and guidance materials are kept up to date***"

JATR Report -
Recommendation 4

"JATR team members recommend that the FAA review and update the regulatory guidance pertaining to the type certification process with particular emphasis on ***early FAA involvement to ensure the FAA is aware of all design assumptions, the aircraft design, and all changes to the design*** *in cases where a changed product process is used"*

"The FAA should consider ***adding feedback paths in the process to ensure that compliance, system safety****, and flight deck/human factors aspects are considered for the aircraft design throughout its development and certification"*

JATR Report -
Recommendation 5

Ensure BASOO has sufficient number of experienced specialists

Ensure ODA engineering members are working without any undue pressure when they are making decisions on behalf of FAA

BASOO = Boeing Aviation Safety Oversight Office
ODA = Boeing Organization Designation Authority

JATR Report -
Recommendation 6

*"JATR team members recommend that the **FAA promote a safety culture that drives a primary focus on the creation of safe products**, which in turn comply with certification requirements. Aircraft functions should be assessed, not in an incremental and fragmented manner, but holistically at the aircraft level …"*

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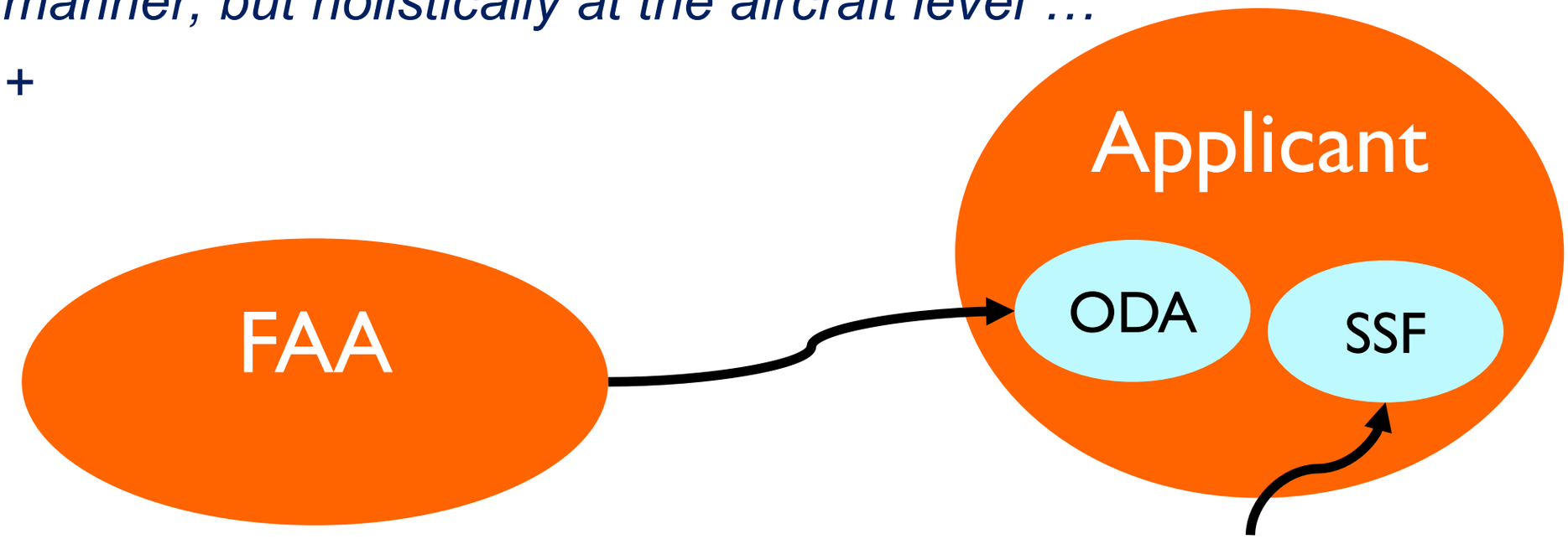

The FAA should encourage applicants to have a system safety function that is independent from the design organization,

with the authority to impartially assess aircraft safety and influence the aircraft/system design details

JATR Report -
Recommendation 7

*"JATR team members recommend that the **FAA integrate and emphasize human factors and human system integration throughout its certification process**. …"*

*"The FAA should expand its **aircraft certification resources in human factors and in human system integration**"*

JATR Report -
Recommendation 8

"JATR team members recommend that the FAA ensure applicants apply industry best practice for development assurance, including requirements management, visibility of assumptions, process assurance activities, and configuration management."

"The FAA should should ***ensure achievement of the close coupling that is required between the applicant safety analysis process and the development assurance process to classify failure conditions and derive the level of rigor of design development and verification****. …"*

JATR Report -
Recommendation 12

“JATR team members recommend that the FAA review its policies for analyzing safety risk and implementing interim airworthiness directive action following a fatal transport aircraft accident. The FAA should ensure that it shares post-accident safety information with the international community to the maximum extent possible”

Boeings Future Plans

to Change the Safety Culture

http://www.boeing.com/resources/boeingdotcom/commercial/737max/assets/10-fundamental-changes.pdf

Discussions

Thank You for Your Attention!