Boeing 737 - MCAS system

PER RUNESON, ANDERS RANTZER, KALLE ÅSTRÖM, REVISED BY BOB
What happened?

PER RUNESON
346 fatalities in two crashes
October 29, 1018 LionAir Flight 610 Jakarta (189)
March 10, 2019 Ethiopian Airlines 320 Addis Abeba (157)
Boeing 737 – a 50 year long history

10 000 produced aircraft
• Original: 737-100 and -200 (1967–1988)
• Classic: 737-300, -400, and -500 (1983–1999)
• Next Generation: 737-600, -700, -800, and -900 (1998–)
• MAX: 737 MAX 7, 8, 9 and 10 (2017–)
How are aircraft evolved?

- Bigger planes are more cost efficient
- Bigger/hotter new engines are more **fuel efficient**
- **Upgrades** involve less costly certification, maintenance and training
How does Boeing solve the problem?

• MCAS – Maneuvering Characteristics Augmentation System
• Software solves the hardware problem

But...
• Redundans wrongly handled
• Training and feedback to pilots insufficient
• Certification bodies weak
Control of unstable systems

ANDERS RANTZER
Birds

The earliest birds, pterosaurs, and flying insects were stable. This is believed to be because in the absence of a highly evolved sensory and nervous system they would have been unable to fly if they were not stable. To a flying animal there are great advantages to be gained by instability. Among the most obvious is manoeuvrability. It is of equal importance to an animal which catches its food in the air and to the animals upon which it preys. It appears that in the birds and at least in some insects the evolution of the sensory and nervous systems rendered the stability found in earlier forms no longer necessary.

John Maynard Smith The Importance of the nervous system in the evolution of animal flight. Evolution, 6 (1952) 127-9.
Stability and Maneuverability

- Wright brothers: Unstable but maneuverable airplane
- JAS Gripen: unstable at subsonic speed, stable at supersonic speed.
Angle of attack

- 6°, steady flow
- 15°, stall point, maximum lift
- 25°, relative wind
- Separation point
- Separated flow

IVA Syd 22/10/2019
Boeing 737 Max

Too high
Safe zone
flight path
How are aircraft evolved?

- Bigger planes are more cost efficient
- Bigger/hotter new engines are more **fuel efficient**
- **Upgrades** involve less costly certification, maintenance and training
The Swedish Warship Vasa

- 16 January 1625 – Gustav II Adolf orders 4 ships.
  - Plans for Vasa - 111 feet keels – one deck of canons
- 30 November 1625
  - Change of requirement – 120 feet keel – larger canons.
- Later
  - Change of requirement – 135 feet keel – two decks of canons
- Changed center of gravity. Risk of instability.
- 10 August 1628 – Vasa sinks – 53 lives lost
The Mercedes A class

- Were soft tire walls the reason for the A class’s rollover? – ”The tires fundamentally played a subordinate role. The problem was rather a combination of the position of the center of gravity and the chassis adjustment in an extreme driving situation.”

- What conclusions do you personally draw from the moose test? – “Without a doubt, the moose test help to move ESP to a breakthrough – and ultimately saved the lives of many people. In hindsight, it’s clear that some good came of it.”
Handling Angle of Attack in Boeing 737Max

MCAS - Maneuvering Characteristics Augmentation System
Ethiopian Airlines 737-8MAX - 10 March 2019

ET302 Preliminary FDR Data

Location, Date: Addis Ababa, Ethiopia, 10 March 2019

Accident #: AI-01/19

PRELIMINARY

Automatic Trim Down Commands

Automatic Trim Command With No Change In Pitch Trim

PRELIMINARY

IVA Syd  22/10/2019
The failed Kalman filter

Only two sensors for angle of attack. European Aviation Safety Agency would prefer three (Aug-19)

Also: Trend towards less manual flight makes pilots less experienced.
"Investigations by international regulators into the cause of the two Max crashes determined that pilots of those flights did not respond as quickly or effectively as Boeing and the F.A.A., using accepted industry standards, presumed they would when designing and evaluating the MCAS software."

Did competitive pressure lead to overlooked safety risks and downplayed needs for pilot training?
Sources

• https://sv.wikipedia.org/wiki/Boeing_737_MAX
• https://sv.wikipedia.org/wiki/Boeing_737
Image rights

- Av PK-REN from Jakarta, Indonesia - Lion Air Boeing 737-MAX8; @CGK 2018, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=73958203
- Bathroom Dmitry Djouce @Flickr CC BY 2.0
- First flight. United States Library of Congress's Prints and Photographs division under the digital ID cph.3a53266.
- Boeing 737-100 Gordon Werner @Flickr CC BY-SA 2.0
- Vasa map from wikipedia, CC-BY-SA-3.0,2.5,2.0,1.0 https://commons.wikimedia.org/wiki/File:Voyage_of_the_Vasa_Locator.svg
- Mercedes A class vurpa. https://www.youtube.com/watch?v=Um-XIKerWvA