Boeing 737 - MCAS system

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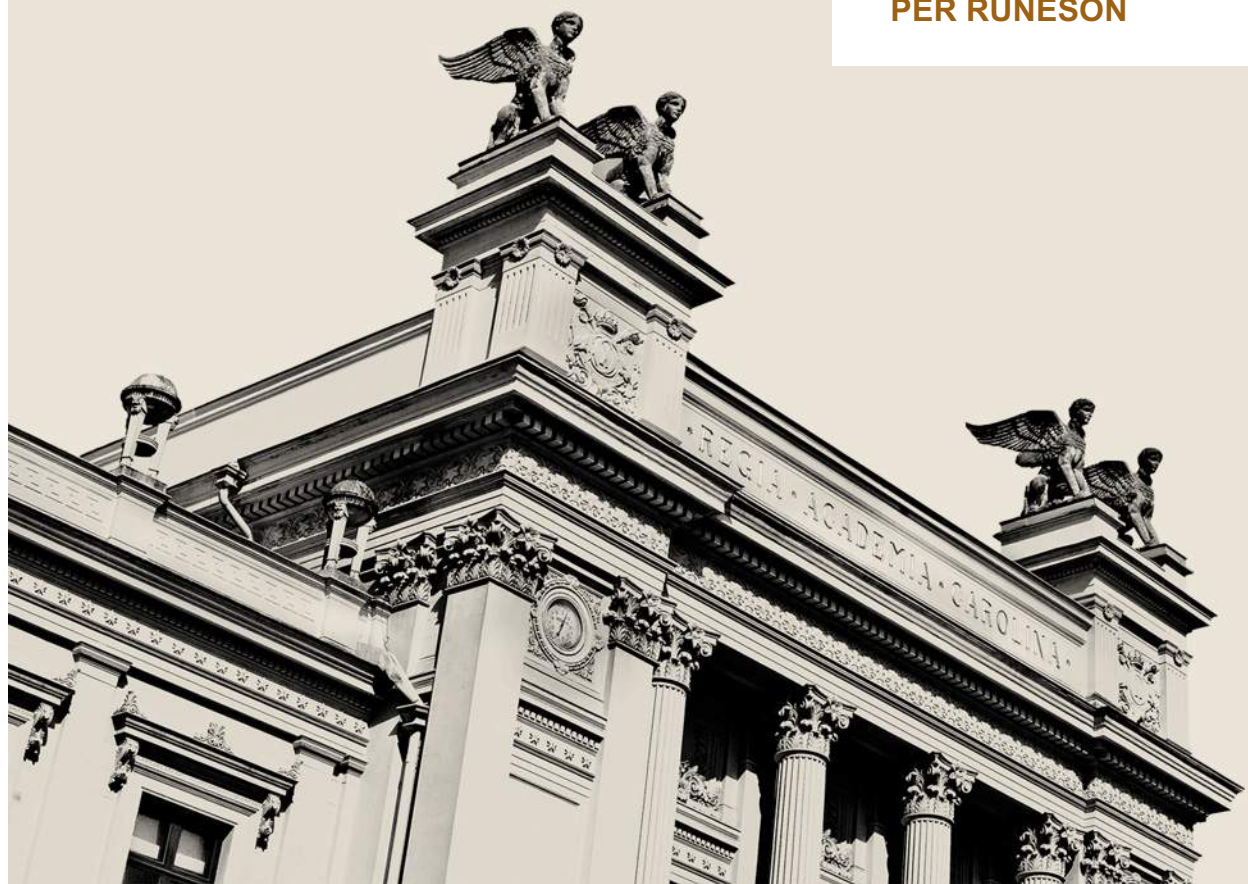
What happened?

PER RUNESON

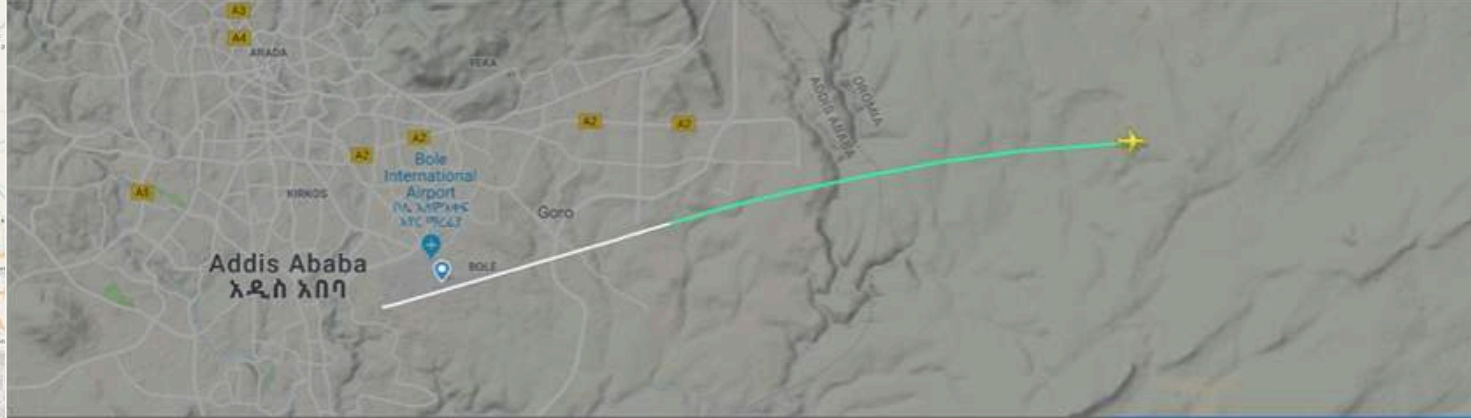**346 fatalities in two crashes**
October 29, 1018 LionAir Flight 610 Jakarta(189)
March 10, 2019 Ethiopian Airlines 320 Addis Abeba(157)

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Playback of flight ET302 / ETH302

GREAT CIRCLE DISTANCE	FROM		TO
1,157 KM	Addis Ababa (ADD)	⤏	Nairobi (NBO)

AVERAGE FLIGHT TIME
1:39

ACTUAL FLIGHT TIME

AVERAGE ARRIVAL DELAY
0:00

TIME	CALIBRATED ALTITUDE	GROUND SPEED	VERTICAL SPEED	TRACK
5:41 AM UTC	8,600 FT	383 KTS	2,624 FPM	86°
	GPS ALTITUDE	TRUE AIRSPEED	INDICATED AIRSPEED	SQUAWK
	N/A	N/A	N/A	2000

flightradar24

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AIRCRAFT
Boeing 737 MAX 8

REGISTRATION
ET-AVJ

SERIAL NUMBER (MSN)
62450

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
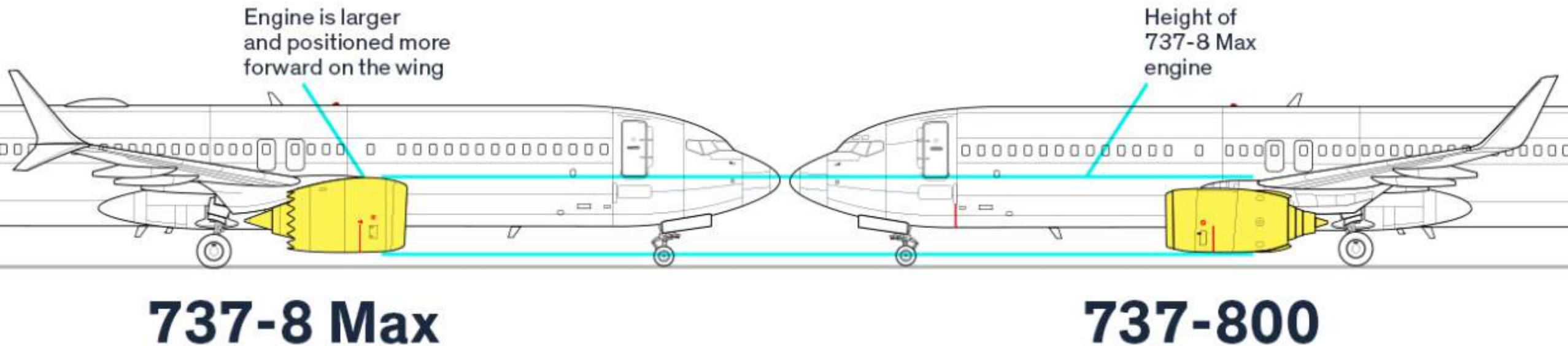
How does Boeing solve the problem?

- 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 sytem in the evolution of aimal flight. Evolution, 6 (1952) 127-9.
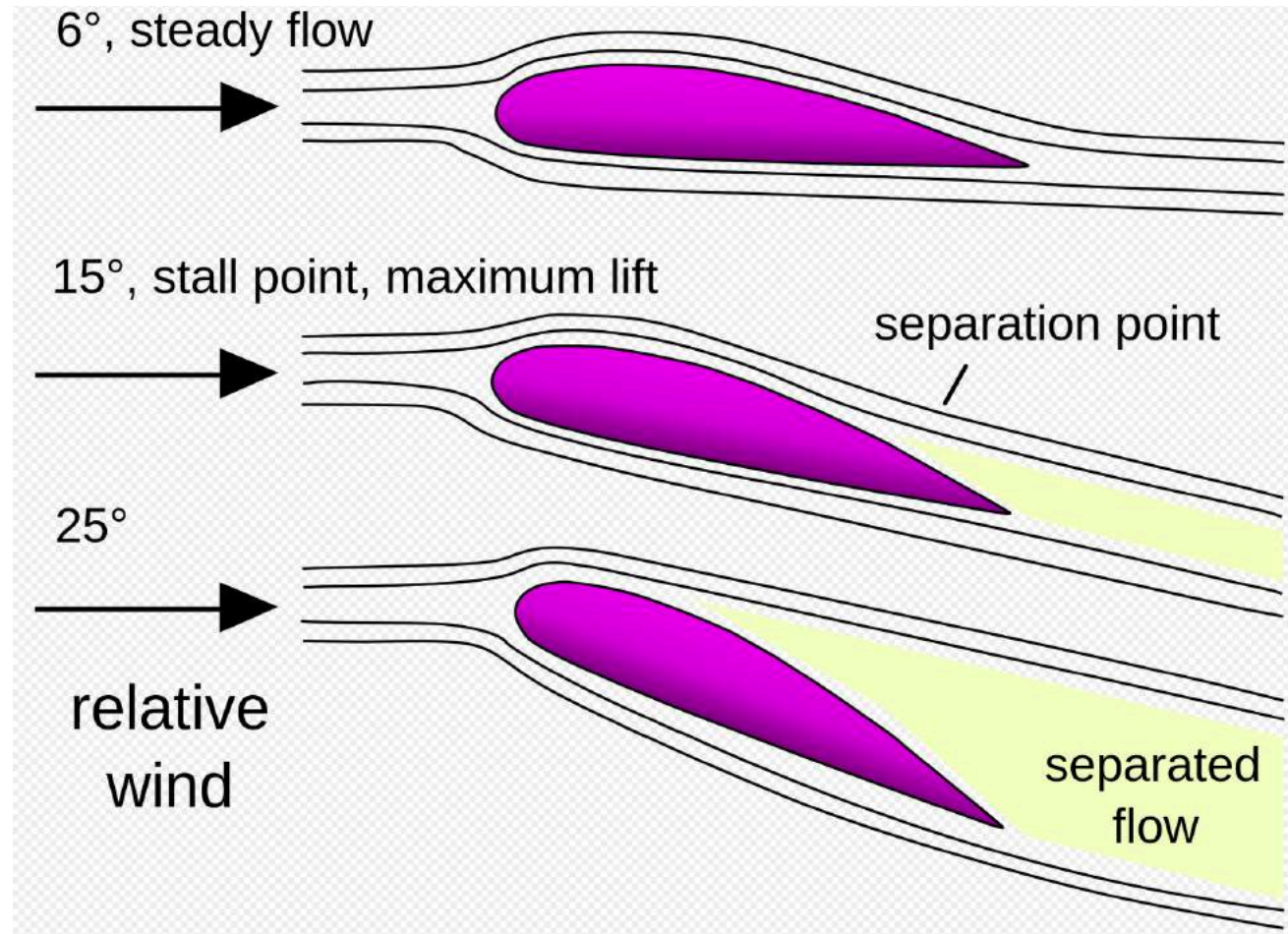
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Stability and Maneuverability
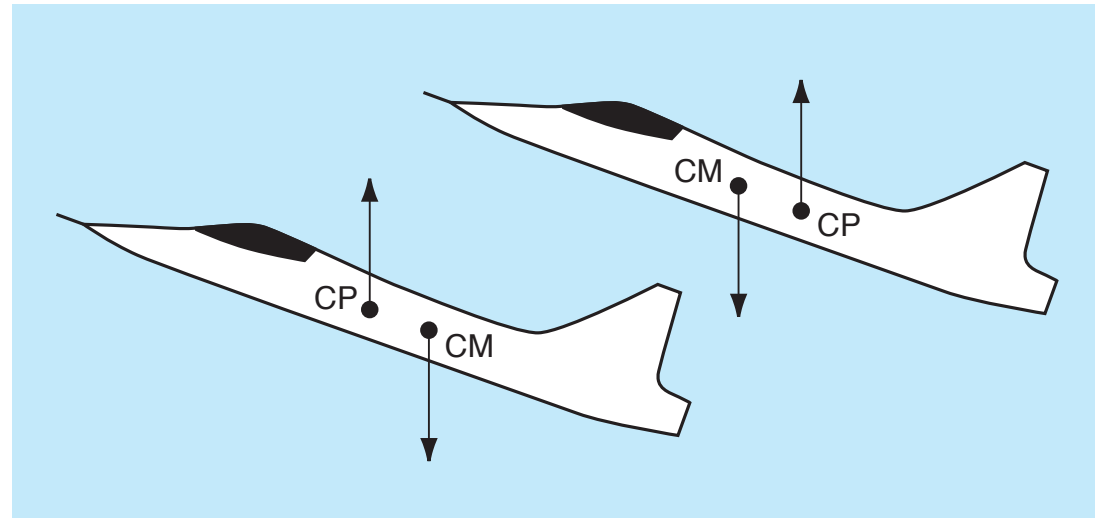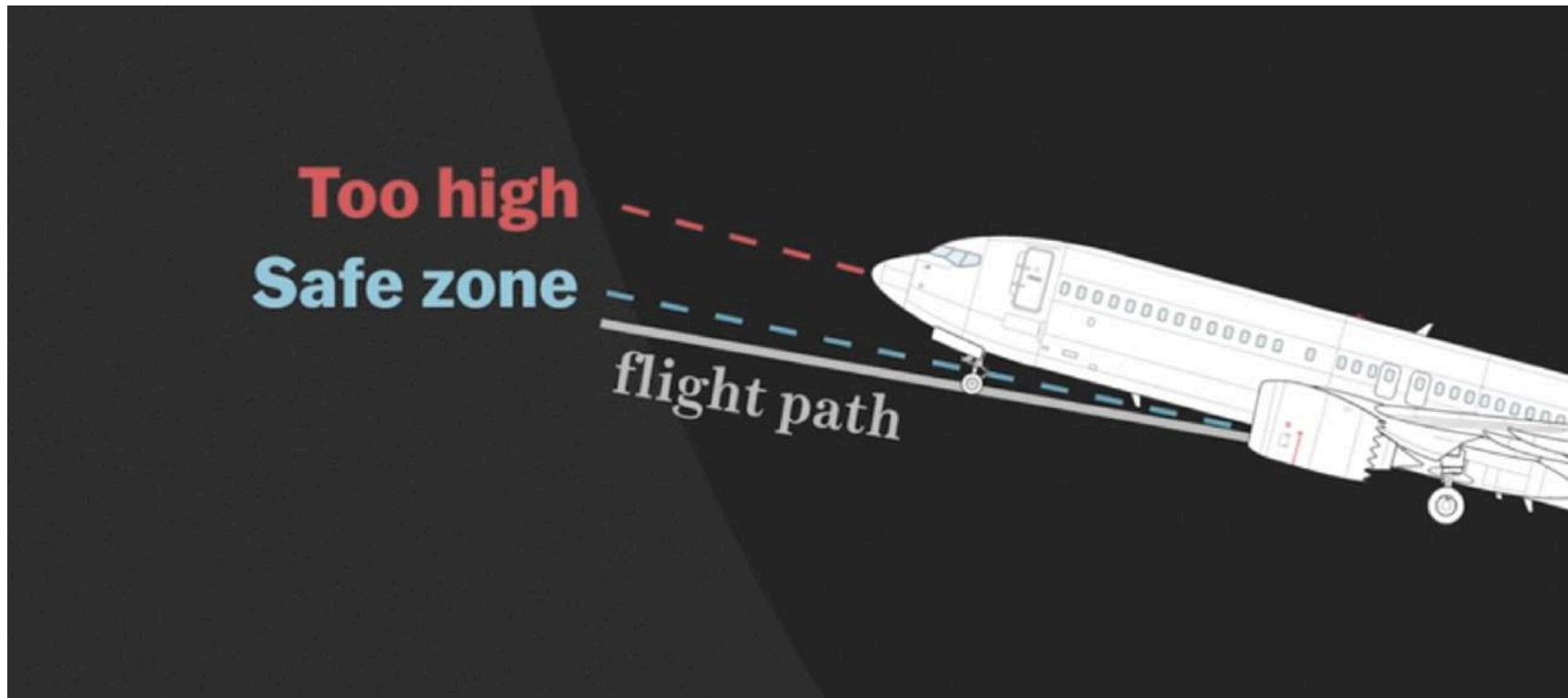

➢ Wright brothers: Unstable but maneuverable airplane

➢ JAS Gripen: unstable at subsonic speed, stable at supersonic speed.

Angle of attack

6°, steady flow

15°, stall point, maximum lift

separation point

25°
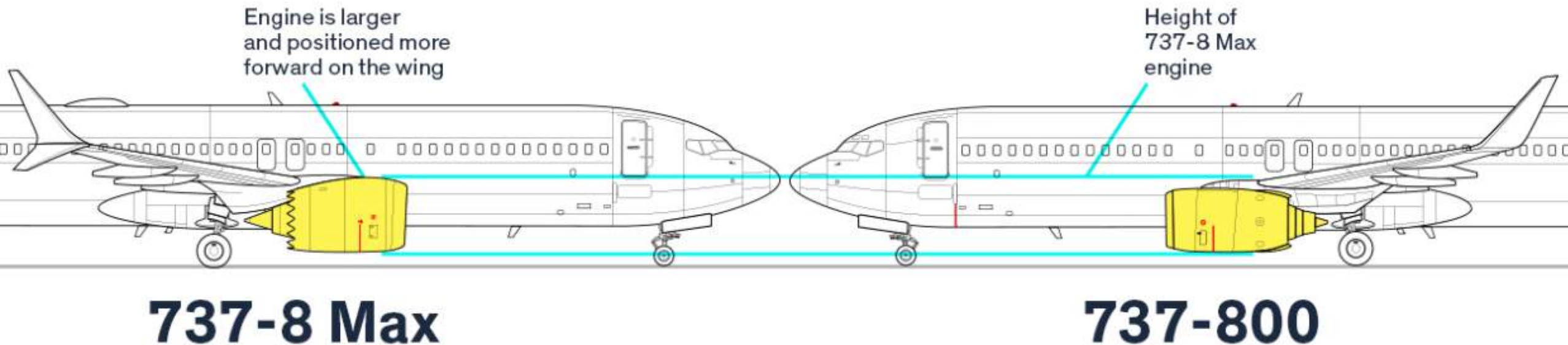
relative wind

separated flow

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Boeing 737 Max

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

Engine is larger and positioned more forward on the wing

Height of 737-8 Max engine

737-8 Max   **737-800**

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
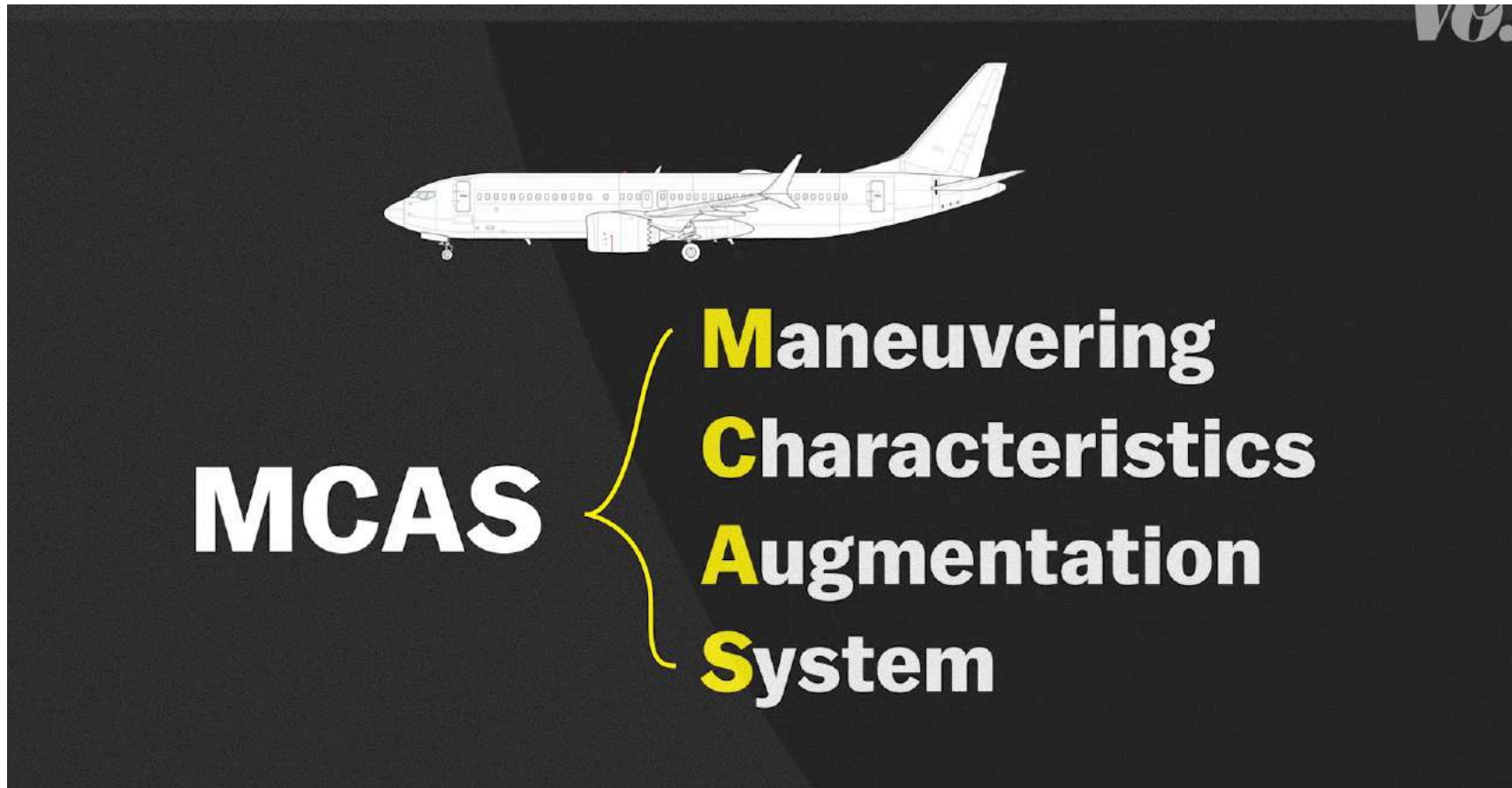
Ethiopian Airlines 737-8MAX - 10 March 2019

ET302 Preliminary FDR Data
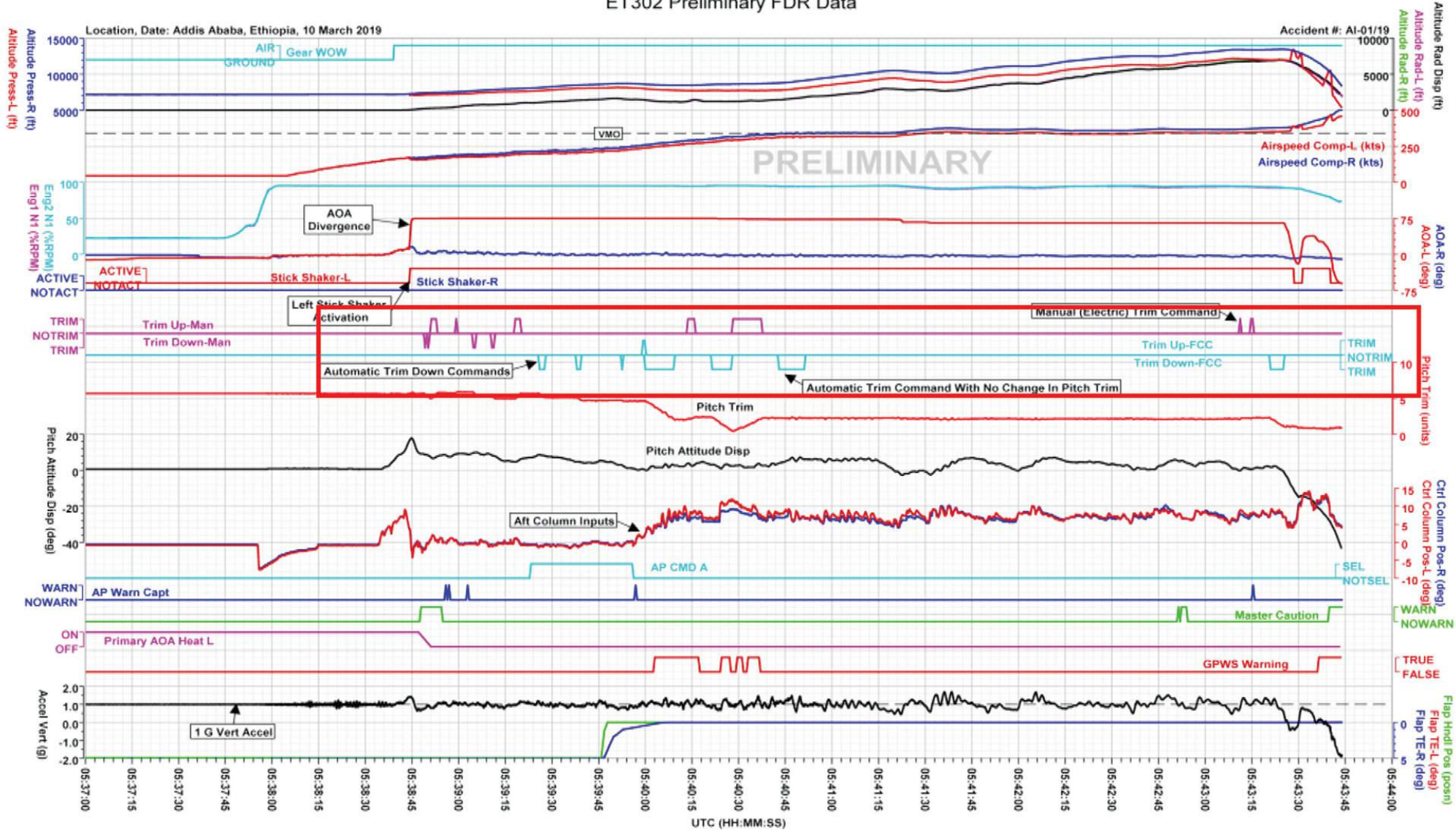
IVA Syd 22/10/2019

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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 ?

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Sources

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- https://sv.wikipedia.org/wiki/Boeing_737_MAX
- https://sv.wikipedia.org/wiki/Boeing_737
- https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

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- LLBG Spotter - Ethiopian Airlines ET-AVJ takeoff from TLV, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=77232751

- A Phoenix7777 - Flightradar24 Data Regarding Lion Air Flight JT610Download the KML fileOpenStreetMap, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=73955138

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- 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

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