

# **Boeing 737 MAX**

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Lion Air Flight 610 and Ethiopian Airlines Flight 302

# The incidents

On 29 October 2018, the Boeing 737 MAX operating Lion Air Flight 610 crashed into the Java Sea 13 minutes after takeoff. All 181 passengers and 8 crew on board were killed.

On 10 March 2019, the Boeing 737 MAX 8 aircraft operating Ethiopian Airlines Flight 302 crashed near the town of Bishoftu six minutes after takeoff. All 149 passengers and 8 crew members on board were killed.

# Causes

Investigation revealed that a new software function in the flight control system caused the aircraft to nose down. Repetitive and uncommanded airplane-nose-down inputs from the Maneuvering Characteristics Augmentation System (MCAS) due to erroneous angle-of-attack AOA sensor input, and its unrecoverable activation system which made the airplane dive with the rate of -33,000 ft/min [ $-170$  m/s] close to the ground was the most probable cause of the accident.

- ECAA final report in the Ethiopian Airlines crash

# Causes

2. Based on the incorrect assumptions about flight-crew response and an incomplete review of associated multiple flight deck effects, MCAS's reliance on a single sensor was deemed appropriate and met all certification requirements.
3. MCAS was designed to rely on a single AoA sensor, making it vulnerable to erroneous input from that sensor.
4. The absence of guidance on MCAS or more detailed use of trim in the flight manuals and in-flight crew training, made it more difficult for flight crews to properly respond to uncommanded MCAS.
  - Komite Nasional Keselamatan Transportasi (KNKT; English: NTSC), "Aircraft Accident Investigation Report"

# Causes

6. The replacement AoA sensor that was installed on the accident aircraft had been miscalibrated during an earlier repair. This miscalibration was not detected during the repair.
8. Lack of documentation ... meant that information was not available to the maintenance crew in Jakarta, nor was it available to the accident crew, making it more difficult for each to take the appropriate actions.
9. The multiple alerts, repetitive MCAS activations, and distractions ... were not able to be effectively managed. ... These performances had previously been identified during training and reappeared during the accident flight.
  - Komite Nasional Keselamatan Transportasi (KNKT; English: NTSC), "Aircraft Accident Investigation Report"

# Financial Consequences

The 737 MAX upgrade program was estimated to be between \$10-12 billion by outside observers.

Entire 737 fleet was grounded globally for 20 months.

\$20 billion in direct costs from the grounding: \$8.6 billion in compensation to customers for having their planes grounded; \$5 billion for unusual costs of production; and \$6.3 billion for increased costs of the 737 Max program.

Department of justice charged Boeing with fraud and conspiracy agreed to pay over \$2.5 billion.

Individual lawsuits by families of the deceased.

# Prevention

Boeing tried to reduce development costs by using software system to account for aerodynamic changes.

Incorrect assumptions were made during development about system behavior and operator behavior.

Single points of failure in sensor system, and concentration of control in a subsystem.

Lack of documentation, procedures, and training.

Regulatory capture and deceptive business practices.

# Sources

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