

Abstract

This case study examined the shortcomings of Boeing's upper management in the engineering and fielding of the B737-Max. Under pressure to build a plane with identical flying characteristics to the B737-NG, Boeing included modifications, but purposely concealed those changes from regulators and the airlines. This decision resulted in two fatal accidents in 2018 and 2019 and caused the deaths of 346 passengers. Unlike previous aviation accidents, these mishaps were entirely preventable and a direct result of Boeing's organizational failures and management shortcomings. This case study analyzed the behavior, decision making process, and reasons which led Boeing to push for the certification of the B737-Max despite these known flaws in the design. Additionally, this poster studied the consequences that followed the investigation of the two crashes. The poster concludes by offering recommendations to the aviation industry on how accidents such as this can be avoided in the future.

Background

Boeing 737 MAX

- The B737-Max is one of Boeing's most successful products, dominating the narrow-body passenger aircraft market, with over 11,100 B737-Max produced.
- The Airbus A320neo challenged this position and introduced several new technologies, increased fuel efficiency, and aerodynamic improvements.
- Boeing's response to the A320neo was the introduction of the B737-Max. The design changes in the B737-Max resulted in an aircraft with significantly different flying characteristics than the legacy 737. To compensate for these differences, the design included an automatic system known as the Maneuvering Characteristics Argumentation System (MCAS).
- Boeing, concerned about losing market share to the A320neo, had strong incentives to speed the development and release of the B737-Max.

First accident: Lion Air Flight 610

On October 29, 2018, Lion Air Flight 610 departed Jakarta, Indonesia, with 189 passengers and crew. It experienced a malfunction of the Angle of Attack (AOA) sensor, and with this erroneous data, the MCAS automatically commanded nose-down trim inputs. The pilots unsuccessfully attempted to maintain control of the aircraft, and the plane crashed into the sea with no survivors.

Second accident: Ethiopian Airlines Flight 302

On 10 March 2019, Ethiopian Airlines 302 departed Addis Ababa, Ethiopia, with 157 passengers and crew onboard. As with the previous accident, erroneous data from one of the AOA sensors caused the MCAS to trim nose down. The crew attempted to return to the airfield but ended up crashing with no survivors.

Grounding and Accident Investigation

- The Federal Aviation Administration (FAA) grounded the entire B737-Max fleet for over 20 months following the two accidents.
- The cause of both crashes were linked to unintended activation of the MCAS system. The AOA system was identified as a single point of failure in the design. Assumptions about pilot responses turned out to be incorrect, and insufficient training was provided to pilots to inform them of the differences of the B737-Max, the MCAS system, and proper procedures to regain control in the event of a malfunction.

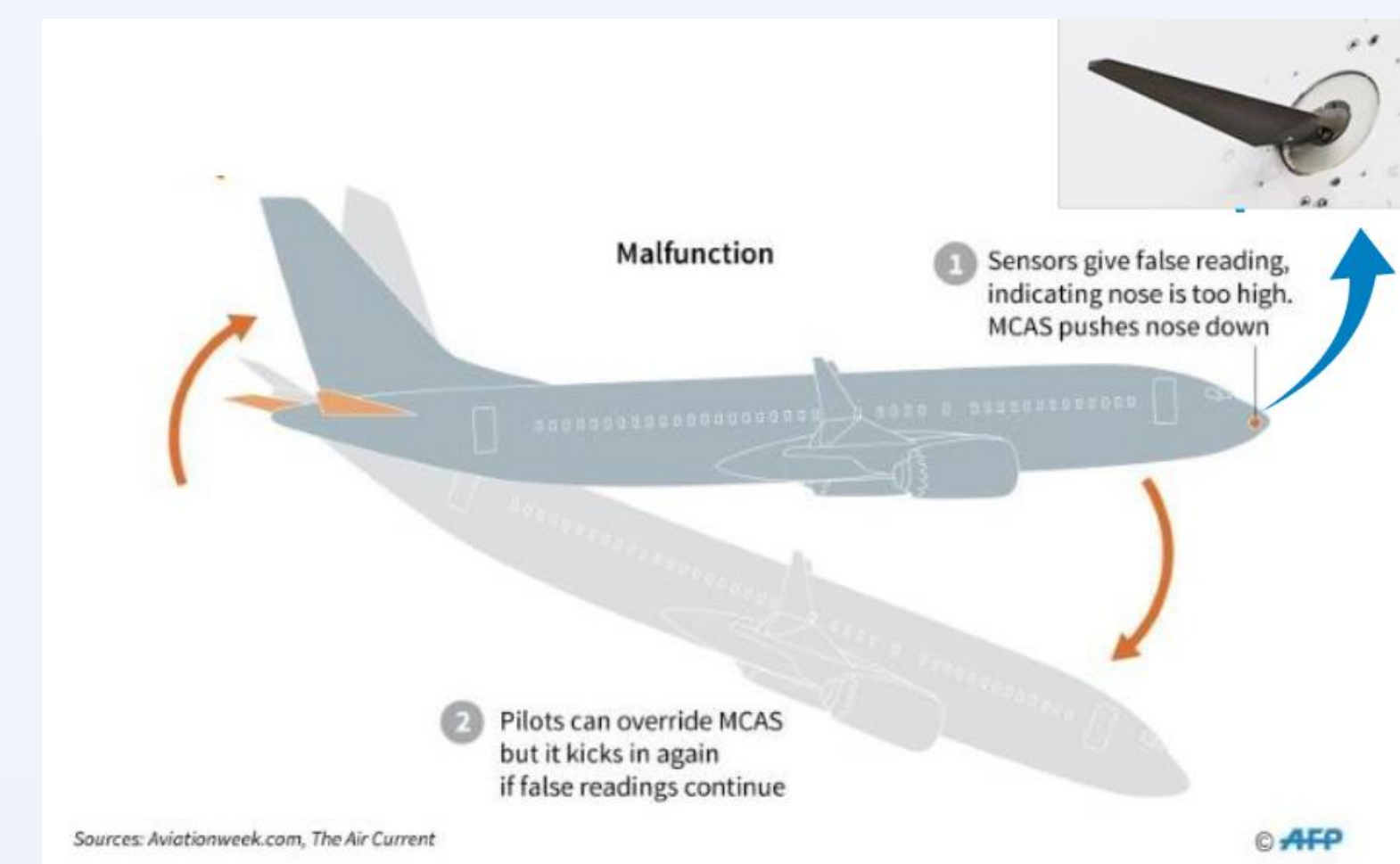
Cutting Cost at All Cost

Pressure from Southwest

- Prior to the release of the B737-Max, Southwest placed the largest order of the new aircraft along with a special request: that it would require minimal training for current B737-Max pilots to fly the B737-Max. Southwest went as far as insisting on a clause in the sales contract stipulating a penalty of \$1 million per airplane delivered if that standard was not met.
- The insistence and pressure of Southwest "infected every aspect of the birth and development of the new B737-Max" leading to deceptive practices and corner-cutting to ensure the certification of the B737-Max at a minimal cost.

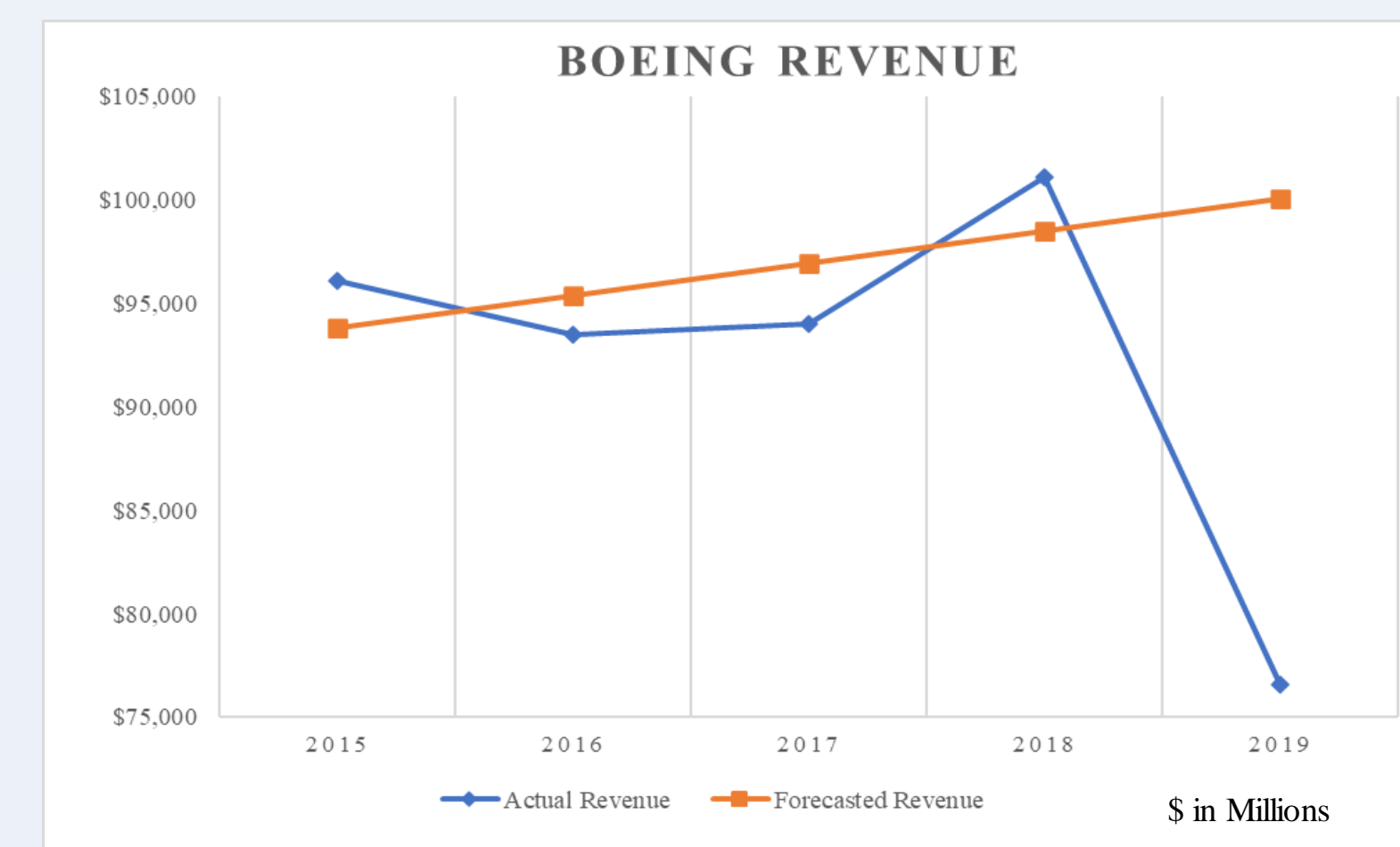
Flaws In The Design

- Due to the competing pressures of building a more efficient aircraft while limiting pilot training requirements, Boeing sought ingenious alternatives to meet both needs.
- To make the B737-Max more efficient, Boeing equipped the aircraft with larger CFM LEAP engines for longer range and greater fuel efficiency. However, the larger engines required Boeing engineers to place them further forward of the wings' leading edge, drastically changing the aircraft's aerodynamics by shifting the center of gravity aft (nose-up moment).
- To remedy to the pitch-up moment, Boeing created the MCAS. However, since Southwest had requested to minimize training requirements and as this new software would have required certification by the FAA, Boeing decided to "fully automate" the MCAS and neglected to mention its existence.
- The flaws of the B737-Max unfortunately do not end with the installation of the MCAS. To cut cost even more, Boeing only offered a single data sensor for the MCAS; an added indicator that would have allowed pilots to cross-check a faulty sensor was only available with an added charge.



Financial Toll

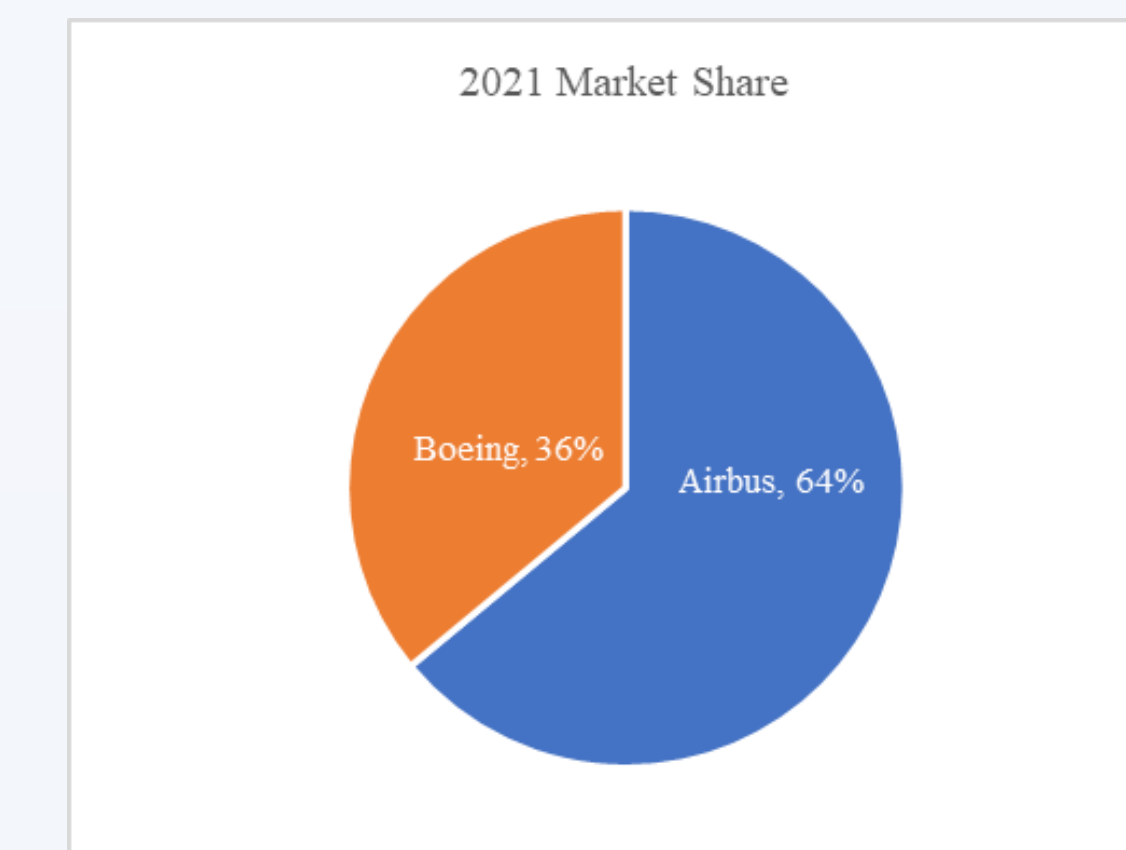
- Based on actual revenue earned between 2015-2018, Boeing's projected gain was \$100,073 for 2019. As a result of the B737-Max mishap, Boeing collected only \$76,559 (23.50%). In addition, the cost to shut down and restart the B737-Max production line exceeded \$4 Billion.



TOTAL LOSS = \$27,514,000,000



- Due to the incident and uncertainty with the B737-Max, orders for Airbus dramatically increased leading to Boeing losing market share in 2021.



Lack of Ethical Practice

Warnings Falling on Deaf Ears

- Although Boeing's engineers and managers made several attempts to warn Boeing's executive board of the multiple flaws and defects of the B737-Max, the board was mostly concerned with releasing the B737-Max on time and as promised. Boeing went as far as removing several references of the MCAS in the pilot's operating manual to bypass the need for pilot training.
- Boeing's narrow vision to prioritize profitability and stock prices over safety also led to the company rejecting a safety system that could have potentially prevented the two fatal crashes in order to minimize cost.

Lack of Accountability

- Following the accidents, Boeing displayed a callous attitude towards the charges being made against them. Boeing did not want to admit they had any culpability in the accidents that occurred and instead blamed the airlines and the pilots.
- As a result of the final accident reports, investigators confirmed that there was nothing that the pilots could have done to override the system no matter how hard they pulled on the yoke.

Unwillingness To Admit The Truth

- Following the investigation and release of the accident report, Boeing remained unwilling to admit to the findings and publicly apologize. Boeing's CEO, Dennie Muilenburg, even went as far as stating that he would have no concerns flying his family in the Boeing 737-Max. He also continued to make overly optimistic projections on how quickly the B737-Max would return to flight.
- Muilenburg's conduct and lack of empathy angered lawmakers, airlines, regulators, and the families of victims. His poor handling of the B737-Max failures eventually led to his dismissal.

FAA Abdication of Responsibilities

- The investigation raised questions on the lack of oversight by the FAA during the design and fielding of the B737-Max. While the FAA maintains strict standards in the inspection and certification of new aircraft, due to the long-term relationships between Boeing and the FAA, the FAA delegates many inspection and certification functions to Boeing's engineers. This created a conflict of interest and lack of oversight and involvement throughout the flawed development of the B737-Max.
- The FAA was further criticized for allowing the B737-Max to continue to fly for five months following the first crash. Undeniably, the FAA failed its duty to protect the flying public as the agency was more focused on assisting Boeing's business-oriented outcomes.

Recommendations and Future Research Study

Aviation Industry

- Prioritize public safety over minimization of cost, competitive pressures, and/or delivery deadlines.
- Foster an environment which allows concerns of engineers to be heard and taken seriously by business executives.
- Ensure proper disclosure and training are provided to pilots and associates upon the release of new aircraft variations with an emphasis on design changes or adjustments which affect the aircraft flight characteristics.
- Ensure the reliability of new software and equipment installed aboard new and old aircraft via thorough analysis and testing.
- Industry leaders, regulators, professional societies, educators and engineers should fulfill their professional ethical obligations by reporting unsafe situations or activities.
- Conduct further research on project management failures to help prevent similar accidents in the future.

FAA

- Ensure the thorough certification process, even for aircraft of similar series, by placing more emphasis on the differences that were implemented in the new aircraft.

References

National Transportation Safety Board. (2019, September 19). *Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance*.

*Additional references available on request