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# COULD BOEING 737 MAX CRASHES BE AVOIDED? FACTORS THAT UNDERMINED PROJECT SAFETY

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**Abstract**

*One year after the two plane crashes that killed 346 people, the U.S. House Committee on Transportation and Infrastructure (HCTI) issued a preliminary report on the investigation findings. Multiple factors were pointed as causes for the accidents, highlighting the pivotal failure software Maneuvering Characteristics Augmentation System (MCAS), primarily designed to address stability issues due to specific flight conditions, kept by Boeing unknown to the pilots. This article is intended to provide scholars, decision-makers, and practitioners with a perspective on the current situation and implications for the company, competitors, and customers, through a descriptive case study, and content analysis. Key findings in the report pointed out five leading factors to Boeing's 737 MAX project failure, after the preliminary investigation: (i) production pressures due to financial and market competition against Airbus; (ii) faulty assumptions; (iii) culture of concealment; (iv) conflicted representation and (vi) Boeing's influence over the FAA's oversight. We analyzed and discussed the critical factors, their impact on the results, and best practices to prevent project failure on the subject under review.*

**Keywords:** Civil aviation, Boeing, Aircraft manufacturer, 737 MAX

## 1.Introduction

The present article investigated the factors that contributed to Boeing's 737 MAX failure project, as the unit of analysis, through a descriptive, single case study (Yin, 1988).

Two plane crashes shocked the world due to their particularities: on 29 October 2018, Indonesian Lion Air flight 610 (precisely 13 minutes after takeoff) departing from Soekarno–Hatta

International Airport (CGK) in Jakarta, with destination to Depati Amir Airport (PGK) in Pangkal Pinang, crashed into the Java Sea, killing all 189 people on board. Unfortunately, one rescue diver died during the recovery operation.

Five months later, on 10 March 2019, the second crash: Ethiopian Airlines flight 302, departing from Addis Ababa, Ethiopia, to Nairobi, Kenya, crashed six minutes after takeoff, killing 157 people. What these two disasters had in common? Both accidents involved brand-new Boeing 737 MAX, certificated by the Federal Aviation Administration (FAA) two years earlier, on 8 March 2017. Both aircraft were also equipped with new software designed to correct stabilization issues, called Maneuvering Characteristics Augmentation System (MCAS). Preliminary findings pointed out software malfunction as one of the causes for both accidents (HCTI, 2020), to be discussed here.

In this article, we focused on the preliminary investigative report issued by the U.S. House Committee on Transportation and Infrastructure (HCTI) in March 2020. The conclusions led to five primary contributing factors to the crashes, including cutting costs on safety procedures, among others. The report, according to the authors, is preliminary because

> there are still more interviews to conduct and records to review. Nonetheless, as the one-year anniversary of the Ethiopian Airlines crash approaches, the Committee wishes to provide an update and publish preliminary investigative findings to help inform Members of the Committee and the public (HCTI, 2020, p.2)

We compared Boeing 737 jet series with the leading competitor, Airbus A320 family, to provide scholars, decision-makers, students, aviation practitioners with a perspective on the civil aviation principal players' dynamics, useful to deepen the understanding on the market, costs, schedule, FAA oversight, among other pressures on Boeing and subsequently the 737 MAX program to compete with Airbus' A320neo aircraft." (HCTI, 2020)

Back in time, North American aircraft manufacturer Boeing company was founded by William Boeing in 1916, at Seattle, Washington state. To date, its estimated market value is $ 176 billion. Moreover, Boeing manufactures civil and military jets. Also, rockets, defense systems, and satellites, among others (Boeing, 2018; Dias, M.O. & Teles, 2018). This article was primarily motivated by past research on the subject (Cruz & Dias, M.O, 2020).

The Boeing 737 MAX series, under review, is the fourth generation of the Boeing 737, the 12th derivative model of the 737 families, a narrow-body airliner that succeeded the Boeing 737 Next Generation (Boeing, 2020). The first 737 was certificated by FAA to operate in 1967.

Figure 1 illustrates the Boeing 737 x Airbus A320 jet families' launching timeline:

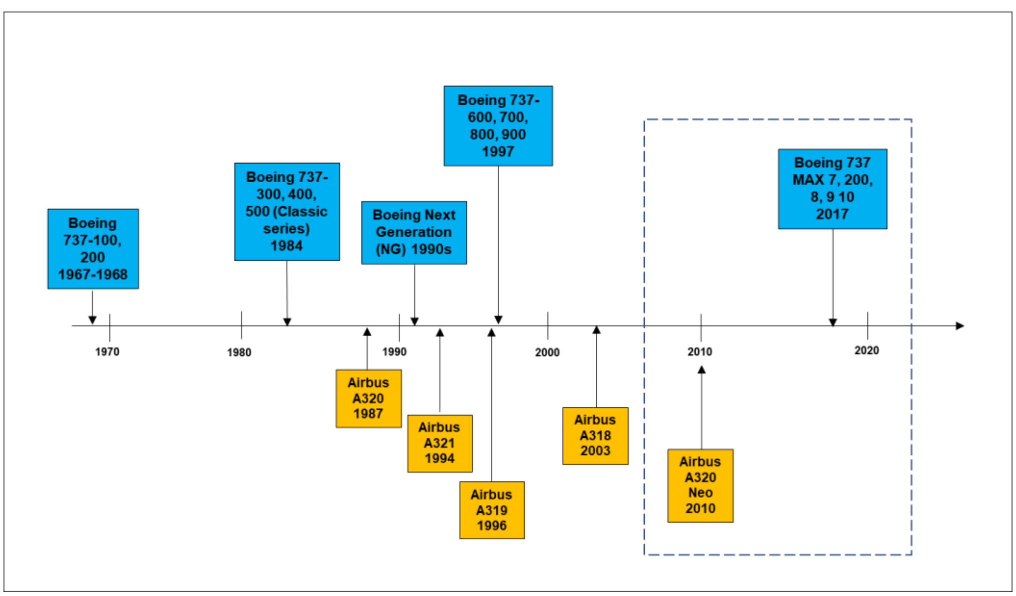


Figure 1 Boeing 737 x Airbus 320 families' timeline. Source: Boeing (2020), Airbus (2020)

Observe in Figure 1 that Boeing 737-100 was launched in 1967. In the next year, the 737-200. Both models endured until 1984 when the Classic series started operations (737-300, 737-400, 737-500). Notice that Airbus A320 jet family launchings are concentrated from 1987 to 2010, competing with Boeing 737 family jets. Finally, the Boeing 737 MAX series and Airbus A320Neo are highlighted in dotted lines to facilitate the visualization of the competitors.

The first 737 MAX-7 jets were publicly announced on 30 August 2011, but it took almost five years to the inaugural flight on 29 January 2016. (Boeing, 2020)

Boeing commercialized the 737 MAX in four versions, (i) Boeing 737 MAX 7, (ii) 737 MAX 8 (including the version 737 MAX 200, with 200 seats); (iii) 737 MAX 9, and (iv) 737 MAX 10, as illustrated in the following Table 1, in comparison to Airbus A320 jet family.

*Table 1*
Comparison between Airbus A320 and Boeing 737 families

| ***Manufacturer*** | ***Aircraft*** | ***Capacity (seats)*** | ***Max Flight Autonomy (km)*** | ***Length (m)*** | ***Wingspan (m)*** | ***MTOW (x 1000 Kg)*** | ***Cost (million USD)*** | ***Max Speed (km/h)*** | ***Max Alt (m)*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Boeing*** | 737-700 | 138 | 5.648 | 31.2 | 34,3 | 66 | 89.1 | 870 | 11.890 |
| | 737-800 | 177-186 | 5.665 | 39.5 | 34,3 | 79,01 | 106.1 | 870 | 11.890 |
| | 737 MAX 7 | 153-172 | 7.130 | 35.56 | 35,92 | 80,28 | 99,7 | 839 | 12.000 |
| | 737 MAX 8 | 178-200 | 6.570 | 39,47 | 35,92 | 82,19 | 121,6 | 839 | 12.000 |
| | 737 MAX 9 | 193-220 | 6.570 | 42,16 | 35,92 | 88,31 | 128,9 | 839 | 12.000 |
| | 737 MAX 10 | 204-230 | 6.110 | 43,8 | 35,92 | 89,76 | 134,9 | 839 | 12.000 |
| ***Airbus*** | A319Neo | 140 | 6.950 | 33,84 | 35,8 | 75,5 | 101,5 | 876 | 12.100 |
| | A320Neo | 165 | 6.500 | 37,57 | 35,8 | 79 | 129,5 | 876 | 12.100 |
| | A321Neo | 206 | 7.400 | 44,51 | 35,8 | 97 | 110,6 | 876 | 12.100 |
| | A320-200 | 132-220 | 5.700 | 37.57 | 34.10 | 42.4 | 99 | 871 | 11.890 |
| | A321-200 | 196 | 5.600 | 44.51 | 34.10 | 48.2 | 116 | 871 | 11.890 |

Source: Boeing (2020), Airbus (2020).

Observe in Table 1 that not all twelve Boeing 737 derivatives are illustrated, only the most significant and commercially active. We considered it pointless to show decommissioned aircraft, once the most recent models are investigated. The current technical lifetime of an aircraft averages 27 years, according to the aviation sector representative, The International Air Transport Association (IATA, 2020).

Notice that Boeing 737 MAX 10 carries up to 230 seats, to compete with the Airbus A320Neo, with 206 seat capacity. Notice also that 737 MAX 7 maximum flight range is 7,130 km, while A321Neo reaches 7,400 km range. Airbus A320Neo series also fly higher (12,100 m altitude) than the 737 MAX series (12,000 m altitude). They are less expensive and faster than the leading competitor (876 km/h vs. 839 km/h), evidencing a fierce competition between Boeing and the rival Airbus, determinant to the decisions are taken by Boeing that culminated with the two crashed planes in a short period, to be discussed in sections three and four.

Finally, the present article followed previous investigations on the subject recently (Dias, M.O., 2019, 2019b; 2019c; 2019d; 2019e; Dias, M.O. & Albergarias, 2019; Dias, M.O. & Pessanha, 2019;

Boeing 2020, 2019, 2018, 2017); Aircraft commercial aviation industry (Dias, M., Teles, and Duzert, 2018; Dias, M.O. and Duzert, 2018), which recommendations are also applicable to plenty of businesses, such as e-business negotiations (Dias & Duzert, 2017); craft beer industry (Dias, M.O. & Falconi, 2018; Dias, M. O., 2018); and debt collection negotiations (Dias, M.O., 2019, 2019b; Dias, M.O. & Albergarias, 2019), among others. Methods and limitations are presented in the next section.

## 2. Methods and Limitations

The present article is a qualitative, descriptive single case study (Yin, 1988), limited to the Boeing 737 series, especially the 737 MAX series, unit of analysis (Yin, 1988). However, comparisons with the rival Airbus A320 series was chosen to provide readers with a perspective on the competition between rivals. This research is also inductive, interpretive, involving extensive archival research, focused in the U.S. Government database, especially the House Committee on Transportation and Infrastructure (HCTI) report, issued in March 2020.

## 3. Turbofans, Angle of Attack and flight stability

Roughly speaking, there is a direct relationship between the number of seats and the size of the turbofan. Figures 2, 3 and 4 compare three generations of Boeing 737s:

Figure 2: Boeing 737-200

Figure 3: Boeing 737-700

Figure 4: Boeing 737-MAX

Observe in Figures 2, 3, and 4 the ever-increasing size of turbofan engines, located right below the wings. The oval shaped-engine intake increases ground clearance. The same happened with the 737-MAX (See Figure 4). Notice that 737 MAX turbofans (see Figure 4) are much closer to the ground than the smaller 737-200 ones (see Figure 2). Therefore, a larger turbofan demands an entire project redesign to stabilize the aircraft flight. Otherwise, it could stall, which is a reduction in the lift coefficient generated by a foil as the angle of attack increases. Therefore, a stall occurs when the critical Angle Of Attack (AOA) of the foil exceeded. Therefore, due to a more substantial engine usage in the 737 MAX new design (two CFM Leap 1B turbofans), the aircraft aerodynamics was significantly altered.

Usually, a plane stalls if the angle of attack increases beyond a certain degree (typically 15 degrees), as illustrated in the following Figure 5. The problem with the 737 MAX design lied on how Boeing tried to solve aircraft stability issues, described in the next section.

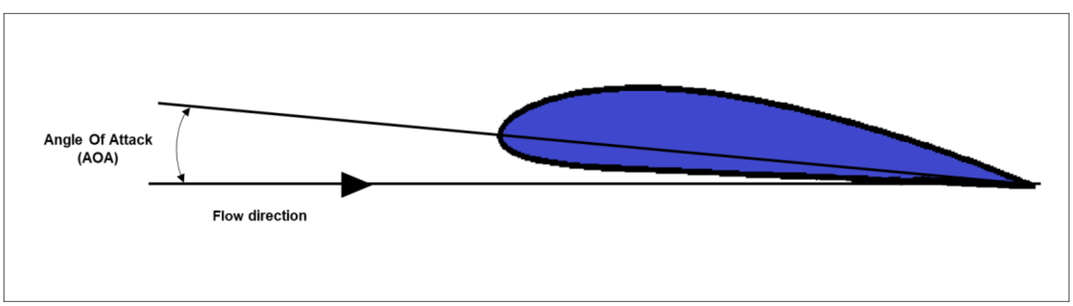


Figure 5 Angle of attack (AOA). Author's picture.

**4. Boeing 737 MAX Maneuvering Characteristics Augmentation System (MCAS) and the Angle of Attack (AOA) sensor:**

Boeing designed a software named MCAS, to correct the AOA of the 737-MAX series automatically. MCAS should push the aircraft nose down, depending on the AOA sensors located at the nose of the aircraft, as depicted in the following Figure 6:


Figure 6: Boeing's 737 MAX Angle of Attack (AOA) sensors. Source: Boeing (2020)

Facing fierce competition and internal pressures to launch the 737 MAX series, as evidenced in the next section, Boeing concealed the information from FAA and even the pilots about the MCAS as a safety-critical system (HCTI, 2020).

A false assumption that the AOA sensor failure would be easily corrected manually by the pilots - unaware and untrained on this particular, concealed a hard reality, according to the HCTI preliminary report:

> If the pilots took more than 10 seconds to identify and respond to a "stabilizer runaway" condition caused by uncommanded MCAS activation the result could be catastrophic. The Committee has found no evidence that Boeing shared this information with the FAA, customers, or 737 MAX pilots. (HCTI, 2020, p.9)

In sum, pilots would have 10 seconds to react in case of the AOA sensor malfunction. They should control the plane stability manually in less than 10 seconds. The same report points out vast evidence that Boeing has been discussing internally over the problem since 2013, and never reported it to the FAA. (HCTI, 2020)

## 5. Preliminary HCTI report findings and analysis

The U.S. House Committee on Transportation and Infrastructure (HCTI, 2020, pp.2-3) preliminary investigative findings pointed five causes for the accidents:

5.1. *Production Pressures.*

Evidence suggests that Boeing succumbed to financial and market pressures, due to fierce competition with Airbus A320Neo, sacrificing safety and quality in the 737 MAX program. The implications involved costs cut with training in flight simulators, for example. According to the HCTI committee, in “several instances where the desire to meet these goals and expectations jeopardized the safety of the flying public.” (HCTI, 2020, pp.2-3). Evidence also suggests that the concerns with safety and quality were secondary in comparison to costs and time constraints.

5.2. *False Assumptions.*

Evidence suggests that Boeing made fundamentally faulty assumptions about the MCAS software. Boeing assumed, contrary to their internal project guidelines, for the 737 MAX program, that MCAS was not a safety-critical system. Boeing assumed that the MCAS software would automatically correct the AOA. Pilots, utterly unaware of the system's existence in most cases, should quickly correct the AOA, which proved to be disastrous in the two crashes. Curiously, one month after the second tragedy, Boeing announced MCAS software corrections. Therefore, the 737 MAXs could soon return operating, while investigation revealed error after error with the project. (HCTI, 2020)

5.3. *Culture of concealment.*

During the investigation, HCTI found substantial evidence that Boeing concealed crucial information from the FAA, pilots and the general public, including

> the very existence of MCAS from 737 MAX pilots and failing to disclose that the AOA disagree alert was inoperable on the majority of the 737 MAX fleet, despite having been certified as a standard cockpit feature. This alert notified the crew if the aircraft’s two AOA sensor readings disagreed, an event that occurs only when one is malfunctioning. Boeing also withheld knowledge that a pilot would need to diagnose and respond to a “stabilizer runaway” condition caused by an erroneous MCAS activation in 10 seconds or less, or risk catastrophic consequences (HCTI, 2020, p.3).

5.4. *Conflicts of Representation*

Evidence suggested conflicts of interest in the FAA oversight process, due to the Authorized Representatives (ARs) structure. In sum, the AR is a Boeing employee who grants special permission to represents FAA interests on validating systems and designs, according to the FAA requirements. The investigation pointed out that the A.R. "failed to take appropriate actions to represent the interests of the FAA and to protect the flying public." (HCTI, 2020, p.3)

5.5. *Boeing’s Influence Over the FAA’s Oversight.*

Evidence revealed that FAA management "overruled the determination of the FAA's technical experts at the behest of Boeing" (HCTI, 2020, p.3). In many circumstances, FAA experts pointed safety issues to be revised in the 737 MAX project, potentially dangerous design approaches that should comply with FAA regulation, "only to have FAA management overrule them and side with Boeing instead." (HCTI, 2020, p.3)

## 6. Discussion

First and foremost, the answer for the research question: yes, the crashes could be avoided, if Boeing treated the 737 MAX program with the same seriousness of previous programs. Financial pressures, time constraints, among others already discussed, undermined safety of the Boeing 737 MAX.

Two months after the second crash, Boeing announced a new MCAS software update (Boeing, 2020b), designed with additional layers of protection, including:

> Flight control system will now compare inputs from both AOA sensors. If the sensors disagree by 5.5 degrees or more with the flaps retracted, MCAS will not activate. An indicator on the flight deck display will alert the pilots.(…) MCAS can never command more stabilizer input than can be counteracted by the flight crew pulling back on the column. The pilots will continue to always have the ability to override MCAS and manually control the airplane. (Boeing, 2020, p.1)

In sum, with the updated MCAS software, if the AOA sensors disagree, the process becomes manual, and a panel display shows the pilot the inconsistency, as depicted in the following Figure 7:


Figure 7: new AOA indicators panel display. Source: Boeing, 2020b.

Boeing (2020b) also updated all the 737 MAX documentation and implemented a mandatory and comprehensive training package of 21-day instructor-led academics and simulator training for 737 MAX certifications. Moreover, "if the pilot is already certified to fly the 737NG (New Generation), they must complete the N.G. to MAX Differences training" (p.1).

Despite Boeing's best efforts on corrective measures, it was too late: the losses overpassed $ 60 million per day, and the institutional damage was done. Therefore, two months before the HCTI investigation report was ready, in January 2020, Boeing announced the discontinuation of the MAX series. (Boeing, 2020)

Finally, as the old saying goes since time immemorial: *haste makes waste*.

## 7. Lessons Learned

The following lessons should be taken seriously into consideration by decision-makers, practitioners, aviation managers, extensive to other fields of business management studies, regarding best managerial practices:

7.1. *Golden rule: safety always comes first*. Critical safety issues are non-negotiable and should always be addressed in the first place, no matter the costs. In this case, Boeing ignored the golden rule, with tragic consequences, where 346 people died.

7.2. *A false assumption jeopardizes the entire project.* The assumption discussed in item 5.2 proved to be false. The assumption that MCAS would correct the AOA automatically, in case of sensors divergence. Also catastrophic was the assumption that pilots would correct any system flaws manually, in ten seconds. These assumptions led the project to failure, combined with other factors (See sections 5.1 to 5.5).

7.3. *The FAA oversight process should be revised.* Boeing’s employees would never be part of the FAA certification approval board under no circumstances, because of interest conflict.

7.4 *Traffic of influence has nefarious consequences to business.* This case showed how financial pressures are dangerous to the 737 MAX project. FAA managers should always comply with technical reports, not overruling them. If the technical department raises safety issues, the managers should defend the public customer from other interests.

7.5. *Avoid the hiding dust under the carpet culture, or concealment culture.* We discussed in section 5.3 the Boeing's attitude of critical information concealment, from FAA, even the pilots and customers. The consequences were catastrophic, representing billions of dollars lost, and even worst: reputation on Boeing's safety damage, incalculable.

## 8. Future research

As the 737 MAX is an ongoing case, future research is encouraged to map the extension of the financial losses, as well as the impact of the COVID-19 on the civil aviation market in general and Boeing in particular. Also, future research should assess Boeing's loss on maintenance contracts, lawsuits, reparations of all sorts, aircraft devolutions, among others.

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