Actor Network Theory Analysis of the Failure of Boeing 737 MAX MCAS and Subsequent Crashes

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Boeing's 737 MAX aircraft entered service in May of 2017 with a new Maneuvering Characteristics Augmentation System (MCAS), a piece of software that was meant to offset the perceived effect of the change in the center of gravity that was a result of the new engines and their placement. The MCAS was designed so that the aircraft's change in handling characteristics from previous 737 models would be imperceptible to the pilots. However, the MCAS was unreliable and pilots were not adequately trained and informed of the system so its failure is blamed for the crashes of Lion Air Flight 610 and Ethiopian Airlines Flight 302.

When analyzing the non-technical factors which resulted in these tragedies, scholars tend to focus on Boeing and how its internal management was the driving force behind the launch of an unsafe commercial aircraft. These perspectives generally overlook the role played by Lion Air and Ethiopian Airlines in the crashes and the overall failure of the 737 MAX. This perspective is limiting as there should be a more comprehensive picture that takes into account the role of external actors in Boeing's 737 MAX network. This narrow perspective may result in Boeing being subject to more blame than what is deserving. I will examine this failure by identifying a network builder and the role they played in constructing their network to achieve a goal which inadvertently led to negligence and the subsequent failure. Actor-Network Theory provides the framework to do this when investigating the failure of Boeing's 737 MAX MCAS and subsequent crashes. This will involve studying the activity of Boeing as a network builder and analyzing the adjacent human and non-human actors which contributed to the crashes of Lion Air Flight 610 and Ethiopian Airlines Flight 302. To support my analysis I will draw on the preliminary accident reports released by the Indonesian National Transportation Safety Committee and Ethiopian Civil Aviation Authority as well as relevant FAA and NTSB reports, as

well as journal articles that cover the poor practices present within Lion Air and Ethiopian Airlines. This argument will provide insight into how time and cost restrictions may interfere with designing safe and reliable avionics systems, as well as how the questionable cost-saving practices of the aforementioned airlines contributed to the tragedies.

Background

On October 29, 2018, Lion Air Flight 610 crashed into the Java Sea 13 minutes after departure from Jakarta (Indonesian National Transportation Safety Committee, 2018). Approximately 5 months later on March 10th, Ethiopian Airlines Flight 302 crashed six minutes after takeoff under similar conditions (Ethiopian Civil Aviation Authority, 2019). These crashes promptly resulted in the long-term grounding of the Boeing 737 MAX 8 fleet. A design flaw in Boeing's MCAS was attributed to both crashes.

Boeing initially designed the 737 to operate at airports with limited service which resulted in it sitting relatively low to the ground so that passengers could enter and exit with stairs, and since its introduction in 1968, the current airframe still sits low to the ground. In 2011 when Boeing decided to upgrade the engines on its 737 due to competition from Airbus and its new A320neo, however, there was not enough room under the wing and Boeing wanted to keep the same airframe to spare further manufacturing and design costs so Boeing engineers decided to move the engine further up on the wing. This changed the handling characteristics of the plane when it was in takeoff and climb power settings as the nose would start pitching too far up (Ethiopian Civil Aviation Authority, 2019). Boeing sought to advertise the 737 MAX as a plane that would require minimal training for 737 pilots and would essentially fly exactly the same as previous 737 models. This led to the implementation of the MCAS, a system that was originally designed to rely on the 737's two angle of attack (AoA) sensors but was revised to only rely on a

single AoA sensor (Hamblen, 2020). The MCAS was designed to push the nose down if an excessively high AoA was detected in order to prevent a stall and maximize climb performance. The crashes were deemed to be caused by the MCAS receiving faulty data from the AoA sensor, as the pilots fought against the MCAS when it unnecessarily forced the nose of the plane downwards.

Literature Review

Despite the recency of the crashes, there exists a wealth of scholarly sources which analyze the social and non-technical factors which contributed to the crash as well as the ethics surrounding the tragedies. These analyses focus on how management at Boeing is the chief actor which enabled people's lives to be put at risk because of its unsafe technology.

At the heart of *Technology strategy and management: Boeing's 737 MAX: a failure of management, not just technology*, Cusumano examines pivotal changes in Boeing's strategy and culture which set the groundwork for Boeing to release its flawed 737 MAX. Namely, Boeing's merger with McDonnell Douglas where McDonnell Douglas executives persuaded Boeing to put a larger emphasis on cost, completion, and shareholder value as opposed to its prior emphasis on safety and engineering excellence. Second, Boeing moved its headquarters from Seattle to Chicago which created distance between leadership and engineering teams working on the 737. Most significantly, Airbus released the A320neo and this meant Boeing faced more intense competition. At the conclusion of this paper, Cusumano points out that even the best companies, like Boeing, can fall prey to competitive pressures as they strive to maximize their profits. Cusumano also argues that government organizations need to be able to protect these companies from themselves when competitive pressures take hold. Lastly, he remarks on how it is concerning that society has reached a point where software and hardware systems are so complex

that government experts are not able to independently certify technologies like the MCAS in the 737 MAX. Also how government agencies are thus delegating a lot of the certification data to the manufacturing companies themselves, essentially allowing the companies to police themselves. The article ends by stating that the 737 MAX and MCAS did not design itself or fail by itself and thus it was predominantly a failure of management.

Hekert et al. in *The Boeing 737 MAX: Lessons for Engineering Ethics*, points out a lot of the issues with Boeing and its management which compounded together and led to an unreliable yet certified aircraft. These issues are similar to what Cusumano discussed in his paper. Specifically, competition with Airbus as well as a concerning relationship with the FAA essentially enabled Boeing to do a lot of the certification of its own aircraft since 2005. However, Hekert et al. delve more into the ethics of the relevant corporate and government agencies as the authors point out 'the problem of many hands' and how it is difficult to assign moral responsibility to the critical decisions taken in this case. Hekert et al. go on to discuss how some design decisions were clearly fundamental errors in engineering judgment, and how at least one Boeing engineer expressed concern regarding the MCAS design prior to any accidents. Following the two crashes one engineer, Curtis Ewbank, filed an internal ethics complaint and several more went public with concerns regarding the 737 MAX's design. The paper concludes with comparisons to the other engineering ethics case studies such as the design of the Ford Pinto (Birsch and Fielder 1994), the GM ignition switch (Jennings and Trautman 2016), as well as the Challenger Shuttle (Werhane 1991) where some engineers were well aware of critical design issues and proceeded anyways. While in the case of the Challenger, some engineers warned their superiors, however, their warnings were unfortunately not heeded. Hekert et al. identify companies not empowering engineers with safety concerns as a driving factor for tragedies not

limited to the 737 MAX crashes, this paper advocates for stronger internal ethics processes and an emphasis on moral courage within engineering ethics education.

The first source by Cusumano focuses on how questionable management within Boeing contributed to the 737 MAX crashes, whereas Hekert et al. use the tragedies as a case study for engineering ethics. Hekert et al. also refer to the problem of many hands existing within Boeing, however, this could exist as a problem throughout the entire network and it may not be entirely fair for Boeing to be the only party that is held accountable. While both sources provide information and an argument tangential to actor-network theory (ANT) it is still important to look at this case through the lens of ANT to identify a network builder and how each of the members of the constructed network, especially rogue actors outside of Boeing contributed to the crashes.

Actor-Network Theory

The 737 MAX MCAS failures and crashes are well suited to be analyzed through the lens of Actor-Network Theory (ANT), as it is evident that Boeing was a network builder with the goal of innovating its 737 design and having a profitable launch of its new aircraft model so that the company could remain financially viable. ANT presents the idea of actors as adversaries and allies as well as rogue actors. Airbus, being Boeing's primary competitor, was an adversary to the 737 MAX engineering network and the A320neo was the direct technical adversary as airlines were opting to purchase more A320neo aircraft as opposed to the 737 models due to the A320neo's superior engines. Allies in the network include the FAA which delegated much of the aircraft certification process to Boeing itself, allowing Boeing to get away with certifying an aircraft with potentially fatal engineering flaws. Rogue actors include the airlines which purchased the 737 MAX, especially Lion Air and Ethiopian Airlines as well as the pilots who

operated the fated aircraft. Boeing also recruited actors re-aligning them to serve its purpose in the launch of the 737 MAX, namely the FAA which allowed for lenient and inattentive certification procedures for the new aircraft.

The application of ANT attempts to follow the complex relationships between technologies, governments, money, and people in recognizable networks (Cressman, 2009). ANT studies network builders who assemble networks of human and non-human actors to accomplish a goal. Furthermore, these heterogeneous networks can be composed of technical, social, natural, and economic actors. In the case of the Boeing 737 MAX crashes, ANT will be used to evaluate the Boeing 737 MAX network to understand the series of faults and omissions which led to two similar fatal crashes.

Argument

While the MCAS is widely regarded to be the primary technical reason for the crash, it is important to understand the external non-technical factors that resulted in flawed engineering and the loss of life which ensued. Analyzing these factors will help guide the design process of many future software and avionics projects as the fundamental social and economic actors remain relevant.

Cutting Corners

Boeing's new managerial practices since the acquisition of McDonnell Douglas laid the foundation for Boeing to cut costs at the expense of safe engineering when it came to the design of the 737 MAX and its MCAS. Boeing 737s are equipped with two AoA sensors and yet the MCAS was only utilizing one to reduce complexity and therefore cost (Cusumano 2021). This resulted in a lack of redundancy in a crucial avionics system. Boeing also failed to require significant additional training for the aircraft (National Transportation Safety Board, 2019). This

lack of training was part of Boeing's marketing. Airlines valued not having to retrain 737 pilots as it meant more time and money was saved if they were to transition to the 737 MAX. This lack of additional training helped it compete with the Airbus A320neo. A significant issue with the lack of training, however, was that there was no mention of the MCAS in the original documentation/training for the 737 MAX (Glanz et al. 2019). Boeing's unwillingness to educate pilots on a new critical system that alters aircraft handling shows disregard for the safety of potential passengers and crew as Boeing should have been well aware that this system could fail, especially since it deliberately lacked the redundancy of the second AoA sensor. This illustrates how Boeing, being the network builder, was in competition against Airbus, a social actor, for the sake of maximizing Boeing's sales and profits which was the economic actor. Boeing sought to accomplish this profit maximization by making crucial engineering errors and by misrepresenting its aircraft to clients and pilots. While Airbus is described as an adversary in Boeing's actor-network it is important to clarify that Airbus should hold no culpability for being a competitor, as Boeing's response to the competition is ultimately more significant, as Boeing could have taken more time and money to engineer a better 737 and suffered more short-term profit losses to launch a more reliable competitor aircraft in an honest fashion.

Network Recruit

Boeing recruited the FAA into its network to help it get the 737 MAX certified and into service as quickly as possible due to Boeing's competition with Airbus. These pressures on Boeing's production were exacerbated by the concerning relationship between Boeing and the FAA, since 2005 the FAA began relying more on the aircraft manufacturers to certify their own planes, (Hekert et al. 2020), and by 2018 Boeing was certifying 96% of its own work. (Kitroeff et al. 2019) This meant that certifying the safety of the MCAS was delegated to Boeing, this

demonstrates the concern present in Cusumano's paper where systems are becoming too complex for experts from government agencies to be able to certify them. While some may argue that this means that the FAA has a very limited responsibility in the crashes, it should be noted that the FAA is meant to be an unbiased agency that protects aviation safety, and the FAA's decision to let manufacturers essentially certify themselves is contrary to its purpose. The fact that Boeing was able to take nearly full control over its own certification process illustrates its success in forming a network that allowed its aircraft to hit the market before being completely outdone by its competition with the A320neo. It also goes to show how supposedly neutral government entities like the FAA can be used to serve a purpose in a network that is not in the interest of public safety.

Rogue actors

Additionally, the airlines involved in these accidents should also be held accountable due to their questionable safety record and hiring practices which contributed to the crashes. An investigation by the New York Times found that Lion Air was overworking pilots, falsifying pilot training records, and "forcing pilots to fly planes they worried were unsafe, including the plane that crashed." (Beech, 2019) Ethiopian Airlines also had questionable hiring practices. For example, the first officer on flight 302 had a mere 361 hours of total flight time (Ethiopian Civil Aviation Authority, 2019), whereas major US airlines require 1500 hours of flight time to be hired. A lack of aviation experience may have contributed to the pilots' inability to quickly disable the MCAS which prevented them from being able to recover the aircraft from its nose dive. This illustrates how the aforementioned airlines participated in Boeing's network as rogue actors which operated outside of Boeing and the FAA's authority, and by cutting corners in a similar fashion to Boeing in order to save money they contributed to a loss of life and the

ultimate failure of Boeing's 737 MAX network. Perhaps if the Boeing 737 MAX only fell into the hands of airlines with safe practices and well-qualified pilots the impacts of a poorly engineered and planned MCAS would have been mitigated and fatal accidents would have been avoided. So while the faulty MCAS was still primarily Boeing's fault, the crashes certainly exacerbated Boeing's failure and that can be partially attributed to the respective airlines.

Boeing's Responsibility

While Ethiopian Airlines and Lion Air should be considered as rogue actors which played a role in their respective crashes, some sources may extend the blame from the airlines back to Boeing (Ahmedet al. 2019) as both Ethiopian Airlines and Lion Air have fleets composed of mostly Boeing aircraft. This argument states that the malpractice of both airlines underscores how Boeing cuts corners to compete with Airbus, as the airlines are effectively representatives of the manufacturer. Additionally, Boeing has authority over its airline customers due to aircraft maintenance, and Boeing's inability to discourage these hazardous practices indicates that sales were prioritized over safety. However, both Ethiopian Airlines and Lion Air exercised their independence in a dangerous way when they did not purchase an equipment package on either of the doomed aircraft that included an indicator light that would alert the pilots if the AoA sensors disagreed with each other. Boeing understood this feature would be standard amongst all of its 737 MAX aircraft, however, there was some internal confusion that made this feature optional (Gelles and Kitroeff, 2019). While Boeing's culpability is still evident here, Ethiopian Airlines and Lion Air still made a decision to purchase an aircraft with minimal safety measures and this omission certainly contributed to both crashes. The negligence of both airlines still played a significant role in the failure of Boeing's network as it pertains to the

individual crashes, however, Boeing still holds the culpability for its poor implementation of the MCAS.

Conclusion

Using Actor-Network Theory, I have argued that Boeing was the network builder whose objective was to have a profitable launch of its 737 MAX aircraft. In the process, Boeing recruited the FAA as an ally in its network which ultimately failed after two crashes and the grounding of the 737 MAX fleet worldwide. Ethiopian Airlines and Lion Air were rogue actors that contributed to the downfall of Boeing's network. However, Boeing's failure was largely due to its management being overly concerned with competing against Airbus and maximizing sales and profit margins. This corporate struggle led to a series of fundamental errors that compounded on each other which culminated in tragedy.

It is important to analyze the failure of the 737 MAX network as avionics systems always require thorough design and testing to ensure safety and reliability, and there are often significant financial and corporate pressures that can hamper the development of a reliable system. Failing to fully understand all the actors at play could put lives at risk in the event that maximizing a company's profits becomes prioritized over creating a well-engineered avionics system.

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