Using ANT to Explore the Role of Regulatory Framework Acting as a Network Builder in Aviation Design Through the Case of the Boeing 737 MAX

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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

On October 29th 2018, a Boeing 737 MAX operated by Lyon Air crashed off the coast of Indonesia, killing all 189 people on board. Just four months later, another Boeing 737 MAX, Ethiopian Airlines Flight 302, crashed killing 149 people onboard. Both of the accidents occurred within 15 minutes after takeoff and the planes themselves contained the newest technologies, designed to be safer and more efficient than ever before. In response, regulatory authorities around the world grounded the 737 MAX from flying within their borders (Pontefract 2019). Post-accident studies found the culprit to be an anti-stalling software referred to as MCAS (Maneuvering Characteristics Augmentation System) which repeatedly forced the plane to dive while ascending. Despite the errors present in the MCAS system being known to Boeing engineers and FAA administrators, the company and regulatory body kept all information regarding the system on a "need to know" basis (Campbell 2019). This lack of transparency, combined with a rushed engineering design and risk management process, is considered to be the root cause of the errors leading to the 737 MAX's fatal accidents (Webb 2019). Although this is true, if we fail to understand the role regulatory frameworks drafted decades ago have in preventing advancements in aviation technology from reaching fruition, we will be bound to a future era of planes offering only incremental advancements over 1960s technology and perhaps even regressing in terms of safety. Consequently, understanding the role of these regulations better will allow upcoming innovators to consider existing challenges when designing more resilient aircraft. Drawing on Actor Network Theory, I argue that it was not only Boeing's and the FAA's rushed development and lack of transparency, but also the existing regulatory frameworks that resulted in the flawed design of the 737 MAX. Through the case of the Boeing 737 MAX, I will use ANT to argue that the FAA regulations, rather than flawed engineering practices at Boeing and lack of independent risk oversight in the aviation industry, are the dominant actors that controls the development and adoption of new aircraft design. I will begin by laying out the evidence for why these regulations have the strongest role in aviation engineering design and why their roll is one of hindering innovation and efficiency rather than maximizing risk mitigation and safety. With this framework in place, I will briefly define and organize the human and non-human actors within the network of narrow-body commercial aircraft by tracking the development of technologies centered around these regulations as a network builder. Within the context of the network, I will show that these regulations dominate all other actors by disincentivizing progressive changes in aircraft design, allowing a pilot to only operate one type of aircraft at a time, pressuring passenger airline companies to buy only similar types of planes for their fleet, and standing in the way of innovative, newer engineering practices focused more on ingenuity than conformance to regulation.

Background

Competition in the airline manufacturing industry is fierce: two major players, Boeing and Airbus, hold a duopoly over the entire narrow-body passenger jet market (Roberts 2015). Hence, when one company gains an edge, the other has to quickly catch up to retain hold of their market share. This was exactly the case when Boeing had to quickly develop a competitor to Airbus's new, more popular A320neo jetliner. Within just months following the release of the A320neo, Boeing released the 737 MAX. This rush in development, along with lack of transparency and systemic problems within the company, is generally considered to be the root cause of the engineering mishaps in the 737 MAX that resulted in two accidents killing over 300 people just minutes after takeoff (ANI 2019). Post-accident investigations revealed that the Maneuvering Characteristics Augmentation System (MCAS), a newly developed emergency software meant to prevent stalling, forced the aircraft to violently enter a down-nose position following each attempt to gain altitude (The Wall St Journal, 2019). For the two flights aforementioned, this resulted in pulverizing crashes into the ground. Boeing and the FAA, having known of the software but not necessarily the fatal flaw, decided to keep MCAS on a "need to know" basis. Hence, nothing was written about it in the flight manual nor was communicated to pilots of the airlines.

Literature Review

Many scholars and aviation experts have analyzed the Boeing 737 MAX and the circumstances leading to its development. The majority of research performs an extensive analysis into the potentially unethical engineering and management practices at Boeing and the minutia of the aircraft's design and infamous MCAS software glitches. Relatively few scholars have examined the responsibility of FAA regulations for antiquated aircraft technology being recycled into new aircraft designs.

In a case study done by Titan Grey, a risk management consulting firm, the main factors held responsible for the flawed Boeing 737 MAX MCAS system were: the lack of independent safety oversight, ineffective escalation channels for engineers to report problems in testing, failed regulatory oversight by the FAA, and lack of communication monitoring of employees (Titan Grey 2019). In effect, their findings revealed that Boeing was vulnerable to gaps in their risk management practices. Furthermore, Titan Grey's case study presents a legitimate case for the FAA to change its approach to safety certification. Currently, the FAA's approach to certifying aircraft safety places most of the regulatory work to aircraft manufacturers themselves. The implications of allowing a private corporation to run their own technical safety inspections presents a conflict-of-interest for the common good and public safety. Titan Grey recommends a streamlined, centralized, and continuously monitored communications infrastructure between all groups involved in the manufacturing and testing process so that concerns are immediately recognized and elevated further up the management hierarchy more efficiently.

Third Bridge Forum, and investment research consulting firm, argues that the monopolization of the airline manufacturing industry allows Boeing and Airbus to get away with flaws in regulatory oversight that resulted in the 737 MAX (Third Bridge Forum, 2019). Third Bridge's research also analyzes the economic implications that Boeing would have needed to consider if they had notified pilots and airlines of the MCAS system. Their findings indicated that the Chinese market, accounting for over 20% of worldwide sales of the 737 MAX, would have been less likely to buy their planes if they had to retrain their pilots on aircraft simulators focused on learning the MCAS system. With aircraft simulator training costing 3-5 times more than computer-based training, the potential loss of Chinese aircraft purchases would be too high a risk for Boeing to consider allowing (Third Bridge Forum, 2019). Hence, Third Bridge implies that this economic risk analysis might have also been a factor in Boeing's lack of transparency surrounding the MCAS software.

Titan Grey and Third Bridge both offer crucial technical, managerial, and economic research into the factors influencing the flawed development of the 737 MAX. Their findings both advocate improved risk oversight in the aviation industry and are of fundamental importance to the approach aircraft manufacturing companies must take to prevent similar accidents from occurring in the future. Where their research is limited concerns the lack of analysis surrounding regulatory framework influencing aircraft design. FAA regulations surrounding type certificates are a large part of the framework around which companies like Boeing and Airbus develop their corporate strategies. In order to better understand their role concerning what goes into an aircraft's design, I have analyzed original regulatory documents pertaining to aircraft certification. Throughout my research, I will use the elements of these regulatory documents to draw relationships between their intentions and implications on aircraft design. Together with building a network of narrow-body commercial aircraft manufacturers via ANT, I will use this research to identify the role of these regulations as a network builder (or primary actor) governing the success of commercial aircraft manufacturing.

Conceptual Framework (ANT)

The concept of Actor Network Theory provides a fundamental framework into which a heterogenous network of actors and actants can be identified in large-scale, multifaceted engineering design systems (STS4500, 2019). In other words, the heterogenous relationships between actors are analyzed simultaneously, independently, mutually, and dynamically. Instead of trying to explain why the network exists, ANT attempts to understand the infrastructure of actor-networks, how they are formed, their network builder, and what weaknesses they have to failure. Power in these networks is achieved not from a single actor's societal hierarchy, but from the associations of each individual node of an actant with the node of the actor, i.e., power is given and shared independently and dynamically. A lower-level decomposition of the process in which these power translations occur is called translation; however, I will be using mainly the concept of heterogenous relationships to examine the failure ensuing from one primary actor's flawed usage of power within the network culminating in system failure. Hence, the focus of my case study will be through the lens of heterogenous relationship aspect of ANT and not the translation process.

The most crucial part to any heterogenous network defined by ANT is the role of the goal-setter, or the network builder. The network builder is the centrally liable party to which the health and longevity of the network and its actants are entrusted in. Since this network builder is not required to be a person, I intend to assign this role to the regulatory frameworks surrounding aircraft design in the scope of the 737 MAX case. After forming my network defined via human and non-human actors centralized around this network builder, I will use evidence found in technical readings, regulatory framework, and peer-reviewed research to better understand the heterogenous relationships that were responsible in the failed development of the 737 MAX.

Analysis

Network Formation

Understanding the narrow-body commercial aircraft network begins with identifying the relevant human and non-human actors within the system. For the sake of a streamlined, robust analysis, I will avoid listing every possible associative actor on the network and instead focus only on the most influential ones that have interdependent relationships with each other and the network. First and foremost, I argue the network builder (primary actor) in the network are the FAA regulations (non-human) that control the key guidelines and barriers to design of aircraft. These regulations' role as network builder involves setting the relevant goals shared commonly throughout the network. A crucial aspect in my analysis of their network building role involves understanding whether or not the current state of regulations pushes the network in a positive or negative direction and the approaches it takes in doing so. Additionally, I will use the heterogenous relationships aspect of ANT to further dive into analyzing how this primary actor exists within the network and the power it exerts on the actors and network itself. The key human actors in the network are the following: (1) the engineers, designers, and scientists at Boeing Corporation, (2) managers, executives, and investors at Boeing Corporation, (3) the families of victims lost in the fatal 737 MAX accidents, and (3) FAA regulators. Additionally, the nonhuman actors are (1) the regulations in place (primary actor) (2) the FAA agency itself; it's goals and mission, and (3) the Boeing Corporation itself; its financial goals and corporate mission. Having built this network, I will elaborate on the individual aspects leading to a negative heterogenous effect that resulted in the failed design and development of the Boeing 737 MAX.

Type Certificates

The FAA requires that every new plane be issued what is referred to as a "type certificate" (Campbell 2019). This type certificate explains where an airplane differs or does not differ from other models in the same type (i.e. 737, 747, A380). If an airline is determined to be of a different type than its predecessor (this would occur if "too many" technological improvements or design changes are made to the aircraft), it could spell disaster for the aircraft manufacturing company and the purchaser of the aircraft. The implicated requirements of this regulation are many-fold. By law, a pilot can only fly one "type" of airplane at a time, so the airline company purchasing the aircraft will either have to hire additional pilots and increase operating expenses, or let go of trained, expert pilots they've had for many years to hire new, inexperienced ones specialized only for the new aircraft.

Commercial aircraft manufacturing is a wildly profitable industry; mainly because there are only two main players, Boeing (USA) and Airbus (France), that control the pricing of their jetliners. In addition to having a monopoly effect on the market, the FAA outsources many regulatory and risk mitigation measures to the private companies themselves (Roberts 2019). In effect, the companies mostly regulate themselves, as they are the ones designing, testing, and in many cases, certifying their own planes (LeBeau, 2019). Although this may sound corrupt and unethical, the FAA estimates that they would need 10,000 new employees and $1.8 billion in funding every year to bring aircraft certification in-house (Campbell 2019). Additionally, there are doubts as to whether a government agency would ever be able to effectively test and certify every manufactured plane by themselves given the speed of delivery required in the airline industry, where day-by-day losses to idleness can cumulate exponentially for the companies involved, thereby placing even higher costs on the consumer. Where their virtually oversight-free operations are limited begins at the written regulations to which they are inflexibly beholden. for many years to hire new, inexperienced ones specialized only for the new aircraft.

Perhaps the most disturbing effect of these regulations is that the FAA openly incentivizes manufacturers to design aircraft that will conform to existing type certificates; an open disregard for innovation and creative ingenuity. For this reason, other than slightly less cabin space and refined interiors, you will not notice much of a difference in design from the first 737 released in 1964 and the 737 MAX of the present era.

By impeding progressive innovation in aircraft design, the "type certificate's" role in the network of narrow-body commercial aircraft is that of a deeply unsuccessful network builder. It prevents the scientific research of Boeing engineers involving real, innovative design improvements from reaching market due forced constraints of economic feasibility surrounding regulative approval. Additional barriers to relaxing type certification guidelines include the voices of concern by the families of victims killed in the Lyon Air and Ethiopian Airlines 737 MAX disasters. Paul Njoroge, whose wife, three children, and mother-in-law died in the Ethiopian Airlines flight 302 crash, testified during a hearing of the House Transportation and Infrastructure Committee that the 737 MAX is "too different from the original certified plane… re-certification must take place in combination with a full legislative fix for the aviation safety system" (Hofacker 2019). Although prior literature review states that the certification process was rushed and flawed, there is little evidence other than the MCAS and minor changes in engine placement resulting in greater efficiency of the 737 MAX that place it in an entirely new league of aircraft from its predecessor. As network builder, regulations concerning aircraft design, specifically these "type certifications" incentivizing manufacturing companies to keep aircraft technologies stagnant, must be able to effectively push all actors in the network further in the name of industry progress.

Type certificates are the main regulatory hurdle to aircraft design changes. It is estimated that training for a new type of aircraft generates cumulative nationwide costs of $50-100m in the US alone. Hence, aircraft manufacturing companies are currently making a forced trade-off preferring conformance over innovation. From a network builder's perspective, imposing these economic burdens to progress on the entire network is a net-negative towards its healthy progress. The FAA and other regulatory authorities must identify what changes must be done to type certificates to better balance the innovation-conformance trade-off caused by their restrictive and economically preventative regulations.

Pilots and Training

Titan Grey and Third Bridge, along with a majority of the scholarly work surrounding the 737 MAX, identified the lack of simulation-based training as a main cause of the gaps in pilot judgement that resulted the MCAS-related accidents on the 737 MAX. Estimates by the FAA put the cost of simulation-based training on any 737 MAX at $1,000 per pilot (Lampert 2020). For companies overseas and operating on tight budgets, spending $1,000 for each of their fleet's pilots to be simulation-trained on the 737 MAX was not seen as important enough given that the flight shared the same type certificate as its predecessor (Root 2020). Given the lack of transparency by Boeing and the FAA concerning the MCAS system, airline companies did not see a compelling reason to train their pilots on such pricey resources and instead favored computer-based training methods. Additionally, the component of lost-time to training that pilots would otherwise be using for flying passengers was also influential in its omittance. Given that pilots are the main functional users of the aircraft, the network builder set flawed goals for their safety preparedness.

Type certificate regulations clearly define that a pilot may only fly one type of airplane at a time. In other words, a 737 pilot may not fly a 787 and vice versa. Hence, the role of the pilot within the network exerted by the network builder is one of forced static complacency. In Levenson's work on human error in complex design, he mentions that risk-resilient design depends on a human operator's information, knowledge, and experience defined in specific terms. Information refers to the procedural guidelines and numeric info available to him in an interventional situation, while knowledge and experience are derived from time spent observing and independently developed cognitive abilities controlling their decision-making process. By withholding pilots from learning on multiple aircraft, they are deprived of the necessity to accumulate knowledge and experience potentially vital for unplanned-for incidents. Normative Accident Theory offers a similar argument with regard to human error in complex systems. A pilot with a greater scope of experience will always have a greater cognitive decision-making repertoire in unplanned for situations such as that which occurred to the pilots trying to correct the MCAS system in aircraft. In Darryl Campbell's reporting on the Boeing 737 MAX, the flight crew preceding that of the fatal Lyon Air crash was able to fix the MCAS system due to the input of the 3rd flight captain, who offered a solution from his own experience of error-mitigation while flying, absent of any information from the flight manual (which wasn't included anyways). We see through this analysis that the primary actant (the regulations surrounding type certifications) prevent the pilots in the network from gaining the necessary knowledge and experience to react effectively in unplanned situations. These regulations should be understood better and if necessary, revised, to promote pilots to gain diverse sets of experience on all types of aircraft. As network builder, they have a responsibility to set not only a structural, but also a mindfulness-promoting standard on all actants.

Conclusion

The sociotechnical concept of ANT provides an effective framework to analyze the network of actors in commercial narrow-body aircraft manufacturing. Through analyzing the case of the Boeing 737 MAX and its systemic failures, the knowledge gained provides insight into the role of regulations have in causing flawed engineering designs to be developed that focus more on conformation rather than innovation.

As network builder, these regulations have the greatest effect in the future design and risk resilience of commercial aircraft. Their current effect on the network of narrow body aircraft is one of imposing economic barriers to pilot training and financial infeasibility of design innovation. Given that many countries and jurisdictions already find workarounds to train pilots on simulators costing $1,000 or more, we must better understand which regulatory initiatives will best prevent accidents while promoting fiscally healthy innovation. All relevant actors, human and nonhuman, should use the research available to understand how these regulations can be amended to bring aircraft manufacturing out of decades of stagnated design and decreased risk resilience.

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