Hybrid Electric Turboprop Aircraft

The Politics of Aircraft Investigation and Innovation

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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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The Politics of Aircraft Investigation and Innovation

Introduction

Since its inception in 1914, the commercial aviation industry has revolutionized the way in which society functions today. In the United States alone, nearly 1.7 million passengers entrust their lives to the engineering feats of aviation everyday. According to the Department of Transportation, air travel is the safest mode of transportation. However, this is in large part due to the mistakes which have been made over the past century and the ways in which they've been resolved. Whenever a tragedy involving aircraft occurs, two things are sure to follow: an investigation and innovation. Yet, with these there are intrinsic politics not too dissimilar from that which may be experienced in the House of Representatives or the Senate. When a billion dollar industry is met with a death toll: lobbyists, corruption, and red herring will, and have, undertaken the justice system. Despite this, aircraft have been shaped by these disasters, making the skies safer for all who fly today. So what are these politics? And how have they led to the safest transportation network enjoyed by modern society? These questions are crucial to understanding the diffusion of not just aircraft into society, but any technology that holds human life in its hands.

As a corresponding technical project, myself and a team of fellow aerospace engineers embarked on understanding this firsthand through the development of a regional hybrid electric turboprop airplane set to be implemented in 2035. Within the next few decades, social and political factors will force the aviation industry into electrical hybridization. The basics of this is an aircraft which uses both traditional jet fuel, and an electrical battery source for propulsion. This is not so much a technical question, but a challenge. The America Institute of Aeronautics and Astronautics releases an annual design challenge which requires competitors to submit a

complete design of a conceptual aircraft. It is necessary to include everything from the basics such as wing and fuselage design, to the precise, such as the type of leather used in the passenger seats. Our task is to identify the social, safety, and design features required of this conceptual regional aircraft and uphold them to the Federal Aviation Agency's (FAA) standards. In doing so, the challenges, roadblocks, and political hurdles that are required of engineers in this field will be made clear to our team.

2022 AIAA Technical Challenge: Hybrid Electrical Turboprop Aircraft

In order to better understand the design requirements needed to innovate a certification intensive industry, the design aspect of this thesis will study the many facets that go into such an innovation. The American Institute of Aeronautics and Astronautics' 2022 design challenge requires just that. Given a list of aircraft characteristic limitations, teams are expected to design an aircraft that is capable of flying fifty passengers up to 1000 nautical miles. The caveat is to do so while implementing a flight architecture that has yet to be fully understood: hybrid electric turboprops. This describes an aircraft that uses conventional internal combustion engines and an electrically powered propulsion system.

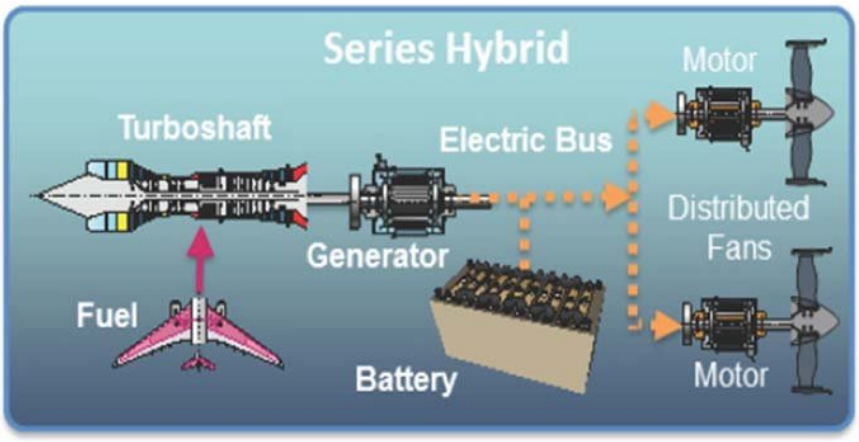

Figure 1: Illustration of Hybrid Electric Aircraft Architecture (Source: Mbarki, Saber '*The innovation of electric and hybrid aircraft*' (2020) 10.13140/RG.2.2.27570.43206

Modern regional turboprop planes play a specific and invaluable role in aviation today. As planes that generally carry less than one hundred passengers, they are limited to travel between less traveled airports, such as Charlottesville Albemarle Airport, to larger international hubs, such as Dulles International Airport. Over the last three decades, regional aircraft traffic has experienced tremendous growth, accounting for 12% of the world's available seat kilometers (the number of available seats multiplied by kilometers traveled). In terms of fleet size, there are

about 5,000 regional turboprops in service today with an average age of 23 years, accounting for nearly 16% of the global fleet. Furthermore, in 2020 regional aircraft accounted for 36% of total flight hours, and an astonishing 36% of airports exclusively rely on turboprop aircraft. While these numbers just begin to touch on the importance of regional aircraft in modern aviation's infrastructure, it is widely believed that these numbers will steadily increase in the following years. Regional air traffic is expected to increase at an average yearly rate of over 4.5% (compared to a 4% rate expected in total commercial aviation) over the next twenty years. This exponential growth will garner a projected $388 billion in market value with some 8,000 new regional aircrafts being delivered (Regional Aircraft).

The business case for regional turboprops is very well documented, but why is this so? Today, the regional turboprop market is dominated by a few players: Aerei da Trasporto Regionale (ATR), Embraer, Bombardier, and De Havilland Canada (owned by Longview Aircraft Company) to name a few. While ATR and De Havilland Canada are the largest actors in the market, they both introduced their current repertoire of turboprops in the mid-1980's. As the market continues to expand and the technology continues to age, airlines and regional aircraft manufacturers will need to innovate to meet the demands of both their customers and the environmental revolution that is being realized across the globe (Justin Hayward). Hybrid-electric regional turboprop planes will be the first to take up our efforts against climate change, hopefully as soon as 2030.

With mostly outdated technology and flight requirements which are less demanding than that of large commercial jets, an interesting experimental testing ground has emerged for the next generation of aircraft, a generation which will be defined by its environmental impact. For the industry as a whole, the advancements made in the regional turboprop sector will be monumental

in the evolution of larger aircraft. In our current understanding of hybrid technology, any solution for larger planes would require huge amounts of weight to be added, providing little additional benefit. While these larger aircraft are mostly responsible for the enormous amount of carbon dioxide released by planes each year, it is nonetheless beneficial to improve our understanding and use with hybrid-electric planes now on smaller aircraft, as to better integrate this machinery once the accommodating technology is readily available for use on larger aircraft.

The main issue in such an architecture is the positive feedback loop created by batteries needed to endorse an electrical propulsor. Jet fuel is notorious for its impressive energy density, i.e. its energy per unit volume. However, batteries are both less dense and heavier. In aviation, a golden rule is to make the aircraft as light as possible to ensure a reliable lift to drag ratio and viable flight stability. Yet, the implementation of a hybrid electric architecture is sure to offset this balance. In order to realize a higher reduction in fuel consumption, more batteries are sure to be needed, thus decreasing lift, which in turn requires even more batteries. Engineering teams have to find a way to resolve this cycle in order to find success in this challenge, but this is not the only issue at hand. Batteries, especially lithium ion batteries, are infamous fire starters, especially in extreme environments.

From this brief illustration alone, it is evident that there are a multitude of obstacles with the implementation of a hybrid electric architecture alone. However, this challenge aims to not only engage our team's problem solving skills but also our understanding of mission requirements, design tradeoffs, and public perception of aircraft. It is vital that our designs uphold both the challenge's quotas and the needs of anyone who would be flying on such an aircraft. This challenge is more than a thought experiment, but an all encompassing design and administrative task to test our ability to turn an outlandish, futuristic idea from the drawing

boards into a tangible model that can be described by mathematical principles and models. Yet, despite the freedom to design the aircraft how we would like, there are a multitude of FAA certifications and regulations that the team must consider and work around to find a solution to implementing their conceptual aircraft. This introduces politics into the equation.

Politics of Aircraft

On March 13th, 2019, following the second crash of a Boeing 737 Max, President Trump issued the first ever national grounding of a commercial aircraft. This was in reaction to two newly delivered planes falling from the sky just 132 days apart, killing 346 passengers. In this alone, there is an evident inherent political nature for aircraft and the need for a centralized body to monitor and ensure aircraft are held to the highest safety standards. This governing body is known as the Federal Aviation Agency. On numerous occasions the FAA has proven its worth, most notably following tragedies in the aviation field, but continuously in the monitoring and auditing of all planes flying within our airspace. The FAA is not void of politics in itself, as its responsibilities include determining fault after investigating crashes and administering the best course of action to avoid future accidents. These investigations are hampered by lobbyists, infighting, and racial and social facets which should not be seen within a court of the public interest, especially when it is often responsible for the safety adaptations which promote safe travel (Defazio, 2020). For example, in 1973 Varig Flight 820 was forced to land following an in-flight fire. The fire, which was caused by a cigarette bud dropped in the aft lavatory, led to the deaths of 123 people. Following this, regulations were placed on smoking mid-flight, yet, due to tobacco lobbyists, it wouldn't be another 17 years and a multitude of disasters later until smoking would be banned on airplanes entirely. Incidents like this prove the value of a governing body, while also highlighting its faults.

Considering that air travel is now a global commodity, it can be said that all of humanity is a relevant social group in terms of aircraft safety. While some countries and regions do not have access to the same aircraft infrastructure as others, the aircraft themselves are still supposed to uphold the international standard defined by the FAA. Despite this, there are disparities in

aircraft safety that have led to tragedy, especially in poorer and less developed countries where these safety standards are often not met by governments and airlines which are hoping to save some revenue. This is yet another example of the reach of the politics of flying—developing nations are more susceptible to the follies of aircraft institutions.

A large reason for politics encapsulating the aviation industry is the main incentive of commercial air travel: profit. The goal of commercial aviation is to sell as many tickets as possible, while making the actual transportation as cheap as possible. In this there can be positives and negatives. One of the positives of high profits is the ability to fund multi-billion dollar studies on how to reduce the carbon footprint of air travel. This is not because airlines love the planet, but because they love their bottom lines. Reducing fuel emissions means reducing fueling costs, which means more profits. To examine a glaring negative of this business model, we can consider how Boeing reacted to the 737 Max's grounding in 2019. First, the manufacturing company attempted to place blame upon anything or anyone other than itself. David Calhoun, former CEO of Boeing during the Lion Air and Ethiopian Air accidents, was quoted as saying to the New York Times during the investigations that overseas pilots "don't have anywhere near the experience that they have here in the US." Reporters then asked if pilots trained in the US would have been able to resolve the issues with the defected plane, to which he responded "Forget it, you can guess the answer" (Snouwaert, 2020). Ironically enough, Lion Air flight 610's captain, Bhavye Suneja, had completed his training here in the United States. Once this failed, the company tried meeting with the American Pilots Association, where they tried bribing the association's lead officials into refusing to testify in front of the congressional committee. As a backstop for this, Boeing's lobbyists "negotiated" with the committee's members as well (Defazio, 2020). Despite their best efforts, the public outcry for the accidents

was too great and Boeing had to admit to their faults. This is a rare case in the aviation industry, as too many times prior the public response has not been strong enough to warrant or demand justice for the lives lost in an accident. More times than not, the blame is dispersed amongst many parties, and the root cause is neither punished nor resolved.

Anecdotes such as this are the simplest and purest way to understand the involvement of politics in the field of aviation. Tragically the only true way for us to understand shortcomings in this field is to have an event happen that is simply too egregious to ignore. For every flight that has crashed there are endless reports of every potential factor and the ways in which they must be improved upon. In these and in between their lines is where the majority of research will be conducted. Understanding the major players in the investigation, from governments and manufacturers, to the public and airlines is key to finding the politics at play. Furthermore, each of the motivations of these groups, and the power that they hold to facilitate change must be examined (Dempsey 2010). Each and every aircraft disaster acts as a crime scene with all parties unsure of the true culprit, in this there is motivation for all to hide their hand and be as deceptive as possible.

Primary Sources

As previously mentioned the majority of contextualization for this thesis will be from numerous literature on the aftermath of aircraft investigations. Such texts will delve into case by case issues and the dynamics that impacted the way in which an accident was resolved. A text which I feel will have great implications to this thesis is Camille Burban's "Human Factors in Air Accident Investigations". This thesis conducted out of Cranfield University looks into the human factors that lead to misinterpretation of aircraft investigation data. For example, there is often a bias that Camille dubs "association" where parties of an investigation will first and foremost try to rid themselves of blame for any crash. There are many factors that go into the reasoning behind this bias, but I believe that further expanding on this thought with examples from former investigation would be comprehensive in showing how differing sides view a crash (Burban, 2016). Another text which I find enlightening for my studies is "The Flight of Information: New Approaches for Investigating Aviation Accident Causation" by Thomas Griffin. This thesis covers how algorithms, simulations, and the data revolution can be used to expedite and even predict the causes of an aircraft's accident. As we know from this course there are a number of biases, politics, and issues that come with any unit of measurement or detection and I find that this is no exception. Griffin also touches on the intricacies of current investigation strategies and how they are able to easily be manipulated by outside factors, often leading to less than ideal outcomes.

In a similar light, Paul Dempsey's "Independence of Aviation Safety Investigation Authorities: Keeping the Foxes from the Henhouse" discusses the need for secularism in aircraft investigations. His paper touches on how the rapid nature of an investigation can lead to entities covering up information from the public domain to better suit their interests. I feel an essay like

this would be critical in defining the motivations behind the actors of an investigation and outlining how they interact with the public to paint themselves in the best light. Dempsey also references the monetary value of an investigation and the ways in which different companies can lose prestige due to ongoing, or poorly depicted investigations (Dempsey, 2010). The final piece of literature that caught my attention was Whipple's "Crash Course: The Decisions That Brought Down United Flight 173". As I intended to do throughout this thesis, Whipple dives into a case study of a number of prior mistakes that led to the downing of Flight 173, which led to the death of ten people in 1978. Inquiring on case studies such as this provides a crucial context to the reader that most crashes are due to a chain of events that begin years or even decades before the doomed plane leaves the ground. In this case, Whipple examines how previous mishaps in investigations, including corruption by airlines using cost cutting measures, led to this tragedy (Whipple, 2015). I believe that viewing cases like United Flight 173 that were caused by a snowballing of politics will be best suited for the intentions of this thesis.

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