Conceptual Design of a Hybrid-Electric Turboprop Regional Aircraft
(Technical Paper)

Investigating Formula One’s 2030 Sustainability Initiative
(STS Paper)

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By
Vincent Fimiani
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Technical Team Members:
Robert Taylor
Christian Prestegard
Catherine DeScisciolo
Danny Lattari
Kazi Nafis
Kyle Hunter
Michael Richwine
Nathan Vu

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.

ADVISORS

Jesse Quinlan, Department of Mechanical and Aerospace Engineering

Bryn E. Seabrook, PhD, Department of Engineering and Society

Introduction

As the saying goes, talk is cheap, and it is much cheaper than incorporating business practices. When that business is operating the world's foremost global motorsport competition or flying thousands of people across the country every day, it looks even cheaper in comparison. Formula One (F1) has been the pinnacle of motorsport since the 1950's, but it has only recently tried to become sustainable. Much effort has been put forth to this end, most notably by rolling back engine regulations from their trademark V8s, V10s, and V12s to a hybrid V6 engine in 2014 (Collins, 2014). Furthermore, F1 declared that they will be net carbon zero by 2030 (F1 Sustainability Strategy, 2019). Likewise, the aviation industry recognizes the need to make air travel more sustainable. Therefore, the American Institute of Aeronautics and Astronautics (AIAA) has developed a Request for Proposal (RFP) for a hybrid-electric regional turboprop aircraft with a 2035 entry into service. The AIAA tasked undergraduate teams across the country to design a concept aircraft that incorporates a hybrid-electric propulsion system while decreasing block fuel consumption by 20% over a 500 nautical mile mission. The proposed concept must also meet several other technical requirements, performance characteristics, size constraints, and economic considerations (American Institute of Aeronautics and Astronautics, 2022a). This STS research project will investigate how F1's sustainability efforts are helping or hindering it from meeting its goal of becoming net carbon zero. In the capstone project, the team will collaborate to ideate, select, and design a novel concept for a hybric-electric regional turboprop aircraft.

Technical Portion – Design of Hybrid-Electric Turboprop Regional Aircraft

The goal of the capstone will be to collaborate with 8 peers in a design group to produce a fully-fledged concept aircraft that satisfies or exceeds all requirements stipulated in the AIAA

RFP. To start the process, the group will ensure full comprehension of the problem and current development efforts through careful analysis of the RFP requirements. After identifying the problem, the group will generate preliminary concepts, including the outer shape of the aircraft and a description of the mission, to select the optimal design for refinement.

Brainstorming will down select the group's individual preliminary concepts to determine the optimal solution. During this process, the group will look at everyone's concept and discuss what design aspects they like and dislike from each individual concept. This process will ensure that the group's optimal solution incorporates the best ideas from every person on the team. The best conceptual designs will then be examined in greater detail. At this point the group will conduct trade studies – a form of analysis that looks at how changing one aspect of the design affects another in order to find the optimal balance of both aspects – to determine feasibility and which ideas to move forwards with. Finally, the group will choose the final concept which will be the subject of in-depth design (Quinlan, 2022a).

The in-depth design will involve running system-level simulations and structural analysis, as well as determining the exact propulsion configuration and how much of the required energy will be electrified. This portion will be highly iterative. The goal will be to parametrize models, assign variables to various features and run optimization functions, where possible. In addition to parametric modeling, it will take trial and error as well as group discussion to increase the concept's readiness level due to limited applications of parametric modeling. However, by performing parametric analysis, the group can remove objectivity from testing and determine exactly which aspects of the design contribute to performance gains. Therefore, the use of parametric analysis will be prioritized during the design process (Quinlan, 2022b).

Throughout this process, documentation will be very important. The AIAA requires justification of the design decisions made by the group. Additionally, acknowledging and justifying why the design did not go in a certain direction with both qualitative and quantitative arguments is imperative to a successful design. The justification can come in the form of research papers, trade studies, and computational models. It will be a priority to keep track of all the information the group will generate and use so that the design is as strong as possible and capable of defending (American Institute of Aeronautics and Astronautics, 2022b).

Our final design will be a fully modeled concept aircraft illustrated in a technical report submitted to the AIAA. This report will cover everything necessary for a concept aircraft to gain funding. First, the group will develop the chosen design mission, aircraft performance summaries, payload range chart, and materials selection. The general design outline will provide a high-level overview of the capabilities of the concept aircraft. Next, the group will deliver a complete geometric description, as well as report aerodynamic performance, a weight statement, and a center of gravity envelope. These characteristics are the basic physical properties of the plane which will serve as the baseline for determining more specific characteristics and qualities of the aircraft. Additionally, we will choose and characterize a propulsion system. Although the plane is required to be hybrid-electric, there are many ways to accomplish this using a variety of propulsion architecture. The primary choice will be to choose a configuration that uses batteries or no batteries. Configurations requiring batteries, such as series/parallel hybrid or parallel hybrid, offer more efficiency gains but require extremely heavy batteries. However, configurations without batteries such as turbo electric or series hybrid are lighter but lack efficiency. From these characteristics, the group will summarize the stability and control characteristics to prove the aircraft is stable. Finally, a cost estimate and business case analysis will identify the cost drivers and economic feasibility of the aircraft (American Institute of Aeronautics and Astronautics, 2022a).

STS Topic – Sustainability in Formula One

Formula One (F1) began its modern sustainability push in 2014 with the introduction of the V6 turbo-hybrid power unit. These engines use 35 percent less fuel than their predecessors and are heavily featured in F1 advertising (Collins, 2014). However, F1 did not stop, releasing a new engine formula for the 2026 season. These engines will run on fully sustainable fuel, reduced another 30 percent from the current engines (Kanal, 2022). But even with these technological advancements, is F1 truly pushing to be sustainable? Their sustainability plan envisions the ambitious goal of being net carbon zero by 2030 (F1 Sustainability Strategy, 2019). However, for all their efforts in making the cars more sustainable, it does not address the root of the problem. According to the 2019 F1 Sustainability Strategy Report, only 0.7% of emissions during the F1 season come from the cars, including all testing conducted before and after the season. 72.2% of all carbon emissions during the F1 season are from logistics and travel. This includes moving the teams' equipment, F1's own equipment, as well as travel and lodging for all the teams as well as F1's own employees (F1 Sustainability Strategy, 2019).

There are several stakeholders involved in this problem, each with their own motivations. The first is the FIA: the world's governing body for motorsport. Their goal is to uphold the rules and regulations of motorsport and preserve it by making it more sustainable. The Formula One Group (including Formula One Management), owned by Liberty Media Group, is responsible for marketing and promoting F1 (Pretorius, 2022). Their goal is to make as much money as possible through television and streaming deals, as well as track fees. Next, there are the 10 teams who compete in F1. Their first and foremost goal is to win the World Driver's Championship and

World Constructors Championship. By winning these championships, the teams earn more prize money and obtain more sponsorships, extending the life and improving the quality of their team. Finally, there are the fans, whose primary motivation is to watch the best racing with the most technically advanced cars. The primary physical artifacts are the F1 cars and power units. Out of all the artifacts, these have the highest visibility to the fans, and have the most exposure to illustrate sustainable change in F1. Other physical artifacts include the biofuels used in the new generation of cars and logistics vehicles, as well as the batteries used in the power units. Biofuels have applications both on the logistics and racing side of Formula 1, producing less direct emissions than their current competitors, but it is unclear if these will offer an overall sustainability improvement during their entire life cycle (Ershov et al., 2022). Along those lines, there are already several concerns raised by the mining and production of lithium-ion batteries used in F1 power units (Murdock et al., 2021). For non-physical artifacts, the logistics network of F1 is the largest. This is the largest contributor to F1's emissions and presents the greatest challenge to solve, as part of F1's draw is that it is a global motorsport championship which competes around the world (F1 Sustainability Strategy, 2019). Additionally, each race has specific timing considerations, such as weather or contractual agreements, meaning that developing an optimized schedule is a challenge.

The technological fix will be the STS framework used for this research. This concept was first coined by Alvin M. Weinberg to describe the use of technology to fix a societal problem. A historical example of this is the use of nuclear weapons to end war (Seabrook, 2022a). However, this framework was quickly criticized by many scholars, who claimed that the technological fix served to "mask the symptoms of complex social problems without addressing their causes or true costs." One of the technological fix's main critics, Byron Newberry, further critiques the framework, claiming that a technological fix quickly becomes an “easy way out,” or “shifts the locus of the problem” (Newberry, 2005). However, this critique provides depth to the framework, and allows for further analysis of how technological fixes do not address the underlying social, political, or environmental problem. During the analysis of F1’s sustainability efforts, the technological fix framework will be applied to determine if F1 is solving their core sustainability problem or simply alleviating the symptoms of the problem through the introduction of new technology.

This research matters because Formula 1 is currently reaching unprecedented levels of popularity in the United States. The Netflix docu-drama “Drive To Survive” sparked F1 fever in the United States during the entertainment-starved COVID-19 pandemic, and the notoriety has only grown from there. The 2021 season was the most viewed in American broadcast history with an average of 949,000 viewers per race and is currently averaging 1.4 million viewers per race for the 2022 season (Hall, 2022). Early in this season, the Saudi Arabian Grand Prix was the most-viewed F1 race on ESPN since they acquired the broadcast rights in 2018, and it was the most viewed F1 event on cable in almost 30 years (Eubanks, 2022). For all this popularity, people deserve to know if the sport they love to watch is actually improving sustainability in a meaningful way.

Research Question and Methods – Wicked Problem Framing

The research question for the STS Topic is “How will F1’s sustainability efforts help or hinder it from meeting its goal of becoming net carbon zero?” Wicked problem framing will be the STS framework used to frame the research question. Selection of this methodology will be prudent because of its applications to sustainability focused problems. Problems concerning sustainability often become wicked problems due to their characteristics. These include how the problem definition depends on the solution and vice versa, stakeholders understanding the problem differently, changing problem constraints, and how the problem is never solved definitively (Seabrook, 2022b). These characteristics aligns well with the given research question, as it meets many of the criteria of wicked problems. First of all, the problem statement in itself – becoming net carbon zero – while seemingly objective, is quite subjective. For example, when using the phrase “net carbon zero,” carbon credits can be used to offset emissions, even if F1 operations still produce carbon. This change in the solution changes the scope of the problem drastically, as F1 now only must reduce carbon emissions, instead of eliminating them. Additionally, all the stakeholders in F1 have very different motivations, and some even oppose the sustainability push, making the problem-solving process much more difficult. Finally, the problem can change and remain unsolved due to the long period of time available to get to a solution. Based on these factors, it is reasonable to conclude that the research question will align with this methodology.

Conclusion

In the STS research project, I will investigate how F1’s sustainability efforts are helping or hindering it from meeting its goal of becoming net carbon zero. In the capstone project, the team will collaborate to ideate, select, and build a novel concept for a hybrid electric regional turboprop. Once completed, the STS research project will serve as a holistic analysis of how F1 is working to meet its sustainability goals and estimate if they will in fact reach their goal. Additionally, it will serve as an investigation into the integrity of their statements on sustainability and help to determine if they are truly genuine in their efforts. The completed capstone project will be submitted to the AIAA to introduce a novel concept for sustainable aviation to industry experts for evaluation. In this submission, cutting edge ideas will contribute to a design that aims to push the boundaries of sustainable aircraft's capabilities. The group hopes to present an innovative solution to reduce block fuel burn for a hybrid electric turboprop regional aircraft in order to advance the effort for sustainable aviation.

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