Thesis Project Portfolio

Conceptual Design of a Hybrid-Electric Turboprop Regional Aircraft

(Technical Report)

Investigating Formula One's 2030 Sustainability Initiative

(STS Research Paper)

An Undergraduate Thesis

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Executive Summary

The relationship between the STS research and capstone projects in this portfolio is an investigation of new technologies and techniques for sustainable transport. Although the topic of the STS research is Formula One motorsport, most of the carbon emissions produced by Formula One are from cargo or personnel transport. The research identifies several cutting-edge technologies which can be used to improve carbon emissions in transport, including alternative fuels for both land and air travel. The goal of the STS project is to determine if Formula One will meet their sustainability target of net zero carbon emissions by 2030. Carbon emission reductions is a shared goal with the capstone project, the subject of which is a conceptual design of a hybrid-electric turboprop regional aircraft which can reduce block fuel burn by twenty percent on a 500 nautical mile mission. A hybrid propulsion architecture is the technology used to meet this goal, specifically applied to a fifty passenger turboprop regional transport aircraft.

This capstone project serves as a submission for the AIAA Hybrid-Electric Regional Turboprop Request for Proposal (RFP). The subject of the RFP is a conceptual design for a fifty passenger turboprop transport aircraft with a hybrid-electric propulsion architecture. The main requirements for the submission are a twenty percent reduction in block fuel burn compared to current turboprops, a reduction in emissions such as carbon dioxide, NOX, and soot compared to current turboprops, and a viable entry into service date of 2035. The capstone team began the design process with nine original designs, of which three were deemed to have the greatest chance of success and were taken into the preliminary design review (PDR) stage. During PDR, one iteration of the aircraft design process was performed on each aircraft. Using NASA's Flight Optimization System (FLOPS), the weights, aerodynamics, propulsion data, and mission performance were obtained for each design. The capstone team then identified the best design

from the three using this data to take to the critical design review (CDR) stage. CDR serves two purposes: to optimize the chosen design through multiple iterations of the aircraft design process, and detailed design for each subsystem aboard the aircraft. The team summarized their findings in a report justifying the design process of their concept, as well as final performance data to prove the conceptual design meets RFP requirements.

Over the past decade, Formula One has set lofty sustainability goals. This paper investigates if Formula One's current efforts towards sustainability will allow them to meet their goal of becoming net carbon zero by 2030. The three main research areas explored in the paper are the production and use of biofuels in Formula One race cars and support vehicles, the production of lithium-ion batteries present in Formula One hybrid power units, and the logistics of the Formula One support system. This investigation will utilize the technological fix framework and will attempt to identify if the current measures implemented by Formula One address the fundamental sustainability problems posed by Formula One operations, or are simply alleviating the symptoms of problems created by using these technologies. Due to limited investment in biofuel production, non-ideal lithium mining practices, and the global nature of Formula One racing, it currently seems unlikely the carbon zero goal will be met in 2030. This research is significant to STS because it provides a new example of an investigation into the technological fix. Additionally, it serves as an insight into the intersection of sports, engineering, and sustainability. The analysis will introduce the perspectives of Allen Weinberg and Byron Newbery on the technological fix and utilize them to determine the efficacy of Formula One's sustainability efforts.

The value of working on both projects simultaneously is improved interdisciplinary thinking and improved familiarity with hybrid technology. Investigating multidisciplinary

sustainability efforts in Formula One encouraged design choices and considerations outside the scope of what was explicitly stated in the RFP in order to meet and exceed RFP requirements. This is due to the wide-ranging scope of Formula One's emissions problem. Although the most visible part of Formula One's carbon emissions is the race cars themselves, the vast majority of emissions are produced by travel to and from race tracks around the world. These considerations sparked additional investigation into the viability of proposed solutions for the capstone project. Additionally, the detailed systems-level analysis required by the capstone project bolstered the understanding of possible solutions for Formula One's carbon emissions. Learning about advanced hybrid-electric concepts strengthened the understanding of Formula One's use of hybrid technology, affording a greater detail of accuracy when determining the viability of proposed solutions for Formula One's sustainability goal.