

Trident: A Response to the NASA University Engineering Design Challenge 2013-2014

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Submitted May 9, 2014

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Abstract

This document contains a Conceptual Design Review for the NASA University Engineering Design Challenge 2013-2014. This design was performed for Purdue's Spring 2014 Aircraft Senior Design course. The objective of this project is to design a high altitude, long endurance system of unmanned aircraft for the purpose of monitoring hurricane development, while minimizing the cost of a six-month long period of continuous observation.

A concept of operations was developed based on the needs of the Client, which required the system to launch from the NASA Neil A. Armstrong Flight Research Center, climb to FL600 in restricted airspace, fly to the surveillance zone off the northwest coast of Africa to collect data, and return to the launch site.

Once the concept of operations was developed, the system architecture was designed and a design mission was prepared. The system was designed using two aircraft in order to provide continuous coverage during the hurricane season. The design mission was created to simulate the most difficult mission for the system, which is carrying the full payload and not dropping any expendable payload.

The best concept created, the OQ451-5 Trident, is powered by hydrogen and able to loiter at 60,000 ft over the surveillance area for seven days. It is a triple boom design of composite construction, with payload located in the center boom and the fuel located in the outer booms.

In order to size the aircraft, a sizing code consisting of a series of MAT LAB functions describing equations of motion was developed and validated on a modular basis. This was done to ensure that the trends produced were consistent with the underlying physics and published references when possible.

Design trade-offs from the conceptual design phase are detailed in this report. Trade-off studies and design decisions were made for endurance length, fuel choice, and aircraft configuration.

In order to assess the aerodynamic performance of the aircraft, a drag buildup was produced. This buildup includes the parasite and induced drag coefficients. The NSF(1)-1015 was selected as a potential airfoil. This airfoil was selected due to its design for high-altitude flight. No high lift devices were implemented in the aircraft because the chosen potential airfoil produces enough lift for the design mission without being altered.

A performance summary is also included in this report. This summary details performance characteristics of the aircraft such as stall velocities and takeoff and landing distances. A payload-range diagram as well as a map showing the endurance of Trident at different locations was generated to further illustrate some of the performance characteristics of the system.

A turbo-compounded hydrogen-fueled piston engine was chosen to power this design. The use of more traditionally fueled turbine or piston engines was considered but not implemented due to the significant decrease in specific fuel consumption offered by hydrogen.

Composite materials were chosen for most of the structure of the aircraft. This decision was made in order to save weight. V-n diagrams were produced for several flight conditions in order to ensure that the aircraft would be able to operate without exceeding structural or stall limitations. A weight breakdown was produced in order to calculate the aircraft's center of gravity at the heaviest design condition. Stability and control analysis was done in order to size the control surfaces as well as calculate the static margin.

A list of advanced technologies implemented in this system is also included in the report. These technologies include the engines and fuel as well as the materials and avionics implemented in the aircraft.

Finally, the system was evaluated based on Key Performance Indicators. It was determined that the most important key performance indicators for the system were the cost and the hurricane surveillance performance. A cost analysis was performed in order to determine the production cost, design cost, and operation. In order to assess the surveillance performance, coverage rates were calculated and compared to the Global Hawk, the aircraft currently filling NASA's high-altitude long-endurance hurricane observation role.