Trailing External Measurements for Pressure Testing (TEMPEST)

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Introduction

Problem Statement:

Design and construct a trailing system that measures the static pressure outside the turbulent wake of an aircraft during flight tests.

Motivation/Background:

Airplanes have onboard pressure sensors that are used to determine the plane's velocity and altitude. Trailing pressure cones that measure the static pressure of the ambient air outside the turbulent wake of the plane are used to calibrate these sensors. Current measurement systems are bulky and take excessive installation time. A new system that is less invasive would ease installation and reduce complexity. This would greatly benefit AeroTEC and its customers.

Product Specifications:

- Static pressure measurement within 90% accuracy of existing systems
- Usable on Part 23-25 aircraft with minimal modifications
- Deployable/retractable in flight
- Self contained power
- Wireless data link
- Flight time of at least four hours
- Integrate with AeroTEC data acquisition system
- Under 25 pounds

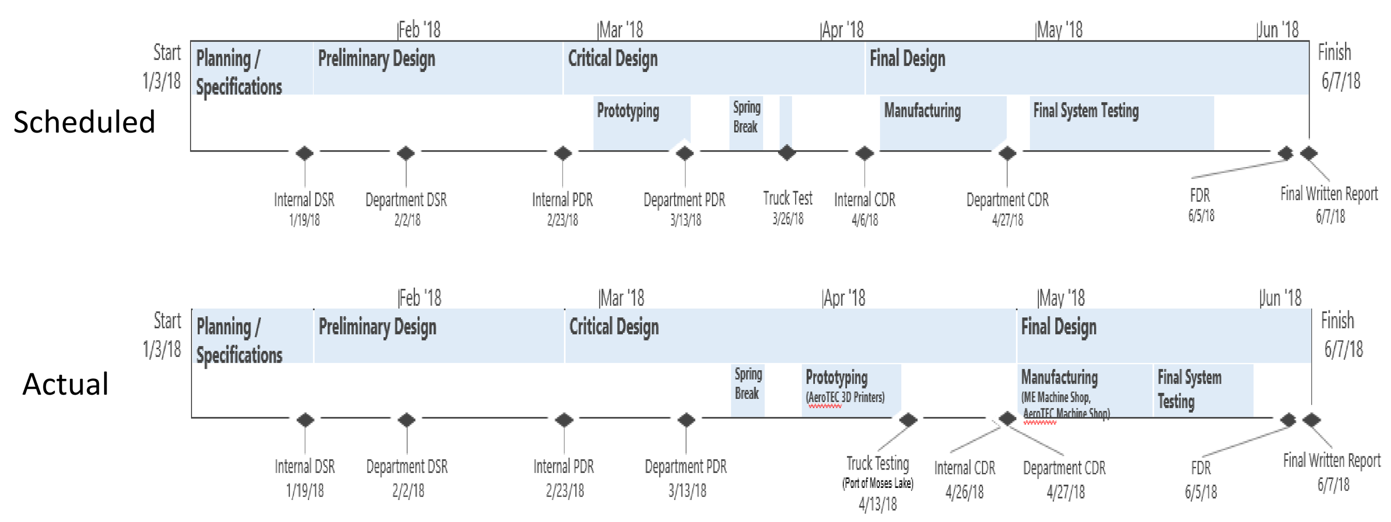
Impact/Contribution:

This project is intended to simplify the processes used to calibrate aircraft instruments. This frees up time and manpower that would be used installing and switching trailing cones to work on other more pressing issues.

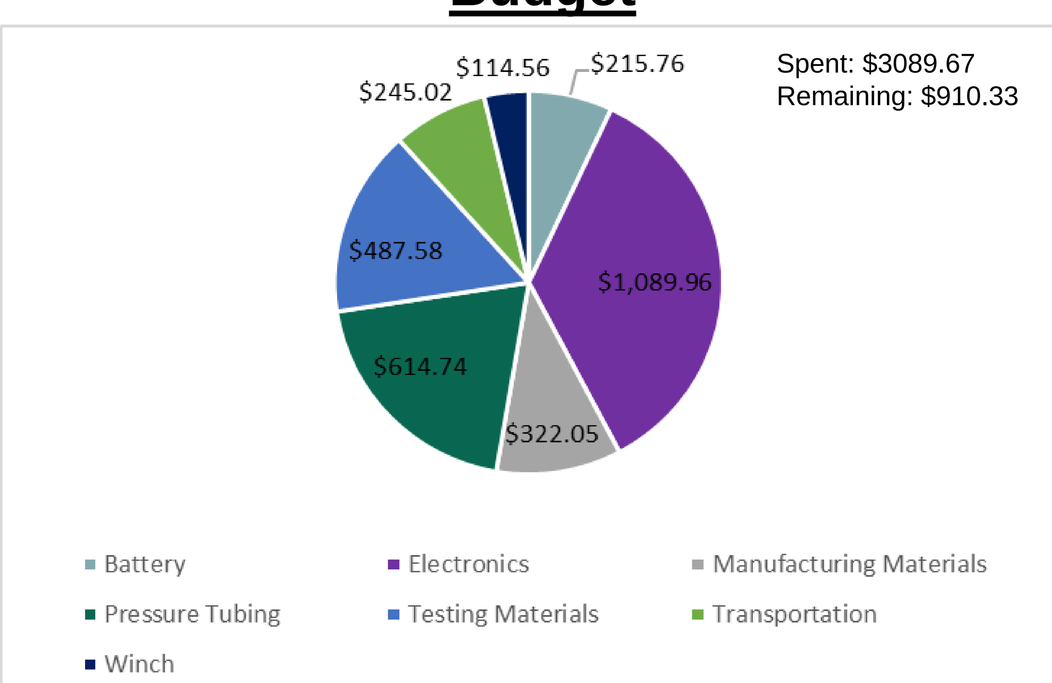
Ethical/Environmental Considerations:

Safety is a major consideration for this project. Any errors in the pressure data could lead to problems for the aircraft while in flight with possibly catastrophic consequences. Additionally, while the product is in use, any failures could cause damage to both the aircraft and any people or structures below.

Timeline



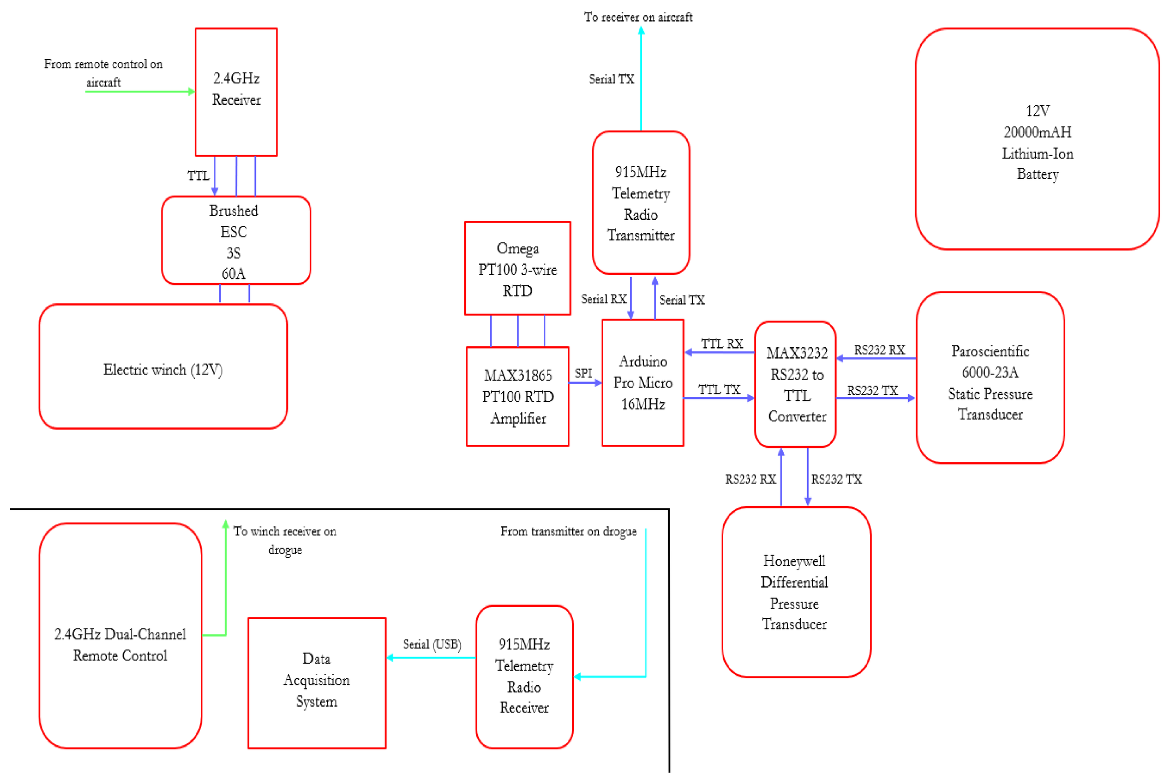
Budget



Product

Electronics System:

The function of the electronics system is to read static pressure, total pressure, and temperature data. The system must also transmit this data to the aircraft in live time.



Paroscientific Series 6000-23A Static Pressure Transducer
- Programmed for continuous RS232 serial data output
- Pressure range: 0-23 psi with 0.01% typical accuracy

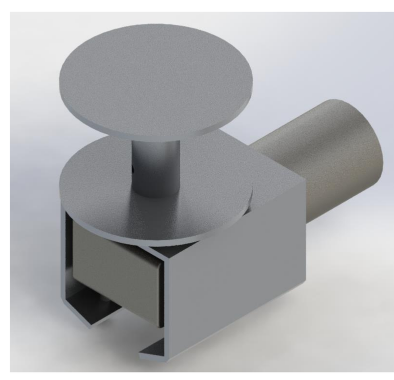
Honeywell Precision Pressure Transducer
- Dual inputs for differential measurement between static and total pressure
- Pressure range: 0-20 psi with 0.1% accuracy

915MHz Telemetry Radio
- Lightweight and compact
- Typical range greater than 300m
- Transmit power up to 20dBm, receiving sensitivity of -121dBm

Omega PT100 Platinum RTD Sensor
- Used to measure static temperature
- Temperature range: -200°C to 500°C
- Accuracy of ±0.5°C

Arduino Pro Micro
- Small and light Arduino board with ATMega32U4
- 12 digital pins, 4 analog pins
- RX/TX hardware serial connections

Winch System:



- Located at front of drogue
- Used to reel the system out from the plane to take measurements and to reel back in when the system is not in use
- Remotely controlled via a 2.4GHz radio system
- Waterproof brushed ESC capable of forward, reverse, and brake with overheat and signal loss protection
- 12V DC Uxcel motor rated at 20kg-cm of torque at 30 RPM
- Aluminum mount and spool manufactured by team
- Holds 80 ft of 2mm line

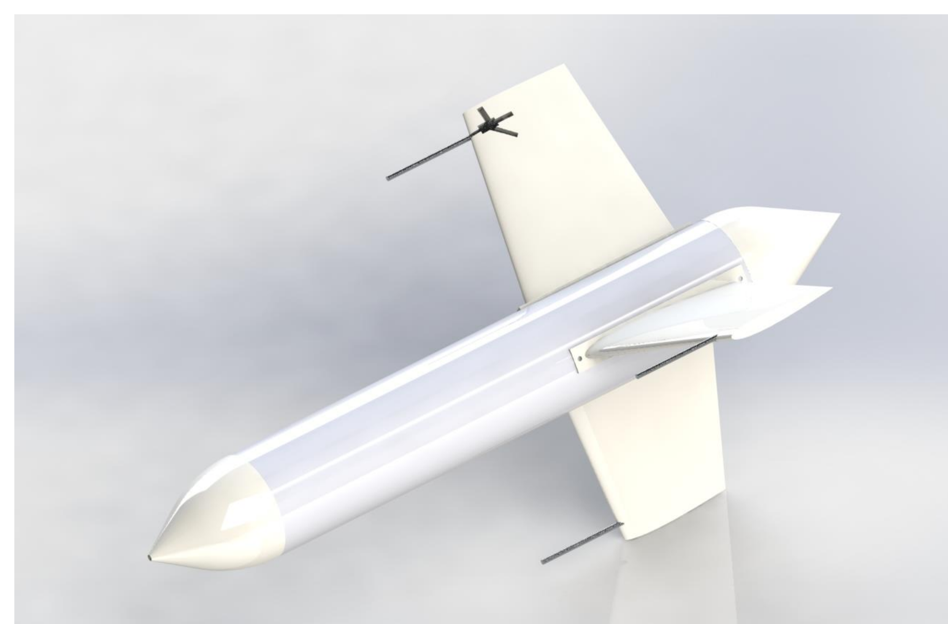
Body Design:

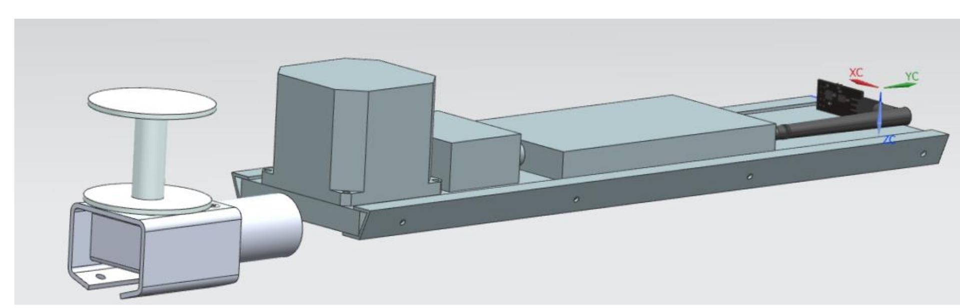
Fuselage:
- 1/32 inch bent aluminum sheet
- Inner diameter of 4.25 inches, length of 22 inches
- Chosen for manufacturability and construction while still saving weight

Nose/Tail Cones:
- 3D printed
- Tail cone length of 5.5 inches , nose cone length of 4.8 inches
- Attached to fuselage with self-drilling screws to allow for removability

Fins:
- Three fins laid out in a symmetric design
- 3D printed to include mount for pitot tubes and routing for pressure tubing
- Symmetric airfoil with root length of 7 inches and tip length of 5 inches

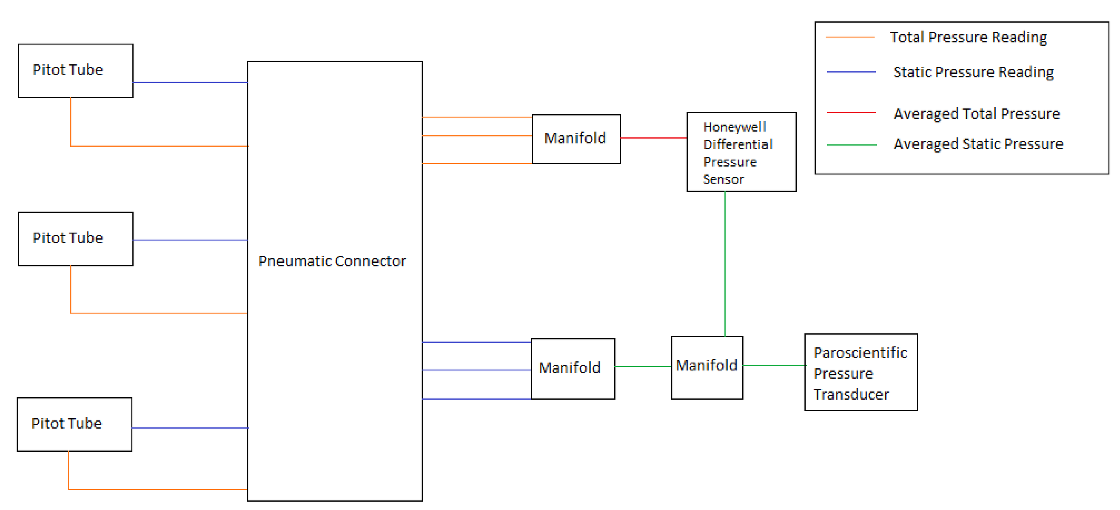
Electronics Payload Housing:
- Electronics mounted directly to plywood board
- Payload 15 inches by 3.5 inches
- Payload slides under aluminum angle bracket riveted to fuselage
- Payload bolted to angle bracket





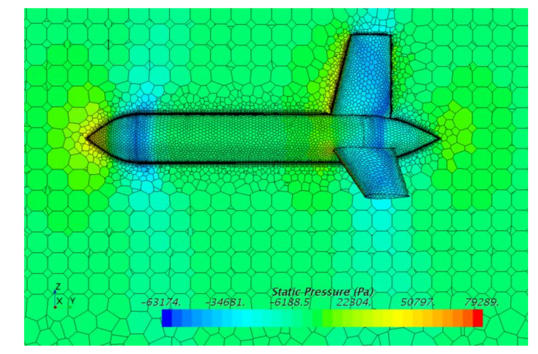
Pressure Routing:

- Tubing runs through channels in fins, is averaged in manifolds, and routed to both pressure sensors
- Tubing separable with pneumatic connector for easy access to electronics payload
- All lines vacuum seal tested



Design Analysis

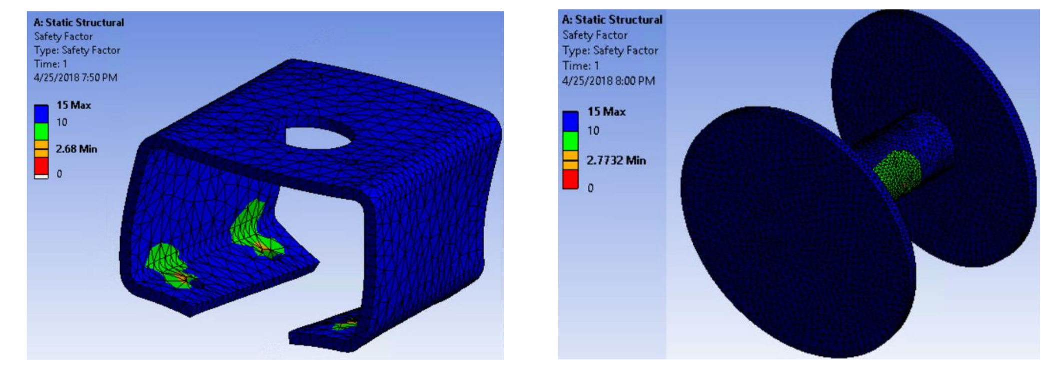
Computational Fluid Dynamics Analysis:



- Simulations on multiple fin configurations to determine lowest drag
- Determined drag and pressure profile of final design at 2 critical speeds: max reel in speed and max speed

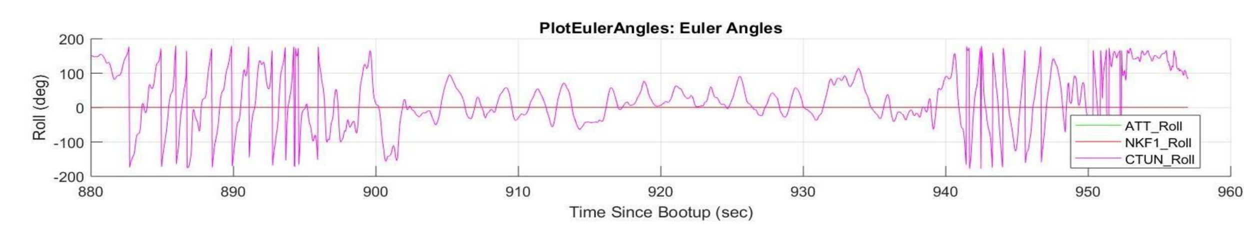
Finite Element Analysis:

- Used to help safely design parts under high loading



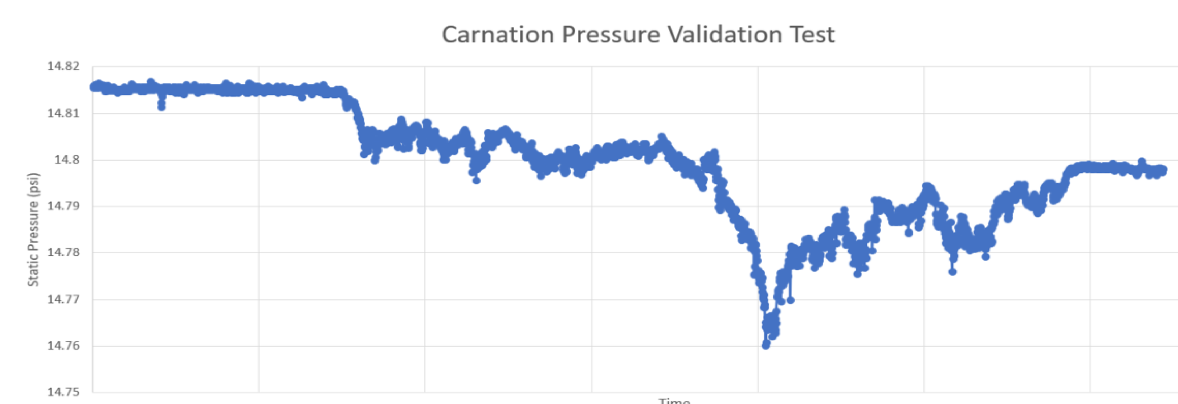
Truck Test:

- Towed scaled down drogues behind a truck at the Port of Moses Lake
- Tested several different fin configurations to decide which design to pursue
- Most stable configuration was selected



Validation Test:

- Tested all data acquisition systems
- Showed ability to collect and transmit reasonable static pressure and temperature that respond as expected with respect to velocity



Conclusions

This system has proven to measure static pressure and static temperature reliably and is able to transmit this signal. Next steps include calibrating the differential pressure sensor, integrating GPS, and performing a full scale flight test.

Acknowledgements

Special thanks to the UW Department of Aeronautics and Astronautics and AeroTEC for this wonderful opportunity. We especially thank our industry mentors, Todd Leighton and Kent Baines. Likewise, the Autonomous Flight Systems Laboratory, especially Hannah Rotta, and our faculty advisor Dr. Christopher Lum.