Development of Modular Dynamometer and Thrust Test Stand

Cameron Gable, Hogan Hsu, Anthony Russo, Sergio Ramirez Sabogal, Brian Sandor

Department of Aerospace Engineering, University of Michigan, Ann Arbor, Michigan

Introduction

Professor George F. Halow has tasked us with developing a modular thrust test stand and dynamometer with the following capabilities:

- Ability to accommodate all propeller sizes currently used by teams participating in the *Aerospace 495 Systems Engineering Leadership Course*
- Measure thrust, torque, RPM, power draw, temperature, pressure, and airspeed
- Must be accurate, reliable, and effective
- Develop the system under a $550 cost cap
- Make the system user-friendly and repairable for extended use

This thrust test stand and dynamometer will allow the teams in Professor Halow's course to eliminate a large time and resource draw from their plans as currently they need to develop their own thrust testing systems.

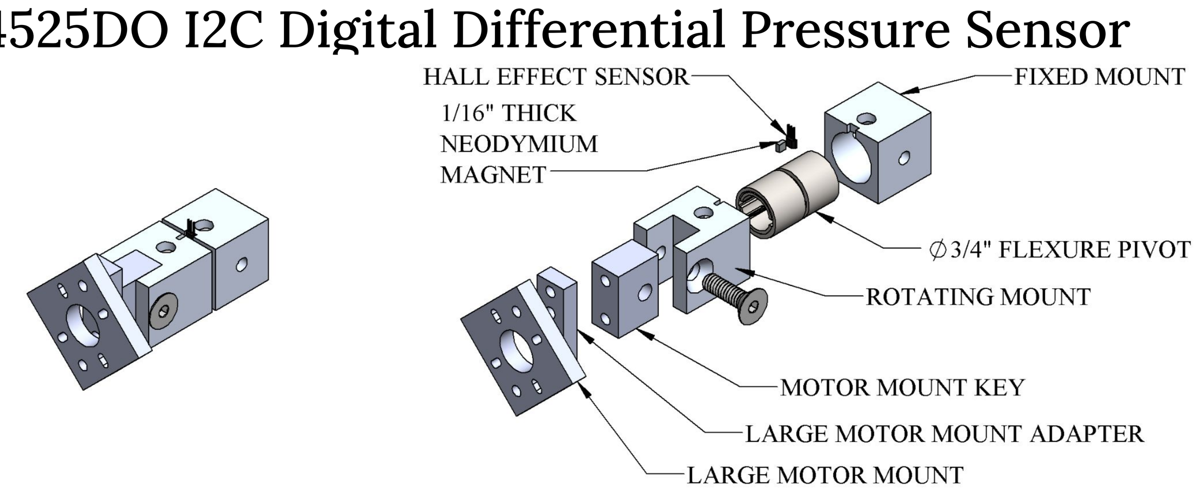
This modular system also accommodates propellers between 5 inches and 20 inches in diameter which is a capability which currently does not exist in off-the-shelf systems.

Criteria Rationale

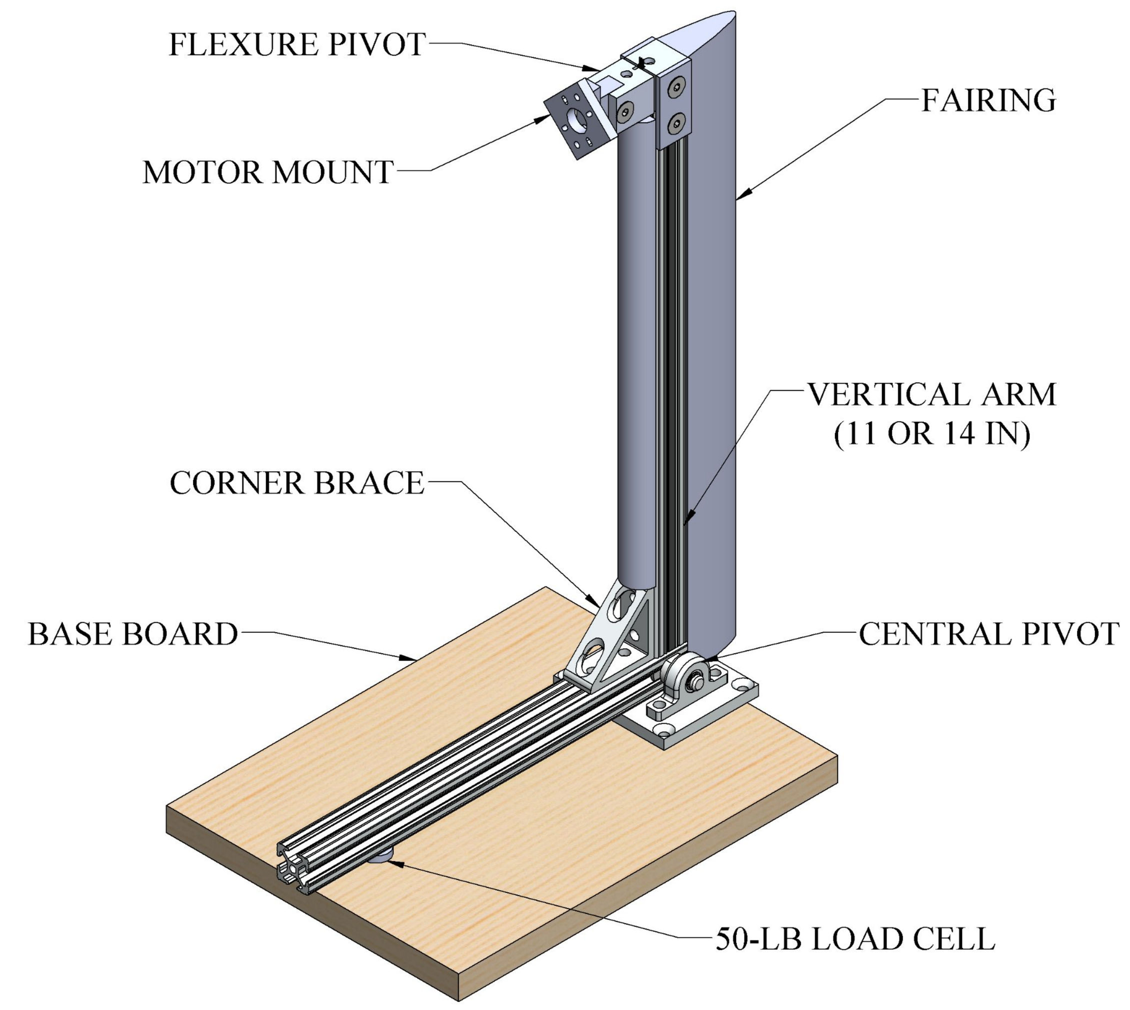
1. The thrust test stand must effectively measure all data within 5% of the actual values for each propeller.
2. Test campaigns must reliably produce the same results within 5% for a given motor and propeller combination
3. Structure and sensor suite must be able to accommodate large range of propeller and motor sizes and be easy to repair, store, and use

Sensor Suite

1. Thrust Load Cell
   a. TE Connectivity 50lb FX29 Analog Load Cell
2. Torque Flexure Sensor (Seen below)
   a. A1302 Hall Effect Sensor with C-Flex I-30 Flexure
3. Custom Tachometer
   a. EK1254 IR Sensor and reflective tape
4. Voltage and Current Sensor
   a. KR Sense 90A Current and Voltage Sensor
5. Pressure and Temperature Sensor
   a. Adafruit BME280 I2C Temperature and Pressure Sensor
6. Airspeed Sensor
   a. 4525DO I2C Digital Differential Pressure Sensor



System Design

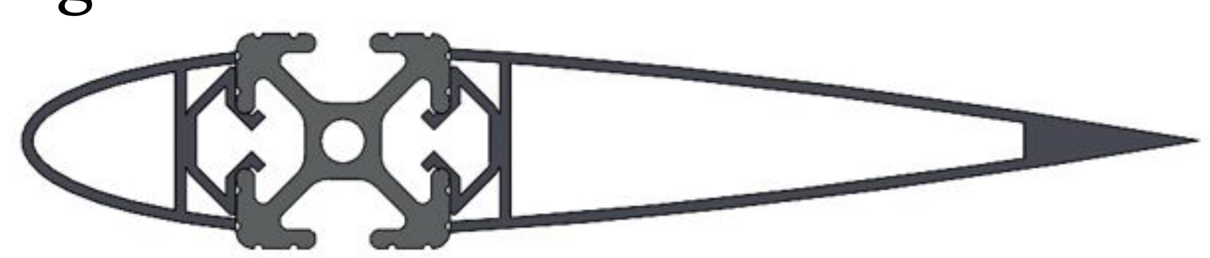


- Modular design with two different arm lengths
- Different lever arms take advantage of full load cell range
- Strength of structure verified through FEA analysis
- Low friction pivot to minimize "stiction" in data

Flexure/Motor Mount Assembly

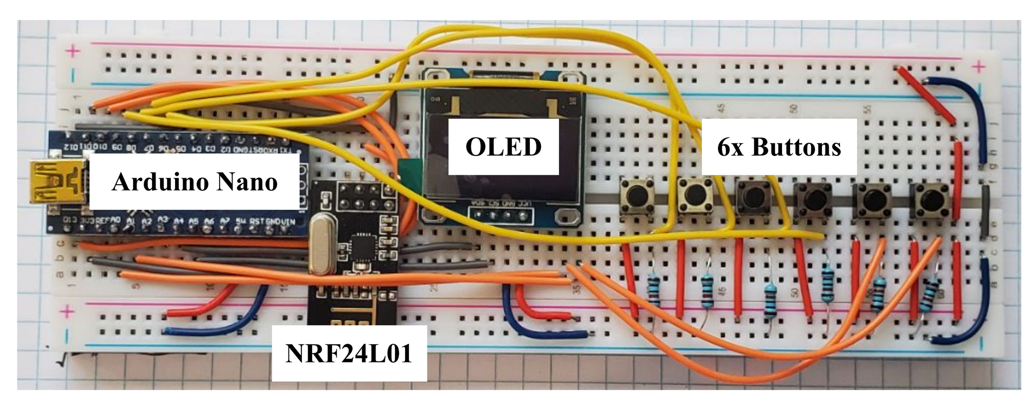
- Minimizes cross-sectional area behind propeller
- Theoretically high precision and repeatability
- Long lifespan and easily repairable

Fairing



- NACA 0015 airfoil fairing for vertical arm of the stand
- Low drag at applicable testing conditions

Hardware



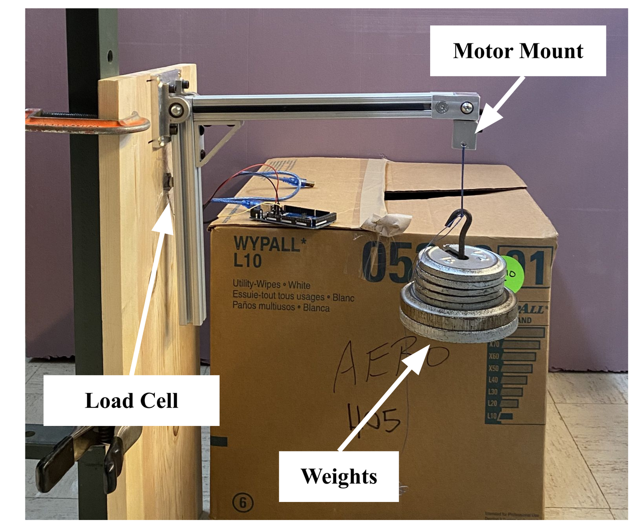
- The remote and base station use Arduino microcontrollers
- nRF24L01 2.4GHz radio transceivers for communication
- Data written to SD card for easy data analysis
- Remote uses SSD1306 OLED display for testing input

Software

- Developed using the arduino programming language
- nRF24L01 reliably uses custom designed data packet
- Remote uses specialized low RAM OLED library
- Github is used for version control and documentation
  - https://github.com/1iggy2/AE405-Thrust_Stand

Calibration and Testing

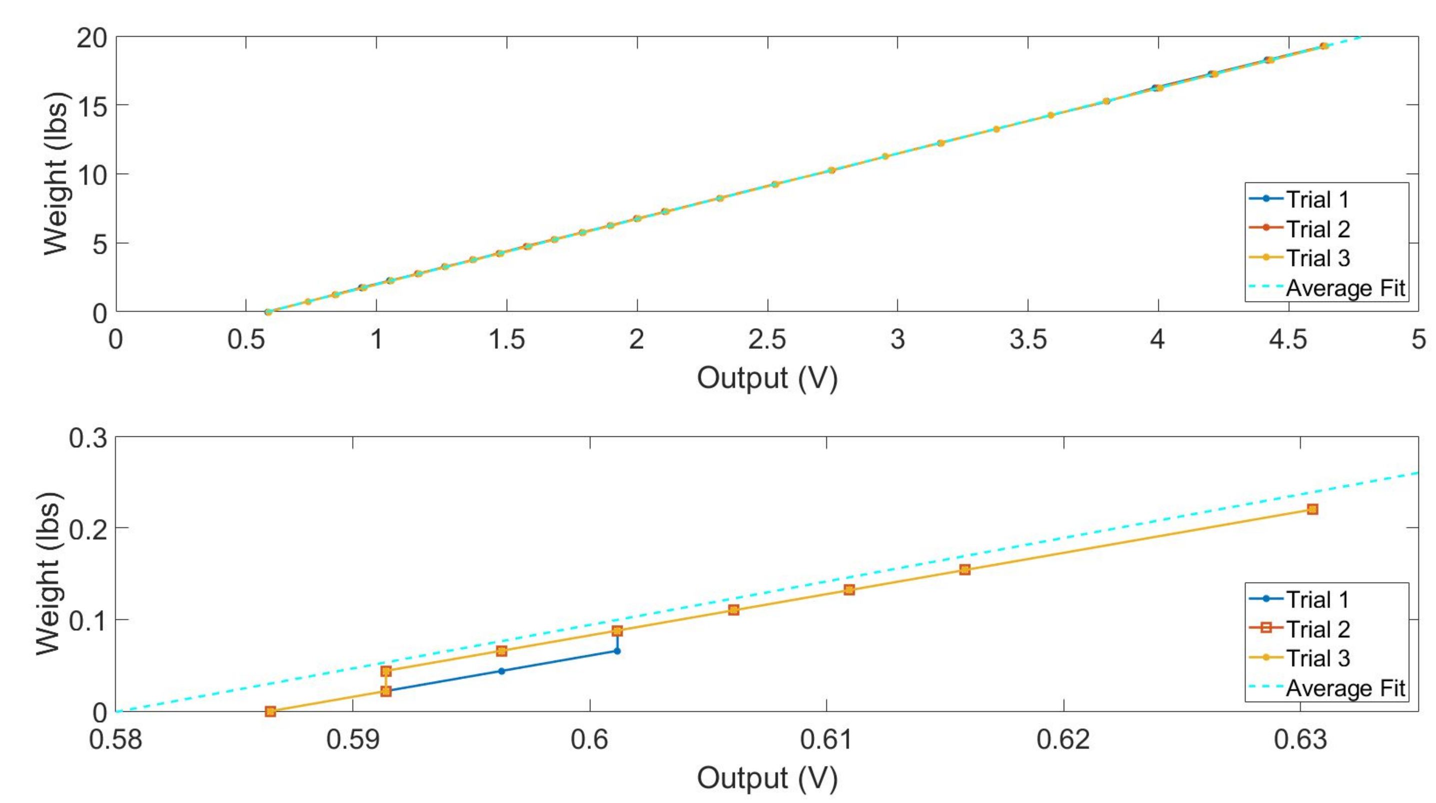
Load Cell Calibration Setup



- Thrust stand mounted vertically
- Measured load cell output with different known weights
- Maximized force applied to load cell for large weights
  - Range 0-20 lbs for long arm
  - Range 0-12.25 lbs for short arm
- Ran fine test from 0-0.22 lbs

Calibration Results

Load Cell Calibration for Large (top) and Small (bottom) Weights



- Calibration demonstrates very repeatable measurements
  - Output within 1% for all tests with both arm lengths
- Demonstrates 0.022 lbs precision from small weight test
- Linear fit with $R^2 = 1$ for large weight test
  - Very slight nonlinearity below 0.5 lbs
- Results for the short arm demonstrate similar trends for linearity, repeatability, and precision

Future Work

- Continue to test unified system with more propeller and motor combinations to ensure validity of results
- Stress test software edge cases
- Test system in wind tunnel to validate dynamic testing
- Validate data collection and output for external analysis
- Develop user guide to ensure ease of use
- Incorporate physical safety systems

Conclusion

- Our system effectively reports actual values of inputs.
- The thrust stand is feasibly usable and accommodates all required propeller sizes
- While the system reliability has not been tested we are confident that with proper calibration we will meet this criterion

References

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