Angle of Attack Sensor Capstone Project

Sponsored by Sagetech

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Background

Angle of Attack - What is it?

- Defined as the angle between the airfoil chord line and **undisturbed** relative wind vector (See Figure 1)

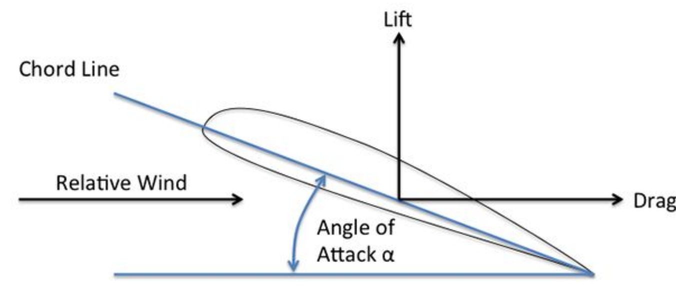


Figure 1: Angle of Attack Visual Guide [1]

Angle of Attack- What is its importance?

Angle of Attack (AoA) is directly linked to aerodynamic efficiency

- AoA controls Lift-to-Drag ratio (See Figure 2)
- Increased Lift-to-Drag ratio improves fuel economy, glide ratio and climb performance
- **There exists a discrete AoA for optimal Lift-to-Drag (L/D) ratio** for a given airfoil... as well as an **AoA that corresponds to airfoil stall**

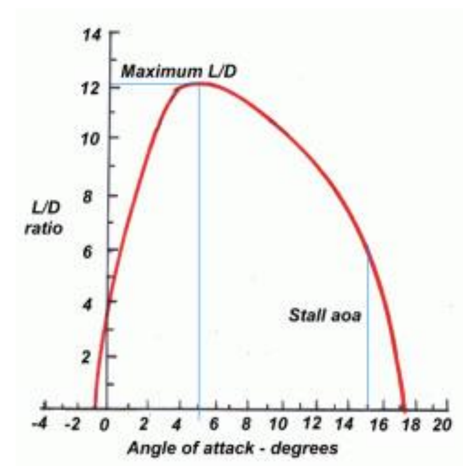


Figure 2: How L/D varies with AoA [2]

Objective: Create a sensor that accurately measures Angle of Attack, as well as airspeed, designed for specific use on small UAS (≤ 55 lbs.) in order to boost aircraft flight efficiency

Sensor Performance/Sagetech Requirements:

- Mass of ≤ 20 grams
- Output AoA data to within an accuracy of 0.5°
- Output data rate of at a minimum of 10 Hz, ideally 50 Hz
- Operational altitude range of sea level to 20,000 ft
- Withstand flight up to 150 mph
- Operational data range of 15 mph to 100 mph*
- No pressure hose tubing

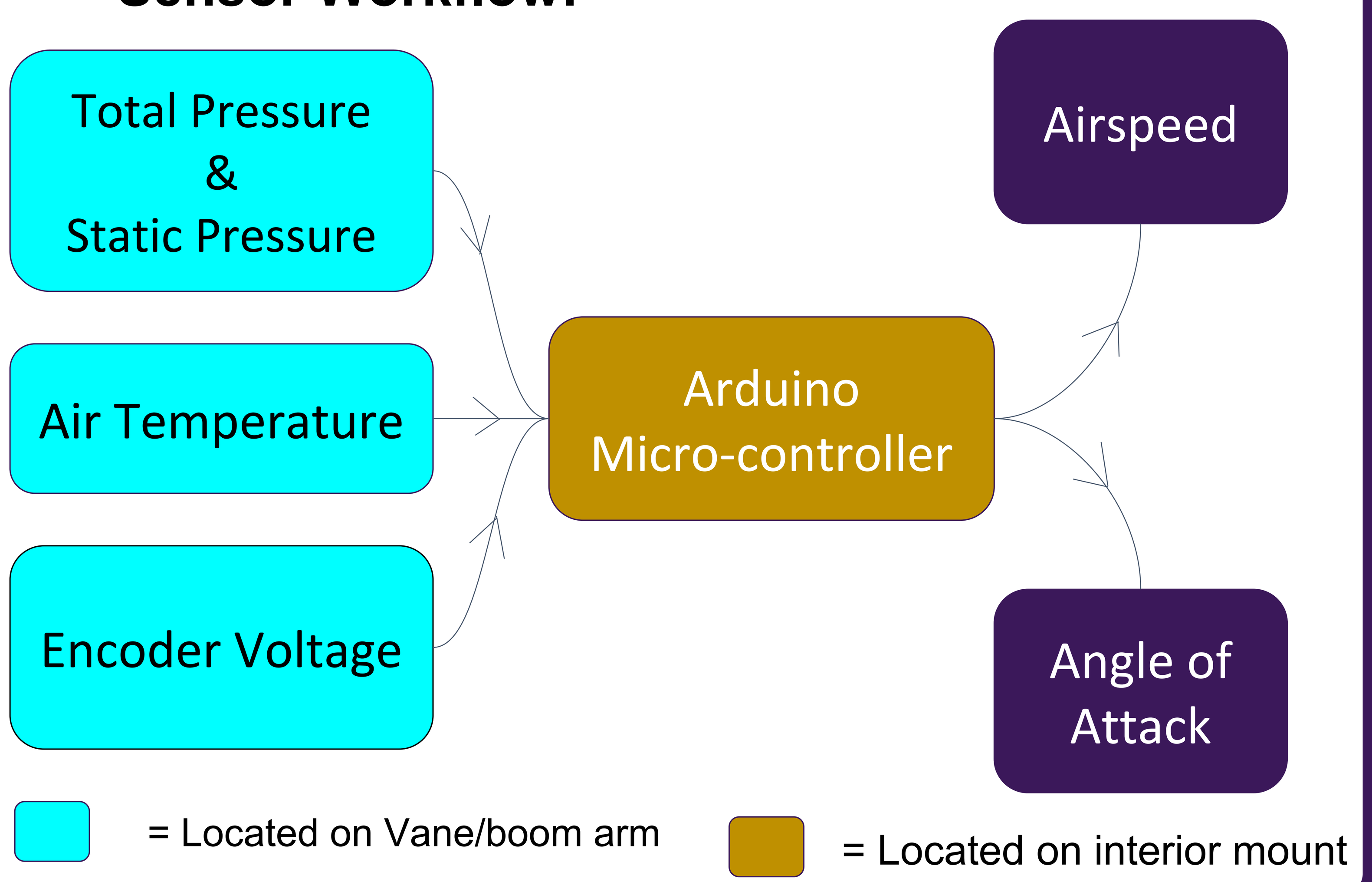
* = Airspeed measurement optional

Key Design Elements:

AoA Measurement: Wind vane device

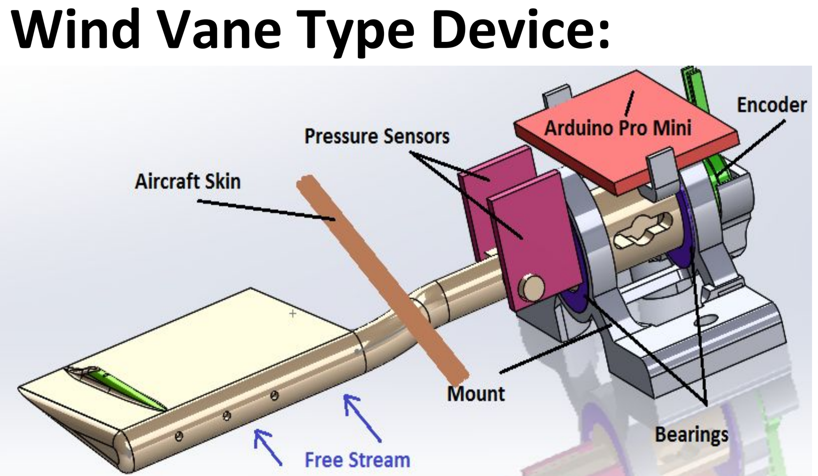
Airspeed Measurement: Embedded pitot-static tube device inside vane. This reduces mass and aerodynamic drag

Sensor Workflow:



Prototype

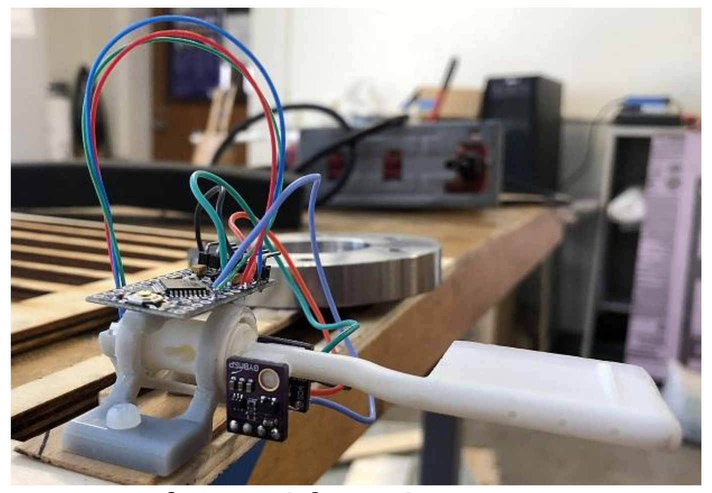
Wind Vane Type Device:



↑**Sensor Assembly Drawing**

- Vane (left of aircraft skin) has 3.5 cm^2 area dimensions
- Embedded Pitot Static System:
  - Green tube contains two static pressure ports
  - Leading edge of vane has three total pressure ports
- Two pressure sensors read both static & total pressures seperately
- Rotation of boom arm is read by encoder (AoA measurement)

Final Sensor→



Ethical/Environmental Considerations:

- **Be honest with data reporting** and sensor performance...If it fails, it fails!
- Potential for **lowered fossil fuel consumption**
- All components of this sensor are **RoHS compliant**

Were requirements met?

- **Met**
  - **Mass = 18.5 grams**
  - **Output data Rate > 50 Hz**
  - **Withstands up to 150 mph**
  - **Reads airspeeds through 100 mph**
- **Not Met**
  - **AoA angle reading resolution > 0.5°**
  - **Operational Airspeed Range for accurate AoA readings**
  - **Working range up to 20,000 ft****

**** = Not tested**

Suggested improvements: Counterbalance vane, reduce wiring restoring torque

Final Cost & Surplus Budget: Total money spent was **$1,918.37**

- **$2,081.63** left

Project Impact: This prototype shows a proof of concept for a currently commercially unavailable AoA sensor. Sagetech can use this prototype as a "jumping-off point" to **perfect a similar sensor through future iterations on this design.** Sagetech may bring this to market in order to **boost fuel efficiency in small UAS** and possibly provide **avoidance of aerodynamic stall**

Key Lessons and Conclusions: **Plan ahead**… Because we received a wind tunnel testing slot very late in the quarter, there was no time to alter/improve our sensor design after test results were analyzed. Secondly, **local airflow disturbances** around nose cones should be taken into account (alters conditions the vane experiences vs. in free stream).

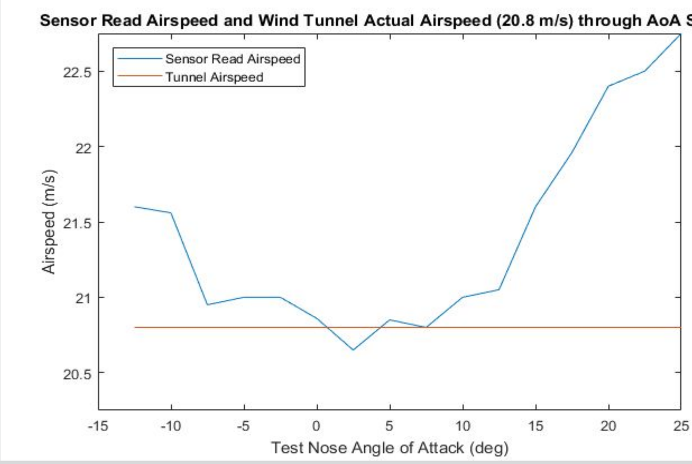
↑ Initial (Left) and Final Project Timeline (Right)

- Wind Tunnel Testing took place in the University of Washington 3' x 3' Wind Tunnel
- 3D Printing (Construction timeline) done by the Department of Aeronautics & Astronautics Engineering, UW and at Comotion Makerspace, UW

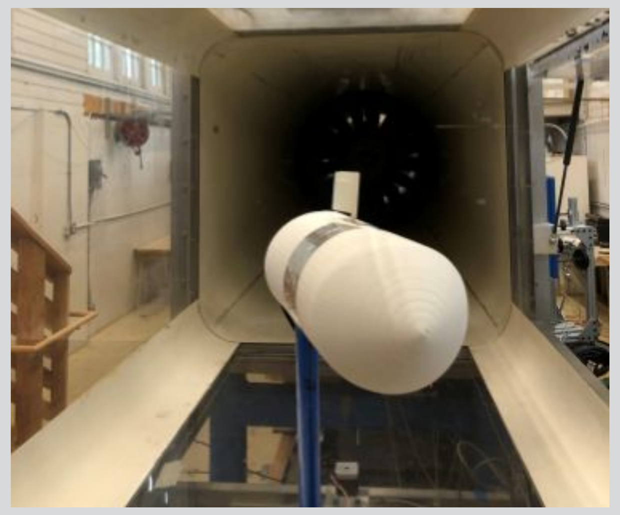
Analytical Tools and Wind Tunnel Results

Tools and Facilities Used:

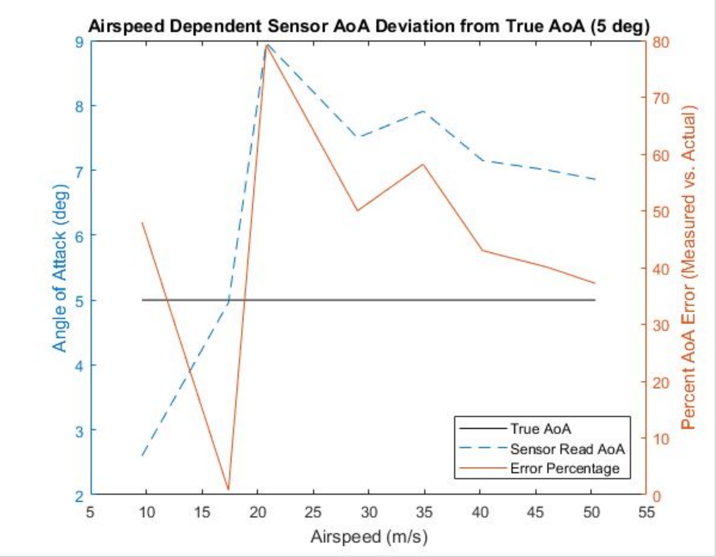
- SolidWorks
- MATLAB
- 3' x 3' Wind Tunnel (University of Washington)



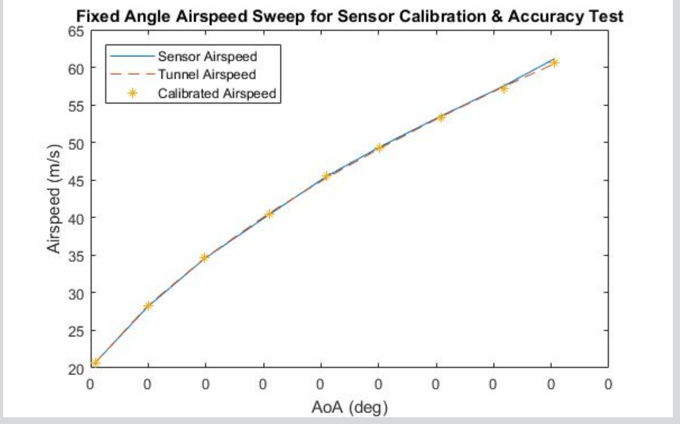
←**Test Three:** Verify sensor reads airspeeds that match the known wind tunnel airspeed at all AoAs. At nose cone angles diverging from 0° AoA, the airspeed shows higher deviation from true tunnel airspeed.



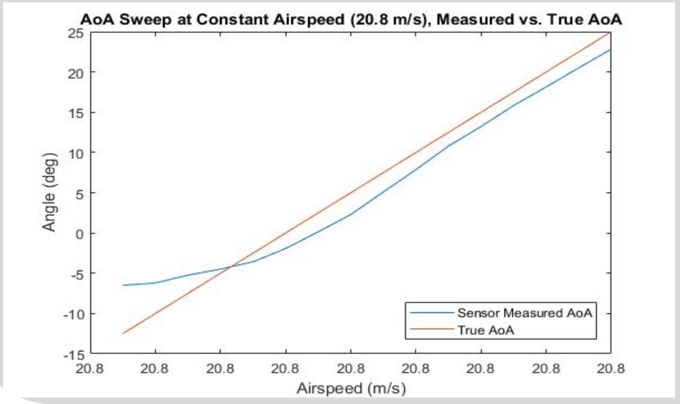
←**Test Setup:** Sensor Vane protrudes from top of test aircraft nose cone. The nose cone was rotated (yawed) to a known angle (True AoA) to simulate pitch up or down. The airspeed and AoA data was measured from the sensor based on the nose cone yaw angle and tunnel airspeed.



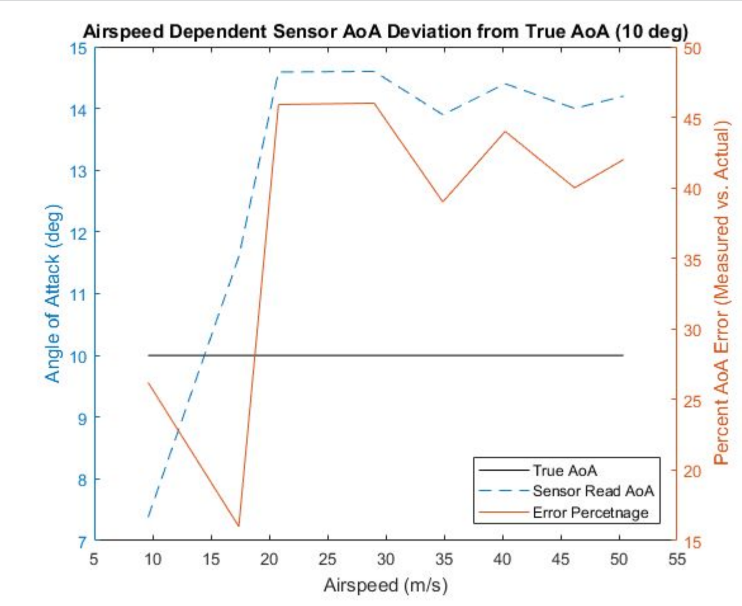
↕ **Test Four:** Verify sensor reads similar AoA to known nose cone AoA for all encountered airspeeds. It can be seen that the sensor read less accurate AoA values as tunnel airspeed diverged from 15 m/s.



←**Test one:** Maintain 0° AoA and verify/calibrate correct airspeed readings. This test showed the initial airspeed sensor read very accurately in an unperturbed flow and nose position. Calibration of the airspeed sensor was then negligible.



← **Test Two:** Verify sensor reads angles similar to known nose cone rotation angles. The most accurate AoA reading was found to be when the nose cone was rotated to -5 degrees for an airspeed of 20.8 m/s. This observation was found to be relatively true across all airspeeds.



References

1. E. H. (n.d.). Angle of Attack. Retrieved from http://code7700.com/aero_angle_of_attack.htm
2. Henderson, G. (2009). Retrieved from http://www.australian-hang-gliding-history.com/concise-histor y/l-d-article.html

Acknowledgments

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