Development of a Meteorologically Instrumented Small Transition Unmanned Aerial System For Urban Boundary Layer Investigations

Victor Alterizio, Andrew Caputo, Anthony Oreo, and Kevin A. Adkins, Ph.D. *(faculty advisor)*

Embry-Riddle Aeronautical University, Daytona Beach, FL

ABSTRACT

It is estimated that more than 55% of the world's population is currently living in urban areas and this number is expected to grow to 70% by 2050. The environment that houses this population is the urban boundary layer (UBL). The UBL is the portion of the atmospheric boundary layer whose characteristics are modified by the presence of a city and is regarded as one of the most complex and least understood environments. In order to investigate this region, an electric hybrid (transition) unmanned aerial system (UAS) was meteorologically instrumented. A hybrid UAS allows the meteorological sensor suite to be protected during vertical launch and recovery, allows for more deployment options in an urban environment, and capitalizes on the efficiency of forward flight. This work, under mentoring by Dr. Kevin Adkins, details the design, assembly and integration of the sensor suite that consists of a multi-hole pressure probe along with a temperature and humidity sensor. Each sensor's data is time and geo-stamped and subsequently post-processed.

THERMODYNAMIC MEASUREMENTS

A HygroClip 2 is used to measure scalar quantities

- Resistance Temperature Detector (RTD)
  - Range: -50 – 100 °C
  - Accuracy: +/-0.1 K
- Capacitive Humidity Sensor
  - Range: 0 – 100% RH
  - Accuracy: +/-0.5% RH

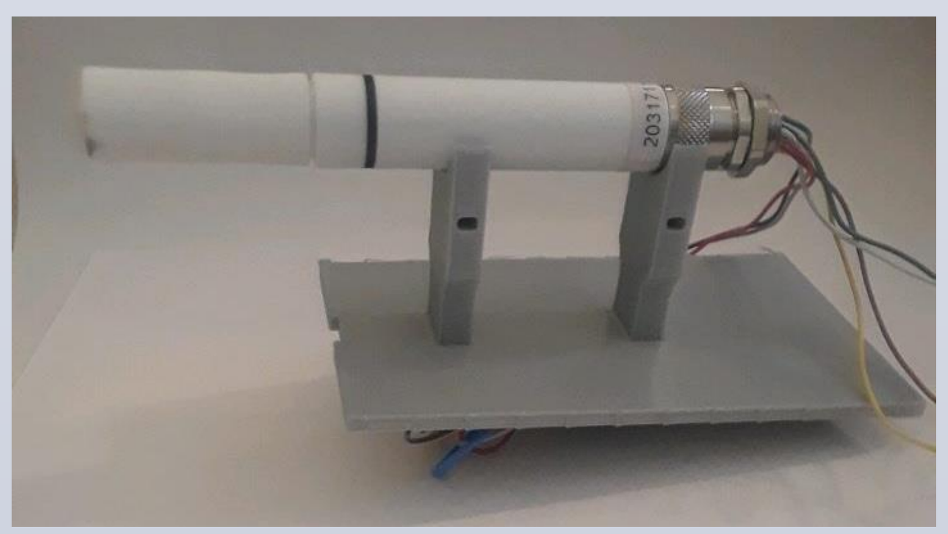
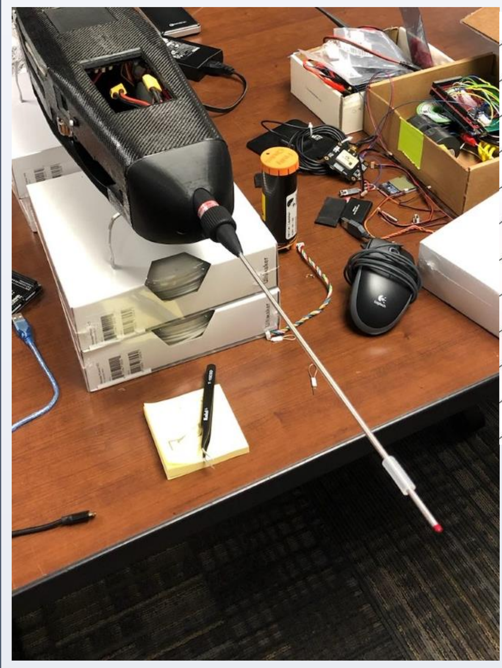


Figure 1. 3D printed mount with the HygroClip HC2A-S for thermodynamic measurements



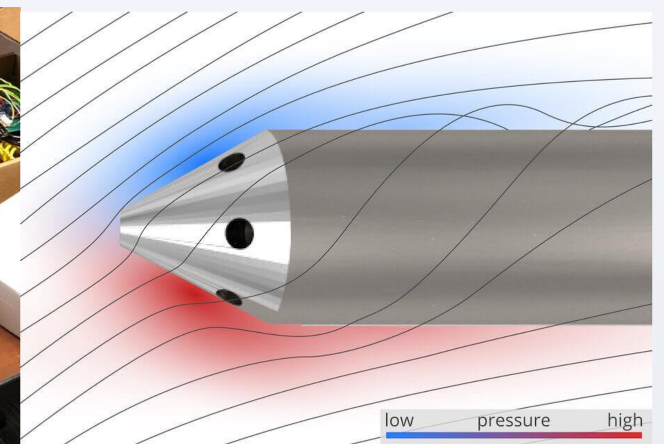


Figure 2. Surrey Sensors ID7HP MHPP mounted in nosecone of the SkyProwler 2 (left). Depiction of airflow over and pressure around MHPP (right).

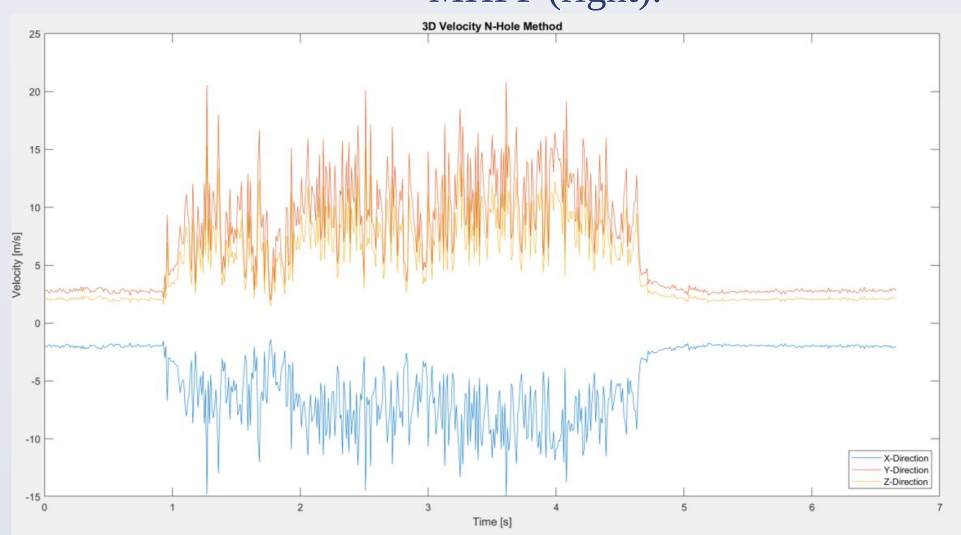


Figure 3. Plot of u, v, and w wind components obtained during an indoor fan test.

3-D WIND MEASUREMENT

Multi-Hole Pressure Probe (MHPP)

- 3-D Pitot Tube
  - Measures differences between stagnation and static pressure
- Six slotted and angled holes surround a center hole
  - Measure different pressures with respect to the center hole
  - 7 holes allow for a 3-dimensional wind measurement
- Sectorizing Method Identifies Region of Highest Pressure
  - Calculations are done within this single region
- Additional required inputs:
  - Air Temperature, Static Pressure, Air Density
- u, v, w Components Calculated through Linear Interpolation
  - Angle of Attack (α) and Angle of Sideslip (β) determined through interpolation of calibration data
- Vehicle motion obtained from autopilot and subtracted out
- Transformation of data from the sensor to the earth frame
- ID7HP Specifications;
  - Data Output Rate: 100 Hz; Weight: 95 grams

SYSTEM INTEGRATION

The system combines time and geo stamped data from the HygroClip 2 and the MHPP and locally writes it to an SD card. To give each measurement context, the spatial and temporal position of the sensor suite is determined by a Kalman filtered output of the Pixhawk 4 microcontroller (translational motion; pitch, roll, and yaw angles) .

The HygroClip 2, MHPP, and Pixhawk are all connected to an Arduino Mega which is powered by an external battery connected through a power switch. When the system is powered, continuous data records are created.

Following each flight, the recorded data is taken from the SD card and Pixhawk and read into a MATLAB post-processing script. The script subtracts vehicle motion from the MHPP measurements and calculates the absolute wind components, u, v, and w. The wind vector is paired with the geo tagged and timestamped scalar measurements to produce a single time and geo referenced file for all measurements.

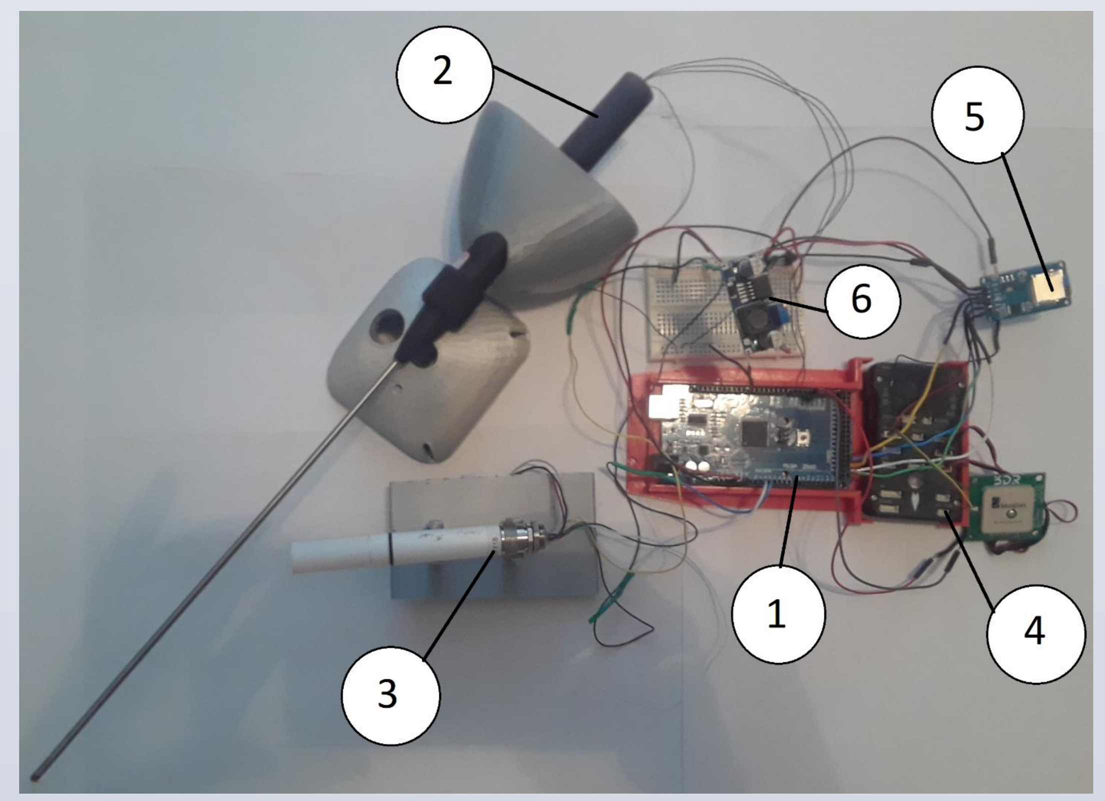


Figure 4. The "breadboard" version of the instrumentation suite, all in custom mounts for the Krossblade aircraft.

1. *The Arduino Mega board powers and controls the entire sensor suite*
2. *The MHPP enables the 3 dimensional measurement of wind*
3. *The HygroClip 2 temperature and humidity sensor*
4. *The Pixhawk 4, used to measure the aircraft's motion and calculate the absolute wind velocity. Additionally used to geotag and timestamp all measurements.*
5. *The SD card module locally writes all tagged sensor data*
6. *The power board ensures all components receive power from the Arduino Mega at the proper voltage*

AIRCRAFT

The Krossblade Skyprowler 2 is an electric uninhabited autonomous transition/hybrid flight vehicle. It utilizes 4 switchblade deployed rotors for vertical launch and recovery. At a specified altitude it transitions to forward flight in order to take advantage of the efficiency gained through the generation of lift. The vertical launch and recovery protects the sensitive instrumentation and affords more deployment options in an urban environment.

Figure 5. Krossblade Skyprowler 2 with VTOL rotors extended.

FUTURE PLANS

- Investigation of the urban boundary layer (UBL)
  - Urban canopy layer (UCL)
  - Roughness sublayer (RSL)
  - Inertial sublayer (ISL)
  - Mixed layer (ML)
- Urban air mobility (UAM) / Advanced Air Mobility (AAM)
- Marine Boundary Layer
- Microclimates

ACKNOWLEDGEMENTS

The authors wish to acknowledge and thank Mr. Peter Wambolt of the Gaetz Aerospace Institute for serving as the remote pilot. The authors also appreciate the support of Surrey Sensors and Krossblade.

RESEARCH POSTER PRESENTATION DESIGN © 2015
www.PosterPresentations.com