University of Colorado
Department of Aerospace Engineering Sciences
ASEN 4018

Project Definition Document (PDD)

Project B.L.I.S.S.
Boundary Layer In-Situ Sensing System

Approvals

	Name	Affiliation	Approved	Date
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Course Coordinator	Dale Lawrence	CU/AES		

Project Customers

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1.0 Problem or Need

The motivation of this project is to collect in-situ wind data and atmospheric cloud observations to provide Northrop Grumman the ability to verify an atmospheric boundary layer model. To accomplish this we will develop three systems. The first, a measurement system, will collect in-situ relative wind data in a volume of airspace defined as a cylinder with a radius of 100 meters and a height of 200 meters above average ground level. The measurements will be post-processed to create a U, V, and W inertial wind velocity vector field and will be accompanied by the temporal and spatial location of each measurement. Data will be recorded for 10 minutes duration, with the maximum radial distance between data points being 30 meters, distributed over the entirety of the cylinder. To transport the measurement system, a delivery system will be developed. The delivery system will transport the measurement system through the air volume, allowing the measurement system to take data at the required spatial and temporal locations within the measurement cylinder. The third system, cloud observation system, will record photographs of the atmospheric conditions above the measurement cylinder. The data collected by this project will be given to Northrop Grumman to provide them the ability to immediately verify their atmospheric boundary layer model. In the long term, Northrop Grumman plans to apply their model to environmental pollution monitoring, firefighting, and to facilitate soldiers in battle conditions.

2.0 Previous Work

Understanding the wind characteristics of the atmospheric boundary layer is of high importance for a large number of applications such as weather forecasting, monitoring transportation and diffusion of pollution, wind turbine placement and optimization, and wild fire protection and forecasting. To understand the wind conditions in a certain area, data is collected on location - this is called an in-situ measurement.

Surface weather stations are useful for monitoring numerous meteorological and non-meteorological variables including winds, pressure, temperature, humidity, precipitation, and particle concentrations. The Automated Surface Observing Weather Station (ASOS) maintained by the National Weather Service is a system used currently to monitor weather conditions for use in weather forecasting and aviation[1]. This system provides time series data of the aforementioned variables with a typical frequency of 1 Hz. ASOS is specifically capable of monitoring sky conditions such as clouds up to 12,000 feet. Weather stations like ASOS are capable of studying boundary layer conditions but are limited because they only represent a single point of measurement.

TAOS, Tethered Atmospheric Observing System, was developed at the National Center for Atmospheric Research as a useful in situ boundary layer measurement system. This system consists of a balloon tethered to the ground with eight sensors spread along the length of the tether[2]. The basic measurement parameters are atmospheric pressure, temperature, relative humidity, wind speed and wind direction. The sensors are powered with common cell phone batteries that last a minimum of 5 hours. The system can be deployed and remain at altitude in winds up to approximately 15 mph while gathering data up to maximum height of 1 km. It was found that certain weather conditions are not conducive to tethered balloon operations such as turbulence or winds exceeding 15 mph.

RECUV, Research and Engineering Center for Unmanned Vehicles is a government, and industry partnership with the University of Colorado, Boulder which develops unmanned aircraft. Past missions have used two different pitot tube sensors to take in-situ wind measurements. The aircraft velocity vector, obtained through GPS data, is summed with the body sensed wind velocity data obtained through pitot tube/s. An Inertial Measurement Unit (IMU) is used to convert between body and inertial coordinates, to end with a three dimensional wind vector in inertial coordinates.

Two forms of technology currently being used by scientists around the world to measure atmospheric wind and turbulence are LiDAR and SODAR. LiDAR, Light Detection and Ranging, is a high resolution method to take data in a multitude of fields, including geology, astronomy, and archeology. LiDAR is a clever utilization of lasers and sensors that track how quickly light bounces back off objects. A laser shines on a specific material, while the resulting reflection of light gets tracked by a certain sensor. For wind sensing, Doppler LiDAR can be used to measure wind velocity and turbulence from up to 200 meters away with an uncertainty less that 1%[5]. On the other hand, SODAR is also a common technique meteorologists use to measure wind velocity. It differs from LiDAR by using sound waves instead of light, but uses a similar method in that it tracks the time for the sound wave to return after reflection off an object. Sodar is more commonly used for wind measurement, but both techniques can be very useful in this area of research[6].

3.0 Specific Objectives

Level 1	• Develop a delivery system that is certified to operate in a rural field inside airspace defined as a cylinder with a 100 meter radius and 200 meter height above ground level. • Develop a wind measurement system to collect relative wind data points with precision of 0.1 meter/second and variance of 1 meter/second. Relative wind is the motion of the air relative to the delivery vehicle. • Collect relative wind data in a ground test to validate the measurement system is capable of providing raw relative wind data with precision of 0.1 meter/second and variance 1 meter/second. • Develop a system that can image the cloud footprint above a 100 meter radius cylinder at TBD Hz for a 10 minute period.
Level 2	• Delivery system follows a pattern through unique points spaced no more than 30 meters apart spanning the defined airspace. This is roughly 240 measurement locations. • Operate delivery system with a replica measurement system on board that has representative mass and volume. • Post-process the relative wind data from a ground test to compute the U, V, W inertial wind velocity vector components. The inertial wind vector is the motion of the air relative to the ground. • Cloud observations are time-stamped images.
Level 3	• Measurement system is an operational payload onboard delivery system. • Collect data through unique points spaced no more than 30 meters apart in the defined airspace. This is roughly 240 measurement locations spanning the entire airspace. • Data is delivered to Northrop Grumman as a U,V,W inertial wind velocity vector field accompanied by the temporal and spatial location of each measurement. • Deliver to Northrop Grumman a time-stamped cloud footprint image overlaid on the ground outline of the measurement airspace with samples taken at TBD Hz during the 10 minute test period.

4.0 Functional Requirements

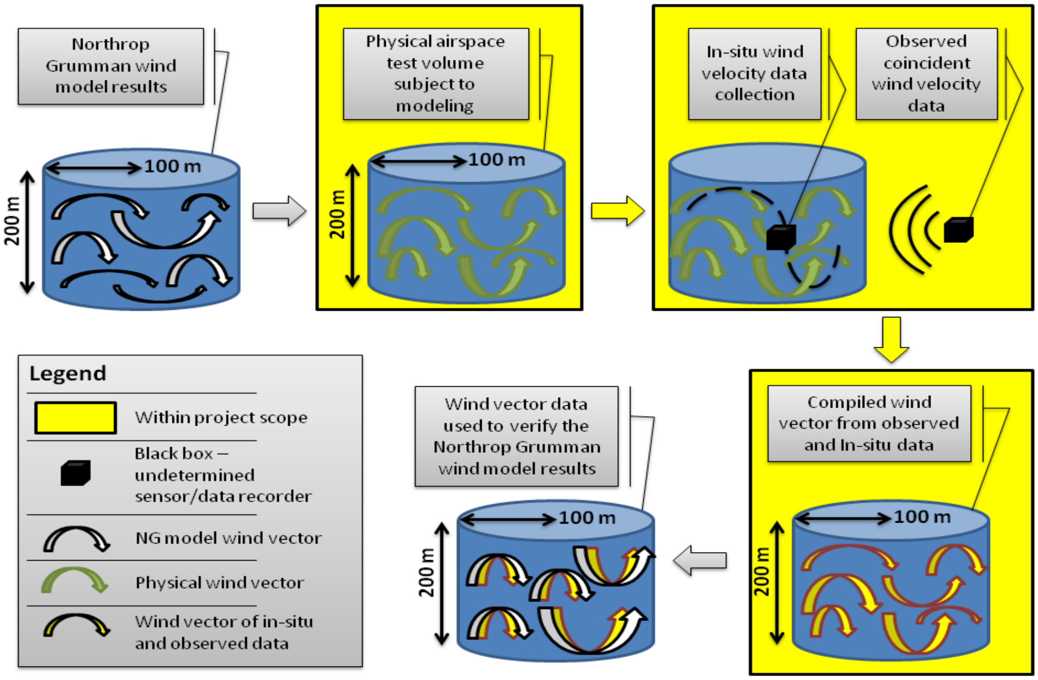

Figure 1: Project Scope CONOPS

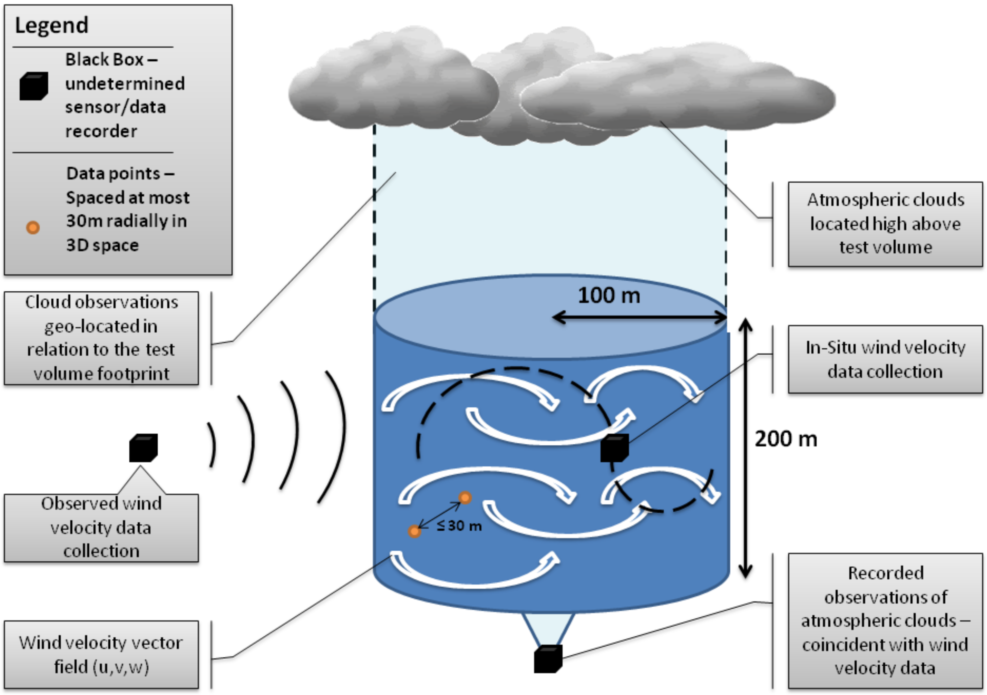

Figure 2: Project CONOPS

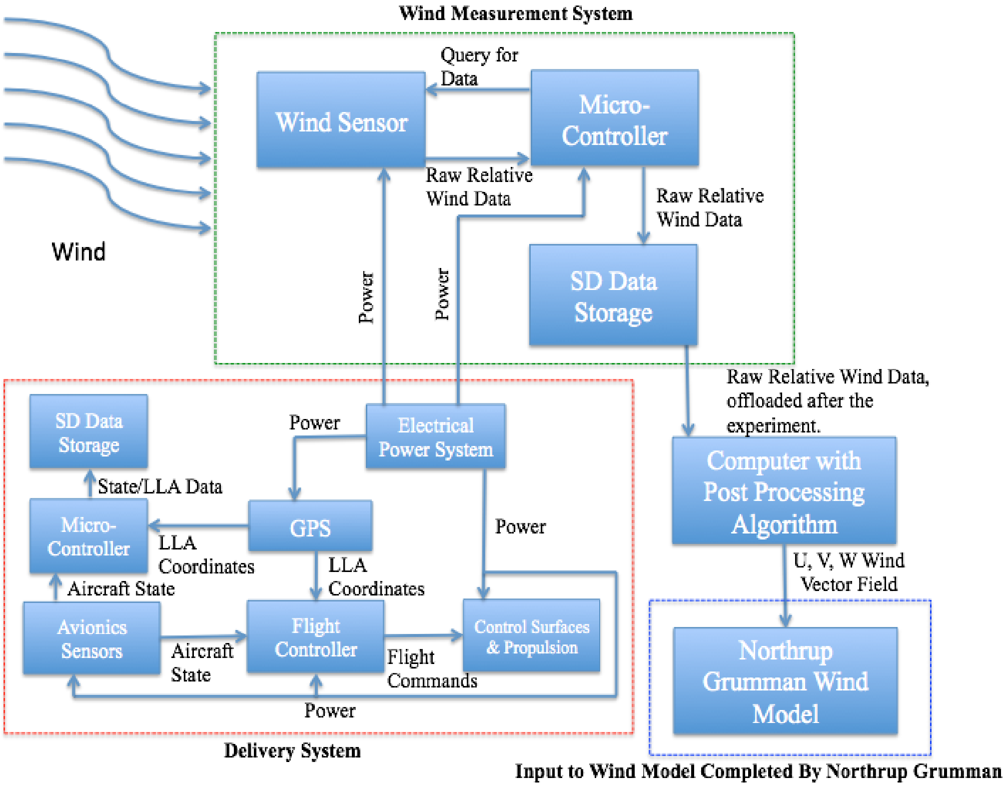

Figure 3: Measurement and Delivery System FBD

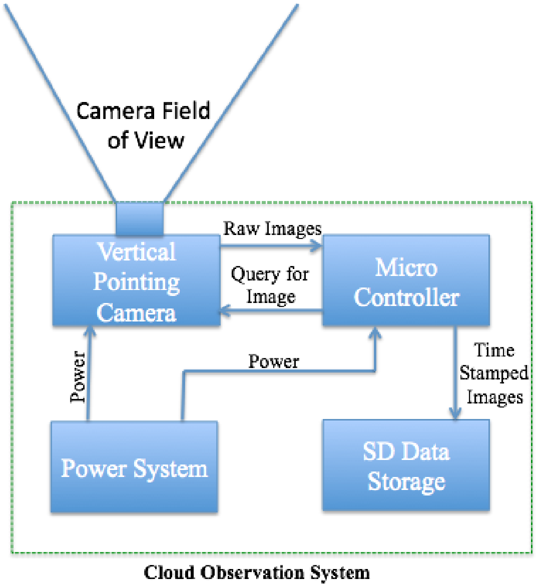

Figure 4: Cloud Observation System FBD

5.0 Critical Project Elements

5.1 A sensor package must be developed or procured that either returns a U,V,W wind vector, or provides enough data that the vector can be backed out from the measurements. The entire sensor package must not exceed the mass budget of the delivery system.

5.1.1 Software must be written that interfaces the wind measurement sensor to the data processing and data storage systems.

5.1.2 Sensor package must tested to insure proper data collection of U,V,W wind velocity vector.

5.2 A delivery system must be able to transport the sensor package to data acquisition points in the measurement cylinder.

5.2.1 Delivery system must be tested in measurement environment to ensure ability to move sensor package around the measurement cylinder in the designated time frame.

5.3 Sensor and Delivery systems must be manufactured or procured according to design specifications.

5.3.1 All systems must be manufactured or procured within a $5,000 project budget.

6.0 Team Skills and Interests

Team skills and interests are listed below in concordance with the Critical Project Elements. Team member skills are demonstrated using (s) and interests (i).

Project Elements	Team Members and Associated Skills/Interests
Sensor interface	Schenderlein (s): Experience integrating sensors with LabView and other control and data collection programs in test-bed applications Lacy(s); Extensive work with integrating hardware electronics Smith (i): Interest in LabView and mechanical aspects of sensor interfacing.
Electronics and embedded systems	Lacy (s): Experience designing circuits and interfacing with microcontroller Corona (s): Experience with the PIC processor and Salvo Embedded OS
Software	Corona (s): Experience writing control system device drivers in C Lacy(s): Experience designing function specific software

Manufacturing and Prototyping	Corkey (s): Experience in CAD/CAM Keyek-Franssen (s): Experienced in computer aided design and manufacturing processes Davis (i): Some experience with Solidworks/Solidcam and the CNC. Would like to learn more. Sloss (i): Interest in learning CAD and Manufacturing Techniques Smith (s): Experience with Solidworks and Catia. Machine shop experience
Unmanned Systems	Sloss (s): Experience with autopilots and unmanned systems including ground station controls Smith (s): Experience with mechanical system design of small scale unmanned craft. Davis (i): Interest in unmanned systems and their controls.
Testing	Davis (s): Experience in flight test programs. Schenderlein (s): Experience with interlocks, capacity testing, and running and diagnosing test systems Corkey (i): Interest in testing Keyek-Franssen (i): Interest in testing Smith (i): Interest in testing
Budget Analysis	Corkey (s): Experience in budgetary analysis, minor in Economics Sloss (i) Interest in Budgeting and Trade Studies

7.0 Resources

Critical Project Elements	**Resources**
Sensor interface	Knowledgeable People: Dr. Lawrence
Electronics and embedded systems	Knowledgeable People: Dr. Akos, Dr. Srdjan Pajic (Urban RF, Longmont, CO)
Sensor software	Knowledgeable People: Dr. Chu, Dr. Akos
Manufacturing and Prototyping	Kyle Corkey and Nathaniel Keyek-Franssen have experience with CAD software and manufacturing Robert Lacy has access and experience with a PCB and milling machine. Knowledgeable People: Matt Rhode, Bobby Hodgkinson
Unmanned Systems	RECUV has several airframes with existing COAs Knowledgeable People: Dr. Lawrence, Dr. Frew, Dr. Argrow, James Mack
Testing	Knowledgeable People: Trudy Schwartz
Budget Analysis	Kyle Corkey is pursuing an economics minor with coursework in budgeting and financial analysis.

8.0 References

[1]"Automated Surface Observing Systems," *National Weather Service* [online database] URL: http://www.srh.noaa.gov/jetstream/remote/asos.htm [cited 10 September 2014]
[2]Chamberlin, N., "Tethered Atmospheric Observing System," *Earth Observing Laboratory* [online] URL: http://data.eol.ucar.edu/codiac/dss/id=77.132 [cited 10 September 2014]
[3]Frew, E., "Senior Design Assistance" Email to Nathaniel Keyek-Franssen 6 Sep. 2014
[4]Mack, J., "ASEN Senior Projects" Email to Nathaniel Keyek-Franssen 10 Sep. 2014
[5]Jamie, C., Schmid, K., "Lidar 101: An Introduction to Lidar Technology, Data, and Applications," *National Oceanic and Atmospheric Association* [online] URL: http://www.csc.noaa.gov/digitalcoast/_/pdf/lidar101.pdf [cited 12 September 2014]
[6]Neal, B., "About Sodar" *Atmospheric Research & Technology* [online] URL: http://www.sodar.com/about_sodar.htm [cited 12 September 2014]