Memorandum

To: Prof Eilaghi

From: Weather Station Capstone Team

Date: 10/31/25

Re: Finalized Testing Plan

Weather Station Capstone Testing Plan

Design Requirements Summary:

Customer Requirements:
CR1- Measurement of Key Weather Parameters - Station will measure temperature, humidity, wind speed and direction, barometric pressure and solar irradiance.
CR2- Data Transmission - Data collected will be transmitted via internet
CR3- Remote Data Access - Live and stored data should be accessible through a web interface
CR4- Renewable Power Supply - Any components which require power must run on solar energy means located at RE Lab
CR5- Weather Durability - Station must withstand outdoor weather conditions
CR6- Low Maintenance - Station should require less than 2 hours of maintenance per year
CR7- User Friendly - User interface should be easily navigable
CR8- Ease of Installation - Installation should require minimal tools or training
CR9- Low Cost - Station should be cost effective and within budget
CR10- Safety Compliance - Must comply with relevant electrical and operational safety standards
CR11- Data Storage - Data should be stored in an accessible and organized database for at least one year.

Engineering Requirements:
ER1- Long Term Data Storage - Database should log data in an organized manner over the course of 4 years
ER2- Increased Data Accuracy - Sensor readings should be highly accurate, within 3% or less of Pulliam Airport reference data when applicable
ER3- Multiple Wind Speed Readings - Wind speed and direction should be measured at both standard height (~30ft) and atop the existing tower at the RE Lab (~90ft), providing at least 2 readings.
ER4- Measured at Industry Standards - Sensors should be properly positioned according to industry standards
ER5- Proper Calibration - Sensors should be properly calibrated to upload accurate data from raw readings within 3% of true values

ER6- Measurement of All Data Types - Station should record 6 data types including temperature, pressure, humidity, solar irradiation, wind speed and wind direction.
ER7- Low Power Requirement - Station should be capable of fully operating under existing solar generated power means located at lab, with a target of 0.2 kWh per day or less.

Testing Summary:

Experiment:	Relevant Design Requirements:
EX1 - Anemometer Calibration Test	CR1, ER2, ER3, ER5, ER6
EX2 - Barometer Data Comparison	CR1, ER2, ER4, ER5, ER6
EX3 - Pyranometer Test	CR1, ER2, ER4, ER5, ER6
EX4 - Temperature Sensor Calibration Test	CR1, ER2, ER4, ER5, ER6
EX5 - Wind Vane Calibration Test	CR1, ER2, ER4, ER5, ER6
EX6 - Boom Mount Stress Test	CR5, CR8, CR10, ER3, ER4
EX7 - Weather Database Test	CR2, CR3, CR7, CR11, ER1, ER6

Detailed Testing Plans:

EX1 - Anemometer Calibration Test

The goal of this test is to ensure the new anemometer is properly calibrated and produces accurate data. Essentially we will be ensuring the calibration certificate from the manufacturer, including the calibration equation, still upholds. In order to perform this test we will need a fan and tachometer, which can be borrowed from Thermo Fluids Lab 111. The rotational speed of the anemometer will be adjusted using the fan settings and measured using the tachometer. This rpm measurement will be plugged into the calibration equation to ensure the voltage output reading results in the same wind velocity measurement.

Steps:

1) Position fan at a distance of 1ft from anemometer and start on highest setting.
2) Record Wind Speed reading output from Raspberry Pi voltage conversion
3) Record rotational speed in rpm from tachometer
4) Convert RPM into wind speed based on geometry of anemometer
5) Compare measured and calculated wind speed
6) Repeat steps 1-5 on lowest fan setting
7) Adjust Calibration equation if needed until wind speeds are equivalent

Results: Outputs from converted Raspberry Pi voltage signal reading (read as Hz) using calibration equation 1 should be within 3% of converted RPM reading using equation 2.

$$v\ [m/s] = 0.75776 \cdot f\ [Hz] + 0.39322 \qquad (1)$$

$$v\ [m/s] = 0.75776 \cdot (RPM)/60 + 0.39322 \qquad (2)$$

EX2 - Barometer Data Comparison

The goal of this test is to ensure the readings from the barometric pressure sensor are within a reasonable range. This range will be defined by the Flagstaff Pulliam Airport barometric pressure data since this reading should not vary much from our testing site to the airport. Since we do not have the means to create a controlled pressure environment to test the sensor, we will have to settle for ensuring the readings match the airport data. The variable measured will be the barometric sensor reading using the manufacturer stated calibration equation.

Steps:

1) Take reading from the barometer output using the manufacturer stated calibration equation.
2) Compare to Flagstaff Pulliam Airport's most recent barometric pressure reading
3) If our data is not within 3% of airport data, adjust the calibration equation and begin again from step 1.

Results: Output from converted Raspberry Pi voltage signal should be within 3% of most recent Flagstaff Pulliam Airport barometric pressure reading.

EX3 - Pyranometer Test

The goal of this test is to ensure the readings from the pyranometer are within a reasonable range. This range will be defined by the Flagstaff Pulliam Airport solar irradiance data since this reading should not vary much from our testing site to the airport. Since we do not have the means to create a controlled solar irradiant environment to test the sensor, we will have to settle for ensuring the readings match the airport data. The only control test we can perform is a black box test in which no solar irradiance should be measured. This black box will be the SRP team's controlled environment with no sunlight piercing the lid. The variable measured will be the solar irradiance reading using the manufacturer stated calibration equation.

Steps:

1) Take reading from the pyranometer output using the manufacturer stated calibration equation.
2) Compare to Flagstaff Pulliam Airport's most recent barometric pressure reading.
3) If our data is not within 3% of airport data, adjust the calibration equation and begin again from step 1.
4) Place the pyranometer inside the SRP capstone box with lid sealed.

5) Ensure zero solar irradiance is measured.

Results: Output from converted Raspberry Pi voltage signal should be within 3% of most recent Flagstaff Pulliam Airport solar irradiance reading. Zero solar irradiance should be measured from black box test.

EX4 - Temperature Sensor Calibration Test

The goal of this test is to ensure the temperature readings from the temperature sensor are within a reasonable range and the calibration equation is correct. The first check will be a comparison of data to Flagstaff Pulliam Airport temperature data. The ambient temperature at the RE Lab may be slightly different than that of the airport due to shade from trees and cloud cover. The SRP capstone team's evaporation box is insulated to be kept at a controlled temperature, which can be used as a control test for our temperature sensor. The converted temperature reading from the raw voltage output should be within 3% of their measured air temperature within the box and within 5% of the airport reading on a day with consistent conditions (sunny, low wind).

Steps:

1) Record converted temperature sensor reading from manufacturer stated calibration equation with sensor placed inside SRP controlled temperature environment.
2) Compare reading to expected temperature within the SRP box.
3) Adjust calibration equation and repeat from step 1 until temperature reading is within 3% of controlled box temperature.
4) Compare temperature sensor reading in standard mounting position (ambient, 6ft off ground).
5) Compare to Flagstaff Pulliam Airport's most recent temperature data

Results: Output from converted voltage signal should be within 3% of controlled box air temperature. Temperature data should be within 5% of airport data on a day with consistent weather conditions (sunny, low wind).

EX5 - Wind Vane Calibration Test

The goal of this test is to ensure that the calibrated degree output from the wind vane voltage signal is accurate. The wind direction will not consistently match that of the Pulliam Airport data due to obstructions such as trees and buildings near the RE Lab which will disrupt the wind flow. Thankfully, there exists a simple way to test the calibration of the wind vane output. Using a compass and a piece of paper, a 360 degree circle will be drawn on the paper with cardinal directions marked and degree increments of 30 degrees marked. The wind vane will be adjusted to each of these incremental marks and the output will be recorded to ensure the degrees of rotation are the same.

Steps:

1) Sketch circle on paper and mark cardinal directions and increments of 30 degrees around the circle.

2) Align wind vane zero point (north) with north mark on paper. Adjust wind vane to align with each cardinal direction and 30 degree increment and log output at each mark.
3) Ensure wind vane output matches 30 degree increments on paper at each point.
4) If output does not match the degree mark on paper, adjust the calibration equation and start over from step 2.
5) Ensure degree reading resets to zero after passing 359.9 degree point

Results:

The degree output from the converted voltage signal through the Raspberry Pi should match the degree mark at which it was taken within 1 degree. These alignments will not be perfect as they will be done by eye, but the outputs should be extremely accurate. The output must reset to zero once the 359.9 degree point is crossed.

EX6 - Boom Mount Stress Test

The goal of this test is to ensure the mounting strategy for attaching the boom mounts to the tower located at the RE Lab. These booms are designed for the mounting of the anemometer and wind vanes, so their attachment to the boom is not at risk of failure. The stress test will ensure the hose clamps used to mount the boom to the tower are capable of keeping the boom in place under heavy wind conditions. This will be tested by attaching weights on a rope to the end of the boom and swinging them to replicate heavy wind gusting.

Steps:

1) Attach boom to tower 3 hose clamps at a height of ~5ft
2) Thoroughly tighten hose clams until the boom is as secure as possible
3) Tie rope with weights to the end of the boom rod.
4) Swing and move weights in semi-random patterns to simulate heavy wind gusting
5) Ensure the boom remains secure in place and hose clams do not loosen.
6) If any major movement or failure of the hose clamps occurs, add additional mounting clamps or adjust mounting position then repeat steps 1-5.
7) Repeat weight swinging trial to ensure the first trial did not lead to a weakening of the boom secure mounting.
8) Repeat steps 1-7 with second boom arm

Results:

The boom arm is permitted to have slight movement during weight swinging but must remain equally secured as it was before the test. No loosening of the hose clamps are permitted. No bending of the boom arm is permitted. The second weight trial must maintain a similar result as the first to ensure fatigue does not lead to failure.

EX7 - Weather Database Test

The goal of this test is to ensure the weather database is working correctly. This includes timely upload of most recent data, proper display of past data, proper display updates when new data comes in, proper labeling of data and no gaps or cut-outs in data collection. No tools or materials will be needed to perform this test.

Steps:

1) Activate Raspberry Pi data collection and transmission to website database for all 6 sensors.
2) Leave the system running, checking data daily.
3) After one week, check for missing data points and compare data points to Flagstaff Pulliam Airport weekly data.
4) If data is not uploaded consistently and/or is outside a reasonable range to airport data, troubleshoot cause of error.

Results:

Data from all 6 sensors should be uploaded consistently at planned intervals. No gaps in data collection should be present in the database. No major deviations from Flagstaff Airport data should be observed.

Specification Sheet Preparation:

Customer Requirement:	**Met? (Y/N)**	**Client Satisfied? (Y/N)**
CR1 - Key Weather Parameters		
CR2 - Data Transmission		
CR3 - Remote Data Access		
CR4 - Renewable Power Supply		
CR5 - Weather Durability		
CR6 - Low Maintenance		
CR7 - User Friendly		
CR8 - Ease of Installation		
CR9 - Low Cost		
CR10 - Safety Compliance		

CR11 - Data Storage		

Engineering Requirement	**Target**	**Tolerance**	**Measured or Calculated Value**	**ER Met (Y/N)**	**Client Satisfied (Y/N)**
ER1 - Long Term Data Storage	4 years	±1 year			
ER2 - Increased Data Accuracy	Airport	± 3%			
ER3 - Multiple Wind Speed Readings	2	N/A			
ER4 - Meets Industry Standards	Yes	2 sensors			
ER5 - Proper Calibration	Yes	± 3%			
ER6 - Measurement of All Data Types	5	N/A			
ER7 - Low Power Requirement	<0.2 kWh	N/A			