The Basilisk Robot

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Problem Statement

This project uses an autonomous surface vehicle to measure wind speed, wind direction, and solar irradiance at Dana Point, providing data that helps offshore energy planners optimize their renewable energy source locations. These three quantities are the standard for siting offshore wind and floating solar installations: available wind power scales with the cube of wind speed, and prevailing wind direction sets turbine alignment [1], while site-level solar irradiance is the primary driver of PV output and an input to solar siting tools [2]. The Basilisk bot and its sensors aimed to answer the hypothesis of whether wind speed increases with distance from the shore due to drag from the rougher water nearshore. It also aimed to gather data on the hypothesis that solar irradiance decreases with distance from shore.

Impact

As offshore wind and solar installations expand globally, understanding how renewable energy resources vary across the nearshore-to-offshore transition helps inform where systems should be deployed. This project provides local measurements of wind and solar conditions, supporting such efforts. The robot's non-invasive sensing avoids pollution, sediment disturbance, and noise. These measurements can also guide placement of small-scale marine energy systems used to power coastal monitoring equipment such as buoys and water quality sensors.

Future Work

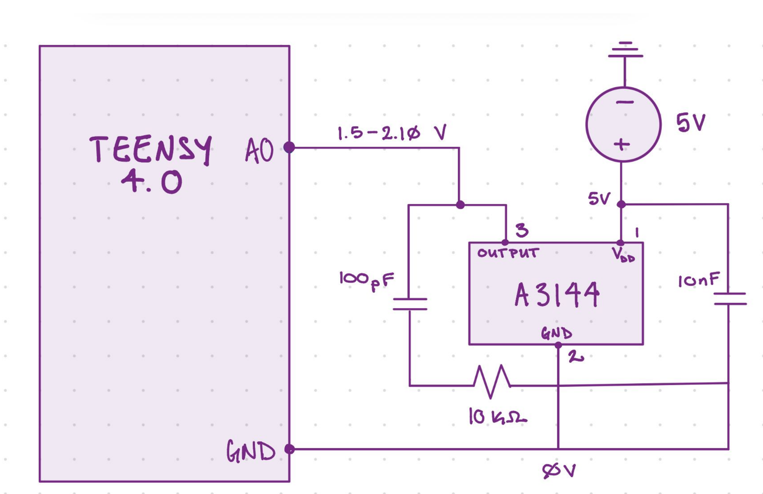
The anemometer failed to keep an accurate pulse count at higher windspeeds so in the future reworking it with a stronger magnet/hall effect sensor would improve its capabilities. Additionally, the bot veered off course in response to disturbances, thus implementing closed loop control would remove the potential for unbounded error. More broadly, gathering data across larger distances would better test the relationship between offshore distance, irradiance, and wind.

Autonomous Underwater Vehicle (AUV) Features

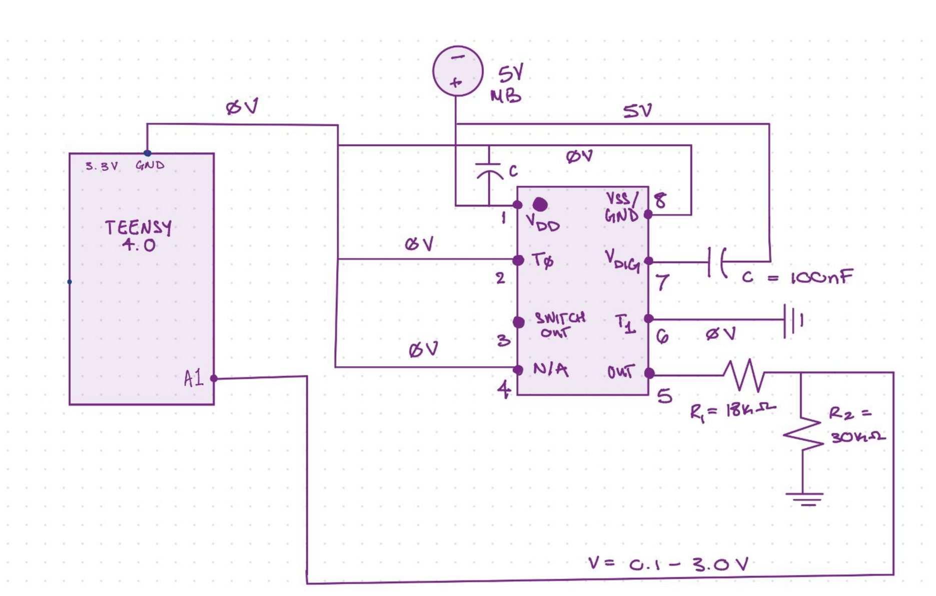
Electrical Schematic & Sensors

Schematics of AH9246, MLX90316, BPW34 with Teensy configuration

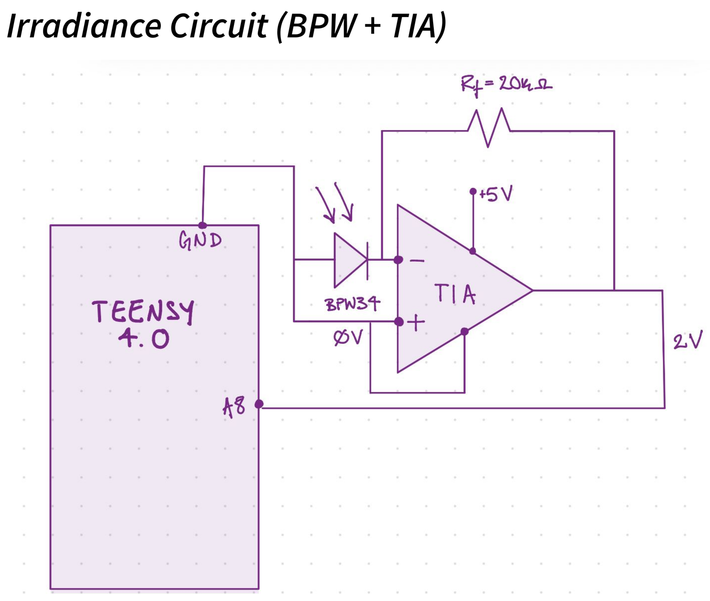
Anemometer Circuit



Weather Vane Circuit

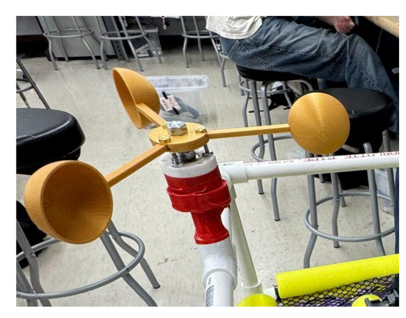


Irradiance Circuit (BPW + TIA)



Mechanical Design & Integration

Sensors:



Anemometer

For the robot, the design aimed to optimize sensor placement and ensure good data collection at Dana Point. The base was made wide to ensure the robot would float and not tip over with passing waves. The outside frame was built to hold the weather vane and anemometer sensors and allow them to move as freely as possible to collect good data. The photodiodes where attached to the circuit box itself as it was protected from the water and allowed for a large sturdy surface the housing could rest on.

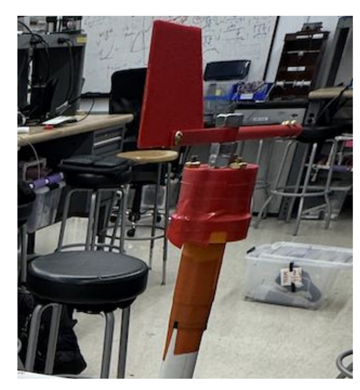
Thrust Calculation:

$$m\frac{d^2z}{dt^2} = F_{Thrust} - F_{Drag}$$

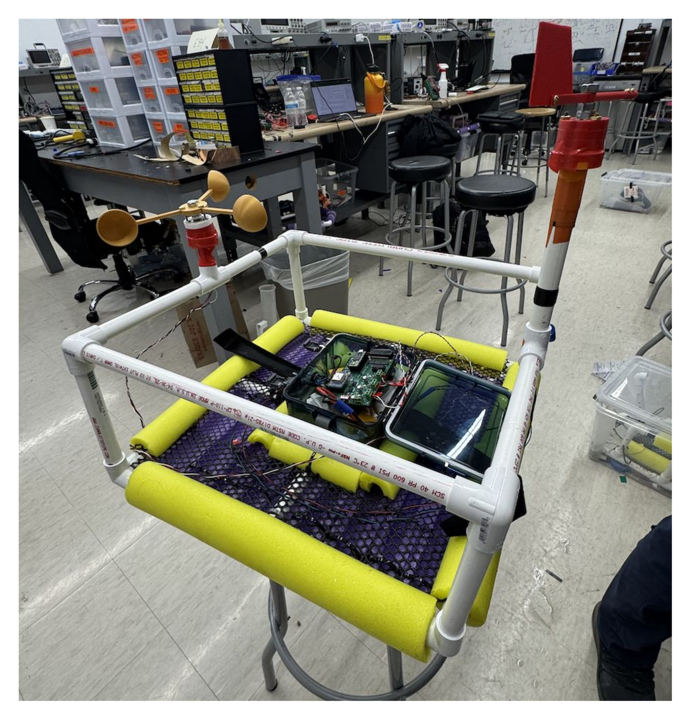
Center of Gravity Calculation:

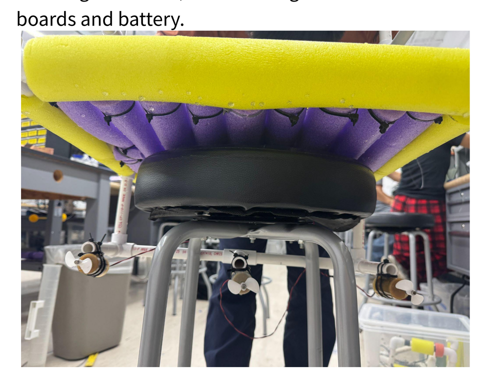
$$CoG = \frac{\Sigma(w \cdot d)}{\Sigma w}$$

Center of Gravity ended up being roughly in the middle of the bot due to the spacing of the sensors, the weight of them, and the weight of the circuit boards and battery.

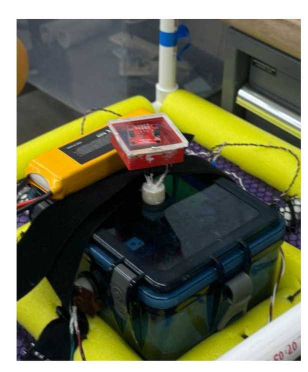


Weather Vane





The motors for the bot were placed on an E-shaped structure underneath the main housing and floatation devices. This structure was created to ensure the motors were placed deep enough into the water to allow the robot to move autonomously and powerfully against the waves. The depth of the motors also minimized the noise the teensy picked up when collecting data.



Photodiode

Experimental Data and Results

Sensor Calibration

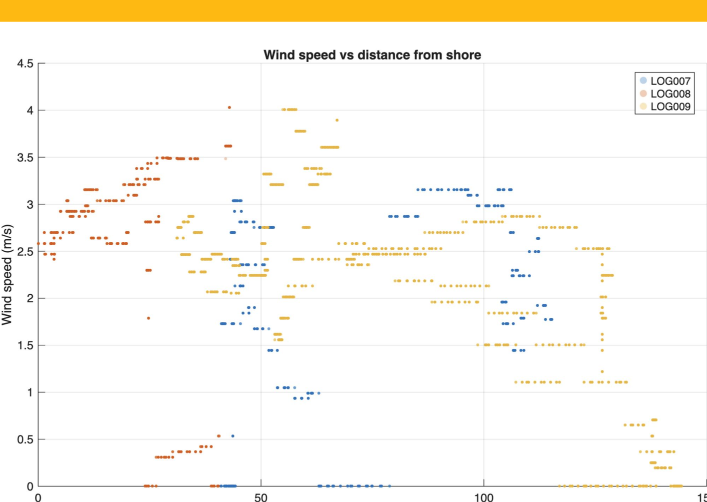
- The anemometer was placed in the wind tunel to match the sensor's RPM (exptrapolated from the pulse count) to a known velocity (m/s)
- The weather vane was rotated 360° to find Vmin and Vmax, mapping the output voltage to degrees relative to the heading of the robot
- The photodiodes were placed in the sun under an acrylic cover during sunset; the output irradiance was matched to the Claremont forecast irradiance

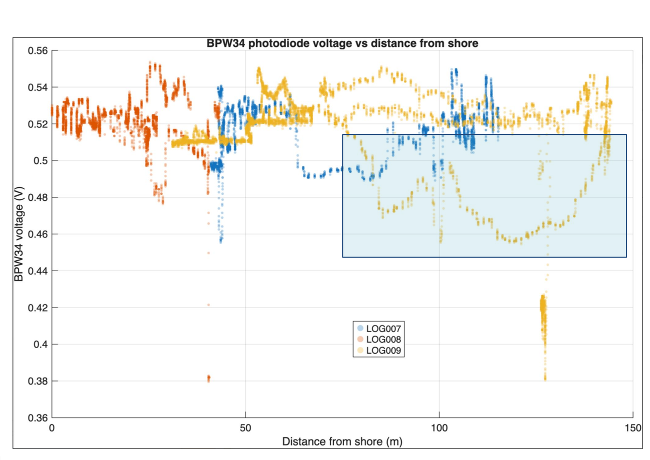
Ground Truth Measurements

Solar irradiance over our deployment window was about 475 W/m^2 according to a nearby ground-based solar irradiance monitoring station; wind speed was 2.57 m/s to 4.12 m/s and wind direction was South to Southwest according to a regional historical weather records service.

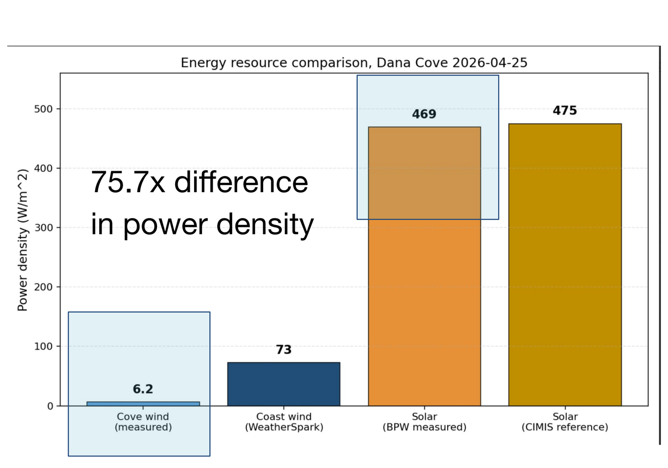
Results & Conclusions

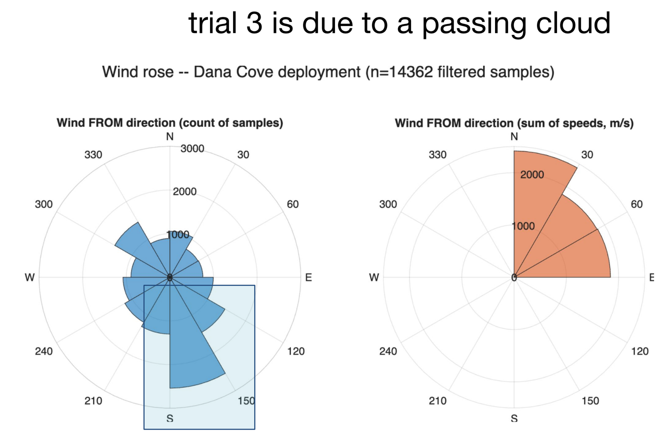
The experimentation found no significant difference in wind speed, wind direction, or irradiance with respect to distance from shore. This went against the proposed hypothesis which predicted that wind would increase from shore while solar irradiance would decrease. However, there were some notable trends. For instance, according to the weathervane, the wind primarily came from the Southeast. There was also significantly more renewable power potential (~76 times) from solar than wind sources in the cove as measured by the calculated avg. power density (W/m^2) from the anemometer and BPW data.





The drop in voltage (irradiance) in trial 3 is due to a passing cloud





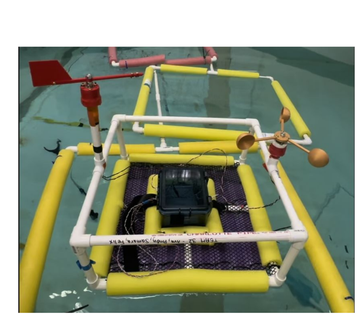
primary wind direction (SE)

Deployment Details

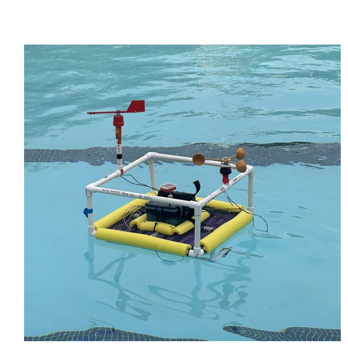
Location(s): Tank Room, Phake Lake, Pitzer Pool, Dana Point

Testing Protocol: Power on robot and verify circuits, power off, upload code to Teensy, secure electronics in housing, then power on and deploy.

Safety: Wore PFDs near water; sealed-enclosure for robot deployed with a floating retrieval tether; buddy system with a designated spotter.



Deployment in Tank Room



Deployment at Pitzer Pool

Deployment at Dana Point

Acknowledgements and References

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References

[1] Manwell, J. F., McGowan, J. G., Rogers, A. L. Wind Energy Explained: Theory, Design and Application, 2nd ed., Wiley, 2009.

[2] NREL System Advisor Model (SAM). https://sam.nrel.gov