Optimized Sailing Trajectories: Team SailTrim

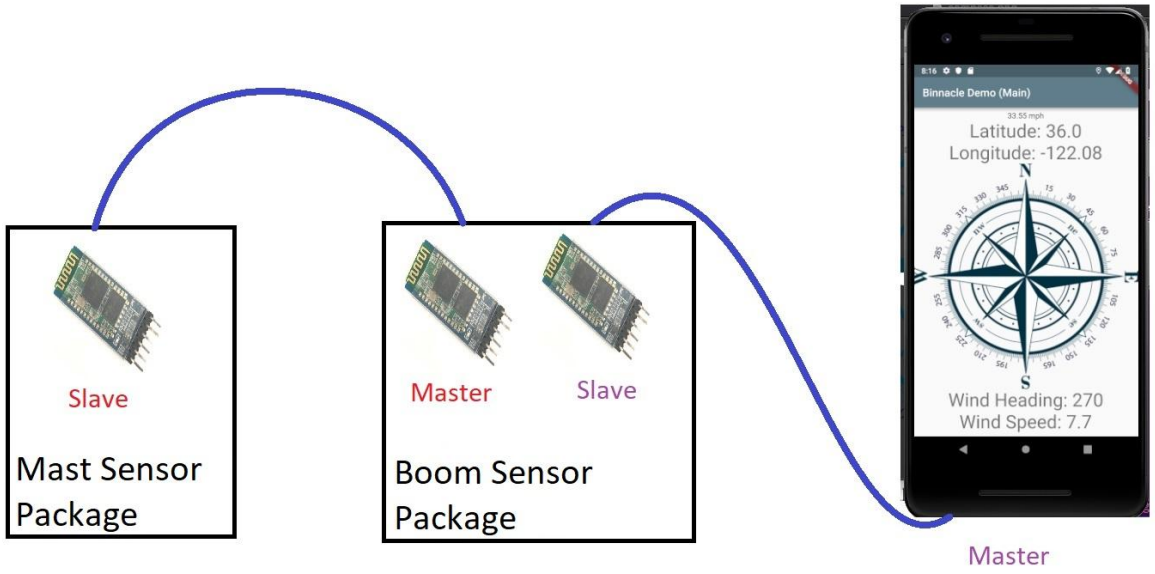
Joseph Skinner, Lucas Hartlage,
Ramess Rogers

System Overview

- **Wind Vane/Anemometer** - wind speed/direction
- **GPS** - boat velocity, course over ground
- **IMU** - heading, attitude for data filter
- **Boom Angle Sensor** - position of sail
- **uC32** - processes data
- **Bluetooth** - transfer of data to mobile app

Bluetooth: Network Config

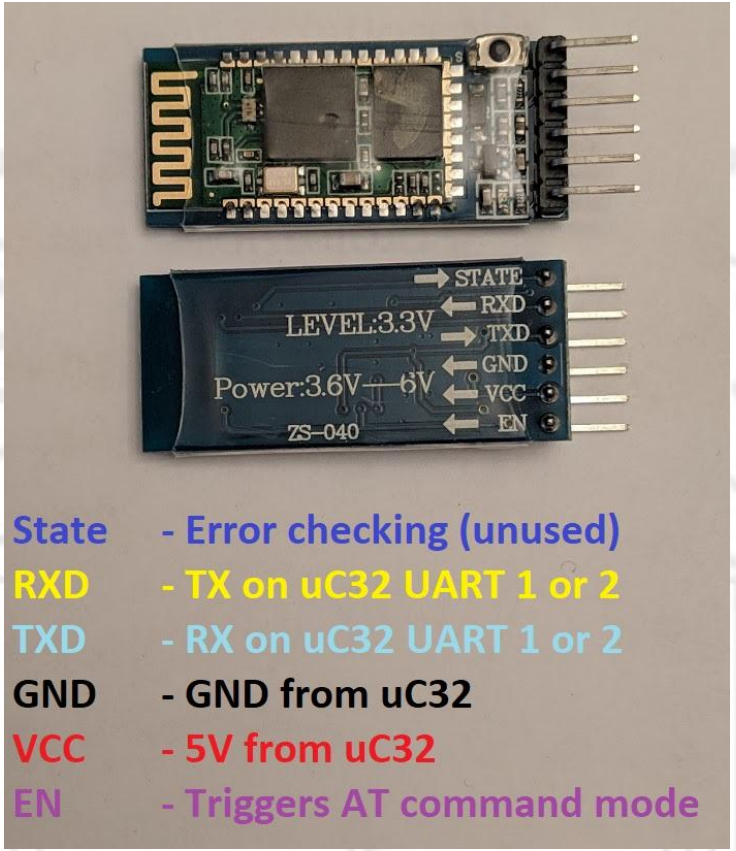
- Three HC-05 Modules, one phone
  - HC-05's: 2 Slaves, 1 Master



Bluetooth: Serial UART

- Max's serial.c modified to support UART2 as well
- Our serialcomm.c built on this to support NMEA use

- Also used to configure HC-05 modules w/ AT commands



Bluetooth: Data Format

- Our custom NMEA based packet:

$GNOST,(filtered?),(lat),(long),(wind speed),(wind dir),(heading),(boom angle),(timestamp),(checksum)\r\n*

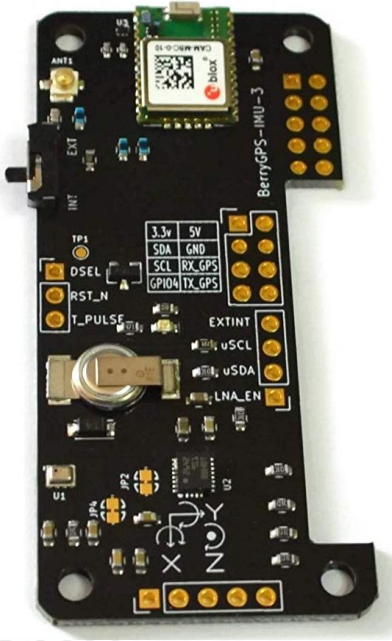
- So far this one has more use:

$GNTST,(speed),(wind speed),(wind dir),(heading),(boom angle),(timestamp),(checksum)\r\n*

- Uses same parser as the GPS data

GPS: Hardware

- BerryGPS-IMUv3 has CAM-M8 (uBlox)
- Uses a serial UART connection



3.3v	5v
SDA (I2C)	GND
SCL (I2C)	RX_GPS
	TX_GPS

GPS: Data Parsing

- Information sent with NMEA data format
- Various packets send wide range of info, we pick and choose what parts we care about

Example:

*$GPRMC,123519,A,4807.38,N,01131.000,E,022.4,230394,003.1,W*6A*

$HEADER,hh:mm:ss,status,lat,N/S,long,E/W,speed,angle,date,mag. var.,
**checksum*

GPS: Data Collection

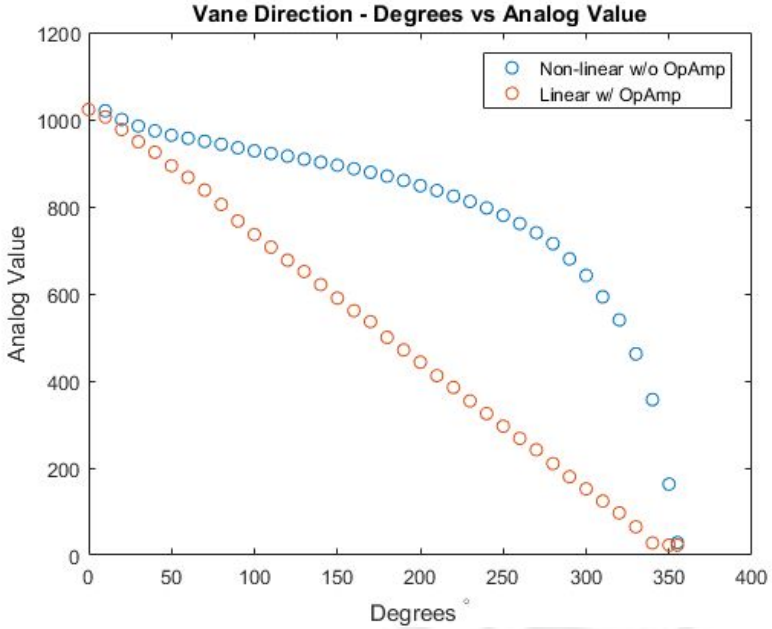
- RMC (Recommended Minimum Data)
  - Latitude and Longitude
  - Speed, direction of travel
- GGA (GPS Fix Information)
  - Number of connected satellites
  - Fix Quality
  - Longitude, Latitude
  - Dilution of precision
- Timestamp collected from both packets

Anemometer and Wind Vane

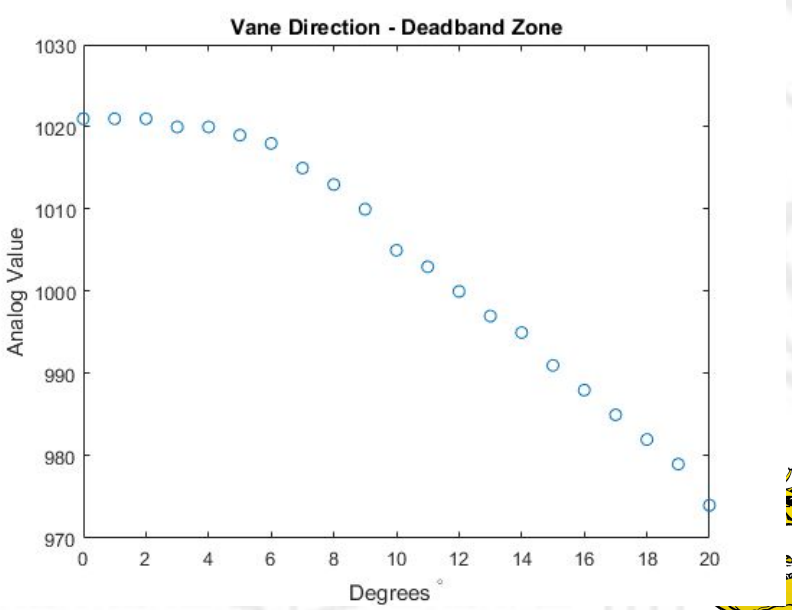
- Davis 7911
  - Wind vane - wind direction
  - Anemometer - wind speed

Wind Vane Circuit

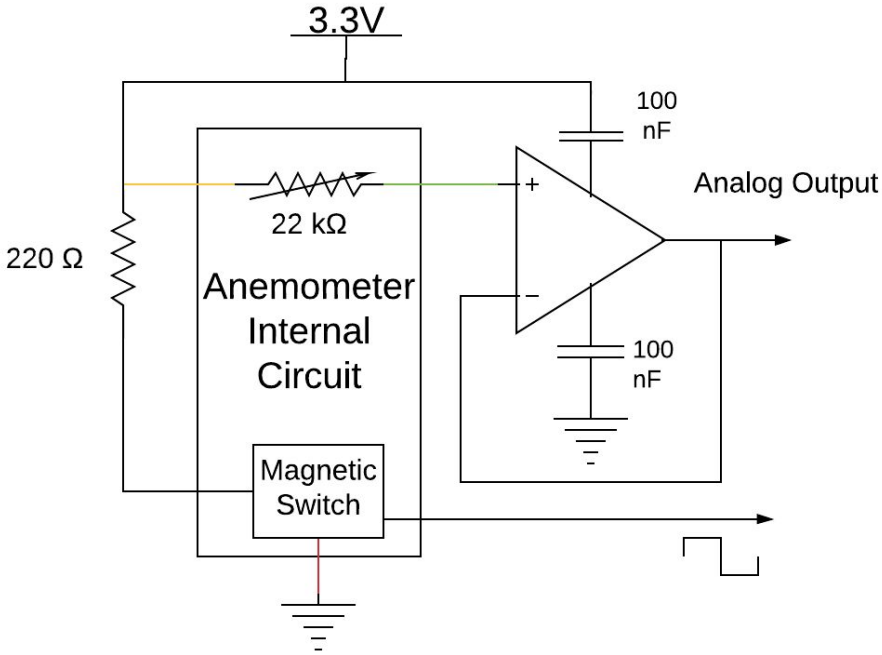
- uC impedance caused disturbance to linearity



- Linear uC readings with small deadzone (345°-10°)



Davis 7911 Circuit



- Fit function excludes deadzone
- Wind vane mounted to have dead zone in irons (no-go zone)

- Accuracy ± 1 ° within (7°-349°)

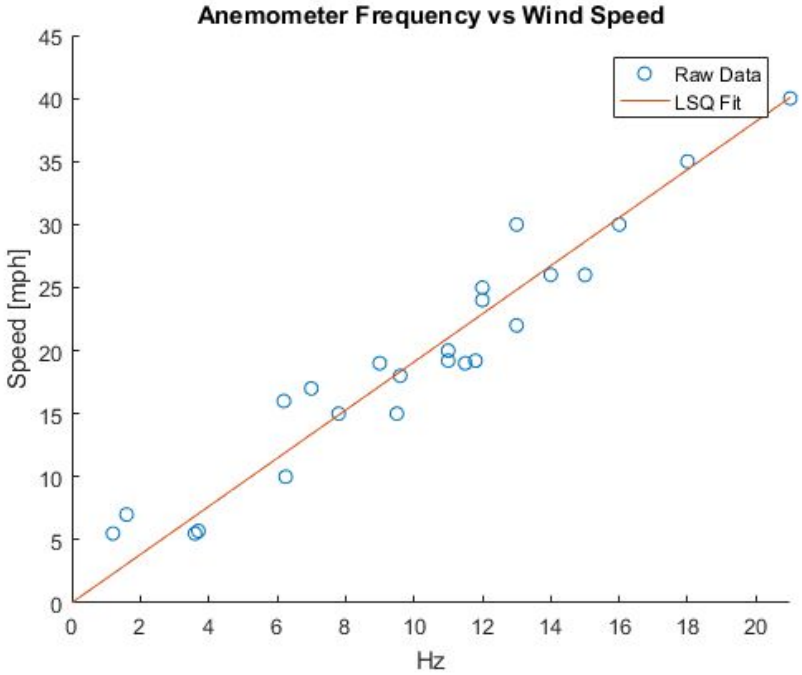
Anemometer: Data Collection

- Square wave signal with falling edge triggers
- Input Capture
  - 40 MHz PCBCLK, 1:256 prescalar, 32 bit timer
- Rollover period of 7.6 hrs
- Required mapping of freq/period to speed

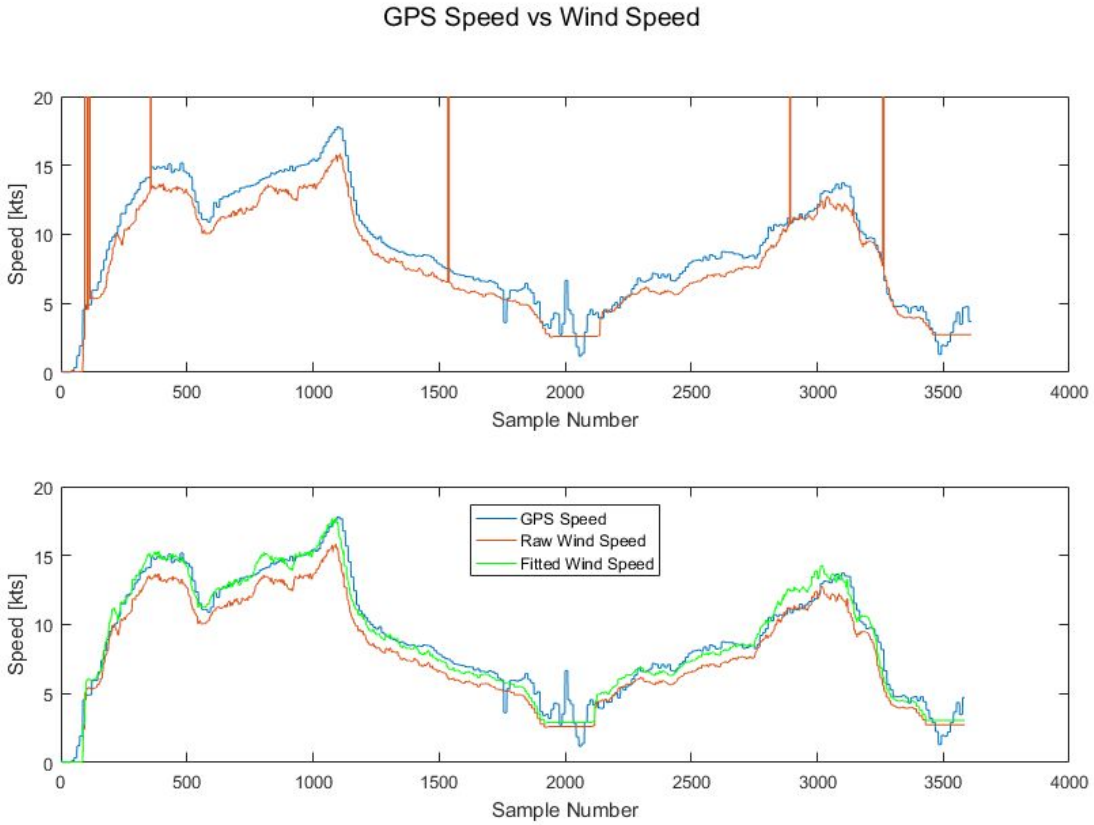
Anemometer: Data Run

- Crude measurements with Garmin GPS, and frequency logging

- Least Squares Fit
  - m = 1.91
  - b = 0.007

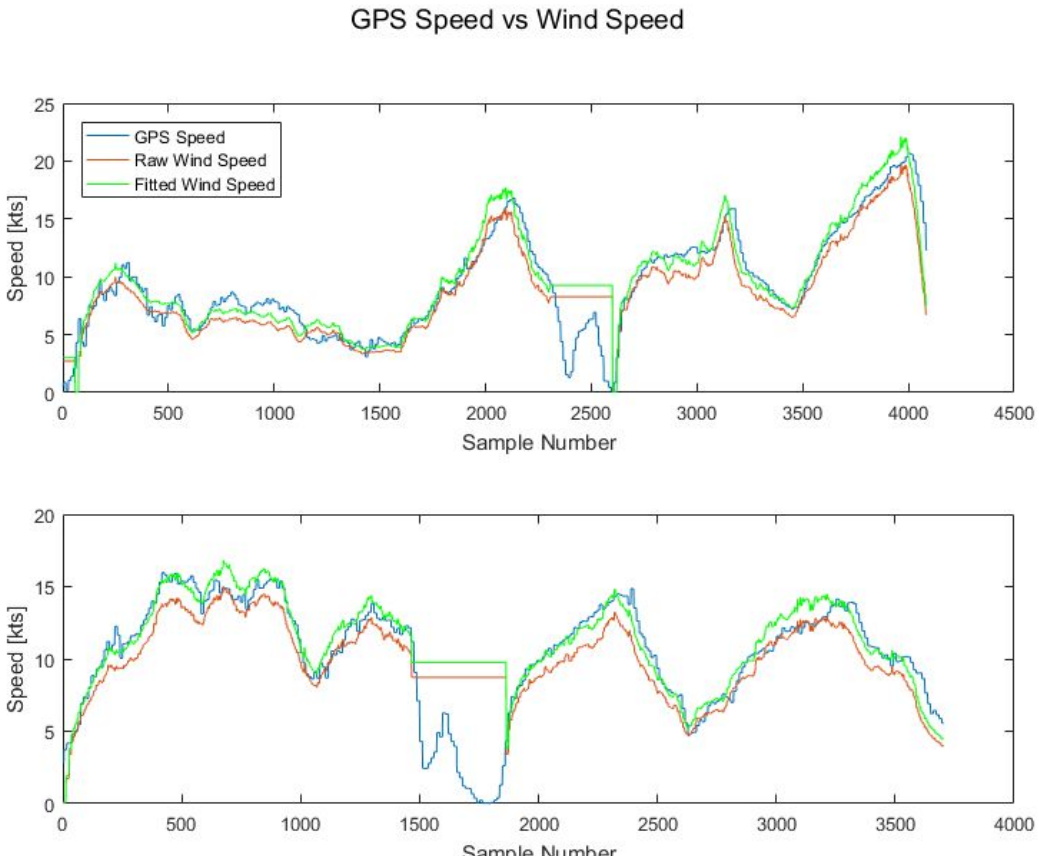


GPS/Anemometer: Data Run



- Data Dropouts
  - Wiring issue - perfboard circuit
- Initial Results:
  - max error: 2.74 knots
  - avg error: 1.06 knots
- Python Script to minimize error

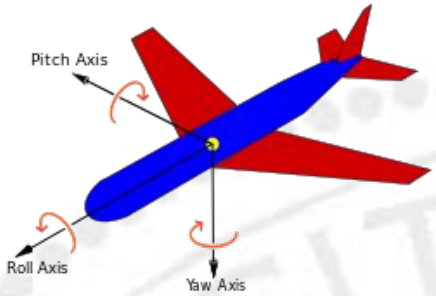
GPS/Anemometer: Data Run



- Good Agreement
  - max error: 1.96 knots
  - avg error: 0.38 knots
- Current Fit
  - 2.46 Hz per 1 knot

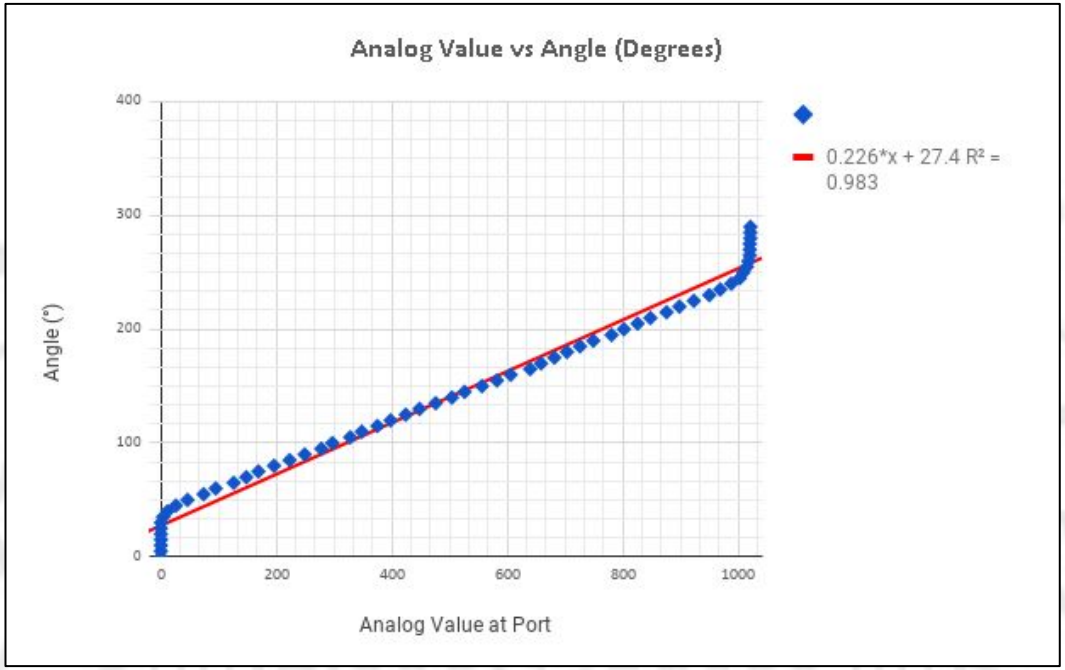
Boom Angle Sensor System Ideation

- Translate rotation of boom into readable signal
- Mount circuit on mast
- Boom offset from hinge by 2 inches
- Boom pitch range =(-90°, 15°)



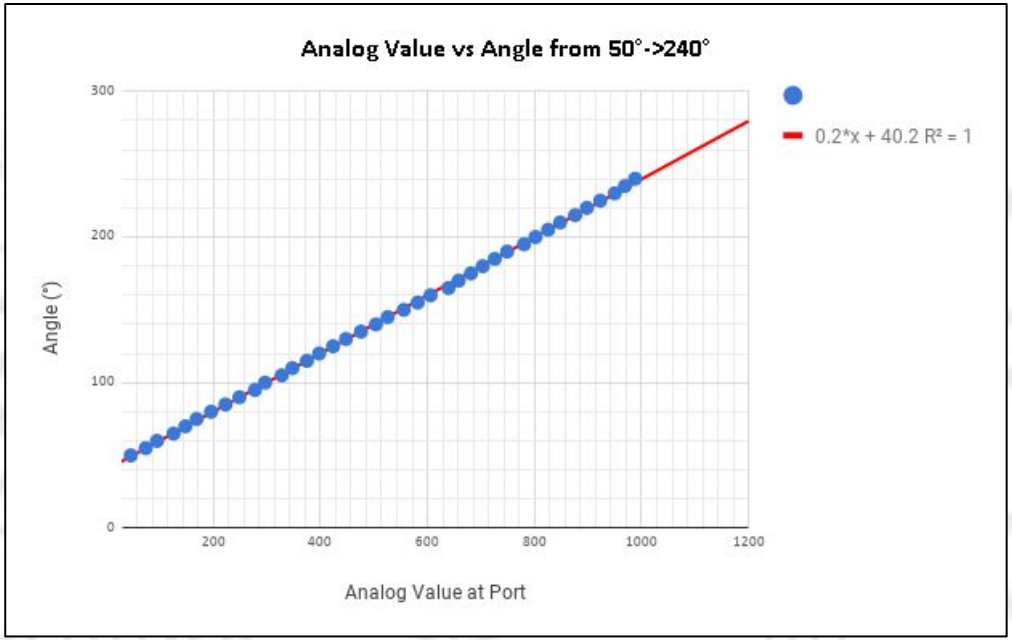
Boom Angle Sensor Library, Calibration

- Inverse fit function:
  0.226*x + 27.4
- Pot dead band at (0° ->30°), (290°->330°)
- Place pot dead band outside of active zone (120 deg)



Boom Angle Sensor Calibration

- New fit function for active zone: 0.2*x + 40.2
- Least squares error: 1
- Piecewise fit function to improve accuracy inside active zone



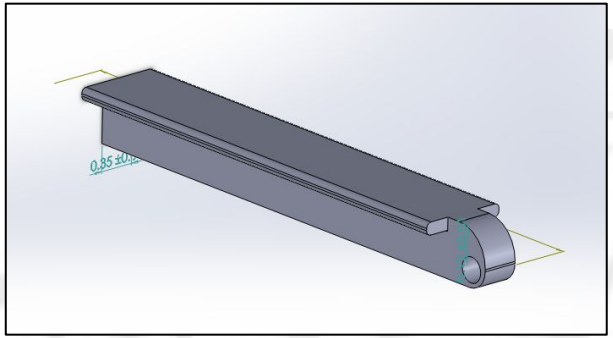
Boom Angle Sensor Measurements

- Few measurements in RS Quest manual, collect them in person at harbor
- Wrap tape along arc length of mast, mark and measure

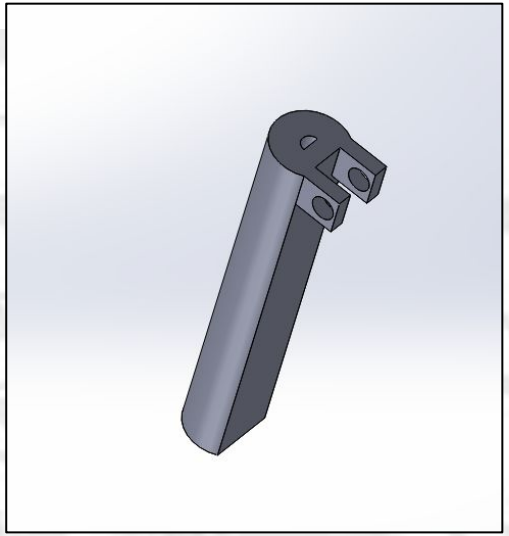
-Mast has airfoil shape, difficult to obtain arc length

Boom Angle Sensor Mechanical System

- Hinge joint in linkage to compensate for offset
- Parts drafted in Solidworks, easy to transfer to .stl for 3D printing and rapid prototyping



-Horizontal Link: slot into boom



-Vertical Link: slot into boom

CAD Mast and Link Assembly

- First drafts did not match shape of mast
- Use modeling clay to wrap around mast and hold shape, create fiberglass mount

-Draft of Mast Mount

-Combined links without fasteners

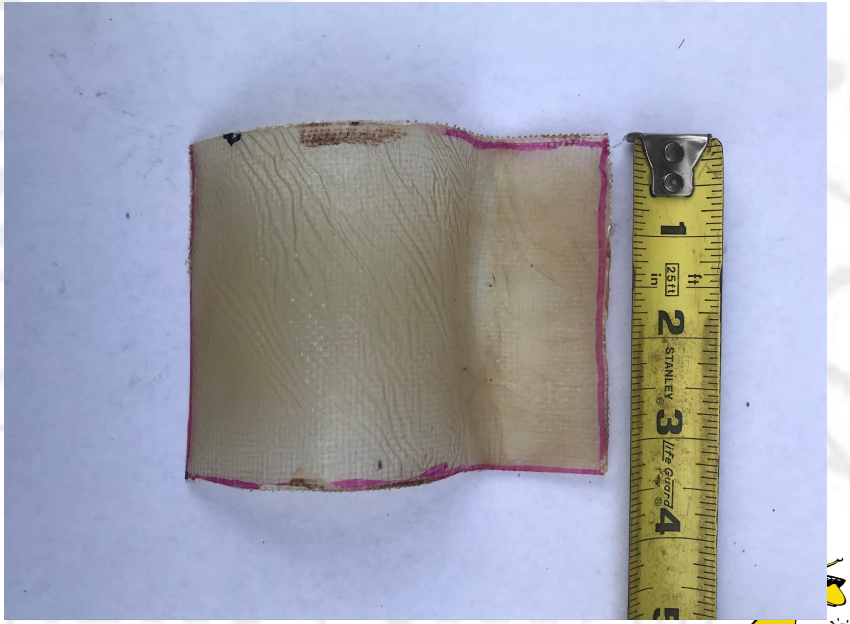
Mast Mount: Development

Modeling Clay for negative mold

Plaster of Paris for positive casting

Mast Mount: Development

Fiberglass prototype



IMU Library Creation, Calibration

- Used Max's MPU9250.h/.c as basis for LSM9DS1_func.h/.c files
- IMU Configuration:
  - accelerometer: +/- 16g
  - magnetometer: +/- 12 gauss
  - gyroscope: 2000 dps
- Accelerometer data pre-calibrated on all axes
- Mag data shifted, scaled to 1

Sensor	Sensitivity	Scale Factor	Null Shift
Accel	+/-16 g	0.732	x: none y: none z: none
Mag	+/-12 gauss	0.43	x: -5.832 y: 133.038 z: -84.509
Gyro	2000 dps	N/A	N/A

Final Remarks

- Bluetooth transfer protocol
- GPS parsing, packet
- Anemometer/wind vane data
- Boom angle data fit
- Initial IMU calibration
- Mast mount prototype development