DATA ACQUISITION MARINE VEHICLE

SEMI-AUTONOMOUS WATER TESTING AND DATALOGGING

Grecia Roman
Clinton Mazone
Danton Wyatt
Michael Genova

PROJECT OVERVIEW

- **Objective**
  - To provide water quality data using a semi-autonomous marine vehicle, reducing the time and resources required compared to traditional testing methods
- **Sensors and Data Logging**
  - Mike Genova
- **Navigation System**
  - Clinton Mazone
- **Marine Vehicle**
  - Grace Roman
- **Propulsion**
  - Danton Wyatt

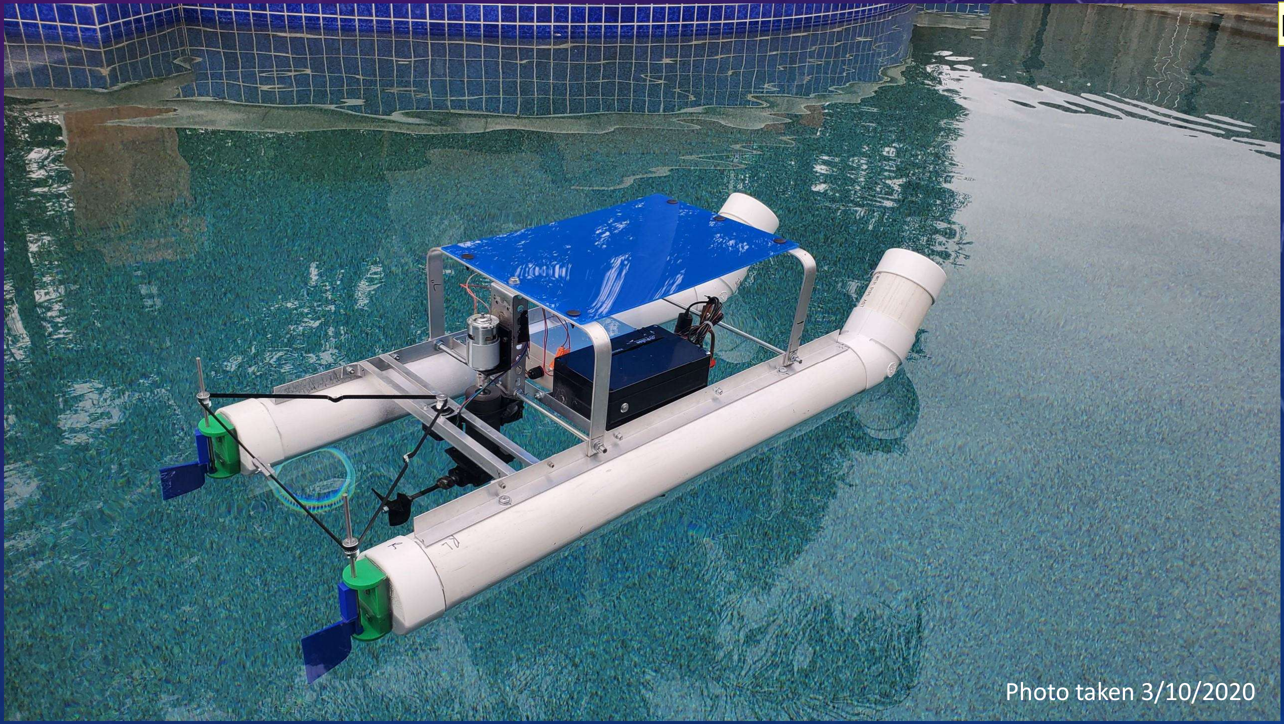


Photo taken 3/10/2020

MG

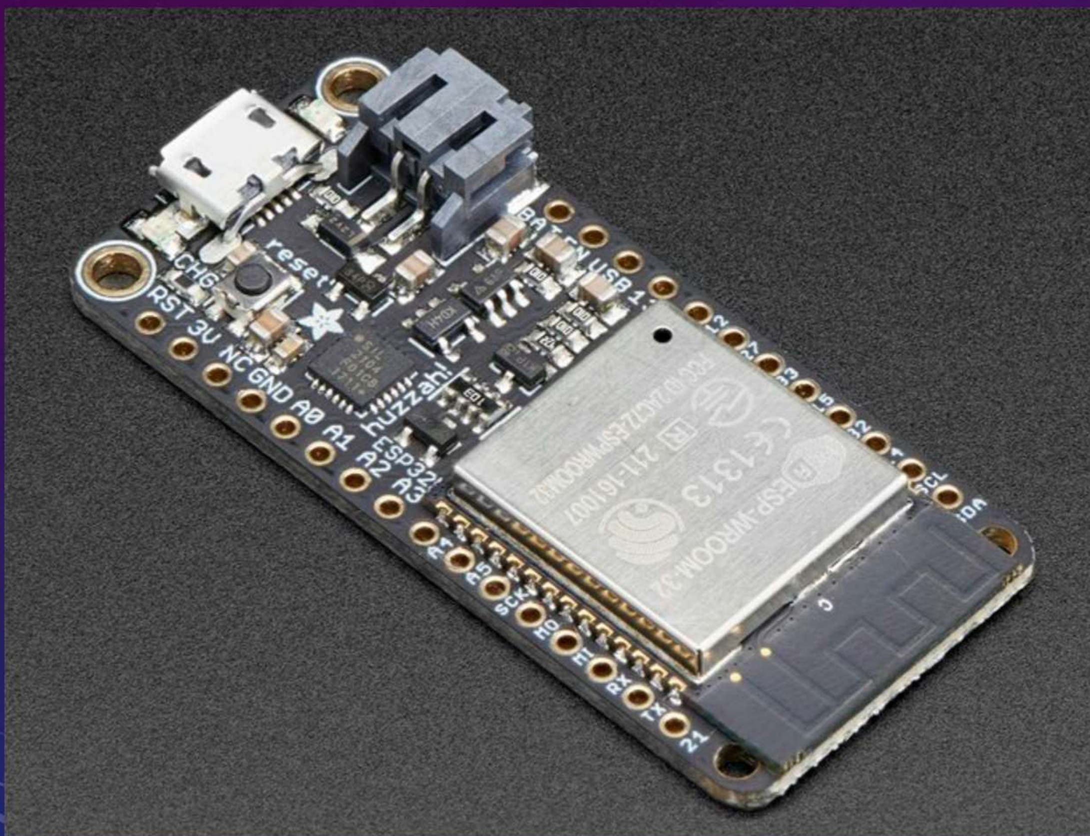
Slide 2

MG1 Michael Genova, 3/10/2020

DATALOGGER AND SENSORS

MIKE GENOVA

DATALOGGER MICROCONTROLLER – ESP32

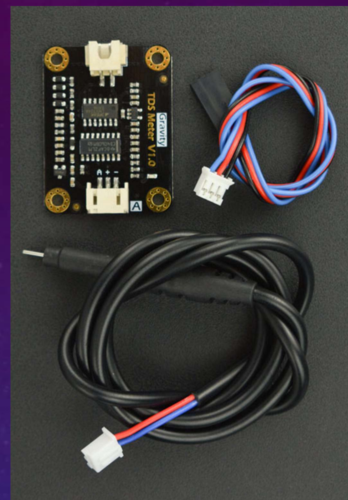


- 240 Mhz dual-core processor
- Wi-Fi + Bluetooth built in
- 3.3v logic can be powered by a single 18650 Li-po
- Uses Arduino IDE
- Plenty of GPIO and comm ports
- Extensive libraries with good documentation

SENSOR SELECTION

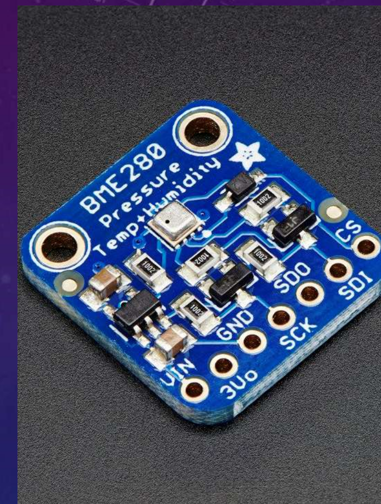
DS18B20 Waterproof Digital Temp Sensor

5v Analog Ph Sensor



5v Analog TDS sensor (Total Dissolved Solids)

5v Analog Turbidity Sensor

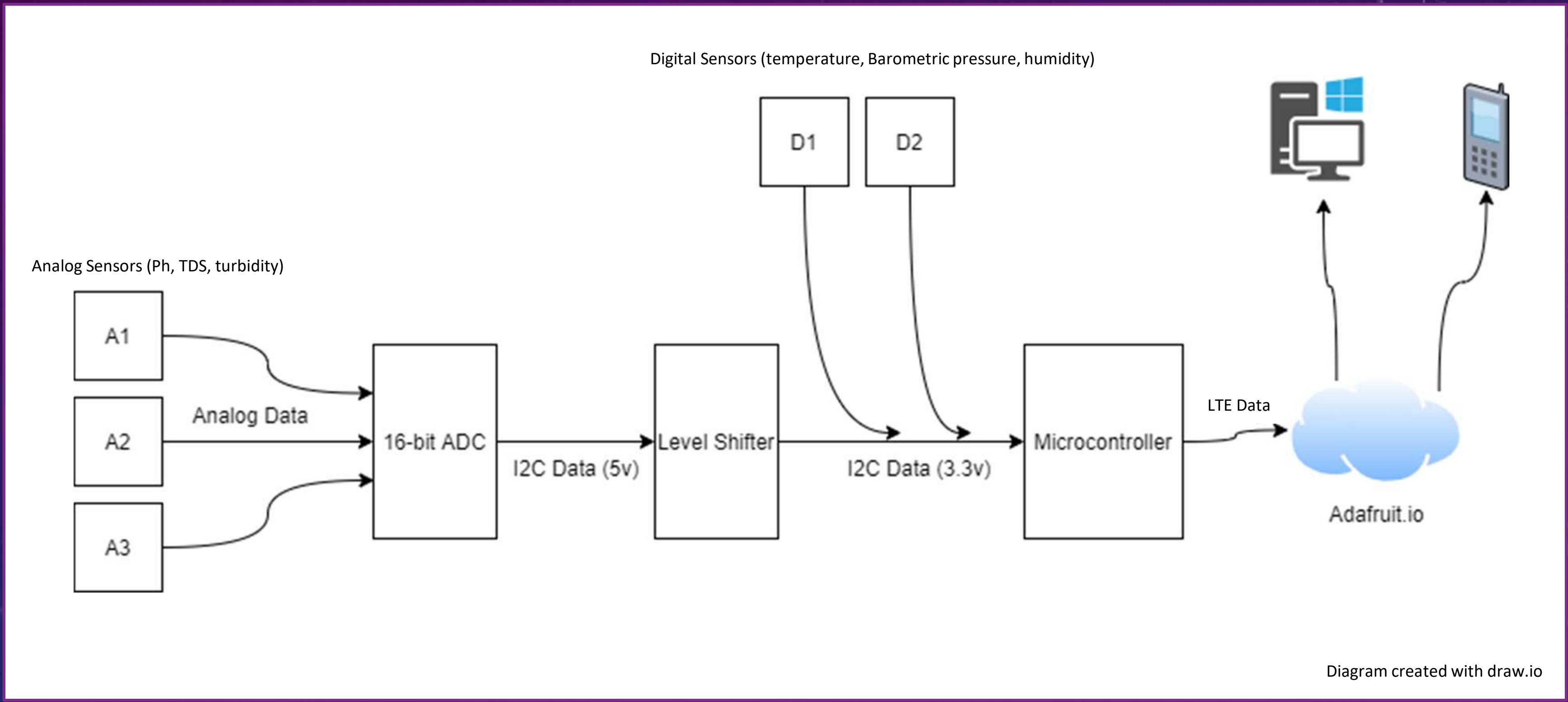


BOSCH BME280 Digital Ambient Air Sensor

3D PRINTED BRACE

- A custom brace was needed to secure the sensors in such a way that would not interfere with the propulsion and navigation systems.
- Diameter of each sensor was measured and organized into a row from smallest to largest.
- Autodesk Fusion 360 software was used to create the bracket
- The part was 3D printed at the CSUB FabLab

DATA FLOW


Digital Sensors (temperature, Barometric pressure, humidity)
D1
D2
Analog Sensors (Ph, TDS, turbidity)
A1
A2
A3
Analog Data
16-bit ADC
I2C Data (5v)
Level Shifter
I2C Data (3.3v)
Microcontroller
LTE Data
Adafruit.io
Diagram created with draw.io

DATALOGGER PROGRAM FUNCTION-STATE DIAGRAM

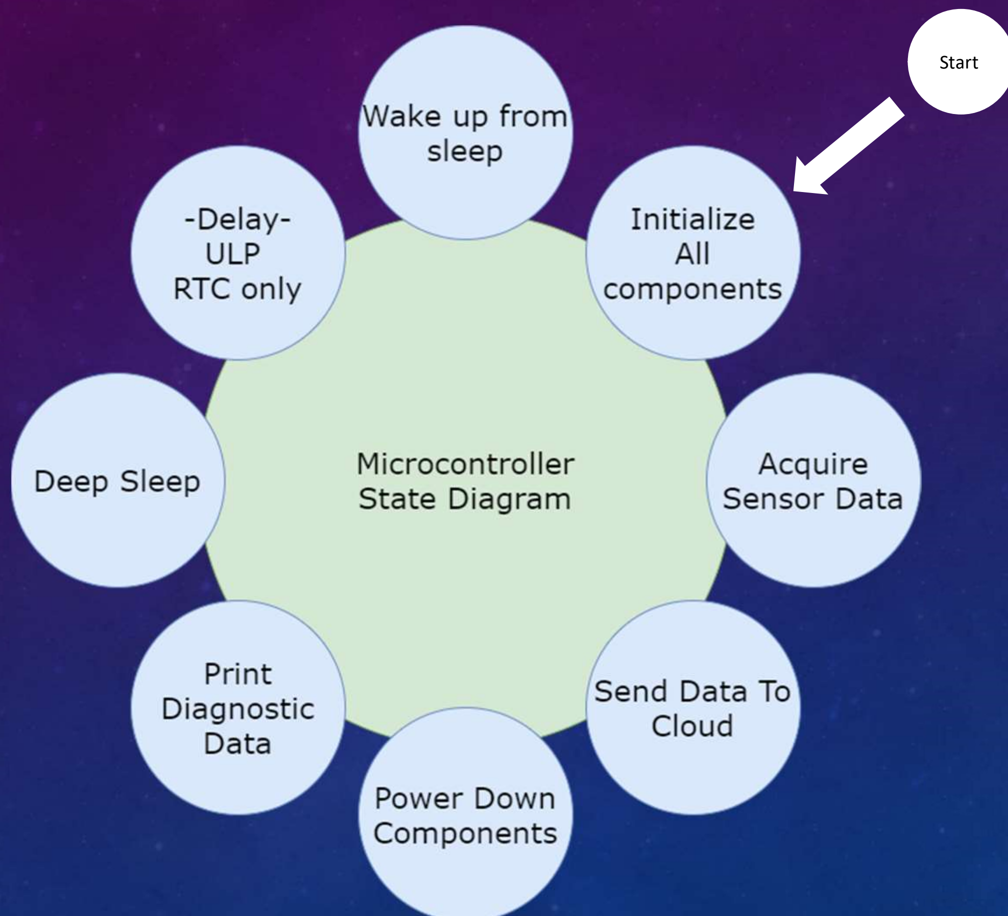
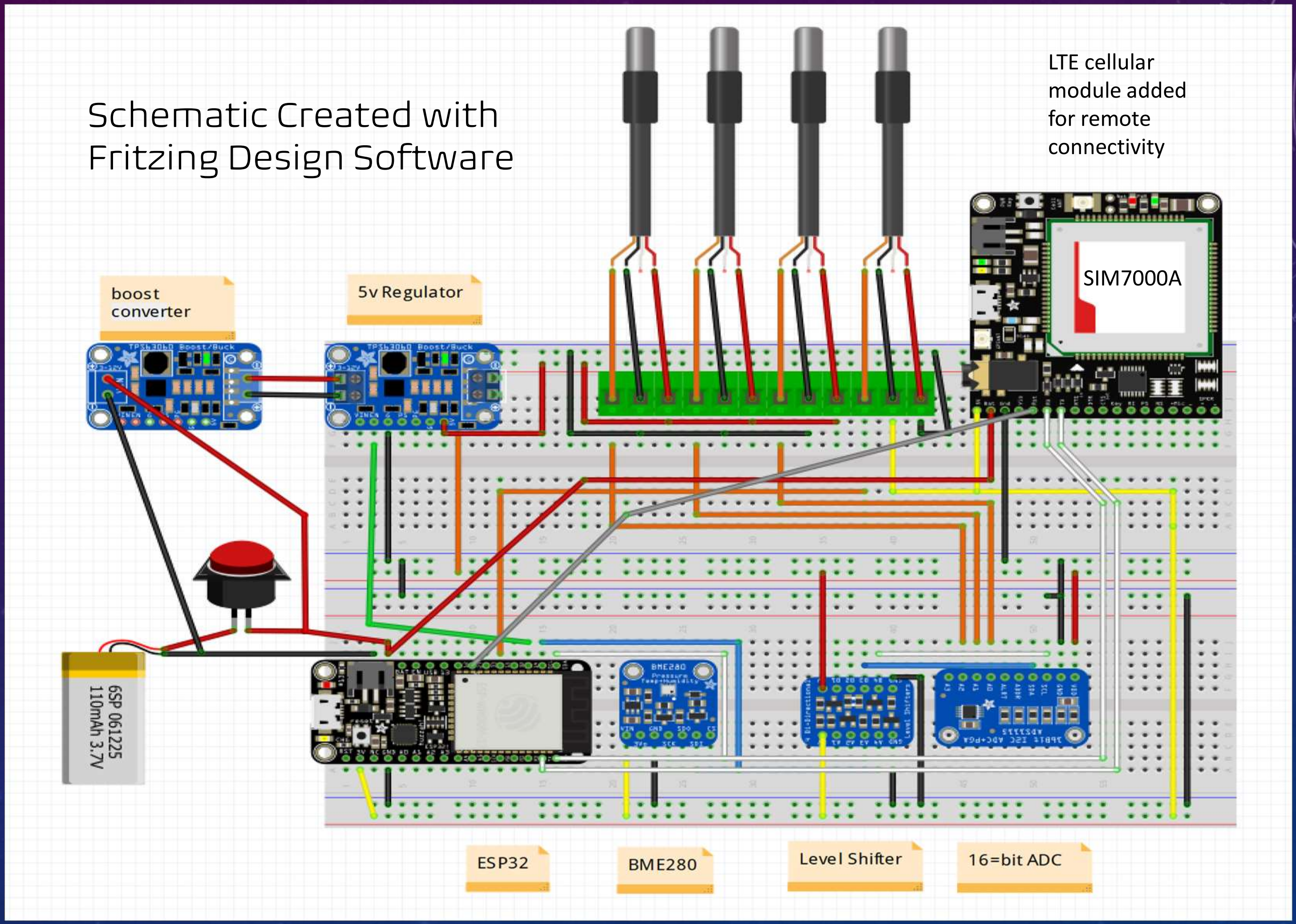
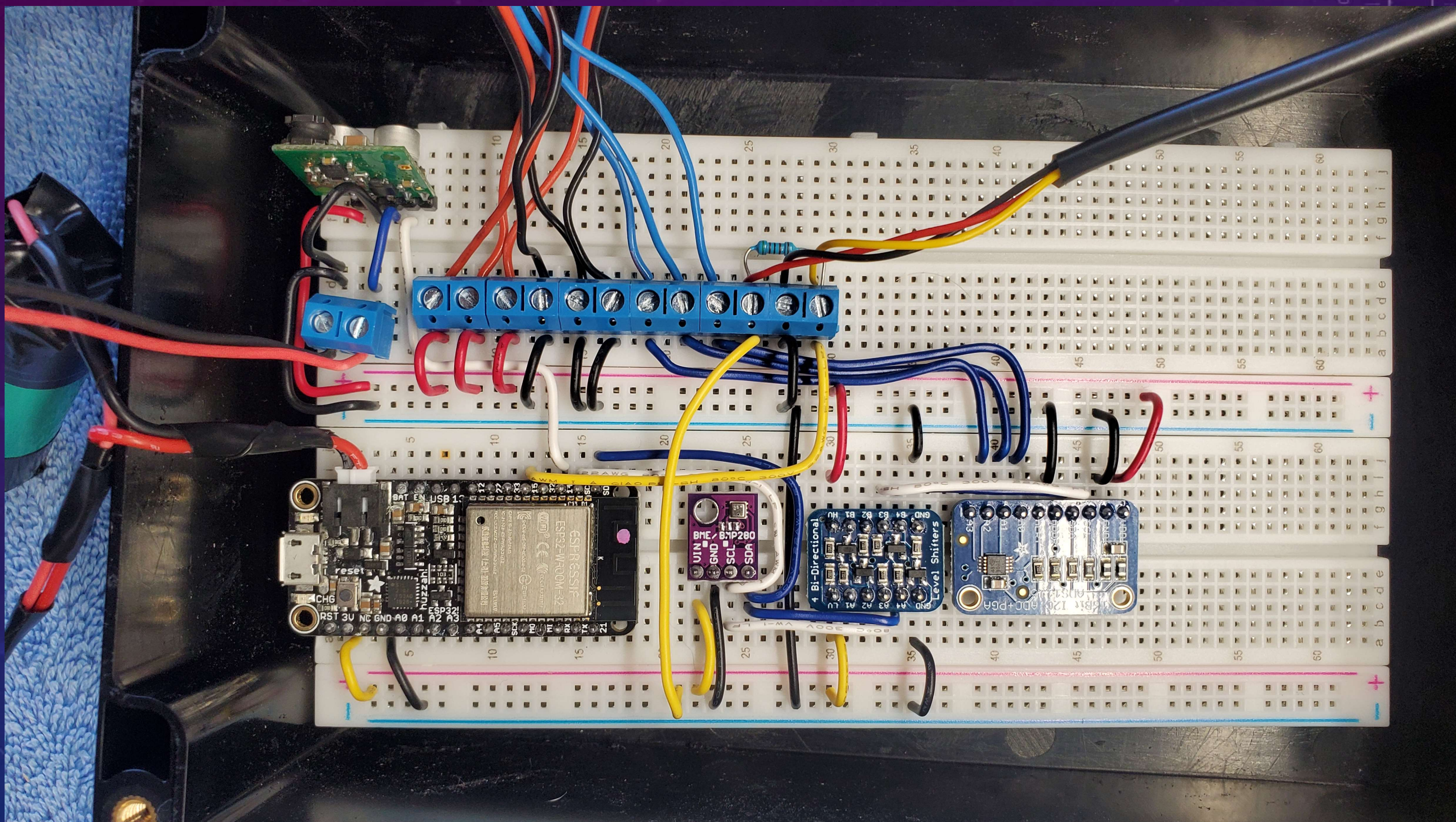


Diagram created with draw.io

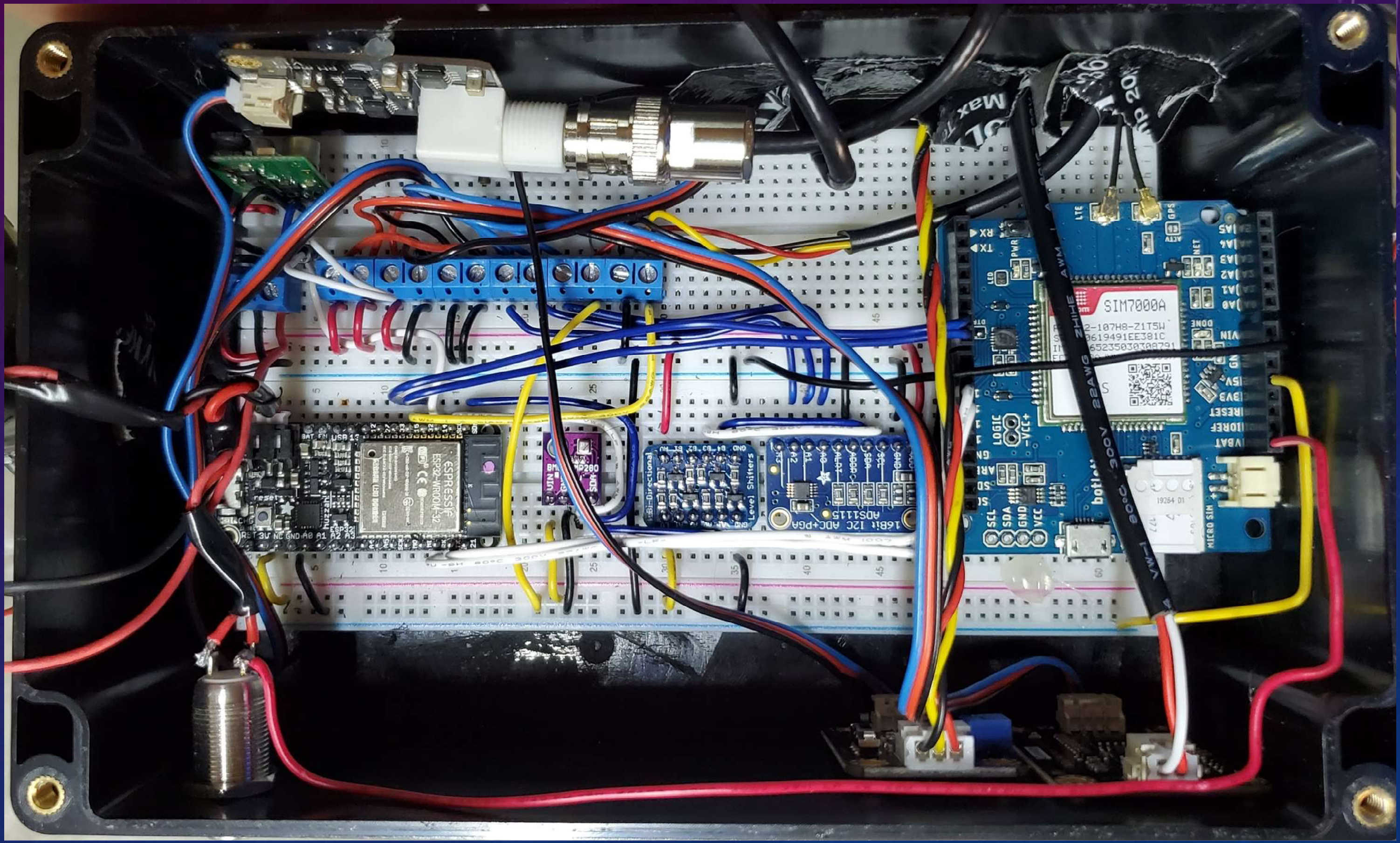
DATALOGGER WIRING SCHEMATIC



DATALOGGER CONTROL BOX REVISION 1



DATALOGGER CONTROL BOX REVISION 2



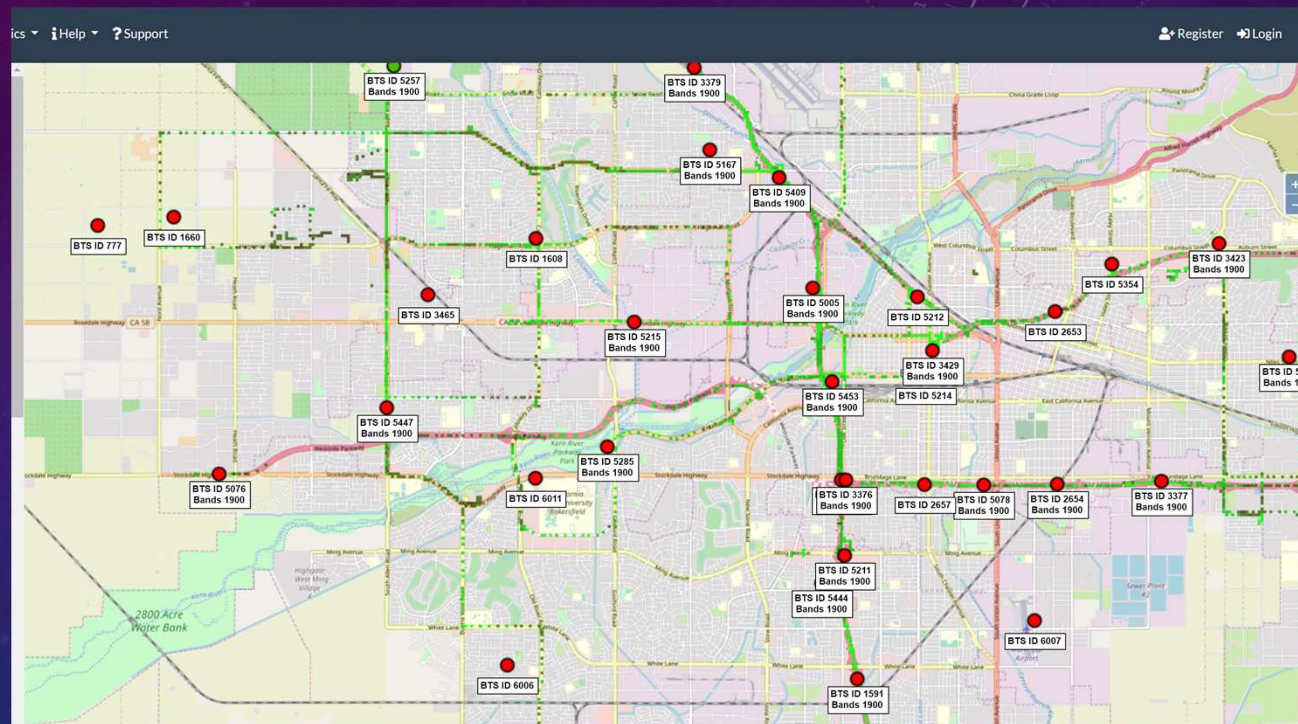
THE PROBLEM WITH IOT CELLULAR TECH

- Most available devices only support 2G connections (such as the Adafruit FONA808).
- The Adafruit 3G version is still under development and has a lot of bugs.
- While the hardware is still supported by its manufacturer, the cell towers they use are being decommissioned in the USA.
- I had purchased this module and a sim card that supported 2G networks. However I learned that in Bakersfield the last remaining 2G towers from T-Mobile have been shut down recently.
- More research needed to be done on cellular IoT connectivity.
- Rather expensive at $80, for something that isn't practical.

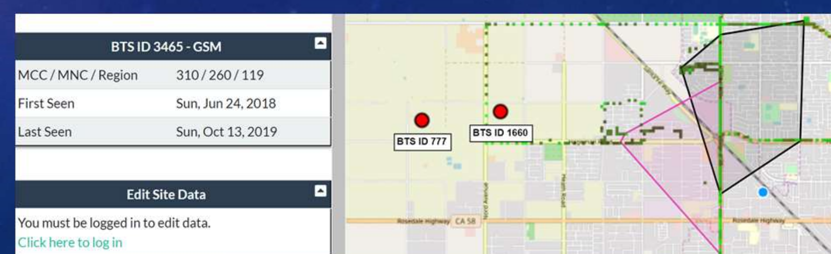
Picture of the Adafruit Fona808 2G cellular module. Taken from Adafruit.com

CELLMAPPER.NET

- Cellmapper.net is a useful tool to check what cellular services are in your area.
- Originally, I had seen all the towers and assumed they were online, it was later that I found out that the towers were offline since October 2019.
- I could have used a different microcontroller from Arduino.CC that has LTE built in, but the code would have to be re-written and the control box would have to be re-wired due to the different GPIO pinouts. This would set us back significantly on our schedule. Also, Wi-Fi is not available on that module.
- Back to the drawing board we go, to look for another cellular solution…

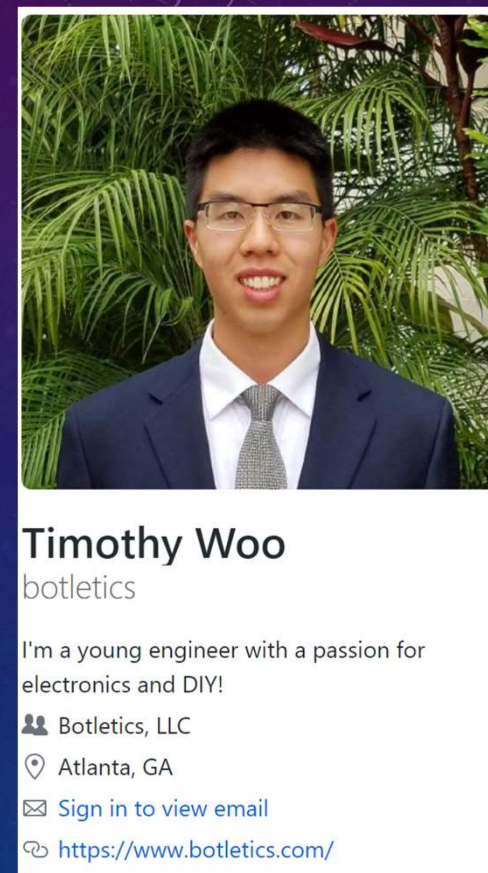


Note: Tower offline



THE SOLUTION

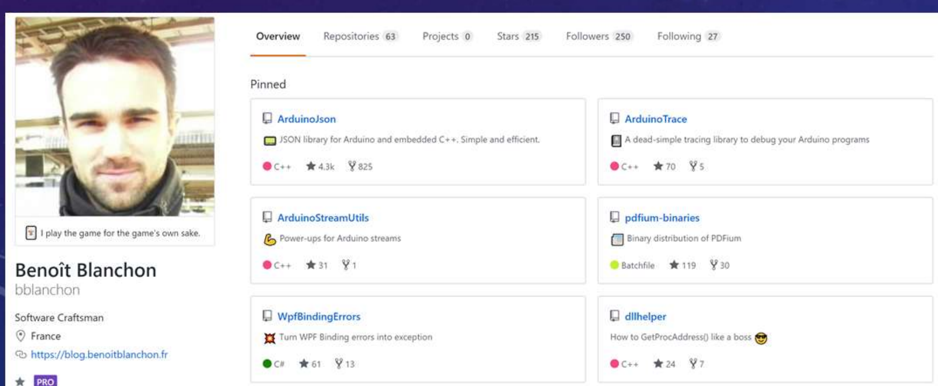
- Newer 5G technologies exist for IoT platforms, mainly NB-IOT and CAT-M1.
- North America uses CAT-M1 technology which is supported by Verizon and AT&T.
- SIMCOM Technologies developed the SIM7000 LTE chip.
- Timothy Woo, a young engineer from Georgia, created a breakout board for the SIM7000 chip and rewrote the open source Adafruit library all by himself. The modified library works with both adafruit's boards, and the botletics LTE board.
- The Botletics SIM7000A board is affordable and available to anyone for $65.



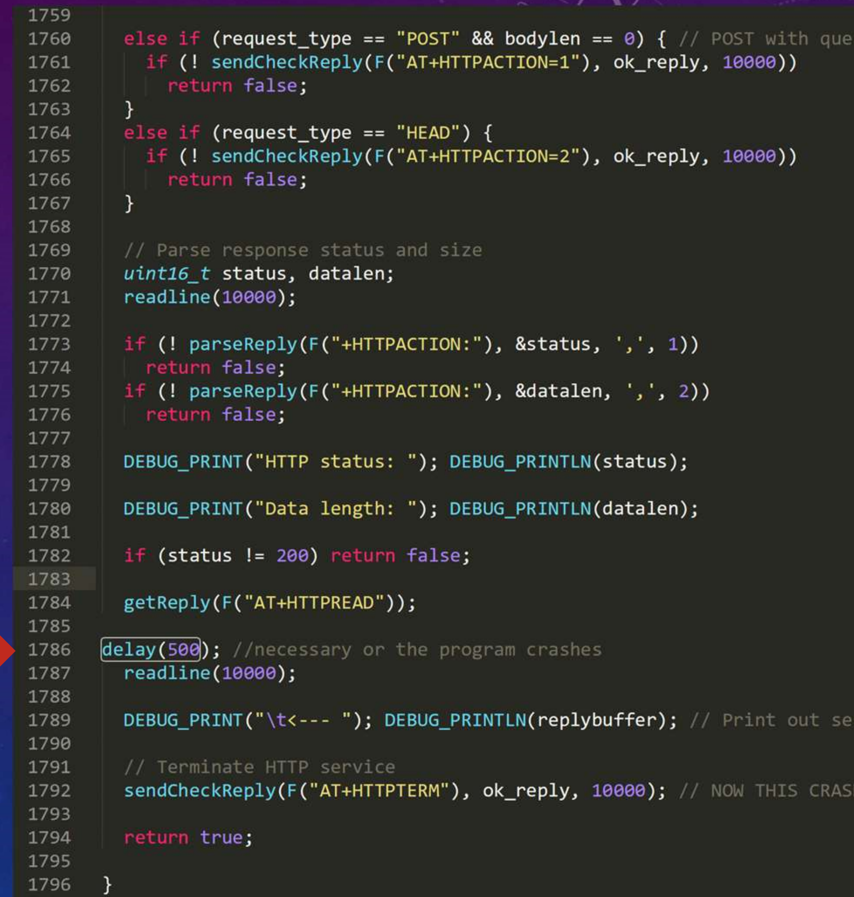
Picture taken from Github.com/botletics

DEBUGGING TIMOTHY WOO'S LIBRARY

- The library worked with the example code given but crashed when implemented into my main program. Clearly it needed some modification.
- There are over 3200 lines of code in the library, and a single line of code somewhere was causing a crash. Arduino IDE does not have a built-in debugger, so an alternate method of troubleshooting was needed.
- The ArduinoTrace library, created by programmer Benoit Blanchon was the best tool for debugging Arduino IDE. Source code can be found on Github. He is also the creator of one of the most used Arduino libraries to date - ArduinoJSON. (see below). The ArduinoJson library was used in the Wi-Fi version of our datalogger to serialize data over Wi-Fi.
- It was found that Timothy Woo's library modifications did not account for large strings of data being returned from a server such as in our project.
- Response from the server was truncated and caused the program to crash
- Debugging revealed that a small 500 ms delay was all that was needed. Thanks Benoit!



Picture taken from Github.com/bblanchon. Benoit is the creator of the ArduinoJson and ArduinoTrace Libraries

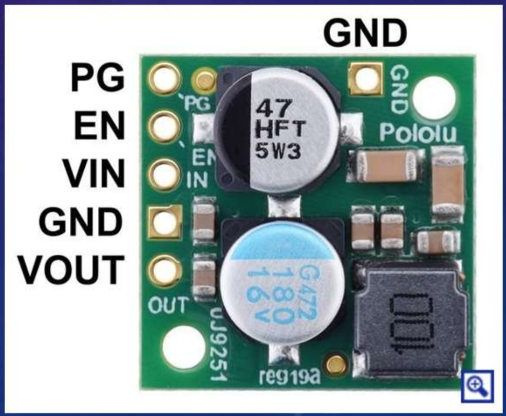


```
  else if (request_type == "POST" && bodylen == 0) { // POST with quer
    if (! sendCheckReply(F("AT+HTTPACTION=1"), ok_reply, 10000))
      return false;
  }
  else if (request_type == "HEAD") {
    if (! sendCheckReply(F("AT+HTTPACTION=2"), ok_reply, 10000))
      return false;
  }

  // Parse response status and size
  uint16_t status, datalen;
  readline(10000);

  if (! parseReply(F("+HTTPACTION:"), &status, ',', 1))
    return false;
  if (! parseReply(F("+HTTPACTION:"), &datalen, ',', 2))
    return false;

  DEBUG_PRINT("HTTP status: "); DEBUG_PRINTLN(status);

  DEBUG_PRINT("Data length: "); DEBUG_PRINTLN(datalen);

  if (status != 200) return false;

  getReply(F("AT+HTTPREAD"));

delay(500); //necessary or the program crashes
  readline(10000);

  DEBUG_PRINT("\t<--- "); DEBUG_PRINTLN(replybuffer); // Print out ser

  // Terminate HTTP service
  sendCheckReply(F("AT+HTTPTERM"), ok_reply, 10000); // NOW THIS CRASH

  return true;

}
```

Screen shot of Sublime text editor and the modified opensource FONA library by adafruit

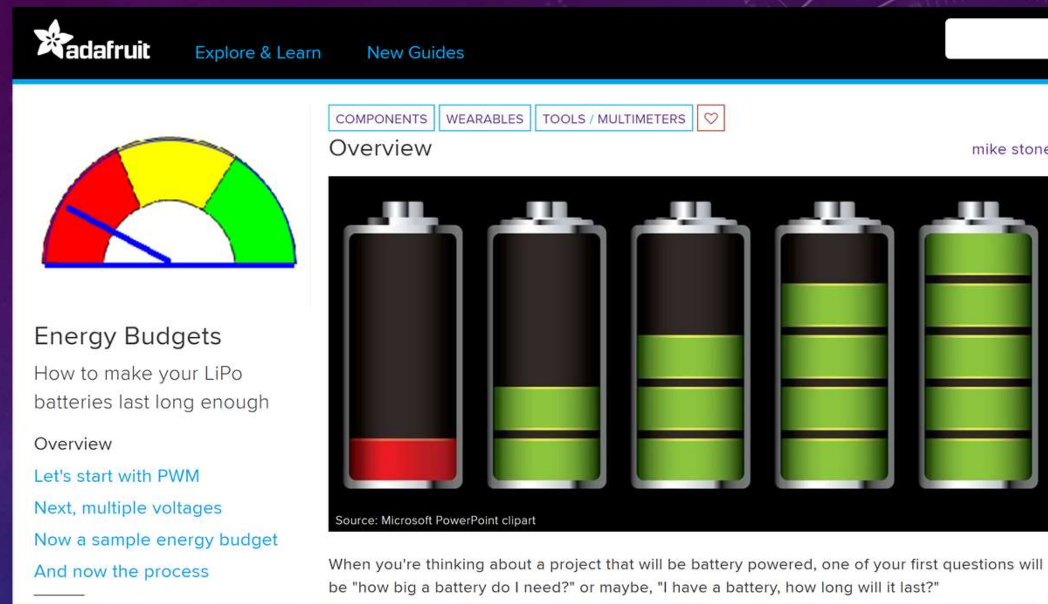
ENERGY SAVING TECHNIQUES – THE D24V22F5 REGULATOR

- Pololu makes high quality electronics for robotics that are made in the USA (Las Vegas).
- The enable pin allows the regulator output to be turned on and off via a microcontroller, drawing less than 5 microamps during standby.
- Produces a clean reference voltage of exactly 5.00 VDC needed for the sensors
- It was found that other regulators produced an output voltage of 5.2-5.7 VDC in order to eliminate a brown out scenario when the regulator is delivering high current loads. This is great for a microcontroller supply, but not for a sensor VCC reference. The higherVCC voltage causes sensor error.
- small enough to fit anywhere
- Low cost - $5.00



Picture of the D24V22F5 regulator taken from https://www.pololu.com/product/2858

ENERGY BUDGETING



Picture taken from https://learn.adafruit.com/energy-budgets Article written by Mike Stone

- With all the bugs finally worked out, We could finally begin analyzing energy consumption.
- Due to the process of multiple states and multiple components, all with different current consumption, estimating battery life and battery capacity requirements can be difficult.
- Average current is very difficult to determine in this scenario.
- The Adafruit article written by Mike Stone on energy budgeting proved very helpful.
- Measure voltage drops, current, and time for each component and convert to Joules
- This makes estimating battery requirements easy

ENERGY SPREADSHEET

ESP32 Feather - Energy budget = 82,200 J					
Item	Voltage (V)	Current (mA)	Power (mW)	Time (s)	Work (J)
Sleep (all 3v3)	3.3	1.65	5.445	300	1.63
Active	3.3	39.5	130.35	5	0.65
sim7000 (GPS)	3.3	100	330	7	2.31
sim7000 (LTE)	3.3	100	330	9	4.62
Quisient (sim7000)	3.7	0.01	0.037	300	0.01
Total					9.22

Datalogger - Energy budget = 82,200 J					
Item	Voltage (V)	Current (mA)	Power (mW)	Time (s)	Work (J)
DS18B20 Temp	3.3	0.5	1.65	5	0.00825
Ph sensor	5	12.5	62.5	5	0.3125
TDS sensor	5	2.7	13.5	5	0.0675
Turbidity sensor	5	8	40	5	0.2
BME280 sensor	3.3	0.48	1.584	5	0.008
5v Buck Regulator	0.4	0.5	0.2	5	1
5V Boost Converter	1.3	0.5	0.65	5	3.25
Level Shifter	5	0.5	2.5	5	0.0125
16-bit ADC	5	0.25	1.25	5	0.00625
Total from BMS	12.3	12.1	148.83	5	0.744
Quiescent BMS	12.3	0.05	0.615	300	0.1845
total from 5v reg	5	23	115	5	0.575
quesient 5v reg	5	0.03	0.15	300	0.0425
Total					6.411

Battery Capacities			
Item	Joules per mAh (J)	Nominal Rating (mAh)	Stored Energy (J)
3V CR1220 coin cell	10.8	40	432
3V CR1620 coin cell	10.8	80	864
3V CR2032 coin cell	10.8	240	2592
1.5v AAA cell	5.4	1200	6480
1.5V AA cell	5.4	2700	14580
1.5V C cell	5.4	8000	42300
1.5V D cell	5.4	12000	64800
3.7V 18650 LiPo single	13.7	3000	41100
7.4V 18650 LiPo 2P	13.7	6000	82200
12V 18650 LiPo 3P	13.7	9000	123300

Total Joules per cycle	Available Joules	Theoretical Cycles	Avg cycle time
15.631	82200	5259	320
	19.47 DAYS		

With the energy budget technique, I estimate 19 days of use between charging.
This is achieved with only two 3.7v 18650 cell batteries in parallel.

ARDUINO CODE

- There is too mush code to show all of it, but here are some interesting pieces.
- Sensor data is converted to a string and stored in a buffer.
- The buffer is sent to the cloud VIA LTE with the fona.postData command.
- Coding for datalogger began in December 2019.
- Documentation by Benoit Blanchon was the major contributing factor to success in the datalogger portion of the project. Without his example code we would be far behind schedule.
- 562 lines of main Arduino code
- 3300 lines in the library
- After upload, the system goes to sleep.

```
dtostrf(h20_temp, 6, 2, h20TempBuff);
dtostrf(h20_ph, 1, 2, phBuff);
dtostrf(h20_tds, 1, 2, tdsBuff);
dtostrf(h20_turbidity, 1, 0, turbBuff);
dtostrf(ambient_temp, 1, 2, ambientBuff);
dtostrf(relative_humidity, 1, 2, rhBuff);
dtostrf(baro_pressure, 1, 2, baroBuff);
dtostrf(bat_voltage, 1, 2, battBuff);
dtostrf(latitude, 1, 6, latBuff);
dtostrf(longitude, 1, 6, longBuff);
dtostrf(altitude, 1, 1, altBuff);
```

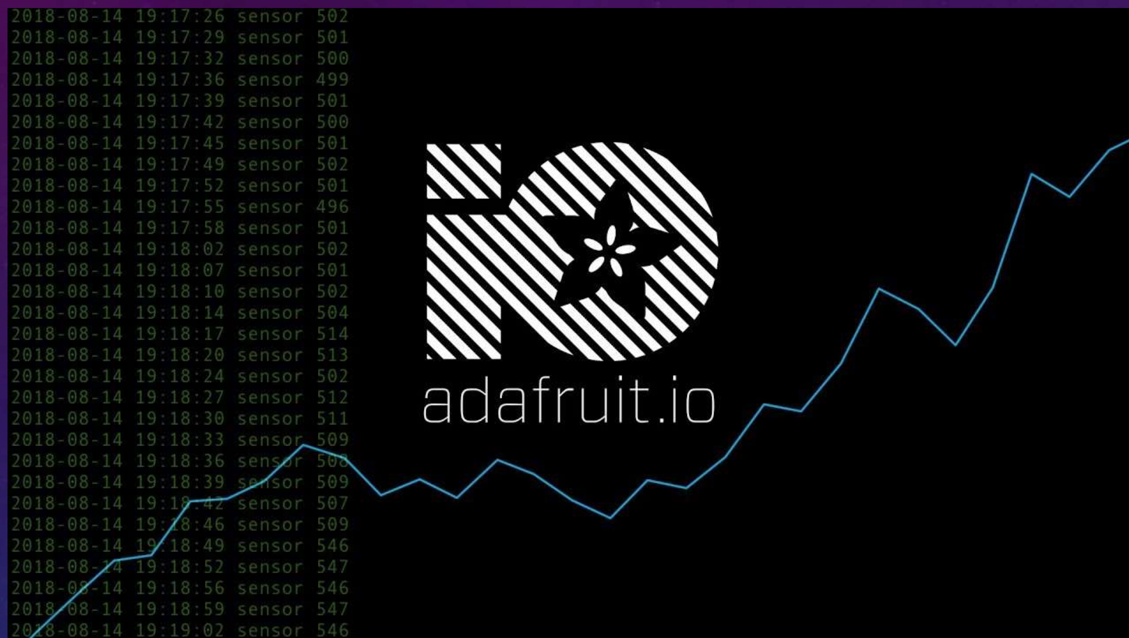
```
  /* sprintf stores the data in the buffer to write later during postData. URL will be defined as what is in the quotes. */
  sprintf(URL, "http://io.adafruit.com/api/v2/mgenova79/groups/damv/data");

  /* Test HTTP Body */
// sprintf(body, "{\"feeds\":[{\"key\":\"h20temp\",\"value\":75.425},{\"key\":\"h20ph\",\"value\":5.128633},{\"key\":\"h20tds\",\"value\":0},{\"

  /* actual HTTP body  - NOTE - I modified Adafruit_FONA.cpp with a 500 ms delay in the getReply function
     to read the response from the adafruit.io server
     because the response is lengthy and the program
     will crash without it */
    sprintf(body, "{\"feeds\":[{\"key\":\"h20temp\",\"value\":%s},{\"key\":\"h20ph\",\"value\":%s},{\"key\":\"h20tds\",\"value\":%s},{\"key\":\"h

  counter = 0; /* number of failed attempts */
  while (counter < 3 && !fona.postData("POST", URL, body)) {
    Serial.println(F("Failed to complete HTTP POST..."));
    counter++;
    delay(1000);
  }

  Serial.println("Data upload complete");
  Serial.print("turning off LTE module...");
  if (!fona.enableGPRS(false)) Serial.println(F("Failed to disable GPRS!"));
  if (!fona.enableGPS(false)) Serial.println(F("Failed to turn off GPS!"));
/* Power off the module. Note that you could instead put it in minimum functionality mode
   instead of completely turning it off. Experiment different ways depending on your application!
   You should see the "PWR" LED turn off after this command  */
  counter = 0;
  while (counter < 3 && !fona.powerDown()) {
    Serial.println(F("Failed to power down FONA!"));
    counter++;
    delay(1000);
  }
}


void go_to_deep_sleep() {
```

ADAFRUIT.IO

- Sample screenshots of the datalogger information stored in the Adafruit.io IoT cloud server
- Unfortunately, the PH sensor is rather erratic, and the turbidity sensor was damaged by water infiltration.
- Next page has the link to live data

ADAFRUIT.IO LINK TO LIVE DATA

Current datalogging session was started with a full battery charge 4/24/2020 at 9pm.



https://io.adafruit.com/mgenova79/dashboards/damv

MATERIALS FOR DATALOGGER (old vs new)

MATERIALS	
ESP32	$20
Ph sensor	$50
TDS sensor	$12
Turbidity sensor	$5
temp sensor	$2
BME280 ambient sensor	$8
I2C ADC	$15
level shifter	$4
5v regulator	$8
Li-po batteries	$20
Enclosure	$15
misc wire etc	$10
Adafruit.io subscription	$10/month
TOTAL	$169

MATERIALS	
ESP32	$20
Ph sensor	$50
TDS sensor	$12
Turbidity sensor	$5
temp sensor	$2
BME280 ambient sensor	$8
I2C ADC	$15
level shifter	$4
5v regulator	$8
Li-po batteries	$20
Enclosure	$15
Simcom7000A LTE module	$65
misc wire etc	$10
Adafruit.io subscription	$10/month
TOTAL	$234

NAVIGATION

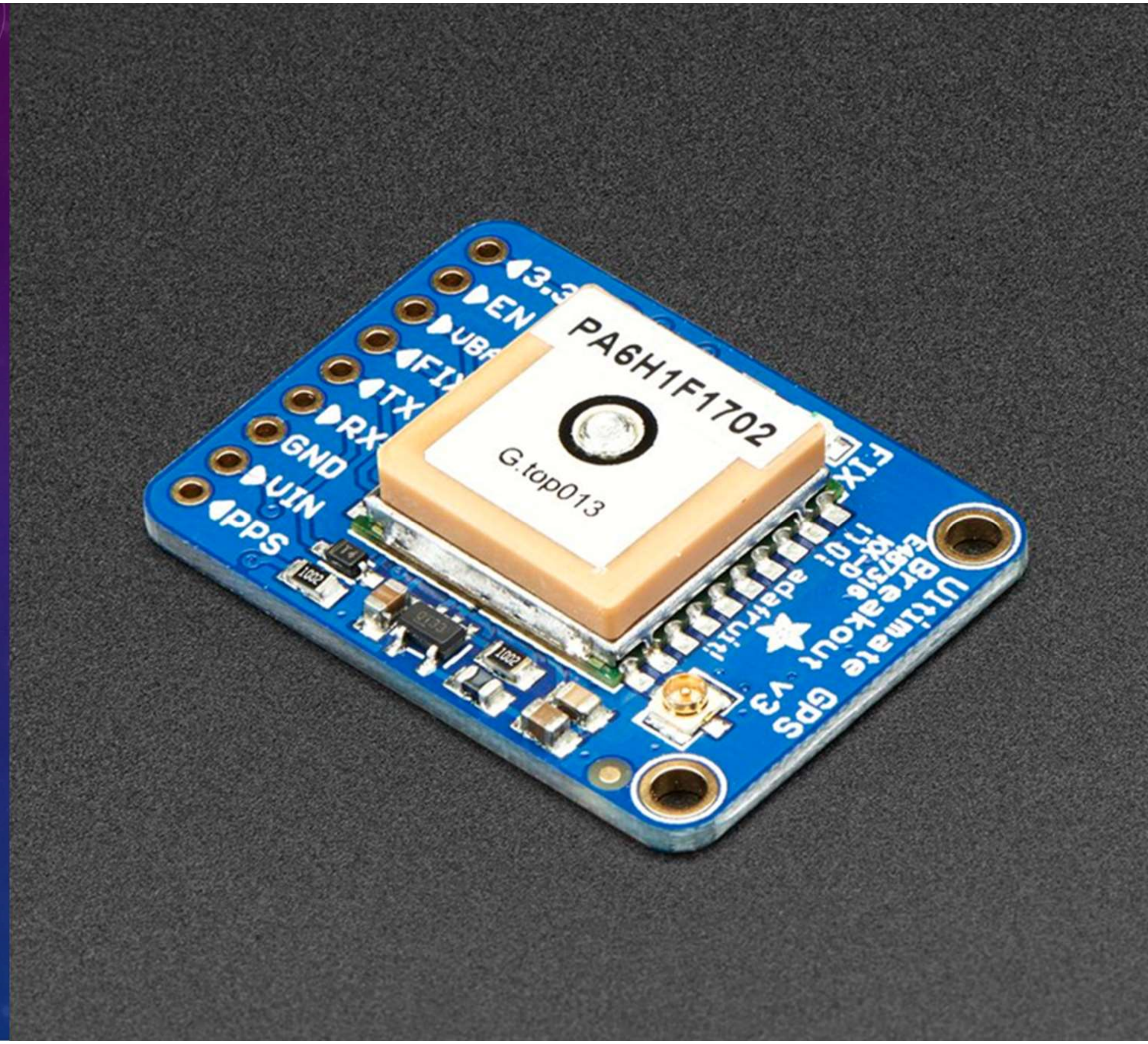
CLINTON MAZONE

PROBLEM

- The vessel must reach target location(s) without active oversite or control by an operator.
- To solve this, we will design a system which will achieve the following:
  1. Take one or multiple sets of target coordinates from the user
  2. Calculate a heading based on current and target location
  3. Use an IMU to monitor the vessel's orientation
  4. Control a rudder and a motor which will steer and propel the vessel in the correct direction

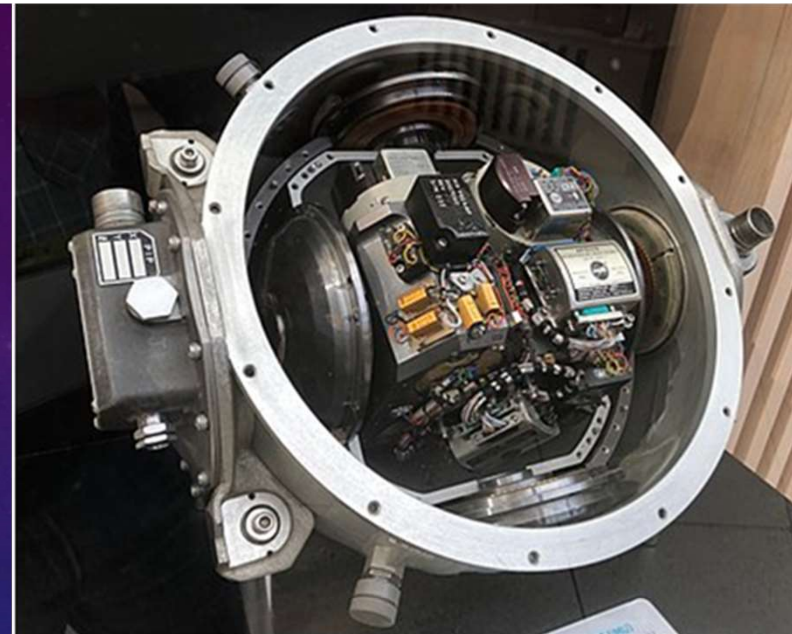
THE GPS MODULE

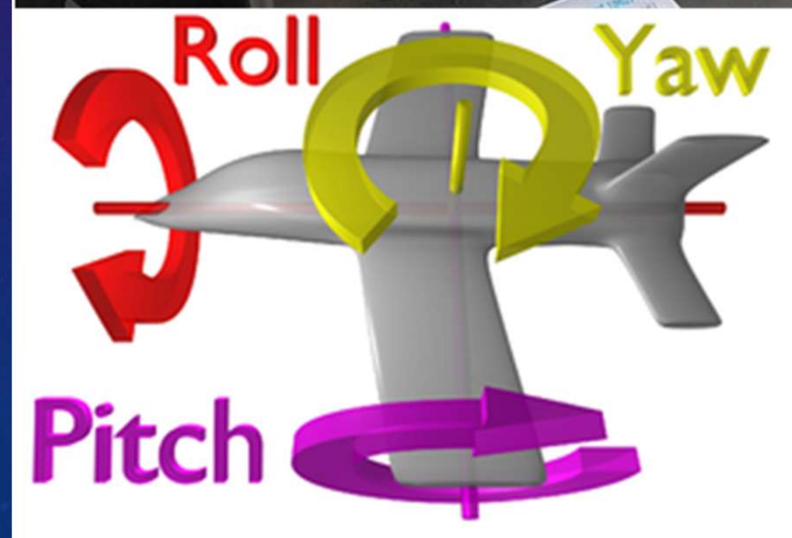
- Communicates with satellites to determine:
    - Location of module in Longitude and Latitude
    - Other useful data which we won’t make much use of in this project.
- Uses serial communication to send data to other devices.



ORIENTATION MODULES

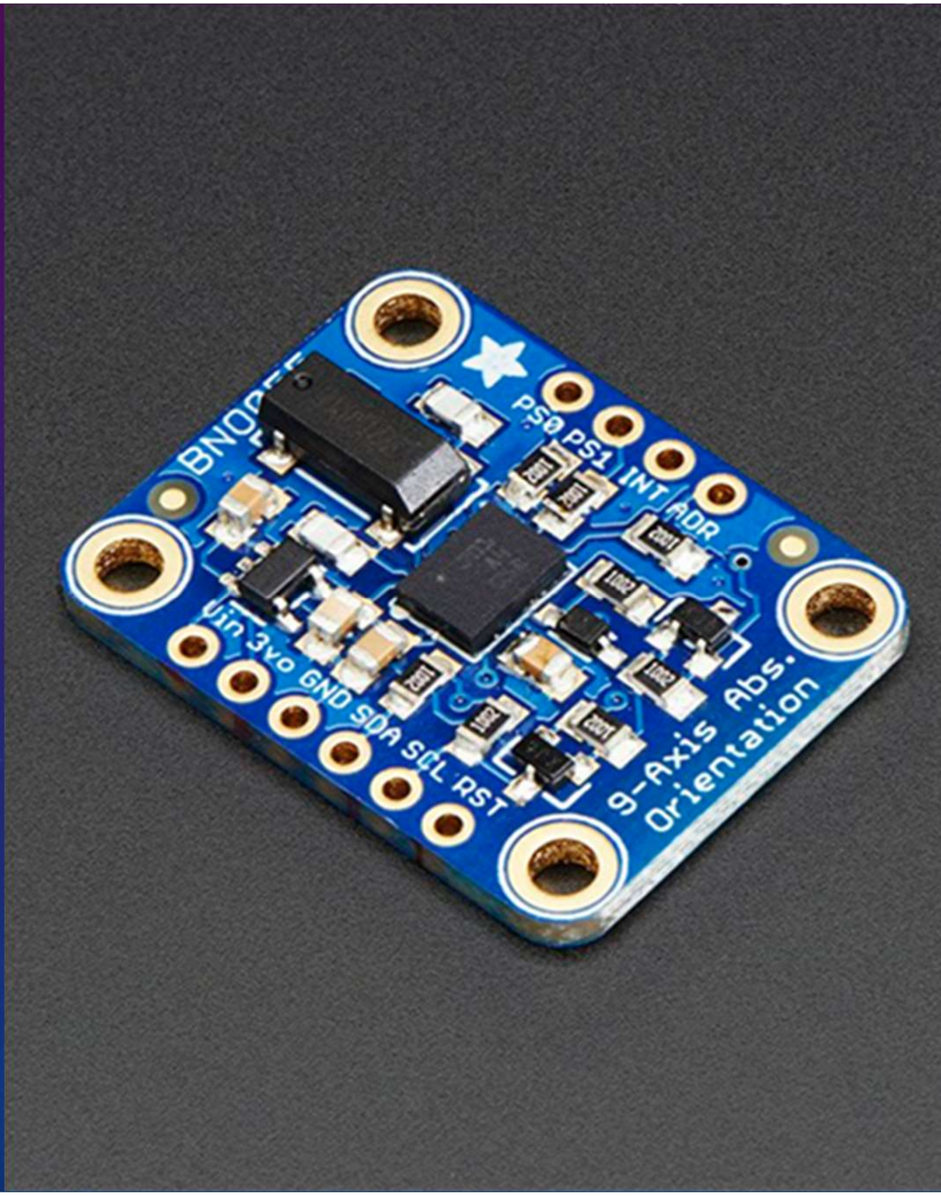
- Used in Aerospace and other applications which require orientation data
- Uses 3 Components:
  - 3-Axis Gyroscope
  - 3-Axis Accelerometer
  - 3-Axis Magnetometer
- Gathered data is processed by a “filter” to give us:
  - Yaw
  - Pitch
  - Roll
- This is essentially a digital compass





THE BNO-055 MODULE

- An orientation module designed by Bosch
- Uses a built-in microcontroller to perform the complicated calculations (i.e. the “filter”)
    - Also frees up the master device (the Arduino) to focus on other tasks
- Communicates via I²C protocol



THE ARDUINO MKR GSM 1400

- Cellular communication module
  - Communicates via the GSM network
  - Easy way to send commands (SMS or internet)
- 48MHz clock speed
- Two serial ports
  - Useful for communicating with the GPS and the PC at the same time
- Built-in LiPo Battery port
- Requires a LiPo battery to provide the high current consumed by the cellular module

COMPUTING TARGET HEADING

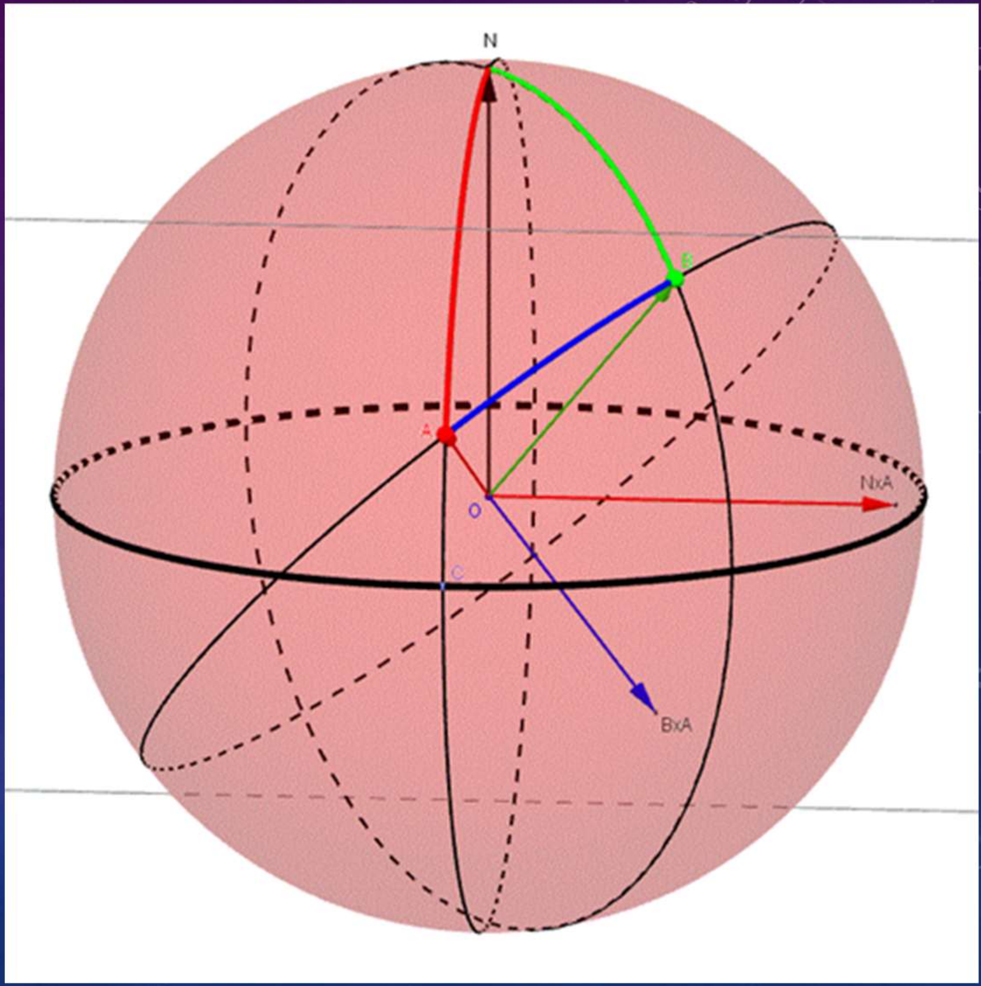
Y = sin(targetLon – currentLon) * cos(targetLat)

X = (cos(currentLat) * sin(targetLat))

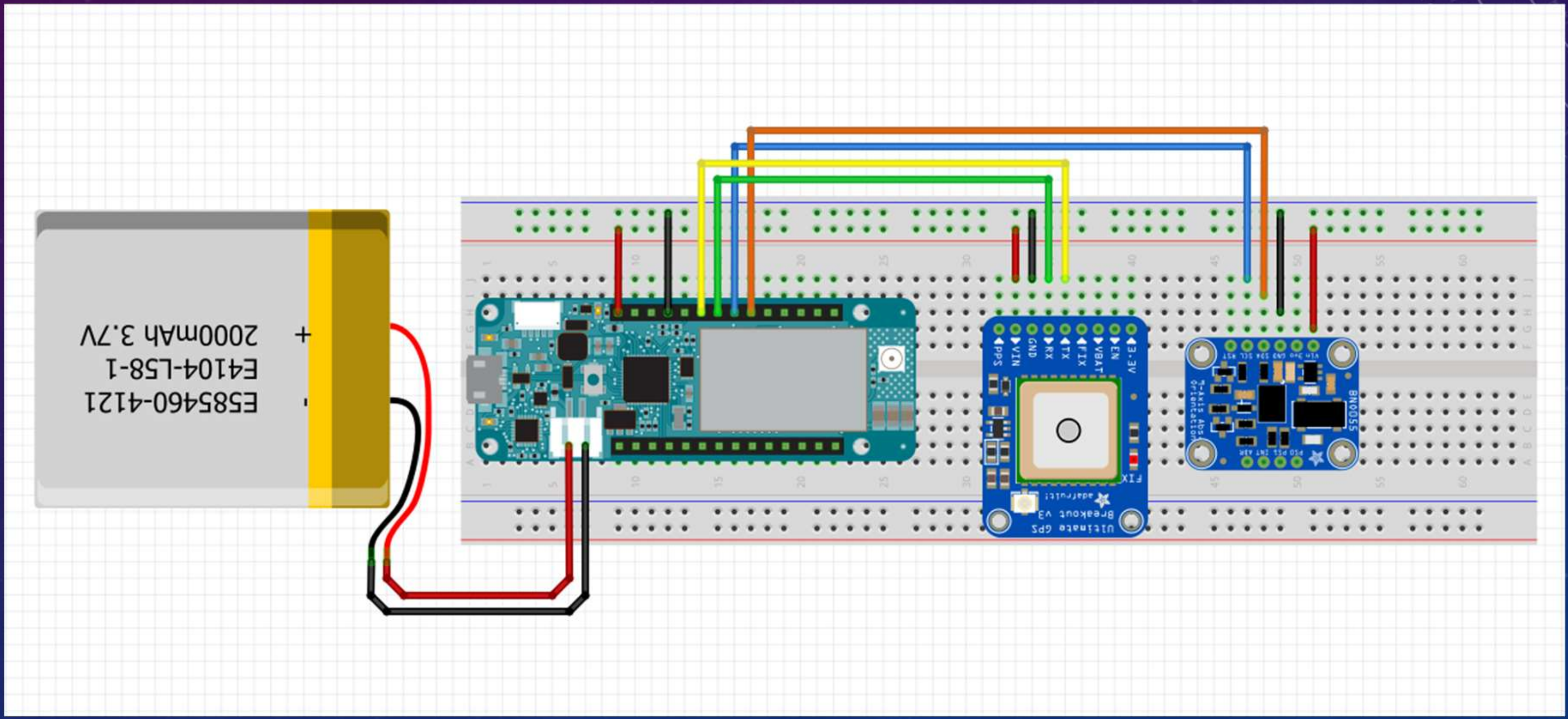
- (sin(currentLat) * cos(targetLat)

* cos(targetLon-currentLon))

targetHeading = atan2(Y , X)



HARDWARE WIRING DIAGRAM

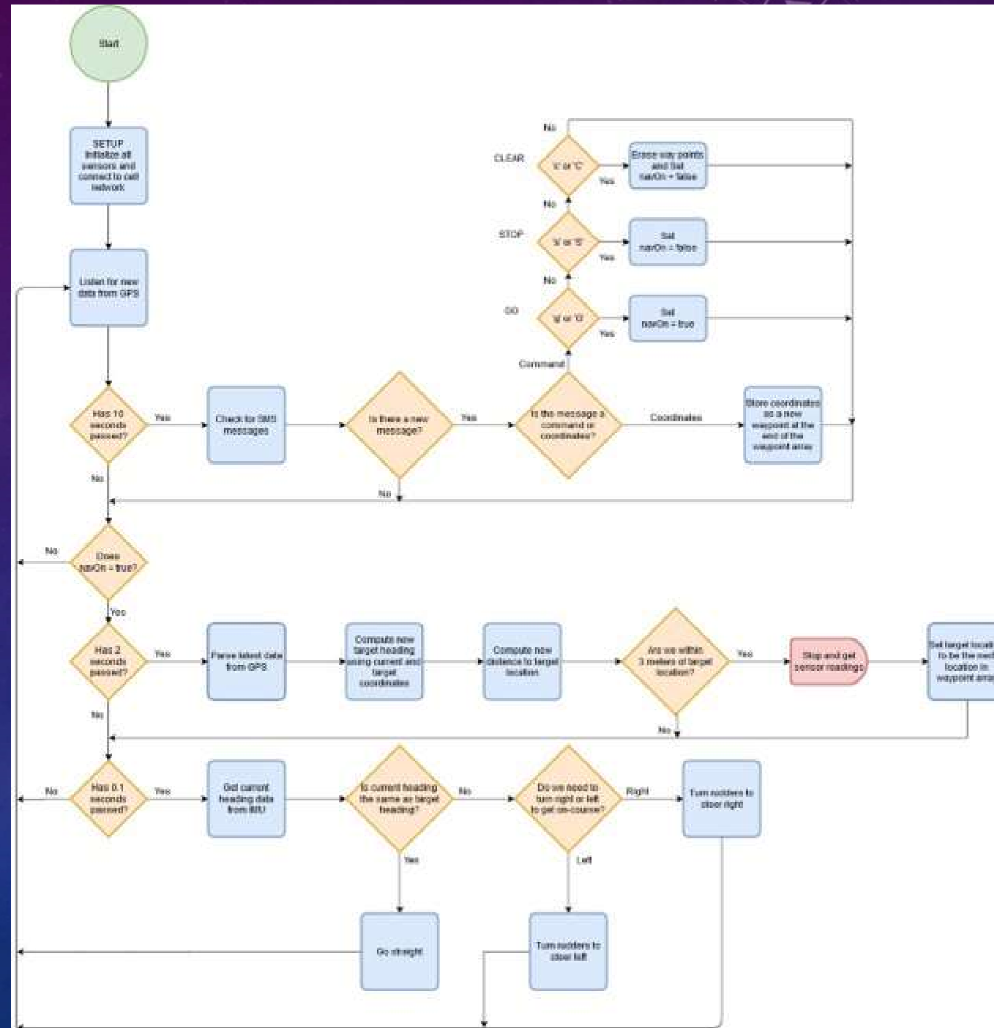


MATERIALS

Component	Price
Arduino MKR GSM 1400 w/antennae	$70
Adafruit Ultimate GPS	$40
Adafruit BNO055 Fusion Breakout	$35
Active GPS Antennae	$15
2500mAh LiPo Battery	$15
Waterproof box	$10
Various connectors and wires	~$30
TOTAL	$215

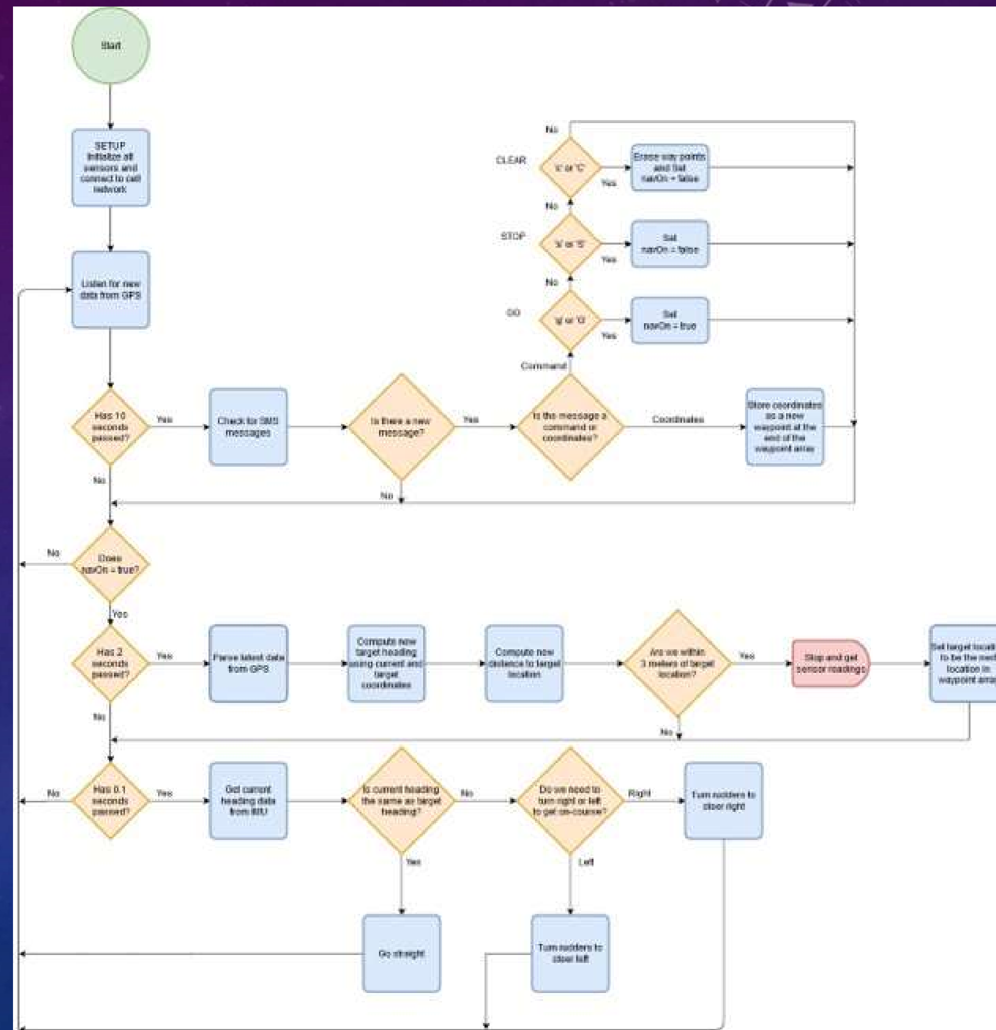
ARDUINO NAVIGATION SOFTWARE FLOWCHART

- Pre-setup:
  - Declare global variables and waypoint array
  - Setup timers
  - Set magnetic declination for region
  - Add radial offset for compass, in case compass is pointing a different direction than the front of the boat.
- Setup:
  - Initialize GPS and IMU
  - Connect to cell network



ARDUINO NAVIGATION SOFTWARE FLOWCHART

- Main loop:
    - Constantly listens for new data from the GPS
    - Other functions are on a timer:
        - Every 10 seconds: Check SMS messages.
        - Every 2 seconds: Recalculate target bearing and distance.
        - Every 0.1 seconds: Check current compass heading and adjust rudder angle and motor speed if needed.



COMPUTING BEARING IN C++

Bearing required to reach target from current location can be given by:

Y = sin(targetLon – currentLon) * cos(targetLat)

X = (cos(currentLat) * sin(targetLat)) - (sin(currentLat) * cos(targetLat) * cos(targetLon-currentLon))

targetHeading = atan2(Y , X)

```
/*************************************************************************/
/*
    Takes the current location and the target location and returns required heading.
*/
/*************************************************************************/
double getRequiredHeading(double targetLat, double targetLon, double currentLat, double currentLon){
    double requiredHeading = 0;
    targetLat *= PI/180;                          // convert from degrees to radians
    targetLon *= PI/180;
    currentLat *= PI/180;
    currentLon *= PI/180;

    double y = sin(targetLon-currentLon)*cos(targetLat);
    double x = cos(currentLat)*sin(targetLat)-sin(currentLat)*cos(targetLat)*cos(targetLon-currentLon);

    requiredHeading = atan2(y,x) * 180/PI;    // compute heading and convert from radians to degrees

    /* We always want bearing to be between 0 and 360 degrees. So, if negative, add 360 degrees */
    if (requiredHeading < 0){
      requiredHeading = requiredHeading + 360;
    }
    return requiredHeading;
}
```

DISTANCE CALCULATION IN C++

Distance from current location to target is given by:

A = sin²((targetLat-currentLat)/2)+cos(currentLat)*cos(targetLat)*sin²((targetLon-currentLon)/2)

Distance = 2*atan2(sqrt(A) , sqrt(1 - A)) * radiusOfEarth

{ radius of the earth = 6,371,000 meters }

```
/**************************************************************************/
/*
    Calculates distance from current location to target location in meters.
*/
/**************************************************************************/
double getDistance(double targetLat, double targetLon, double currentLat, double currentLon){
  targetLat *= PI/180;      // convert from degrees to radians
  targetLon *= PI/180;
  currentLat *= PI/180;
  currentLon *= PI/180;
  double a = (pow(sin((targetLat-currentLat)/2),2) + (cos(currentLat)*cos(targetLat)*pow(sin((targetLon-currentLon)/2),2)));
  double c = 2*atan2(sqrt(a),sqrt(1-a));
  return (6371000 * c);   // radius of earth is 6,371 km
}
```

SMS COMMANDS

- SMS commands allow simple control over the navigation system
- Currently availiable commands:
  - Add waypoint (simply send it any latitude and longitude coordinate)
  - GO ('G' or 'g')
  - STOP ('S' or 's')
  - CLEAR WAYPOINTS ('C' or 'c')

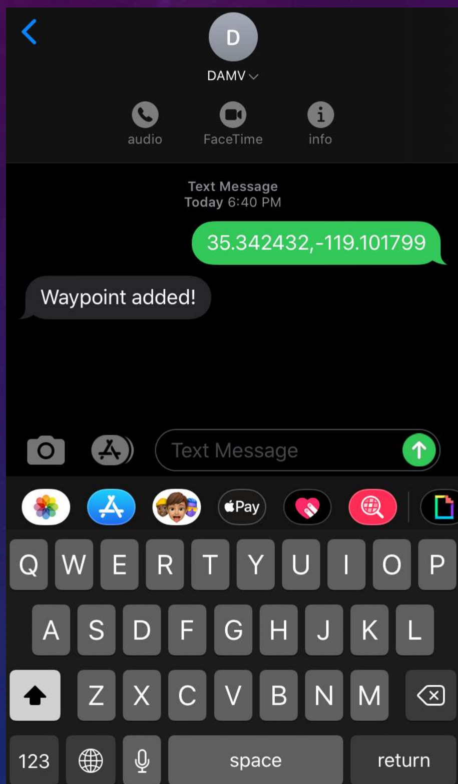
```
/***** checks for text messages every 10 seconds. if there is a text, this will add it to the
      next available spot in the waypoint array. If no availiable spots, it does nothing. *****/
 if (SMStimer > millis()) SMStimer = millis();
 if(millis() - SMStimer > 10000){
   SMStimer = millis();                       // reset SMS timer

   if(sms.available()){
     char senderNumber[20];                   // for storing sender number
     sms.remoteNumber(senderNumber,20);       // store sender number

     switch (sms.peek()){
       case 'G':                              // GO
       case 'g':
         navOn = true;
         sms.beginSMS(senderNumber);
         sms.print("Navigation started!");
         sms.endSMS();
         break;
       case 'S':                              //STOP
       case 's':
         navOn = false;
         sms.beginSMS(senderNumber);
         sms.print("Navigation stopped!");
         sms.endSMS();
         break;
       case 'C':                              // CLEAR WAYPOINTS
       case 'c':
         for(int i=0; i<maxWaypoints ; i++){
           navOn = false;
           waypoints[i][lat] = 0;
           waypoints[i][lon] = 0;
         }
         currentWaypoint = 0;
         lastWaypoint = -1;
         sms.beginSMS(senderNumber);
         sms.print("Waypoints cleared, and navigation stopped!");
         sms.endSMS();
         break;
```

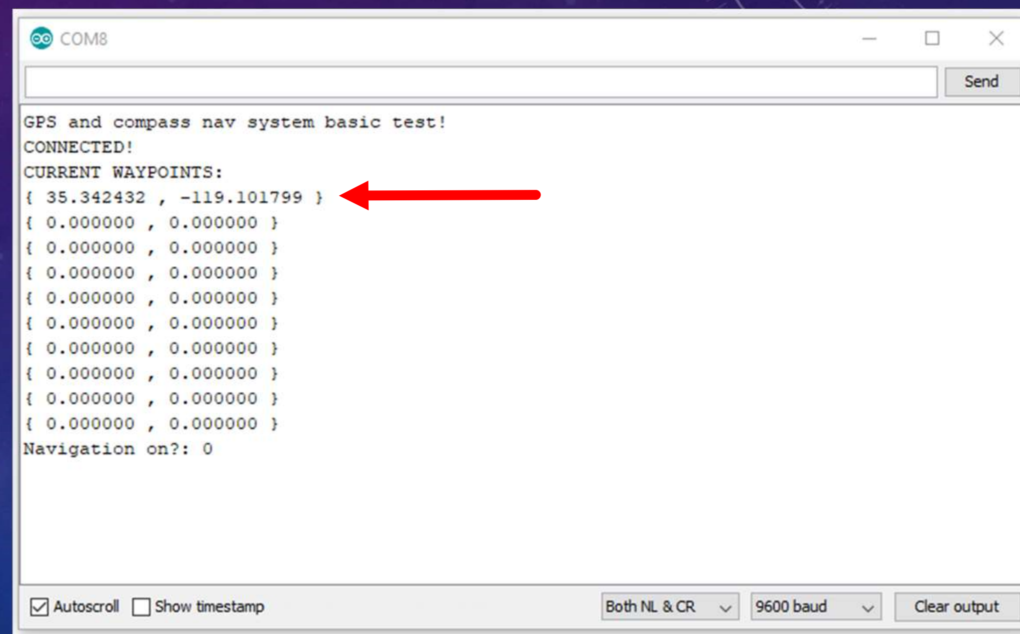
SMS COMMANDS

- SMS commands allow simple control over the navigation system
- Currently availiable commands:
  - Add waypoint (simply send it any latitude and longitude coordinate)
  - GO ('G' or 'g')
  - STOP ('S' or 's')
  - CLEAR WAYPOINTS ('C' or 'c')

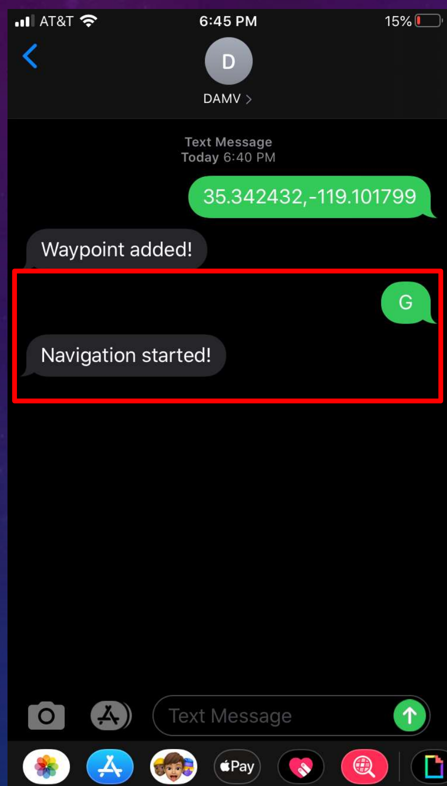
```
  default:                                  // ASSUMES MESSAGE IS COORDINATES: adds content
    if((lastWaypoint+1) < maxWaypoints){    // check if there is enough space in waypoi
      int d;                                // variable for storing incoming sms charact
      bool comma = false;                   // checks if a comma has been reached. Lat a
      int i = 0;                            // for adding latitude to an array
      int j = 0;                            // for adding longitude to an array
      char newLat[20];                      // array to store characters which will make
      char newLon[20];                      // array to store characters which will make
      while((d = sms.read()) != -1){
        if(!comma){
          if((char)d == ','){
            comma = true;
          }
          else{
            newLat[i] = (char)d;
          }
          i++;
        }
        else{
          newLon[j] = (char)d;
          j++;
        }
      }

      lastWaypoint++;
      String latString = String(newLat);
      String lonString = String(newLon);
      waypoints[lastWaypoint][lat] = latString.toDouble();
      waypoints[lastWaypoint][lon] = lonString.toDouble();

      sms.beginSMS(senderNumber);
      sms.print("Waypoint added!");
      sms.endSMS();
    }
    else{
      sms.beginSMS(senderNumber);
      sms.print("No availiable space for additional waypoints.");
      sms.endSMS();
    }
    break; // break out of default case statement. This is probably not needed.
}
sms.flush();
```

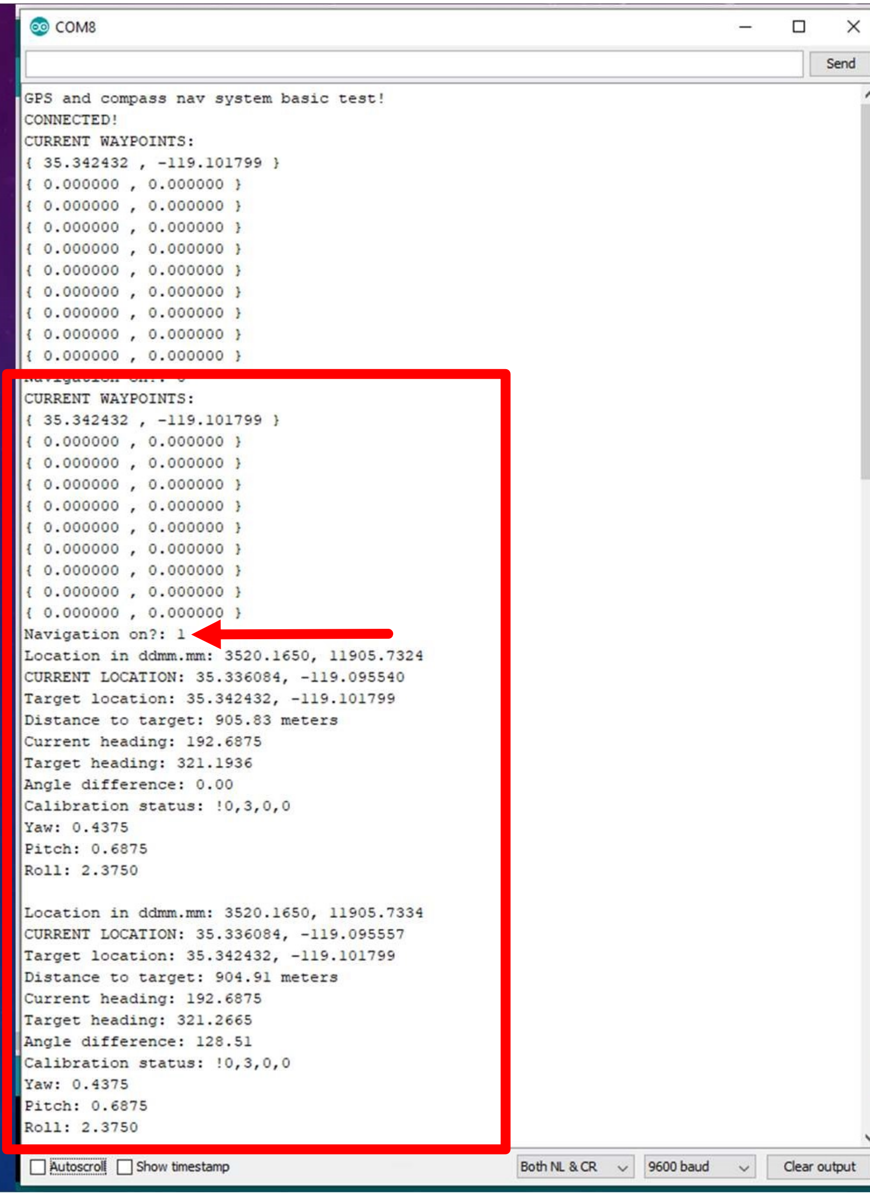
SMS COMMANDS: ADD WAYPOINT



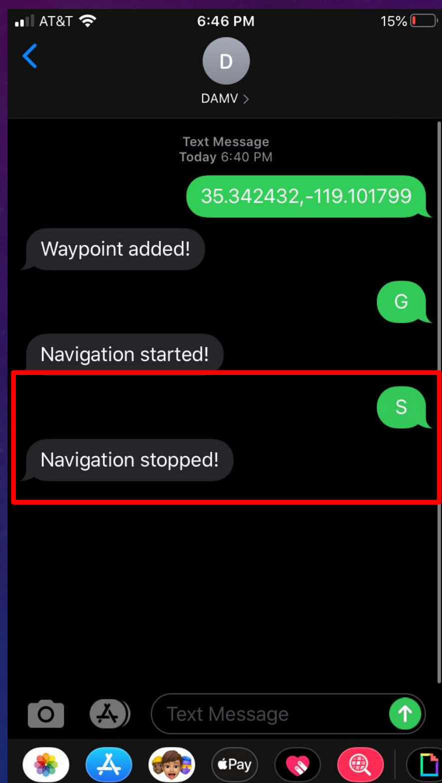


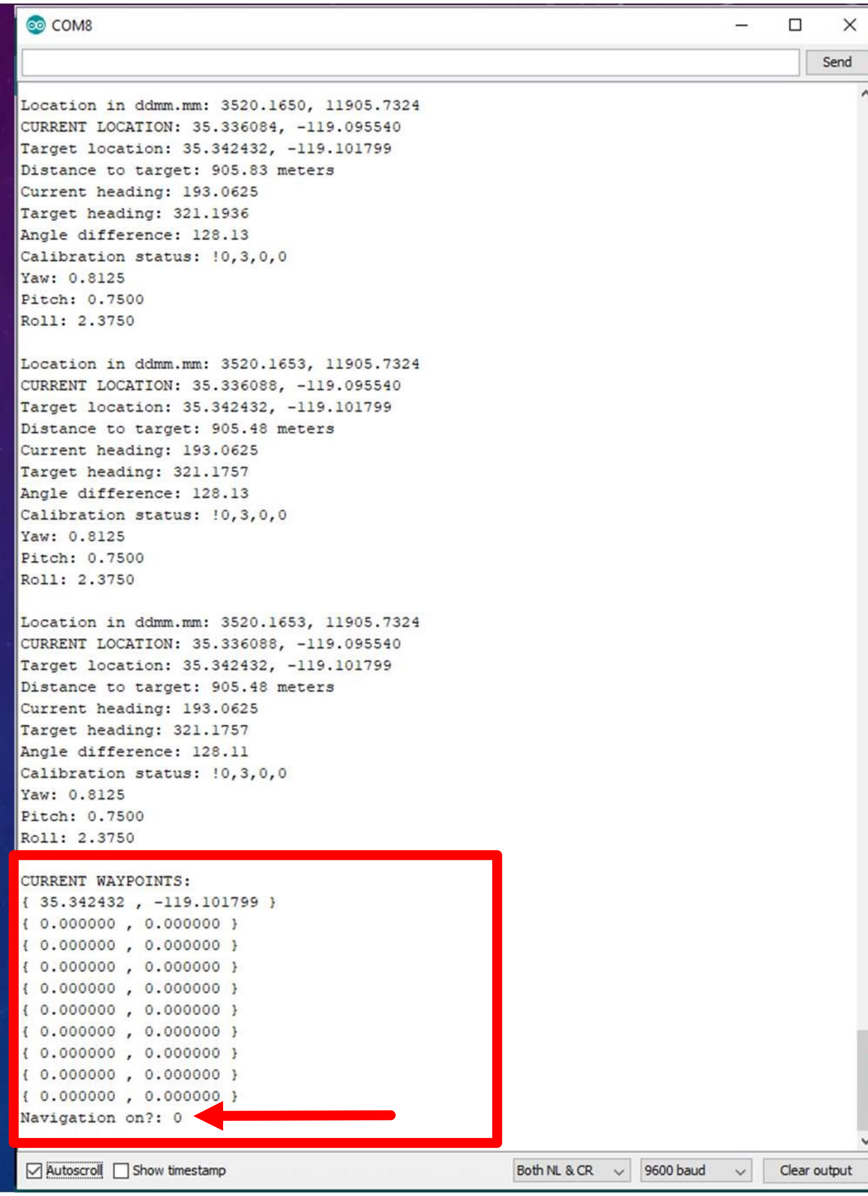
SMS COMMANDS: GO



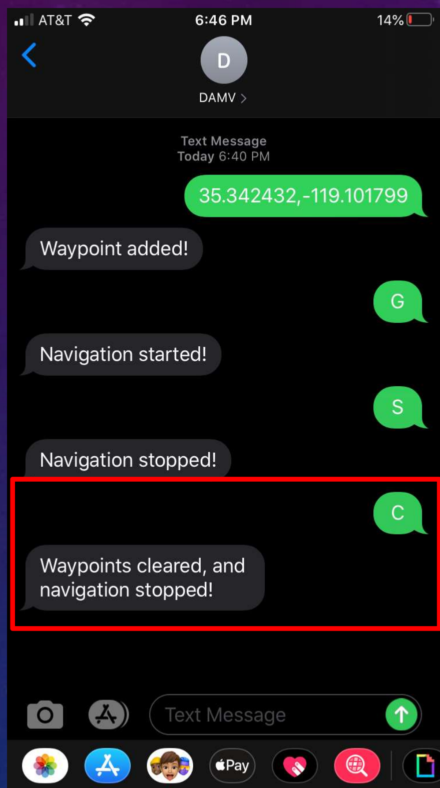


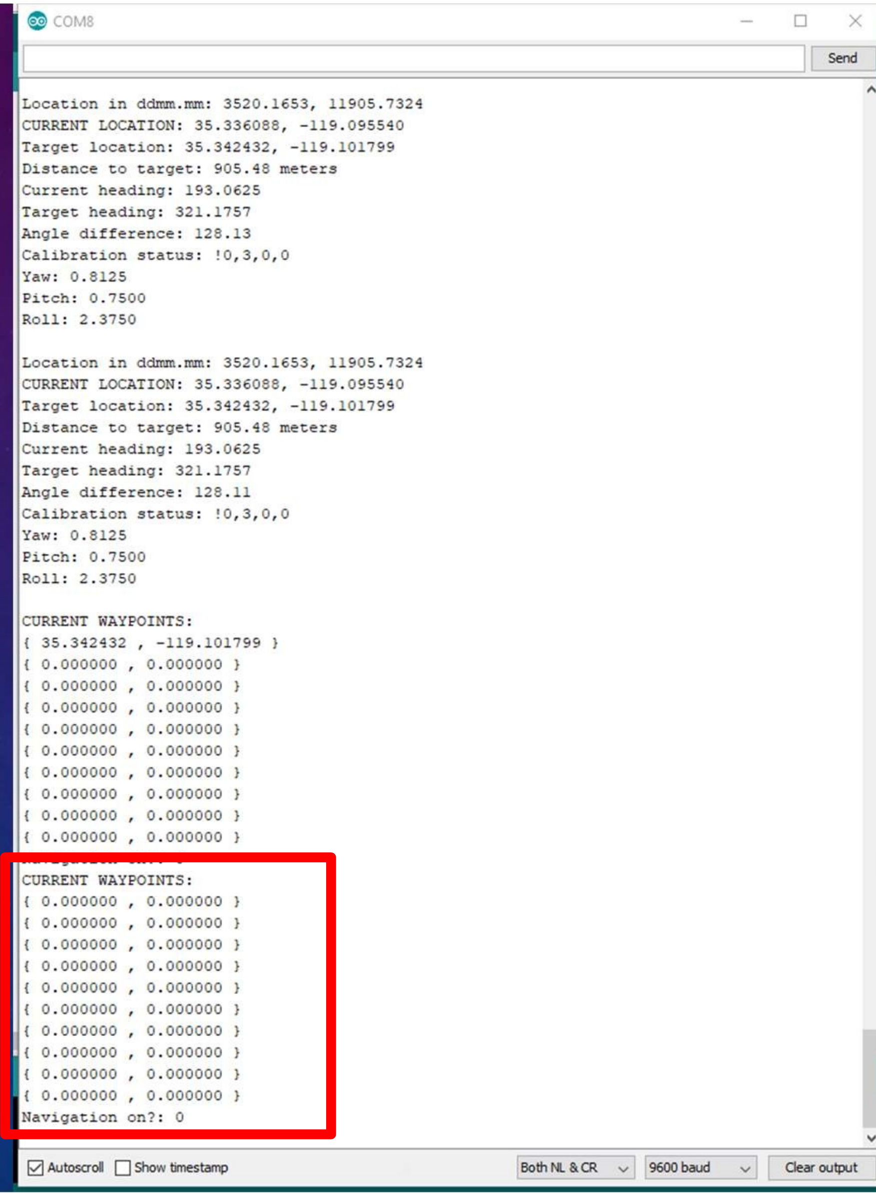
SMS COMMANDS: STOP



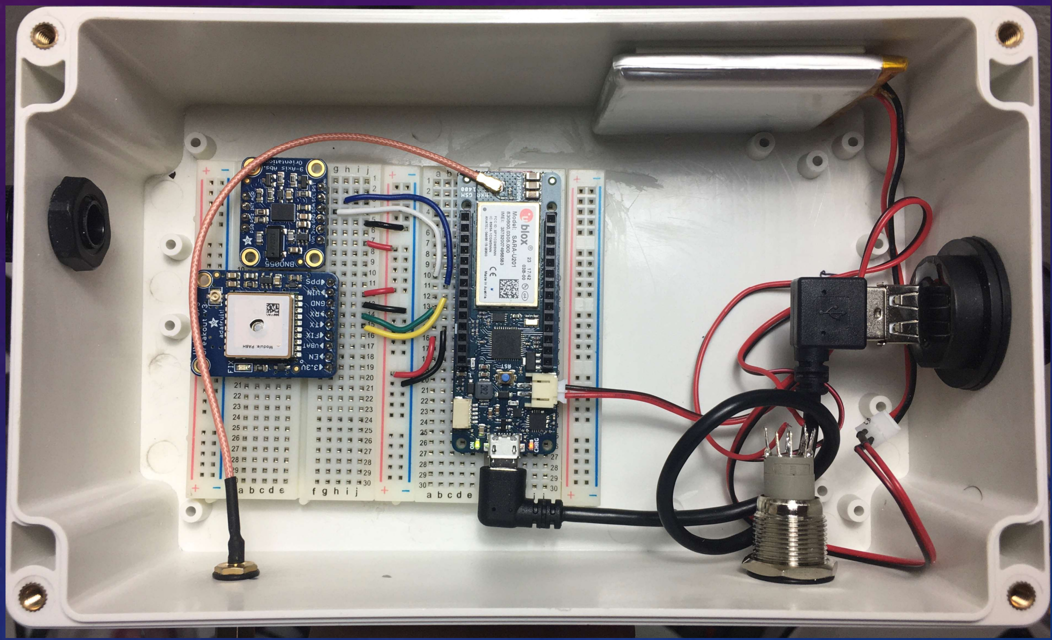


SMS COMMANDS: CLEAR WAYPOINTS



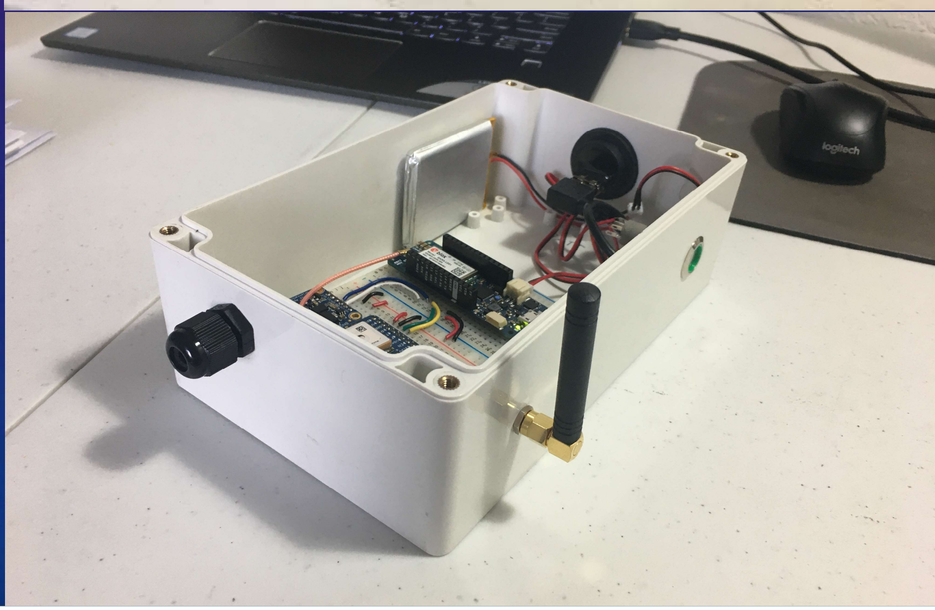


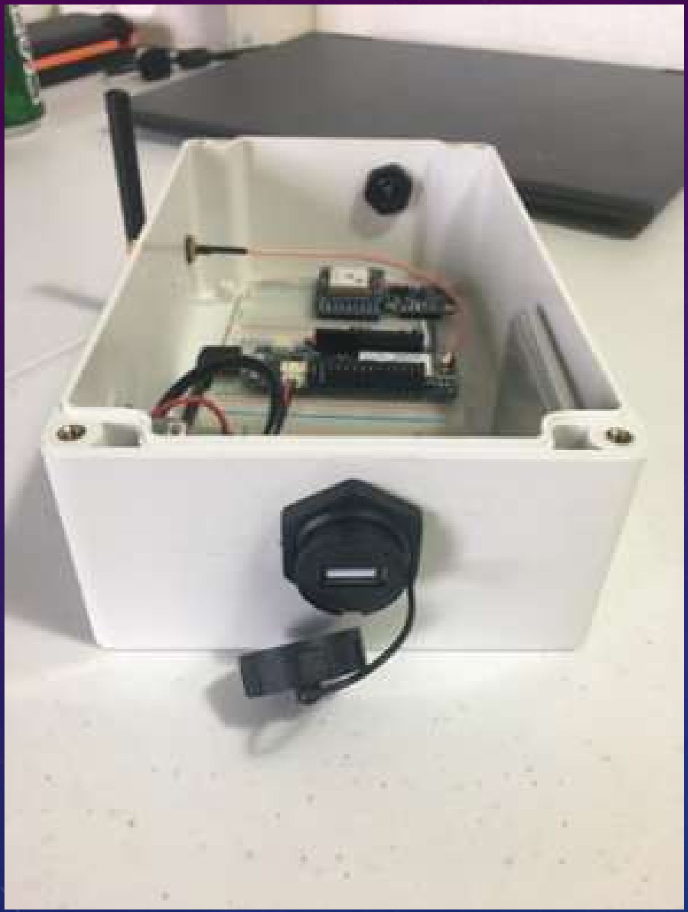
NAVIGATION SYSTEM ENCLOSURE



NAVIGATION ENCLOSURE

- Waterproof on/off switch to disconnect battery
- Waterproof cellular antennae port
- Waterproof USB port for debugging and charging battery
- Cable gland to connect to propulsion box





MARINE VEHICLE PROTOTYPE

GRACE ROMAN

MARINE VEHICLE OVERVIEW

- Original Plan - Submersible Vehicle
  - This was the original plan until we discovered that it is much harder to send radio signals through water than air.
  - Drones are typically not operated by remote control and are completely autonomous, navigating with onboard computers and sensors. This idea was to intricate given our time frame for the project.
  - We did not have enough time for this type of implementation.
- New Plan- Floating Vehicle
  - Easier to build in given time frame.
  - Fastest solution to begin water testing .

MATERIAL FOR MARINE VEHICLE

Component	Qty	Cost/Item
4” PVC Pipe	2	-
5/16 Threaded Rod	2	$2.92
4” 90D Elbow	2	$4.98
36X3” Aluminum Angle Bar	2	$4.79
36X1” Aluminum Angle Bar	2	$5.96
36X1” Flat Aluminum Bar	2	$7.58
Misc	-	$38.50
Total		$90.96

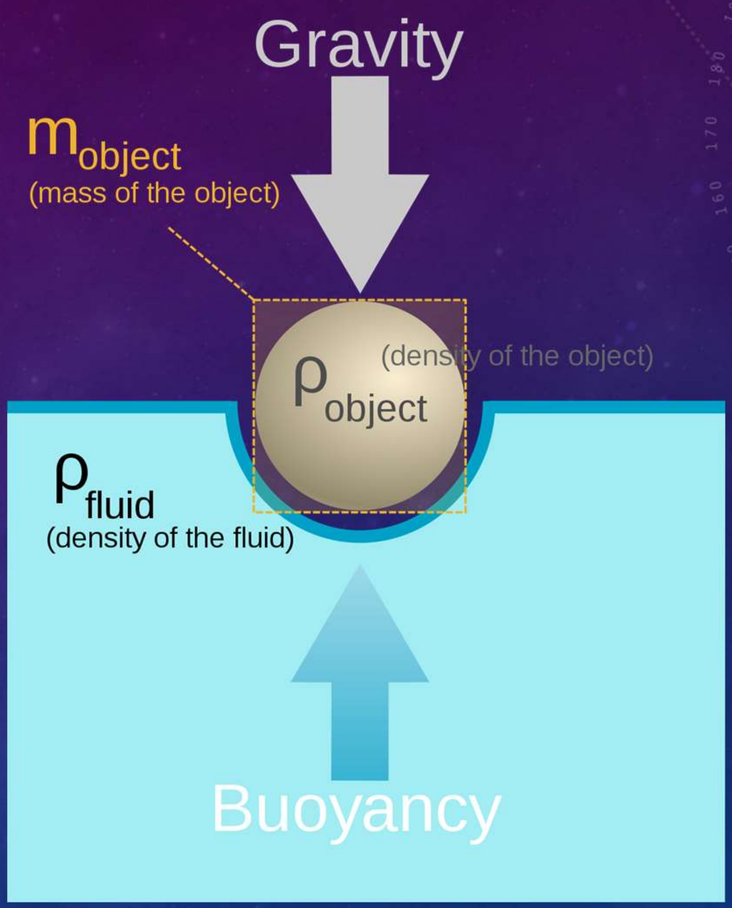
BUOYANT FORCE

$$F_{buoyant} = \rho g V_f$$

$\rho = fluid\ density$

$g = 9.8\frac{m}{s^2}$

$V_f = volume\ of\ displaced\ fluid$



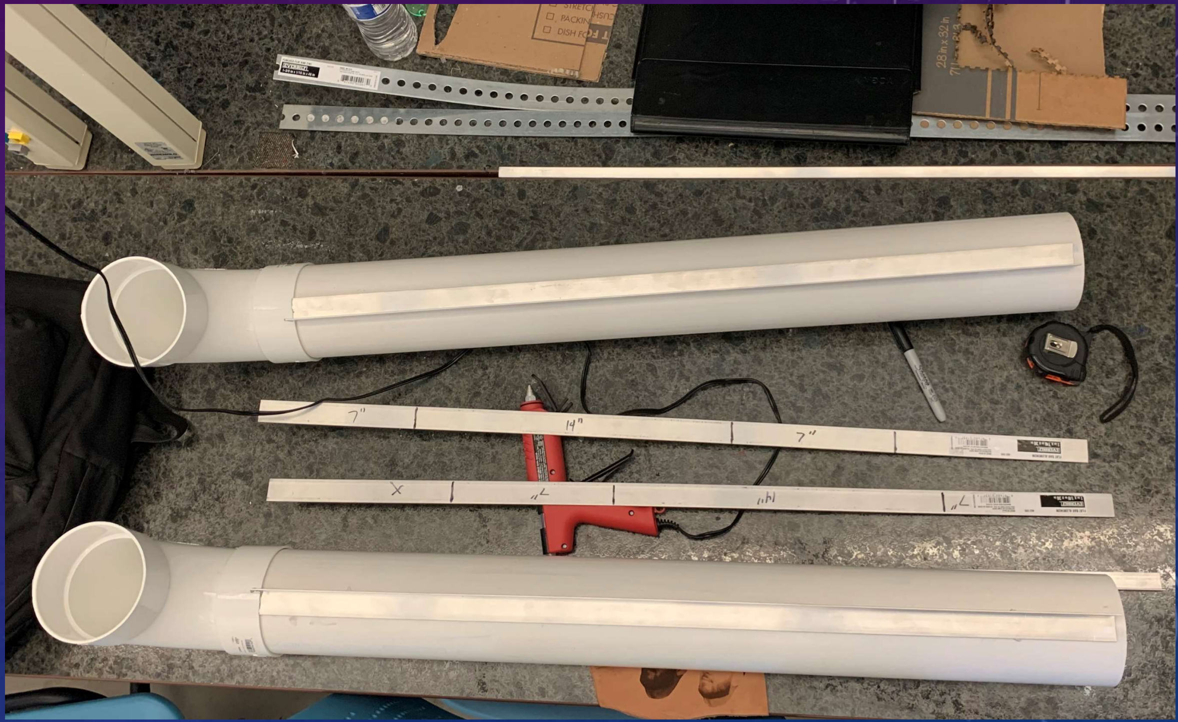
BUOYANT FORCE

- Buoyancy calculations were essential for max load capacity.
- Calculation results: 36” X 4” diameter pipes required for a 20 lbs load.
- Once we had max load parameters this served as a guide for purchasing frame materials and electronic components.

- $F_{buoyant} = \rho g V_f$
- $\rho = fluid\ density$
- $g = 9.8 \frac{m}{s^2}$
- $V_f = volume\ of displaced\ fluid$

MARINE VEHICLE ASSEMBLY

- 4” X 36” PVC Pipe
- Flat Aluminum bars for frame
- Aluminum angle bars for mounting frame to PVC pipes.

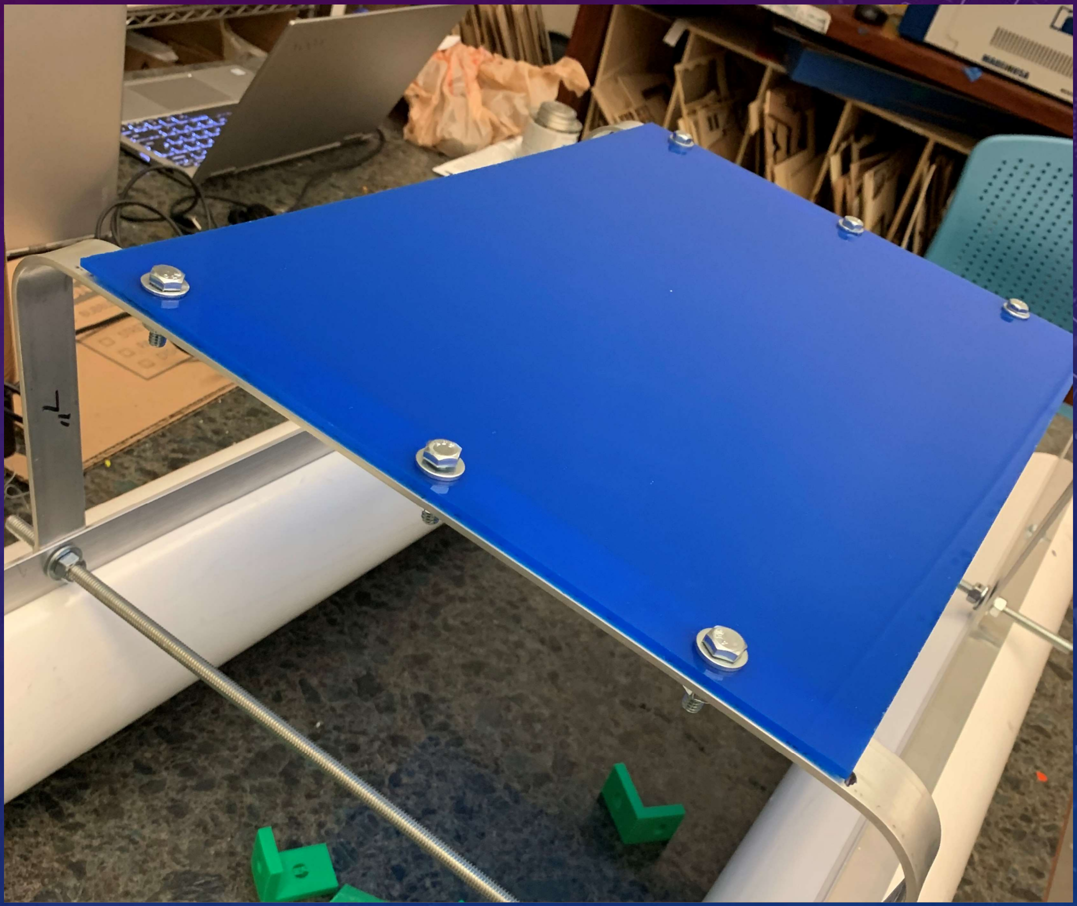


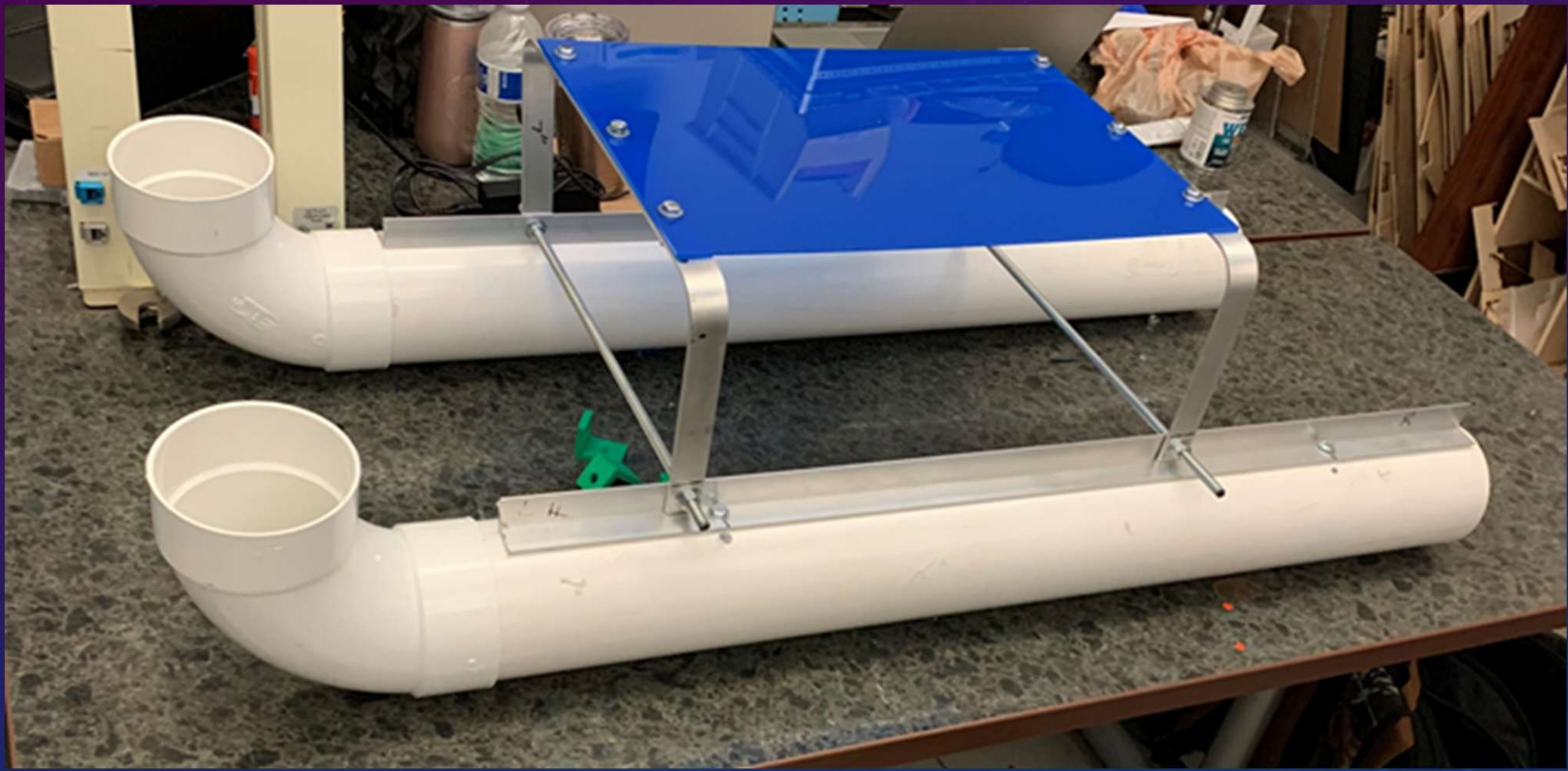
MARINE VEHICLE ASSEMBLY

- 1” X 28” Aluminum bars for frame.
- 5/16 Threaded rod for frame stability and mount for motor.

MARINE VEHICLE ASSEMBLY

- Acrylic sheet for mounting all electronic components.
- Laser cut mounting guides for bolts.

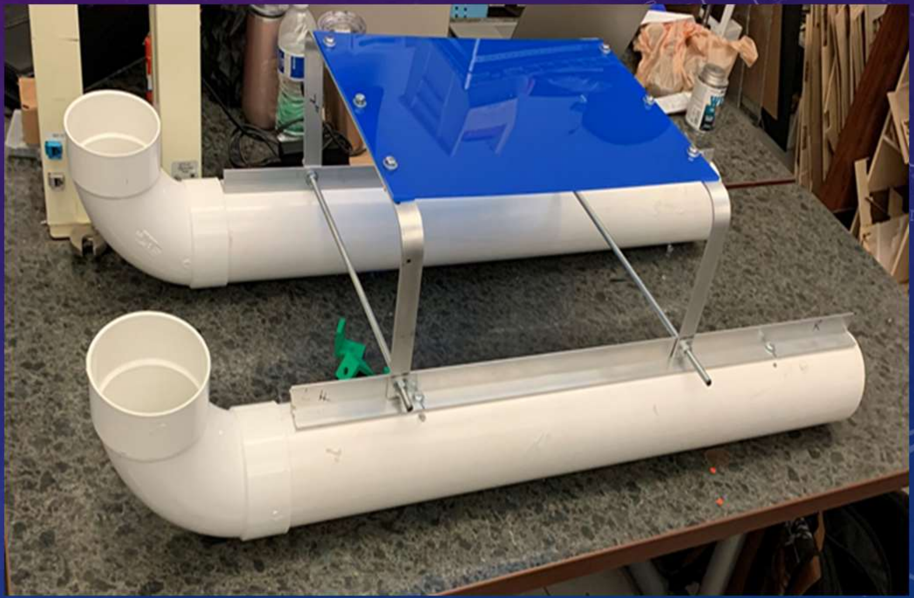




FIRST PRESENTATION RESULTS

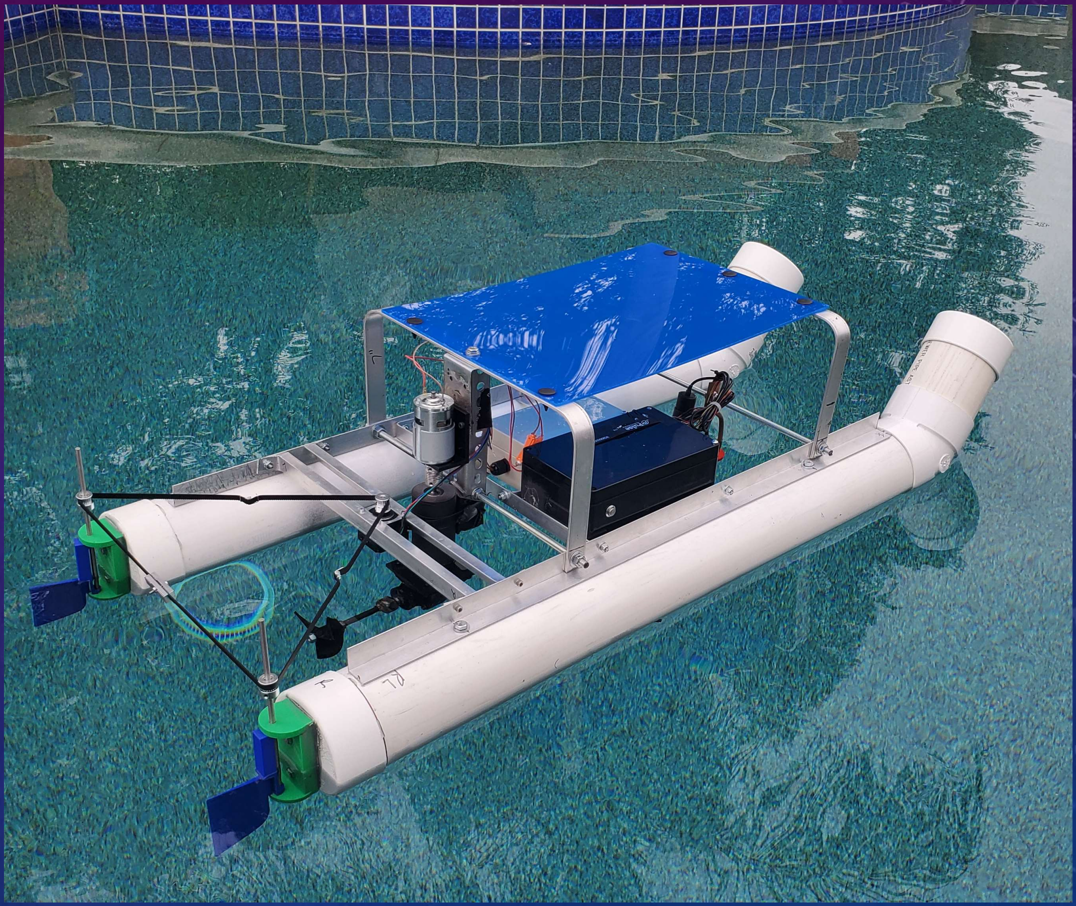
Future Updates

- Add 3D printed end caps and rudders.
- Switch from 90-degree elbows to 45-degree.
- Test on water



UPDATED MARINE VEHICLE

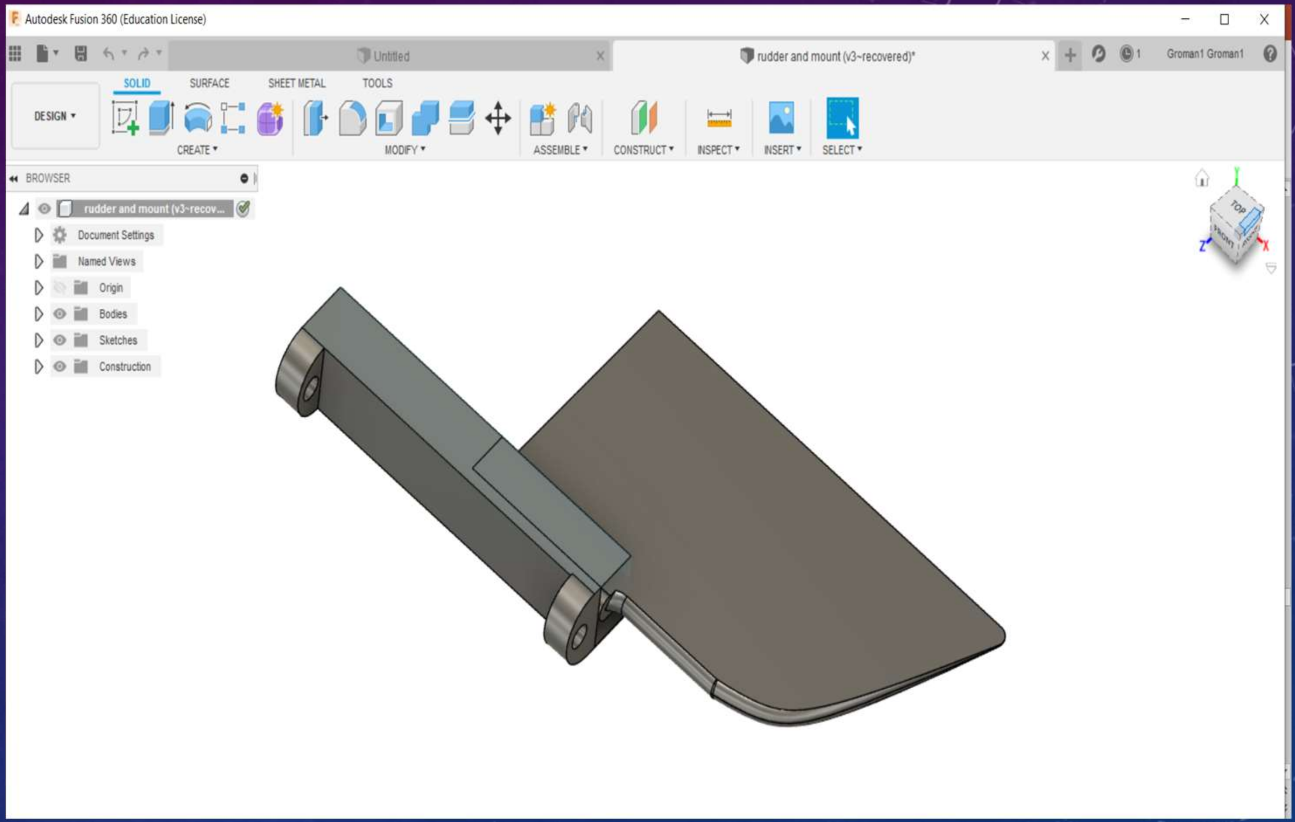
- Vehicle is now assembled for testing.
- Minor modifications are still required:
  - Such as rudders. Rudder length needs to be increased. Once rudders have appropriate dimension modification prototypes will be 3D printed using PLA plastic.



RUDDERS

RUDDERS

- Rudders were designed using Autodesk Fusion 360.
- The rudders are attached to a block that can fit a 5mm shaft that will be used for steering in conjunction with the navigation system.

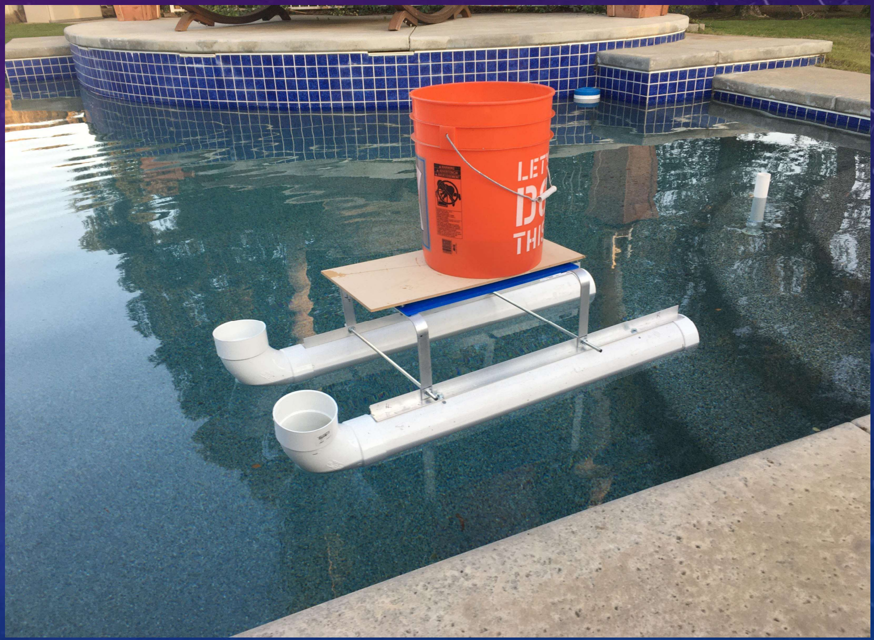


UPDATED MARINE VEHICLE

Max Weight Capacity= 20lbs

UPDATED MARINE VEHICLE

- Marine Vehicle carrying 20lbs.
- Here we can see the marine vehicle is able to carry 20lbs load effortlessly.
- The water level reaches the half-way point of the PVC pipes as predicted by buoyancy calculations.



MARINE VEHICLE IN ACTION

Future updates are:

- the modification of rudders is required.
- Waterproofing marine vehicle.
- Testing in non-ideal conditions.

PROPULSION & STEERING

DANTON WYATT

PROPULSION

- Motor
  - Motor was completed
  - Made of electric motor and gearbox from old angle grinder
  - 3D printed propeller

MAKING OUR MOTOR

- Disassembled this angle grinder

MAKING OUR MOTOR

- Removed windings, weights, fan, and insulation

MAKING OUR MOTOR

- Removed windings, weights, fan, and insulation

MAKING OUR MOTOR

- Machined an additional 5mm shaft for attaching to motor coupling

MAKING OUR MOTOR

- Attached 3D printed fittings and covered drive shaft with pvc pipe

MAKING OUR MOTOR

- Brazed threaded rod onto nut to attach propeller to gearbox

MAKING OUR MOTOR

- Assembled with electric motor and attached to vehicle

CONTROLLING OUR MOTOR

- Will use data from navigation module to determine when to run motor
- Need to pulse width modulate
  - Will reduce current needed and extend battery life
  - Must use a motor driver

CONTROLLING OUR MOTOR

Motor Driver

- Looked into using L298N and DRV8871 motor drivers
    - Have around a 2V voltage drop
    - Motor would not start until around 60-70% duty cycle for PWM
    - Neither gave the performance we desired

CONTROLLING OUR MOTOR

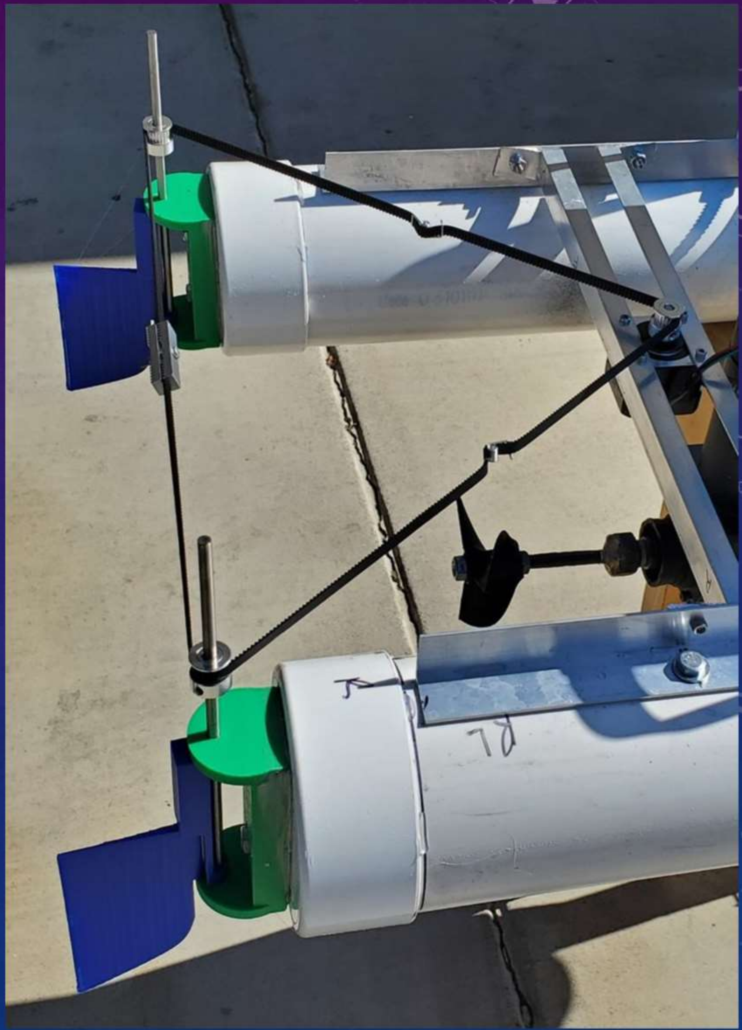
Motor Driver

- Decided to use VNH5019 motor driver
  - Has a negligible voltage drop
  - Motor will start even at duty cycles of 10% with PWM
  - Will allow us to conserve more power from batteries
  - Testing indicates that a 20% duty cycle will sufficiently move our craft

STEERING

Dual Rudder System

- Uses two 3D printed rudders (one on each pontoon)
- Controlled by a single stepper motor and belt system
- Uses an A4988 StepStick driver to control stepper motor



STEERING

Considerations

- Rudders begin to lose steering efficiency around 35°
  - Need to limit travel of rudders
- Stepper motors have no default home position
  - Need to keep track of position of rudders

STEERING

```
int rudderPos = 0; //Global variable to track position of the rudders.  Should remain in the range of -35 to 35.
```

```
if(degTurn < -35){ //Check to see if a turn more than 35 degrees to the left is required
  digitalWrite(dirPin, LEFT);  //Set the direction of the stepper motor to turn rudders to the left
  for(rudderPos; rudderPos > degTurn; rudderPos--){ //Turn rudders to the left until they reach max number of steps (35)
    if(rudderPos == -35) break; //If the rudder is at the max turn break out of the loop
    else{ //If rudder is not at max turn step with stepper motor
      digitalWrite(stepPin, HIGH);
      delay(1);
      digitalWrite(stepPin, LOW);
      delay(1);
    }
  } //rudderPos will be decremented after each iteration of loop
}

if(rudderPos < degTurn){  //Check to see if the rudder needs to start returning to position 0
  digitalWrite(dirPin, RIGHT); //Change direction of stepper motor to step back toward position 0
  for(rudderPos; rudderPos < degTurn; rudderPos++){  //Step back toward postion 0 if required turn is between -35 and 0 degrees
    if(rudderPos == 35) break; //Break out of loop if the rudder is at max turn position
    else{ //Step once with stepper motor
      digitalWrite(stepPin, HIGH);
      delay(1);
      digitalWrite(stepPin, LOW);
      delay(1);
    }
  } //rudderPos will be incremented after each iteration of loop
}
```

Relevant code to turn left

- RudderPos variable will serve as an index for the position of the stepper motor
- Rudders will automatically adjust when the vehicle is turning toward its target heading

STEERING

Relevant code to turn right

- RudderPos variable will serve as an index for the position of the stepper motor
- Rudders will automatically adjust when the vehicle is turning toward its target heading

```
if(degTurn > 35){ //Check to see if a turn more than 35 degrees to the right is required
  digitalWrite(dirPin, RIGHT); //Set direction of stepper motor to turn rudders to the right
  for(rudderPos; rudderPos < degTurn; rudderPos++){ //Turn rudders to the left until they reach max number of steps (35)
    if(rudderPos == 35) break; //If the rudder is at max turn break out of the loop
    else{ //If rudder is not at max turn then take a step with stepper motor
      digitalWrite(stepPin, HIGH);
      delay(1);
      digitalWrite(stepPin, LOW);
      delay(1);
    }
  } //rudderPos will be incremented after each iteration of loop
}

if(rudderPos > degTurn){ //Check to see if the rudder needs to start returning to position 0
  digitalWrite(dirPin, LEFT); //Change direction of stepper motor to turn rudders back toward position 0
  for(rudderPos; rudderPos > degTurn; rudderPos--){ //Step back toward position 0 if required turn is between 0 and 35 degrees
    if(rudderPos == -35) break; //break out of the loop if the rudder is at max turn
    else{ //If rudder is not at max turn the take a step
      digitalWrite(stepPin, HIGH);
      delay(1);
      digitalWrite(stepPin, LOW);
      delay(1);
    }
  } //rudderPos will be decremented after each iteration of loop
}
```

STEERING

Future tasks

- Rudders need a way to calibrate and set home position when starting the vehicle
    - Mechanical switches
    - Optical sensors
    - Hall effect sensors

COMBINING HARDWARE AND NAVIGATION SOFTWARE

PROCESS OVERVIEW

- Take GPS and compass data
- Determine the required correction to reach destination
- Turn on motor and set speed
- Adjust stepper motor to control rudders to steer
- Turn off motor when destination is reached

CONTROLLING MOTOR AND SPEED

- Motor will turn on when a GPS waypoint is received
- Will run at full speed until 10m away
- Will run at half speed until 3m away
- Will stop when within 3m of GPS coordinate and then take readings

```
if( distanceToTarget > 10 ){
  motorSpeed = fullSpeed;
} else{
  motorSpeed = halfSpeed;
}
if( distanceToTarget < 3 ){
  // Stop motor and get sensor readings
  motorSpeed = 0;
  analogWrite(motorControlPin, motorSpeed);
```

ISSUES FROM INITIAL TESTING

- Stepper motor would "bounce" back and forth when not adjusting rudders
- Rudders would easily turn one way but not the other

FIXING THE ISSUES

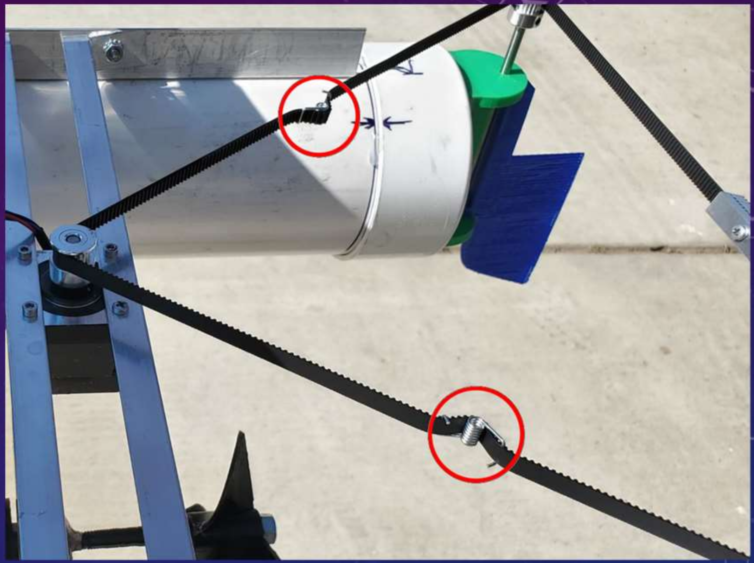
STEPPER MOTOR BOUNCE

- Assumed issue was software related
- Bouncing when on course trying to make minor corrections
- Solution was to create a 2° dead zone around target heading
- Stepper motor would be put into sleep mode when within 2° of target heading
- This prevent stepper motor from rapidly stepping back and forth

FIXING THE ISSUES

ASYMMETRIC RUDDER TURNING

- Assumed issue was software related
- Debugging showed software was functioning as intended
- Issue was related to the belt tensioners on the steering system
- Removed one tensioner and changed its position
- Ended up simplifying steering code as well



STEERING CODE CHANGE

BEFORE

- Stepper motor would make small adjustments if course correction was small

```
if(rudderPosition < correction){
  digitalWrite(stepDirection, LOW);
  for(rudderPosition; rudderPosition < correction; rudderPosition++){
    if(rudderPosition >= 35) break;
    else{
      digitalWrite(stepEnable, HIGH);
    }
    getCorrection(targetHeading, currentHeading);
  }
}
```

AFTER

- Stepper motor turns rudders to a set position regardless of size of course correction

```
if( angleDifference > 0 ){
  newRudderPosition = 15; // right
}
/* Go left */
else{
  newRudderPosition = -15; // left
}
```

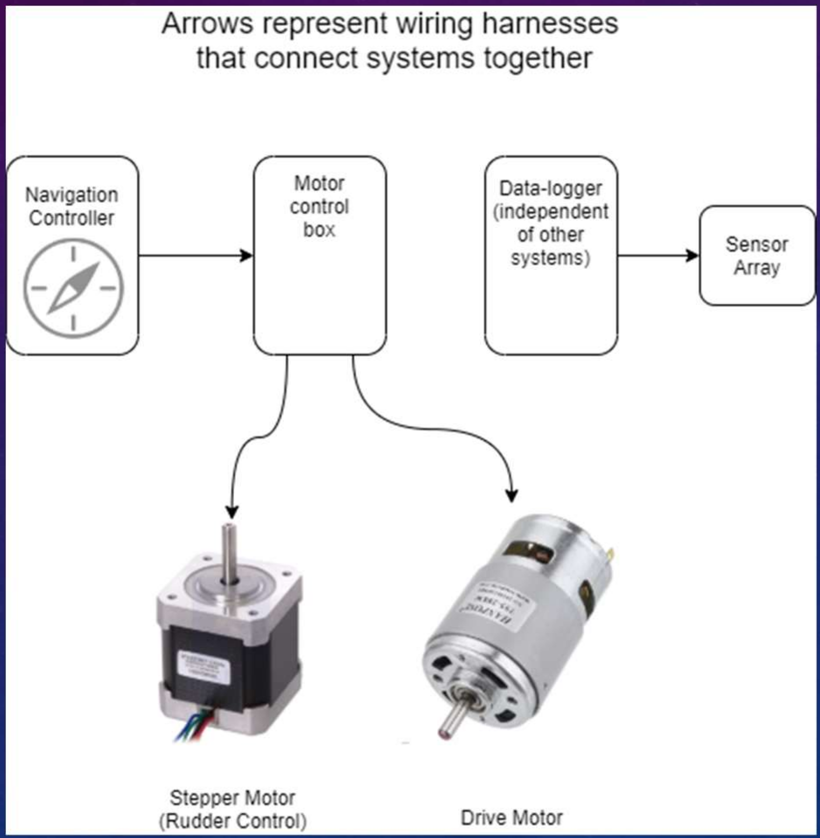
```
if(rudderPosition < newRudderPosition){
  incrementDirection = 1;
  digitalWrite(stepDirectionPin,LOW);
}
else{
  incrementDirection = -1;
  digitalWrite(stepDirectionPin,HIGH);
}
```

```
for( rudderPosition; (rudderPosition != newRudderPosition); rudderPosition += incrementDirection){
  digitalWrite(stepEnablePin, HIGH);
  delay(stepDelay);
  digitalWrite(stepEnablePin, LOW);
  delay(stepDelay);
```

CONNECTING EVERYTHING TOGETHER

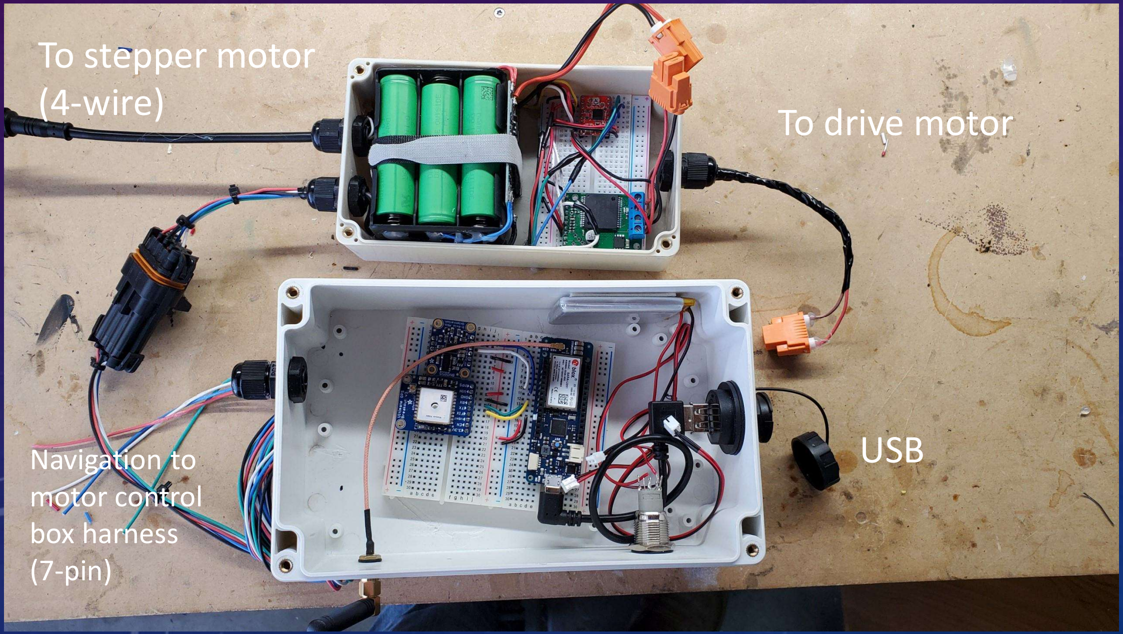
FINALIZING PROTOTYPE FOR TESTING

CONNECTING EVERYTHING TOGETHER



Delphi Metri-Pack Connectors

- Our design is modular, so connections between control boxes are necessary.
- To simplify disassembly we used waterproof connectors such as the Delphi Metri-Pack 150, and other various connectors from Adafruit and home depot.
- The Delphi connectors are automotive grade and must be crimped and assembled by hand.

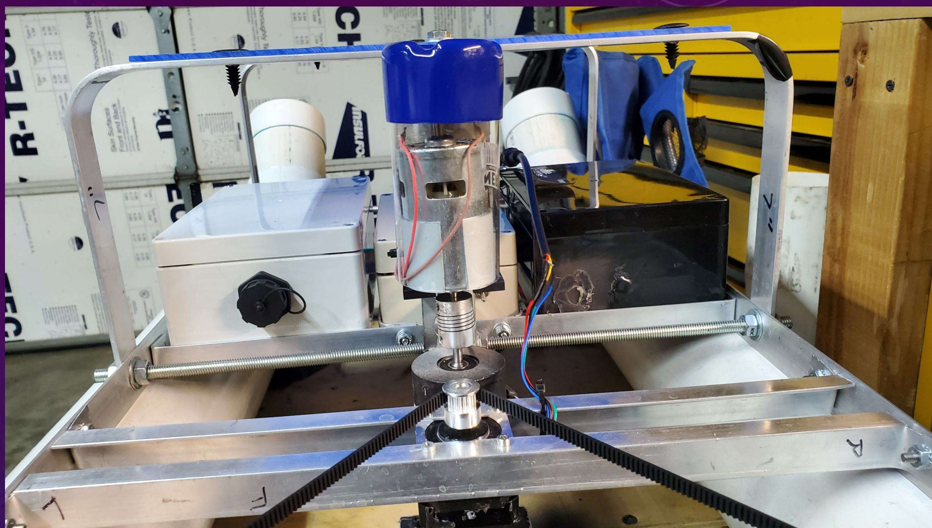


STEPPER AND DRIVE MOTOR CONNECTORS


Adafruit weatherproof 4 wire connector

- Ideal brand power plug connectors were used between the motor and the motor control box. They can handle high current and are well insulated
- The stepper motor requires 4 wires. The Adafruit weatherproof 4 wire connector was used to connect the stepper motor to the motor control box

MOUNTING CONTROL BOXES



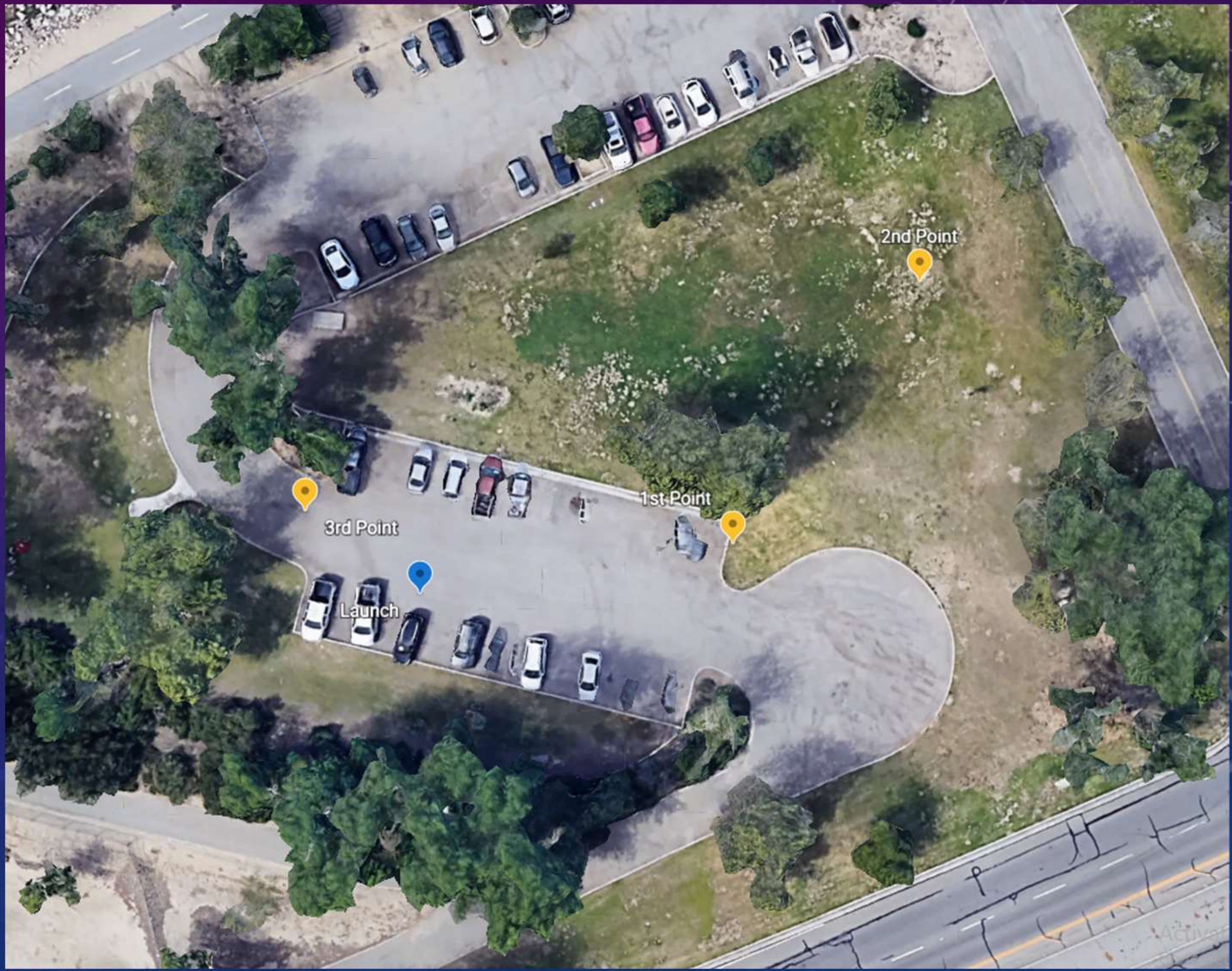
- All control boxes are now wired up, mounted to the frame, and secured with industrial grade Velcro.
- The boxes can easily be removed and serviced by unplugging the connectors and separating the Velcro.

NAVIGATION TESTS

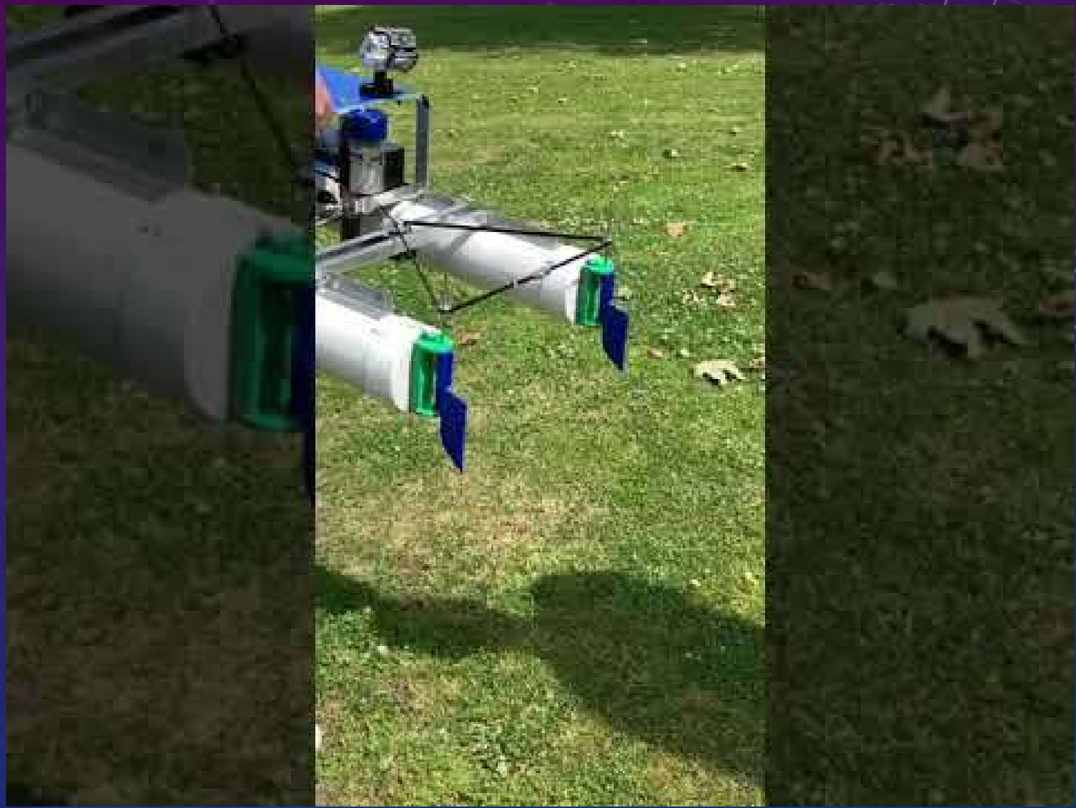
ALL MEMBERS

THE LAND TEST

- Points were chosen at various points at Truxtun Park
  - We sent the GPS points the boat via SMS, and started navigation
  - We then walked the boat towards whichever direction the rudders were attempting to steer the boat.
- Results:
  - Success!
  - Made a few tweaks to the rudder angles and the navigation sensitivity.



THE LAND TEST

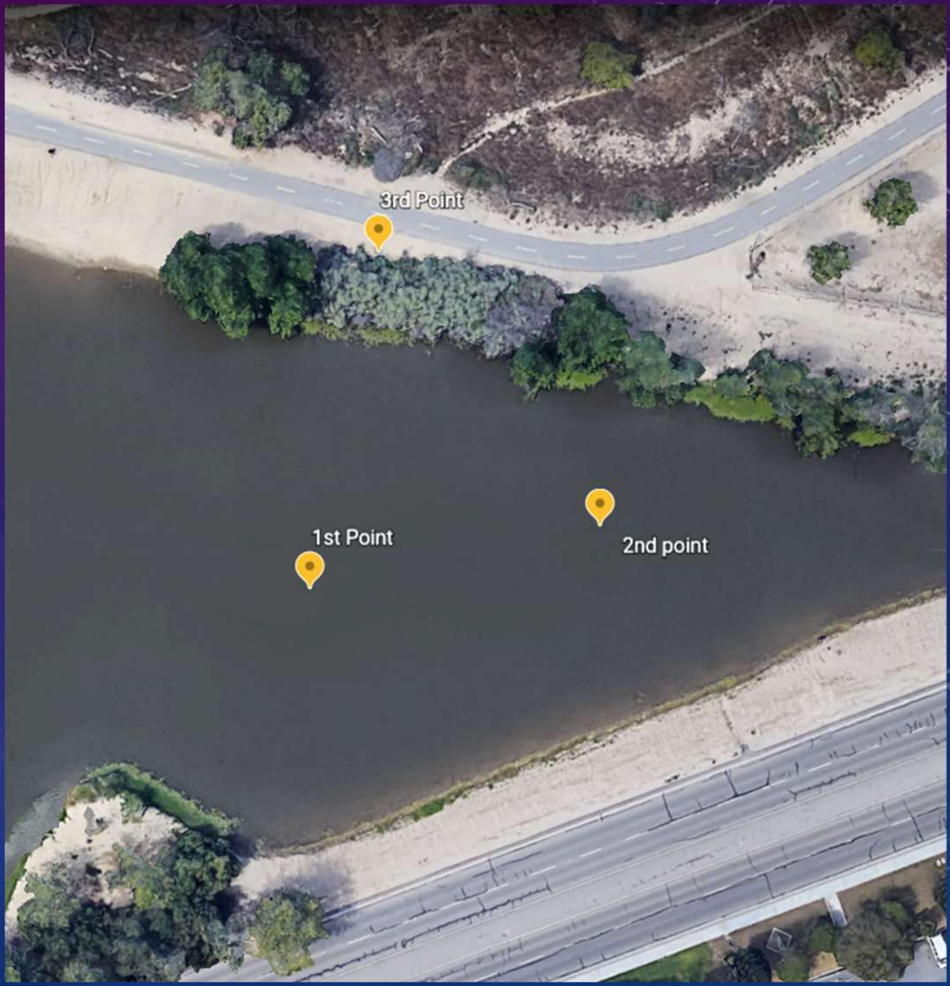


LAKE TEST 1

- Points were chosen at various points at Truxtun Lake
    - We sent the GPS points the boat via SMS, and started navigation
    - We then walked the boat towards whichever direction the rudders were attempting to steer the boat.
- Results:
    - Motor speed setting would not propel the boat fast enough for the rudders to be effective. We increased the speed and started again in lake test 2.

LAKE TEST 2

- Coordinates were chosen at various points at Truxtun Lake
  - We sent the GPS points the boat via SMS, and started navigation
  - We then launched the boat and sent it the Go command ('G') via SMS to start the navigation program.



LAKE TEST 2 VIDEOS

LAKE TEST 2 RESULTS

- The navigation program seemed to work properly, and the motor speeds where sufficient.
- Interference from wind and currents prevented the boat from reaching its destination and pushed it into some plants where it got tangled. Modifications to the boat frame will need to be made.

LAKE TEST 2 VIDEO LINKS

- HTTPS://YOUTU.BE/AER44KZLQVI (FROM DRONE)
- HTTPS://YOUTU.BE/_QWNF4K1MIC (FROM BOAT)

- FULL PROJECT PLAYLIST:
  HTTPS://WWW.YOUTUBE.COM/PLAYLIST?LIST=PLKAWA3EJRKQ59IKXWH1VIJO3MERQEU8-J

COVID-19 IMPACT

- Most of the project had been completed before the shelter in place order, so sufficient testing came to a standstill.
- Since the project was completely assembled, the remainder of the work was mostly code modification.
- Alternate methods were used to discuss improvements to the project.
- Coding was something that could be done at home. What we did was upload to OneDrive and another team member would upload the file to the microcontroller to test.
- Webcam and Zoom were used to show the effects of code changes to other members of the group.

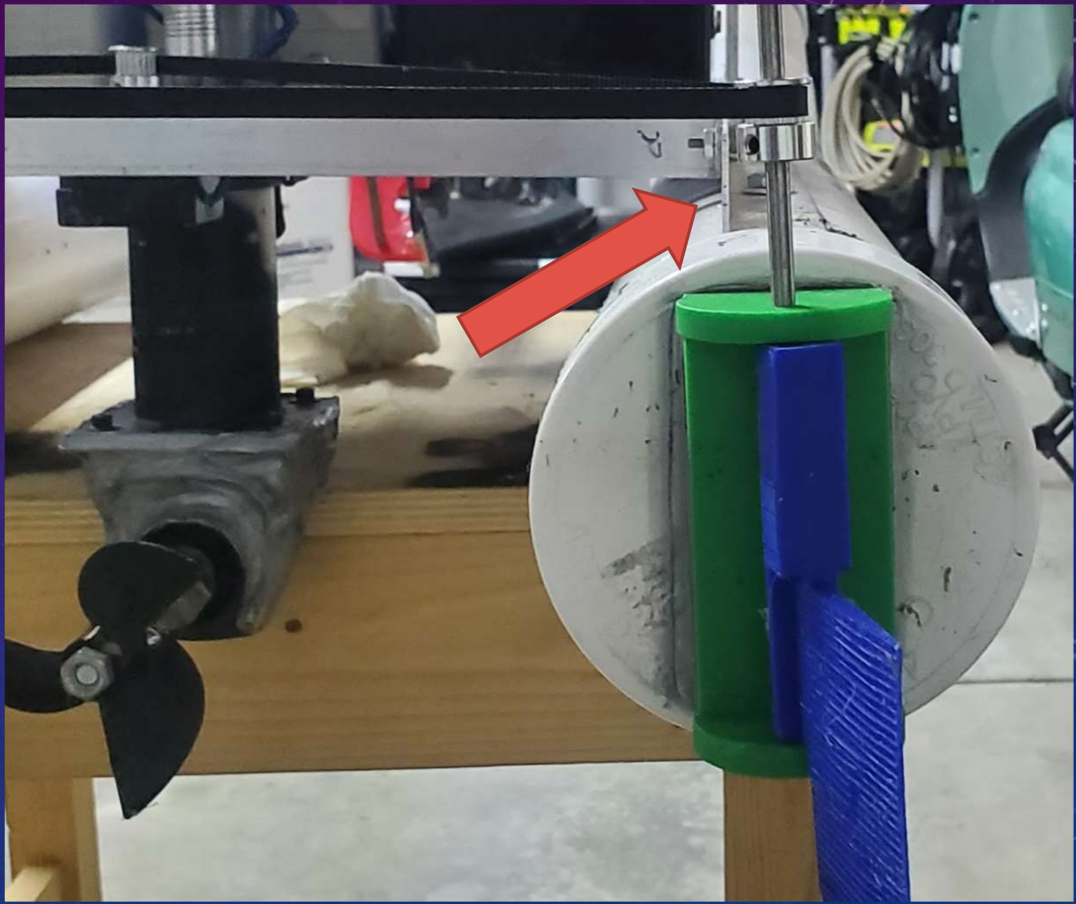
MECHANICAL ISSUES AFTER LAKE TEST

GRECIA ROMAN

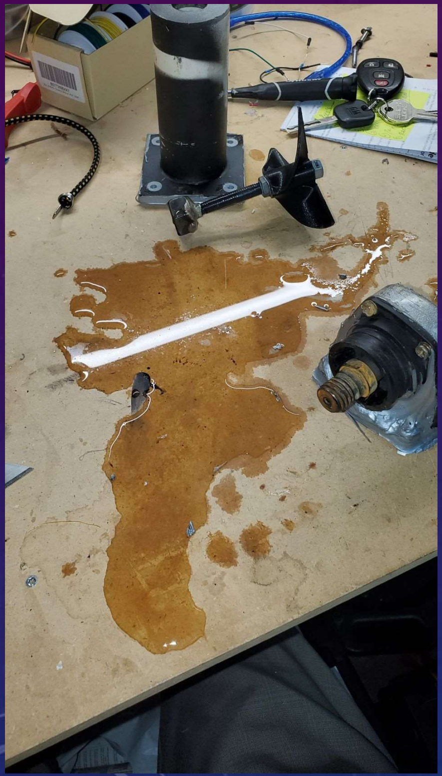
SUGGESTIONS FOR IMPROVEMENTS TO BOAT FRAME

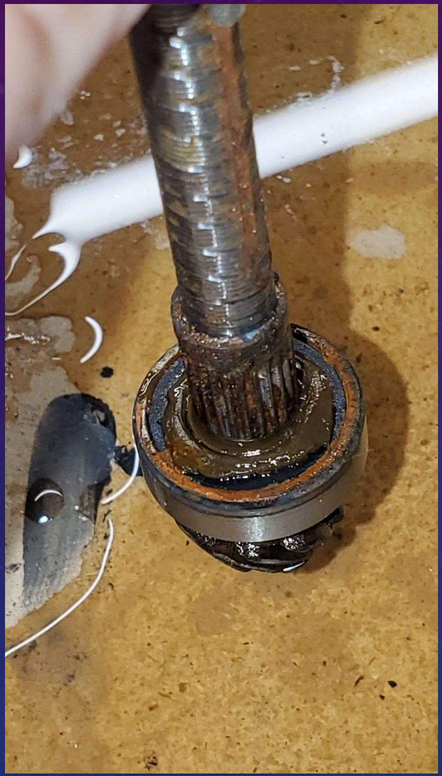
After testing on the lake, we discovered the following areas for improvement:

- Add fins to the front side of the boat for course stability and wind resistance.
- Increase size of the rudders for more turning power.
- Stronger braces to support steering belt tension, which would tweak rudder shaft angles.



PROBLEMS AND SOLUTIONS – WATERPROOFING THE GEARBOX





- Water was entering the gearbox and corroding the bearings ultimately causing bearing seizure.
- New improved sealed bearings were installed, which also failed, twice.
- Coating all mating surfaces with silicone sealant to prevent water penetration was required to ensure this problem would not happen again.

BONUS VIDEO: RESCUE MISSION