Autonomous Oceanographic Research Vessel

Assembly Manual

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Autonomous Boogie Board Assembly Manual

Contents

1   Introduction

Welcome! This is a how-to guide to build a low-cost oceanographic research vessel. It is built primarily using off-the-shelf parts available on Amazon.com, with select pieces 3D printed. The files to print these pieces are available at the end of the manual. Take note when assembling that the parts that you choose to buy may be slightly different than ours, and measurements may not be exactly the same. We hope this serves as a blueprint from which you modify to build the ideal craft for your application.
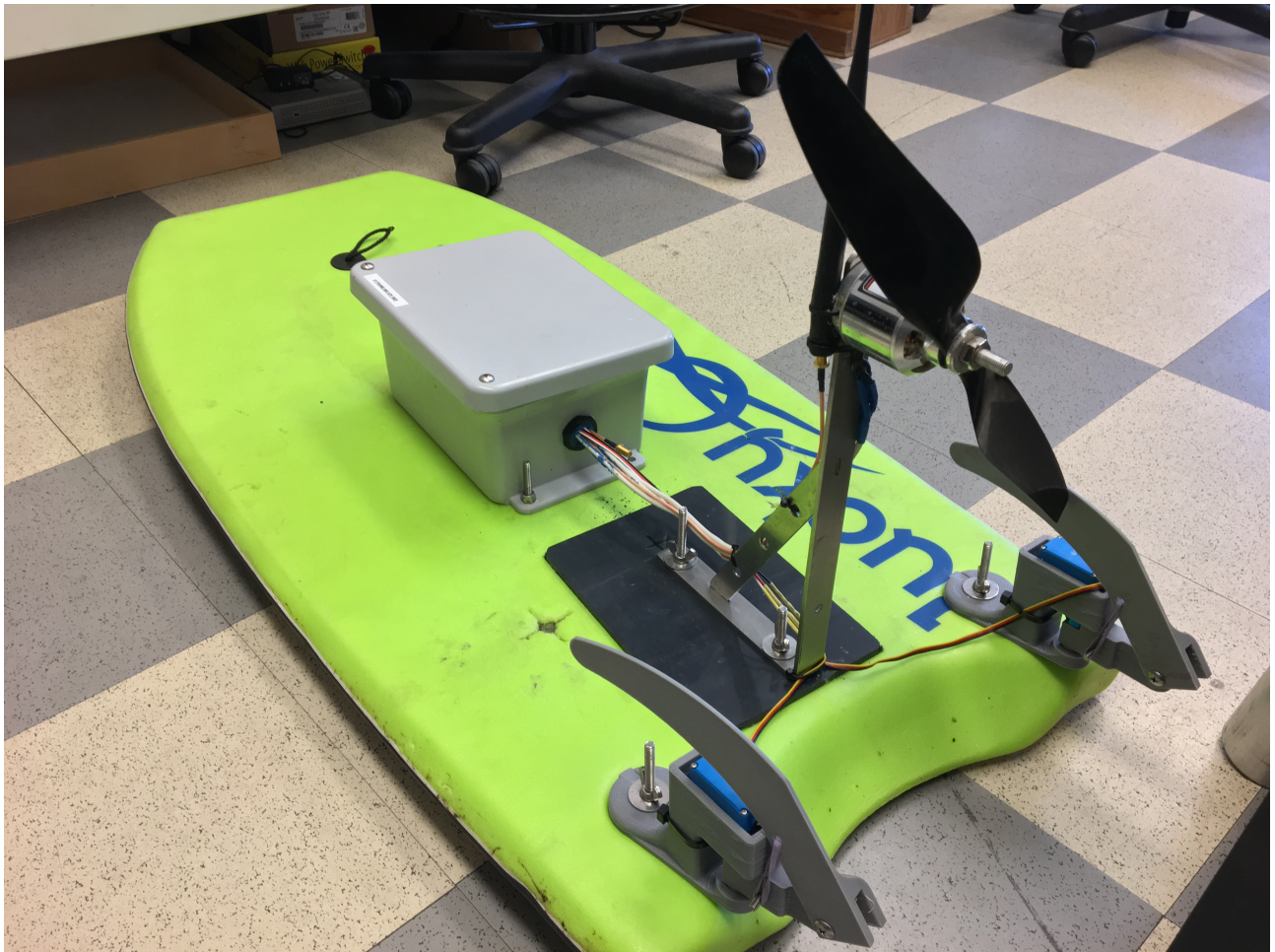
2   Assembly Instructions

2.1   Board Setup

1. Obtain a boogie board from your local surf or hobby shop. It must have a laminated bottom. Remove lanyard.

2. Identify and mark the center of the board on the top of the board. Additionally, mark the rudder mount spots on underside of board, 3" from the rear of the lamination and 3" in from either side, as shown in Figure 1.

Figure 1: All of the required mounting holes.

3. Mark the point on the centerline of the board 6" from the rear. This will be where the motor will be mounted. Using the hole pattern from the bracket, drill mounting points for your motor mount, ensuring that the motor itself will be at the 6" mark.

4. Center the electronics enclosure over the center point of the board as marked in step 1. Use the hole pattern for the enclosure to drill mounting points.

2.2 Motor

2.2.1 Mounting Bracket

1. Drill motor mounting holes as shown in Figure 2. Use the template included with your motor, drilling the inner holes. We were forced to rotate ours to fit all mounting holes.

2. Attach the motor. We recommend using a threadlocker to minimize the risk of failure.

Figure 2: You might need to widen the preexisting hole if the motor shaft diameter is too large.

3. Drill through PVC motor mount spacer, using your hole layout.

4. Push bolts from bottom of board through motor mount spacer. From bottom: bolt head, oversize washer, board, plastic mount, threads. See Figure 3. For this, and for the majority of other times screws are referenced in this manual, use the standard 1/4" bolts mentioned in appendix A.

5. Mount modified heavy duty bracket, and secure with medium size washer and nylock.

Figure 3: Ensure that the bracket is mounted with all required hardware to avoid failure.

2.2.2   Mounting Telemetry Unit and Antenna

1. Connect SMA wire from electronics enclosure to telemetry unit (inside enclosure) and antenna (outside enclosure).

2. Using two zipties, mount telemetry antenna to motor bracket, as shown in Figure 4.
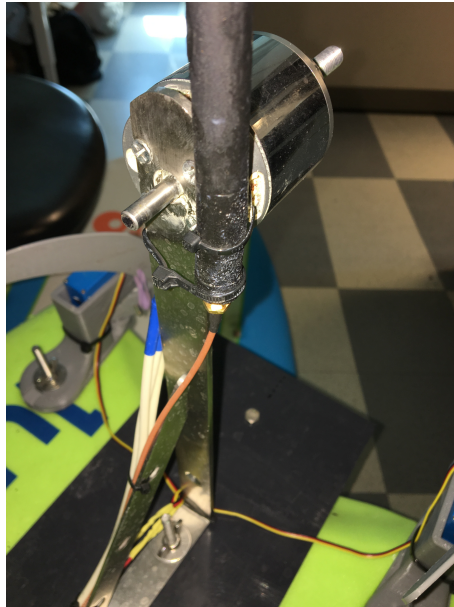
Figure 4: Attach the antenna securely in a vertical position, as high as possible.

2.3   Mounting Electronics Enclosure

1. Before mounting the electronics enclosure, you must drill a hole for the bulkhead. This hole should be 7/8" diameter, provided you are using the recommended bulkhead. Otherwise, ensure your hole is just large enough for your bulkhead.

2. Center this hole on the side of the box that will face the back of the board, 1 3/4" off of the bottom of the box. This positioning is essential for everything to fit together.

3. Our enclosure came with feet instead of tabs, so we will be discussing our mounting approach. Adapt this to the box you have.

4. Center enclosure on center marking on board.

5. From bottom of board: Bolt, washer, board, nylock.

6. Use all mounting points for stability.

2.4   Rudder Assembly

1. Print two sets of the four pieces found in Appendix A, Figure 14.

2. Place bolt and washer through the rudder mounting hole from the underside of the board.

3. Attach the metal servo extensions to the servos. Secure all three locking screws so they are snug.

4. Place the servo in the servo mount. It should be a snug fit. Attach the printed servo arm to the servo. It will slide together as shown in Figure 5.
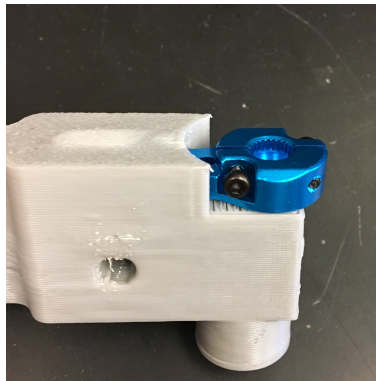
Figure 5: After it is attached to the servo, insert the metal servo attachment into the arm.

5. Place rudder bottom followed by the servo mount on the bolt, as shown in Figure 6. Tighten the bolt enough that the pieces lock together.
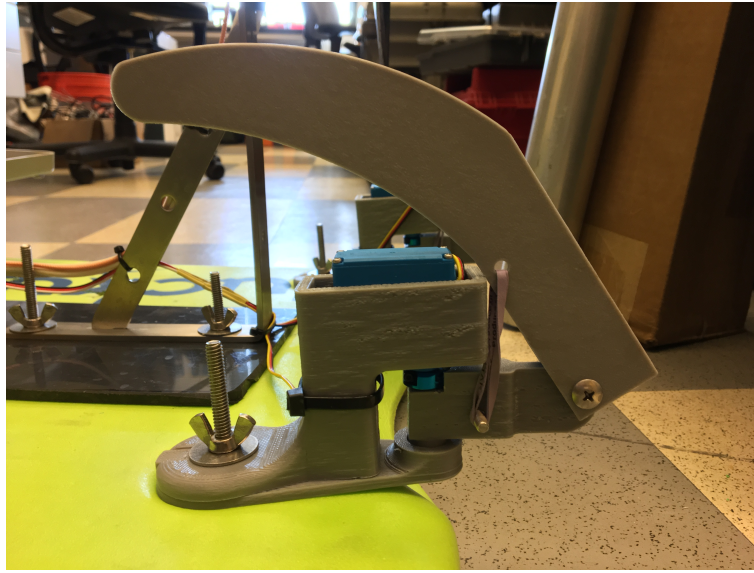
Figure 6: The rudder setup.

6. Mount rudder to servo arm with a 5/32" (or similar) bolt and secure with Nylock. Install rubber band across the rudder hinge. Ensure that the rubber band is tight enough that it holds the rudder down, but flexible enough that the rudder will deflect with a one-finger push.

7. Repeat for the other rudder.

2.5   Wiring

2.5.1   Connecting ESC to Motor

1. Cut bullet connectors off from motor. Cut three extension wires. These will run from the housing to the ESC, so use that distance as a minimum and minimize slack.

2. Solder connections between extensions and ESC. Add shrink tubing for each joint (total of six sleeves, two per wire). Shrink one on each connection, saving the other for the connection with the motor (which will be done at a later point). Be generous with the shrink tubing - this is your only barrier against corrosion here!

3. For extra protection, use a product like liquid tape on the solder joints.

4. Leave connection to motor un-soldered at this point.

2.5.2   Bulkhead Assembly

1. In this section, we will be routing all necessary cables through the bulkhead into the electronics enclosure. Add extensions where necessary - make sure nothing is under tension.

2. Organize servo cables from servo mounts through bulkhead connector.

3. Route telemetry wires through bulkhead.

4. Connect SMA wire (auxiliary antenna) through bulkhead, ensuring that the majority of the excess wire is contained within the enclosure.

5. Route ADCP/auxiliary battery cable through bulkhead, with 8" of slack in the box.

6. Route on/off cable through bulkhead with switch on outside of bulkhead.

7. Route positive and negative battery cables through bulkhead.

8. Route ESC cables through bulkhead. At this point, solder the ESC extension cables to the motor and shrink the shrink tubing around the joints.

9. Verify that all cables are present and facing the right direction. Minimize slack and extra coils. Use a ziptie to ensure that servo cables stay clear of the propeller.

10. Lay out all wires on board as shown in Figure 7.
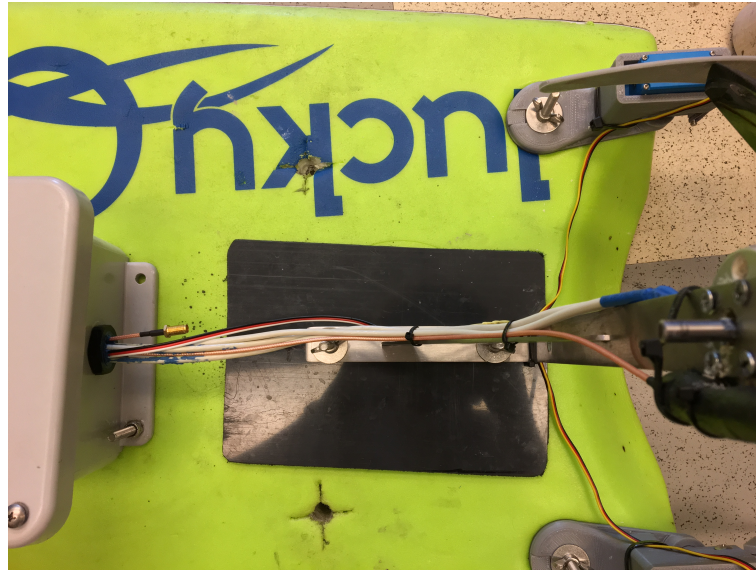
Figure 7: Ensure that all wires are present in their correct lengths. Additionally, check that the SMA cables are oriented with the correct connectors inside and outside of the bulkhead.

2.5.3 Waterproofing

1. For this step, remove the bulkhead from the electronics enclosure. Try and keep the cables at the same length throughout this process.

2. Tape around edge of bulkhead and nearby cables.

3. Starting at inside end of bulkhead, fill with gasket maker. Ensure that the inside is completely filled, especially around all of the wires.

4. Allow 24 hours to cure.

5. Install bulkhead into electronics enclosure.

6. Use zip-ties to hold all loose wires in place, ensuring that no wires are under tension and that all wires are clear of the propeller.

7. If you do not want to cut into the board, use zipties to tidy up cables and keep them out of the way of the rudder and propeller.

2.6 Autopilot

2.6.1 Autopilot Wiring

NOTE: double check that the correct ends of each cable are connected to the autopilot unit.

Figure 8: Note the orientation of all of the cables. Ensure everything is plugged in to the correct port with the correct polarity.

1. Connect rudder servo wire to channel 1 main out.

2. Connect RC reciever to RC input channel on autopilot

3. Connect telemetry cable to telemetry port 1.

4. Connect ESC cable (motor) to autopilot channel 3 out.

5. Connect power module cable to power input on autopilot. (The other side should be connected to the power source.)

6. Connect GPS power cable to GPS input on autopilot. Ensure that the arrow on the autopilot unit is facing the front of the board when it is affixed to the velcro.

7. Connect CAN cable from GPS to autopilot.

8. Connect buzzer to autopilot.

9. Connect power module to ESC.

10. Connect external antenna to the telemetry transmitter.

2.6.2   Mounting Flight Controller

1. Affix heavy duty velcro to the autopilot unit and the autopilot shelf, using the hook side on the mount, and the fuzzy side on the autopilot unit.

2. Attach autopilot to shelf, ensuring no cables are under tension. See diagram.

3. Securely mount GPS to platform, ensuring that the arrow on the device is pointing towards the front of the vessel. See Figure 9.

Figure 9: The devices use compasses to guide the board, so they must be oriented correctly. The front of the board is on the left side of the image.

3　Programming, Tuning, and Calibration

3.1　Programming Remote Controller

Note: These are instructions for the Radiolink T8FB Transmitter. If you are using a different transmitter, follow setup instructions for your device.

1. Match code with transmitter:

   (a) Put the transmitter and the reciever close to each other (within 1.5').

   (b) Turn on the T8FB transmitter, then power on the R8EF module.

   (c) Hold the binding button (black button, on the R8EF) for two seconds, then release. The receiver light should start blinking. Eight blinks indicate that the code matching has been successful and the receiver signal LED will stay on.

2. Switch receiver from PWM to PPM. Press binding button once and LED should go from red to purple. Your setup should match Figure 10, except inside the electronics enclosure.

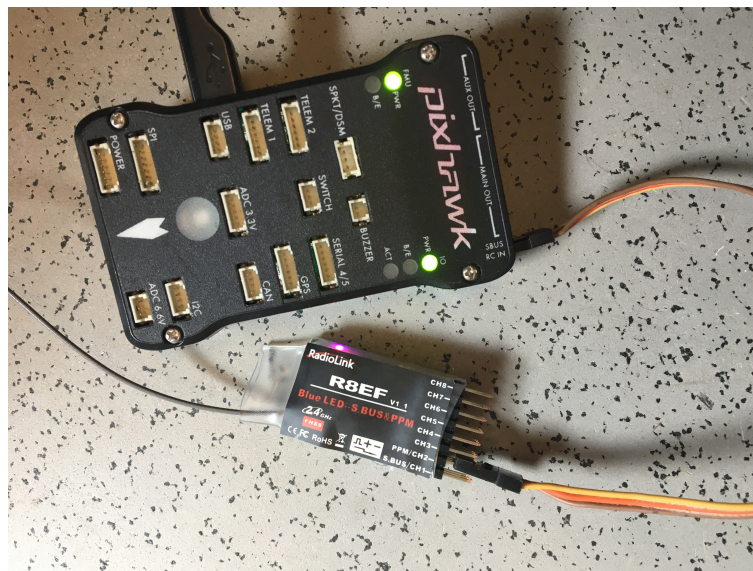Figure 10: Ensure you have a purple light on the receiver module, and that channel 2 on the receiver is connected to RC IN on the PixHawk.

3. Zero out the trim. On all four toggles, click back and forth until you hear a higher pitch. This indicates that the toggle is centered.

4. Ensure that all switches at the bottom of the transmitter are set on "N." This is a factory default, and no change should be required.

5. In Mission Planner: Initial Setup → Radio Calibration, click "Calibrate Radio" and follow onscreen instructions.

3.2 Flashing Autopilot Firmware

1. The following instructions are for a never-before-programmed autopilot unit. This must be done after everything else is connected and the autopilot is mounted correctly on the board. Do not skip ahead to this step.

2. Open Mission Planner.

3. Connect the autopilot unit to computer and identify which COM port the autopilot is connected to. Select this port.

4. Set BAUD Rate to 115200. Do NOT click "Connect."

5. Go to Initial Setup → Initial Firmware. Select *Ardurover* firmware and follow onscreen instructions.

6. After installation, connect to autopilot unit through Mission Planner software.

3.3 Autopilot Programming

1. Config/Tuning → Full Parameter: search for ARMING CHECK. Change value from 1 to 0.

2. Change MODE CH from 8 (default) to 5. Note: this is only required for the recommended Radiolink transmitter.

3. Change BRD SAFETYENABLE value from 1 to 0. Click "Write Params."

4. Config/Tuning → Flight Modes: Change Flight Mode 1 to "Auto." Change Flight Modes 3 and 4 to "Loiter." Verify that Flight Mode 6 is "Manual."

5. Initial Setup → Optional Hardware → Battery Monitor: set Monitor to Analog Voltage and Current, Sensor to 3DR Power Module, and APM to Pixhawk.

6. Initial setup → Mandatory Hardware: click calibrate accelerometer (3 axis). Follow onscreen instructions.

7. Initial Setup → Compass: set quick-configure to Pixhawk/PX4, and ensure that the battery enclosure is closed and the components are secured. Click start under Onboard Mag Calibration and follow onscreen instructions.

8. Initial Setup → Radio Calibration: click Calibrate Radio and follow onscreen instructions. Refer to online resources if you encounter errors.

3.4   Basic Tuning

1. Config/Tuning → Basic Tuning: ensure that the settings match those shown in Figure 11.

Figure 11: These settings are for the Pixhawk 4 (recommended) autopilot.

3.5   ESC Tuning

1. Refer to online resources here: ESC Tuning

2. Note: The process will be different depending on your ESC.

3.6   Power Module Calibration

This calibration must be done after **Basic Tuning** has been completed.

1. **Caution:** You will be testing full-throttle. Make sure the board is secured and that nothing could obstruct the propeller. We highly recommend enlisting the help of a second individual.

2. You will need a wattmeter with 20A+ capacity for this section. We recommend: Wattsup, RC Electronics USA.

3. Place your wattmeter in-line from the battery to the autopilot unit. (Connect the autopilot end first for safety.)

4. Connect telemetry. In Mission Planner, under "Initial Setup," click on Battery Monitor. Copy the following settings, as shown in Figure 12. For "Battery Capacity," calculate 80% of your battery's capacity (in mAh) and enter it here.
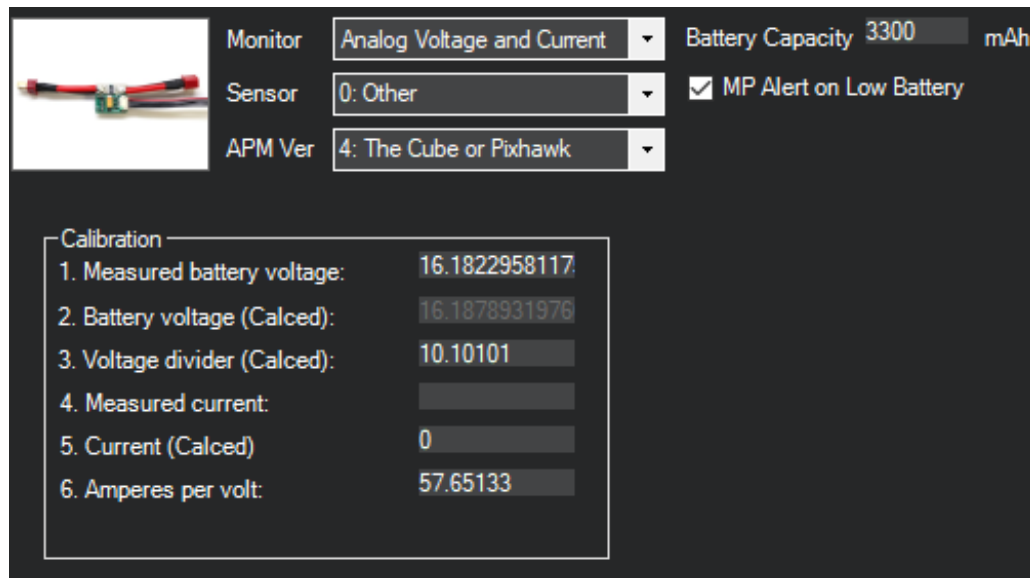
Figure 12: Copy these exactly, provided you are using all of the recommended parts.

5. Arm the vehicle.

6. Check again that the board is secure and the propeller is clear. Slowly accelerate to full throttle.

7. Check the wattmeter, it should be between 2A and 5A, depending on your propeller.

8. Hold full throttle for 5 seconds and watch for an average amperage draw. While still holding full throttle, input this value into the "Measured Current." Refer to Figure 12. Click enter, and throttle down to zero.

9. In flight data screen, you should be able to see the current voltage and amp draw. To quickly test that this has been successful, throttle back up and you should see voltage drop slightly and amperage increase. The amperage should be within 0.2A of the wattmeter reading.

4 Usage

4.1 Mission Planning

The following instructions are for using the board for autonomous radar calibration. Suit these to your needs. It is of utmost importance that you follow every step, in order.

4.1.1 Finding your HF radar

1. Open mission planner and click on the flight plan Tab located near the top left side of the screen. It may not appear until you mouse over the top of the window.

2. Type in your coordinates for the Receive antenna in the Home Location Lat Long input box located near the bottom center of the window. A pop up window may appear prompting you to click on the map. You can cancel or click ok and then go ahead and enter your coordinates to set the home waypoint.

3. You should now see your antenna on the screen. Depending on your area of interest Google might not have a high res image for your area. If this is the case, you will use your typed in waypoint as your center.

4. **Verify that your antenna location is correct.**

4.1.2 Creating Waypoint Mission

1. Add a new waypoint by left clicking on your exact take off location (prior site scouting might be required with a GPS). Don't worry about where your home location, this waypoint will be deleted in a later step.

2. Add a new waypoint offshore perpendicular to the coastline. **It is very important ensure that there are no obstacles on this flight path (trees, power lines, buildings).**

3. Right click exactly over the antenna and select Create Wp Circle under the Auto WP tab. **It is very important to click right on the exact antenna's location as this will be your absolute center for the circular flight path.** Set radius to 300, and number of points to generate circle to 100.

4. Type 1 for direction of circle. 1 = CW, -1 = CCW. Once you complete this mission you, will make the same mission going CCW.

5. Type 0 for angle (depending on your coastline you might need to change this value, ideally you want waypoint 1 at the coast).

6. Trim the endpoints by deleting them so that your first and last waypoints are over the ocean not the beach, for safety purposes.

7. Insert two new waypoints so that you crate a mirror image of the first two waypoints that you created, ensuring that the last waypoint is exactly where you will land.

8. Double check everything.

9. To make a CCW pattern simply right click anywhere on the map and go to the Map Tool tab then select the reverse WP's option.

4.2   Pre-Mission Procedures

1. Ensure that controller is fully charged.

2. Using a LiPo battery checker, ensure that the voltage for the board battery is near 100%. Follow instructions for your specific battery checker.

3. Ensure that laptop (ground control station) is fully charged.

4. Ensure that all washers and wingnuts are secured on board.

5. Ensure that propeller is in good condition and that all fasteners are tightened.

6. Upon arrival at the launch site, power on board, controller, and laptop.

7. Ensure that electronics enclosure is tightly sealed.

8. Flip down rudders. At this point you are ready to arm the vehicle and launch.

4.3   Post-Mission Procedures

1. Override from auto to manual control to take over and beach the craft. There is no right way to do this, and it is only through crash landing and observation that you will improve.

2. Once the craft is safely in your possession, bring the rudders up. Keep hands, fingers, and hair away from the propellor as long as it is armed!

3. Use a spray bottle or hose to rinse the enclosure of sand and debris.

4. Dry the exterior of the box, open it up, and disconnect the batteries from the board and the signal source. Check for overheated components or the smell of burnt electronics. Only now is the propellor disarmed.

5. Once powered off, rinse the entire board, taking extra care to rinse the servos and the motor. Spray the motor with WD40 to increase its lifespan.

4.4 Common Issues and Resolutions

1. Loss of link: Usually occurs when telemetry modules aren't talking. Look for red and green light on the ground station for connection confirmation.You should have a solid green light, with a flashing red light indicating data transfer. If you don't see this, double check all connections.

2. Board flips over: If your board is consistently flipping over, your center of gravity may not be at the center of the board. Check to make sure any added weight is centered or balanced. This could also be a result of using it in high wind conditions.

3. Board is unresponsive: Check power module and connectors, ensure that everything is secure and there is no corrosion. Check for signs of fried electronic components (likely would be the power module or the ESC). If all else fails, turn the board off and turn it back on.

4. Board acting erratically: Generally an issue with compass calibration or magnetic interference in the electronics enclosure. Recalibrate the compass.

5. Battery draining quickly: Check power supply, ensure that the motor is not overheating. You may also have a bad battery.

6. Underpowered propeller: Likely in an ESC failsafe mode. Operating in a low voltage setting, your propeller will be in "limp" mode. Recharge your battery.

7. Under autonomous navigation, board doesn't follow path: Check compass on land, see if compass is reading true. Recalibrate compass if it is not. Ensure that servos track in the correct direction.

4.5 Operational Limits

- Ocean Conditions

  - It is not recommended to use this device when the swell is over 4'. This is likely to flip the board and will make launching and recovering very difficult.

  - If the swell is higher than the antenna is off of the surface of the board, exercise caution as the line-of-sight can be broken and you will not have control over the board.

  - Current is generally not an issue, as there is very little resistance under the surface of the board.

- – Ensure that your mission does not interfere with local traffic. If you will be operating in a channel or other busy area, it is highly recommended that you have a VHF radio on hand (Channel 16).

- Weather Conditions

  - – Do not attempt to use the board in winds greater than 10mph. Check the forecast using a website like windy.tv.

  - – If your "headquarters" is in the sun, bring some kind of shade so the screen is legible. Turning up the brightness will decrease battery life, and you want to have your laptop on for the duration of the mission.

- Launch Site

  - – The ideal launch site is a sandy, shallow beach.

  - – It is recommended to have two people to launch and recover the board. In good conditions, it is possible to do alone, but we advise against this.

5   Cyril Signal Source Setup

5.1   In the CSS Box

The Cyril Signal Source (CSS) box should include the CSS device, the 2 piece housing for protecting the circuit board, and the CSS dipole wire antenna.

5.1.1   Power

- The CSS requires a minimum of 11.0v to operate; The 2 piece housing was specially designed to accommodate the 3cell 12.6v lithium polymer battery described above.

- The CSS does NOT shut down upon low battery voltage. Users MUST ensure that the remaining battery capacity is sufficient for AAPM duration. Calibration source draws 70mA.

- Make sure the LiPo battery is fully charged before each AAPM. Lipo battery checker should read 4.1v 4.2v for each cell before takeoff.

5.1.2   Communications

With the CSS powered, connect to the CSS via the TTL cable using your favorite serial terminal with the following parameters. Turning on and off while connected should reprint the following screen.

> 9600baud, 8 data bits, No parity, 1 stop bit, no flow control
> Upon connecting the following should be displayed
> Small signal generator revA.c compiled 14-May-15 20:06:11
>
> Current information loaded onto eeprom:
> Switch position 0: ref10 10000000Hz
> Switch position 1: 20MHz 20000000Hz
> Switch position 2 (Not entered yet)
> Switch position 3 (Not entered yet)
> Switch position 4 (Not entered yet)
> Switch position 5 (Not entered yet)
> Switch position 6 (Not entered yet)
> Switch position 7 (Not entered yet)
>
> Single key commands:
> 'L' to load site info to eeprom
> 'C' to calibrate compared to 10MHZ precision source
> '?' key to print this out again
> Switch 0: Site: ref10 10000000Hz
> Using cal number 447392927
> Using the "L" command enter site identifying info and then
> frequency for each switch position.

5.1.3 Programing the CSS

1. Establish a connection to the CSS. You might need to power cycle the board to reprint instructions on terminal window. Recommended: Leave the unit power switch left on the on position and disconnect the battery to turn it off or on.

2. Using a small plastic slot head screwdriver, rotate the dial to switch position 1.

3. Type uppercase "L".

4. Follow onscreen instructions.

5. If you're at your CODAR site, verify the new frequency using CODAR's "Spectrum Analyzer" found in SeaSonde software. If you?re at the lab, you will need to verify with an alternative method such as a software defined radio, etc.

6. **Remember to add a 50Hz offset from your site frequency.**

5.2   Mounting Antenna on Board

1. NOTE: If using a stainless mount, protect the antenna from touching it. We did this by wrapping the wire in electrical tape.

2. Solder two wires to your SMA connector. The red wire is the center conductor. Solder the other end to the antenna. See Figure 13.
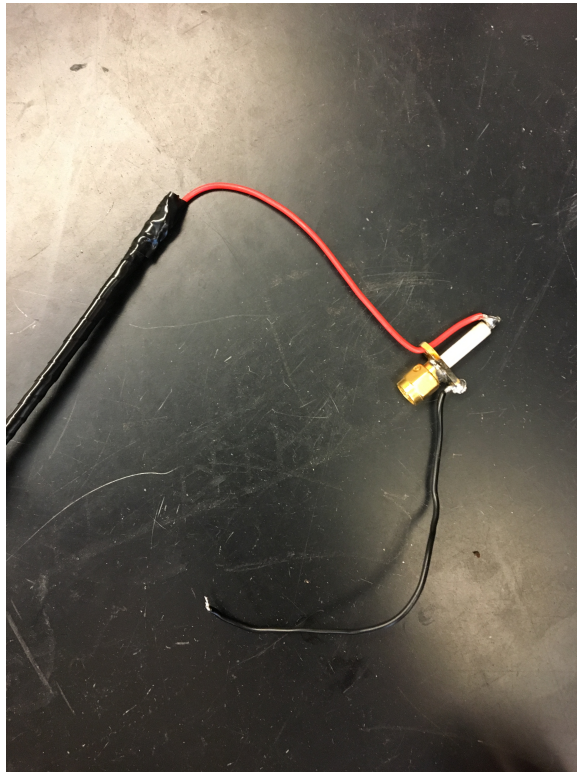

Figure 13: This is how you will build your own antenna for the board.

3. Mount the wire antenna to the motor mount using zipties. The black (ground) wire coming out of the SMA connector is to be wrapped around a bolt that goes through the board, grounding it to the ocean.

6   Maintenance

6.1   Centering Servos (first run only)

1. This comes after the system is on, functional, and calibrated.

2. Remove rudder mount wingnut and remove servo mount, granting access to the servo itself.

3. Loosen both small black set screws and remove larger silver locking screw from the metal servo arm.

4. Visually approximate the center position of the servo arm and tighten all screws.

5. Repeat for the other servo.

6. Once both are centered and re-mounted, check that both rudders deflect equally when the joystick on the controller is moved.

7. With the board facing away from you, the rudders should spin counterclockwise when you steer right on the controller.

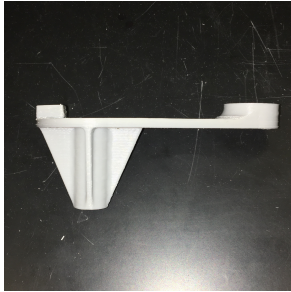## 6.2   Batteries and Charging

Recommended Batteries

- For board: Bioenno 12V 12Ah LFP Battery

- For controller: any rechargeable AA batteries.

- For signal source: Turnigy E3 Compact 2S/3S Lipo Charger

For each battery, read and follow recommended care and charging routines. Safety should always come first.
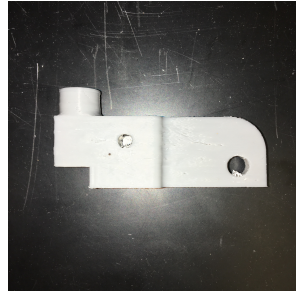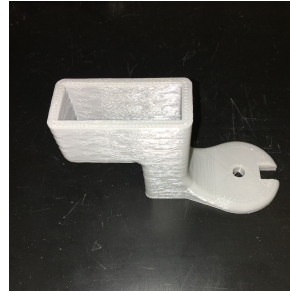
A   Parts List

- 3D printed parts

  – Rudder Base
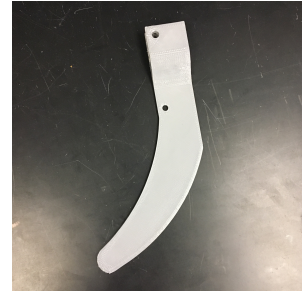

(a) Rudder   (b) Servo Arm   (c) Servo Mount   (d) Rudder Blade

Figure 14: These four parts constitute one rudder. You will need two of them.
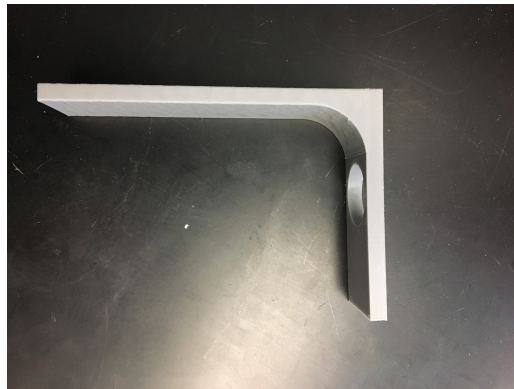
  – Flight Control Mount

Figure 15: This goes on the inside of the electronics enclosure and holds the autopilot and compass.

- Purchased Parts

  An Amazon.com cart with the parts we use may be found here: Boogie Board Parts. The table below contains information about the parts in case the link is no longer active, and to serve as a reference if you will be making changes to the plans.

Part	Manufacturer	Name
Battery Charger	Bioenno	2A AC-to-DC Charger (DC Plug) for 12V LiFePO4 Batteries
Battery	Bioenno	12V 12Ah LFP Battery
Board	Lucky Bums	Body Board with EPS Core Slick Bottom
Motor	Turnigy	SK3 - 5055 - 280kv Brushless Outrunner Motor
Motor Mount Spacer	N/A	Plastic Cutting Board
Washers	N/A	1/2" x 2" OD Grade 18-8 Stainless Steel Fender Washers (10 Pack)
Bolts	N/A	1/4"-20 x 3" Stainless Phillips Truss Head Machine Screw (25 Pack)
Radio Controller	Radiolink	T8FB 8CH 2.4GHz Radio Controller (SBUS/PPM/PWM)
GPS Compass	Readytosky	M8N GPS Module with GPS Antenna Mount for Standard Pixhawk
Telemetry Kit	Readytosky	3DR Radio Telemetry Kit 915MHz 100mW Air+Ground Module for Standard Pixhawk
Servo Wire	N/A	10? 22AWG Futaba Style Servo Wire
Speed Controller	RCelectricparts.com	60A RC Brushless Motor ESC with XT60 and 3.5mm bullet plugs
Antenna Adapter	Padarsey	2x 90mm FPV SMA Female to SMA Male Antennae Adapter
Propeller	APC Landing	Standard propeller, 17 x 10
Current Sensor	FPVDrone	Power Module Current Sensor for Pixhawk (with XT60 Plug)
Flight Controller	Readytosky	Pixhawk PX4 Autopilot with 16GB SD Card
Servo Arms	Hobbypark	Metal 24T Aluminum Servo Horn M3 Threads for Hitec Servo Motors (5 Pack)
Servos	Hitec	32646W HS-646WP Waterproof Analog Servo (IP-67 Rated) [2x]
Gasket Maker	Permatex	80022 Sensor-Safe Blue RTV Silicone Gasket Maker
Motor Mount Bracket	Amarine	Stainless Steel Solid Shelf Bracket (12?x6-1/2?)
Antenna Extension Cable	Padarsey	100cm FPV Antenna Extension Cable RP-SMA Male to RP-SMA Female Antenna Adapter

- Below are specific images of parts used. This is to help clarify what parts are being referenced.

(a) Compass   (b) ESC   (c) PixHawk Autopilot

(d) RC Receiver   (e) Telemetry Unit

B   Further Reading

If you run into issues, or are using a setup other than what is recommended, we suggest searching through these sites for information. This is by no means a comprehensive list, rather it is a starting point for troubleshooting or further research.

pixhawk.org
ardupilot.org
diydrones.com

hobbyking.com
bioennopower.com

C   Credits

Thank you to Ed Romero, Sean Jawetz, and Libe Washburn for putting this project together.