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# Project Ladon

Building an Autonomous Sailboat to  
Circumnavigate the Earth

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# Motivation

- Robots have crossed ocean basins
- None have circumnavigated
- Potentially useful for:
  - Ocean research
  - Cargo delivery
  - Ocean monitoring



~45,000 km, extended by going farther north to avoid ice  
~12,000 km to Cape Horn  
2-3 years at sea  
If we make it to the Falklands, we'll probably succeed



Significant wave heights to 30m  
Gale force winds 10 days/mo  
Drifting ice in the winter and spring  
Cloud cover averages 7/8th year round

# Things to Do

- Continuous position, weather & sea state logging
- Pictures of the ocean and wildlife
- Space for instruments
  - In the hull
  - On the keel
  - On the masts

Total instrument budget is ~50 kg/1 m<sup>3</sup>  
Power budget ~50W, with load shedding

A 3D rendering of a conceptual boat hull and mast structure. The hull is a light brown, curved shape with a deep keel. Two tall, yellow masts are mounted on the deck. Each mast has a horizontal spar with a small rectangular sail attached. The background is a solid teal color.

## Conceptual Design

- Hull 4.2m long
- Sails 4m high, 4.8 m<sup>2</sup> area
- Keel 1m deep
- Displacement 300 kg
- Ballast 100 kg
- Hull based on Phil Bolger Junebug

A little more than 4m long (~14 ft)

Based loosely on the Bolger Junebug

Propelled by self-tending wingsails

Two wingsails eliminate the need for a rudder

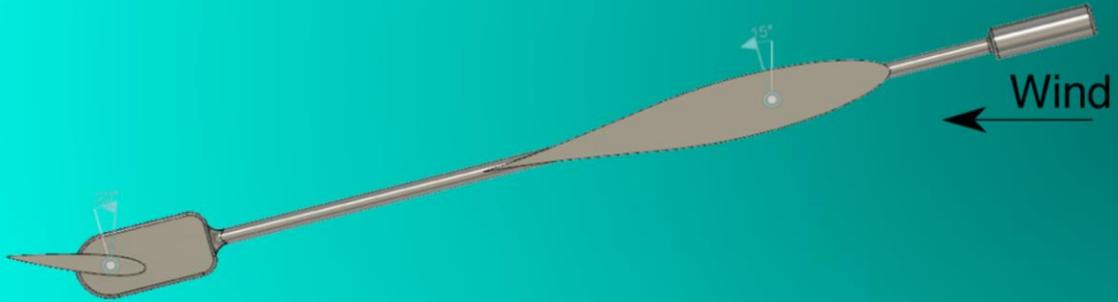
Rudders are a major point of failure for previous long-distance USV projects

Solar panels laminated to the wings and deck, ~200W total

Control power budget ~10W

Battery capacity for a week with zero sun

# How the sail works



Works like an airplane

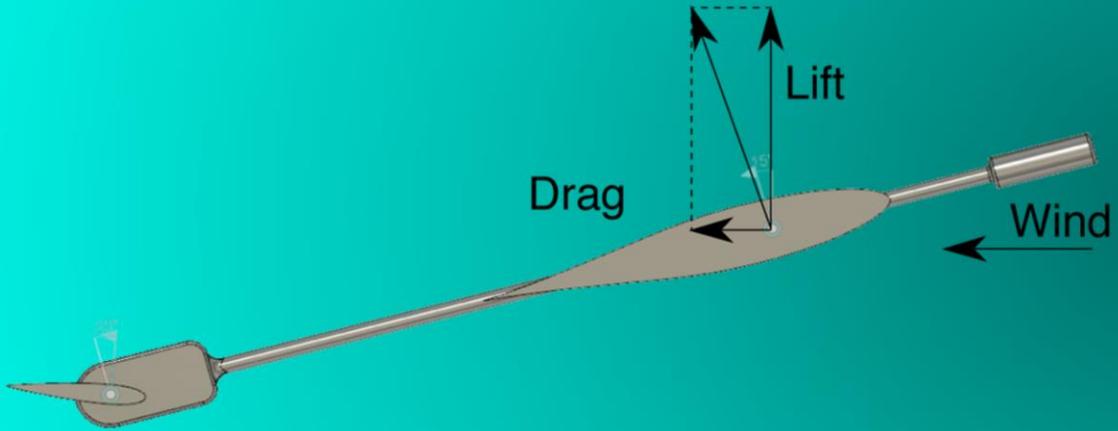
- Tail sets the angle of attack

- Tail force resists pitching moment

Invented by Peter Worsely of the AYRS in the 1980s

Requires only one small actuator, well out of the water

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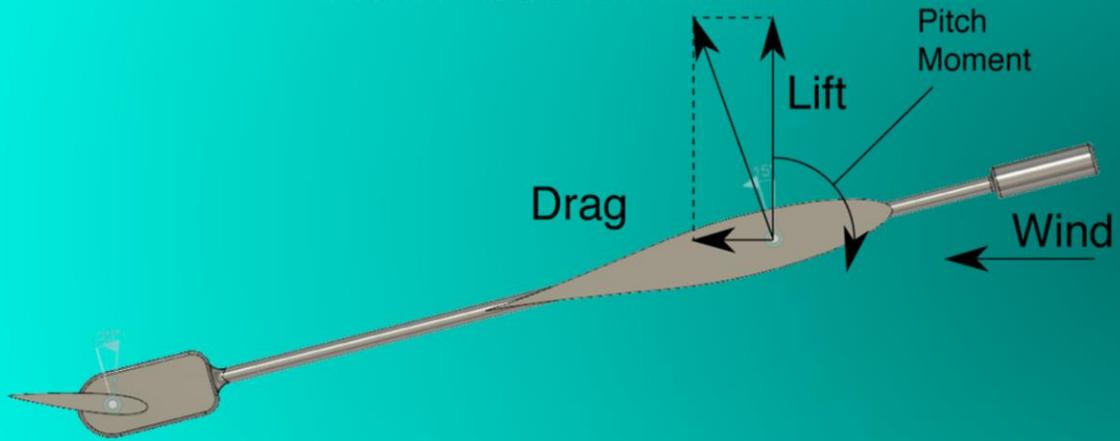
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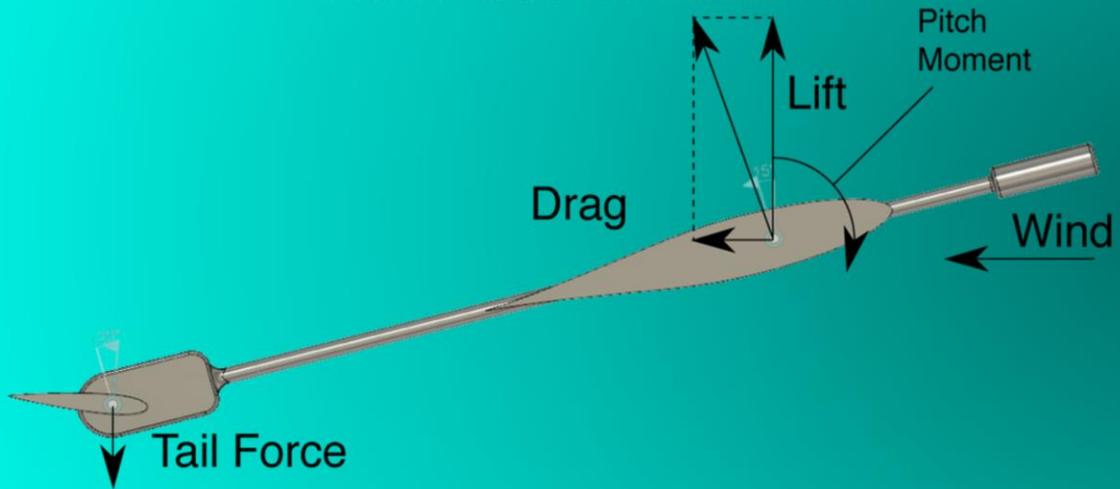
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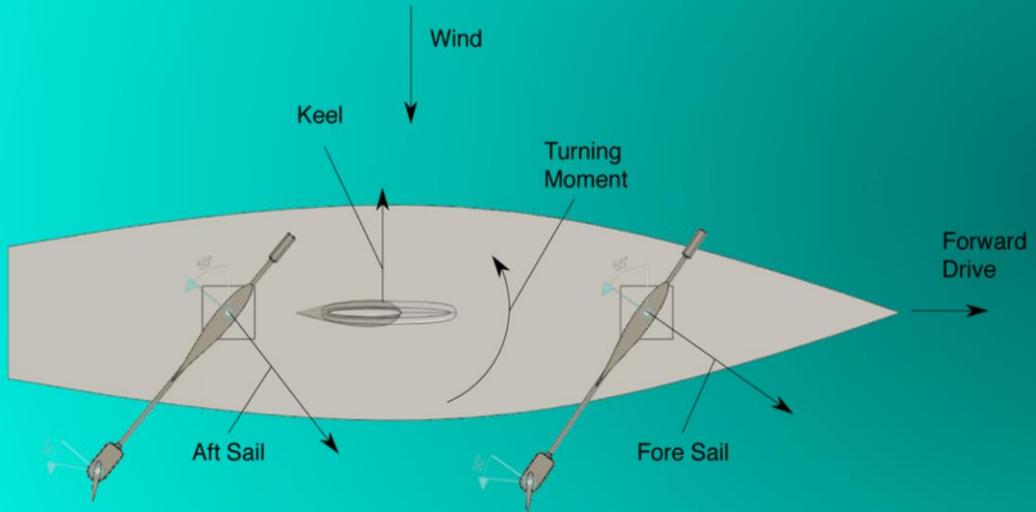
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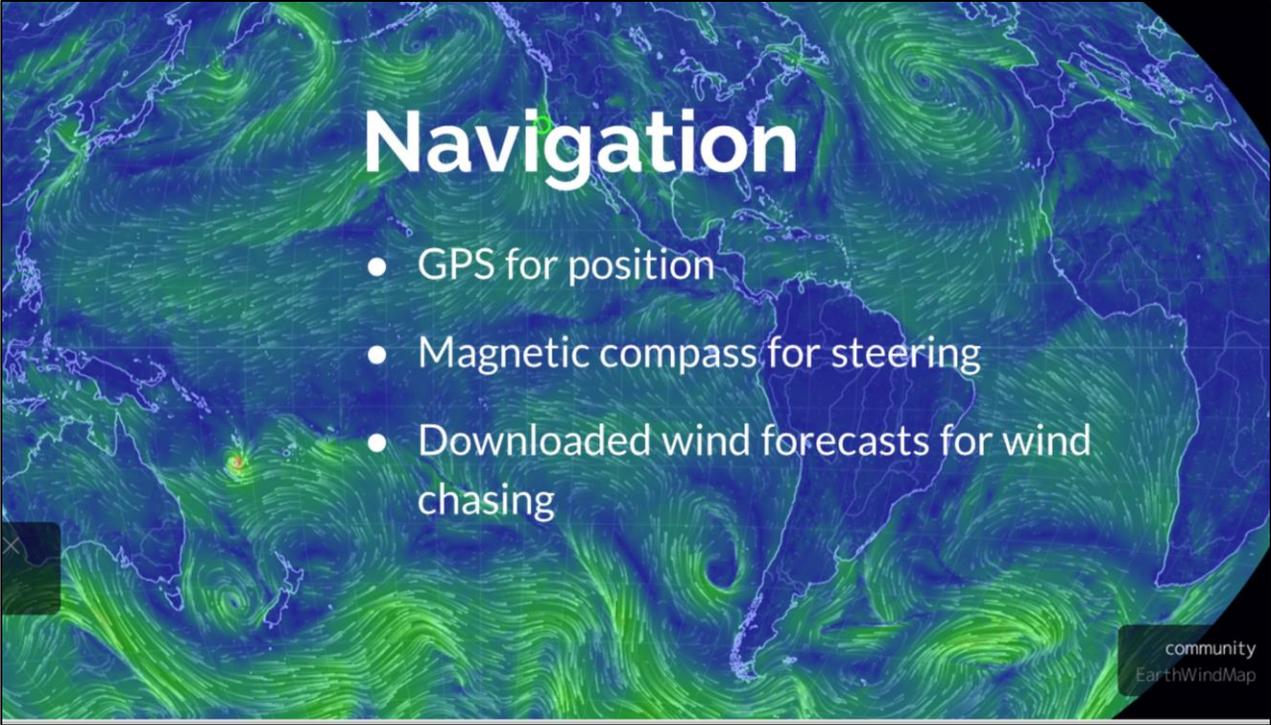
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# Look Ma, no rudder!



Two sails can be set differently to produce a turning torque  
Keel force balances both  
Filed for a provisional patent



# Navigation

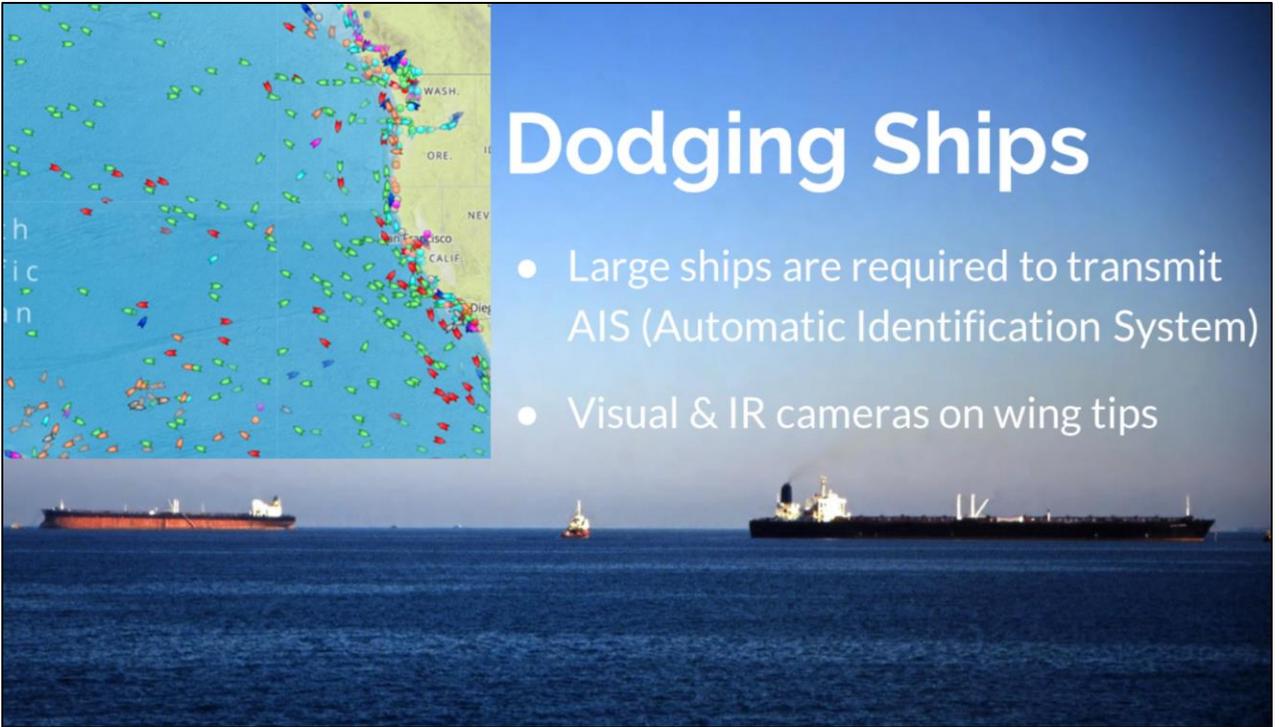
- GPS for position
- Magnetic compass for steering
- Downloaded wind forecasts for wind chasing

community  
EarthWindMap

Wind forecasts available 48 hrs in advance in 6 hr increments

Resolution is 1 arc-minute (~1.8 km latitude)

Use path-finding algo to plot route with best distance made good to next waypoint.



# Dodging Ships

- Large ships are required to transmit AIS (Automatic Identification System)
- Visual & IR cameras on wing tips

AIS provide ship course, speed, size, and identity

Large ships are required to transmit AIS, but many fail to do so.

We're using a dAISy receiver kindly donated by the creator

Ships are clear targets in both visual and IR -- will use machine vision techniques to track and avoid them

We shall teach our robot fear.

# Project Ladon Pre-History

- Conversations started in 2011
- Dropped it for a couple of years when we heard about Saildrone
- All talk until 2014
- Original name was Hackerboat, changed to avoid conflicting with yacht maker

We tried to get in the water for Toorcamp 2014 (where we capsized)  
Hackerboat still shows up all over our internet presence



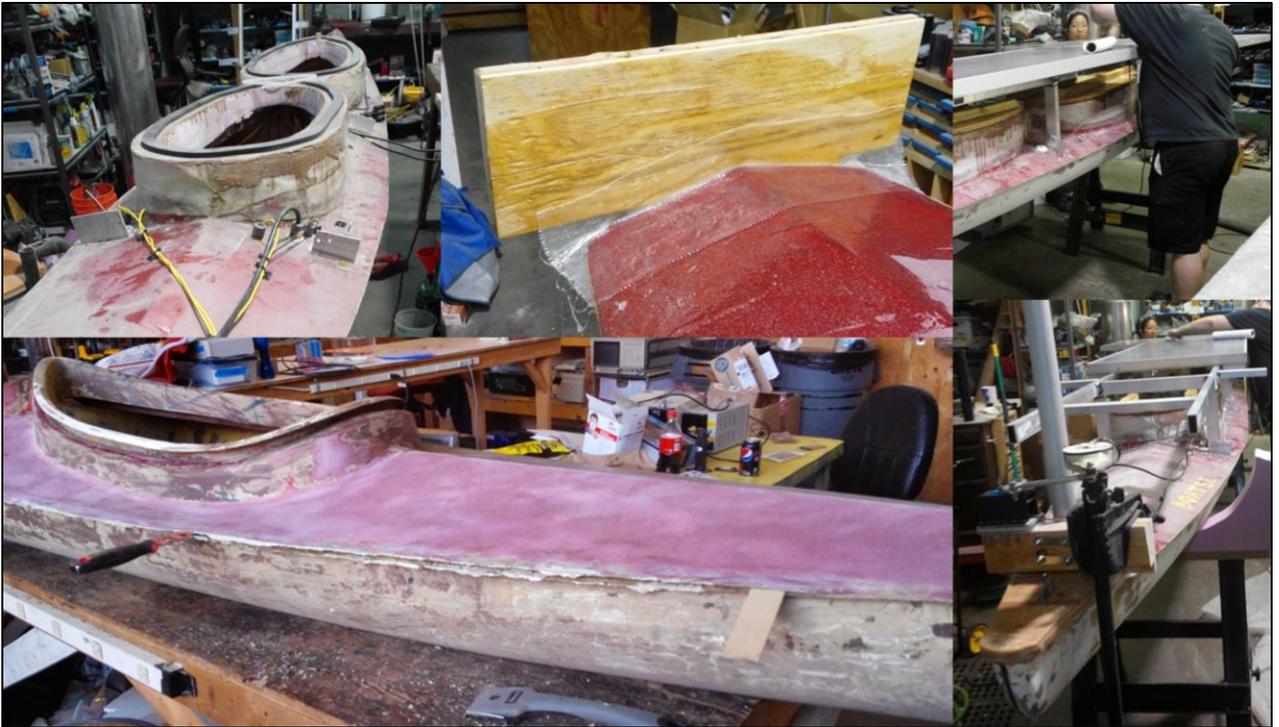
Left is right after painting for MFBA16, with diode stripe

Center is April testing

Line is 100 ft floating catch line

Right is first successful launch

We get our ship names from the Culture



Cheapest two hole fiberglass kayak on Craigslist

It had some issues...

Initial thought was our first boat would be solar-electric and go around the world

We reinforced the hull to provide mounting points

We created hatch coamings with foam and fiberglass so we had something to seal to.

Probably would have been no harder to scratch build.



Right hand images are fill and paint for MFBA16

Left images are internal shots showing...

Top is forward compartment with horn and battery carrier

Bottom is aft compartment with battery carrier, speed control box, and bilge pump



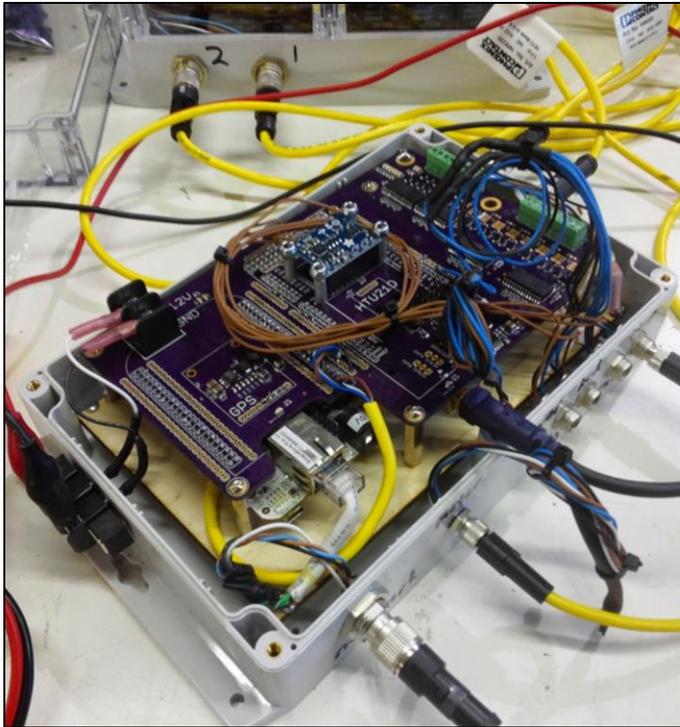
# Propulsion

- Minn-Kota 30 lb thrust trolling motor
- 30A @ 12V full throttle
- HiTec waterproof servo with ServoCity reduction gear
- Throttle control with a box of relays
- Max speed ~1.5 m/s (5.4 km/h)

Reduction gear was result of early thoughts that we were going to send the first boat around the world.

May delete it for better control authority

Next generation of brain will have a proper PWM controller



# First Brain

- Arduino & Beaglebone White federated system
- Dry box size restricts expansion/substitution
- Federation introduced unnecessary complications

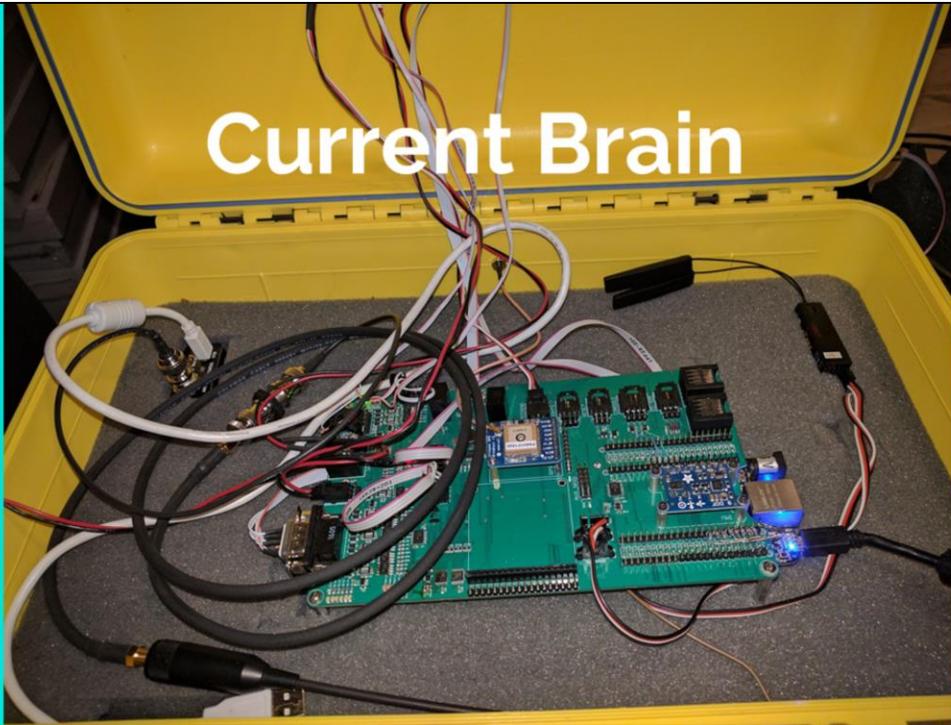
Original idea was for the BBW to sleep most of the time and the Arduino to handle low-level real time functions

You can see the motor drive relay box above the brain

Designed to connect to external 900 MHz IP bridge for ship to shore

In practice, range was only ~0.5 km due to low antenna height

# Current Brain



Uses BBB, no Arduino  
GPS and 9-DoF IMU installed on board  
dAISy in the top left, RC receiver in the top right  
Has space for attaching Adafruit cell phone module  
Has set up for connecting ethernet from BBB to PoE powered Picostation  
We're using a WiFi dongle on the BBB to connect to a MiFi for ship to shore  
Enabled drop-replacement with certain sat com systems

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rocketgeek/Dashboards/Hackerboat Control

# Web Control Panel

Command `\{"command":"SetMode","argument":"\{"mode":"Disarmed"\}\}` mode Disarmed,None,Waypoint,None Heading

Fault String None Rudder

Command Command Command Command

Waypoint Disarm Anchor Return

Position 0

Heading 152.13 Magnetic Deg

Battery 15.33 Volts

Use Adafuit.io beta for control panel & ship to shore  
Wish it allowed more feeds  
Wish it was faster



# April Testing

- Yellow is planned track (clockwise)
- Blue is actual path
- The boat fled waypoints rather than steering towards them
- Boat also not compensating for magnetic declination

Fleeing the first waypoint ran the boat into the rocks -- we used the trail rope to pull it off and continue.

We deleted the first waypoint and tried again

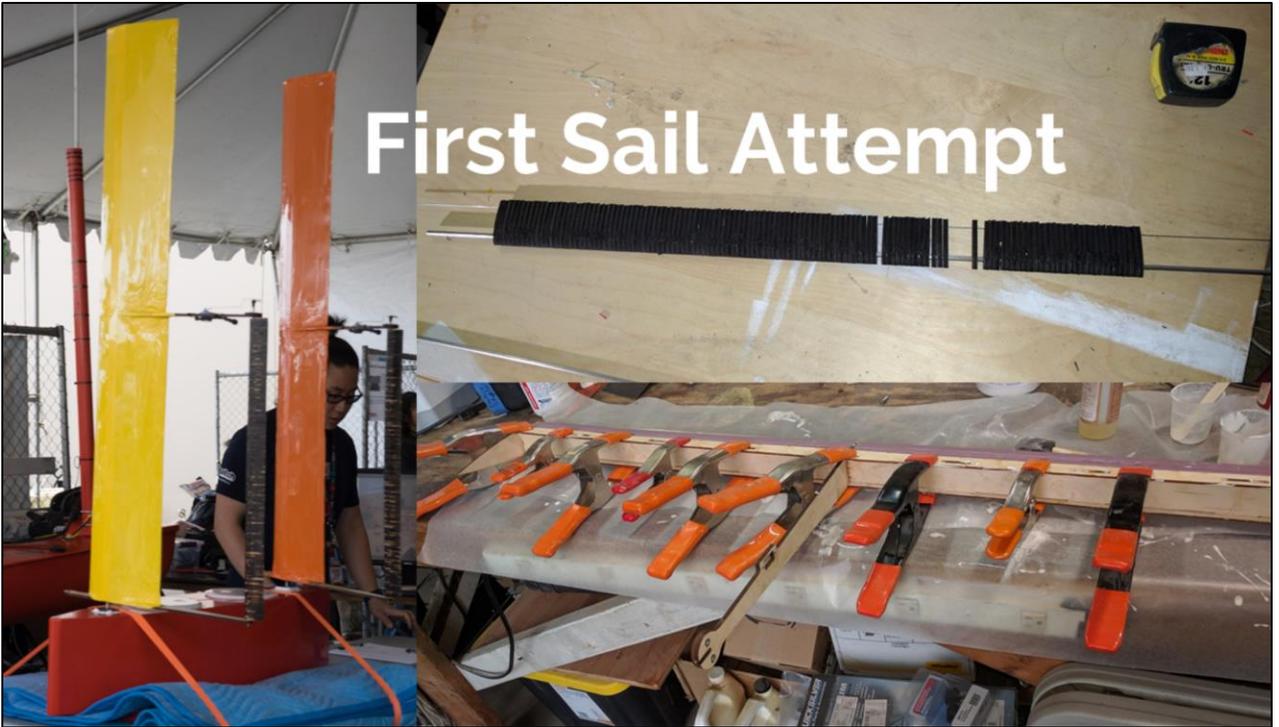
Then we figured out it was running from waypoints (but not before a third go)

Drove it around the large ship anchored out in the harbor before packing it in.

Was planning to test earlier in May, but a combination of family/work obligations on the part of the team and weather



Laser cut baltic birch FTW  
Uses Open Beam bearing blocks for the masts



# First Sail Attempt

Laser cut baltic birch, wire cut foam, and heat shrink film  
Tail is a stack of laser cut slices, aligned with stainless steel rods  
Wire cutting is way harder than it looks  
    Blew up a transformer!  
Won't balance because tail is too heavy and long  
First try at heat shrink film was not so successful...



# New Sails

- Combination of 3D printed and laser cut parts
- Electronics embedded in boom
- These can balance!

Designed with Fusion 360

Grid setups are made with Slicer

Made from printed ABS

All electronics and wiring embedded in boom (b/c 3D printing is awesome)

Printed with \$300 Monoprice printer

Laser cutting done at Metrix Create Space

# Summer 2017 Goals

- Extended TSV cruise (10 km+)
- Sailing under manual control
- Implement AIS ship avoidance
- Implement machine vision obstacle avoidance.

# More Information & How to Help

- We need ~\$15k to build the around the world boat.
- Patreon: [www.patreon.com/hackerboat](http://www.patreon.com/hackerboat)
- Hackaday.io: <https://hackaday.io/project/8522-project-ladon>
- Github:  
<https://github.com/JeremyRuhland/hackerboat>

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