BoatBot ASV: Finding the Cordelière

Background

- The Battle of Saint-Mathieu took place on the 10^{th} August 1512 near Brest, France.
- Opposing sides were the English and Franco-Breton fleets.
- Both sides were to see losses. The English lost their flagship “the Regent” and the Franco-Bretons lost their flagship “Marie la Cordelière”.

Background

The simultaneous destruction of Marie-la-Cordelière and the Regent.
Depicted by Pierre-Julien Gilbert

Contemporary picture of the Breton Marie-la-Cordelière and the English Regent flagships ablaze.
The Cordelière flies the Kroaz Du, whilst the Regent flies St. George's Cross.

Background

- In 2018, the French government, the Brittany region, universities and industry partners started to search for the wrecks of the sunken warships “Cordelière” and “Regent”.
- But….
- The trouble is no-one knows exactly where the Battle of Saint-Mathieu took place.

Determining the Location

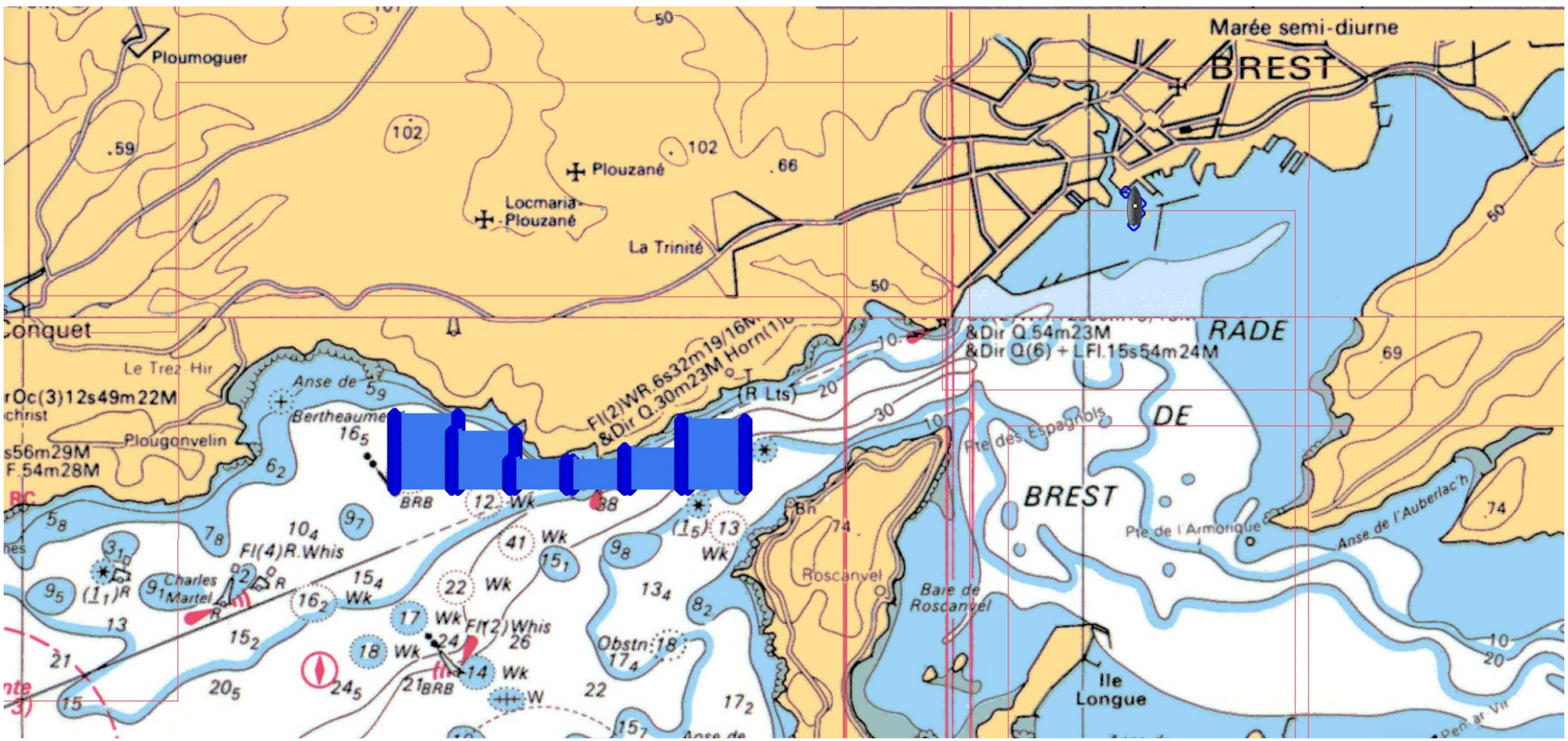
- Since earlier efforts to locate the ships…
- Tides and currents have been recalculated.
- Naval charts of the sea floor have been re-examined.
- Historians are looking through the few contemporary accounts of the battle, and the search is on for clues from parish and other archives.

Determining the Location

- Theories..
- French fleet was anchored near the goulet on the southern side of the outer bay, near the village of Camaret-sur-Mer, based on a contemporary report that it was sheltering from a southerly wind. Therefore, the battle must have taken place in waters to the north of Camaret.
- Based on this theory...
- Mr L'Hour has begun conducting back-and-forth combing operations with the vessel, the “André Malraux”, dragging an array of magnetic detectors and a sonar.

Determining the Location

- Based on previous research and theories, the search area was defined.

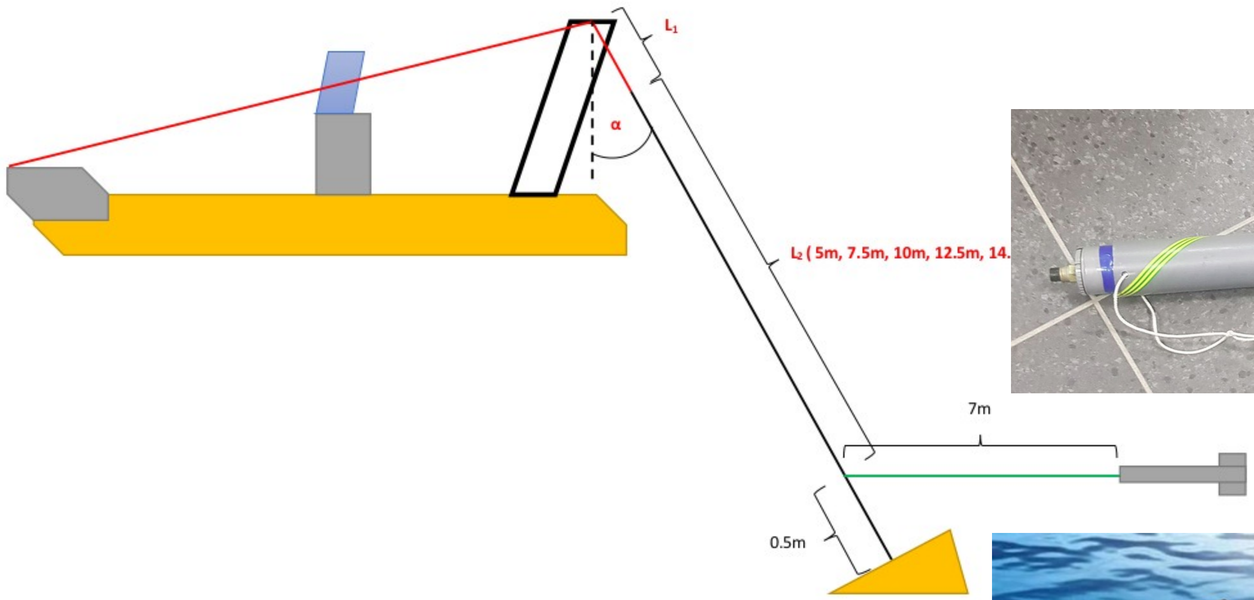


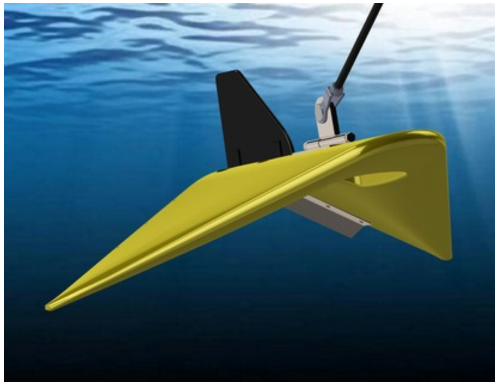
Construction of the ASV

- In order to find the Cordelière, we assumed the detection of the warships cannon would be the most efficient method.
- We needed an Autonomous Surface Vessel capable of towing a magnetometer sensor to generate magnetic maps of the sea floor such that we could spot anomalies and identify the ship wreck via it’s canon.

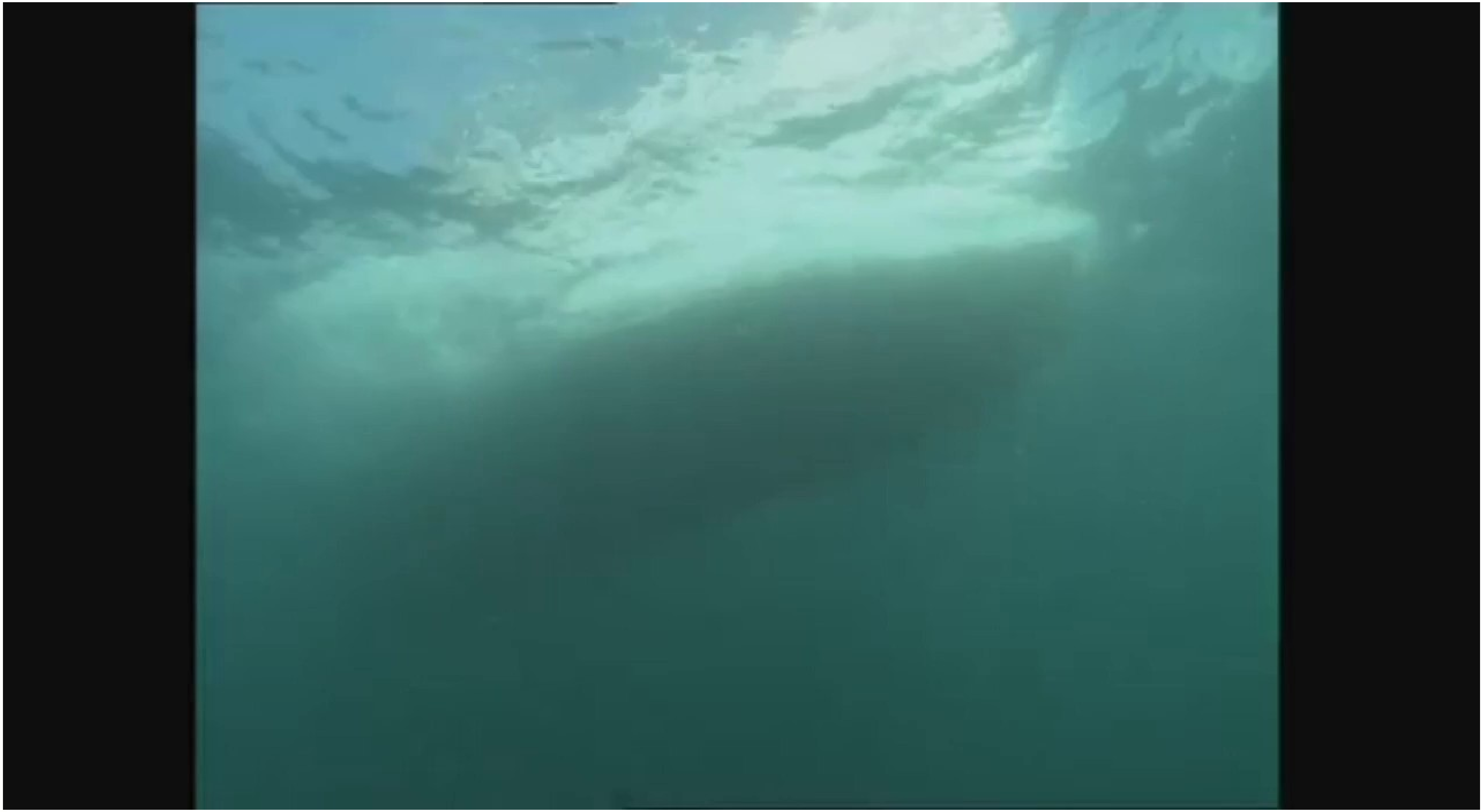
Construction of the ASV

- BoatBot tows a magnetometer which maintains it’s submersion via a depressor.



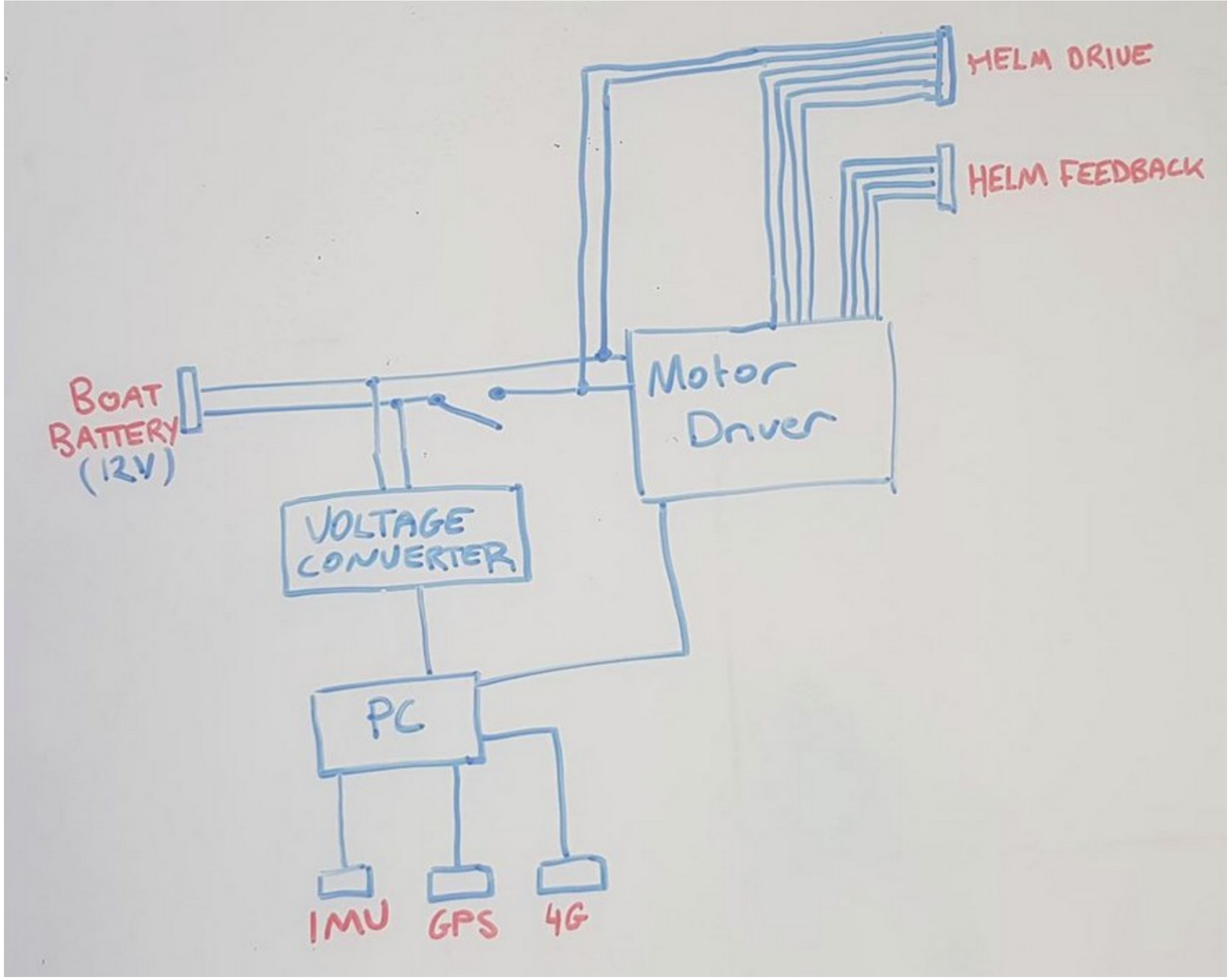


Construction of the ASV



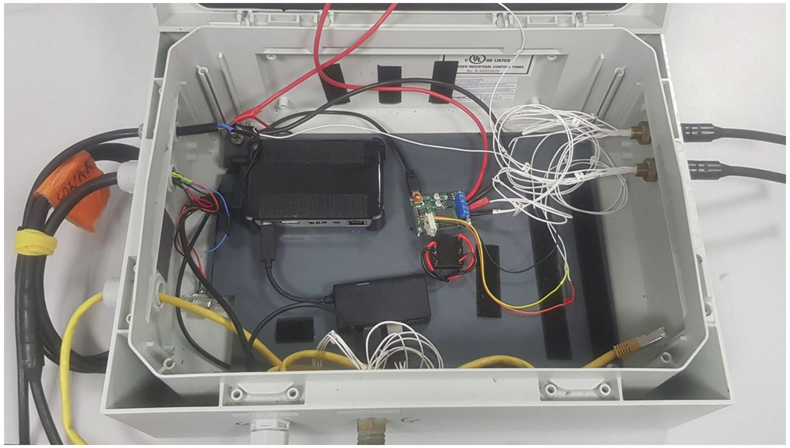
Construction of the ASV

- Prototype controller system overview (Hardware)



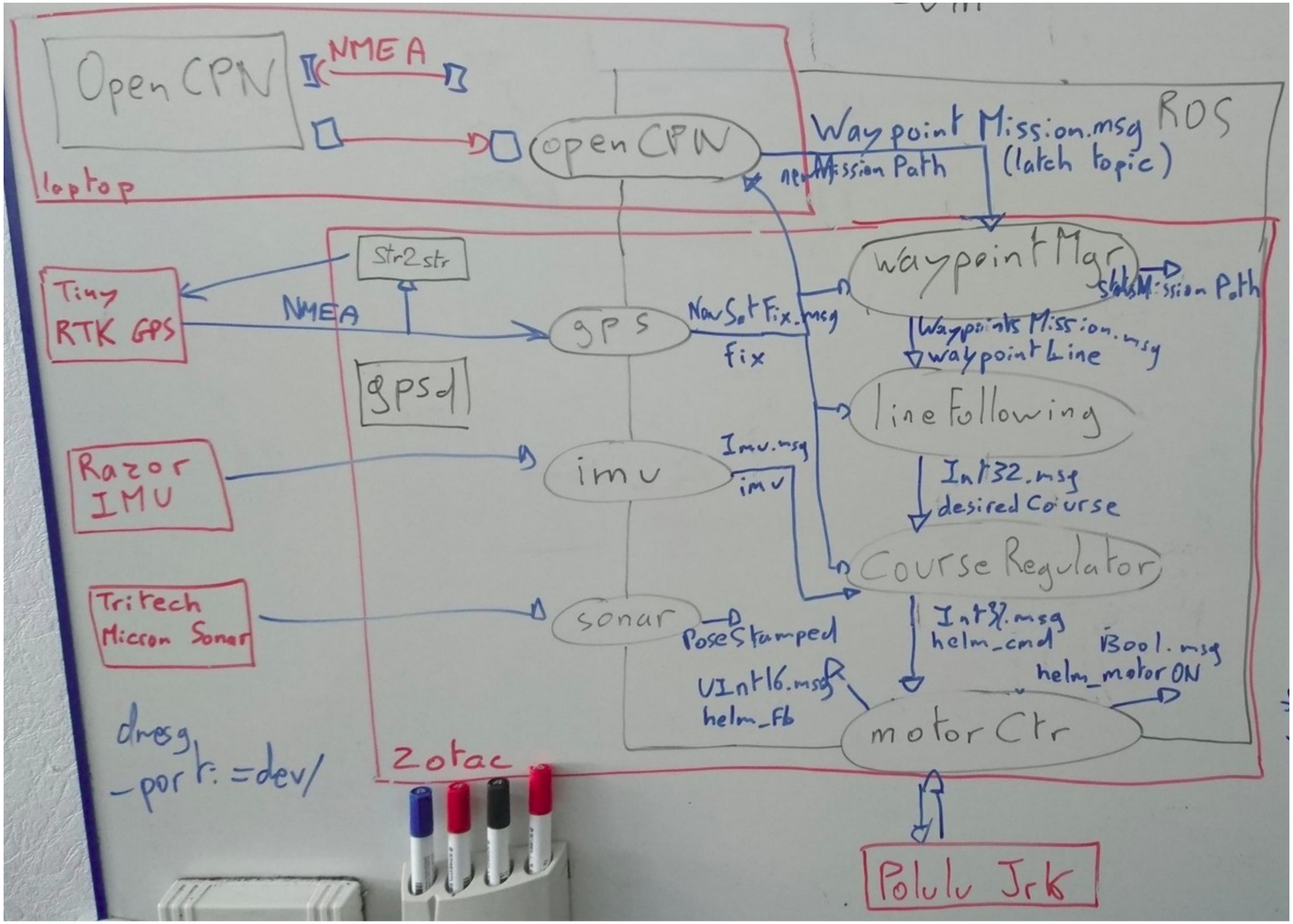
Construction of the ASV

- Prototype controller hardware…
- ZOTAC (Ubuntu / ROS), SBG IMU, U-blox GPS, USB Motor Controller, 4G USB Modem
- Large, cumbersome, messy, not exactly waterproof...



Construction of the ASV

- Prototype controller system overview (ROS)

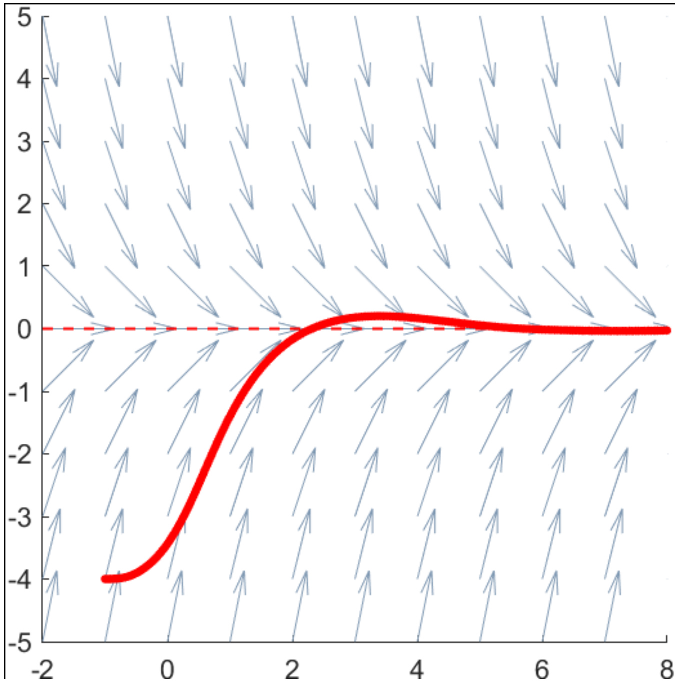


Construction of the ASV

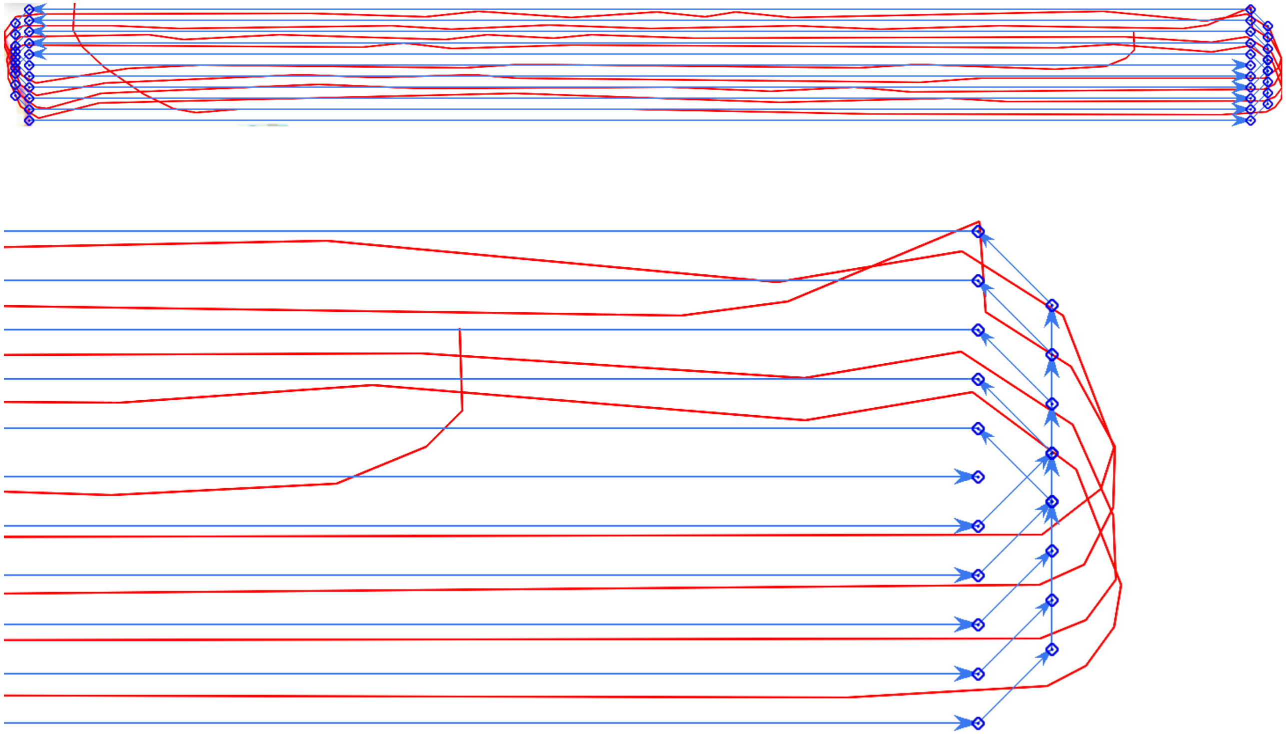
- Prototype controller software...
- Based on a PID + arctan controller
- Controls BoatBot heading based on distance to desired track via a vector field

Construction of the ASV

- Prototype controller results...



Simulation results: Disregarding currents and wind



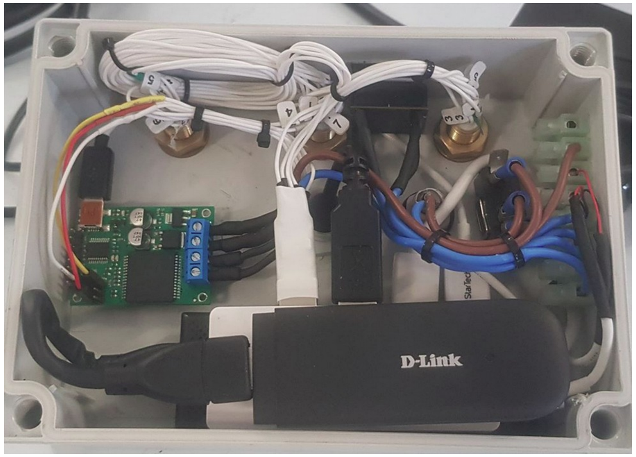
Physical results: OpenCPN Track demonstrates overshoot

Construction of the ASV

- Prototype controller issues...
- Does not take curvature of vector field into account
- PID controller can only be optimized for 1 speed (3 Knots)
- Results in overshoot and oscillations

Construction of the ASV

- Final product hardware…
- Intel Compute Stick (Ubuntu / ROS), USB motor controller, U-Blox GPS, SBG IMU, 4G USB modem
- Much more compact, plug and play, actually waterproof, easier to work with



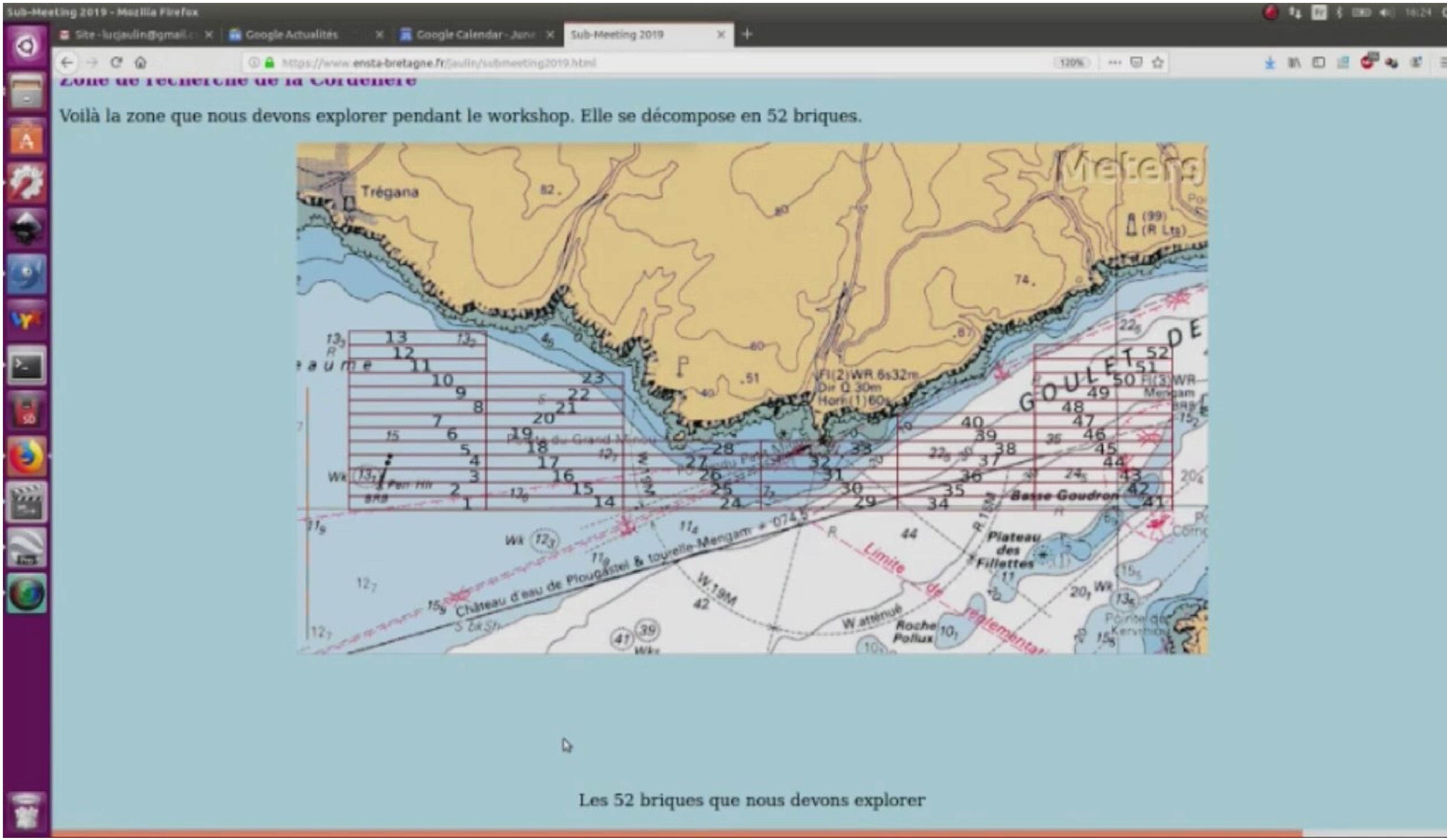

Results / Data Visualization

- We were able to map several briques during the SubMeeting 2019. Namely briques 6, 7, 8, 9, 10 and 52
- Each brique takes approximately 1.5 hours to map
- In order to construct the magnetic maps of the briques, the GPS and magnetometer must be merged via timestamps

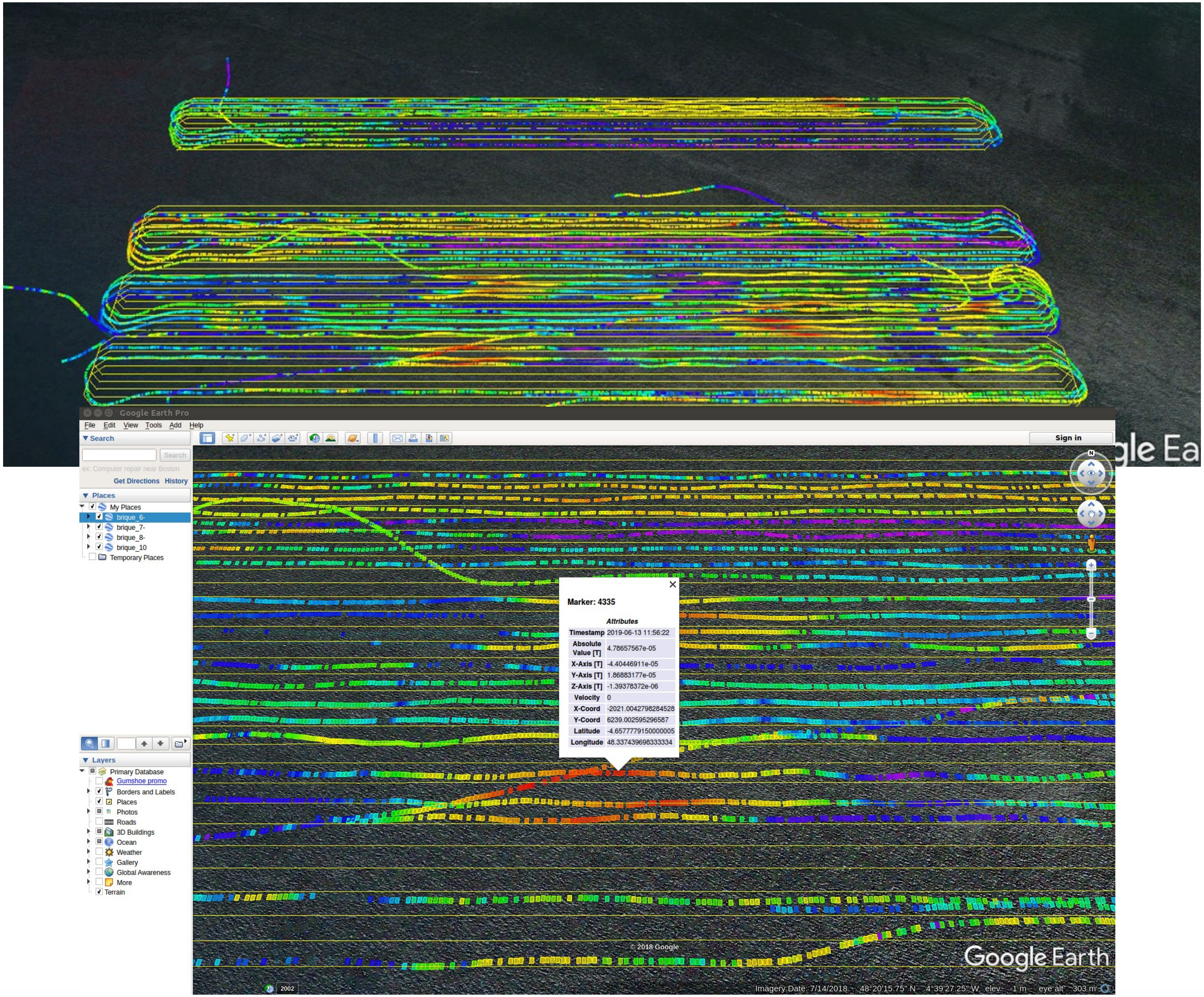
Results / Data Visualization

- This was done using Python3
- Data was merged from the GPS and magnetometer logs, normalized then used to construct magnetic heat maps that could be visualized using Google Earth

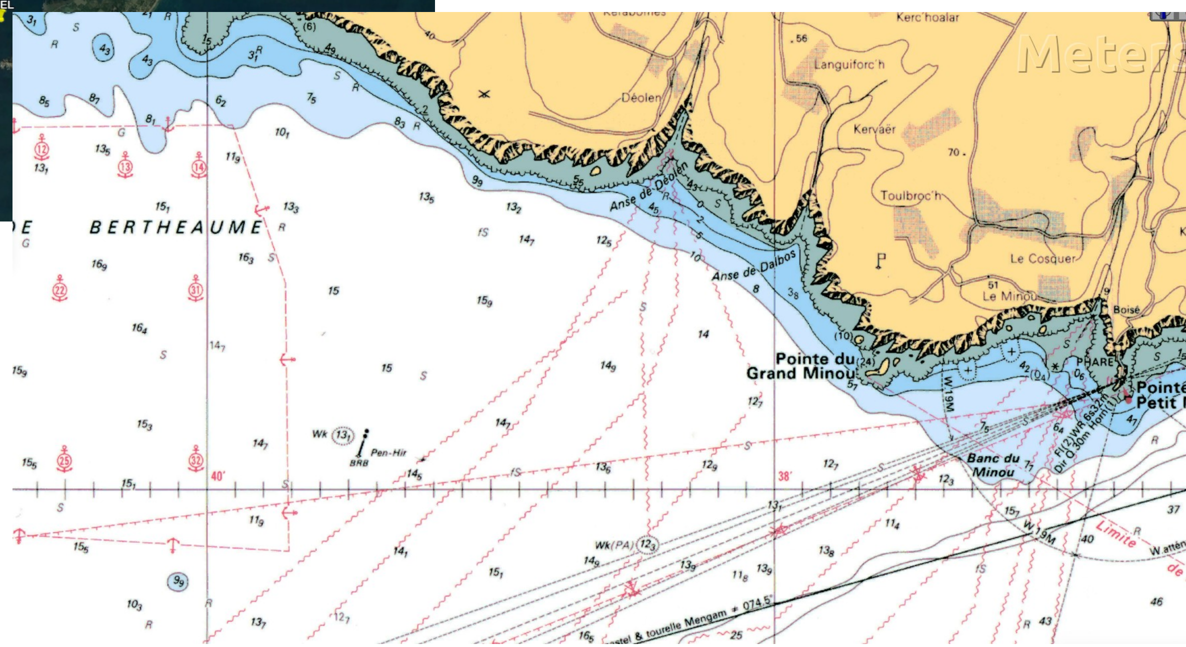
Results / Data Visualization



Results / Data Visualization



Results / Data Visualization

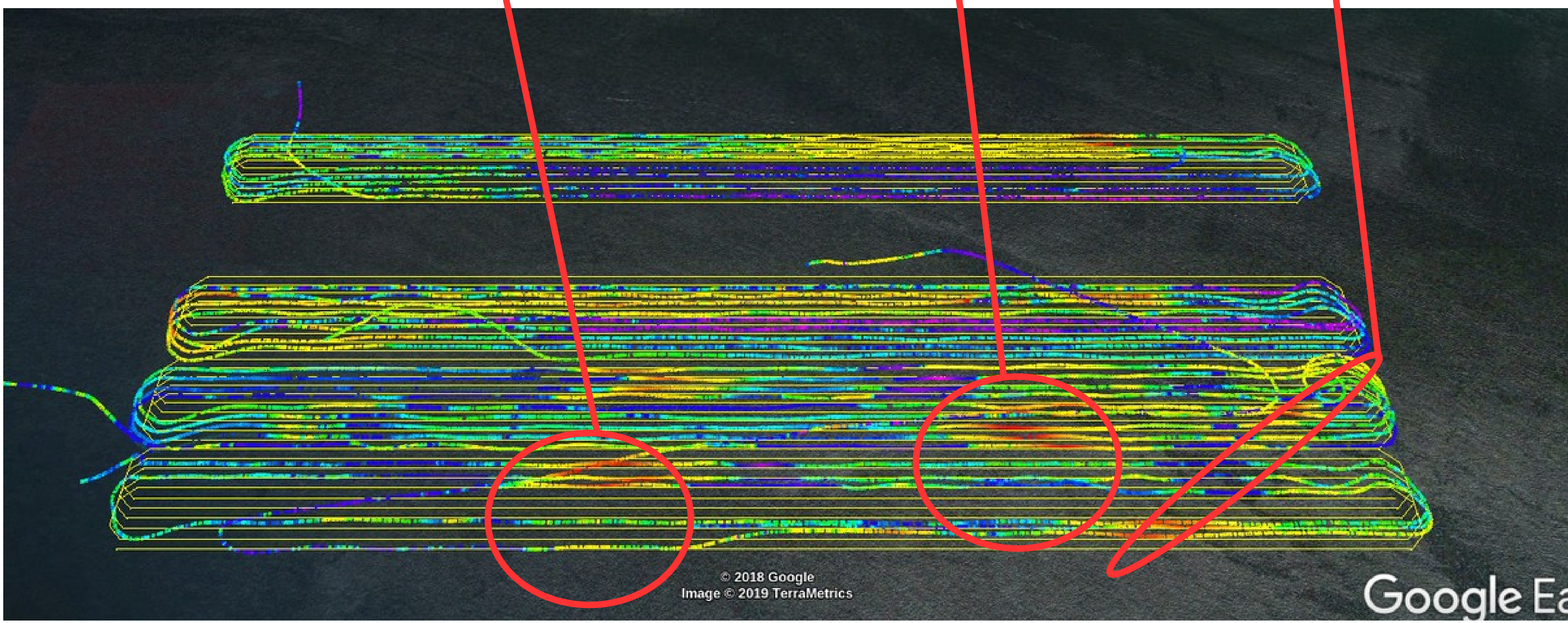


Results / Data Visualization

Shipwreck of a small steamship “Penhir”. The ship was on her way
from Brest to Nantes when she hit the rocks at the bottom and sank in 1935.

Geological fault

Possibly an old cable

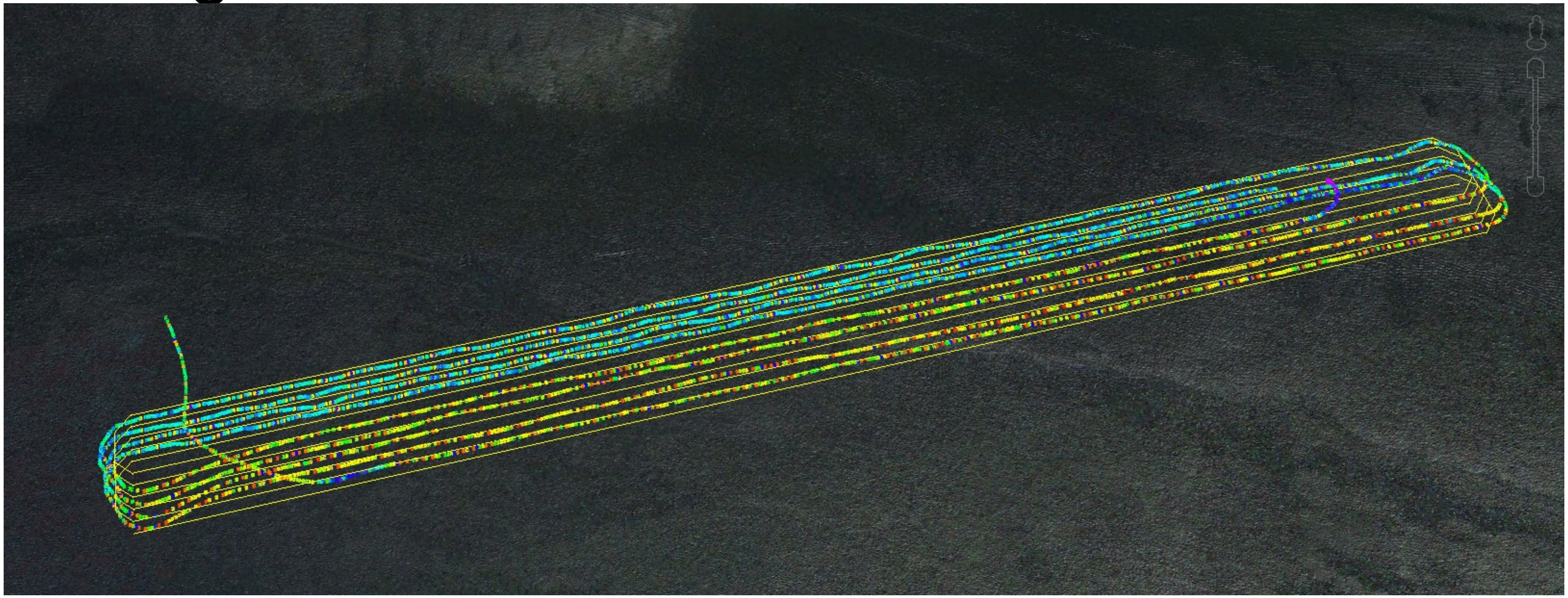


Future Improvements

- Controller does not follow GPS tracks optimally.
- Controller does not control speed of boat. Difficult to maintain desired speed in strong currents.

Future Improvements

- Controller does not control speed of boat. Difficult to manually maintain desired speed in strong currents.



Current Progress / Future Improvements

- <u>Step 1:</u> Linear feedback controller designed to follow a given vector field perfectly under optimal conditions → based on a Dubin's car

$$\begin{pmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{pmatrix} = \begin{pmatrix} \cos x_3 \\ \sin x_3 \\ u \end{pmatrix}$$

$$u = -x_3 - \arctan x_2 - \frac{\sin x_3}{1 + x_2^2}$$

Current Progress / Future Improvements

- Step 2: Linear feedback controller that takes currents and speed over water into account → requires estimation of currents

$$\begin{pmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{pmatrix} = \begin{pmatrix} p_1 \cdot \cos x_3 + p_2 \\ p_1 \cdot \sin x_3 + p_3 \\ u \end{pmatrix}$$

$$a = p_1 \cdot \cos x_3 + p_2$$
$$da = -p_1^2 \cdot \sin x_3$$
$$b = p_1 \cdot \sin x_3 + p_3$$
$$db = p_1^2 \cdot \cos x_3$$
$$w = \frac{a \cdot db - b \cdot da}{a^2 + b^2}$$
$$y = \arctan\left(\frac{p_1 \cdot \sin x_3 + p_3}{p_1 \cdot \cos x_3 + p_2}\right) + \tanh x_2$$
$$u = \frac{-y - b \cdot (\operatorname{sech} x_2)^2}{w}$$

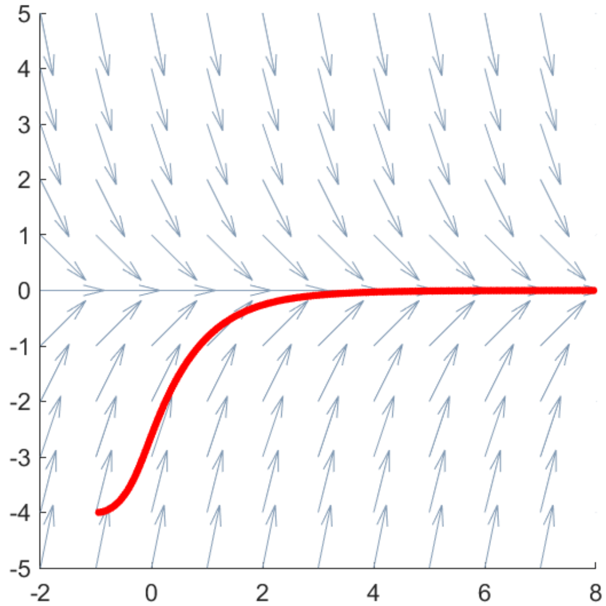
Current Progress / Future Improvements

- <u>Step 3:</u> Use of a second order model, required for estimating speeds with a Kalman filter and to take accelerations into account

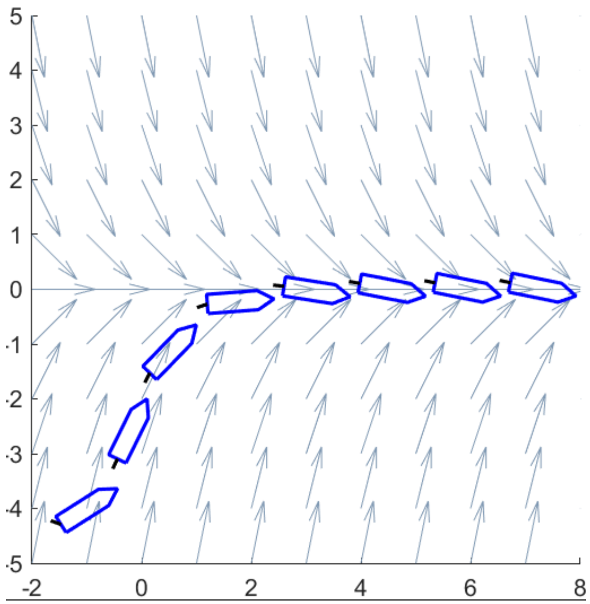
$$\begin{pmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \\ \dot{x_4} \\ \dot{x_5} \\ \dot{x_6} \end{pmatrix} = \begin{pmatrix} \cos x_4 + p_2 \\ \sin x_5 + p_3 \\ x_6 \\ p_1 \cdot \cos x_3 + p_2 \\ p_1 \cdot \sin x_3 + p_3 \\ p_1 \cdot sinu - x_6 \end{pmatrix}$$

Current Progress / Future Improvements

- New controller simulation results…



Fixed speed (1)
Current = 0 North



Fixed speed (1).
Current = 0.2 North

Conclusion

- With the prototype system, the ASV was able to successfully survey several briques and obtain reasonably accurate data
- Since then, various improvements have been made to both the hardware and software of the ASV which should serve to improve data accuracy and make the surveying process easier
- We were not able to locate the Cordelière, yet…

Questions?