Protei

Open Source Sailing Drone

Abstract :

Authors :

ISBN :

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Introduction

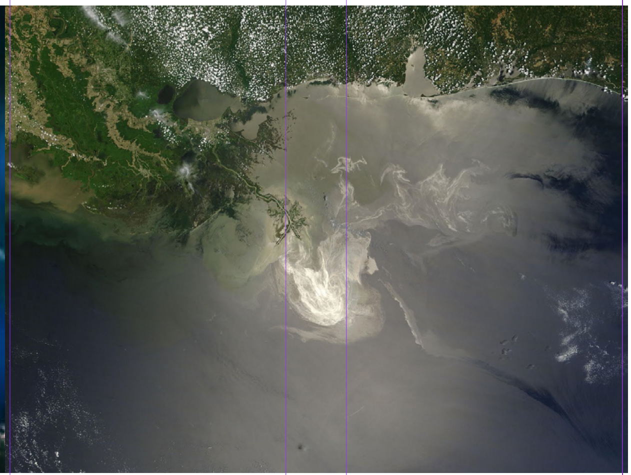
Open_sailing is a growing international community, with the goal of developing open-source technologies to explore, study, and preserve oceans. This summer, a group converged in Rotterdam to develop Protei_006, a fleet of low-cost, shape-shifting, DIY, semi-autonomous oil-collecting sailboats, that each sails upwind and collects oil sheens off the top of the water near the sites of spills. This robotic sailboat is self-righting, durable, inexpensive, and easily reproducible.

The goal this summer was to develop, test and document the making of a full-sized (3 meter) Protei vessel, as well as to emphasize that an articulated hulled boat sailing upwind can more effectively collect oil than the existing pollution-cleaning technologies. Current methods for cleaning oil pollution on water, such as those implemented in the BP oil spill in the Gulf of Mexico, only collect 3% of materials, expose workers to toxic chemicals, and are constrained by weather conditions (Kerr, 2010).

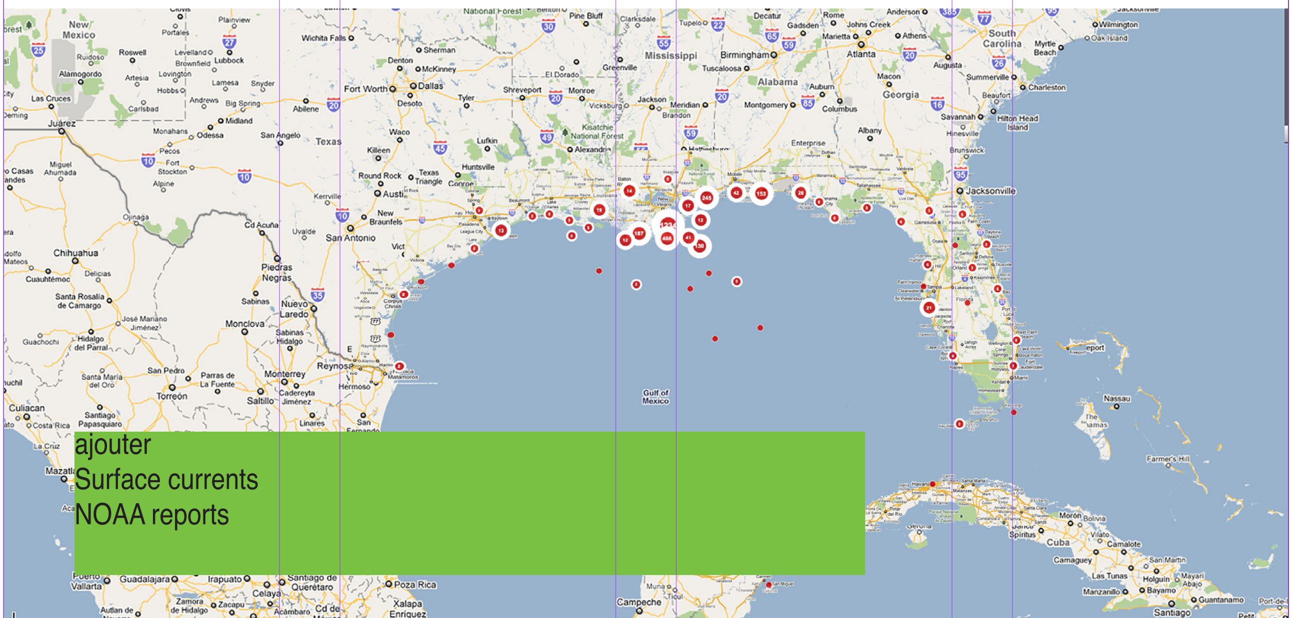
Protei, alternatively, is unmanned, uses accessible, inexpensive or recycled materials, and tolerates chemically hazardous and rough weather conditions. Because of its open hardware philosophy, and its ease and cost of reproduction, it can be constructed and deployed on a large scale. It can eventually be appropriated for other purposes, such as cleaning other chemical pollutants and material waste off of water, as well as ocean surveillance.

The design and implementation of Protei will be an ongoing evolution, as people all over the world continue to build and deploy it, and contribute to its efficiency and robustness.

Solving a man-made problem with the power of nature



General informations about the oil spill
Amount
Area
Type of oil
Worst environmental disaster in the history of USA
Twchnology used.



ajouter
Surface currents
NOAA reports

diagram with order of cleaning

The Oil spill?

Crude oil fromn the depths of the oceans

Brief characterization of an oil spill and the different orders of cleaning

[diagram]

1st order / at the source, closing taps with ROVs

2nd order/ Capturing right at the source with a “top kill hat” or a bell

3rd order / perimeter on the surface

>> 4h order/ cleaning out of control spreading in thin sheens to heavy slacks and tarballs (controlled burning, dispersant, skimmers,

5th / containement and absorbtion on large area

6th order / on the beach

7th order / at the bottom of the ocean

(I made up that classification from my study of the oil spill in the gulf of mexico)

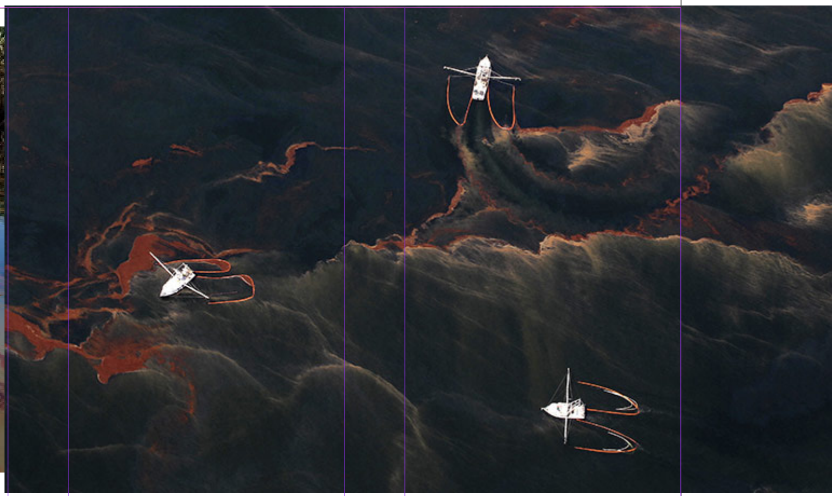
Our class of oil.

large areas

thin sheen of oil

Oil going towards the sea (as opposed to go towards the land)


greenpeace



AP

The issues related oil collected by fishermen with repurposed fishing vessels :

Exposing health of cleaners -> autonomous

Cannot operate during a storm -> can operate during a storm

Cannot operate at night -> can

Sensing limited to human eye sight -> sensing technology + based on oil prediction program with wind and surface current trajectory

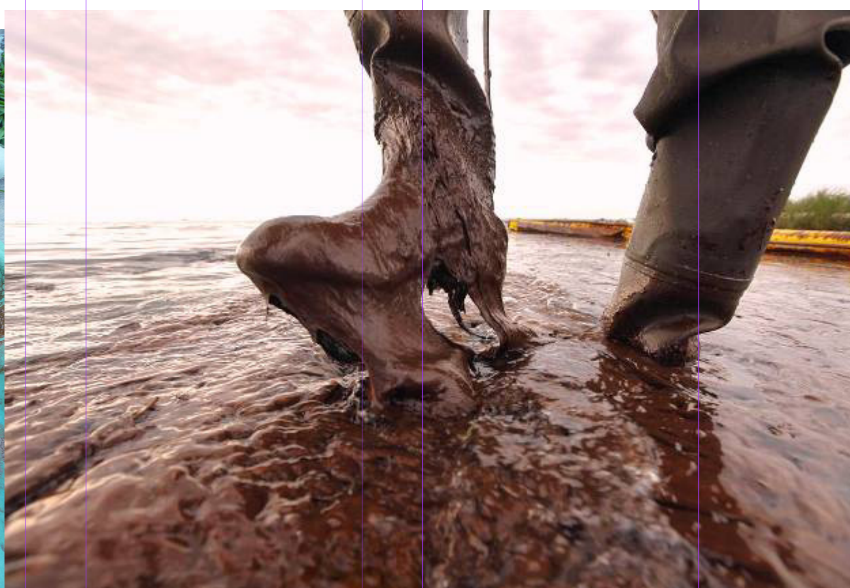
Autonomy of vessels -> renewable energy.

Oil-powered crafts -> renewable energies

Expensive Cost -> cheap

Proprietary -> Open Hardware so we can solve other probems with the technology.

Environmentaly destructive (drving oil powered vessels) -> using wind, also in sync with the environment.



Wind and surface currents

WInd ans surface currents is what moves the oil. We wan tuse the same froces to clean up the oil.

3 digrams

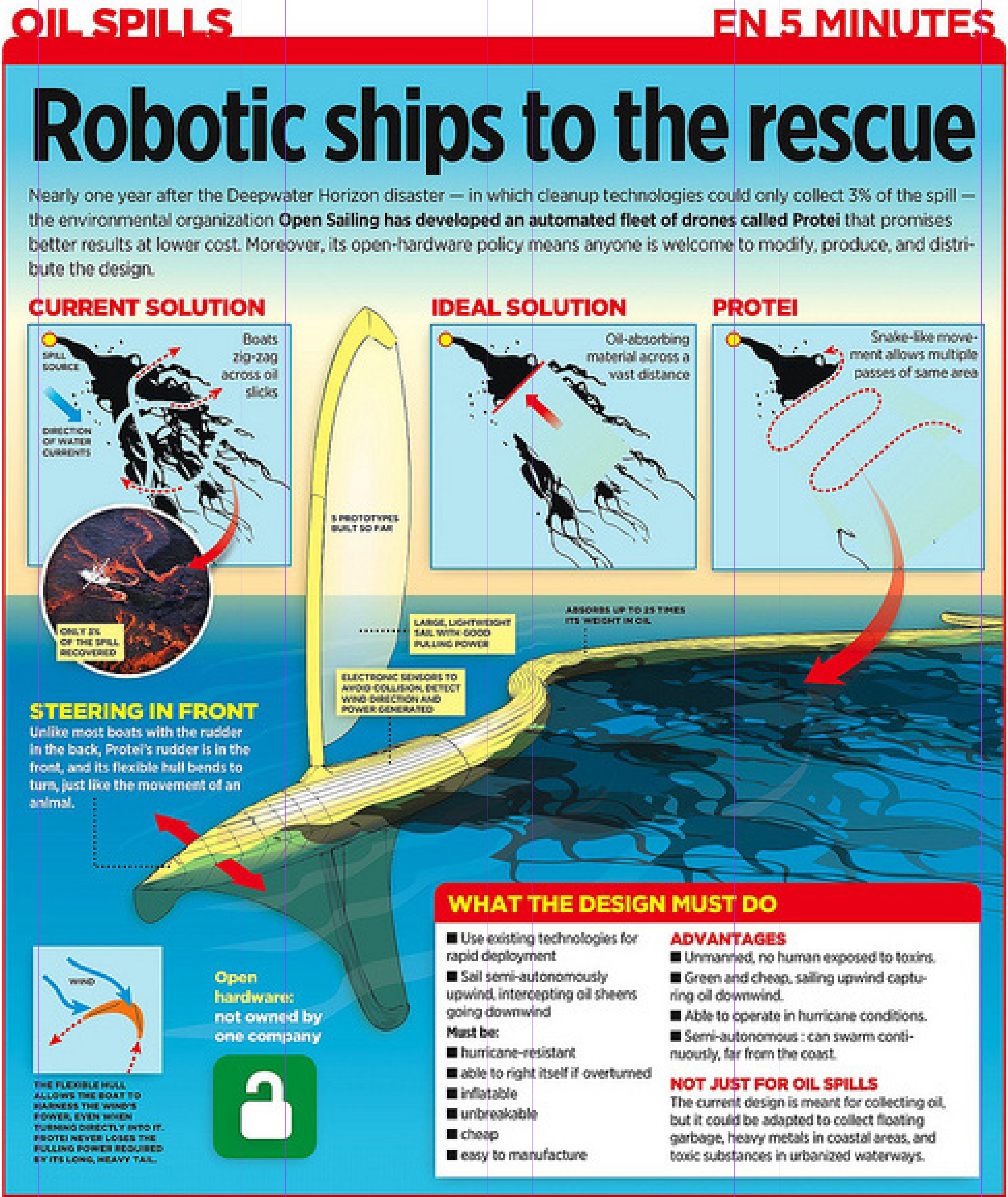
-skimmers cleaning celan path in a sea of oil
- one long piece going upwind
multiple long pieces going wind
protei taking upwind.

diagram with order of cleaning

diagram with order of cleaning

diagram with order of cleaning

diagram with order of cleaning



OIL SPILLS | EN 5 MINUTES

Robotic ships to the rescue

Nearly one year after the Deepwater Horizon disaster — in which cleanup technologies could only collect 3% of the spill — the environmental organization **Open Sailing has developed an automated fleet of drones called Protei** that promises better results at lower cost. Moreover, its open-hardware policy means anyone is welcome to modify, produce, and distribute the design.

CURRENT SOLUTION

IDEAL SOLUTION

PROTEI

STEERING IN FRONT

Unlike most boats with the rudder in the back, Protei's rudder is in the front, and its flexible hull bends to turn, just like the movement of an animal.

WHAT THE DESIGN MUST DO

- Use existing technologies for rapid deployment
- Sail semi-autonomously upwind, intercepting oil sheens going downwind

Must be:

- hurricane-resistant
- able to right itself if overturned
- inflatable
- unbreakable
- cheap
- easy to manufacture

ADVANTAGES

- Unmanned, no human exposed to toxins.
- Green and cheap, sailing upwind capturing oil downwind.
- Able to operate in hurricane conditions.
- Semi-autonomous : can swarm continuously, far from the coast.

NOT JUST FOR OIL SPILLS

The current design is meant for collecting oil, but it could be adapted to collect floating garbage, heavy metals in coastal areas, and toxic substances in urbanized waterways.

SOURCES : OPENSAILING.NET, PROTEI.ORG

RECHERCHE KINIA ADAMCZYK — INFOGRAPHIE JUSTIN STAHLMAN, AGENCE QMI

ideas to contribute to the science of sailing, fluid mechanics and oil spill cleaning

Why a saili boat with an articulated hull?

1/ back rudder
2/ front rudder
3/ front and back rudder
4/ articulated hull

Some ideas to contribute to the science of sailing with an articlated hull
low speed implication
Better directional control of long heavy loads
Better power control of long heavy loads
Upwind sailing (with articulated hull + 2 sails)
Better control of heading and resistance to lateral drift with more wet surface
Less turbulences (no separate centerboard + Rudder)
Less mechanical effort, less energy on actuation
Less impact on waves (flexible body following waves)
High speed implication
Lateral lift
Optimization of upwind sailing
Optimization of trajectory

Frequently asked questions

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Scope

This manual documents the building of Protei by the Protei_team. This manual has been put together in from June 1st, 2011 and September, 11th 2011 in Rotterdam. It is aimed at describing the design and construction of the Protei. It is not a detailed construction manual, but it should provide sufficient information to motivation, versions and research goals behind the design of the successive Protei versions.

As well as providing background information about the project, the instructional portion of this manual is divided into the mechanical construction and the electrical design, as the Protei team was divided into these sections in building this prototype. The mechanical and the electrical elements should be developed in parallel, as they are closely linked.

Each section is divided into subsections corresponding to specific structural elements, for example, the sail, the winch, the cable system, and the GPS. For each element, there is overview information, specific information on its construction, and troubleshooting tips.

How to use this manual

The architecture of this manual is highly modular so one can download and print on demand an isolated chapter and still have a self standing meaningful document. The content of this manual is expandable, anybody is welcome to expand a section or suggest new ones. Just as we build succesive versions of Protei, successive version of this manual are edited..
The size format of the paper is industry standard A4, published on-demand for environmental concerns. The binding of the manual is preferrably a ring binder so each reader can easily add notes and expand this documentation.

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Intellectual Property
Open_Hardware

The typical business model for a company pursuing technological innovation generally operates in the following order of priorities: Profit, technology, environment, people;(um, i (gaby) sort of forgot - have to check if this makes sense). Protei, on the other hand, reverses that business model, making the highest priority the environment, followed by the contentment of the workers, followed by the technological developments, followed by profit. ...This business model lends itself to the open-source nature of the project.

talk about challenges - how to make profit / succeed with this business model longer term... efficiency in the work environment; legal issues

The concept of Protei functions primarily as an open-source project. The design will be an ongoing evolution, as people throughout the world continue to build and implement it, and contribute to its efficiency and robustness. Its implementation depends on people willingly participating, collaborating, and sharing unique skillsets. It depends on accessible information and affordable components, and the sharing of ideas based on a multitude of areas of expertise.

Protei is made of open-source hardwares and softwares for the control, power and communication (between the vessel and an operator on land), including Arduino, Xbee, and a variety of sensors. Many of the mechanical components and materials are extracted from common and industrial products, such as power drills, plumbing equipment, and intact wooden scraps.

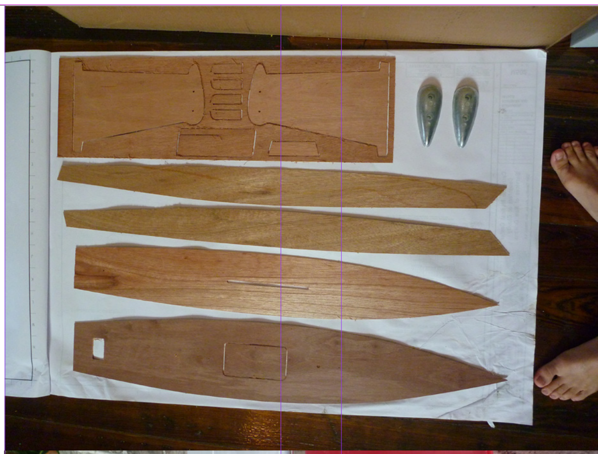
The entire nature of the construction of Protei is based on an open-source approach. Rather than a hierarchical chain of command, people share their own ideas for each aspect of the project, including hardware, software, fabrication, design, and testing.

In order to successfully grow into a fleet of DIY drones that can have impact on the oceans, the team needs to document, distribute and share the information of the mechanical build and electronic components. This feeds back into Protei's success, which depends on ongoing contributions to its design and functionality.

Open_Hardware

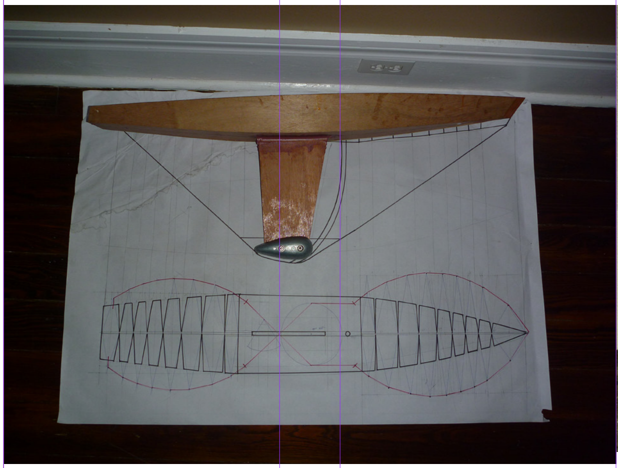
Object mechanical design	Documentation, textes, photos, videos, communication materials	Codes	Name, tradmark

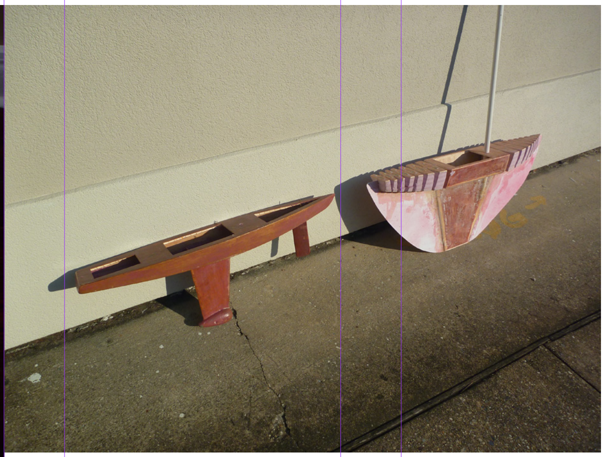
Protei_001

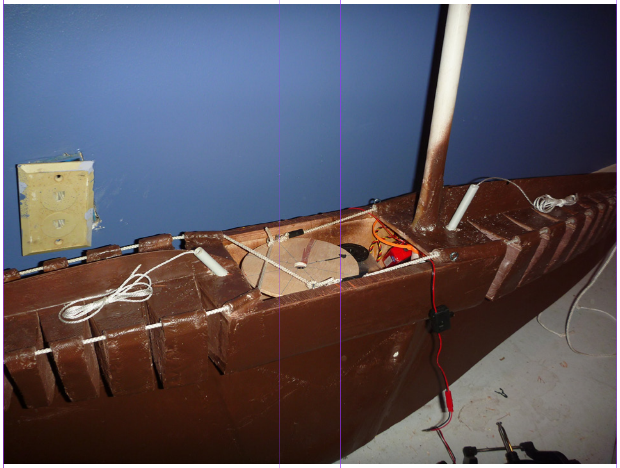


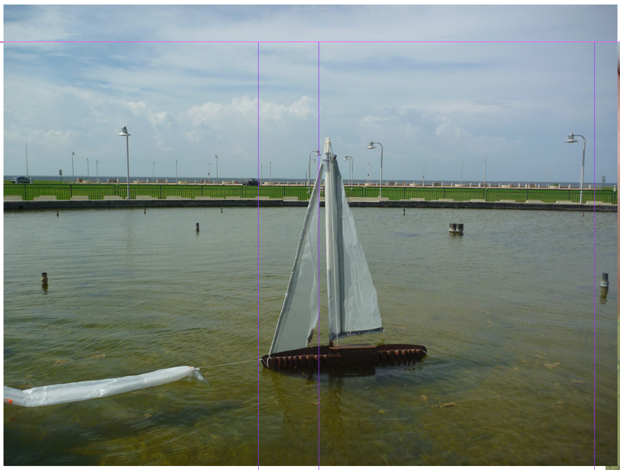

LOUISIANA
BUCKET
BRIGADE
Clean Air, Justice, Sustainability.

Protei_002

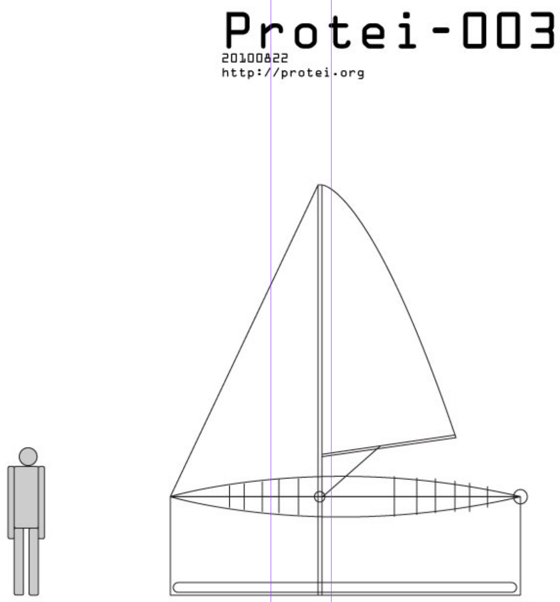


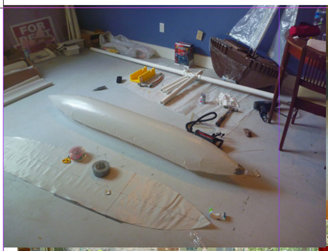






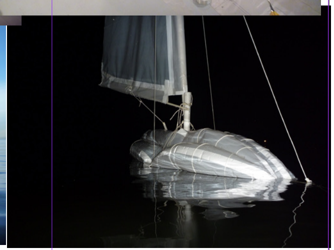
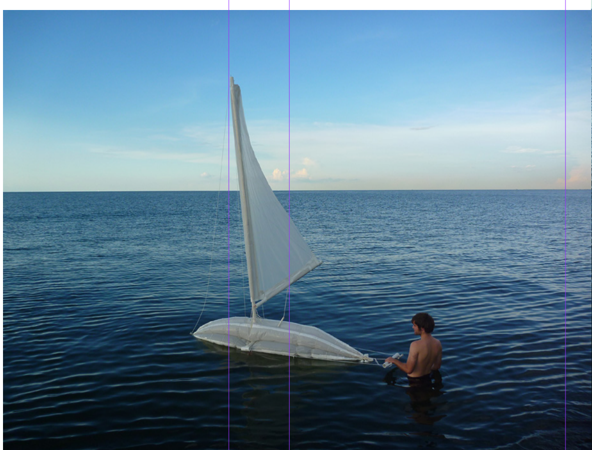
Protei_003



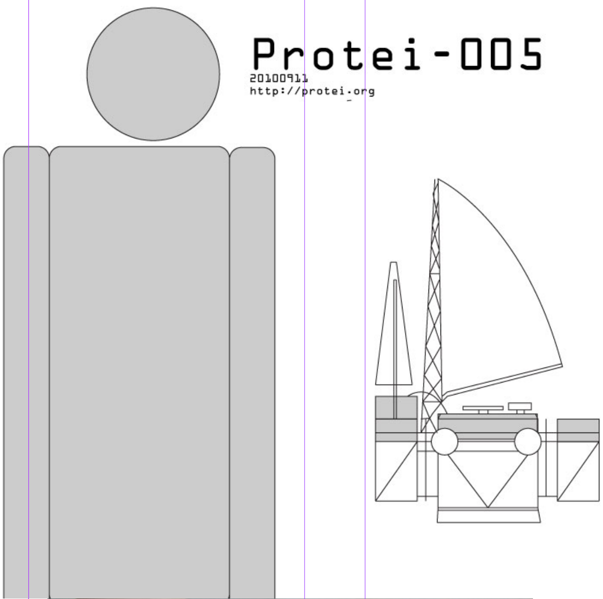


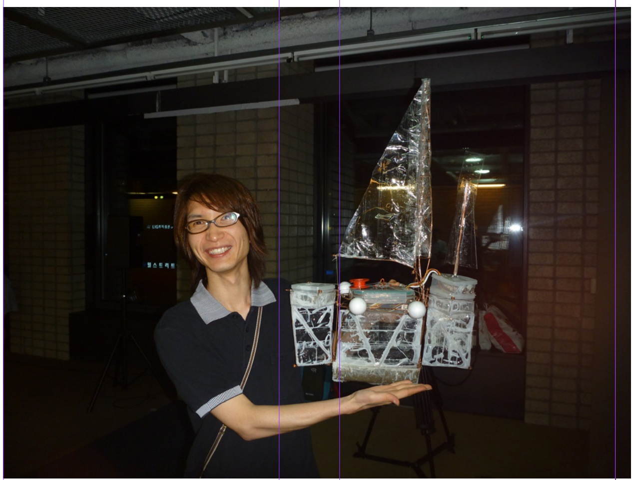


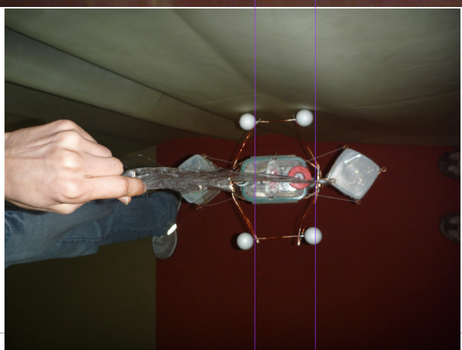


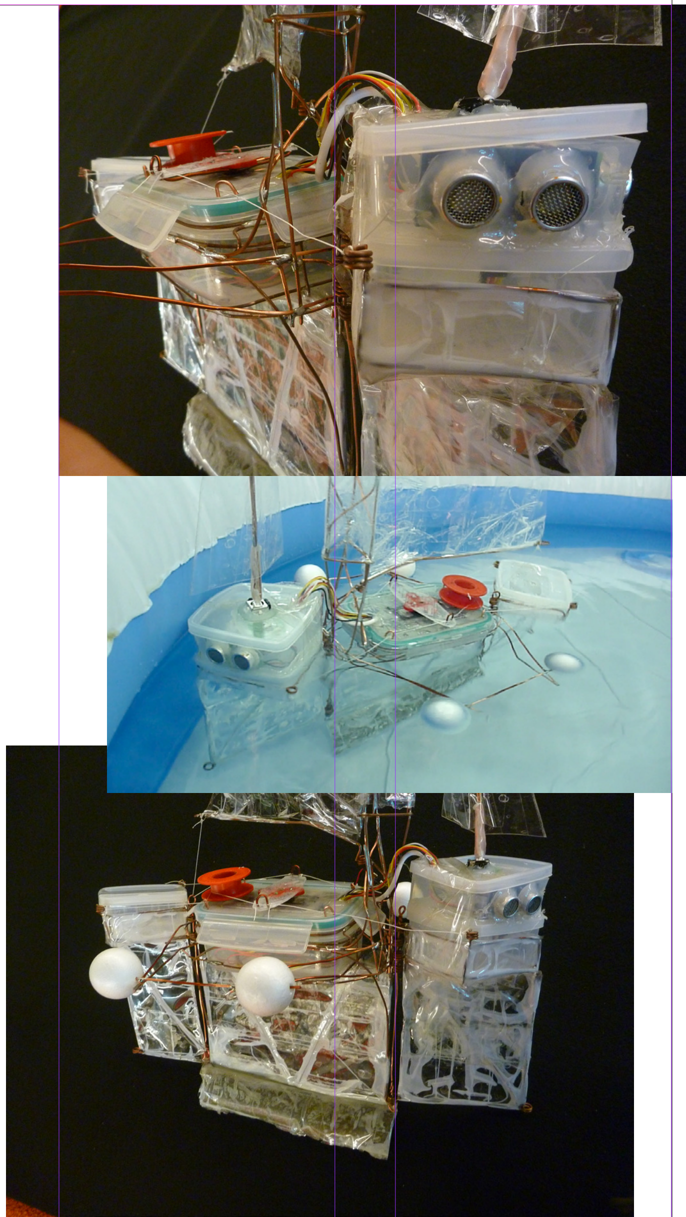





Protei_005

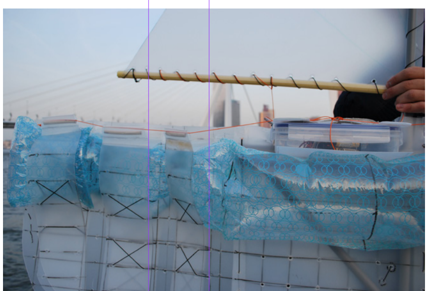


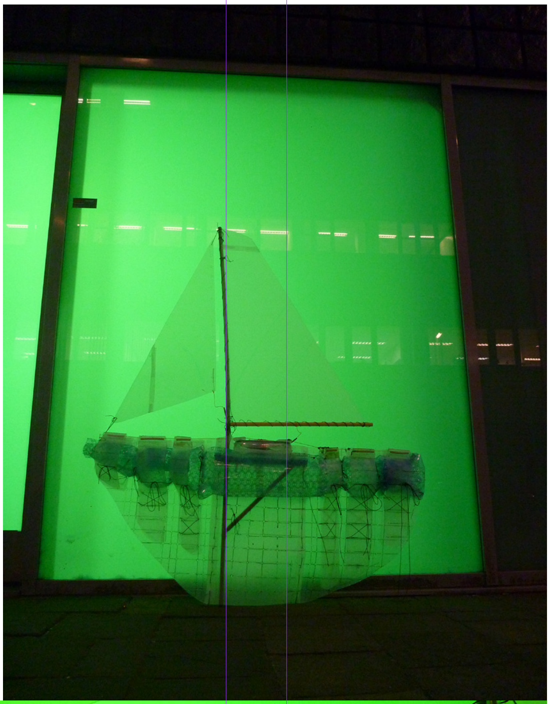


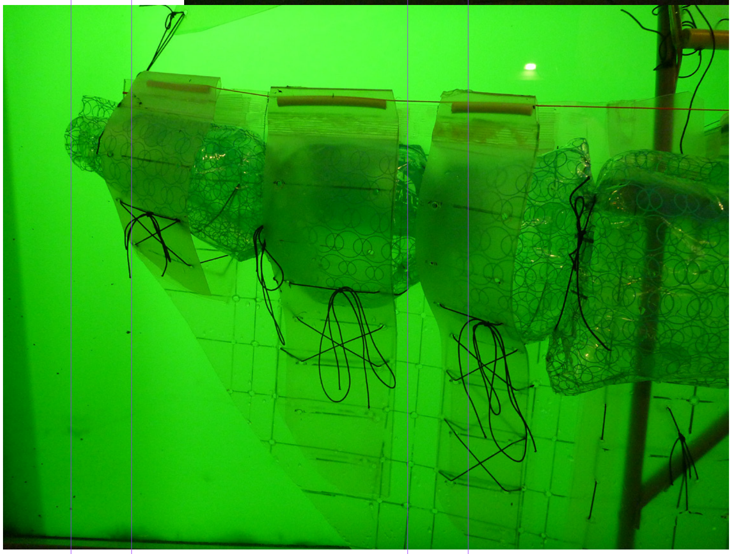




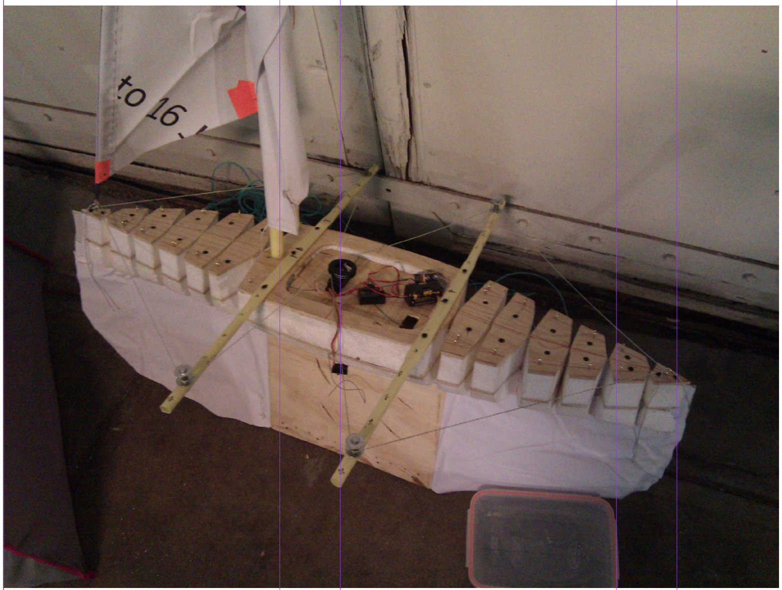
Protei_005.1

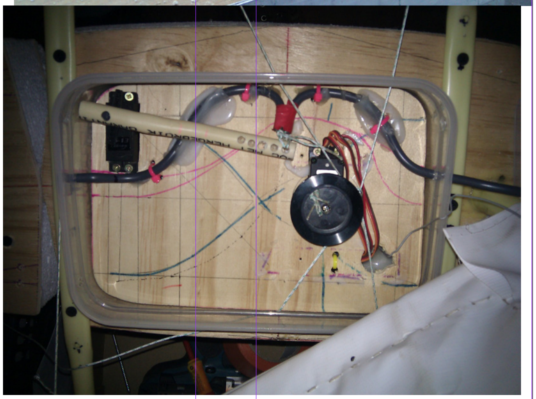






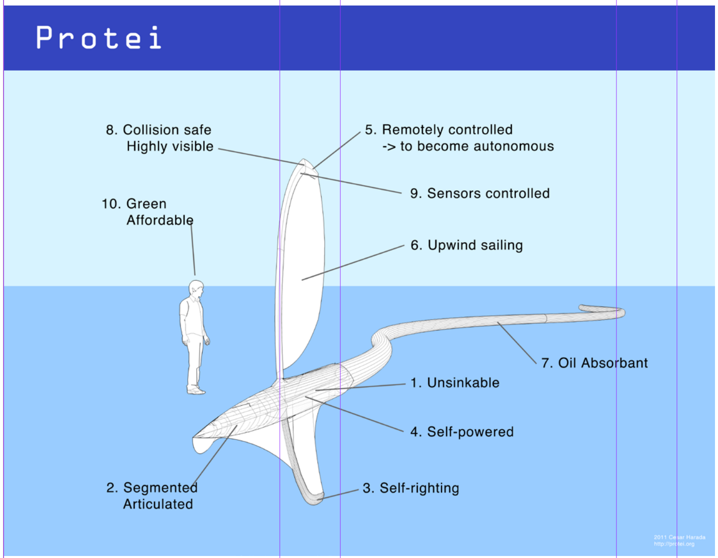
Protei_005.3





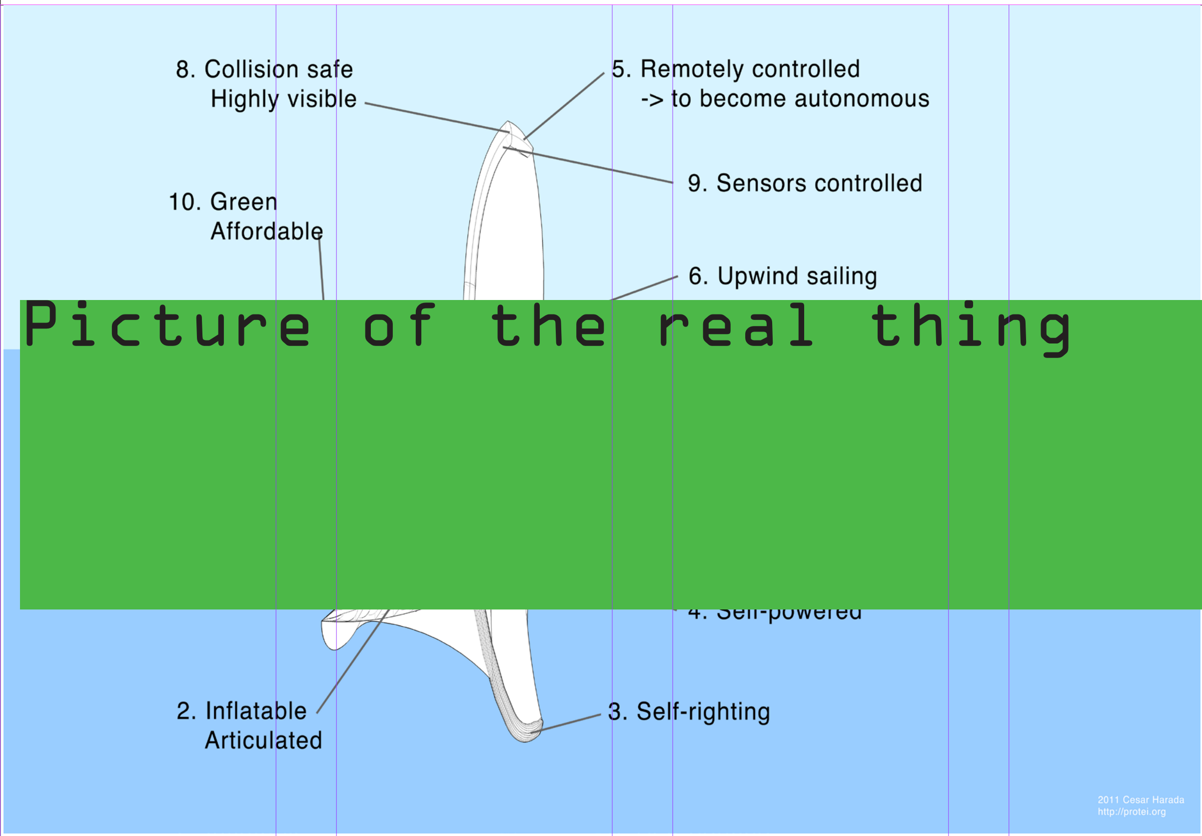
Protei_006

Introduction



In order to make suitable technical choices for the materials and methods using in the construction of Protei, we have listed the global properties (see “Property” column in table x.x) we want to achieve, and we have select solutions for each property (see “Criteria” column in table x.x). The criteria are meant as refinements (what do you mean refinements?) of each global property, and can be associated with a testing protocol, used to validate the technical solution.
For example, the criteria that Protei_006 be self-righting is tested by manually heeling Protei_006 in the water to 90° and evaluating if it returns its original position. If it does so, we can state that the combination of the Ballasted Keel and the Light Superstructure meets the self-righting criteria.

Propery	Criteria	Solution
Maneuverable	Steerable while towing	Shape-shifting through a flexible hull
	Optimised to sail upwind	Control of the sail
Stable	Self righting	Ballasted Keel
		Light Superstructure
	unsinkable	Puncture Proof Buoyancy Material
		Enough Buoyancy
	Robust	Neoprene Skin and use of robust materials
Safe	Collision-safe	COLREGS Compliant lighting system
Towing Capable	Can tow sorbent	Enough Pulling force
		Boom hooking point
Unmanned and automated	RC (for steering and sail trim) up to 1000m) Determines position data	Xbee module GPS Module
	Store GPS data	SD card shield



Picture of the real thing

General properties

Protei_006 is a 3 meter remote-controlled boat, that requires a user to be in sight of it in order to control it from nearby (500-1000 meters). It has a segmented, shape-shifting hull, accomplished constructed of flexible spines that run lengthwise (through cross sectional bulkheads) and bend under stress. A flexible skin tightly encases the skeleton. There is one sail (4 meters tall) and a large keel that extends downwards 1.2 meters from the hull. The majority of the boat's ballast is housed at the lowest point of the keel, which provides most of the stability. The hull's round shape and the boat's low center of weight allows the boat an elastic quality, so that when it heels in the wind, it can easily rotate in both directions to adjust itself as the conditions change. This also enables Protei_006 to be somewhat self-righting.

For steering and control, Protei_006 has three motors - one spins a winch to control the trim of the sail. The other two are attached to linear actuators that each control the articulation of the bow and the stern, which curve independently. The actuators pull and release cables that run throughout the longitudinal spines of the hull.

The battery and linear actuators, which provide most of the weight of the boat, are at the bottom of the keel, along with 25kg lead ballast. The main electronics, the winch, and the GPS are housed in the waterproof, shockproof pelican cases# compartments of the hull (which make up the separate segments). Protei_006 stores GPS data from its trips.

Comments about stablity

Please Fiona, explain how stability is affected by the cross section of the hull and the displacement of center of floatability when th boat heels. In our case, the body is nearly cylindrical and very unstable. Most righting momentum comes from our ballast to right Protei. In case of a violent gust of wind Protei sail goes flat on the water, safeguarding it from destruction.

Comment maneuverabilty

Weight Distribution

Comments about the hull mecanism <cesar> + <Sebastian>[e]

Parts List

Item Manufacturer Reference Price
1COLREGS : International Regulations for Preventing Collisions at sea
Mast
Sail Battery tube Linear actuators tubes RC receiver tube Longitudinal Spines Section Ribs Sail Boom
Microcontroller: Arduino Mega 2560
Arduino Mega Shield
RC transcievers: 2x Xbee Pro 900 Series 1
2x 50A Freescale H-Bridge motor driver
12V, 10Ah NiMH battery
Linear actuator and gearboxes, extracted from Bosch drills (14.4V)
Windshield wiper motor (12V)
Misc. electrical components (resistors, capacitors, wire, etc)
Skin
Prolimit STX C60 RDM
Neilpryde 230- 275 X5
Arduino SparkFun Digi Elechouse
Varies
Bosch
Varies
Varies
http://www.sparkfun.com/products/ 9949
http://www.sparkfun.com/products/ 9346
http://www.sparkfun.com/ products/9097
http://www.elechouse.com/ elechouse/index.php? main_page=product_info&cPath=1 00_146&products_id=667
http://www.all-battery.com/ flatnimh12v10000mah120whbatter ypackwith96voutputcustomize.asp x
http://www.amazon.com/Bosch- 34614-14-4-Volt-2-Inch-Compact/ dp/B000VZP5W2
For example, http:// www.amazon.com/A1-Cardone- 40192-Remanufactured- Windshield/dp/ B000C491BI
See electrical schematics for details
$64.95 $17.95 $85.90 $107.80
$98.99
$349.96
$56.46, varies
Varies

System overview

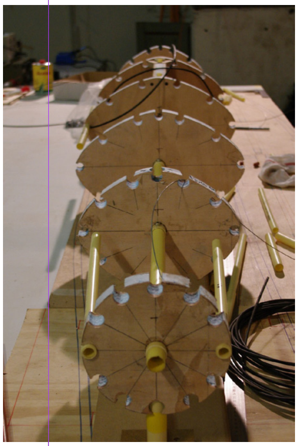
tests au debut

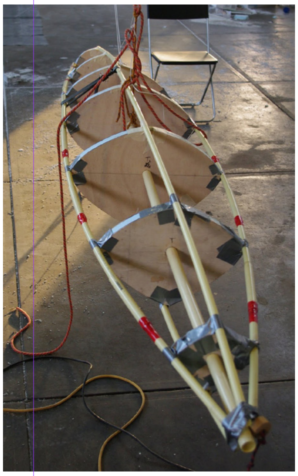
Mechanics
System overview

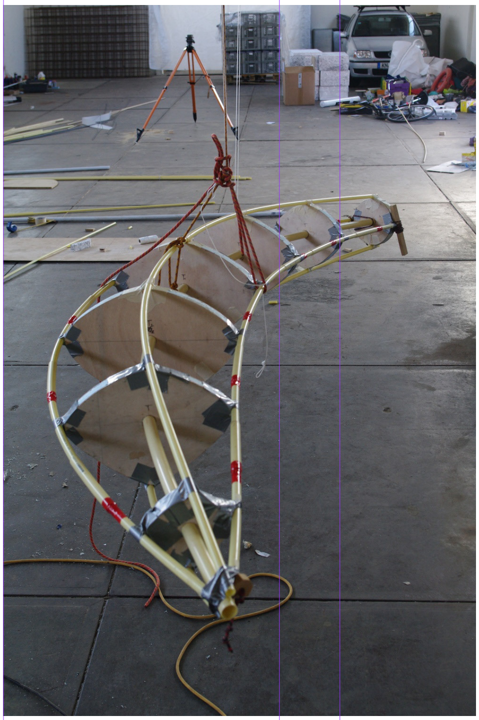
Protei_006 is the first “large scale” Protei prototype. She is meant to be an articulated sailboat that can carry hardware to perform oil collection and remote sensing at sea . The design is a bio-inspired design, with almost elliptical hull profiles. The construction of Protei is meant to be replicable by amateur builders and enthusiats. This section describes the process of building and assembling the mechanical components of Protei. In addition to this document, CAD files and drawings are provided on the website so that laser cutting and CNC machining are possible.

Hull

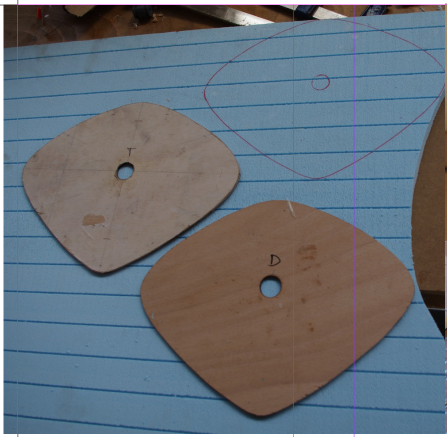
The hull of Protei is based on the of the concept a skeletal structure composed of cross sectional bulkheads and longitudinal spines. sebastian will come up with 1000 ways to word this better, so he told me. let's get his input. The hull is divided into segments that are delimited by bulkheads (sometimes referred to as "ribs") which define the shape of Protei. The bulkheads are connected via PVC tubes that are referred to as "spines". There are twelve outer spines that define the shape of the hull and one central spine that holds the bulkheads together and which around everything bends . The spines are comprised of tubes of different diameters so that they slide into each other and allow the hull to bend. The outer spines are attached to each bulkhead by rivets, this allows for each segment to be dismantled without having to reconnect tubes again.







Hull Construction and Assembly
Bulkheads Building the hull starts with making the bulkheads. DXF drawings are provided for all 7 of them, they
Hull under construction showing all bulkheads and 4 spines
are numbered 1 through 7 with 1 being the one farthest forward (note that bulkheads 3 and 4 are the same shape.) Two copies of each bulkhead are cut out of 3.5mm wood and then stuck to a piece of foam (without the spine holes) using two component epoxy. After they are dry the holes can be drilled throught them The holes through the foam are drilled at an angle to the vertical so that they conform to the bending of the spines. The angle is different for every section and is listed in the table below.



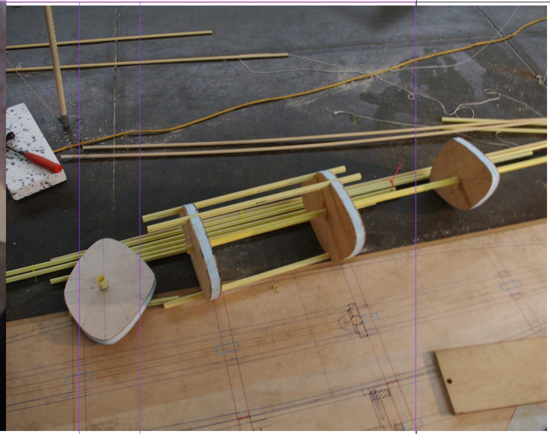
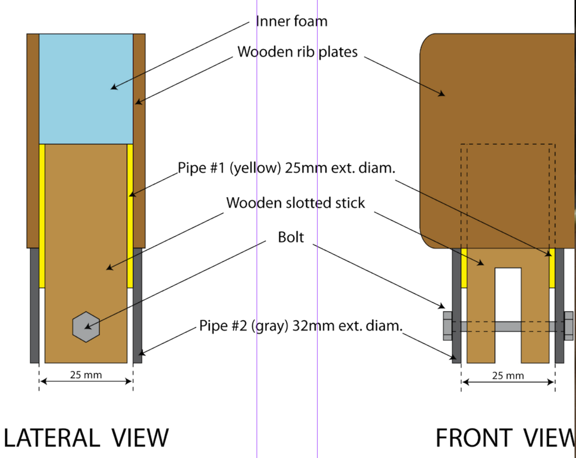
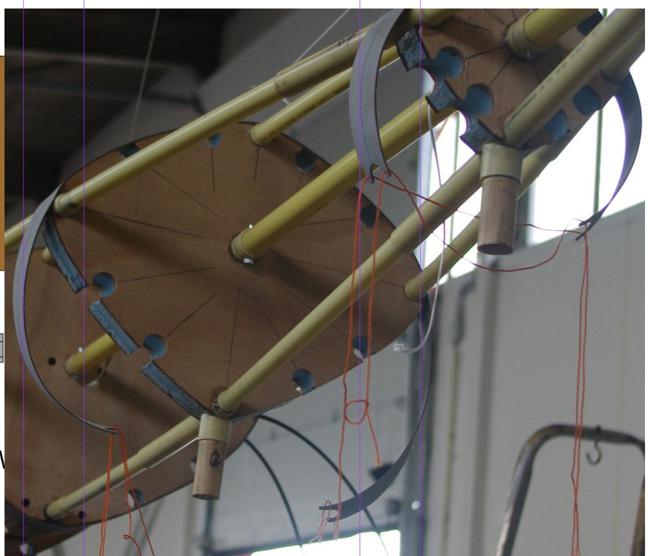


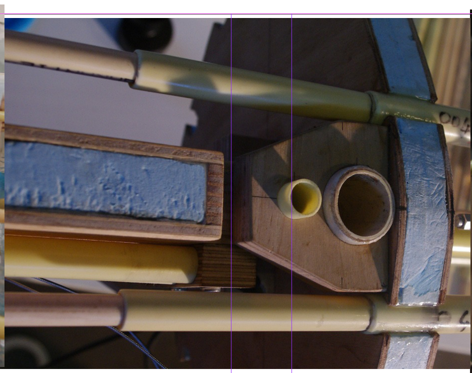
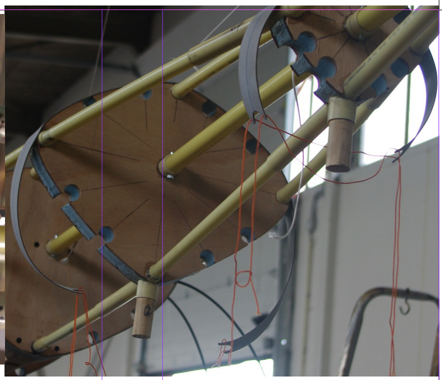
TABLE OF ANGLES

Next a pvc and wood tube are added to the bottom of every bulk head. This will eventually transform into the connection to the keel as well as provide good anchoring points for a possible fixture. After making the bulkheads the connection between bulkhead 3 and 4 must be made. A 3D view of the part is provided below (consult the appendix for the technical drawing). This piece is a composite of wood and This piece fits between bulkhead 3 and 4 and is kept together by 4 wooden fixtures that attach to the bulkheads and 4 aluminum pins that allow the central piece to pivot.



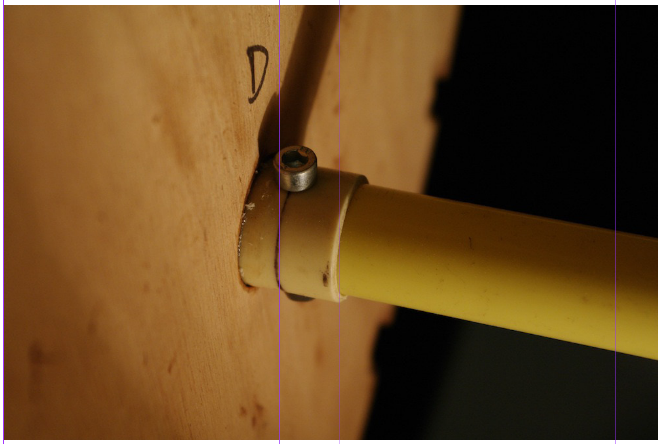


6) Next the connection between bulkhead 3 and 4 is built using the technical drawings to construct the 3-4 connection pieces from a wood and foam sandwich. In addition to the main sandwich piece, there are 4 aluminum pins and 4 wooden supports that maintain the connection attached to bulkheads 3 and 4.
After the parts are fabricated, the wooden supports are screwed into the bulkheads 3 and 4, and the sandwich is connected to these supports using four pins (these pins can be PVC but preferably should be aluminum).

B) Pipe Cutting and Assembly of Spines

The central spine is made up of a long (dimensions?) PVC tube that runs across all the body. To constrain ribs laterally, 50mm pieces of PVC (dimension) pipe are glued to the bulkheads (see detail below) and then the spine is passed through these and a screw and nut are used to connect the long spine and the 50mm pieces.



Next step is to cut the PVC tubes for the lateral spines, from now on the document refers to two different types of tubes: the tubes of the type "active" refers to tubes that do have Bowden cables inside (there are 4 of them, top,bottom starboard and port) whereas "passive" spines do not have Bowden cables in them (there are 8 of these).

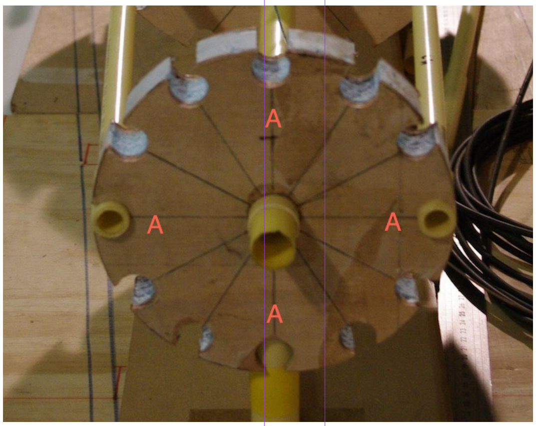


fig. Bulkhead 7 with the slots for the active spines labeled (the unlabeled are passive)

Assembling the Active Spines

Assembling the Passive Spines

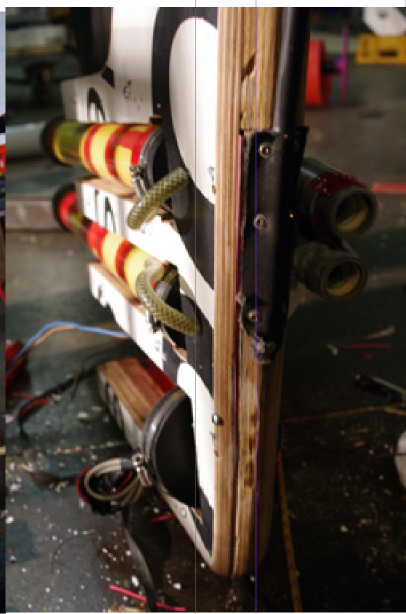
The 8 passive spines are assembled in a similar but more straightforward way than the active spines. Shorter pieces of the middle tube are glued around the smallest tube at a certain offset from the end, the middle tube fits into the bulkhead holes (these get riveted to the bulkheads later).
After the tubes are put through the bulkheads, they are ready to be riveted to the bulkheads.

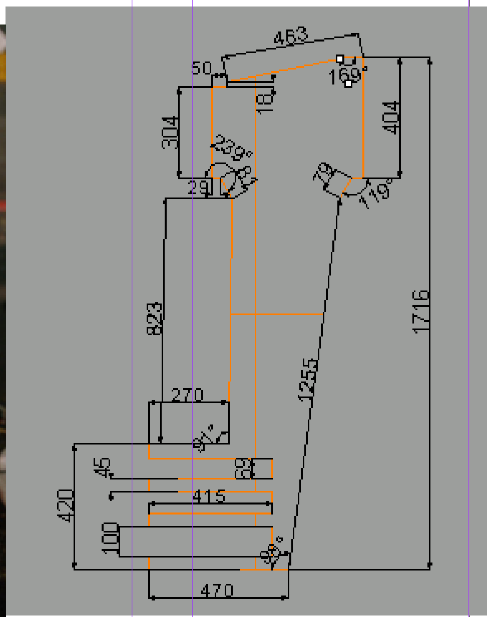
Keel

The keel is comprised of vertical layers of wood sandwiched together by two outer plates on either side. It extends downwards from the body of the boat 1.2 meters, and houses most of the boat's ballast at its lowest point, which keeps the boat upright. Three horizontal slots are cut in the very bottom of the keel, one for the battery tube and ballast, and two for the linear actuators. In the inner vertical plates of the keel, there are two narrow slots running vertically from the horizontal slots, to the compartment in the body of the boat that houses the electronics and the winch. Through these slots runs tubing which holds the wiring from the batteries and the linear actuators in the kee to the control box.
The two outer plates are screwed in at multiple points, yet removable. The three horizontal slots at the bottom of the keel enable easy removal of the linear actuators and the batteries. A meter part has been embedded into the joint area of the three slots to reinforce the wooden structure.

Keel Construction and Assembly

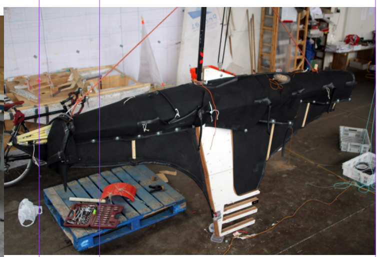
The keel is composed of four wooden plates, two for each side, cut to the following dimensions (Fig. x.x). These four sections are sandwiched around the neoprene with two outer plates that are and bolted in (see the “x” marks in Fig. x.x). The grooves allow for the tubing for the cables and the wiring to run





Skin

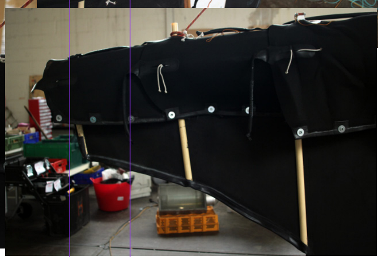


Rivet the skin

The skin is constructed from neoprene segments, organized in an ‘armadillo armor plate’ fashion. Each segment will slide over the other, allowing the articulated hull to curve. At the front sides of each segment, the skin is riveted onto the frame of the hull. At the backsides, each segment is hold in position by slightly pre-tensioned rubber straps. The rubber straps make sure that the entire skin will return in the straight position after the hull is being bent. The neoprene is reinforced on all the edges with rubber, to prevent ripping. The skin is not waterproofing the hull, as that is not the aim. It’s major task is to streamline the hull and to add to the buoyancy of the vessel.t





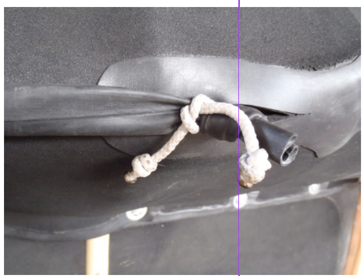


Reinforce the edges

The skin consists of seven segments, draped over the hull and attached to the keel and the frame. [Insert overview photo of the skin]
The pattern of the skin: [Insert Illustrator file with patterns]
Each segment is secured by a flexible rubber connection. The pattern of the connection patches: [insert pattern of the wooden stencil]
At the bottom, the skin is attached to the rubber keel with bolts, nuts and washers. This is the schematic pattern for the reinforcement at the bottom:
[insert pattern]

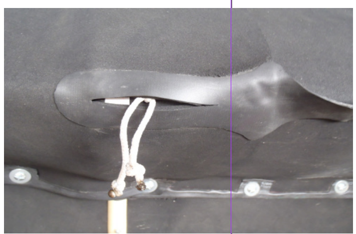
Glue rubber and Neoprene

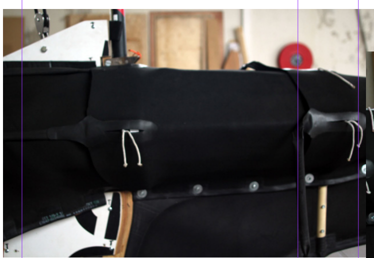
xxx glue and xxxx binder are used to glue the rubber to the neoprene. A few drops of the binder is stirred into the glue, until they are well-mixed and a homogeneous color. The rubber is sanded thoroughly and cleaned with acetone. A layer of the glue on is applied to both surfaces. After drying for a few minutes, the rubber and the neoprene are pressed firmly together, at every contact point. Applying force is more important than the duration of the pressure. To prevent buckling of the rubber, it is stretched slightly when attached to the neoprene.

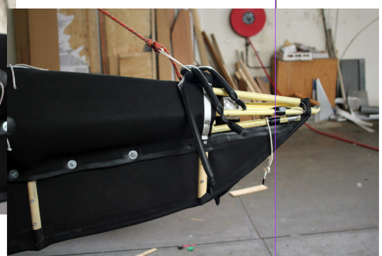


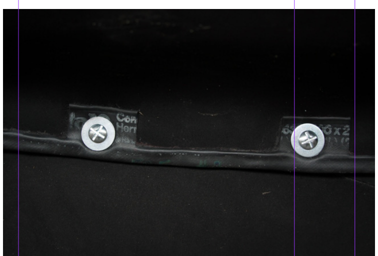
Add flexible connections

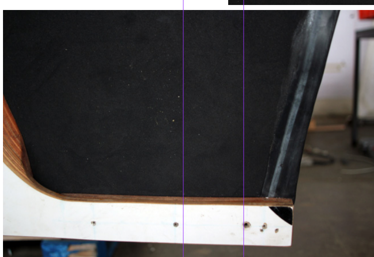
Flexible rubber straps are glued to the sides of each skin-segment. Inner tubes are also appropriate here. A slit is cut at one end (of what?the strap or the tube or the segment...), and the edges are rounded off. The cut inner tube can be slid over the side (of what?) and glued to the neoprene. Make sure to use the most flexible ones (what?) you can find! The straps hold the skin in position, therefore they must apply a certain tension to the skin. High elasticity is key because if the tension of the skin is too high, the motors will be strained when curving the hull. For extra reinforcement, rubber sheet connection patches (seen in figure...?) can be glued on top of the straps. Stencil (figure x.x) refers to the shape that the strap should be cut.   Once cut to shape, a slit is cut in the middle (of what?) so that the ropes can be pulled through and tied to the rubber strap of each segment in front.
[insert photo of white rope + knot]

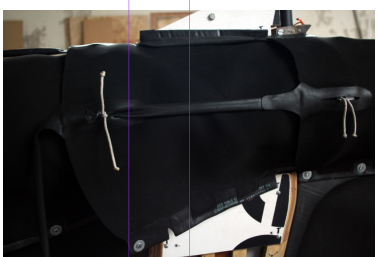












How to build (pictures, tips & howto's) Rivet the skin

Cut out the pattern pieces of the skin segments and drape them over the hull. Cut six straps from rip-stop material, lengths according to the circumference of each hull slice. We used left-overs from the sail to create the straps. Position the strap in the centre of a hull slice and drill a hole that fits your rivet. Start at the bottom of one side. Fasten the first rivet. If it is hard to push it in, gently hammer it. Pull the strap tight and work your way around the segment. Repeat this procedure for each part of the skin. Please note that each skin segment should only be attached on the front sides. The backsides stay loose in order to be able to reach the electronics inside the hull.

[insert photo of rivets and white strap]

The first segment, the 'nose', is an exception. This one is not riveted. Sew a few inches to close the nose and slide it over the frame.

Reinforce the edges

The skin needs to be reinforced with rubber on every part where force is applied. More specifically, at the bottom where it connects to the keel and around every cut-out on top. Inner tubes from bicycle wheels are very suitable to do the trick. Most of them will have a fold, which you can use to slip it around the edges easily.

For the bottom parts: cut the tubes open as shown in the picture, to benefit from he fold and to maximize the area where the bolts and washers will be attached later on.

[insert sketch of cutting the inner tube]

Glue rubber and Neoprene

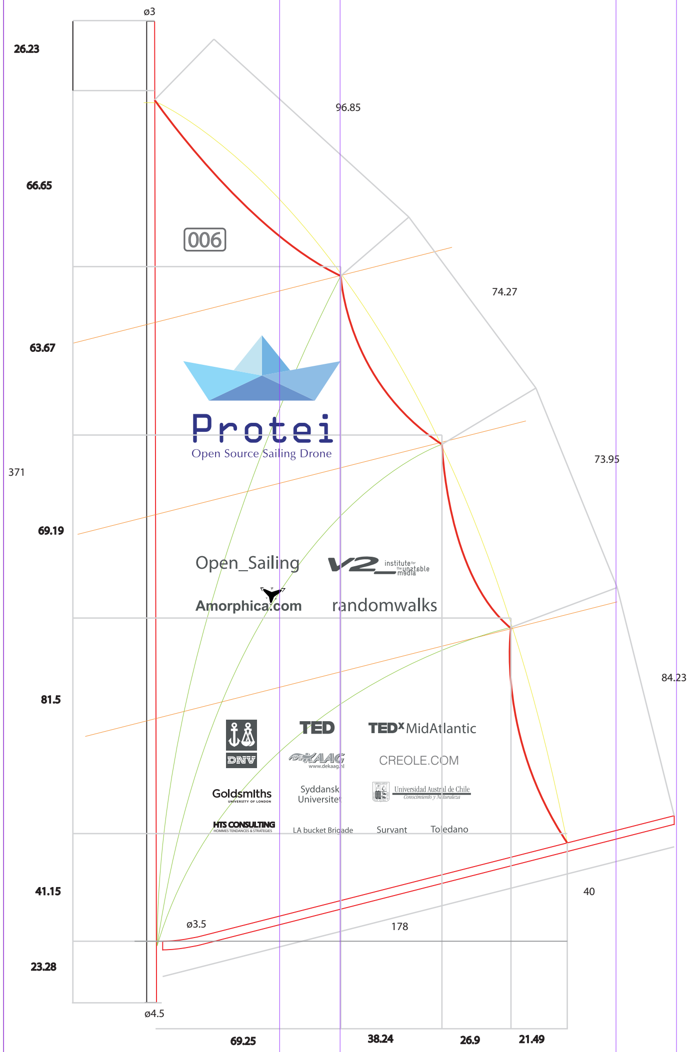
To glue the rubber on the neoprene, we used glue and a binder. Add only a few drops of binder. Stir the two components until they are mixed well and you reach a homogeneous color. Sand the rubber thoroughly and clean it with acetone. Apply a layer of the glue on both surfaces. Let it dry for a few minutes, then press both parts together. Note that it is contact glue, so you really need to press every single inch. Applying force is more important than the duration of the pressure. To prevent buckling of the rubber, stretch it a little bit when attaching it to the neoprene.

Add flexible connections Flexible rubber straps are glued to the sides of each skin-segment.

Again, inner tubes can be used. Cut a slit at one end. Round-off the edges. Slide it over the side and glue it to the neoprene. Make sure to use the most flexible ones you can find! The straps are meant to hold the skin in position, therefor they must apply a certain tension to the skin. However, all these forces add up and will give the motors a hard time when curving the hull. High elasticity is key.
For extra reinforcement (and better looks), we glued rubber sheet connection patches on top of the straps. See stencil for the shape. Cut a slit in the middle. Pull the ropes through. Tie the rope to the rubber strap of the segment in front of it.
[insert photo of white rope + knot]
Connection to the keel
Finally, the skin is closed around the hull by connecting it to the keel. Make holes through the upper part of the keel and both sides of each skin segment. Put a bolt through, with washers on both sides. We used these special ones, for a nice finishing:
xxx
[insert picture]
Trouble shooting, conclusions etc
For the prototype of Protei 006, we used neoprene to construct the skin and the keel. Advantages are the flexibility and the buoyancy properties. However, we did not research the chemical aspects yet: how will it be affected when in contact with crude oil?
Furthermore, neoprene rips or tears easily when there is a small scratch. One might want to research similar materials that are stronger.
Same chemical consideration goes for the PVC tubes!

Sail

Inspiration



Pic-
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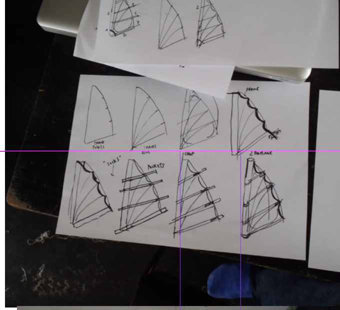
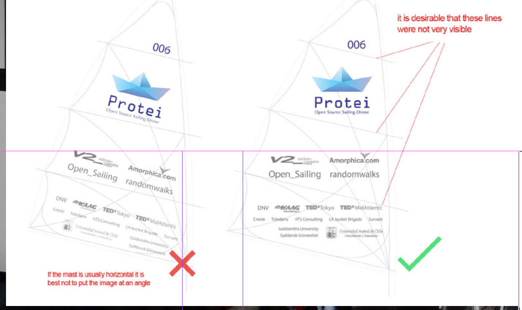
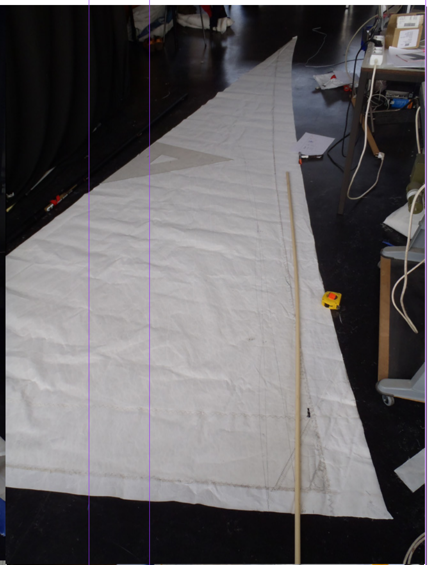
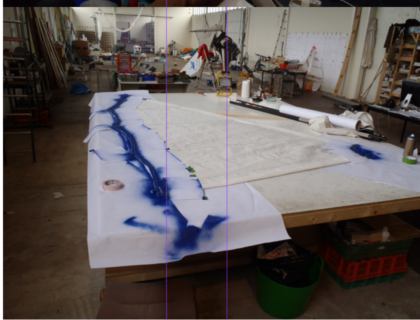



it is desirable that these lines were not very visible
006
Protei
Open_Sailing
randomwalks
Amorphica.com
If the mast is usually horizontal it is best not to put the image at an angle






CREOLE.COM
Goldsmiths


006
Protei
Open Source Sailing Drone
Open_Sailing
randomwalks
Amorphica.com

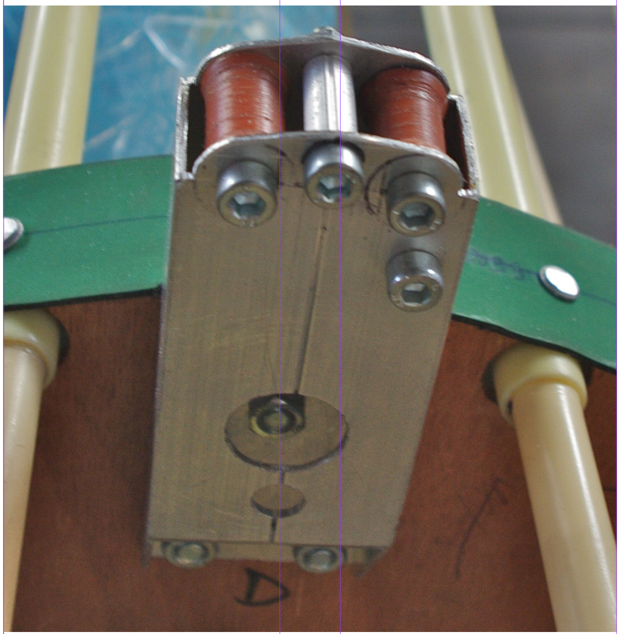
Picture of the real thing

Picture of the real thing

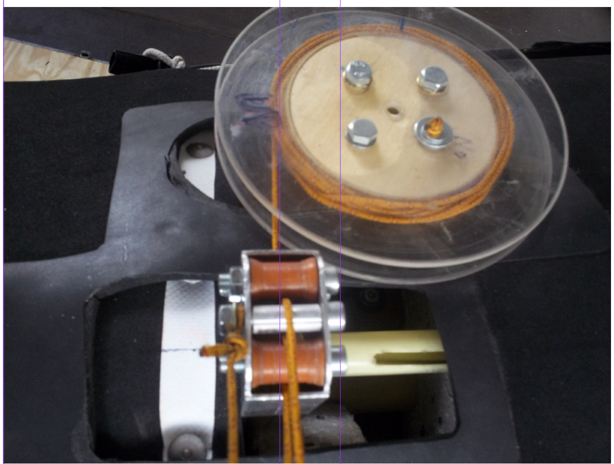
Ropes

Sail Winch

Overview of the system



Main block



Drum and main block wired

Sail winch overview

The sail winch provides the control of the main sail of the the boat, by reeling in or out the main sheet. It consists of a drum, which shaft is coupled to a DC motor, a lid for water-proofing, and three blocks for wiring. The main block is fixed to the hull and consists of three rolls that distribute the main sheet to the second block, a traditional double pulley.
The last block is a simple shackle connected to the boom by a wooden clamp. Between the double pulley and the shackle, there is only one sheet that is doubled by a shorter rubber band, in order to keep tension at any time.

Sail winch as-sembly

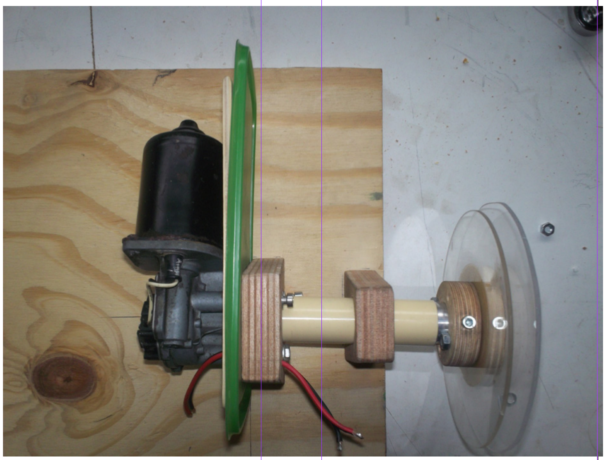
The assembly for the winch is divided into the following steps : 1. Assembling and fixing the winch motor box 2. Assembling and fixing the main block
Overview of the system
Main block
Drum and main block wired
3. 4. 5.
Assembling the boom clamp Wiring the drum, the main block and the double pulley Wiring the shackle

Assembling and fixing the winch motor box

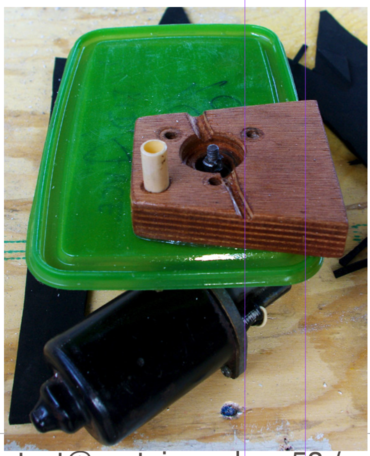
The winch motor box is composed of : □ a 12V DC geared motor. We used a car winds-creen wiper motor :
□ a lid and the associated box for water-proofing □ a wooden support, that will be screwed to one of the boat's ribs. This support has a hole for the
shaft, three holes for the vertical screws, and a hole for the power cables □ a small piece of PVC tube glued inside the hole for power cables to let the power cables go
through the lid.

an aluminum coupling that fits inside the hollow shaft and around the motor shaft
an aluminum hollow shaft with a coupling for the motor. 28mm, length : 125mm

a wooden drum support (58mm, 2cm long) with a centered hole of 28mm, a drum : two round slices of Plexiglas (14cm) and an inner drum of 8cm.



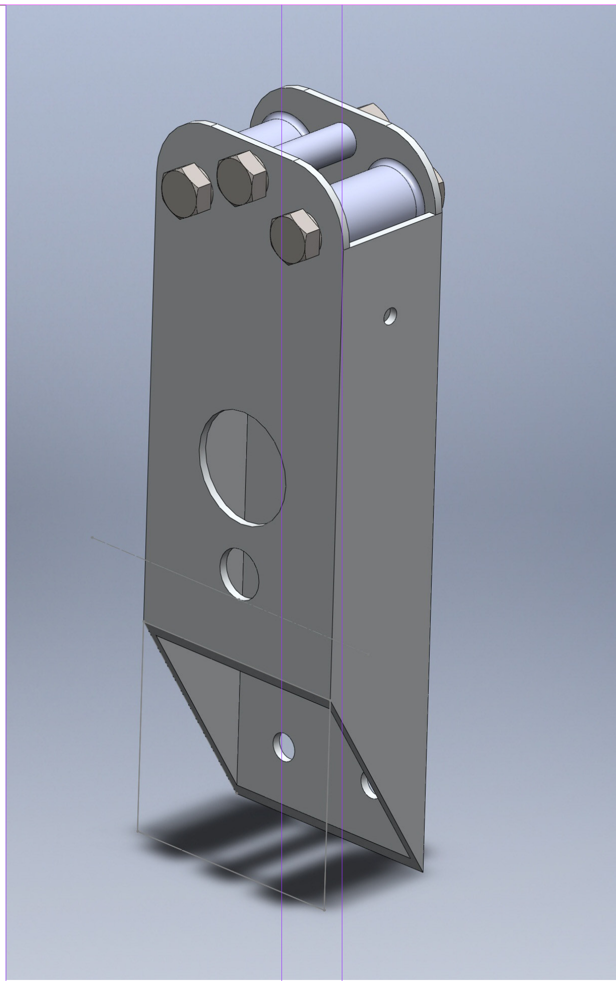
We used three vertical screws to hold the mo-tor, the lid and the wooden support together.
In order to provide efficient coupling with the motor, we drilled a 4mm hole trough the motor output shaft and we threaded it (M4 standard metric — ISO 965). We used two M4 screws to hold the motor shaft, the coupling and the aluminum shaft.
The wooden drum support is then screwed horizontally to the top of the aluminum shaft.
The drum is then screwed vertically to the support. In order to avoid tearing the skin or increase jamming probability, the screw heads are counter-sinked.
A flexible rubber tube running to the control box can then be clamped to the output of the PVC tube, to provide efficient waterproofing.

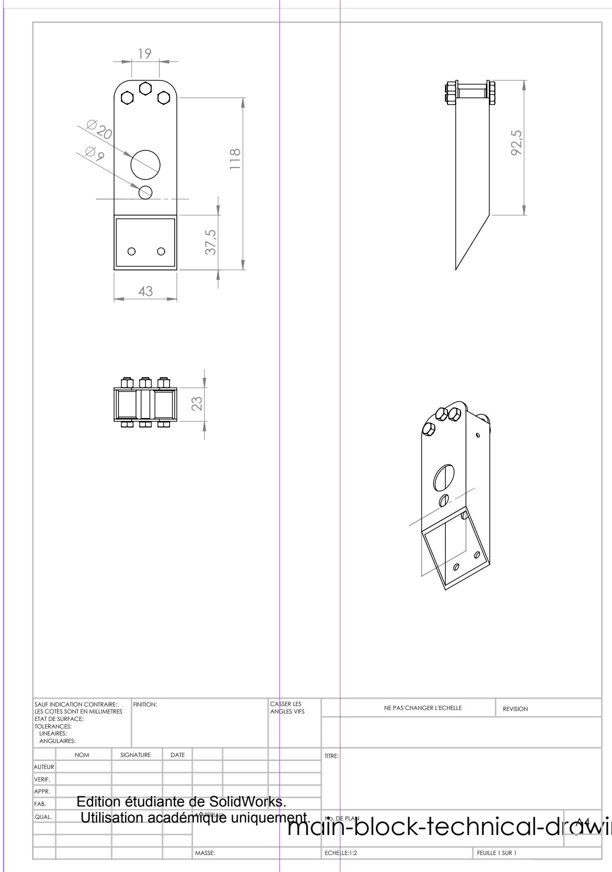


Motor, shaft, coupling, lid and wooden support.
Motor,lid and wooden support assembled
Motor,lid and support with screws
Aluminum shaft with coupling
Motor, lid, support and aluminum shaft
PVC Guide added

Assembling and fixing the main block

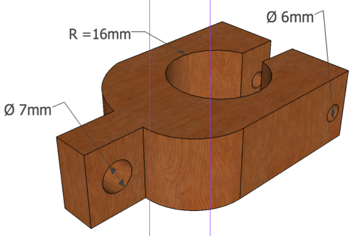
Here is a 3D view of the main block:
the central hole (□20mm) is designed to let one of the skeleton spine go through
the secondary hole (□9mm) is designed to access one of the bolt that holds the main block to the rib.
the back holes (□5mm) are also designed to hold the main block to the rib.
The lateral hole (□3mm) is the entry point for the sheet coming from the drum.





Assembling the boom clamp

Here is a 3D view of the boom clamp :
The shackle is attached to the 7mm hole.
A bolt is going through the 6mm hole to clamp the boom, which goes through the 32mm main hole.



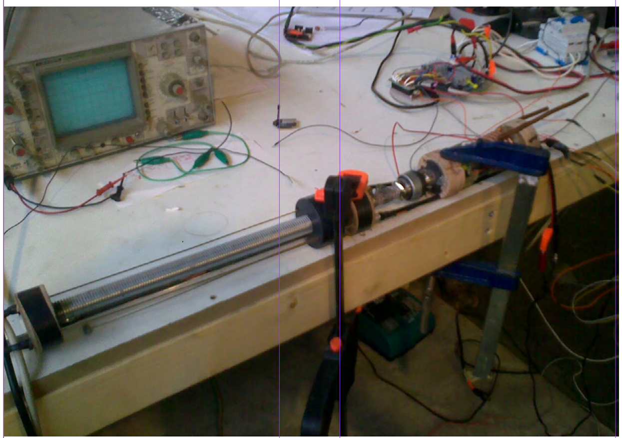
Wiring the drum, the main block and the double pulley

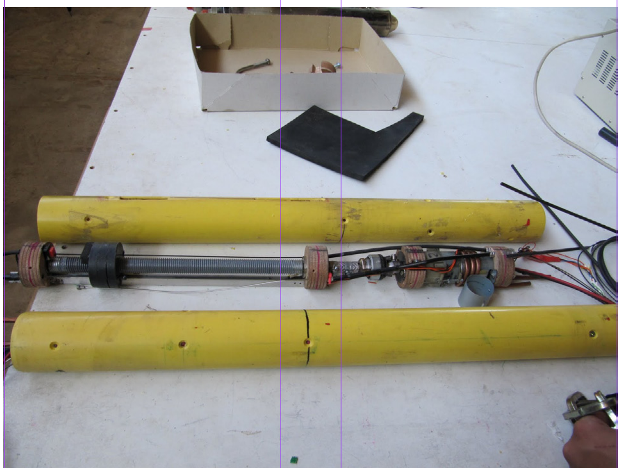
Attach the sheet around the drum and follow these steps :
insert sheet into the lateral hole from the main block
go around one of the main rollers
go around one of the double pulley rollers
go around the second main roller of the main block
go around the other double pulley roller
attach the end of the sheet to the central roller of the main block.
Wiring the shackle

Fix the shackle to the 7mm hole of the boom clamp.
Wire the shackle to the double pulley with a 10cm sheet.
Cut a 7cm piece of rubber band and attach it between the shackle and the double pulley.
Make sure it is shorter than the sheet, but long enough not to break when tension is applied (the sheet should then support the tension)

Linear actuator<Qiuyang>

As mentioned in the previous chapter, Protei is a boat with a shape shifting hull. Thus external power (force) is required to control the shape of the hull. The linear actuators are built to fulfill this functionality. The maneuverability control of Protei is through its shape changing, like the behavior of fish, not by the conventional rudder. Hence, a powerful and reliable linear actuator is a crucial factor to the survival of Protei in the open ocean.
Two identical linear actuators are constructed for Protei 6: one for the bow and the other is for the stern. So by appropriate control algorithm, we can control the bow and the stern separately.
And besides the banana shape of Protei, we can also make an s-shape of protei.
Overview





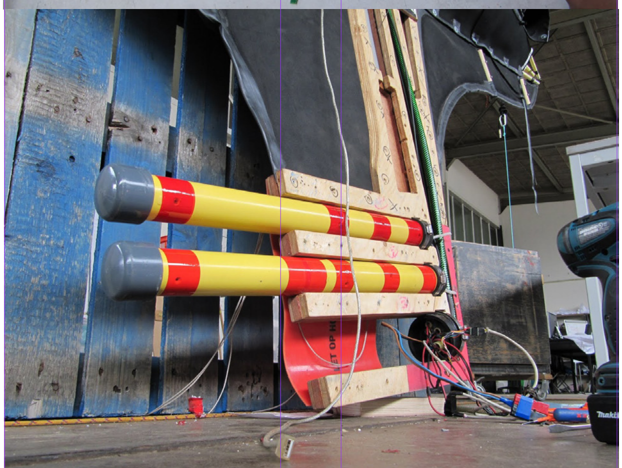


Fig. Mounting the linear actuator to the keel
After testing, the linear actuator are encapsulated into the yellow PVC tubes and fixed by screws. The yellow PVC tubes are used as both the frame and the water proof shield. When mounted to the keel, these actuators are located at the bottom.

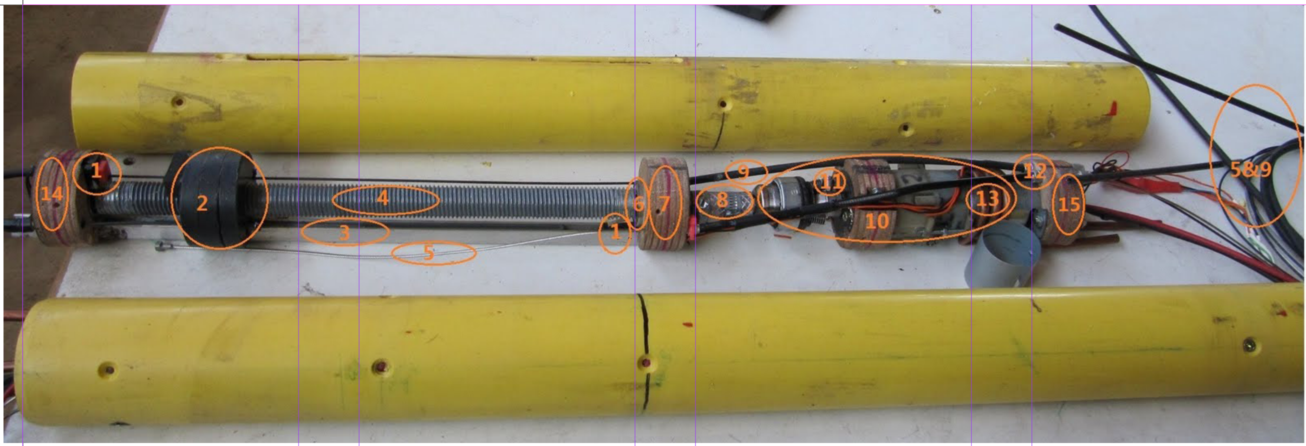


Fig. structure of the linear actuator
Component list:
Limit switch
Pulling part (with a nut inside)
U-shape aluminum guide
thread shaft
bowden cable
bearing
Wooden support part B
soft coupling tube and holes-clamp
bowden cable housing
DC motor with gear box and clamp (from electric hand drill)
magnet sensor
Bowden cable guiding nut
water circulation tube
Wooden support part A
Wooden support part C

How does it works

As shown in the above picture, there is bowden cable fixed on the pulling part. when the DC motor rotates, the pulling part moving back and forth, thus the bowden cable is pulled or released. When one side of the bowden cable is being pulled, the bowden cable on the other side is releasd, resulting in the boat curving to one side. The limit switches are used to detect the extreme position of the pulling part. When one of the limit switch is being trigged, the motor has to stop rotating immediately and reverses the direction. The magnet, together with a hall-effect sensor, is used to count the number of rotation. From the number of rotation, we get an indication about the moving distance of the pulling part.

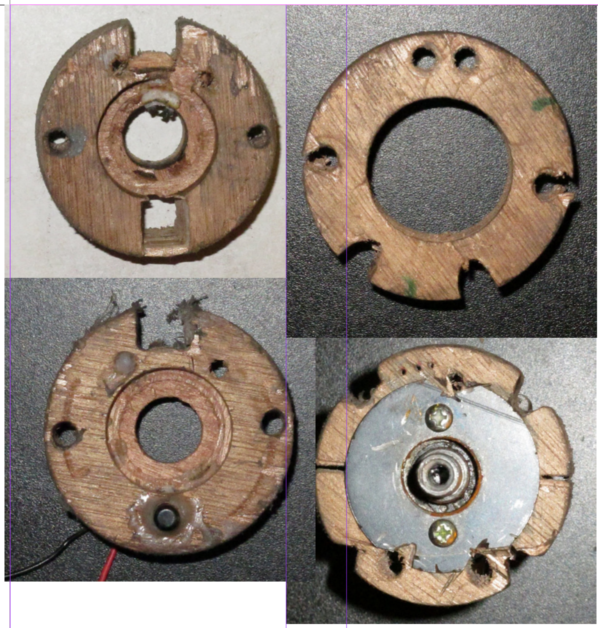
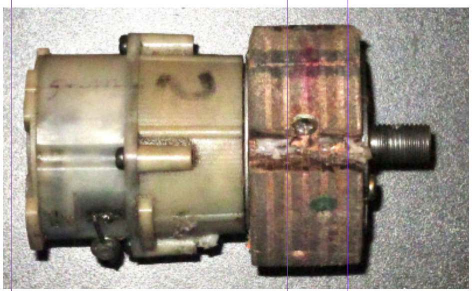


Fig. wooden support for the gear box of the DC motor

All the wooden supports has the same outer diameter, so that they can be mounted into the same tube and keep the shaft concentric. One of the disadvantages of these wooden parts is that although they are very easy to manufacture, they are not strong enough to endure strong force. We have already switched to aluminum materials for these supports.



The idea of water circulation tube is to cool the DC motor while its own cooling fan doesn't work. When Protei is moving, it creates water pressure which force the water comes in through one of the tube and goes out through another tube. To make this circulation possible, at the inlet of the tube we put a trumpet shape connector to collect water pressure. This connectors are composed of several tubes in different diameters mounting together.

Fig. Trumpet shape connector for water circulation tubes

Electric & Electronics Overview

Protei's electrical system is designer to accomplish two tasks: communicate reliably with an onshore transmitter, and precisely control the on board actuators.
Communication is accomplished using Xbee modems, which allow for medium range (maximum 500–1000m) bidirectional wireless communication.
Two of the actuators control linear movements, these are located in the keel. Through the use of limit switches and a rotational sensor, these can be position controlled in closed loop feedback. The third actuator, the sail winch, can only be open loop controlled at the moment, though connections have been built into the microcontroller to allow for future closed loop control using a rotational sensor.
The diagram below shows a schematic representation of the data and power connections between components on Protei. It also provides a not-to-scale representation of the physical location of these items. Each item is described in further detail on the following pages. Larger schematic images can be found in Appendix B, and source code can be found in Appendix C. This is also provided online on Protei's git repository, at: https://github.com/Protei/Protei-005-6.

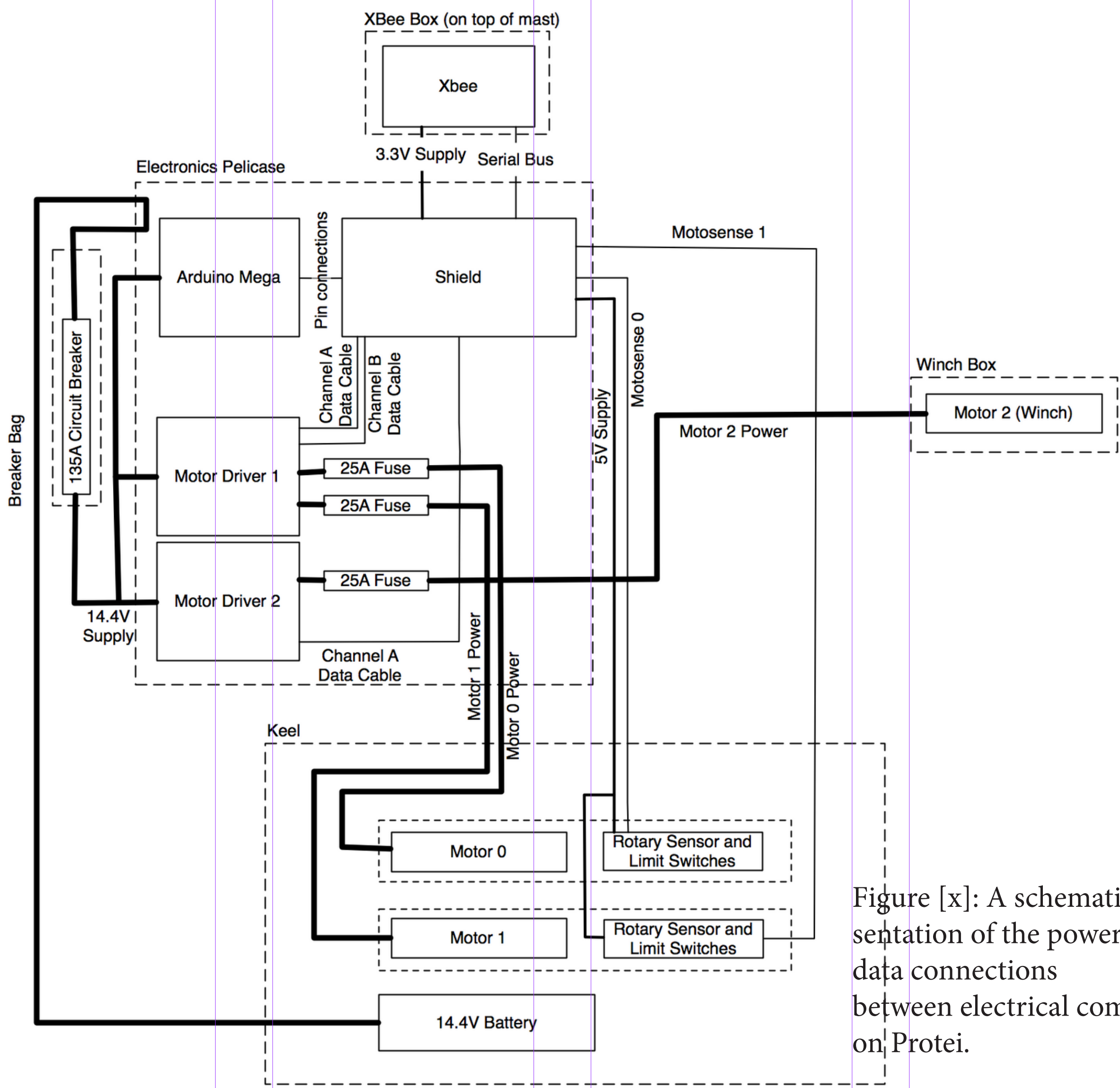
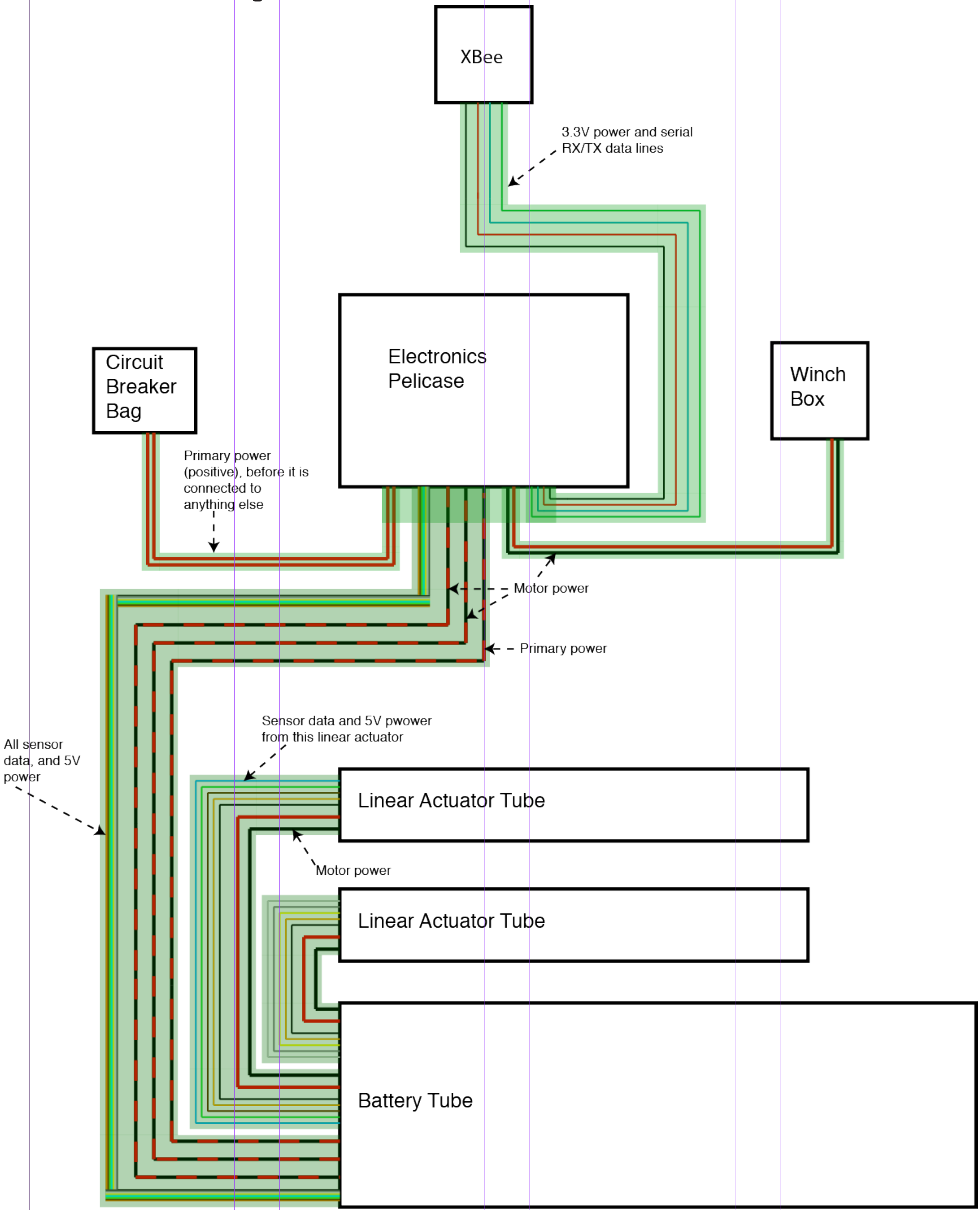
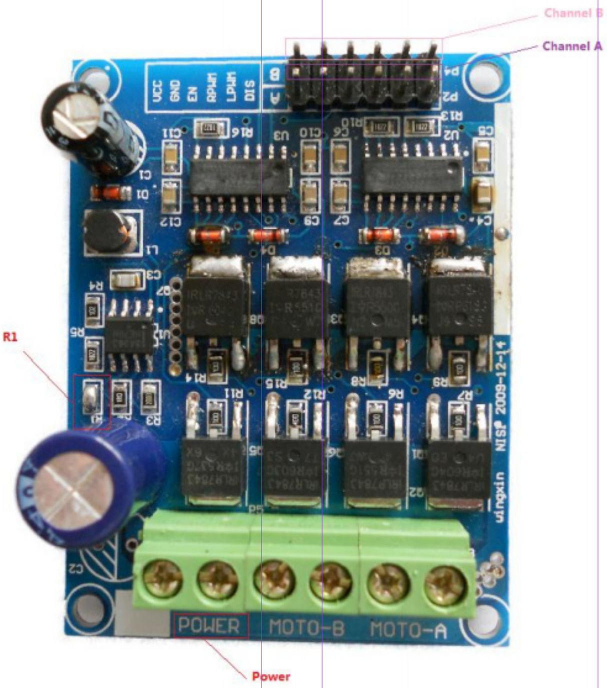


Figure [x]: A schematic representation of the power and data connections between electrical components on Protei.

Cable Layout





3.2.1 Linear actuators

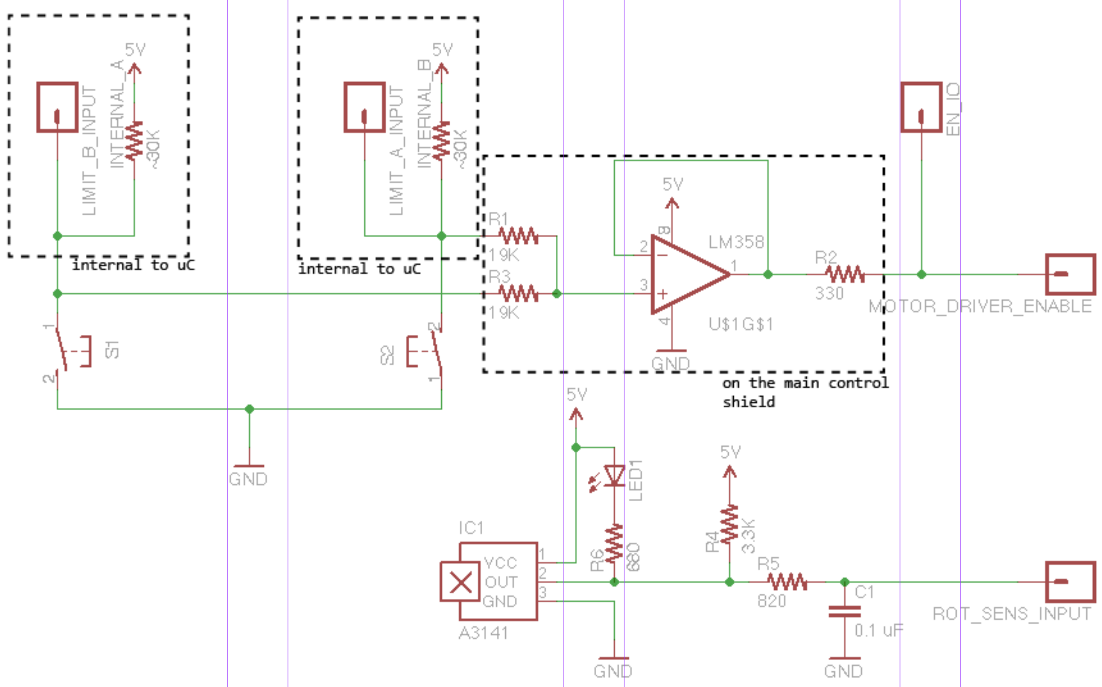
The linear actuators on Protei provide the pulling force necessary to bend the boat. The mechanical design has already been described above, this section focuses on the electrical design of the actuators. Electrically, there are two separate mechanisms — the driving mechanism, and the sensing mechanism.

3.2.1.1 Driving

The motor is driven through an H-Bridge motor driver, purchased from Elechouse. The manufacturer claims that it will work with 12V motors at 50A continuous and 100A peak current. We have not thoroughly tested these claims.

As shown above, each channel has six logic inputs — VCC, GND, EN (enable), RPWM (“right pulse width modulation” — this drives the right hand side of the H-Bridge), LPWM (“left pulse width modulation”), and DIS (disable). DIS is always left unconnected, as we do not need the functionality that it provides. VCC is connected to +5V, GND to the GND of the microcontroller, and RPWM and LPWM are connected to two PWM capable output pins from the microcontroller. EN is connected as described below in the sensing section. 12V straight from the main battery is connected to the POWER header on the opposite side. Each motor is connected to the controller in series with a 25A fuse to prevent the motor from damaging the motor driver.

Sensing



Sensing is accomplished through two mechanical limit switches, on either end of the actuator's linear range, and a Hall Effect sensor, which detects the rotation of a magnet attached to the motor's shaft. A schematic of the sensing mechanism is shown below. This is, of course, duplicated for each actuator. An Eagle Layout Editor file for this schematic, and all other referenced electrical drawings, is available on the Protei git repository: https://github.com/Protei/Protei-005-6.

(((60
A circuit
breaker)))(((25A fuse)))

The most complicated part of the above schematic is the limit switch function. The limit switches have two functions: the microcontroller can detect the state of each limit switch individually; and, if either switch is depressed, the motor driver will be disabled, until the microcontroller re-enables it. This is implemented through use of the tri-state logic capability of the microcontroller digital I/O. When the EN_IO pin is set to high impedance (input) mode, the value of the motor driver enable pin is entirely set by the state of the switches. When one of the switches is toggled, the enable pin goes low, and can be reasserted high by changing EN_IO to output mode. In this way, the actuator is protected against software failure, and does not solely rely on the microcontroller for detecting switch presses. Obviously this only works if the default state of EN_IO is high impedance.

The rotary sensor uses an Allegro A3141 hall effect sensor to detect the presence of a magnet on the motor shaft. R4 serves as a pull-up resistor and R5/C1 is a lowpass filter. The output is briefly set low once per revolution, as the magnet passes the sensor. This can be read with a digital input on the microcontroller.

Communication system

The communication system uses two Xbee Pro 900 Series 1 devices for short range (~1000m) bidirectional radio communication. These communicate using the following simple protocol. The source code for the transmitter is in ArduinoRC.pde, and for the receiver on Protei, in ArduinoControl/comm.h.

Every 100 ms, the joystick controller (transmitter) sends three pieces of information to Protei: the position of its left joystick, the position of its right joystick, and the status of its buttons (127 if no buttons or all buttons are pressed, 0 if just the left button, 255 if just the right button). These three bytes are split into two half bytes of 4 bits each, and each half byte is encoded with a Hamming7,4 code plus an overall parity bit to improve reliability of communication.

`S’
[halfByte1A]
[halfByte1B]
[halfByte2A]
[halfByte2B]
[halfByte3A]
[halfByte3B]
`E’

After Protei receives and processes the data from the transmitter, it responds by sending a message with a similar protocol, containing status information of the boat.

`S’
[statusHalfA]
[statusHalfB]
`E’

statusHalf, prior to being split into two half bytes and encoded with a Hamming7,4 code, is a bitmap with the following values:

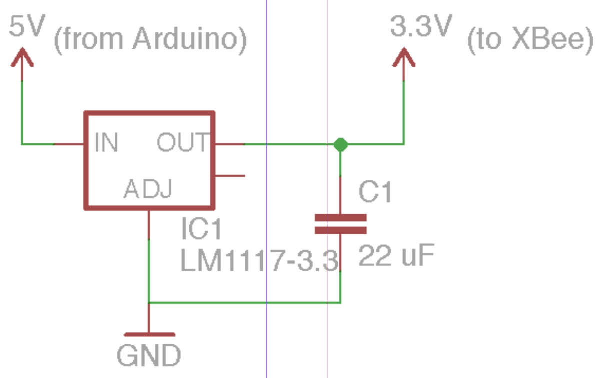
MSB							LSB
N/A	N/A	Stern Actuator Rotation sensor (HIGH or LOW)	Stern limit switch B	Bow limit switch B	Bow rotation sensor	Bow limit switch B	Stern limit Switch A

This information is used by the joystick controller to display six status lights. A seventh status light blinks with each successful radio exchange, and an eighth simply indicates when the controller has power.

3.4 Microcontroller and connection shield

The primary microcontroller on Protei is the Arduino Mega 2560. We designed and built a custom connection shield for the Arduino. The purpose of this shield is threefold: to contain the logic for controlling the motor driver enable pins, as described in the “Linear Actuators / Sensing” section above; to provide a regulated 3.3V supply with sufficient current for the XBee; and to make easy connections between the motor drivers and sensor inputs, and the pins on the Arduino Mega. The voltage regulator used is an LM1117, with a 22 uF capacitor on the output (required by the LM1117 for stability), as shown below:

Figure [x]: The XBee power supply.
A list of the pin connections is shown below. Pin choices were made by required functionality (PWM, a hardware serial port, etc), then by physical convenience (their location on the Arduino Mega).



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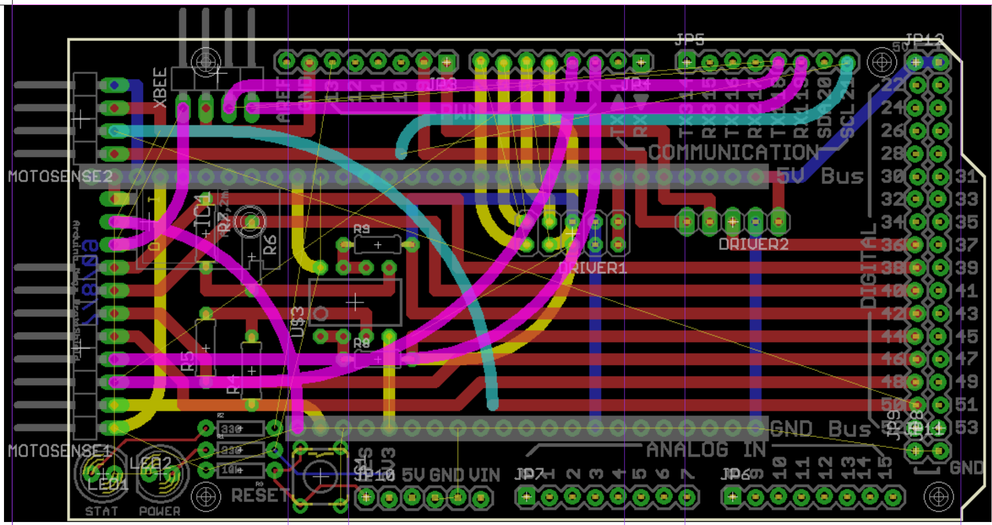
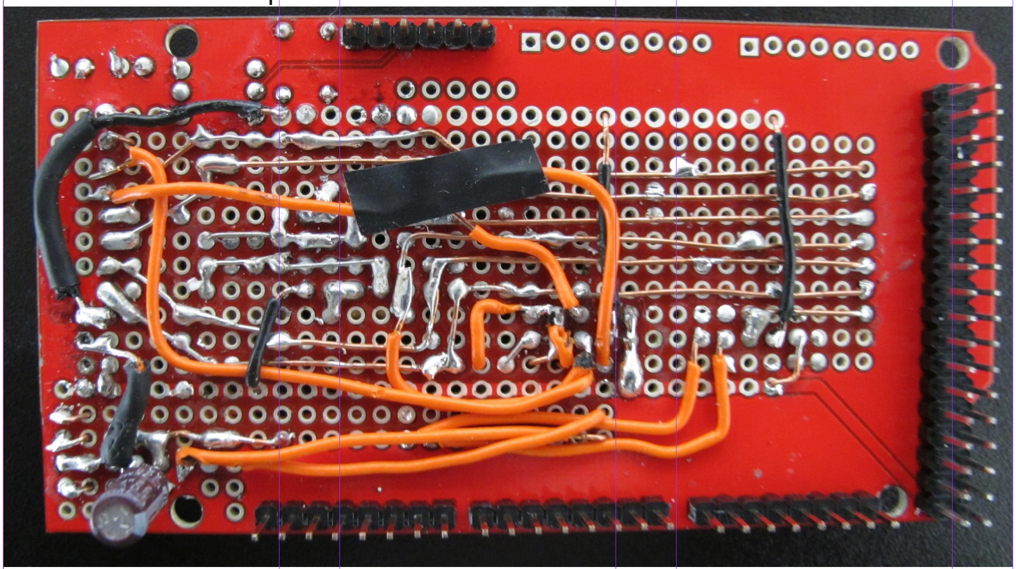
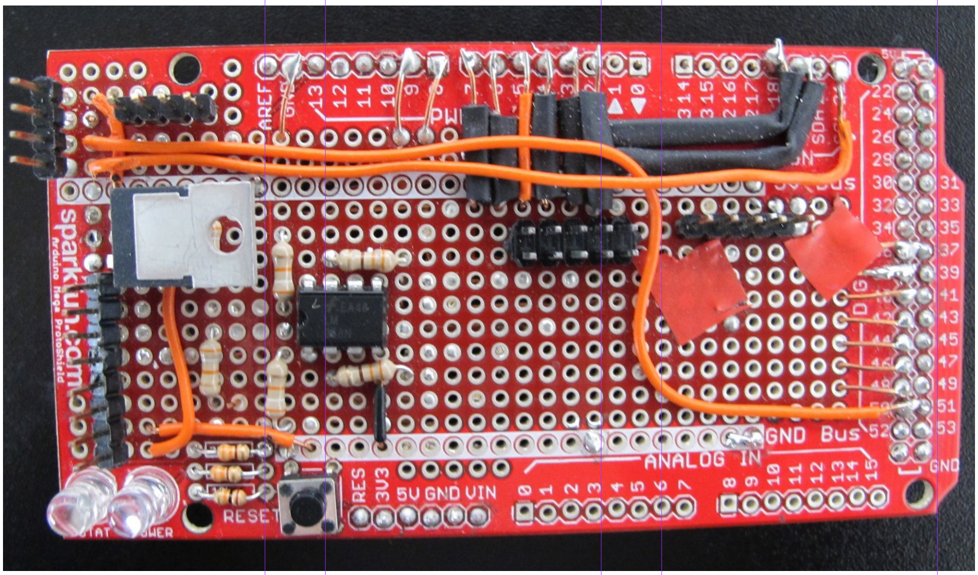
Motor Driver 1, Channel A, Enable	42 (Digital input/output)
1A, RPWM	5 (PWM)
1A, LPWM	6 (PWM)
1B, Enable	44 (Digital input/output)
1B, RPWM	4 (PWM)
1B, LPWM	7 (PWM)
2A, Enable	36 (Digital input/output)
2A, RPWM	8 (PWM)
2A, LPWM	9 (PWM)
Bow Actuator, Rotation Sensor	2 (Interrupt 0)
Bow Actuator, Limit A (lower)	38 (Digital input)
Bow Actuator, Limit B (upper)	40 (Digital input)
Stern Actuator, Rotation Sensor	3 (Interrupt 1)
Stern Actuator, Limit A (lower)	46 (Digital input)
Stern Actuator, Limit B (upper)	48 (Digital input)
Winch, Rotation Sensor (currently unused)	21 (Interrupt 2)
Winch, Limit (currently unused)	50 (Digital input)
Xbee, DIN	18 (Serial1)
Xbee, DOUT	19 (Serial1)

A schematic of the layout for this shield is shown below. Red indicates connections directly along the surface of the protoboard, and other colors indicate connections made using wires attached to the protoboard. Note the LM358 in the center left, and the voltage regulator in the upper left.



The Arduino Mega 2560, with its input shield, is mounted with the motor drivers and protection fuses inside a waterproof Pelicase.





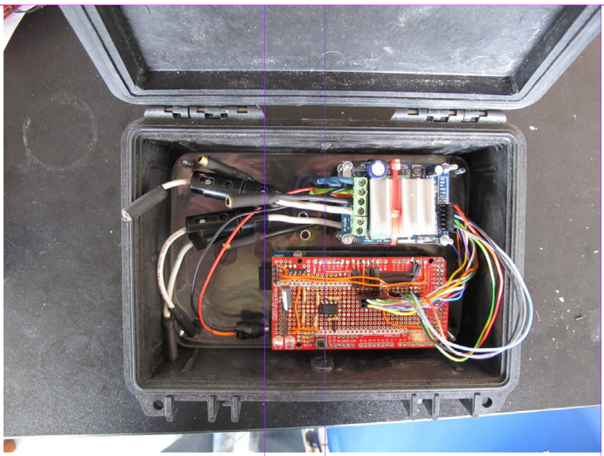


Figure [x]: The mounting of the Arduino Mega (with shield), and the two motor drivers (stacked on top of each other) inside the waterproof Pelicase. The colorful cables on the right connect the shield to the motor drivers, and the thick wires on the left provide connections for the motor cables (which enter though a tube on the back of the Pelicase).[r]

The connector labeled “MOTOSENSE1” has the following connections, from bottom to top: 5V, ground, rotational sensor for actuator 2, rotational sensor for actuator 1, limit switch B for actuator 2, limit A for actuator 2, limit B for actuator 1, limit A for actuator 1. MOTOSENSE2 is not connected in Protei_006, but the connections have been installed for future use. From bottom to top: winch rotational sensor, winch limit switch, ground, 5V. The XBee connector from left to right is: 3.3V, ground, XBee DIN, XBee, DOUT. The motor driver connections are, from left to right, LPWM, RPWM, Enable, ground, 5V.

Two images of each side of the completed Arduino shield are shown below. In the future, it would make sense to have a real printed circuit board professionally fabricated, for the rapid pace of development of Protei 6, it did not.

Power

Power for Protei is supplied by a 14.4V, 10Ah nickel metal hydride (NiMH) battery in the keel (see section Keel Construction, above). Power distribution for this Protei revision is extremely simple — battery power goes through a high current (((60A))) (((135A)))) circuit breaker, and from there is distributed to the motor drivers and to the Arduino Mega. Each motor driver output is further protected by a 25A fuse, to protect both the motor driver and the motor in the event of a stall or short circuit. The Arduino provides a 5V power bus, and a 3.3V voltage regulator (described above), provides 3.3V power for the Xbee.

Picture of the batteries

Control firmware

The control process will be summarized below, but for full details, one should examine the source code and its comments directly. This is available on Protei's git repository. [3]
The control firmware is based around a 20 Hz (period of 50 ms) control loop. Each loop cycle, the following tasks are performed:
Read and process any data the Xbee has received.
Send status information back to the transmitter.
Each MotorController object runs their main loop:
Calculate the power output necessary for the closed loop actuators.
Send the correct power levels to the two motor driver channels.
Send the winch motor power level.
Every 4 loops, print any debug information.
There are two important C++ classes used in the control software. The Motor class[4] has references to the 3 pins necessary for motor control, as described above, and to the three necessary input pins (Limit A, Limit B, and the rotation sensor). Through an interrupt (which must, due to the limitations of the Arduino environment, be set up outside of the class), a Motor object can keep track of the number of rotations that it has turned. The move function has some extra logic besides sending the correct PWM values — it also makes sure that the motor comes to a stop before reversing direction (to avoid miscounting rotations), prevents the motor from stopping while the rotation sensor is active (can cause rotation miscounts), prevents very small values from being sent to the motor (to save power), prevents the motor from moving against the limit sensor, and can reassert the Motor driver enable pins after a limit sensor is depressed.
A MotorController class[5] takes a target number of rotations, and a Motor object, and calculates the power level that should be sent to the motor. If the error (target rotations - current rotations) is less than 2, the motor is told to brake. Otherwise, the motor is told to move at K*error, where K is the gain of the object.

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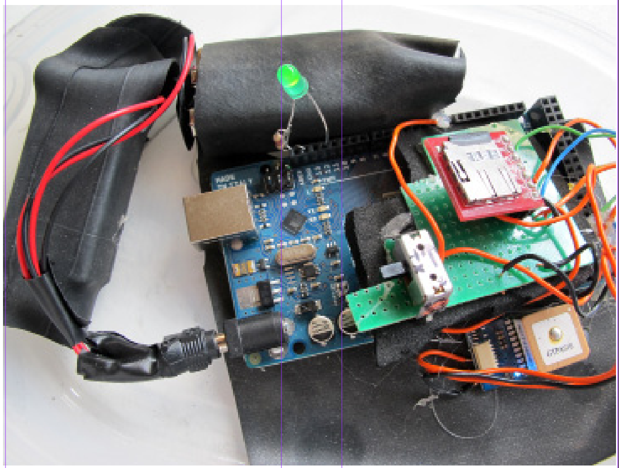
3.6 Positional Sensing and GPS <Gab>

The positional control system is performed using the MediaTek MT3329 GPS. It is an isolated system run off of two 9V batteries, enclosed in a box that fits above the winch box. The GPS transmits incoming NMEA (National Marine Electronics Association) sentences at 10Hz to the Arduino Mega. The NMEA sentences are stored as a text file on a microSD card, using the microSD card reader, from Sparkfun.com, sku#DEV-09802.

Example of GPS strings:
$GPGGA,215341.000,5155.9653,N,00428.0063,E,1,5,4.22,28.1,M,47.,,4
$GPGGA,215342.000,5155.9671,N,00428.0060,E,1,5,4.22,28.0,M,47.1,M,,*6.01
$GPGGA,215343.000,5155.9674,N,00428.0061,E,1,5,4.41,28.2,M,47.1,0E,
$GPGGA,215344.000,5155.9672,N,00428.0059,E,1,5,4.42,29.1,M,47.1,M,,*6A
$GPGGA,215345.000,5155.9683,N,00428.0054,E,1,5,4.22,29.9,M,47.1,M,,*62303R6A

NMEA sentences are specified electronically transmitted strings of data, containing global positioning information. For Protei_006, the useful information might include latitude, longitude, course, bearing, speed, time, date, satellite ID's, checksum, and altitude. For more information about NMEA sentences and standards, see http://www.nmea.org/ or http://wiki.openstreetmap.org/wiki/NMEA

With the GPS data, Protei_006's trip can be visualized on a map simply by uploading the entire text file (or pasting its contents) into GPS Visualizer (http://gpsvisualizer.com).



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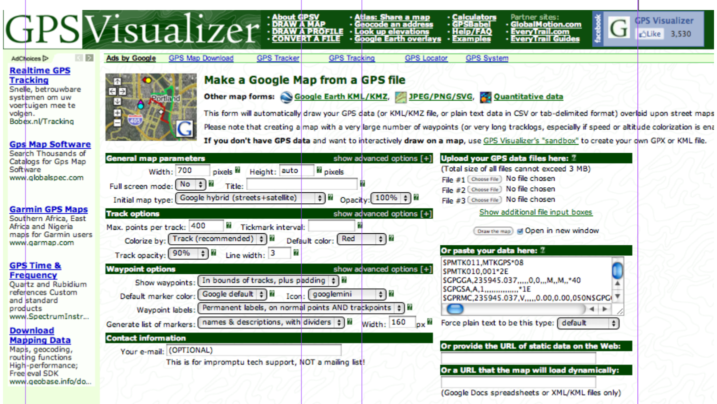

Code

Oil Absorbtion

Protei_007

Future Developments <g...>
Chart of ethics

Known Issues and Proposed Improvements

The current model of Protei is well balanced, maneuverable (by adjusting the trim of the sail and the curvature of the hull), responds to R/C control, and heels in the wind while staying upright. Because of its round, serpent-shaped hull, its heavy ballast, and its low center of gravity, in high winds and unstable conditions Protei lies flat on the water until conditions improve and it can right itself. (is this true? footnote saying we have to do more extensive testing?).
However, There are improvements for the build of Protei_007, to optimize its behavior, robustness, and maneuverability. Some improvements include the following:
Protei must be able to successfully tack back and forth across the wind - this will be achieved by better control over the hull articulation (the current motors have been replaced with more powerful ones). More tests must be performed towing the oil boom as it gets saturated with oil, as well as in rough oceanic and meteorological conditions. Eventually, Protei will need to be able to obey R/C commands from longer distances than the XBee's can provide.
The biggest improvement for Protei_007 will be one waterproofed unit in which all the electromechanical equipment live (rather than multiple separate units for each component). With one centralized compartment, it will be easier to find the source of a leak, as well as developing an automated system to rid water during the leak with the use of a water sensor and a bilge pump.
We must implement a better system for launching and retrieving the vessel, such as with a small crane or pulley mechanism. For the first test of Protei_006, the boat was lowered vertically 2 meters into the water. When retrieving it, the neoprene skin tore (about 2 cm) as it rubbed along the wall.

Trouble shooting, conclusions etc

This paragraph will move to 'the future' section.
For the prototype of Protei 006, we used neoprene to construct the skin and the keel. Advantages of this system are increased flexibility and the buoyancy. However, we did not research the chemical aspects of neoprete yet, including how it will be affected when in contact with crude oil. A downside to neoprene is that it rips or tears somewhat easily when in contact with a sharp object.
Same chemical consideration goes for the PVC tubes!

Evolution

As the design of the individual Protei vessel improves, further versions will develop towards the behavior of multiple vessels, making up a swarm of sailing drones. As we progress, the vessel will move towards energetic autonomy, possessing sensing and decision-making skills, and eventually, will evolve from centralised swarm control to a decentralised system of systems.

The evolution of Protei is divided into six levels of networked systems, each building towards a more autonomous agent (the individual boat) with the capability of complex interactions (amongst the individual agents, and between multiple networks of agents). Eventually, Protei will be a self-organizing, multi- platformed network, with web-interface capabilities, to enable over-riding a unit (or units) of the swarm, whilst not disturbing the network as a whole. This current Protei model is between level 1 and 2: It

is a radio controlled vessel, needing a human controller nearby (within RF range) to steer and control it. It is beginning to log environmental and positional data about itself and its journey (by storing GPS information).

The multiple Platforms of Protei

INDIVIDUAL VESSELS (1, 2, and 3):

1. Radio controlled with 1 user: The first platform for Protei is one single boat, with remote control, requiring 1 user to control it remotely. Control includes steering by directing the articulation of the hull, as well as determining the trim of the sail.t

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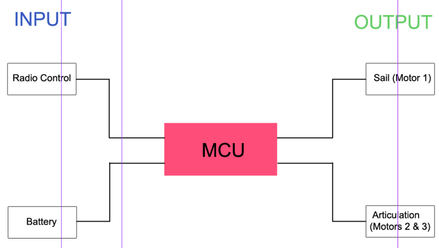
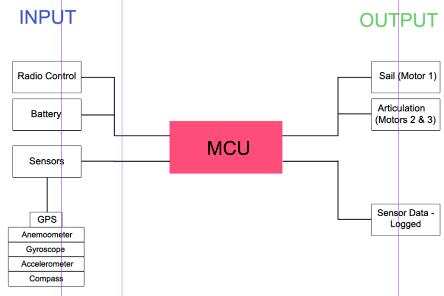
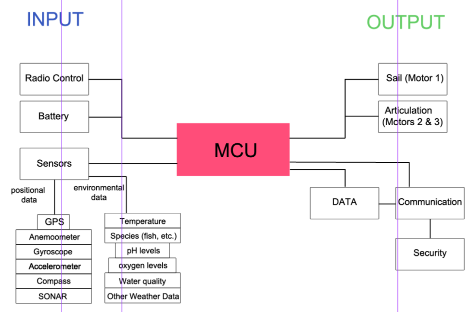


2. Radio controlled + sensing (semi-autonomous): The second Protei platform is a radio-controlled vessel, capable of sensing and storing data about its surroundings. It requires 1 user to control it remotely, but it has built in positional and environmental sensors (including a GPS, compass, gyroscope, accelerometer and anemometer).

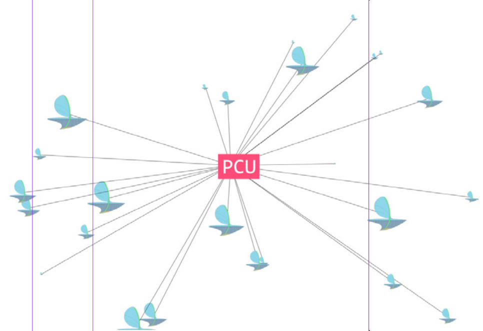


3. Autonomous: The third platform of Protei is a fully autonomous unit, that takes in data about itself and its surroundings, and makes decisions about appropriate behavior and actions to take. This platform no longer needs a human operator. The vessel sails independently, follows way points, rights itself, tacks across the wind, and adjusts its behavior due to changing environmental stimuli.

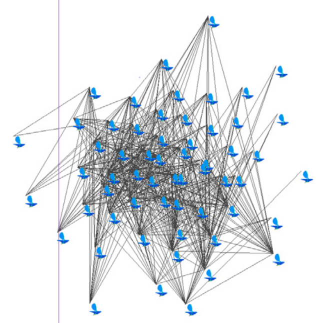


MULTIPLE UNITS making up a complex system of vessels (4, 5, and 6):

4. Swarm: Centralized The fourth evolution of Protei is a network of multiple individual vessels that obey commands from one centralized PCU master which controls group behavior. Each individual vessel is autonomous, and knows its position with regards to the master, but there is no communication between vessels. This requires minimal network optimization, and the group moves as one unit. If one unit gets too far from the master, it will get lost.
(master-slave model: a PCU governs slave behavior, and the slaves communicate back to the master)



5. Swarm: Decentralized The fifth evolution of Protei is a non-linear, complex, self organizing system, consisting of subsystems and individuals. Each individual possesses intelligence to compute its position in the environment, relative to nearby individuals, and to the entire group. A suite of behavioral characteristics drive each organism's actions and interactions. This platform requires that each individual makes predictions about environmental characteristics, such as wind and current, through receipt and transmission of peer-peer information. At this level, the control system of Protei moves beyond Arduino, to a more complex, multi- level operating system, such as Android.
(COMPLEX SYSTEM BEHAVIOR; Peer-to-peer communication; Input and output information sent through individuals, the network, and sub-networks)



6. Multi-Platform The most complex level of the Protei Platform brings back the human interface. This level includes multiple independent networks of vessels, with an MCU that is an interface between humans and the networks of vessels. This allows for a web platform for individuals (people) to take control of single or multiple vessels to override its control mechanisms, without disruption of the network as a whole. This allows for a robust, adaptable system, with many behavioral levels, including groups, sub-groups, and individuals. This adaptive, emergent system is dependent on complex algorithms and network optimization protocols.

Applications

Protei can eventually be appropriated for other purposes, such as cleaning other chemical pollutants and material waste off of water, as well as collecting samples for ocean research. As we move towards Protei_007 and beyond, the build will move towards a more modular one, made from recycled materials, so that the vessel is an adaptable platform for multiple purposes. Some other applications for Protei might include:

1. Plastic collection

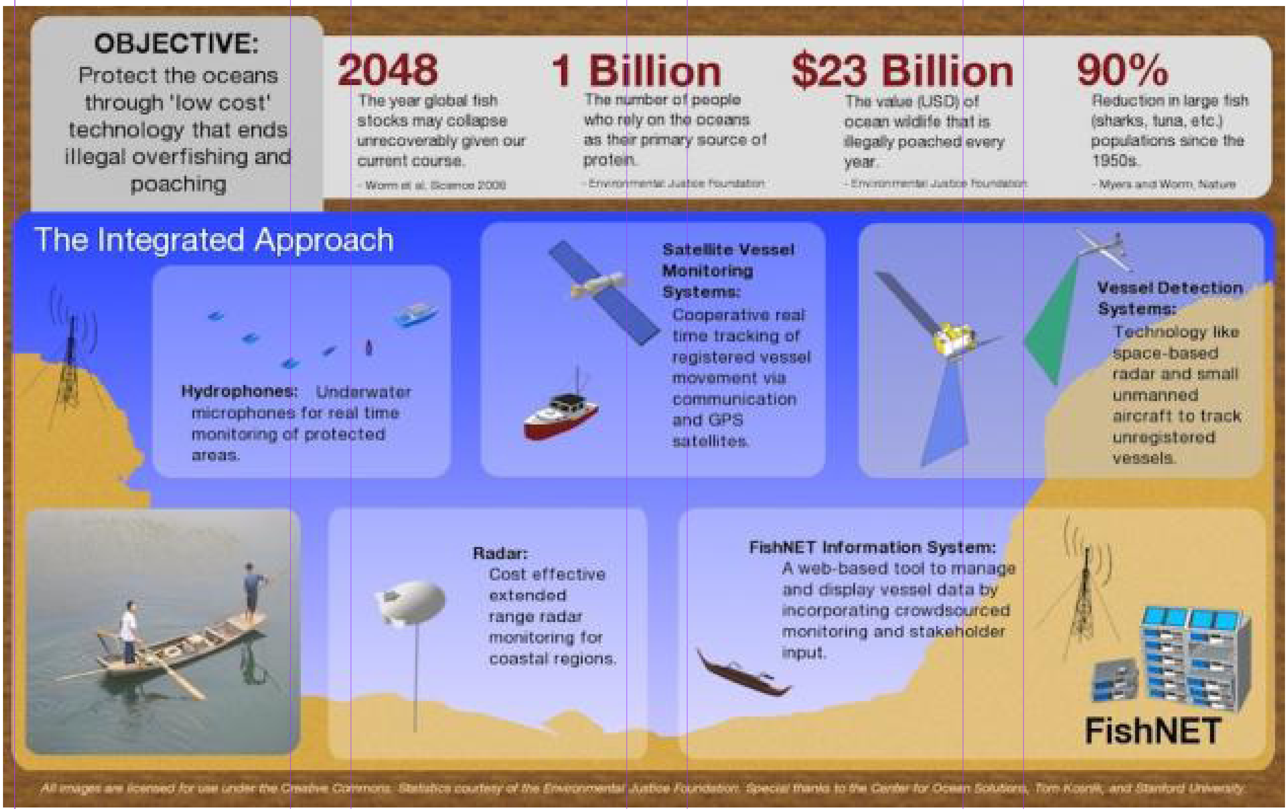
in the big gyres: involving fishermen to collect the plastic at one end and waste valorization industry at the other end to use/treat the collected plastic. Plastic is bio and photo degraded so it becomes micro and necessits very finely meshed nets.

2. Water sampling and quality monitoring in coastal areas

Measuring the concentration in "invisible" toxics as PCBs, HAP in sensitive areas. In Europe the European Commission is rolling out an extensive water quality assessment program (Water Directive 2020) - but they need loads of samples. If we can help them design a cheap and reliable way to collect samples, and even measure on-site the water quality, that will be appreciated!

3. Water radioactivty

<cesar>



4. Marine Protected Areas monitoring

The MPAs are occupying vast surfaces and it is way to expensive to send a boat with Park Rangers to check them out. So if a robot can patrol, report any event, redirect any intrusion, like a real Park Ranger, that would save a lot of money. Same can be done to monitor coastal fisheries, where Protei fits into a network of open source telecom system as a surface information relay, together with underwater microphones and air balloons/ land based relays.
(Creative Commons - Shah Selbe - FishNET - Centre for Ocean Solutions)

References
1. Richard A. Kerr (13 August 2010). «A Lot of Oil on the Loose, Not So Much to Be Found». Science 329 (5993): 734–5. doi:10.1126/science.329.5993.734. PMID 20705818. http://www.sciencemag.org/content/329/5993/734

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