Blott Matthews Challenge 2019

Pole to Pole

Apex

Abingdon School

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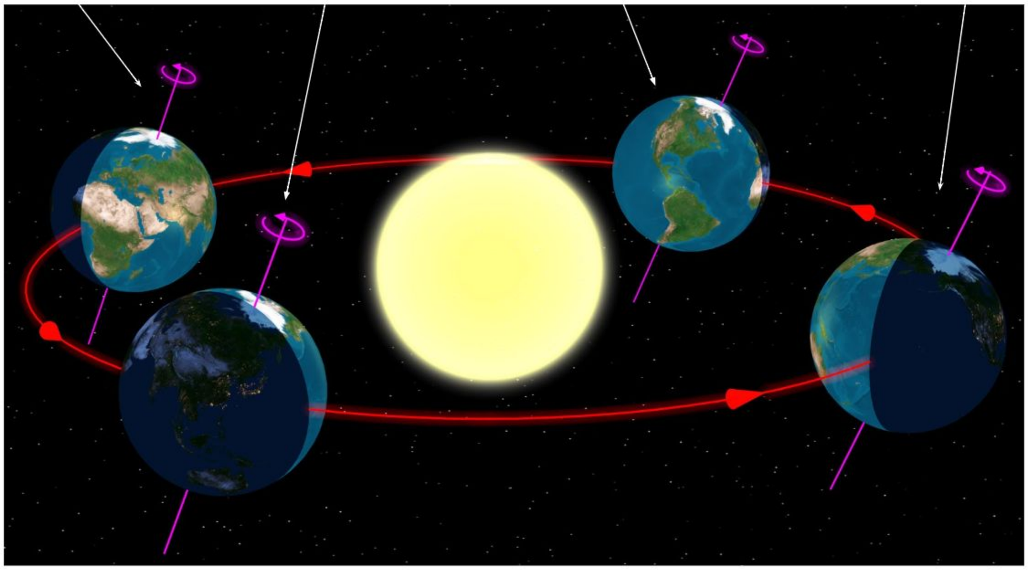
Overview

The aim of this project was to get a one ton box from the North Pole to the South Pole without taking it by air. For the majority of this route we are travelling on water as it is easier and more efficient. We have designed an amphibious boat that is able to withstand the pressures from the environment such as high wind speeds, varying temperatures and sea ice. This design brings together some old but trusted methods of travel as well as some new and even future technologies. We have aimed to use our youthful ambition to create a completely unique design that is far different from the normal methods that are used today. We are trying to prove that there are other methods for what may originally seem a simple job that can prove to be more effective when given a bit of thought.

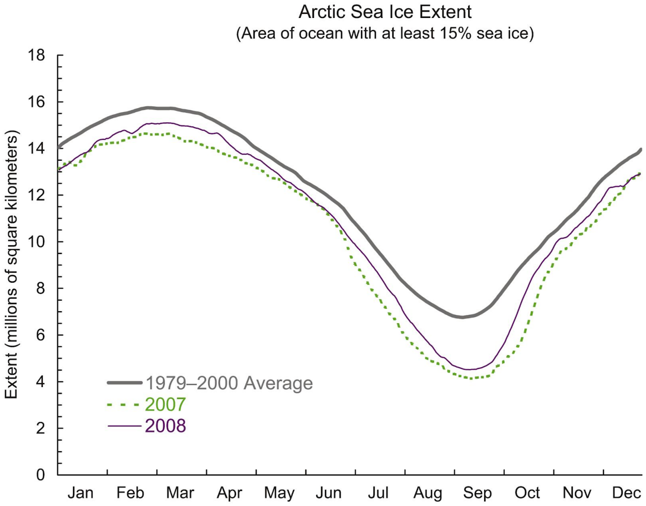
Timings

For this challenge the time frame for the one tonne box to get to the South Pole from the North Pole is one year. However we have chosen not to use all this time due to light hours in the poles. Our journey begins at the start of June when light hours are maximised. This is important for us as one of our energy sources is solar power so the 24 hours of light a day means that we will always have sufficient power for the stages of our journey in the Arctic and Antarctic circles. The earth has an axial tilt of about 23.4 degrees. The northern solstice where the northern hemisphere tilts the most towards the sun is on June 21st and the southern solstice is on December 21st exactly 6 months after. However, in order to not decrease the time we have to complete this expedition, we have compromised and are starting the trip on 1st June and finishing in February (the finish date cannot be confirmed as the weather is very unpredictable).



Another factor that had to be considered when planning this route is the amount of sea ice at the poles during this time. The shape and size of the sea ice varies from year to year so in order to avoid the dangers of icebergs which will slow our expedition down, we plan to be doing the stages of the expedition that are at the poles when the ice is at its minimum. However, there is a delay between the maximum day of sunlight hours and the minimum amount of sea ice which is called seasonal lag. Seasonal lag can range from 15 days to 2.5 months. Usually the minimum level of ice for the Arctic is in September and the minimum level for the Antarctic is in March. Although the difference in efficiencies of travel can be better on ice, due to the unpredictable nature of the ice, and to maximise ease of travel we have tried to limit the time spent on the ice.

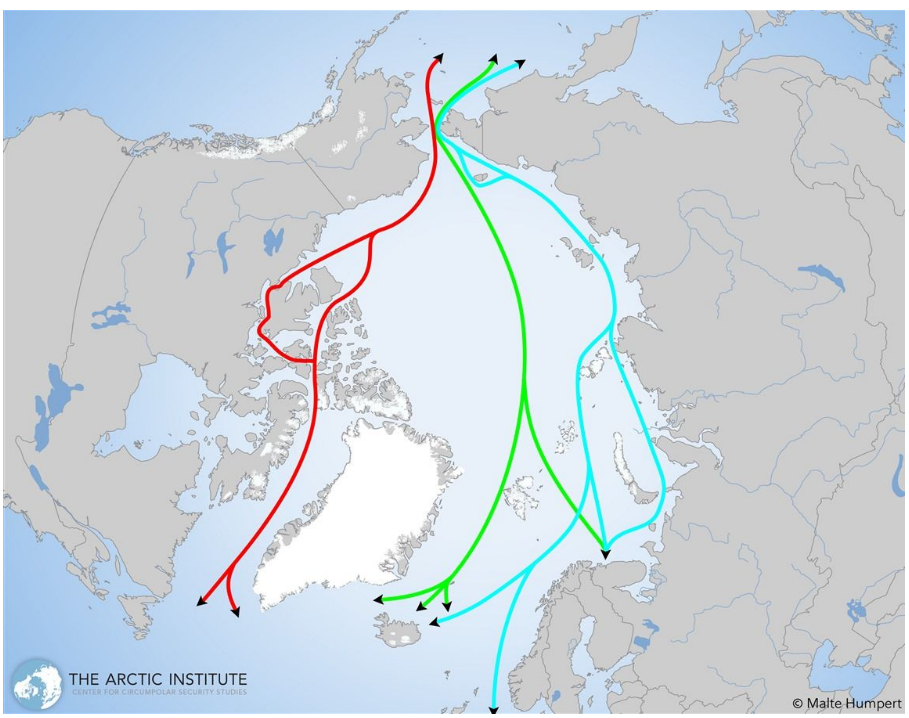
In order to compromise between the maximum sunlight hours, the minimum sea ice whilst maximising the time we have on water in order to reduce the power output needed, our conclusion for our time schedule is to start on 1st June, leave the Arctic circle in August, arrive at the Antarctic at the end of December and reach the South Pole during February.

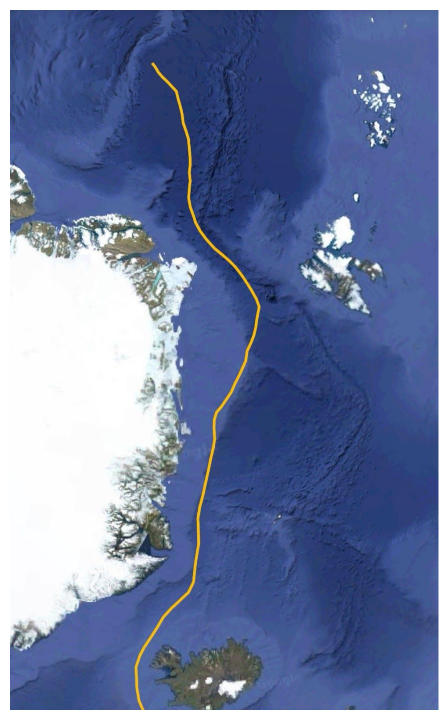


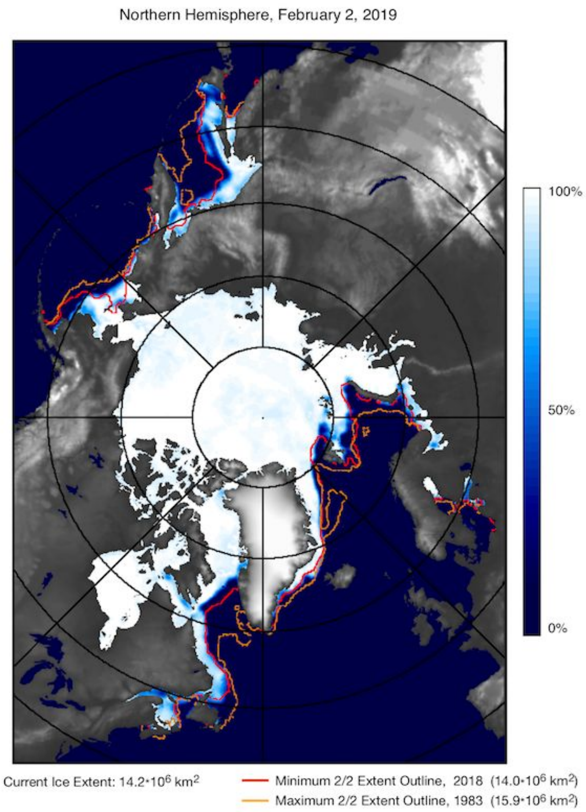
Route

There are three main sections to the journey. The first is in the Arctic where there is part of the journey on the ice. Then the majority of the distance is covered on water and then the final stretch is in the Antarctic.

Our route starts in the Arctic circle where a large part of the Arctic is covered by ice all year round. The geographic North Pole sits on ice so the start of the the journey is on the sea ice. As seen in the map below, in the next ten years it is predicted that the green shipping route will be available due to global warming and melting sea ice. This lane will make the journey through the Arctic circle a lot easier and more efficient. It is hard to say the exact route through the Arctic but with the use of satellites and sensors on the boat (which are covered in more detail in the design section) these will decide the exact intricacies of the route. As the ice at the poles is constantly changing an exact route cannot be formulated.

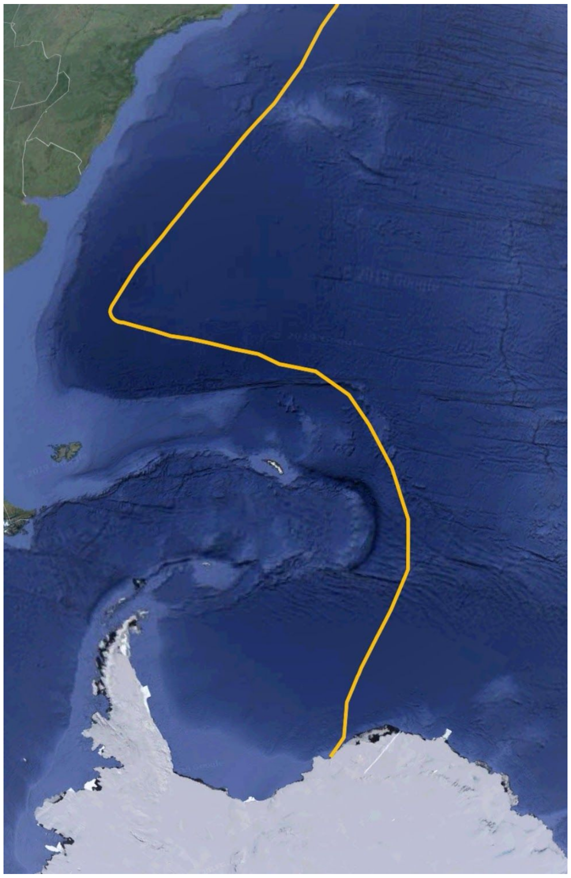


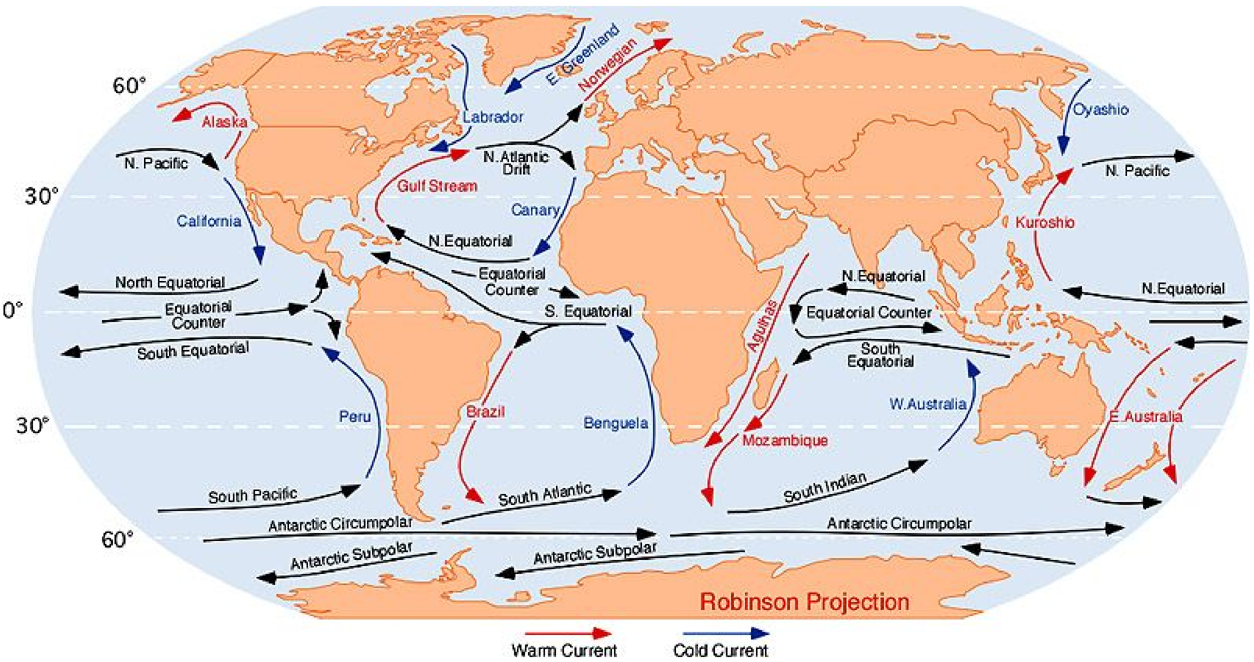




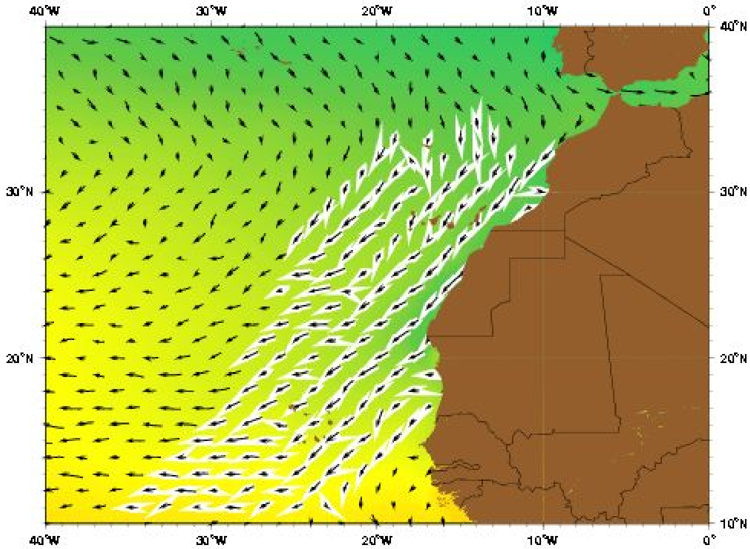
This map to the left shows the extent of the sea ice in the Arctic circle during the summer and winter. As you can see we are taking the shortest route on the ice as we meet the water north of Svalbard.

The next stage of the journey is through the Atlantic Ocean. We have decided to take this route in order to maximise the use of ocean currents on our route. Once leaving the Arctic circle we first utilise the cold East Greenland current before crossing over to the Canary current that is on the West coast of Africa. The next part of the course is to cross the equator. This will be during the end of the hurricane season so we may encounter tropical storms. Hurricanes start from moist hot air rising from the sea off the coast of West Africa. These tropical uprisings then make their way across the atlantic picking up more moisture and gaining more energy. The most threatening part of these tropical storms is the strong winds which could cause damage to the boat or halt progress. These strong winds are created by the spin of the earth which causes them to spin which creates the fast circling wind. At this time the temperature will also be at its hottest which provides another challenge such as expansion of materials due to heating but this will be covered in the design section. The next part of the trip is down the east coast of Brazil and Argentina before avoiding the Falkland Islands to reach Antarctica.





The velocity of ocean currents is very variable. They depend on the lunar cycle as well as weather patterns and temperature. The largest ocean current is the gulf stream which dictates a lot of the weather in Europe. The gulf stream has a speed of up to 2.5m/s. In our route we are not able to utilise the gulf stream as it runs north east from the gulf of Mexico to Europe across the atlantic ocean. Currents are a useful way to increase the speed of the boat which will mean a reduced power output. For example the canary current, which is 500m deep, can reach speeds of around 0.75 m/s. However this tends to be during the winter (northern hemisphere winter) and at this time we intend to be on Antarctica. During autumn time which is when the boat is passing west africa, the canary current is at its lowest of 0.1 m/s. This will not impact the progress as much as if the current is faster but it is useful to reduce our power output needed to complete the journey. Off the west coast of Africa there are multiple eddies which are swirling currents due to diffraction around islands. This can be seen in this map below.

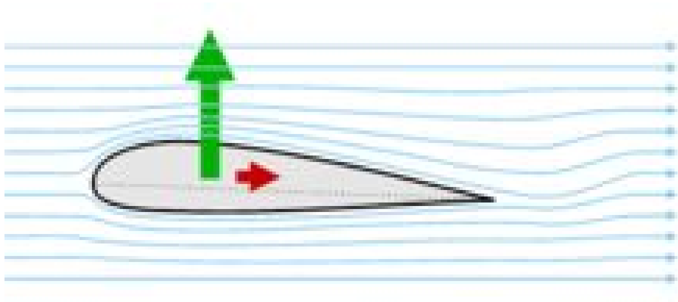


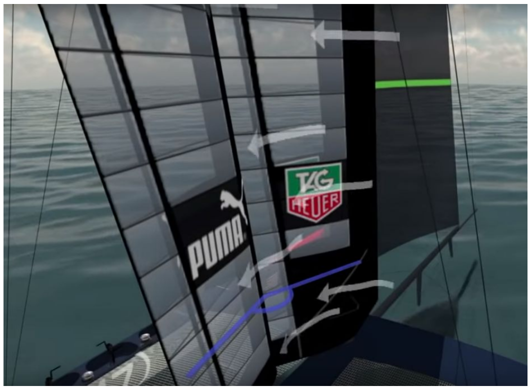
The route on Antarctica is probably the most challenging part of the journey. With about 3000 km of this 24000 km journey covered on the driest and most bleak continent, this part of the route was the hardest to plan. Our first main objective when planning this route was to make sure we did not cross the transatlantic mountains. This was one of the main factors that influenced our decision to travel across the atlantic ocean rather than the pacific. When we arrive at Antarctica we get to the brunt ice shelf. Here there is a landing spot for people getting to the Halley research centre which is a British owned scientific research centre that monitors the Antarctic environment. From this ice shelf there is an ascent which will require the caterpillar tracks which are the best solution for ascents on ice. However, from here the journey to the South Pole is reasonably flat and should be fast progress as the use of the sail for ice yachting makes the journey fast.

Design

The shape of the boat is a catamaran which is a popular shape in boat racing due to its lack of contact with the water and the increased lift it receives. We have also decided to use this shape as it is very stable due to it being quite wide with the two hulls of the boat being spaced apart. In each hull there is a rechargeable battery that is connected to a motor. The reason for this is that when there is little wind or when we are going through a storm which means that the sail is down, extra power will be provided by the motor using the energy from the rechargeable batteries. When on the ice, the batteries are connected to the caterpillar tracks as seen in the diagrams. The inspiration for the design on ice came from skidoos which are very popular machines that are used on ice. On the bottom of each hull are two electromechanical double-leaf sliding plug door drives to allow the skis and the caterpillar tracks to be lowered as the catamaran gets onto land. The sail will also be utilised when on the ice. Ice yachting is a sport that has been played for years and people have reached speeds of over 100 mph. Although we do not predict to reach speeds of anywhere near this, this can be a useful way to do this part of the journey as the route on Antarctica is very flat. When doing this, the caterpillar tracks will be put into neutral however they will still provide stability.

An important part of the design is the use of a solid sail. Solid sails have been a success in recent times as they provide a lot of lift and minimal drag. They are known as wingsails in the sailing industry and have been very successful on racing boats as well as larger vessels such as in the america's cup. The wingsail is 30 m tall which is nearly the size of the wing of a plane. The wingsail is made of two different parts (the front element and the trailing element) and by adjusting the angle of these elements depending on the wind direction you can create lots of horsepower by deflecting the wind from one part of the sail to the other. The wingsail also creates a difference in pressure on each side of the sail which causes it to tip slightly and creates higher speeds. On these racing boats these wingsails can create speeds of up to three times the wind speed. Another advantage of using wingsails is that they are not affected by sailing into the wind. Although it is not as fast as sailing downwind, they still create good speeds. This is useful as it means the motors will not have to be used as much and also the sail will not have to be brought down. The boat also uses L-shaped hydrofoils that lift the boat out of the water at higher speeds. This reduces the water resistance on the boat increasing the resultant force on the boat and providing a greater acceleration and ultimately a greater terminal velocity. We do not anticipate for the boat to be out of the water as much as seen in racing boats due to the weight of our boat. However, any increased lift from the wingsail and the hydrofoils means that there is a reduced amount of boat in the water so reduced drag.





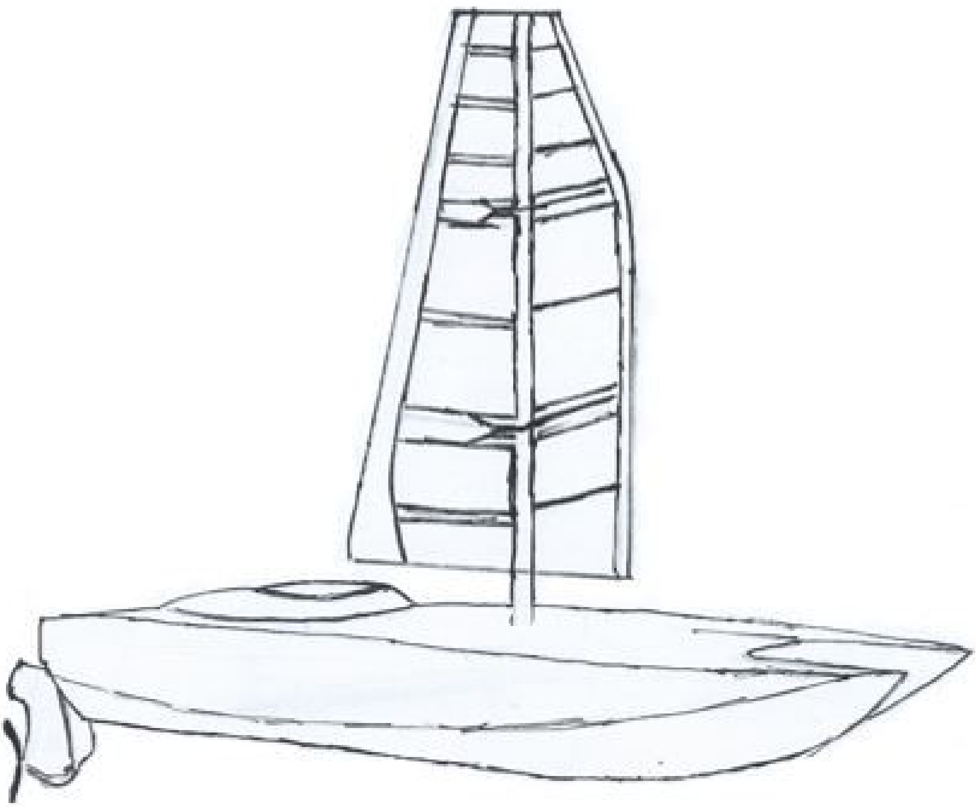
Another challenging part of the design was to combat getting onto ice shelves. We realise our boat is not large enough and powerful enough to smash through several metres of ice. So to combat this we have designed a jack that grips onto the top of an ice shelf and then pulls the boat up onto the ice shelf. This is for worst case scenarios where there is not a gradient to slide up. Another alternative is the use of the sensor system and satellites. The boat will be equipped with laser distance sensors that will be able to detect icebergs or land from over 100m away. This is useful as if an iceberg cannot be seen on satellite imagery, the laser sensors can pick this up and add the information to the map of the route and the algorithm will take a new route, similar to the way a sat nav does. In the next ten years it could be possible that artificial intelligence is so strong that it could control the route of the boat more easily and be more cost effective. However, we have chosen not to draft this in as it is hard to tell how much this will affect our plan.

The dimensions of the boat are quite important in order to get the correct ratio of the size of the sail to the the size of the boat. Each hull of the catamaran is 12 metres long and 1 metre wide with 8 metres between each hull. The sail is nearly 30 metres high which will create a large amount of power and some high speeds. We have also included in our design a mechanism for lowering the solid sail. Within the sail, there is a carbon fibre mast similar to a traditional sail. The rest of the sail includes hinges which means that it can be folded down in a concertina style. This is done by a metal rope pulley system which is powered by a winch. On the sail there will be solar panels attached which are easily stuck onto the sail and connected to the rechargeable batteries.

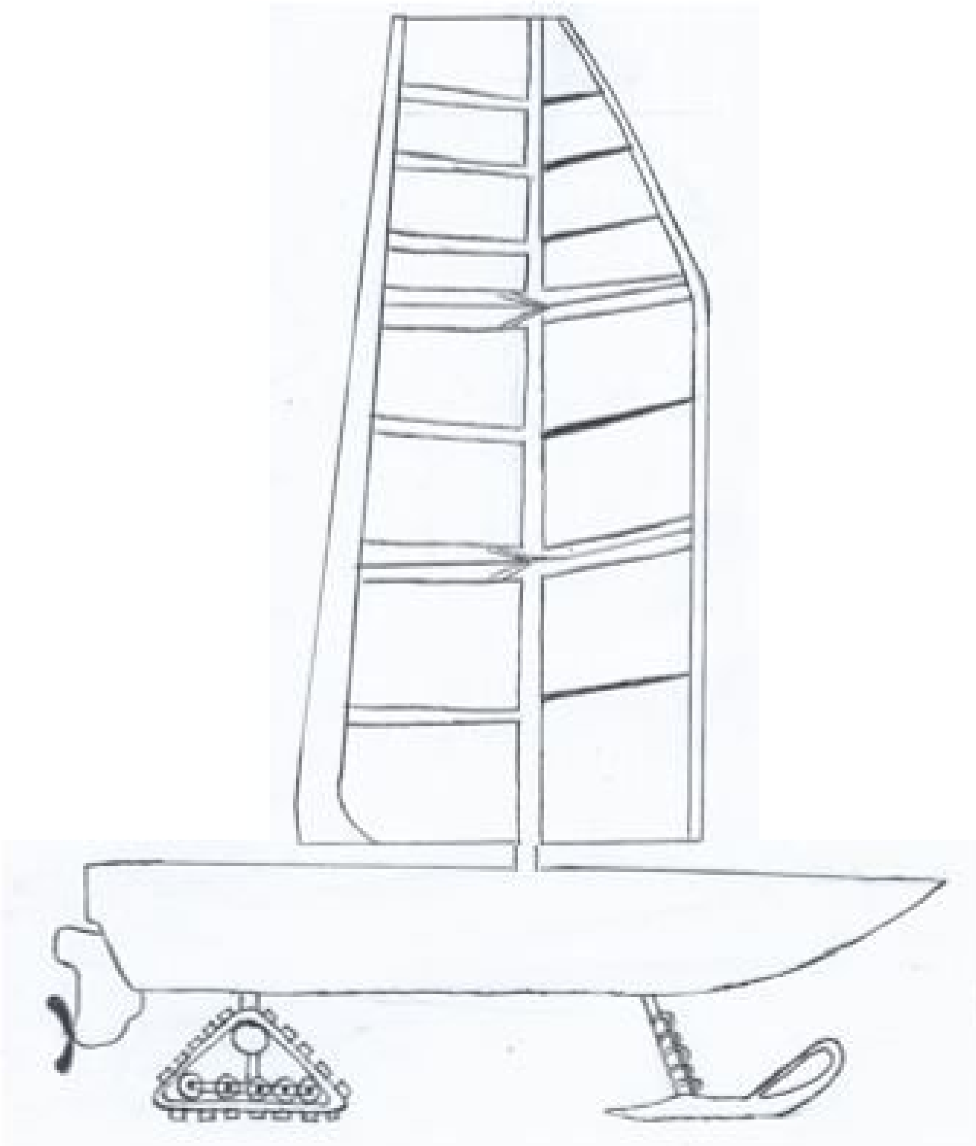
A large factor of our design that makes it unique is the fact that this expedition is being done completely unmanned. All the navigation and the directing is done by a computer system. We have chosen to use software called Maxsea which has data about wind speeds, currents as well as a navigation system that allows you to plot a route and it can adapt to changes in course due to storms or high currents. This system will be attached to the rudder and sail which are powered by motors in each hull. As well as this we have onboard sensors such as weathervanes and anemometers that can send information to the Maxsea software which makes decisions. In the future this could be controlled by artificial intelligence that will be able to make better decisions.

In each hull of the catamaran, there is a motor and rechargeable battery. The solar panels which convert the solar energy into electrical energy ae connected to the rechargeable batteries. The motors have several different connections. The main one is the powering of the propellers when on water and the caterpillar tracks when on the ice. Also the motors have a function to change the direction of the rudder and change the angle of the sail. The motors are also needed to power the winch that puts the sail up and down as well as powering the jack. In order for this to occur, the motors have multiple cylinders so there can be more than one power output.

On water:

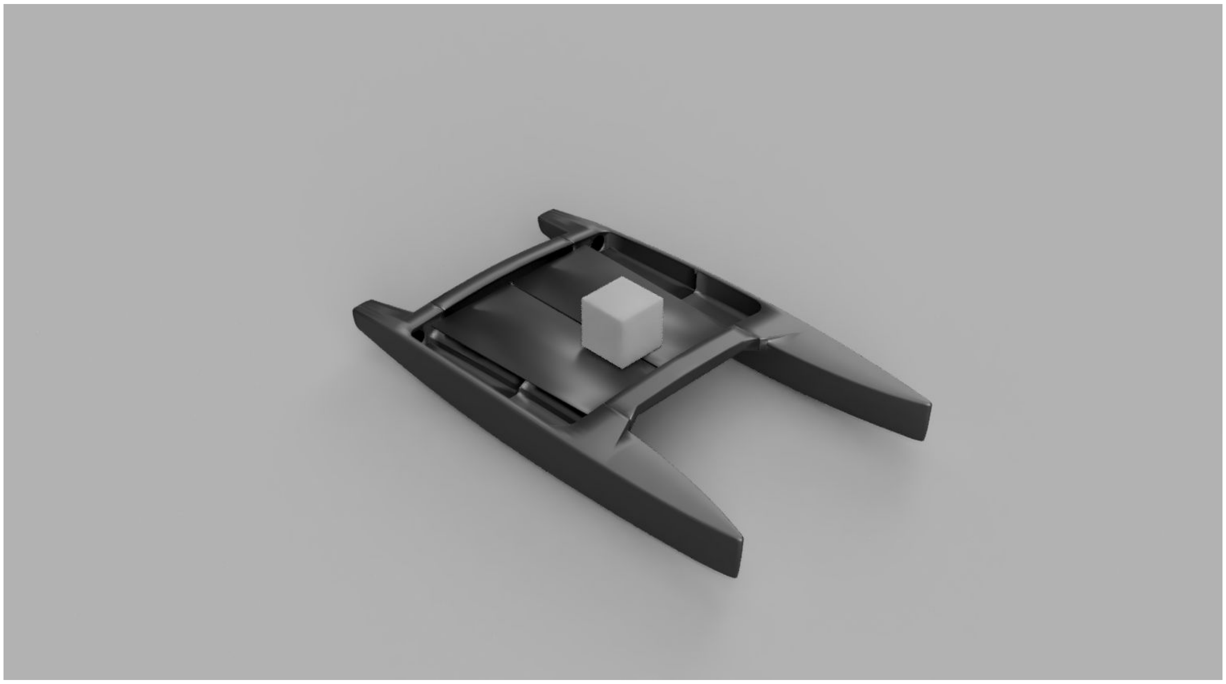


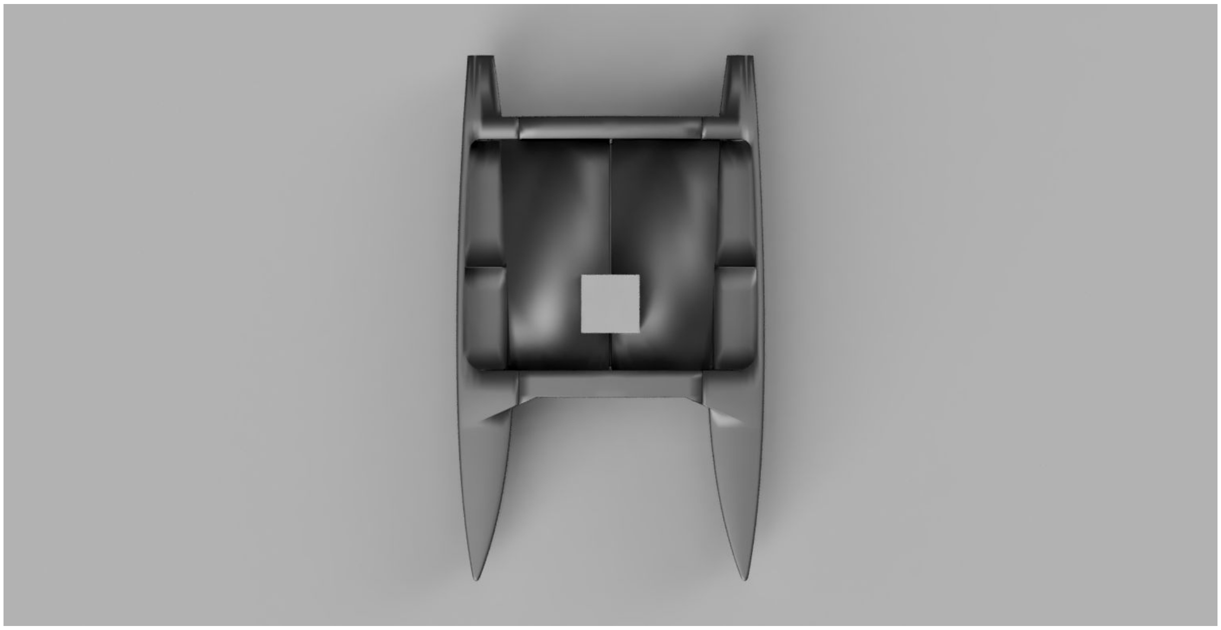
On land:

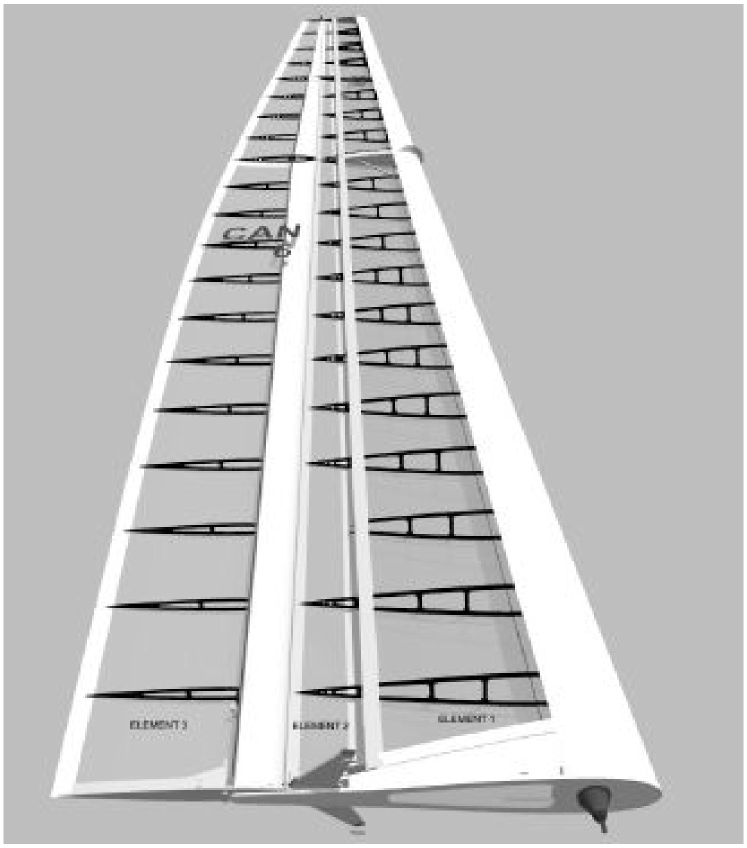


Computer Aided Design (CAD):

These computer designed models show the hull of the catamaran and the wingsail. In the actual boat, the box is covered over in order to make it more aerodynamic.






ELEMENT 3
ELEMENT 2
ELEMENT 1

Materials

For the hull:

Currently the hulls of the catamaran will be made with honeycombed aluminium with a layer of fibreglass surrounding it. Aluminium is a commonly used material as it is relatively lightweight compared to other metals and it is also very strong. This is why it is used for the body of planes as well as for our boat. Fibreglass is used to protect the aluminium, stopping any corrosion despite aluminium being quite unreactive due to the layer of oxide that forms around it. However, the fibreglass is used as it has a high thermal conductivity and a low coefficient of thermal expansion. In the aluminium, gaps will be created in order to stop the aluminium putting pressure on the outer fibreglass layer when it expands. We need to include these due to the vast changes in temperature of up to 70K throughout the journey. Another reason for using these materials is that they are relatively cheap and their malleability make the manufacturing process easier.

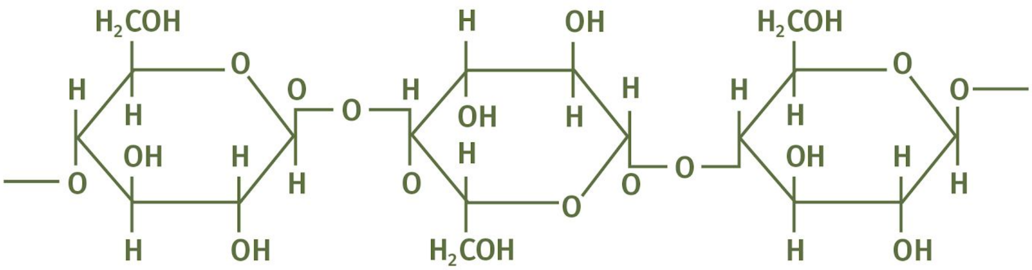
However, in the near future we could use Cellulose Nanocrystal Composites which are currently in their infant stage but will soon be available. Cellulose is the main building block of trees and plants. Its nanocrystals are organized in a structure of strongly ordered crystalline particles which have been engineered by nature to be inherently strong and lightweight. It is also biodegradable and renewable as its main source is wood-pulp and cotton fibres. They can be surface functionalized to meet various challenging requirements, such as the development of high-performance nanocomposites, using hydrophobic polymer matrices. Their bulk density is low at 1.6 g/cc, but they exhibit incredible strength. An elastic modulus of nearly 150 GPa, and a tensile strength of nearly 10 GPa. A near-term goal for the cost of CNCs is $10 per kilogram, but large-scale production should reduce that figure to one or two dollars a kilo.

The outside of the boat is covered in teflon (polytetrafluoroethene or PTFE). We have chosen to use teflon mainly due to its property that it has a very low coefficient of friction of 0.05 when compared to polished steel. It is the plastic with the lowest coefficient of friction and the third lowest overall after BAM (a compound made of boron, aluminium and magnesium) and diamond. However, we have chosen to use teflon due to its price and ease of use and application. Teflon has a low coefficient of friction due to its resistance to Van Der Waals forces which are forces of attraction between neighbouring molecules when temporary dipoles are induced. Teflon also has other properties such as a reasonably high melting point and being very unreactive and corrosion free. Teflon is most commonly known for being used on non-stick pans however its use in spacecraft shows it is perfect for the uses we have for it.

For the sail:

The wingsail is a complex mix of Kevlar and carbon fibre as well as other plastic membranes. These wingsails are expertly designed and are used for high speed racing so include some very complex engineering that is kept secret as it is part of the competitivity of racing.

Cellulose: Polymer of β-(1→4) Glucoser



Solar cells

There are many factors that we must consider when we choose our solar panels.

Firstly, our journey from the North Pole and South Pole means that the temperature and climate varies significantly. Therefore, we must choose solar panels that can operate in extremely high and low temperatures. In order for the solar cells to work efficiently, their operating temperature range must be quite large, together with a low temperature coefficient. The temperature coefficient is how much the efficiency of the solar cells decrease for every 1 °C rise above 25°C.

Secondly, the solar cells must be as compact and lightweight as possible. If the solar panels are too heavy, it would be counterproductive to use solar cells on our boat. The heavier the boat is, the more power is required to accelerate and move forwards, while the drag force opposing motion would increase as well, due to having a larger portion of the boat submerged in the water. Therefore, the solar panels that we choose must have a high power output to weight ratio.

Along with the significant variance of temperature, weather conditions also vary significantly. The changes in humidity, with moist conditions in the ocean and dry conditions in the antarctic; the changes in wind speed, with the possibility of storms and hurricanes in the sea requires the solar panels to be resistant to impact. This is especially important as our solar panels will be installed on the sails of our boat, and is likely to be exposed to gusts.

Together with other more obvious requirements such as efficiency, here is a list of requirements which we consider important:

1. HIgh efficiency
2. Low temperature coefficient
3. Large range of operating temperature
4. Lightweight
5. Small surface area
6. Durable

Therefore, we have chosen the following model for our boat:

Sunpower SPR-X21-345 Solar Panels

SPR-X21-345

Average efficiency at standard test conditions (1000 W/m^2 irradiance, AM 1.5, 25° C): 21.5%

Power temperature coefficient: −0.29% / °C

Operating Temperature: −40° C to +85° C

Mass: 11.4 kg / m^2

Max Load: Wind: 62 psf, 3000 Pa front & back

(3000 Pa roughly equals to 250 km/h or 150 mph winds)

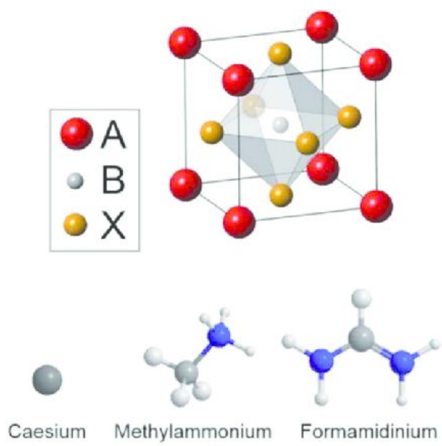
As one of the solar panels with very high efficiency (>20%), the temperature coefficient of this particular model is very low, at -0.29% / °C. This model is also snow, wind, hail and fire resistant, and is expected to be very durable.

Cost: £280.60 for 1558 mm x 1046 mm (about £172 per m^2)

However, the power generated by solar cells is not expected to cover all the power we need throughout the journey. Our design of sails and route planning should make sure that our boat is also propelled forwards by the wind and ocean currents. The solar panels are installed to increase the speed of the boat, especially when weather conditions and ocean currents are not favourable for our route.

We have also conducted research on developments of solar panels that may become viable in the future.

Perovskite Solar Cells



A perovskite solar cell is a type of solar cell which includes a perovskite-structured compound, most commonly a hybrid organic-inorganic lead or tin halide-based material, as the light-harvesting active layer.

A perovskite is any material with the same type of crystal structure as calcium titanium oxide (CaTiO3), known as the perovskite structure, or XIIA2+VIB4+X2−3 with the oxygen in the edge centres.

Perovskite materials such as methylammonium lead halides and all-inorganic caesium lead halide are cheap to produce and simple to manufacture.

The raw materials used, and the possible fabrication methods (such as various printing techniques) are both low cost. Their high absorption coefficient enables ultrathin films of around 500 nm to absorb the complete visible solar spectrum. These features combined result in the possibility to create low cost, high efficiency, thin, lightweight and flexible solar modules.

Efficiency

In July 2015 major hurdles were that the largest perovskite solar cell was only the size of a fingernail and that they degraded quickly in moist environments. However, researchers from EPFL published in June 2017, a work successfully demonstrating large-scale perovskite solar modules with no observed degradation over one year. Now, together with other organizations, the research team aims to develop a fully printable perovskite solar cell with 22% efficiency and with 90% of performance after ageing tests. Oxford PV is claiming a new efficiency record, aiming to create an efficient solar cell with efficiency over 30% by 2020.

Solar Batteries

There are many similarities between what we are looking for in our solar panels ard our solar batteries.

The most important factor when choosing a solar battery is the range of operating temperature. At extremely high temperatures, the capacity of the battery may decrease significantly, and at extremely low temperatures, the battery may fail to function completely.

Other important factors to consider would be the efficiency, mass and size of the battery, as this affects the efficiency of the boat as a whole.

Therefore we have chosen the Tesla Powerwall.

Tesla Powerwall

Usable Energy: 13.5 kWh

Scalable up to 10 powerwalls

Round Trip Efficiency: 90%

100% Depth of Discharge

Operating Temperature: -20°C to 50°C

Size: 1150 mm x 755 mm x 155 mm (0.135 m^3)

Mass: 125 kg

Operating Humidity: Up to 100%, condensing

IP67 rating (dust and water resistance)

According to our calculations, 27 kWh would be approximately enough to support the energy needs of our boat during the night, therefore, we will have 2 batteries connected directly to the motors on each hull.

The main reason that we chose this particular model is because it can be for outdoor use, with a good range of operating temperature, water resistance, and it is able to operate in very humid conditions. It also contains a built in liquid cooler which can be used to control the temperature.

The 90% efficiency of this battery ensures that most of the energy generated can be stored and used. Furthermore, this model of battery is designed to be scalable and 2 batteries can be easily connected to each other.

Solar batteries are DC power supplies, so this battery model also has a built in inverter to convert DC to AC if necessary for other electrical devices on the boat.

Cost: £11100

Calculations

1. Mass
2. Depth of Hull Submerged
3. Velocity
4. Drag
5. Power Required
6. Area of Solar Panels Needed
7. Capacity of Battery Required

Mass

Density of Aluminium: 2700 kg / m^3

As the 2 hulls are 12 m long and 1 m wide each, estimating the aluminium to be 5 cm thick and covering the bottom surface and the two sides, the volume of aluminium required is about:

12 * 1 * 0.05 * 3 * 2 = 3.6 m^3

Mass of Aluminium on the hulls: 3.6 * 2700 = 9720 kg

With the hull becoming narrower at each end of the catamaran, we expect that the estimated mass of aluminium above is more than the actual mass of aluminium. Since the layer of fibreglass is relatively thin and that the fibreglass itself is quite light, we estimate that 9720 kg would be the mass in total of each hull, including the aluminium and fibreglass layers. The mass of the teflon layer is negligible.

The volume of the material between the 2 hulls on either side of the catamaran is estimated to be

8 m * 6 m * 0.03 m = 1.44 m^3, with length of 6 m, width of 8 m, and thickness of 3 cm

It is made of fibreglass, and its density is about 1500 kg / m^3

Mass = 1.44 * 1500 = 2160 kg

We estimate that the mass of the sail is about 100 kg.

The mass of our solar power system is about 998 kg for the panels and 250 kg for the batteries, with 1248 kg in total.

With 1 tonne of load, we estimate the mass of the catamaran to be about 14.2 tonnes. (3sf)

Depth of Hull Submerged

Upthrust required must be equal to the weight of the boat, and equals the weight of water displaced.

With a mass of 14,200 kg, the water displaced must also have a mass of 14,200 kg.

Volume of water displaced = 14,200 / 1030 = 13.8 m^3

Base area of the hull is approximately 24 m^2.

Therefore, the boat would be able to float easily, with about 50 cm of the hull in the water.

Speed

Distance: 24000 km

Distance in metres = 24000 × 1000 = 2.4×10^7 metres

Time: about 150 days

Time in seconds = 150 × 24 × 60 × 60 = 12 960 000 seconds

Velocity = 2.4×10^7 / 12 960 000

= 1.85 ms^{-1} (3sf)

Drag

Drag Equation:

$$F_D = \frac{1}{2}\,\rho\,u^2\,C_D\,A$$

F_D Drag Force

ρ Density of liquid (seawater): 1030 kgm^{-3}

u Velocity: 1.85 ms^{-1}

C_D Drag coefficient: 0.43 (Teflon on water)

A Area: about 25 m^2

Drag Force = ½ × 1030 × 1.85^2 × 0.43 × 25 = 19000 N (2sf)

Power Required from Solar Panels

Energy Transferred = 19000 × 2.4 × 10^7 = 4.5 * 10^{11} J

Power Required = 4.5 × 10^{11} / (150 × 24 × 60 × 60) = 3.5 * 10^4 W (2sf)

We expect that the role of the power generated by the solar panels is to assist the thrust given by the sails, so the solar cells only need to provide about 10% of the power we need.

Area of Solar Panels Needed

Solar Panel efficiency = 21.5%

Due to effects of temperature, which may lower the efficiency, in this calculation, we assume the efficiency to be about 20%.

When the sun is directly above the earth, the earth receives about 1050 W/m^2.

However, as weather conditions vary, with a few hours during the night every day, and the fact that sunlight is weaker near the poles, we estimate an average light intensity of 200W/m^2.

35000 * 0.1 / (200 * 0.2)

= 87.5 m^2 of solar panels are needed.

With 11.4 kg / m^2 of solar panels,

11.4 * 87.5 = 998 kg

about 998 kg of solar panels are required.

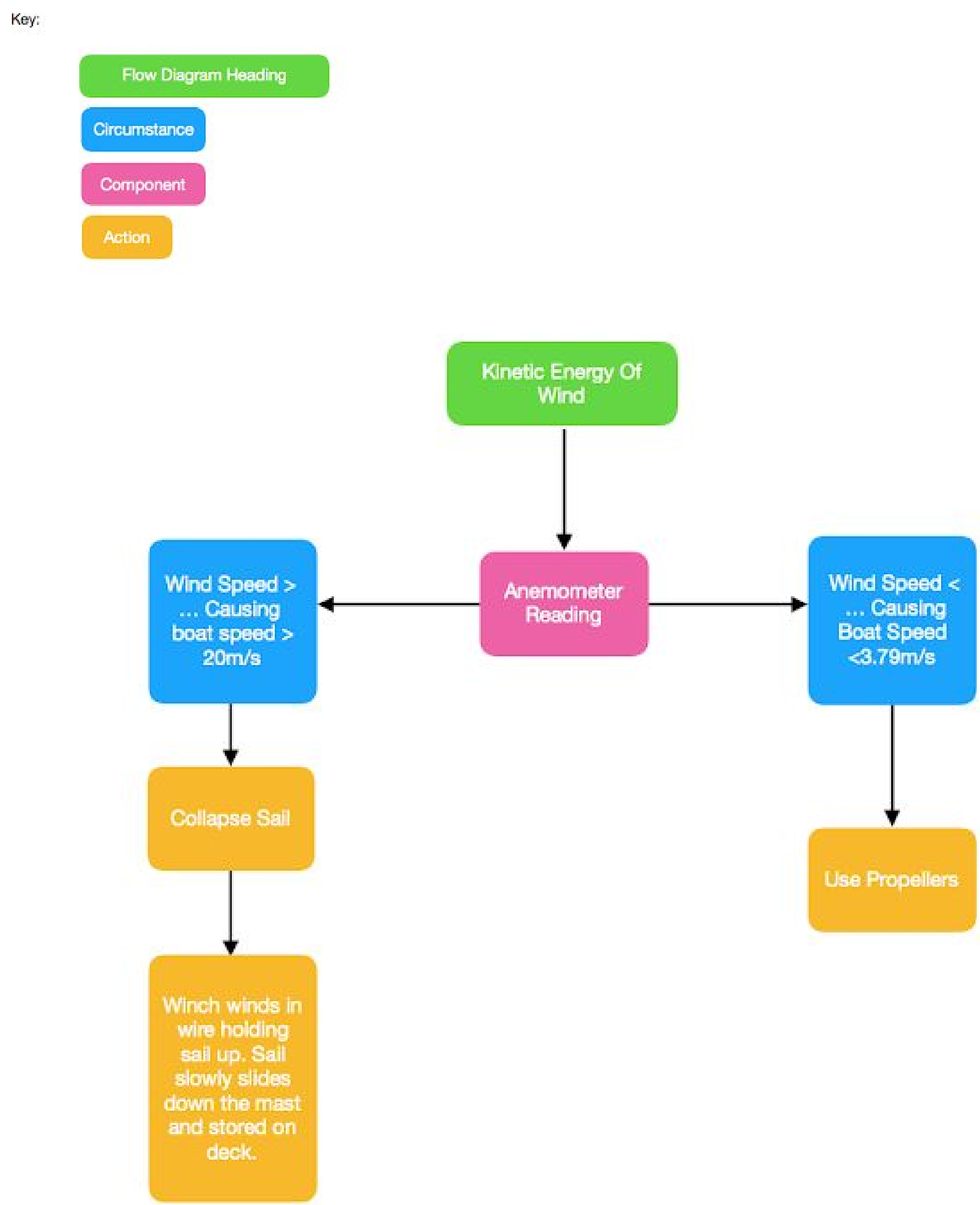
Energy Capacity of Batteries Required

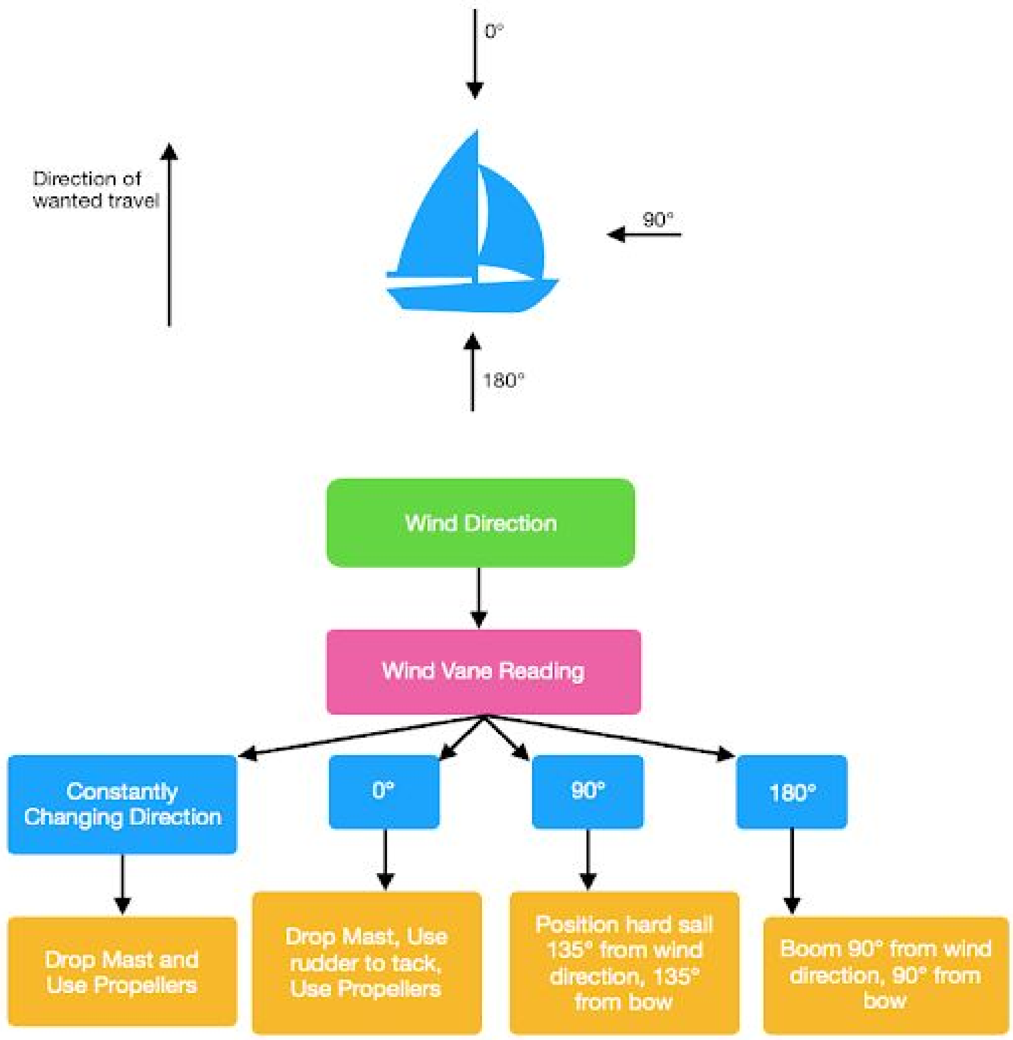
Size of battery to power through the night 3500W * 8 = 28000 Wh

With the use of 2 Tesla 13.5 kWh batteries with 90% efficiency, it can provide 24.3 kWh of energy throughout the night (enough for 87% of the power provided by the motors during the day). Since the sails will provide the majority of the power needed, a small reduction of power provided by motors would have a negligible effect on the speed of the boat.

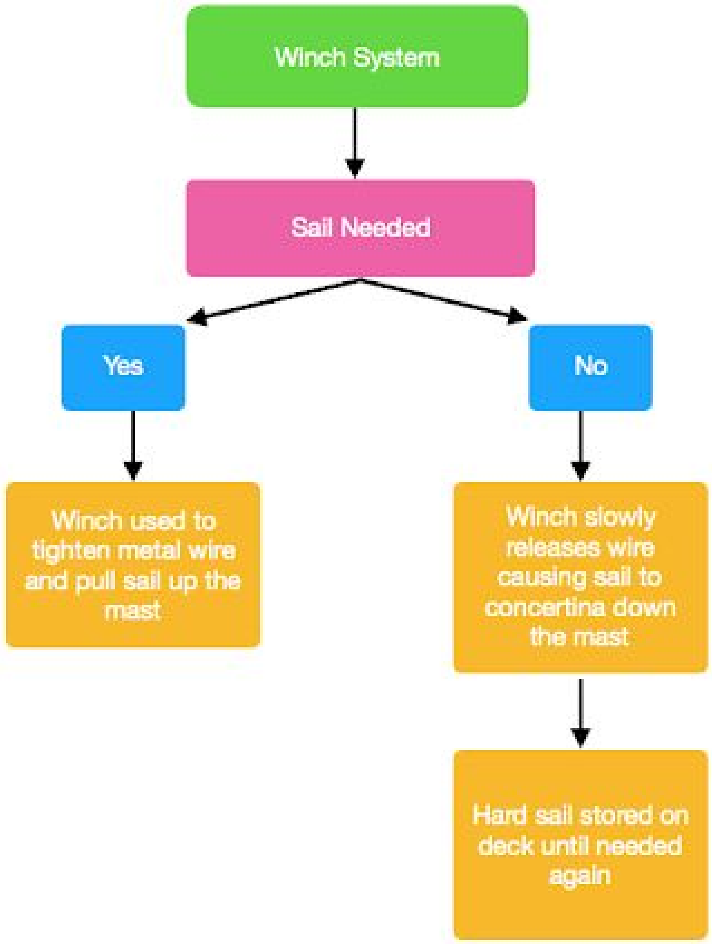
The total mass of batteries is 250 kg.

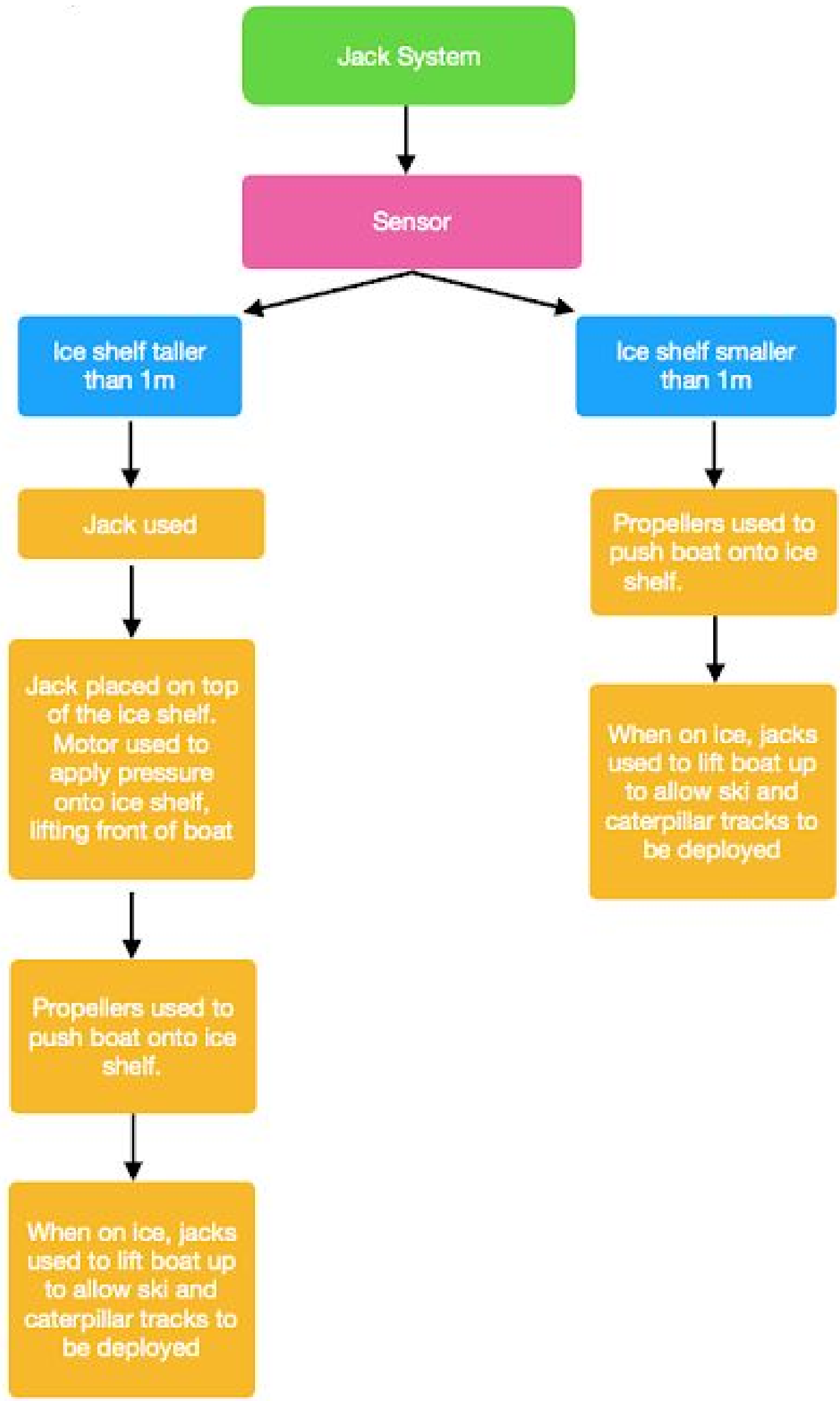
Flow Diagrams





0°
Direction of wanted travel
90°
180°
Wind Direction
Wind Vane Reading
Constantly Changing Direction
0°
90°
180°
Drop Mast and Use Propellers
Drop Mast, Use rudder to tack, Use Propellers
Position hard sail 135° from wind direction, 135° from bow
Boom 90° from wind direction, 90° from bow


Winch System
Sail Needed
Yes
No
Winch used to tighten metal wire and pull sail up the mast
Winch slowly releases wire causing sail to concertina down the mast
Hard sail stored on deck until needed again


Jack System
Sensor
Ice shelf taller than 1m
Ice shelf smaller than 1m
Jack used
Jack placed on top of the ice shelf. Motor used to apply pressure onto ice shelf, lifting front of boat
Propellers used to push boat onto ice shelf.
When on ice, jacks used to lift boat up to allow ski and caterpillar tracks to be deployed
Propellers used to push boat onto ice shelf.
When on ice, jacks used to lift boat up to allow ski and caterpillar tracks to be deployed

Cost

The main cost in this project is the design of the boat. The high tech design which creates the extra speeds is very expensive however it is justifiable as this technology could influence the future of the sea transport industry. It is possible that we could have made savings here for example using a traditional sheet sail rather than a solid one. However, people have been sailing around the world for years using a traditional sail and in this design we are doing something different. Another large cost is the fact that we are not using man power to guide the boat. This part of the costing is very difficult as this exact use of this technology would not have been used before. As this design is changing the transport industry, we expect a large amount of sponsoring that will keep the overall cost down. For example, companies like airbus and red bull advanced technologies are interested in expeditions like this and would contribute.

Cost of Using Solar Energy

The batteries are expected to cost £11100.

The solar panels cost roughly £172 per m^2. With about 87.5 m^2 of solar panels, this is expected to cost about £15050.

Therefore, the total cost of solar power generation system costs about £26150.

Cost of Materials

The price of aluminium is about £2.7 per kg. We estimated that we would need about 9720 kg of aluminium.

2.7 * 9720 = 26,244

Therefore the cost of aluminium is expected to be about £26,244.

The price of fibreglass is about £3.4 per kg. We need about 2200 kg of fibreglass.

3.4 * 2200 = 7480

Therefore, the cost of fibreglass is expected to be about £7480.

Cost of Teflon - £200

Cost of Design specifics

The sail is hard to cost as it will be custom made and if it is as high tech as the racing ones which it does not need to be then it will be near £3million. However, we only expect for it to cost about £100,000 as our sail is not as large as the ones used on racing boats as that is not our aim. We feel this cost is justifiable as it is a completely new technology compared to the a traditional sail which shows how our idea is unique.

The mechanism for the bringing up of the propellers and the dropping of the caterpillar tracks is completely unique. However, it is just a simple mechanism so we have only budgeted £1000 for this. The caterpillar tracks will cost £5000 each as they are better quality and more efficient and powerful than ones used on a tractor. The propellers cost £750 each and the rudder is £500. Each 20kW battery will cost £2500 as it will be able to power many devices in the circuit at once.

Cost of navigation and tracking equipment.

The Maxsea professional software costs £1150. Also we have fitted the boat with a 1500m Laser Distance Sensor SKD-1500 which is £500. We are also using a WindSonic anemometer to get accurate measurements about the weather. This costs £700.

Labour costs

This model will take a long time to make and some of the labour will need to be very specified. To create the shape of the hull moulds will need to be created and a lot of specialist equipment will need to be used. These costs will be huge and could be in the millions of pounds.

Overall cost - £180,424 plus labour costs

Firstly this is not an exact value as some of the costs vary depending on demand and availability and some costs are just estimations as they are not known. However, if a traditional sail was used rather than a wingsail, the cost could be around £100,000. However this would be less effective and it may mean we would have to compensate for it in different areas such as having more solar panels.

The Team

Alex Glover - Project manager

In this project I led the team, setting out the work needed to do by each member and making sure deadlines were met. I ensured communications were the best possible throughout the project in our team in order to reduce confusion considering a lot of the work was done independently. I also planned the route and design of the boat as well as sorting out the costings.

Jason Ng

I am the maths man in this team as I did the majority of the calculations. Some of these calculations were challenging, however, I now feel that I have good enough predictions to show that our design will work.

Brandon Long

My role in this project was in the creation of the design. I was part of the team that decided on what elements are included in the design and I brought it to life with my drawings and computer model.

Aaron Mara

In this project I worked closely with Brandon and also Alex to create this design. We went through many different possibilities but eventually we agreed on this design which I feel has a good balance of ambition whilst still being very possible as seen by the calculations. I also planned the materials that the boat will be made out of and I made the flow diagrams for some of the processes that happen on our boat.

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