BMC 2018/19

Pole to Pole Challenge

“The Unsinkable Hovercraft”

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October 2018- February 2019

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Introduction

The Document:

This document presents our ideas for the BMC 2018/19 Pole to Pole challenge.

The Team:

Harrison Pinsker - I am a first year Mathematics, Physics and Computer Science Student at Havant and South Downs college. I am primarily interested in the Technical and engineering aspects of this project since I am experienced in said fields. Outside of A-Level study I regularly attend Portsmouth University Physics Society lectures on topics such as Dark Matter and Quantum Physics.

Solomon Sanderson - I am a first-year A-Level student at Havant and South Downs College studying Maths, Physics and Chemistry. After completion of my A-levels I hope to go on to study either Physics or Engineering at university. Outside of college and the pole to pole challenge I attend the HE+ program at Peter Symonds College as well as physics lectures on topics such as dark matter at Portsmouth University.

Adam Soutar - I am a first year Computer Science, Physics and Mathematics student at Havant and South Downs College. I also regularly attend Physics lectures at Portsmouth University on topics such as Quantum Physics and Looking for life on Mars. Furthermore, I have extensive experience with web and software development and am looking to use these skills in this project.

James Spurgeon - My name is James Spurgeon. I study physics, chemistry and maths at college and I am looking to study physics with astrophysics at university.

The Journey

Timing:

It can be presumed throughout this document that any times or dates used will be based around UTC (Coordinated Universal Time) as it is a constant time no matter the latitude or longitude of our vessel. The use of this time zone will prevent confusion and therefore increase the overall efficiency of the mission.

Schedule:

As our vehicle is going to rely on solar power it is important that we try to work with the difference in seasons of the north and southern hemisphere in order to get the maximum daylight time in each hemisphere. As well as this the North and South pole can be in complete darkness for months at a time. For example, at the north pole from September 25th to October the 8th the sunlight levels decrease significantly, with the only light being from twilights and the sun not actually being visible. After the 8th of October the North Pole enters total darkness until the 29th of January. The graphic below displays the average sunlight hours at each pole for each month.

From looking at this data we can see that the optimum time to leave the North pole would be in mid-late September, this is because it leaves room for change either way and there is still a reasonable amount of light in the north pole to ensure that we can proceed with our journey once out of the arctic circle. It also gives us a very large amount of room for error in the case that there are problems we will still have roughly 3 months of complete daylight in the south pole which is more than enough room for error.

Route:

The route that we will take depends on a range of things. As we are using a hovercraft there is possibility for us to take the vehicle and its load across either land or water. However, on land there are a multitude of obstacles such as mountains and other natural features as well as cities and other manmade structures. To avoid this issue, we will be taking the hovercraft across the sea from the north to the south pole, other than at each of the poles where the hovercraft will be able to travel across the large plains of ice, as there are many less obstacles. One of the major factors that we must consider, as we plan for our route to be predominantly across the sea, is the locations, and directions of sea currents, as well as shipping lanes and the rules that come with travelling in these areas. There are also many weather factors that should be considered.

Weather Factors:

Weather factors could prove to be of danger to the progress of our vessel. For example, in very rough seas our rate of progress would drop dramatically or possibly even stop the progress of our craft in the event that there is extremely high waves or similar. Oppositely if there is a lot of sun and a lot of power generated by the solar panels on the vessel then we will be able to increase the speed and, in turn increase our rate of progress. As a result of this, most of the dates that we put throughout this document are merely estimates, this will be shown by the ≈ symbol.

Shipping lanes and Their Respective Rules:

If in the night, we must anchor the vehicle as there is not enough power for the vessel to carry on travelling through the night then we must ensure that we don't stop in a shipping lane as this would be a violation of the international sailing laws. There are also a lot of other rules that should be followed. Those that should have particular attention paid to them include:

Part B - Rule 5: Every vehicle should at all times maintain a proper lookout by sight and hearing to avoid collision.

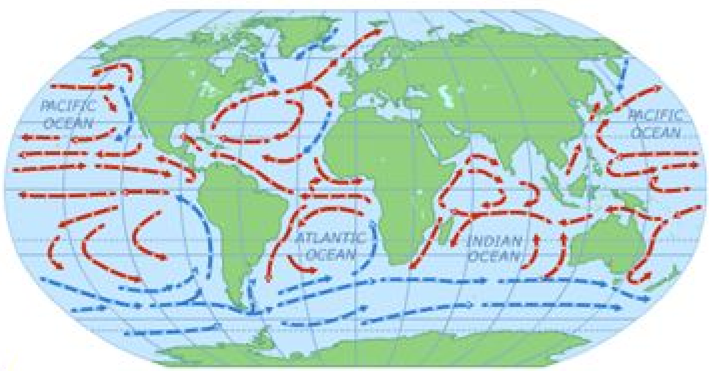
Part B - Rule 10: Vessels must cross traffic lanes at as near to right angle as possible.

Part B – Rule 14: In head on situations each vessel must move to the starboard side (the right-hand side of the ship when looking towards the front of the vessel)

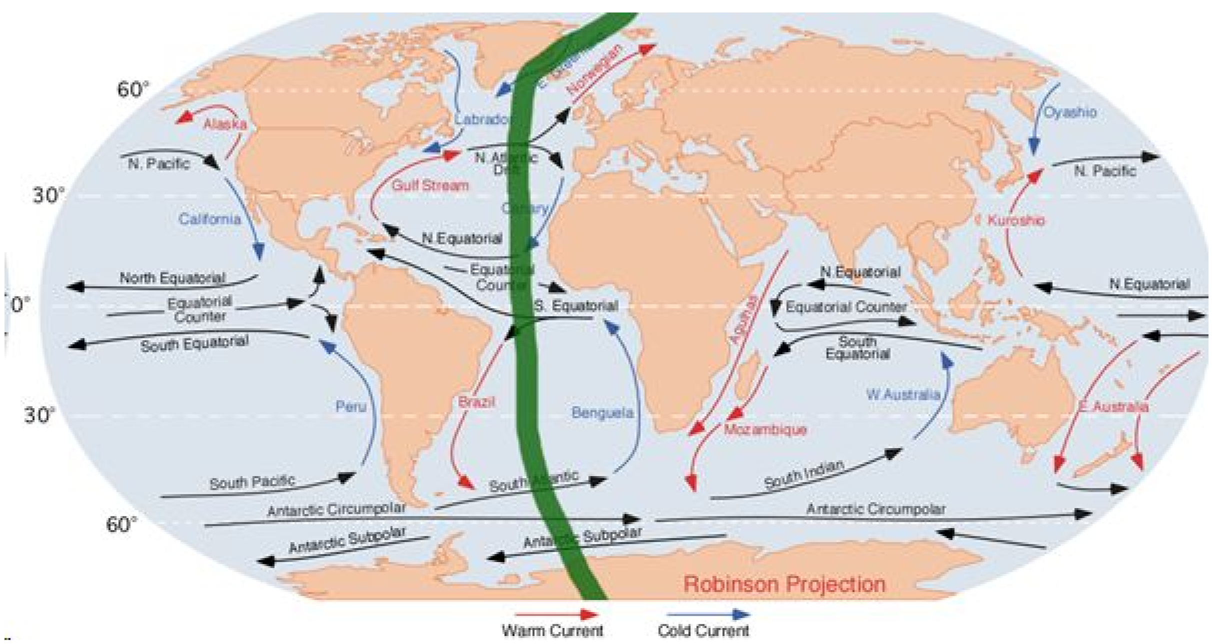
It is also important that our vessel is equipped with the correct lights and horns for communication with other vehicles such as warnings and distress calls in case of emergency.

Ocean Currents:

The image below displays the currents from the north pole to the south pole and many of them are positioned in such a way that we can take advantage of the currents on our journey from the north pole to the south pole by travelling with them and avoiding those that travel in an opposite direction to conserve power and increase efficiency. The wind also takes a similar route to the currents of the sea so in following the sea currents we will reduce the drag on our vessel. However despite this we should make efforts to decrease the air resistance on the craft – an area that is covered in the section of this document that covers the design of the vehicle.



The diagram below shows the approximate route that we plan on our craft taking. The green line highlights is the area that we would travel in and allows for variation in the route to account for weather events etc.



Power Sources, Storage and Propulsion

Sources:

There are a range of considerations that have to be taken into place to find the ideal power source for our vessel. There is a wide range of finite and infinite sources with which we could power the vehicle and charge its batteries. The table below displays both the pros and cons of each power source.

Source:	Pros:	Cons:
Solar	Solar panels can produce power for as long as there is sunlight, this means that the range of the hovercraft will not be impeded if there is a need for a detour- For example in the case of extreme weather. It is also a renewable source of energy meaning that there are no emissions and as a result there will be no environmental impact.	There is always a chance that sunlight could be very low for a long period of time and in this case, it could be very hard to produce enough power to provide the lift for the hovercraft. The solar panels also weigh a lot relative to the other options with the average solar panel and all of its mounting hardware weighing in at around 10-20kg per m^2
Wind	Wind is not only limited to the day time unlike solar energy, this means that no matter the time of day the craft can be manoeuvred. Further, the sail is very light which reduces the energy needed to lift the hovercraft. Like solar wind Is also a renewable source of energy meaning that there is no emissions or greenhouse gases produced.	There are a few downfalls to the use of wind power however. The most suitable way of harvesting the power of the wind is by using a sail, the issue with this is that it is directional and power and that the craft can only be moved in a direction similar to the wind. As well as this a significant drag force will be produced by a sail if it is used with a secondary power source. Further the energy produced by a sail cannot be transferred to electrical energy meaning that it must

		be used in combination with another source that can provide a source of electrical power. This is a necessity as electricity is needed to power the crafts electrical systems as well as the lift fan for the hovercraft's air cushion.
Nuclear	Nuclear power is a zero-emissions power source. It is a finite, yet very high yield power source. It also doesn't have any weather based requirements like solar and wind energy.	However, there are some very large risks involved with the use of nuclear power sources with possibility for a nuclear meltdown or a nuclear disaster in the event that the concrete containment shield becomes damaged – for example in an accident. As well as this nuclear reactors aren't very durable and the stresses on the reactor and its containment shield as a result of rough seas and surfaces in the north and south poles is a disaster waiting to happen. To add the downsides of using a nuclear reactor the shielding is often made of lead and concrete that can be metres thick in some circumstances. As a result of this huge mass (with the density of concrete coming in at a huge 2400 kg/m3) making it likely impossible.
Petrol/Diesel	The use of petrol or diesel would mean that for as long as there is a supply of petrol the craft can continue moving. As well as this as the fuel is used the weight of the craft will decrease meaning that the efficiency will increase	The downsides to using fuel are that it is very expensive and that a huge volume of fuel would be needed to provide enough power for the whole journey with excess to account for any changes. The weight of this would be

	throughout the journey. The energy produced by engines can also be converted to electrical energy to	extremely high. As there is no possibility for refuelling at points along the journey it is not a flexible enough fuel source for the task. Further, the combustion of fuel produces greenhouse gasses like Carbon Dioxide and other environmental effects such as acid rain as a result of sulphur dioxide that is formed during combustion of petrol. Combustion engines are also incredibly inefficient with a large amount of energy being dissipated to the surroundings as heat.

Final Decision on Power Source:

We have decided to use solar energy. There are many reasons for using solar panels to harvest energy. One of the main benefits to using solar energy is that as long as there is sunlight the craft cannot run out of fuel. This leaves us with plenty of room for unseen issues on the trip. For example, in the case of higher power usage than expected as a result of rough seas or strong headwinds, as long as the solar panels can harvest enough energy, there will be no effect on our journey other than slower progress. As well as this because the energy produced by solar panels is already electrical meaning that there will be no need to convert the energy to another form and that it can be used immediately meaning that it is more efficient than using fuel such as combustion of petrol. Another Major factor for solar panels is that they require very little maintenance something that is essential when at sea with no access to spare parts or and help teams.

Energy Storage:

The only form of energy storage that is realistic for holding large amounts of energy is using rechargeable batteries.

The table that follows indicates the pros and cons of various rechargeable battery technology:

Battery Type:	Pros:	Cons:
Lithium Ion	Lithium ion batteries have an incredibly high energy density- this is why they can be found in many electric devices such as phones which need to be small but require a high amount of energy. The high energy density is a very large advantage for us as on the craft we need to save as much weight as possible as the weight directly impacts the energy used by the hovercrafts lift fan. There are also a lot of other direct advantages to using a lithium ion battery with it being the only one out of those that we investigated with a low self-discharge meaning that any of the power harvested by solar panels and the initial charge will be held until needed with very minor losses.	Lithium ion batteries do however have their downsides. For example, whilst they are more robust than the nickel batteries lithium batteries are still very much susceptible to damage from overcharging and discharging too far and as with nickel metal halide batteries extra technology is needed to protect them from this. As well as this they are relatively expensive with the cost typically being 40% higher than that of an equivalent nickel cadmium cell.
Nickel Cadmium	Have a low internal resistance and have very good conductivity meaning that they can be recharged rapidly and also provide a very large current with little stress on the battery. AS well as this they have other features that could be useful on our journey. One of these features is the ability for the batteries to be stored in a discharged state, something that is a possibility on our journey as there is a risk that the batteries may not get a lot of charge from solar panels	There are also a range of issues. For example, Cadmium is a toxic metal and in the event that there is an accident involving our craft and the batteries leak there could be a n environmental impact such as poisoning sea animals and plants. Additionally, they have a high self-discharged, this means that if they are stored for a long period of time a large amount of energy can be lost and the battery needs to be recharged. There is also a strange feature of nickel

	during the day. They also come in a large range of sizes which would allow us to get a capacity that is appropriate for our craft so that no unnecessary weight is added to the craft. Lastly, one of the most important benefits of the battery is that they have good performance at low temperatures which is one of the largest challenges in the north and south poles.	cadmium which is known as the memory effect- this is when discharge is very similar each time the battery can lose some of its capacity. For example, if the battery is drained to 25% of its full capacity for numerous cycles then there is a chance that 25% of the battery's capacity can be lost.
Nickel Metal Hydride	Nickel Metal hydride batteries are less prone to the memory effect than nickel cadmium batteries and also have a 30-40% higher capacity on average. They are also much more environmentally friendly as they only contain mild toxins. This means that in the event of an accident environmental damage will be minimal. As well as this after the journey the nickel in the batteries is recyclable decreasing the environmental impact.	Whilst there are many benefits to this option it may also be impossible to use this battery for our craft. This is because the batteries do not absorb overcharge well which is something that could occur if the batteries are full and there is still power being generated- and whilst this issue could be overcome using smart charging devices and the like it is another possible point of failure that could be overcome by using another type of battery. Further the batteries have a limited life with large discharging causing damage and the batteries losing a lot of energy as heat due to a low efficiency. These batteries also have a high self-discharge similar to the nickel cadmium batteries.

Final Decision on Battery Type:

With 2 incredibly good properties- high energy density and low self-discharge- Lithium ion batteries will be used to store power on our vessel. We plan on using the same types of cells as found on Teslas, and other electric cars, these are known as 18650 cells and would be used in large banks on our vessel to hold sufficient charge. We will use enough of these cells to form a 130kW battery to provide lift for a number of days even without bright sun.

Power Calculations:

Power Generation:

On Average in good sunlight, per M^2 of solar panel, between 150w and 200w of power are generated. Our craft has 69.28m^2 of solar panels on its surface. And assuming that all of the solar panels are in equal levels of sunlight between 10.392kw and 13.856kw of power will be generated as shown in the calculations below:

150W×69.28M^2=10392 W=10.329kW

200W×69.28M^2=13856W=13.856kW

This gives us an average value of 12.0925kW

The equinox on the 21st is when we plan to reach the equator with the total journey of 21,000km being completed over the space of weeks. There will be a 11,000km stretch from the north pole to the equator followed by another stretch of 10,000km to the South Pole.

Date (first day of each week throughout journey)	Latitude (^{0})	Longitude (^{0})	Average Hours of Sunlight per Day.
Start: 24/08/19	90.0000	0.0000	24
31/08/19	73.0000	-15.0000	16
07/09/19	49.7000	-22.3500	13
14/09/19	2.9170	-19.7770	12
21/09/19	-20.9900	-19.2600	12
28/09/19	-44.3639	-18.5130	12
05/10/19	-67.8400	-14.8700	14
End: 12/10/19	-90.0000	0.0000	24

Using the figures and the average value of 12.0925kW power in good sunlight we can calculate the average amount of power generated per day using this general equation.

12.0925kW×number of hours=Power generated daily

Week (by starting date)	Average Hours of Sunlight per Day	Power generated (kW/h) (per day)
Start: 24/08/19	24	290.3
31/08/19	16	193.5
07/09/19	13	157.2
14/09/19	12	145.1
21/09/19	12	145.1
28/09/19	12	145.1
05/10/19	14	169.3
End: 12/10/19	24	290.3

8 weeks is 56 days or 1344 hours. To make it possible for us to travel the distance in 2 months we will need to hit an average speed of 15.6km/h or 2620 km a week.

We must also consider the energy used to keep the cushion of the hovercraft inflated. As it is very complex to calculate the energy required to lift the hovercraft we used an online calculator

Hull Length (m)	10
Hull width (m)	6
Weight of craft (kg)	3000
Estimated Engine lift power kW	~2.75
Estimated fan diameter (m)	0.68

With 2.75 kw on average required to lift the hovercraft we estimate that we will use 66kW/h a day to keep the hovercraft afloat this leaves us with 75 kWh of energy left per day that should be split

into primarily forward movement and charging the batteries on board of the hovercraft with some also going toward operating AI systems and telecoms.

Control and Communication

Autonomous Versus Human Control:

When it comes to controlling our vessel, the big decision was between a manned and unmanned vessel. The benefits of manning the vessel are that it does not rely on satellite communication of computers in order to move as would be the case with a remote-controlled system with integrate autonomous control. On top of this the person on the ship can be trained to fix any mechanical or technical issues that may arise on the trip making it possible carry on. It also means that there is someone on board who can analyse weather and make alterations to the route as they feel appropriate.

There are however a lot of downsides to manning the craft. For example, it will be extremely expensive to train someone as a mechanic as well as a pilot for a hovercraft and it places a large amount of stress on one individual. There is also a lot of mental and physical issues that could arise. For example, spending 2 months alone at sea will likely take a large toll on their mental health with implications such as loneliness and stress possibly leading to an inability to complete the journey. There are many other possible issues that could arise such as a medical episode that could put the pilot of the craft out of action for an extended period – once again slowing our progress. As well as this the sustenance for required to keep a human well nourished would be very heavy and take up a large amount of space on the vessel, the increase in weight means that there will be an increased power consumption to lift and propel the hovercraft. The needs for nourishment also mean that there is a limited range on the vehicle because when supplies run out there will be no way for us to continue. And with no method of resupplying the vehicle means that if there is a delay and it takes longer than expected there will be no option but to terminate the journey.

Differently, with the use of computers and AI there is no need for food and water meaning the weight can be dramatically reduced and there is no chance of medical events. However, having an unmanned ship means that there is no way that the vessel can be repaired in the event that there is a mechanical fault. As well as this we would have to control the vehicle using AI and using remote controls from a base situated on land.

Whilst there is always a risk that there could be an issue with parts in computers it will still weigh a lot less to run a single computer and then have two or three as a backup for if there is a hardware fault. As well as this it would be possible for us to reboot the computers and reflash software in the case of a failure.

There are also a range of options with which we can communicate with the craft however these all rely on satellite communication which can be patchy and unreliable. As a result of all of the above factors we have decided that the vehicle will be unmanned and that we will use a combination of autonomous and remote control where necessary.

Autonomous Control:

We will integrate autonomous control into our craft as it will be unmanned, and it is almost impossible to maintain a reliable wireless signal at all times. A system for autonomous control is made up of a range of sensors such as radar, computer vision, Lidar, Sonar, GPS and any others that are required. Computer vision is the process through which a computer acquires, processes and analyses data to produce decisions in the form of data and can be used for object recognition that is something that could prove useful in avoiding obstacles in the sea such as icebergs when in the arctic circle and near the north and south poles as well as ships and other possible debris in the sea. We can also use radar and lidar technology to measure the depth of the water and/or find debris underneath the surface of the water.

There are several benefits to the use of autonomous control such as there being no possibility for human error to lead the craft wildly off course. As well as this we can implement links between data from weather forecasting as well as other sources of data such as location of other vessels as well as sea currents to pick the most efficient route and avoid dangerous conditions.

In order for us to use automation to run the hovercraft we will need a range of different sensors and devices:

GPS:

A GPS system is very crucial to our journey, as it will be the main means with which we will find the vessel. This would be a very important piece of equipment no matter whether the craft is manned or not, as we will always need to know a very exact location so that we can look at the applicable weather data and the like as well as know where the craft is in the event an emergency.

LIDAR:

Lidar is a system in which ultraviolet light is used to measure distance to a target and for other surveillance applications. We will use lidar for detection of obstacles that are surrounding the craft. Out of the three different types of lidar we would use the phased arrays system. The advantages of this system are that the cost is dramatically decreased over other systems with the cost being reduced to that of a small electronic chip. This is much more reliable with about 100 times the life span at approximately 100,000 hours. It is also about $200,000 dollars cheaper than the more complex electromechanical systems. The lidar system will work in combination with the GPS unit to give us an absolute position. The drawbacks of lidar are that it does not work at night or in heavy fog, it is because of this that we will use this technology in combination with a range of other sensors.

RADAR:

Radar detection is a technology that uses radio waves to determine the range angle and velocity of objects. It can be used to detect weather systems as well as a range of other obstacles. Radar uses a radio wave transmitter with a transmitting antenna as well as a receiving antenna (these antennas are often merged). One of its largest applications is in the marine industry in which the radar antennas are used to measure distance and bearings of ships in order to prevent collision, especially in busy waters. The data that can be provided by radar is limited by line of sight and the sensitivity of the radar used. Our craft would be fitted with a slotted waveguide antenna which is moved mechanically to scan. This sort of antenna will be particularly applicable to our craft as they have a small surface area which will reduce the likelihood of damage and also reduce air resistance on the hovercraft.

Gyroscope:

A gyroscope will provide us with data on the orientation of the craft in order for us to maintain stability. We can also use an accelerometer (another type of gyroscope) to determine acceleration and velocity of the object which can then be fed into the autonomous systems on the hovercraft.

Cameras:

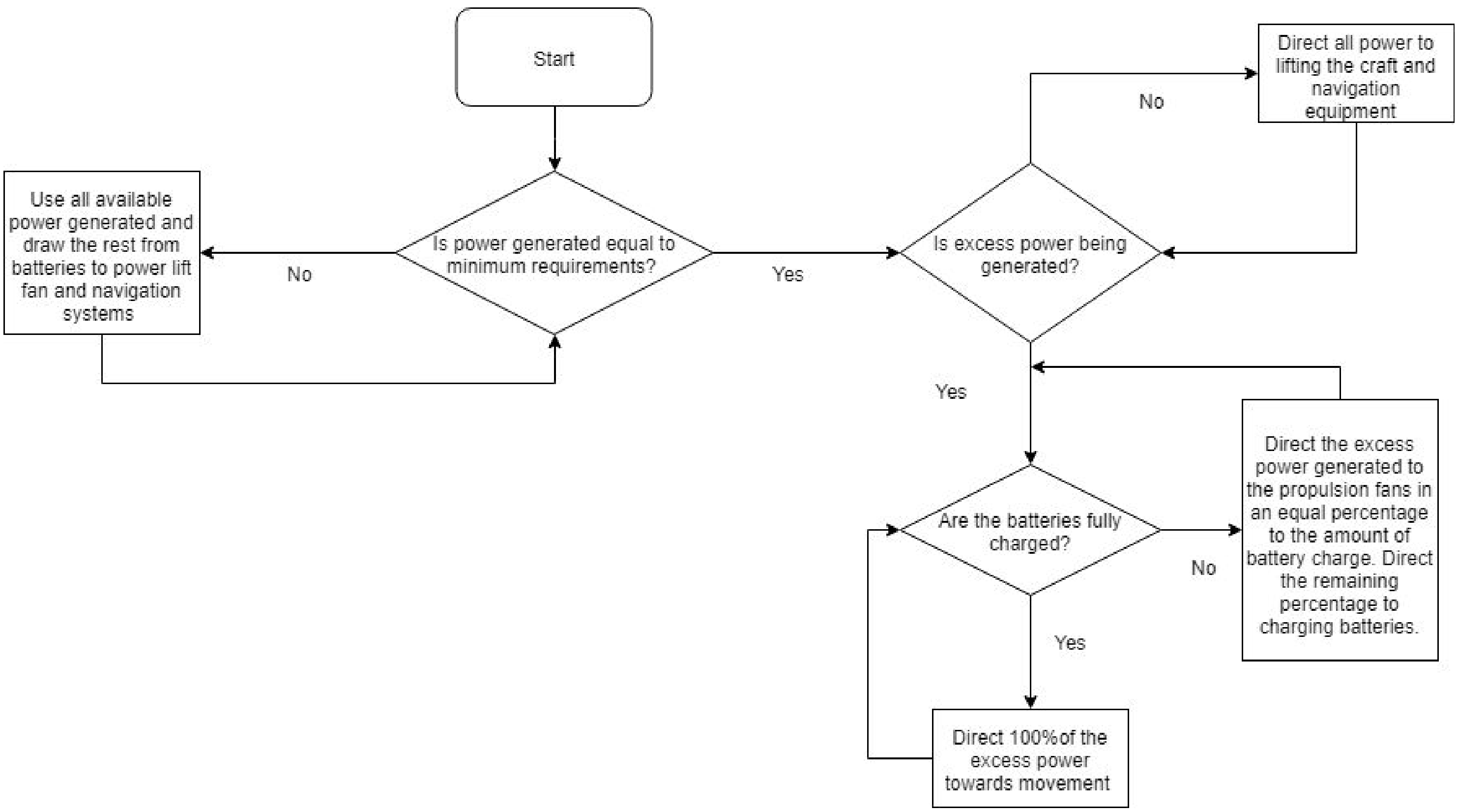
We also plan to place a range of cameras around the edge of the vessel for monitoring of the surroundings from our control centre so that we can see other vessels or obstacles that could need to be overcome.

Sensor Fusion:

Sensor fusion is the combining of data from a range of sensors in order to produce one continuous data stream with a much lower uncertainty than if the data from the sensors was used individually. This gives much more reliable data than if the sensors were used individually as the software that is used to combine incoming sources of data meaning that if the data from one of the sensors is invalid it can still rely on the other data sources.

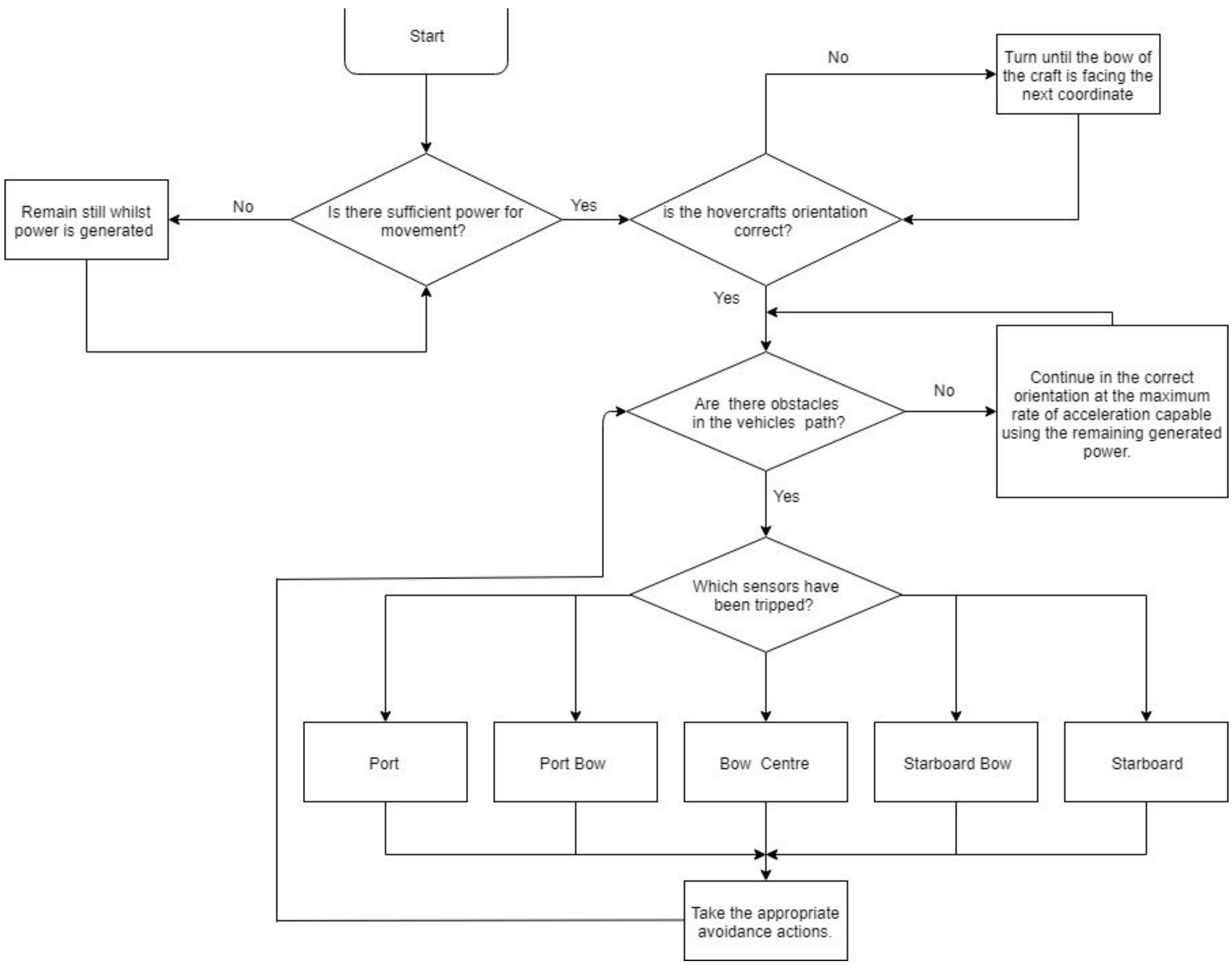
Power Distribution:

This flowchart shows how the onboard computers will manage the power to ensure that there is enough power in the batteries whilst also maintaining as high speed as possible throughout the journey. We have decided to use a basic algorithm in which the percentage of the charge in the battery is equal to the power directed towards propulsion of the craft.



Navigation and Movement:

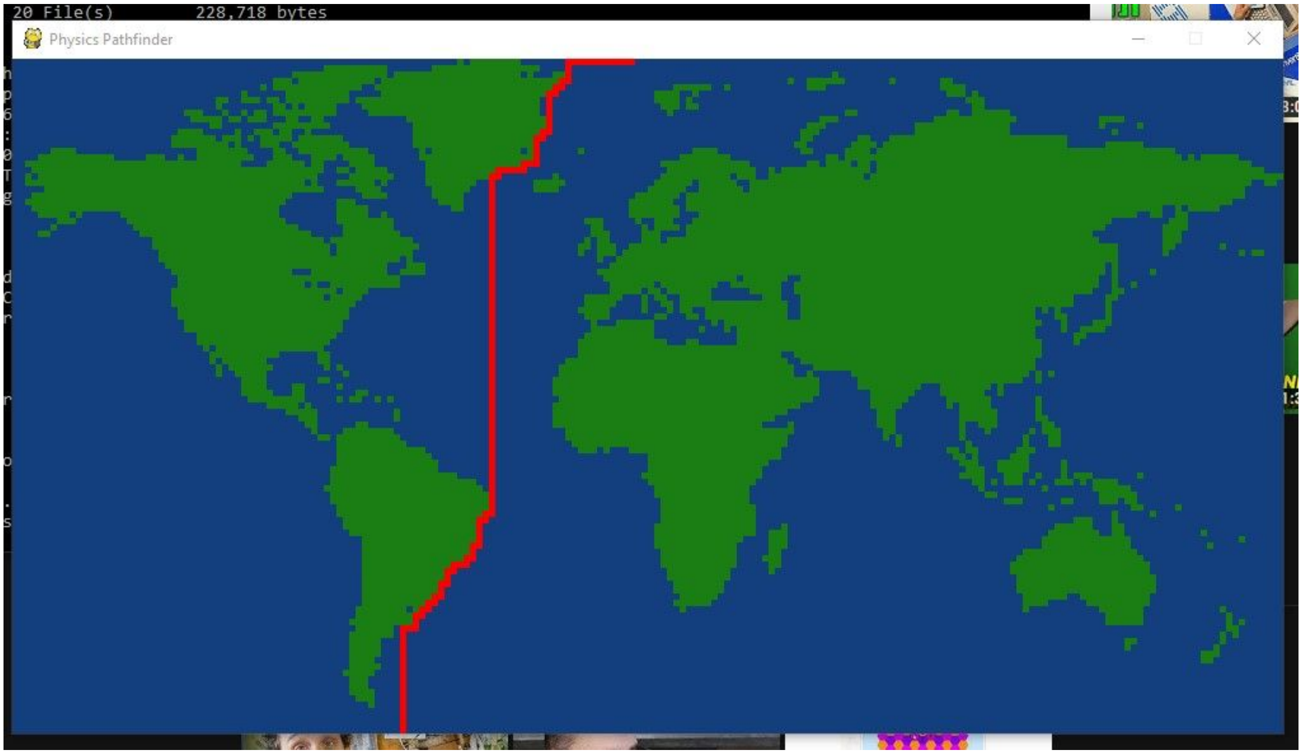
This flowchart shows the basic process that the computers used for the autonomous control will go through in order to decide on the next step that they should take. This flow chart has been designed so that it is continuous as the sensors will be constantly scanning so that the craft can redirect itself and adjust its position accordingly to changes in its surroundings.



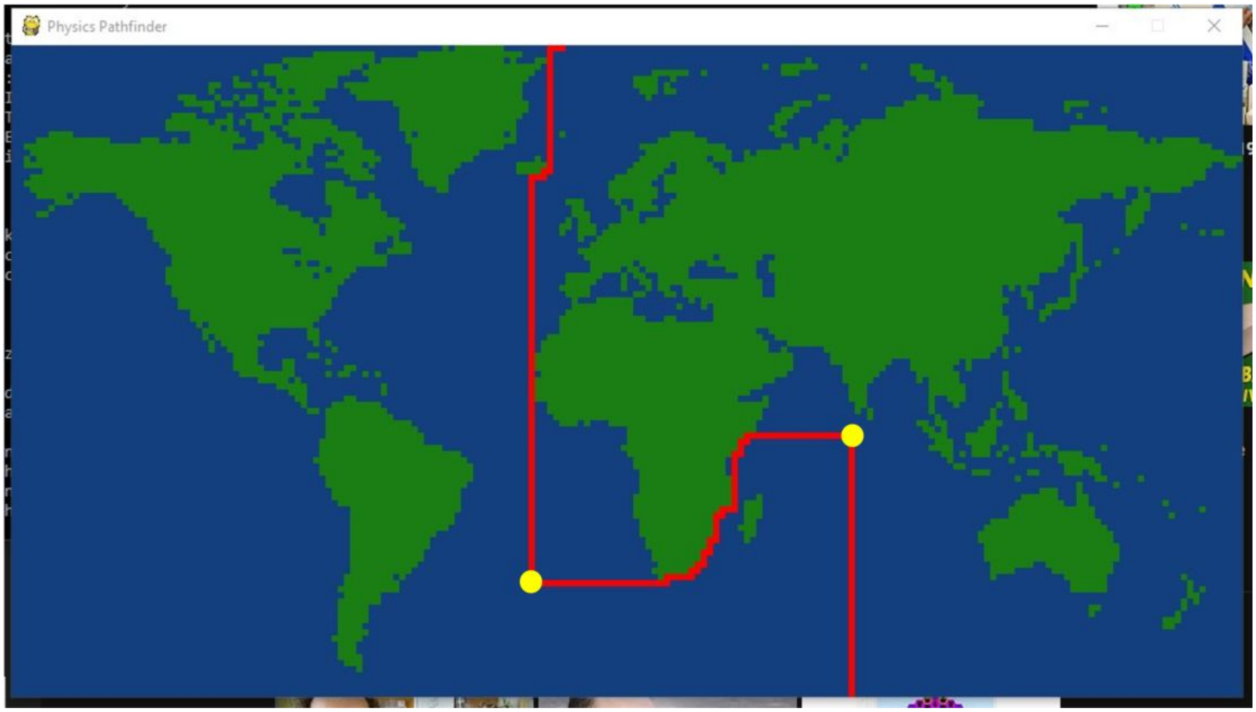
Pathfinding Software:

We have created some software using python with which we can form a path across a map of the globe between two point set. The line can then be altered through dragging it to the desired position. The software will then find the shortest route between the 2 points without travelling over any land masses other than the ice at either of the poles. This program then generates coordinates for the routes and finds the distance for the whole trip including waypoints in kilometres.

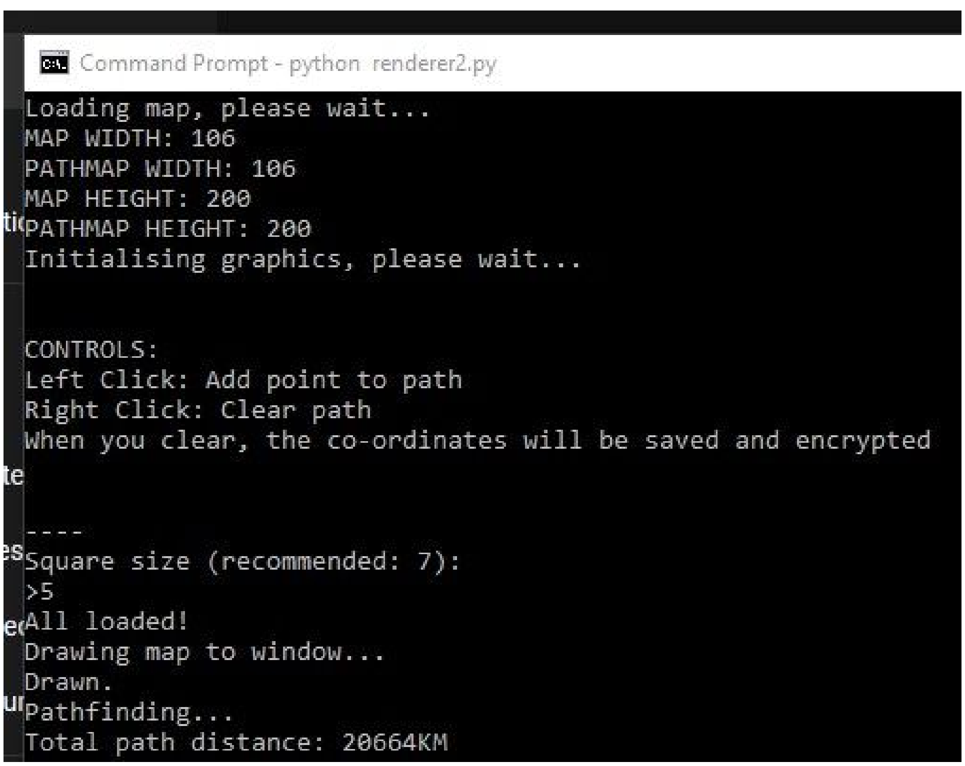
This image shows the software taking the shortest route from one point to another whilst avoiding land. This can be seen as the red line across the map.



The image below shows the program generating the shortest possible route from point to point with 2 waypoints along the way. These way points can be entered as coordinates or the red line can be dragged using a mouse from one point to another. They are displayed as yellow circles on the screenshot below.



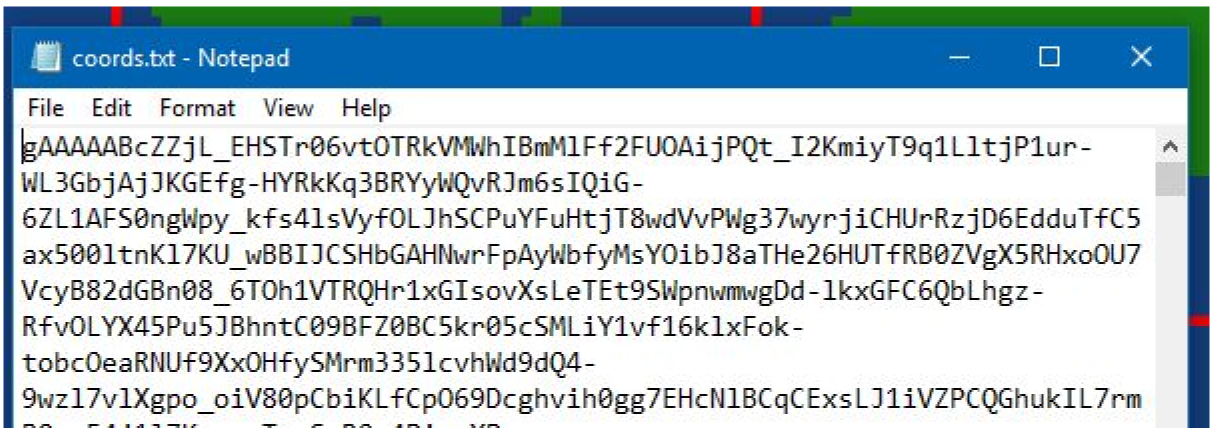
Here you can see the basic control panel for the piece of software. Highlighted in yellow is the information regarding use of the software. This is followed by a information stream (highlighted in orange). The last line then displays the total distance of the trip in km.



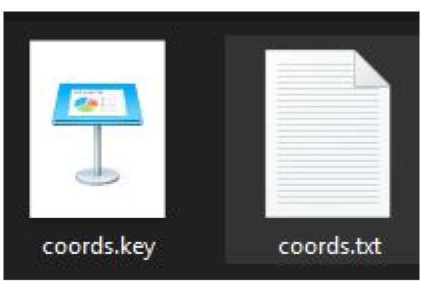
Encryption:

We have also created a piece of software that can encrypt the coordinates. This means that in the event that we have to change the course of the vessel then we will be able to send the coordinates to the vessel safely so that people can not interfere wit the path that the craft will take. The encrypted coordinates can be decrypted with the use of a key that will be loaded onto the onboard computers of the hovercraft.

This image shows the coordinates that have been encrypted directly from the pathfinding software:



Here you can see the encrypted coordinates in the form of a notepad document with their respective key:



Construction of the Hovercraft

Terminology Summary:

When referring to the different sides of the ship throughout this section of the document we will refer to each side using the correct nautical terminology in order to avoid confusion. The front of the vessel is referred to as the bow whilst the rear is referred to as the stern. Left and right ,when facing the front of the ship are then referred to as port and starboard respectively.

Selecting Materials:

Weight is a large consideration for which materials we can use for the construction of the hovercraft as the larger the weight the more energy. Despite the need for very light materials we also need very high strength and durable materials that can withstand the strain of spending many months at sea. We have researched a range of materials that are used in the making of sea vessels- ranging from Olympic grade sailing boats to cruise liners.

Material:	Advantages	Disadvantages
Glass Reinforced Plastic (Also known as GRP or fibre glass)	Fiberglass is very easy to mould to any required shape. As well as this there is minimal maintenance needed if the Gel coat is intact (the protective coat) with a lifespan of between 10-15 years.	In the case of the gelcoat becoming damaged the durability is drastically decreased as the fibre glass absorbs water and starts to delaminate. As well as this fiberglass is quite a heavy material. Further there can be some large variations in strength with the thickness, and quality of the polyester used.
Aluminium	Has a high strength and low weight and is also nonmagnetic meaning that there will be no effect on	The downsides of using aluminium are that it can be very difficult to weld with special metalworking skills

	navigation instruments. Aluminium is also a very malleable and can be shaped relatively easily in comparison to other metals such as steel. As well as this there is no requirements for painting aluminium, this would merely be aesthetic. This is because aluminium reacts very quickly with oxygen in the air forming an aluminium oxide layer on the metal that is unreactive and therefore resistant to corrosion. It also has an infinite lifespan if the effects of electrolysis are kept at bay however this shouldn't be too much of an issue for our vessel as the metal will not be submerged permanently in water.	often required as poor welds can be very weak and risky. As well as this the strength of aluminium varies with its grade and place of manufacture. Due to the low weight of aluminium a rough ride is a likely possibility however the air cushion should reduce this.
Steel	Great boat building material as it is immensely strong and has a very low price. It can also be worked with basic skills and tools. It also has an infinite lifespan along as the effects of rust are kept at bay.	There is however a large amount of issues with steel with its extreme weight making it an unlikely contender for our craft. To add to this the need for detailed sandblasting and high-quality paint job to prevent rust could prove to be an issue as our craft will be at sea for a long period of time.
Carbon Fibre	Carbon fibre has many excellent properties for the marine environment with a high tensile strength and	The downsides to carbon fibre are that it can be very expensive to fabricate and

	lightweight. This makes it extremely useful for masts and, more importantly for us, propellers. The reduced weight is a major factor for concern with our vessel. It is used throughout the marine industry especially in sporting and competition.	

Aluminium Grading:

The main two grades of aluminium used in the building of boats

• 5052: This is the highest strength, non-heat treatable alloy. It has a higher resistance to fatigue than other grades of aluminium. One of its more attractive properties for our application is its good resistance to the marine environment and salt water. It also has an excellent malleability and can easily be drawn into intricate shapes.

• 6061: Is the most versatile of heat treatable alloys. Whilst it holds most of the useful properties of aluminium it has excellent corrosion resistance and mechanical properties.it can also be worked using basic techniques and with ease. It can be welded using any method or can be brazed. It is also made in tubing which is typically also very versatile and high strength.

• 7075: this is an incredibly strong aluminium and is widely in the aerospace industry however as it cannot be welded there is likely no application for it as we plan on using the aluminium to make up the main framework of the craft.

Choice of Materials:

As their properties are idea for our application it is likely that our craft will be mostly made of 6061 aluminium tubing and framework with a mix of aluminium and carbon fibre panels depending on application.

Shape of Cushion/Skirt:

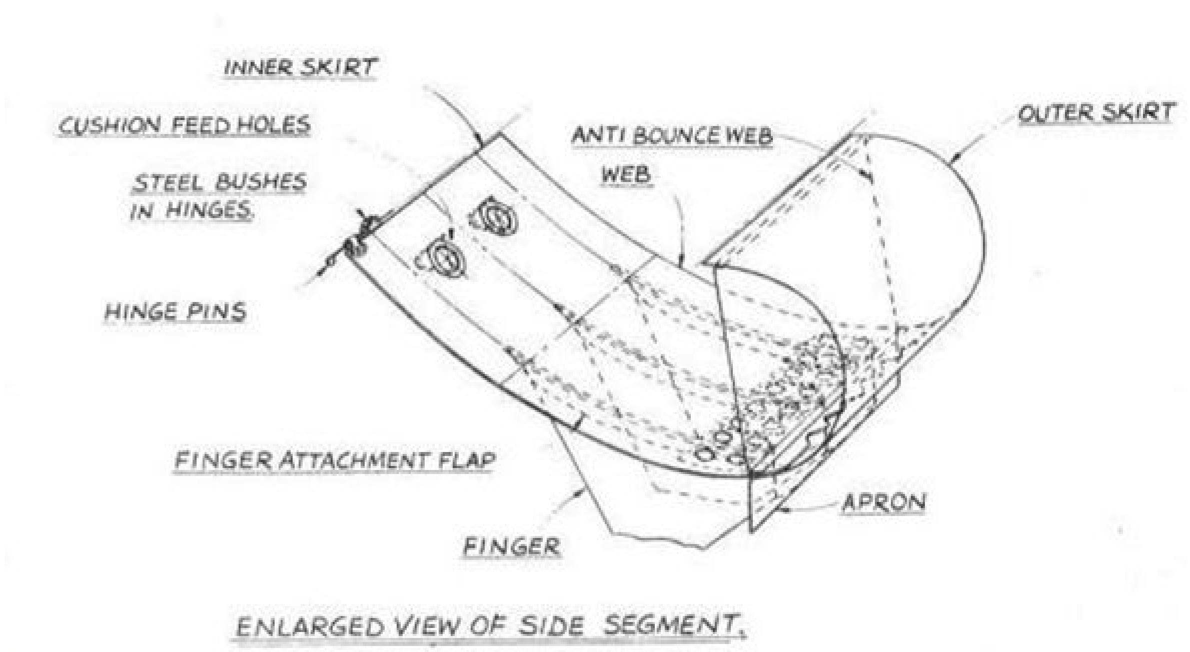
There is a specific sequence of decisions that must be made when designing a skirt for a hovercraft. This is because there are a range of different shapes and variations that can be made to the skirt to give different properties. The three main types of skirt are: the bag skirt, the finger/segment skirt and the bag and finger skirt.

	Description	Advantages	Disadvantages
The Bag Skirt	The bag skirt consists of two main air chambers. There is the main loop around the outside that has a higher pressure than the main air cushion underneath the hovercraft. There is then the second chamber, this is the main air chamber underneath the hovercraft. This can be achieved in two ways however the best of the 2 is the full flow system as it has a much higher durability than the no flow system and means that pressure can be altered between the 2 compartments to account for damage and other conditions.	The advantages to the bag skirt are that in general the design is simple and easy to construct. As well as this the outer inflated loop of the skirt is very stiff, this is ideal for craft like ours that mostly travel over water.	There is a much harder ride than the other skirts that are available which could lead to a larger amount of stress on the equipment inside and the components on the hovercraft. As well as this there is a high drag over undulating surfaces- a challenge that we are likely to come across at both poles and under stormy conditions at sea. This would lead to increased energy usage and as a result, increase the amount of solar energy we would have to rely on our solar panels collecting.
Finger Skirt	The finger skirt is made up of a number of segments that can	One of the main advantages of the finger skirt is segments moving	This cushion can Sometimes be prone to air loss when going over

	slide independently from each other to conform with water, or terrain that the hovercraft passes across. These segments (otherwise known as segments) are not connected in any way, it is this that allows for the conformity of the skirt	independently from each other the skirt is only connected at the corners and along the top edge to the hovercraft. The very high conformity of this skirt mean that it is commonly used as a skirt for the bow (front) of the vessel as it allows for much greater clearance over obstacles. This is added to as by the soft and flexible nature of the cushion which makes it more compliant than others. It is also easy to design. It also gives a very smooth ride and has very low friction n – something that is a very important feature for our craft. it is also ideal for travelling at high speed over rough terrain or seas.	rough terrain. To combat this a joining strip can be placed around the edge of the inner compartments. Doing so does somewhat reduce the compliance of the segments however this skirt still outperforms the others in rough scenarios.
The Bag and finger skirt.	As the name would suggest this skirt is a compromise	The advantage of using this skirt is that it provides a	There are also a range of disadvantages to

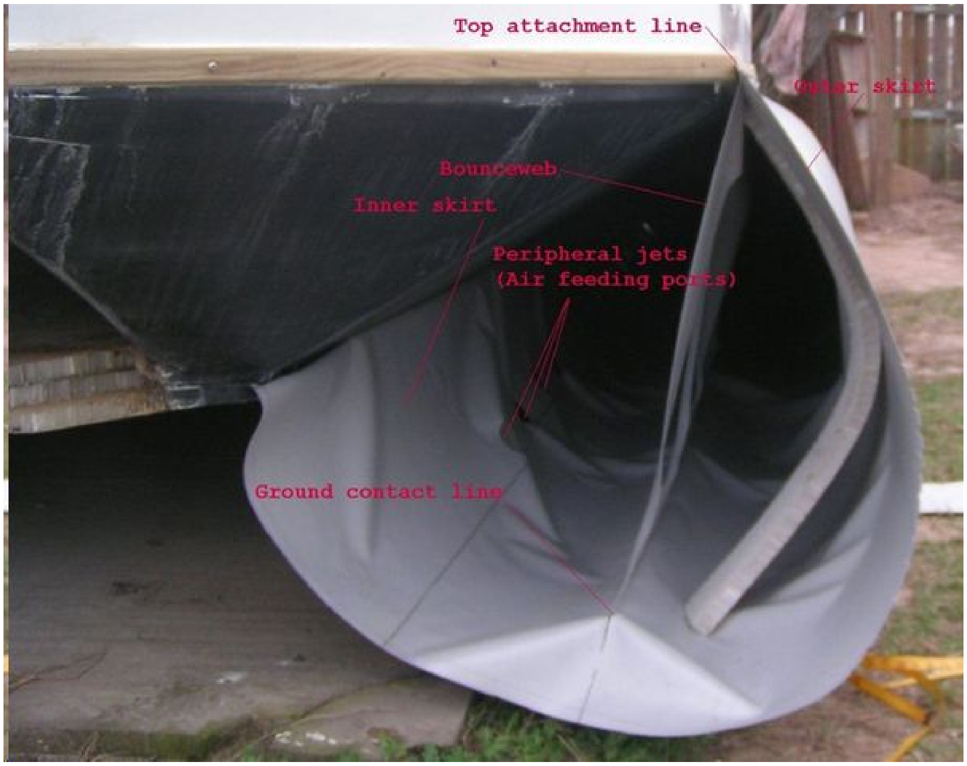
	between the flexibility of the finger skirt and the economy of the bag skirt. It is the most complicated system used and is a combination of a pressurised bag and finger skirt and is the most commonly used by commercial and non-commercial craft.	fairly smooth ride over most surfaces with the finger section of the skirt quickly adjusting to any changes in the environment. As well as this there is a lot of room for failure as the many fingers are all independent of each other and in the event that one of them is damaged the others will stay inflated- to further this many test have proved that it is incredibly unlikely that multiple fingers will fail at once. As well as this the finger and bag skirt has reduced “plow in” (this is where the hovercraft dives slightly under water) in comparison to the other options. This provides much greater stability and also absorbs large forces to the bow of the craft. The biggest benefits to the use of a bag/finger	this skirt. As a result of the multiple parts and sheer amount of material needed, the weight is very high. It is also quite a complicated design and requires the most labour and therefore gives it the highest cost out of all the designs

		skirt being to craft that travel over ice, water and land.	



This is a diagram of a bag and finger skirt. You can see labelled at the bottom of the image there is the finger attached to the main "bag" part of the cushion.

Above is an image of a finger skirt which has only been partly assembled. You can see the holes that feed air into the individual “fingers” of the skirt and how they attack to the hovercraft.

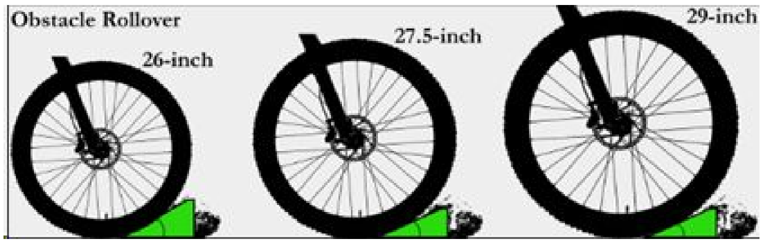


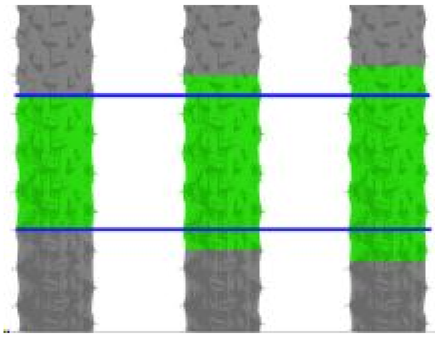
This diagram shows a bag skirt and the simplicity of it. With it using a simple sheet of plastic or rubber attached to the top and bottom edges of the craft.

For our craft we will use a 1.2m tall bag and finger skirt as the finger skirt provides a very high durability which is a very important factor. As well as this the bag and finger skirt has a very high compliance which will make it much easier for the craft to overcome obstacles at the poles and other possible debris that we could come across in the ocean whilst the cushion will also provide little enough drag that we can maintain speed whilst having a good power efficiency

Incident Angle of the Bow cushion:

In the last few years the size of the wheels used on mountain bikes has increased from a diameter of 26 inch to 29 inch. The logic behind this is that the angle at which the tyre will meet and obstacle on the ground (the incident angle) will decrease. The decrease in the incident angle in turn means that there is less forwards momentum transferred to the y axis and that a larger amount is maintained as forwards momentum. This means that the forwards velocity of the bike is impacted less. This idea is shown by this image





We Think that we can apply this logic to the front of the hovercrafts cushion as if we increase the radius of the cushion at the front of the hovercraft then the incident angle of the cushion will be smaller when it comes into contact with the possible obstacles that we will come into contact with throughout our trip and also for mounting the ice when we eventually reach the south pole.

Chassis Frame Design:

For the chassis of the craft we will use round 6061 aluminium tubing that has been welded together with the use of cross braces where necessary to form triangular shapes within the frame. The use of these triangular shapes - as a result of the use of cross braces- within the frame is to increase the structural strength of the chassis as triangles are known to be the strongest shape with a large ability to hold large loads without deformation such as buckling or bowing. The best way that the strength of a triangle can be demonstrated is through comparison with a rectangular shape. For example, if four rods are taken and pinned together in a manner such that they are free to move then the rectangular shape will collapse as soon as any load is applied to the top as the shape allows for the movement of the sides without the need for any change in size. Oppositely in a triangle, with the same pinned, freely moving corners it is impossible for any movement to occur without the length of the sides changing.

Type of Tubing:

We have decided to use Round tubes of aluminium for our crafts chassis as typically rounded tube provides is lighter than its square counterpart with the same diameter and the strengths are very similar. There are a number of different properties each of the different formats of the tube have. Round tubing is much less prone to twisting than its square counterpart however square tube has a lesser likelihood of bending than round tubing. We have demonstrated this in the table below that we have filled in using data from the website super 7th heaven. The table compares thickness and diameter of tubing to the second moment of area (this is a measurement of a material's ability to resist flex and distortion) and the Torsional constants

(These are a measure of resistance to twisting, the larger the value the higher the resistance of the material).

Square tubing:

Diameter of tubing (mm)	Thickness of tubing (mm)	Second Moment of Area (cm^4)	Torsional Constants (cm^3)
20	2	0.692	1.06
20	2.5	0.766	1.19
25	2	1.480	1.8
25	2.5	1.690	2.07
25	3	1.840	2.27

Round Tubing:

Outside diameter (diameter of entire tube)(mm)	Thickness(mm)	Second Moment of area (cm^4)	Torsional Constants (cm^3)
21.3	2	0.571	1.07
21.3	2.5	0.664	1.25
21.3	3	0.741	1.39
26.9	2	1.22	1.81
26.9	2.5	1.44	2.14
26.9	3	1.63	2.42

By looking at the above data we can see that despite being a narrower diameter than the round tubing the square tubing has a higher second moment of area. This demonstrates the strength advantage of square tubes. However oppositely the torsional constraints of the round tubing are considerably higher than that of the square tubing providing evidence to prove how the properties of square and round tubing differ.

In general, round tubing has a higher resistance to flex and twisting than square tubing per given weight meaning that it is possible to build a chassis from round tube that is both lighter and stronger than there square tubing counterparts. However it is more difficult to fabricate round tube structures as there is issues with a 'fish mouth' at the end of each tube which is where a half circle must be drilled or cut from the end of each tube using a hole saw or similar to ensure than the subes can slot over each other appropriately.

In other industries, for example the automotive industry, the main debate between round and square tubes is whether the benefits such as lowered weight for the same strength really outweigh the ease of fabrication that lies with using square tubing. With the main benefits to using square tubing being that attaching panels to flat surfaces on square tubing is much more easier than attaching them to the round ones. It is because of this that box tubing is used in nascar and for a lot of homemade applications.

The final verdict for our choice on the tube is that we will use round tubing as the loss of weight is much more important with every kilo lost increasing the efficiency of the craft. As well as this the increase in torsion resistance will be important to help protect against jarring impacts on the vessel.

Types Of Paneling:

For the panelling on our craft we plan to use a combination of both carbon fibre and aluminium.

To make carbon fibre parts a mould should first be made. The way that this mould is constructed depends on the technique being used however it is always covered in a release agent (which is a chemical that prevents the formation of bonds between to surfaces allowing for the carbon fibre panelling or part to be removed from the mould.

The use of an open mold is in general low cost and is often used for the decks of hulls and boats- an application that is very similar to ours. Once this mould has then been made the carbon fibre can be sprayed into the mould using a tool known as a chopper gun which cuts up a long lengths of continuous carbon fibre into much shorter lengths. Simultaneously resin and gelcoat is sprayed into the mold to ensure that the carbon fibre sets evenly for maximum achievable strength. Alternatively the fibres can be applied in woven sheets with layers of epoxy between each piece- this process is known as laying up and can be done by hand depending on the number of the product required and other factors such as the shape.

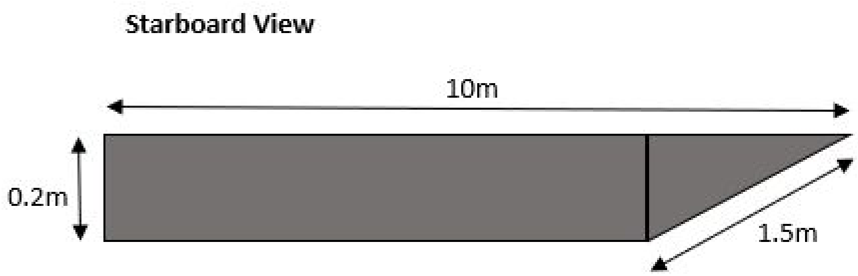
The Carbon Fibre must then be cured, to do this a vacuum bag is placed around the layers of carbon fibre in combination with heat. When heated the temperature at which the carbon fibre is held is steadily increased and decreased in order to prevent distortion or warp of the product as a result of its expansion and contraction with heat. Doing this ensures that the epoxy has fully saturated the carbon fibre sheeting as well as massively reducing issues that can arise.

These carbon fibre panels and other parts can be mounted to the framework and other carbon fibre parts using mechanical fasteners or adhesives. Typically adhesives are used in lower stress applications where there is no movement required whilst mechanical ones have almost completely the opposite function. However as a result of carbon fibres flexibility we will use metal inserts in the carbon fibre panels and parts so that we can use mechanical fasteners on carbon fibre panels to join them to the aluminium frame.

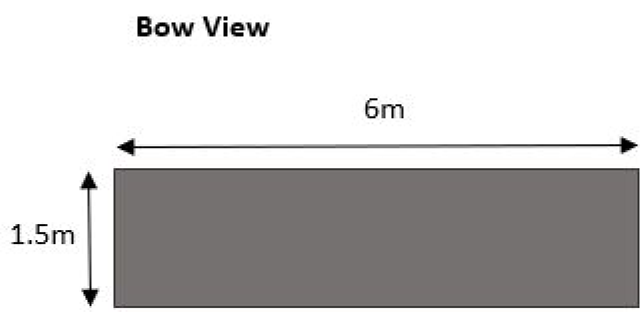
Chassis Dimensions and Design:

Aluminium Panelling:

This diagram shows dimensions of the chassis panels to allow for usa to calculate the amount of aluminium panelling that will be needed for it:

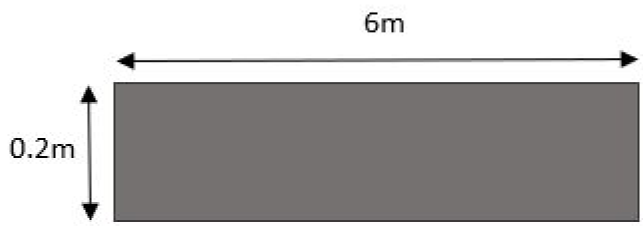


This gives an area of 2.15m^2 per side meaning that the area for both sides will be 4.3m^2



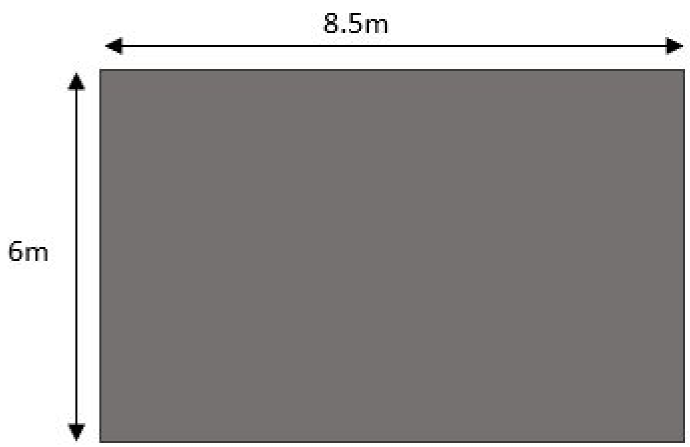
This panel has an area of 9m^2

Stern View



This panel has an area of 1.2m^2

Bottom Panel



This panel has an area of 51m^2

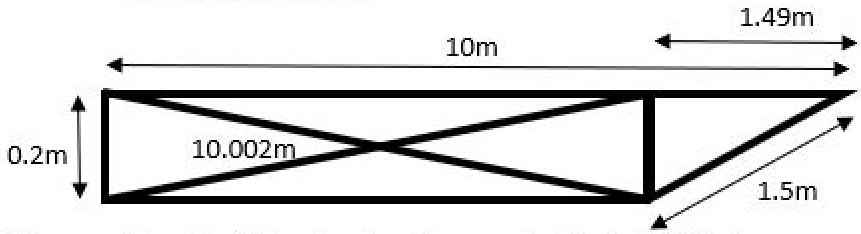
The top panel that makes up the deck has an area of 64m^2

The sum of these areas is 129.5m^2

Aluminium Tubing:

The diagrams and calculations below shows how we will weld together the tubing of the craft so that we can calculate the amount of tubing required and the respective costs:

Starboard/Port View



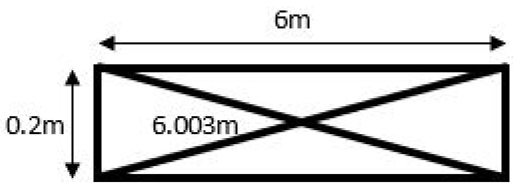
Below are the calculations for the tube required to build this frame:

$(0.2 \times 2) + (10.002 \times 2) + 10 + 1.5 + 8.51 = 40.414m$

This value should then be multiplied by 2 to account for both sides:

$40.414 \times 2 = 80.282m$

Stern View



These are the calculations for the stern piece of the craft: (notice that the 0.2m length on each end is not accounted for as it has already been considered of on the previous set of calculations.

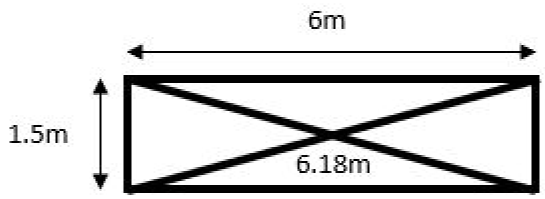
$(6.003 \times 2) + (6 \times 2) = 24.006\text{m}$

This must then be multiplied by 2 as there is a piece like this at the front and rear of the vessel:

$24.006 \times 2 = 48.012m$

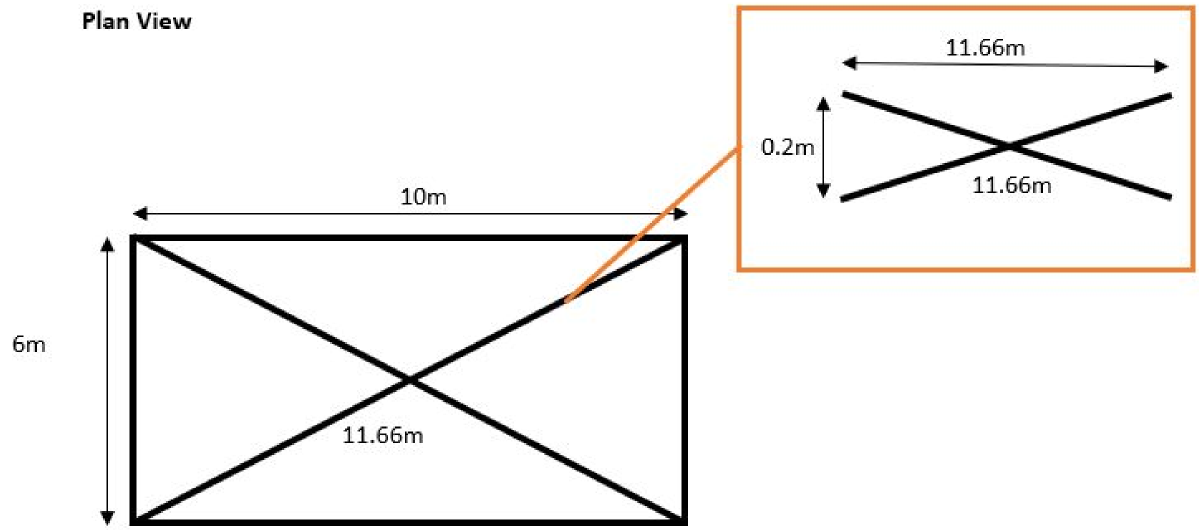
Bow View:

These are the calculations for the front triangle of the vessel



$$6.18 \times 2 + 6 = 18.36m$$

Plan View



Below are the rest of the calculations for the amount of tubing needed: (Notice that the outer 6m and 10m pieces are not accounted for as they have already been considered in the above calculations)

$$11.66 \times 2 = 23.32m$$

This means that the total amount of tubing required to construct the chassis is as below:

$$80.282 + 48.012 + 18.36 + 23.32 = 169.974m$$

Adhesives and Sealants:

It is very important that we use the applicable adhesives on our craft to give the best longevity and strength possible. There are a range of advantages to using adhesives such as some having the ability to seal gaps as well as a weight reduction in comparison to the use of bolts and mechanical fasteners. However there are also a range of challenges as it is very important that the products used adhere to both of the surfaces properly otherwise the surfaces will not bond properly or even at all. There are also 2 main categories of boat sealant; there is non adhesive boat sealant which relies on the use of a mechanical fastener and essentially forms a waterproof gasket which provides no joining properties, then there is adhesive sealant which is a combination between glue and a non adhesive sealant. Below is a table comparing a range of aerospace and marine adhesives and sealants.

Type of Adhesive /sealant	Advantages	Disadvantages
Silicone sealant	Silicone sealant is resistant to ultraviolet light, is also heat resistant and a great insulator making it very useful for creating seals around engines, motors and other components that have a high heat output.	Silicone does have some adhesive properties however they are typically weak and as a result of this is not normally used below the waterline.
Polyurethane	These sealants create an incredibly strong bond when used on certain surfaces. This high level of strength and strong seal means that these sealants can be submerged. Similarly to silicone polyurethane sealants also have UV resistant properties. This sealant is often used in private, unpressurised aircraft to stick the windows on - a demonstration of the sealants strength.	There are some drawbacks to polyurethane. For example they do not adhere properly to some acrylic and other plastic surfaces.
Polysulfides	These have very similar properties to polyurethane sealants as they form very	This is quite an expensive sealant and manufacture of the sealant is very expensive

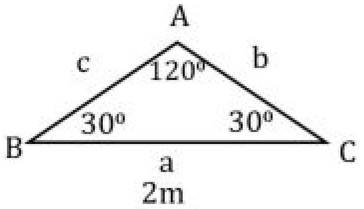
	strong bonds and are UV resistant. They also have other properties such as being unaffected by chemicals such as fuel and oil. It is also a very good electrical insulator and is resistant to vibration, shock, impact and drastic changes in temperature.	to manufacture. It also has a very long cure time.
Butyl	Butyl sealant is non adhesive and is normally found in the form of tape and is described as having characteristics like that of chewing gum. It can be used multiple times and much easier to work with other than traditional sealants	It doesn't age well and is very susceptible to UV damage and is not suitable for use below the waterline.

On our craft we will mostly use polysulfide sealant where there is a need for an adhesive properties and silicone for when only sealing properties are required. Polysulfide is ideal for use on our craft as there will be a lot of stress and strain acting on the adhesive. It could also be very useful for sealing off areas such as the battery compartment due to the sealants low reactivity.

Solar Panels:

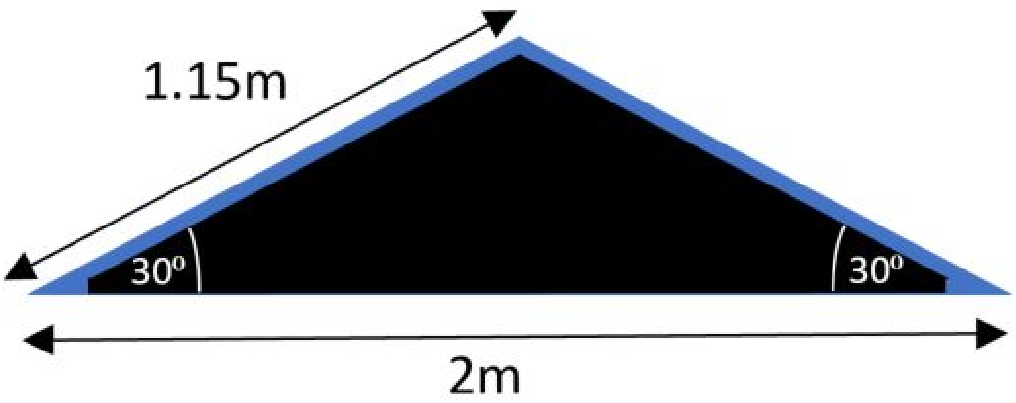
Solar panels are going to be the lone power source for our craft and will be position above all of the other components of the hovercraft on the roof. This will ensure that there are no obstructions and that the solar panels can obtain the maximum amount of sun possible. The vessels roof has an area of 6m * 10m but to maximise the area of solar panels that we could fit on the craft we have decided to position them in a zig zag arrangement. This means that when the sun is out we will gain a lot more energy as we will have $9.28M^2$ extra of solar panel in comparison to if we simply laid the panels flat on the top of the craft. As well as this we decided to angle the panels at 30° to the horizontal as it allows for us to gain a large amount of extra area without losing out on too much area as a result of shadowing for the other panels. This diagram and calculations demonstrate how we calculated the area of the solar panels for our craft:

FInding the length of the 2 Blue sides of the triangle:



$$\frac{a}{sinA} = \frac{b}{sinB} \qquad \frac{2}{\sin(120)} = \frac{b}{\sin(30)} \qquad \frac{2\sin(30)}{\sin(120)} = b$$

$$b = 1.15$$



As the craft is 6m wide 1.15 must be multiplied by 6:

$$1.15 \times 6 = 6.9$$

There is then 10 rows of the solar panels so 6.9 must be multiplied by 10:

$$6.9 \times 10 = 69.0$$

This gives the final answer of 69m^2 of solar panels.

Battery Safety:

After some of us attended a lecture on thermal runaway of lithium ion batteries at the University of Portsmouth (courtesy of the Portsmouth Physics Society) we realised that batteries when not looked after in the proper ways can become very dangerous and also very polluting to the environment. Some of the main dangers to batteries are overheating, water damage and punctures. If any of the individual cells become damaged by any of the above factors or similar then there is a likelihood that the battery will enter into a very dangerous process through which a battery goes through an exothermic reaction. This release of energy then increases rate of the reaction in the battery. This releases more heat as the exothermic reaction increases. This is known as thermal runaway and as described previously is when the heat generated by a battery spirals out of control. The occurrence of this in one cell can have a domino effect causing other batteries to reach extreme heat and go through the same process. In order to prevent this domino effect within the lithium ion cells in our craft we have come up with a range of solutions.

The battery compartment should be split into 6 compartments each separated by a multilayered divider. There should be a 8mm thick sheet of aluminium, followed by tightly packed fibreglass insulation (we chose this as it has excellent fire retardant properties and is very good at minimizing heat transfer) which will prevent the escape of the heat generated by the batteries. We would use high quality fiberglass insulation with an r-value of 3.8 (the R-value is a material's resistance to fire with 4 being the highest value and 0 being the lowest). with a This something that will be very useful at the north and south poles where incredibly low temperatures could prevent the batteries from functioning properly. After the layer of insulation there would be another layer of aluminium which would prevent shrapnel from exploding batteries as would the first layer.

Lithium ion batteries are very stable and can take a lot of abuse so there will be no need for shock absorbers or anything similar. However in order to dampen vibrations and limit the stress that the batteries are placed under, the cells will be packed in cellulose. The reason for this is that the cellulose will dampen the forces on the batteries as it has cushioning properties. As well as this it should prevent any fires breaking out as it contains no oxygen when compacted. This means that it will be impossible for a fire to start as there will be no oxygen to facilitate a reaction. Other benefits to using cellulose are that it is a very environmentally friendly as it is made out of recycled cardboard paper and other similar materials whilst maintaining very high R-values that range from R-3.1 to R-3.7.

In order to prevent damage to the batteries through the entry of water to the compartment we will use polysulfide sealant in combination with mechanical fasteners to build the battery compartment. We will use this sealant as it typically has very unreactive properties. This means that in the event that there is a battery failure then the sealant will contain any fluids that are produced as a result of the explosion and the sealant will not react with any of the chemicals released and break down. This is a very important feature of our hovercraft as it was recently found that lithium batteries that go through thermal runaway release over 100 toxic gases to the environment. The use of this sealant is very important as it prevents the entry of water into the battery compartment. This in turn prevents the short circuiting of a battery which leads to a large current flowing over a short period of time causing the release of a large amount of heat.

We will also install thermistors into each individual battery compartment so that if the temperature of the battery reaches a temperature that is too high for safe operation a switch can be triggered in order to stop power being drawn from the battery until it has cooled to a safe temperature.

Placement of Sensors:

As our craft will be entirely controlled either remotely or using a trained, artificial intelligence system the sensors on the craft are extremely critical to our mission. We have placed the sensors on the hovercraft in accordance with their function whilst also trying to keep them as protected, and sheltered from the marine environment as possible. Whilst some of the sensors that we plan to use will be durable enough to use at sea and will be able to withstand the harsh conditions there are some that may not. These less durable sensors and their respective aerials such as the GPS and the cameras for the live feed to the control centre will be placed in an enclosed case (known as a radome) around the main compartment (this can be seen in a blue colour on the CAD model later in the document). This idea takes inspiration from the nose cones that can be found on many modern aircraft which are made out of a special type of carbon known as pyrolytic carbon which is a special type of carbon. This materials is used to due to the extremely high temperatures that can be experienced as a result of air resistance and for the radome on our craft we will just use normal carbon fibre as it has no properties that would cause significant interference with any of the waves produced by the GPS and communications devices.

It is also very important that the sensors and radar sensors that we use are not inhibited by ice and cold temperatures. To combat this we will use multiple sensors that are located in different positions on the craft. As well as this we will follow the theme that can be seen throughout the document and we will use the highest possible end sensors.

Temperature Control:

As we are travelling all the way from the North Pole to the South Pole we will experience nearly all off the weather conditions on the earth ranging from the extreme cold at the the North and South poles of 0C and -60C respectively. We will also experience the highest temperatures in the world in the area surrounding the equator where the temperature can reach 31C.

These extreme temperatures could prove to be a challenge on our journey as lithium ion batteries cannot be charged at temperatures below 0C and they must be at a temperature of at least -20C in order to be discharged. Because of this we will install heaters into the main compartment of the hovercraft to maintain the temperature of the computers and other electronics, we will then install separate heaters into the battery compartments to maintain the temperatures of the batteries so that they can be continuously used. We would likely use a convection heater as they usually have built in thermostats, this is an important feature as it means that we can conserve as much power as possible whilst also achieving a suitable temperature. They also do not have incredibly high surface temperatures making them safe for use around highly combustible materials and batteries.

As we do not know any information about the load other than its dimensions and that it is non-metallic. Because of this, in order to make sure that the load reaches the destination in the best possible conditions we will take a range of precautions.

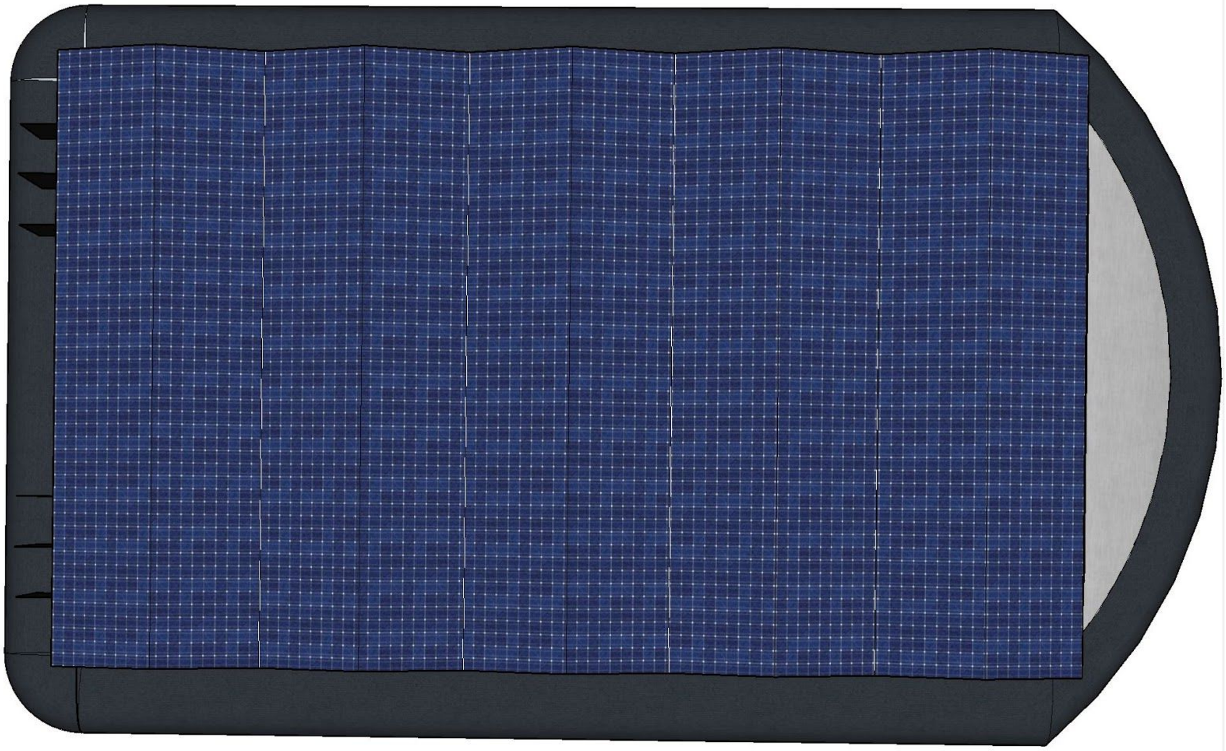
The first of these precautions is that we will use a heater to ensure that the temperature of the container that the object will be held in is approximately 5C as this is above the freezing point of water and will prevent damage to the object such as freeze thawing if the object contains any amount of water. If we didnt take this precaution there could be a chance that there was moisture inside the substance it could expand as the temperature decreases and the water freezes causing pieces to break off from the substance. Maintenance of the temperature also means that the material is not subject to thermal stress which is when an object changes in size etc as result of temperature change which can lead to a change in size and sometimes cause the object to be weakened as a result.

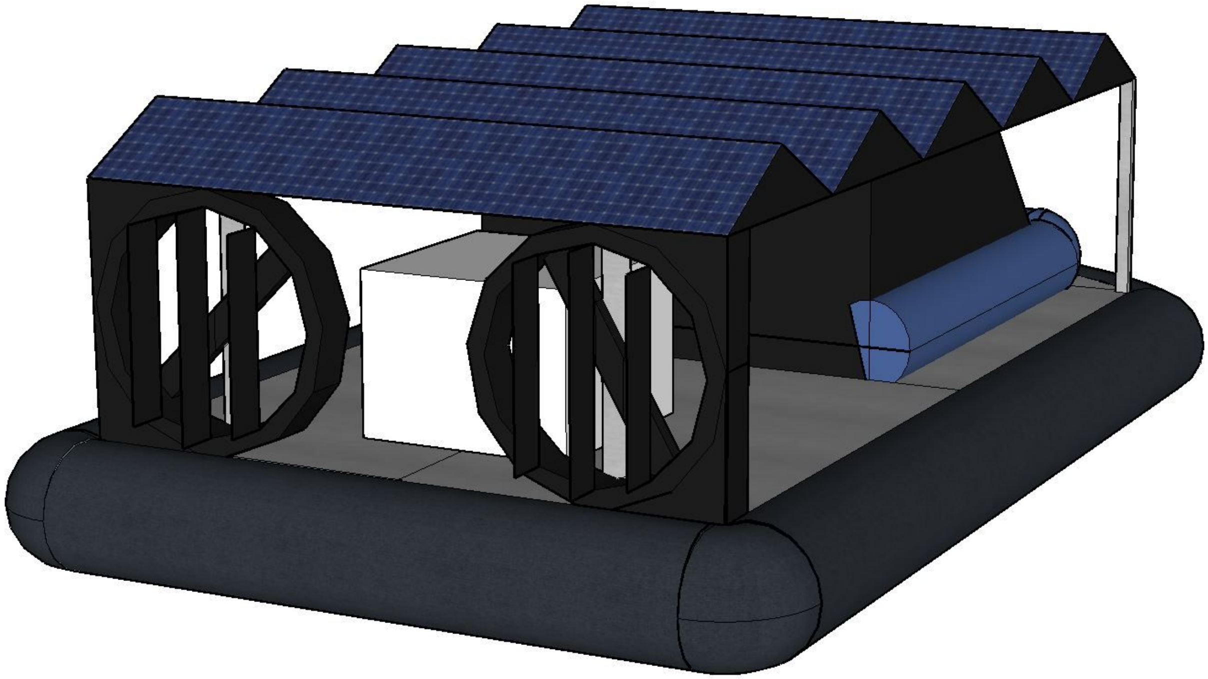
The second of these precautions is to ensure that the container that the load is held in will be fully waterproofed using the polysulfide sealant to adhere the carbon panels together with the use of a rubber gasket around the door of the compartment to ensure that the compartment is watertight. This will ensure that the load is not damaged by sea water which can be corrosive to some substances.

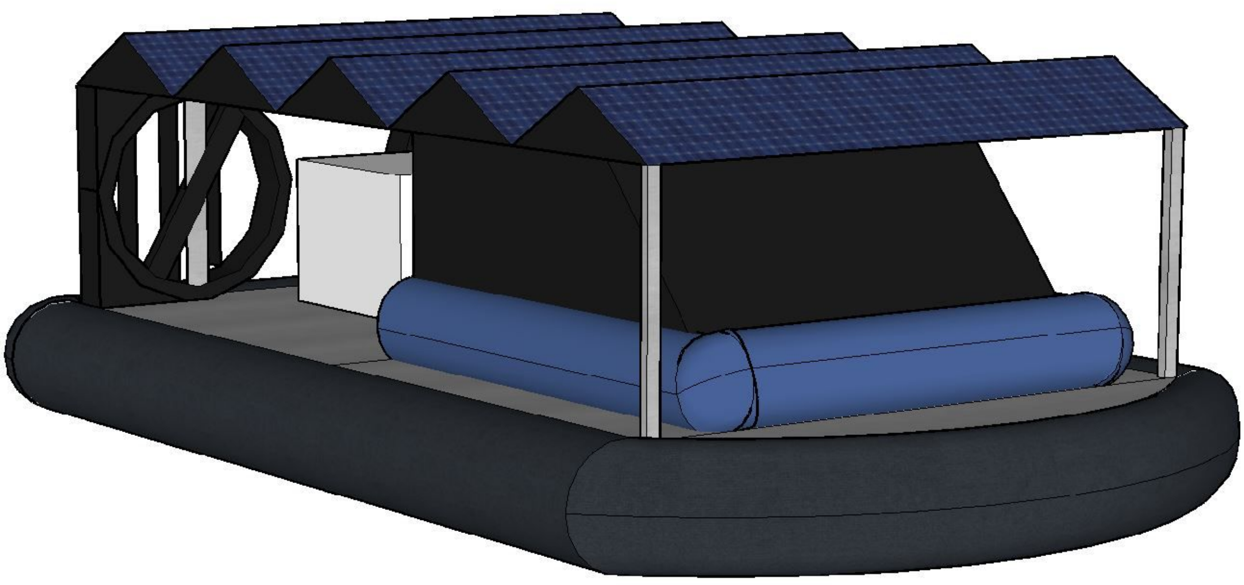
CAD Model:

We used SketchUp to make a scale 3D model of our craft this aided us with finding any oversights in our design and ensure that objects could be placed as we wanted using the decided dimensions. The grey coloured parts of the model suc has the main deck and the supports for the roof are made out of aluminium whilst the black parts such as the propulsion fans and their supports as well as the main Compartment that will contain the computers for control as well as the batteries etc. On the roof of the craft you can see the solar panels, textured using an imported image. The load that we are carrying is the untextured white block towards the stern of the craft in the centre is the 1 tonne load that we are carrying from the north pole to the south. When making the model all of the correct measurements were used meaning that the model is entirely to scale.

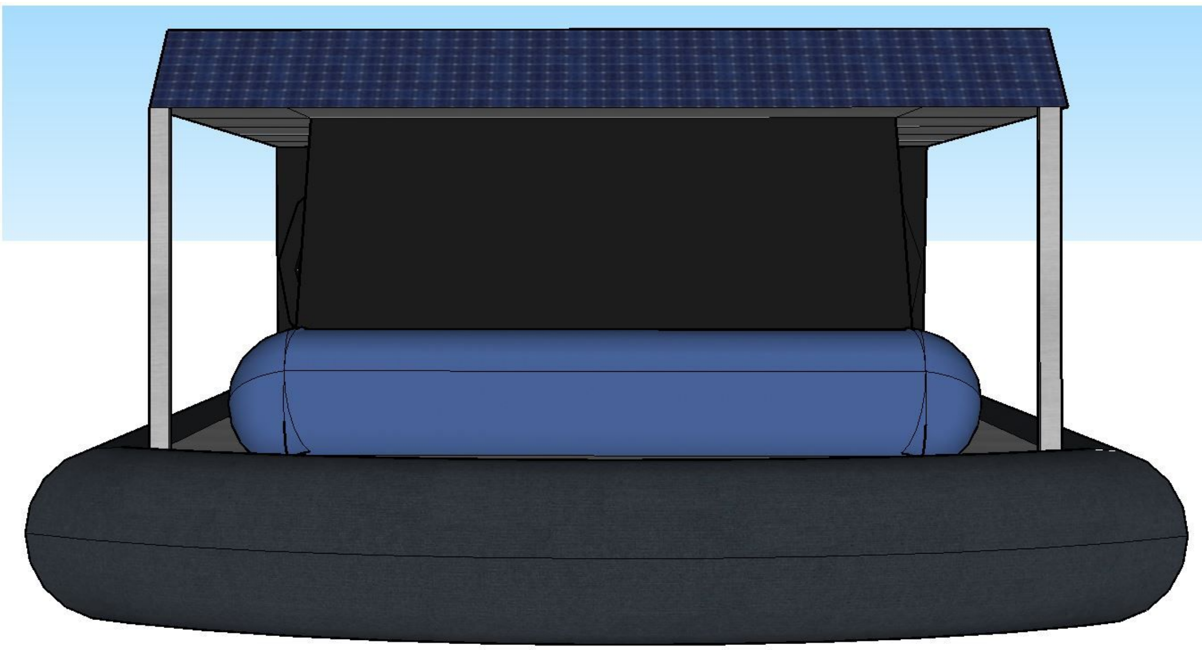
Plan View:



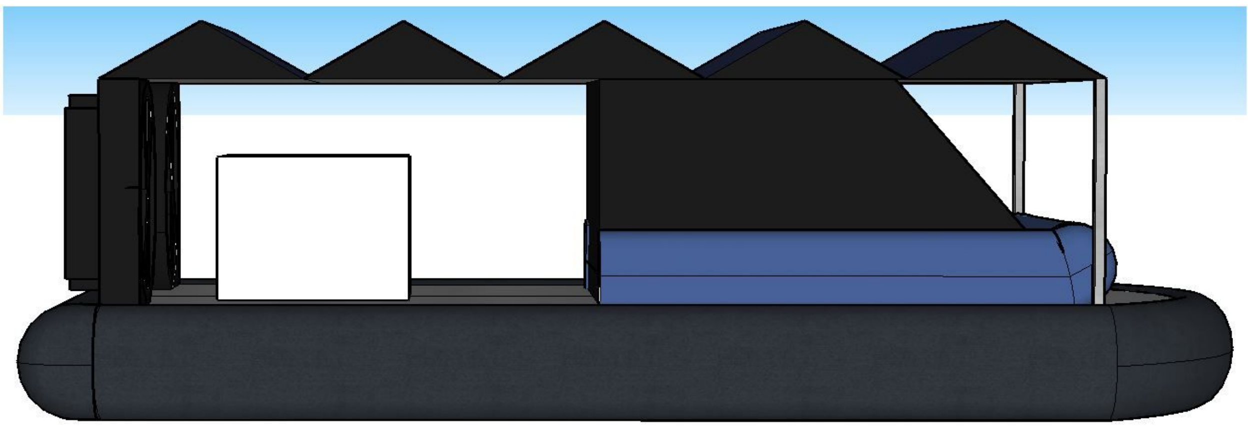




View of the Bow:



View of the craft's starboard side:



Costs

The cost of our craft will likely be very high as we decided to take a no compromises approach in order to make sure that the craft will reach the final destination with as little problems as possible.

Materials:

Our craft uses a ranged of very high end aerospace and marine materials which have excellent properties such as high strength and low weight. This is however accompanied by high costs.

For every meter of 6061 aluminium tubing with an outer diameter of 22.23mm and a wall thickness of 3mm there is a cost of ~£33.00 per meter length. As we need ~170m of aluminium tubing for the chassis plus some extra to leave margin for error we will buy 185m. This will have a cost of ~£6105.00

The cost per m^2 of 6061 Aluminium sheeting is ~ £86.00. The surface area of the aluminium panelling on the deck is 129.5m^2. We will then need to give room for error so will buy an extra 15.5m^2. This gives a total area of 145m^2 and cost of ~£12470.00

The total cost of the aluminium for the project is £18575.00

On average the cost of the materials used for making a carbon fibre component is ~£17.40 per kg. This cost includes the epoxy resin used as well as the woven carbon fibre sheets that make up the component. This price does vary with the intricacy and other requirements for the component. There are then also additional costs for the machining of moulds that vary from product.

Labour:

In order to weld the aluminium chassis and other components it is likely that a highly skilled team of between 3 and 4 people will be required. This is due the 6061 alloy of aluminium having properties that make it more difficult to weld. As well as this the decision to use round tubing due to its decreased weight means that welding the tubing will take longer than average. The average pay for a welder in the UK is £10.56 and as we will need engineers and tradesmen that are highly skilled in their profession it is likely we will pay a wage towards the top of the pay scale, this is between £13 and £15 an hour.

The average cost for labour per kg of carbon fibre is ~ £70.00 and makes up most of the cost of carbon fibre components. This is set to become up to 70% cheaper with advances in manufacturing and technology which will lead to reduction in the man hours required to make the final product.

We will also need to hire mechanical engineers to assemble the hovercraft in accordance with our brief. The average salary for a mechanical engineer in the UK is £11.60 but as we need to maintain a high quality it is likely that we will need to pay between £15 and £22 an hour.

Other Components:

Solar Panels:

On average in the UK it costs ~£238 per square meter to buy a solar panel . As our hovercraft has 69 square metres of solar panels then it will cost us ~£16422.00 to buy all of the panels for the roof of the hovercraft.

Autopilot and Sensors:

It is very difficult to decide on a price for the computer and the sensors involved with the system. However the costs will be very high as hiring development teams to software will create the software will be incredibly expensive with the average wage of a software engineer being £20.59 per hour and the project likely taking hundreds of man hours to design. The closest thing to the onboard computers that we would put on our craft is the autonomous computers that can be found onboard Tesla cars. The system that Tesla uses costs between £3000 and £6000 and we estimate that the cost of our system will be more than this as it will be custom made. It is also likely that the computers required to run this software will cost thousands of pounds as we will require high powered machines due to the software being incredibly demanding.

Batteries:

We have a 130 kWh lithium ion battery on board our craft. The average price for lithium ion batteries per kWh is $205. This means that our battery will cost ~$26650 which is ~£20443.39.

Costing Conclusion:

The cos of the craft will cost many thousands of pounds. The price of aluminium used in the project will be £18,575 alone plus the price of the battery which is over £20k. However finding the total cost is very hard as it is almost impossible work out how long it will take for the engineers and the welders to build the hovercraft   and therefore the costs for labour. As well as this it is very difficult to work out the prices of making moulds for custom parts and components. Our final estimate on price is at least £80k.

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"A titanic effort of a document"