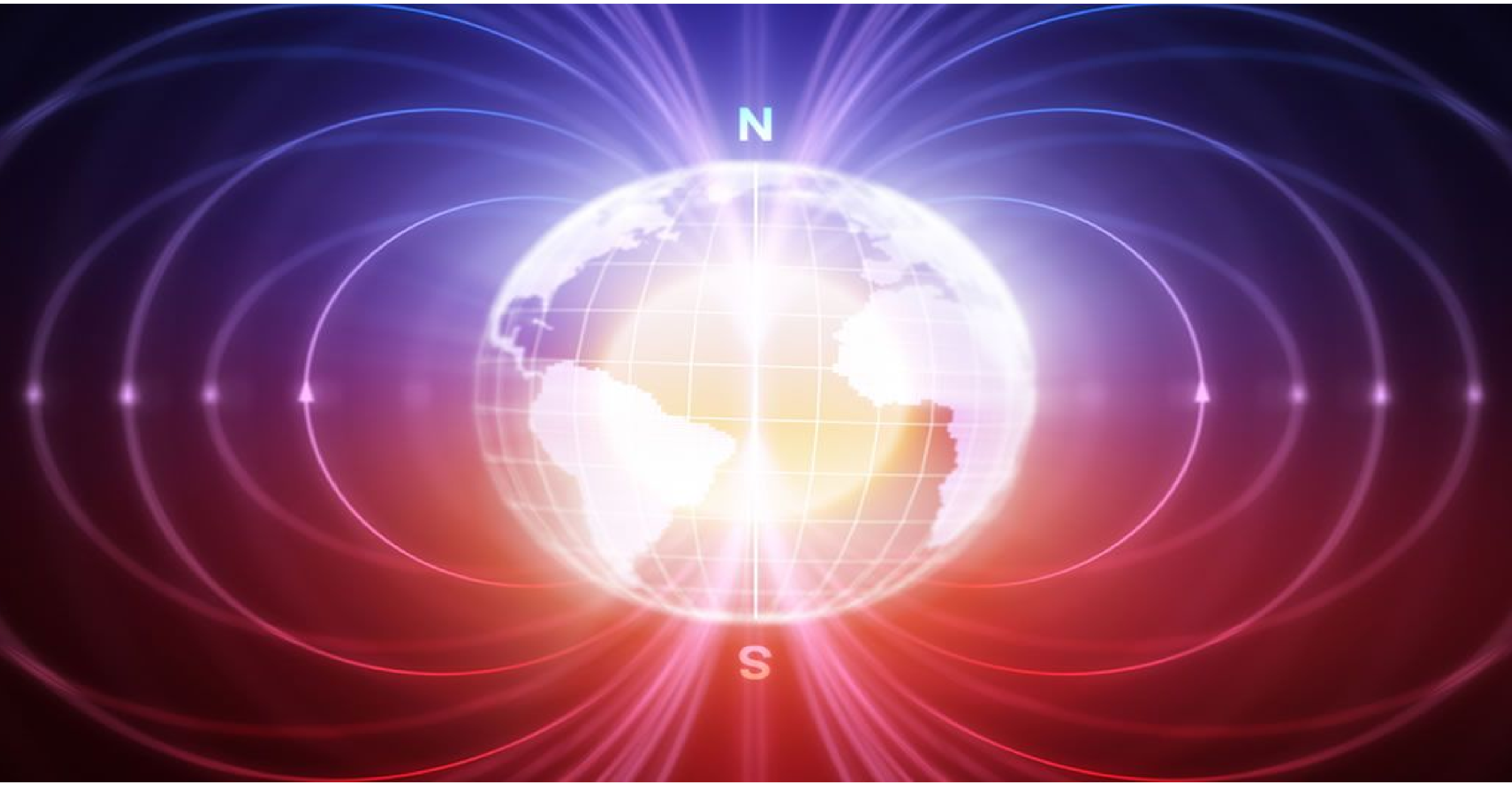
Project Report: Pole-To-Pole

Portsmouth College - Team NaPOLEon



Team NaPOLEon

22.02.2019

Year 12 BMC

INTRODUCTION

The Task - Pole to Pole

We were set with the task of transporting a 1-ton load from the North Pole to the South Pole - without using flight. The journey must take under 12 months, with no gathering resources en route, except for water. All the equipment used must start at the North Pole. Existing roads and bridges may be used but harbours may not be used, and an element of automation/robotics is encouraged, with an evaluation of automated techniques versus human-dependent methods. From the brief we were able to identify 3 main target points of this task and they were Energy, Transport and AI.

Energy

To overcome this “problem” we identified main points that we would need to discuss/work through; the first and foremost being ‘How are we going to power this, if at all?’. We came up with a criteria for our choice of power source. This criteria was:

- Economical (money does not grow on trees)
- Efficient (that way we will waste less and it would be more economical)
- Environmentally friendly (we hope to at least complete the project with minimal effects and damage to the environment)
- It had to last so we would not need to refuel along the way

Transport

In terms of transport the requirements for the project only specified we could not put the payload in flight and the journey had to be completed within one year. That left many options available left, as modes of transport, however, many of these had implications which we brainstormed to overcome if possible. The criteria that we created for transport was that it had to :

- Be able to travel on both land and or sea.
- Be able to travel long journeys in different or extreme conditions
- Be able to carry minimum 1 tonne of cargo.

AI

The requirements in the brief never specified the use of AI but did encourage the use of it. AI currently is this futuristic idea that can do almost anything, it is also being integrated slowly into society. As a team we thought it would be a great idea to integrate AI into our own systems. With this project there were practically no limitations to what we could do with AI, it was completely up to us and our own imaginations. As a result, there was no criteria for AI.

THE TEAM

ABOUT THE COLLEGE

Portsmouth College remains an independent FE college in a time of cuts, mergers, and academisation. In spite of the lowest number of local school leavers in the last five years, we continue to grow in student numbers thanks to our innovative integration of Apple iPads in teaching and learning; our late-start timetable with a 2h30 morning lesson and 2h afternoon lesson; and our strong presence in the community.

Ben Searle (Representing Portsmouth College)

The College has taken part in the Blott Matthews Challenge since it began in 2015, and we entirely hand the reins over to our students. After an initial briefing on the details of the competition, and some guidance on how to structure the report and start researching, it is entirely in the students' hands. They volunteer themselves for roles such as Project Manager and Report Editor, and divide up into sub-groups to tackle the different report areas. As the Senior Technician and overseeing staff member, I am only there to answer questions (without too much detail) and nudge the students back on track if I feel they are straying from the competition brief.

I am thrilled to be able to present two teams this year - the response was far greater than previous years, with 18 students signing up right away, and most committing to weekly meetings right through the entire process. While it would be incredible to build on the past two years' second prize successes and gain a win; the real prize here regardless of outcome is the valuable experience both teams have gained in report writing, research, leadership, and working both independently and as a team.

Best of luck to both teams, I am proud of the work you have put in to these reports, and I hope you all go on to successful careers in your chosen sectors.

Pinky

I'm Pinky, I study Biology, Chemistry and Psychology. I decided to take part in BMC because I believed it has given me skills that I find necessary for my future, helping me with any career choice like engineering.

Ryan

I'm Ryan, I study Maths, Physics and Computer Science and I took part in the Blott-Mathews Challenge because I wish to pursue a career in engineering of some sort.

Lucy

I'm Lucy and I study Chemistry, Physics and Maths. I chose to take part in the BMC because it was recommended to me by my teachers. In the future I hope to go to university to study a science course, probably in chemistry.

Ollie

I am Ollie and I study Physics, Maths and Computer Science. I chose to take part in BMC due to the experience in an engineering-oriented project. In the future I would like to go to university to study computers engineering or something similar in the field of computer science/engineering.

Ariana

I am Ariana and I study Chemistry, Biology and Psychology. I joined this project because I have an interest in having a future career in science, so I thought it would be a good idea to take part in this project to learn some skills and have an idea about what it would be like to work in an environment where I need skills like time management, teamwork and communication skills.

Caitlin

I am Caitlin, and I joined this project so I could meet new people and develop skills such as time management and communication. My A levels are not completely science based and I do not think they need to be to take part in this project, this project in my opinion is about problem solving and teamwork none of which you need a science background.

Chloe

I am Chloe and I study Chemistry, Biology and Maths as A-levels. I joined this project because I thought it would be a good way to meet new people and learn new skills like teamwork and communication.

Helen

I am Helen and I study French, Biology and Chemistry for A Levels. I chose to take part in Blott-Mathew challenge because it was recommended to me in my chemistry class and I found it very interesting.

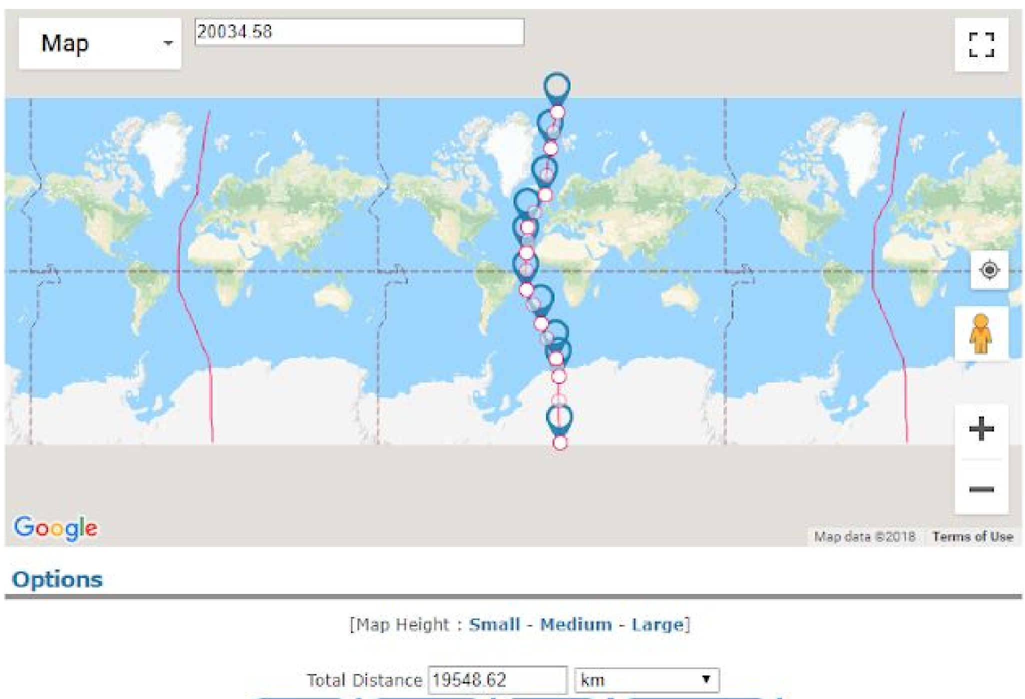
Khadija

I'm Khadija and I study physics chemistry biology and maths for a level. I took part in the Blott-Mathews challenge because I have an interest in engineering and I thought it would be fun. This project would be abreast way to enhance and improve on skills I already have such as communication, and time management.

The Route

Our cargo will be travelling from the geographic North Pole to the geographic South Pole. The geographic North and South pole are the points at which the Earth tilts on its axis. From the North Pole, down through the North and South Atlantic Oceans, the distance our cargo will need to be transported is around 20,000 km; as you can see from this map.

The climate at the North Pole can vary on average between -24°C to 15°C[36], which is something we will need to keep in mind as climate can affect time taken to travel and distance, as a change in climate or weather can cause delays in the journey.



© Google Maps, The route that we will take from north to south pole

The time limit given to us is one year, however, we are hoping to complete the journey within 3 months. The average speed of a container ship is around 24 knots (12.35 m/s). We are going to assume that our ship will travel around 20 knots (10.3 m/s). We calculated that to complete the journey within 3 months we would have to travel at 10.1 ms^{-1} - 2.52 * 4 = 10.08 m/s. If we travel at an average velocity of 10.1 m/s it would take 0.75 months which is roughly 23 days.[35](see appendix 1)

ENERGY

The project began by researching potential energy sources, uses, their advantages and disadvantages, the impacts, the costs whilst sticking to our criteria we outlined in the introduction; we then used this information to conclude which energy type we should use. Our findings can be found below:

Initial Research

Biomass energy

Biomass can be used as a fuel to generate electricity. It is burned in a combustor generating hot gas, which is fed into a boiler to generate steam, which is expanded through a steam turbine to produce electrical energy. In the United States small-scale biomass electric plants have installed costs of $3,000 to $4,000 per Kw and a levelized cost of energy of $0.08 to $0.15 per kilowatt per hour (1 kWh=3.6 megajoules). We estimate that it costs 11.77p per kWh which equates to 3.27p per megajoule. [1]

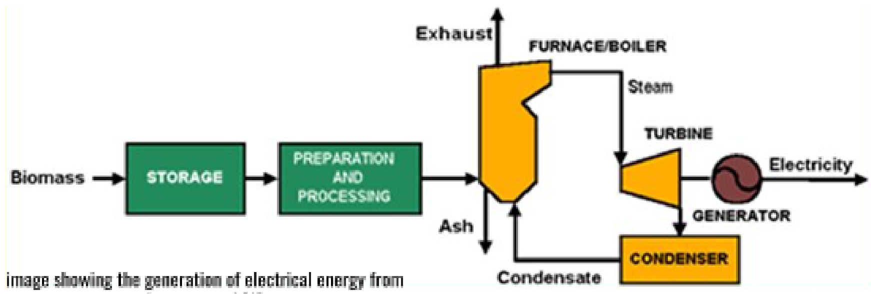


image showing the generation of electrical energy from biomass fuel [1]

The Advantages and Disadvantages

Advantages	Disadvantages
Carbon Neutral	Deforestation
Cheap in comparison to alternative energy	Requires too much space
Renewable and less dependent on fossil fuels	In-efficient
Widely available	

Summary

To summarise, biomass would be an inefficient energy source to use to power the vehicle. This is because of the amount of space biomass would require; the vehicle would have to be much larger than an ideal size and so would increase costs.

Diesel Energy

A diesel engine is a type of combustion engine where the fuel is burned inside the main part of the engine. Internal combustion engines are more efficient in energy production than external combustion engines because the heat doesn't have to flow from where its produced into the cylinder because it is produced in the cylinder. [2] 1 litre of diesel-oil amounts to 10 kWh (35.9 megajoules) of energy.[3] The average cost of diesel is 11.2p per kWh. Diesel is used to power lots of vehicles because it's a reliable energy source that is unlikely to fail. [4]

The Advantages and Disadvantages

[5][6]

Advantages	Disadvantages
Lower co2 emissions by 20% than petrol	Produce nitrogen dioxide and carbon dioxide which is contributes to greenhouse gases resulting in an increase in global warming.
Diesel engines usually have a long-life span because they are engineered to withstand high temperatures.	

Hydrogen Energy

What is a Fuel Cell?

A fuel cell is a device that generates electrical power through a chemical reaction by converting a fuel (hydrogen) into electricity. Although fuel cells and batteries are both considered electrochemical cells and consist of similar structure, fuel cells require a continuous source of fuel and oxygen to run; like how an internal combustion engine needs a continuous flow of gasoline or diesel.

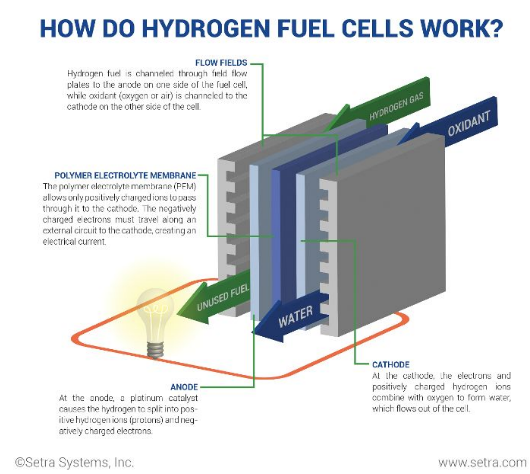


Image from reference [7]

How Does it Work?

A fuel cell needs three main components to create the chemical reaction: an anode, cathode and an electrolyte. First, a hydrogen fuel is channelled to the anode via flow fields. Hydrogen atoms become ionized (stripped of its electrons), and now carry only a positive charge. Then, oxygen enters the fuel cell at the cathode, where it combines with electrons returning from the electrical circuit and the ionized hydrogen atoms. Next, after the oxygen atom picks up the electrons, it then travels through the electrolyte to combine with the hydrogen ion. The combination of oxygen and ionized hydrogen serve as the basis for the chemical reaction. A polymer electrolyte membrane permits the appropriate ions to pass between the anode and the cathode. If the electrolyte gave free control for all electrons or ions to pass freely, it would disrupt the chemical reaction. At the end of the process the positively charged hydrogen atoms react with the oxygen to form both water and heat while creating electrical charge. Within the fuel market there are many different applications with different power requirements. In order to provide adequate power, individual fuel cells can be assembled together forming a stack. A fuel cell stack can be sized for just the right amount of energy for the application. [7]

The Advantages and Disadvantages

[9]

Advantages	Disadvantages
Carbon emission free	Nitrogen Dioxide emission
Accessible and clean	Storage issues
Renewable energy source	High cost
Fuel efficiency	Storage issues
	High cost

Solar Energy

Simply put, a solar panel works by allowing photons, or particles of light, to knock electrons free from atoms, generating a flow of electricity. Solar panels comprise of many, smaller units called photovoltaic cells. (Photovoltaic simply means they convert sunlight into electricity.) Many cells linked together make up a solar panel. Each photovoltaic cell is basically a sandwich made up of two slices of semiconducting material, usually silicon — the same stuff used in microelectronics. To work, photovoltaic cells need to establish an electric field. Much like a magnetic field, which occurs due to opposite poles, an electric field occurs when opposite charges are separated. To get this field, manufacturers "dope" silicon with other materials, giving each slice of the sandwich a positive or negative electrical charge. Specifically, they seed phosphorus into the top layer of silicon, which adds extra electrons, with a negative charge, to that layer. Meanwhile, the bottom layer gets a dose of boron, which results in fewer electrons, or a positive charge. This all adds up to an electric field at the junction between the silicon layers. Then, when a photon of sunlight knocks an electron free, the electric field will push that electron out of the silicon junction. A couple of other components of the cell turn these electrons into usable power. Metal conductive plates on the sides of the cell collect the electrons and transfer them to wires. At that point, the electrons can flow like any other source of electricity. [10]

The Advantages and Disadvantages

[11]

Advantages	Disadvantages
Renewable	Expensive
Abundant	Intermittent
Environmentally friendly	Storage is expensive
Sustainable	Pollution
Good availability	Exotic materials needed
Low maintenance	Requires large amount of space

Wind energy

Wind turbines convert kinetic energy in wind into mechanical power when the wind turns the blades of the turbine which spins a shaft connecting to the generator, the generator converts mechanical power into electricity. [12] Wind turbines under 100 kilowatts cost roughly $3,000 to $8,000 per kilowatt of capacity. A 10-kilowatt machine (the

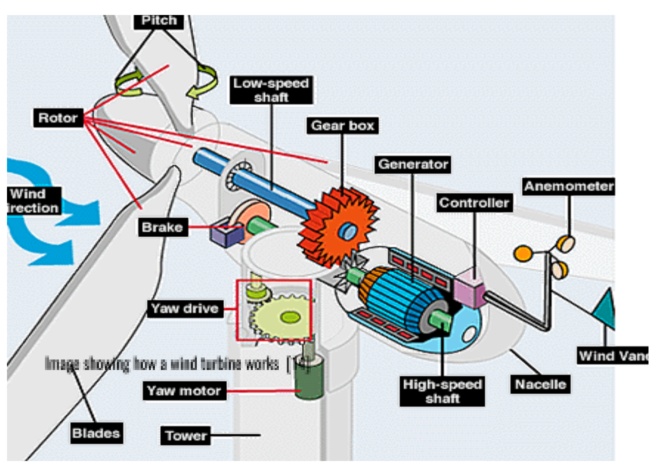


Image showing how a wind turbine works [14] size needed to power a large home) might have an installer cost of $50,000 to $80,000 (or more). If a wind farm was used as a way to make energy it could either be onshore (not on vehicle) or offshore (on vehicle).[13] Offshore wind farms means that windmills will be less intrusive on land and therefore minimising complaints. Typically, out at sea, there is a much higher wind speed allowing for more energy to create at a time. When placing wind farms there are fewer physical restrictions like hills or buildings that could block the wind flow. However, generally offshore wind farms are very expensive; for a comparison, they're 90 percent more expensive than fossil fuel generators and 50 percent more expensive than nuclear fuel generators. This is because a whole platform must be built to support the farm. On the other hand, onshore wind farms are relatively cheap allowing for mass farms of wind turbines, they're also very quick to install (a couple of months), unlike a nuclear power station, for example, which can take over twenty years. Many deem onshore wind farms to be an eyesore on the landscape and they don't produce as much energy as offshore wind farms mostly because of physical blockages (building and hills). There are many variables as to whether onshore or offshore wind farms are better, including financial and geographical. For this project onshore wind farms are the best suited energy source because there's more space on land to set up wind farms than there is on our vehicle that we are limiting the size of. They are also generally cheaper than offshore wind farming which is beneficial to minimising the cost for energy. [14]

The Advantages and Disadvantages

[15]

Advantages	Disadvantages
Clean source of power	Noise pollution
Cost effective as once set up, wind is free, and the only cost is to run the generator so long term the original wind turbine cost is paid back with the amount of energy they can produce.	Wind isn't reliable
	Threat to wildlife (edges of the turbine can be unsafe to animals like birds)

Our Plan

We decided to use a hydrogen fuel cell because it is a powerful and reliable energy source even though it's expensive. We calculated the costs of having each type (see appendix 2). Wind and wave are cheap but not reliable. Biomass is cheap but needs a lot of storage space. The reason as to why we chose to do Hydrogen fuel as our main energy source was because the hydrogen can be compressed and stored easily. Hydrogen is easily accessible and clean as it is always readily available as it is a simple element its supply in the atmosphere is abundant. The result is a clean and powerful source of energy. In addition to this hydrogen is easily portable and produces large amount of energy depending on the use but in this instance, we will need large amounts of energy to travel the vast distance that we are travelling. We chose wind as our back up energy because there is always wind whether that be generated by the boat's movement cause the small wind turbine to move and generate electricity of there is wind at sea, which will essentially charge the boats batteries an the appliances in the boat i.e running the refrigerator and the recreation room appliances. All of this will be done wirelessly through a large electromagnetic charging pad in the lower deck of the ship that will be able to supply sufficient energy from the wind.

TRANSPORT

Initially when thinking of ideas for modes of transport we looked at vehicles. We looked at both land and sea vehicles, such as trains and ships. However, like energy they came with numerous implications such as border security and laws, international waters.

Vehicles

Land Vehicles

At first we looked at land vehicles, such as large trucks. They are an item which is less theoretical, and minimum changes would be needed. To travel by land, we would have to map existing routes and tackle things such as traffic, borders and still have to travel over some bodies of water- this is why we have decided it would be more efficient to travel by water- so a large truck is no longer applicable to our scenario.

Water Vehicles

One established water vehicle we could use is a submarine. Although a submarine can efficiently take us across the water, there is a barrier for us while crossing the Antarctic as the solid ice means we can not travel below sea level.

A positive about the nuclear submarine is that it’s not required to be refueled and brought to the surface again and most of the nuclear submarines have diesel generators as the alternate power source that is used in case of the fault in the nuclear reactor. The nuclear submarines can go for several years before they need to be refueled.

With rising oil prices, the nuclear ships might be more economical than the conventionally powered ships, since savings in the fuel costs might offset the additional up-front costs of nuclear-powered ships.

Are main concern about a nuclear submarine is the reactor needs to be cooled even when the submarine is not moving, The nuclear fission generates enormous amounts of the harmful radiation that if it is leaked , it can damage both the human and the marine life which we wouldn’t want.

The nuclear submarines cost a lot of money, they require many specialized equipment, facilities, and knowledge to both operate and maintain. And as we aim for minimal crew and an economical journey with minimal damage to the environment, the risks of the nuclear reactor is too great, and the price is not ideal.

Amphibious vehicle

To combat that we have to travel in land and water our median is an amphibious vehicle. Smaller amphibious vehicles are very tangible. Many small amphibious vehicle models have been specifically designed to deal with challenging terrain, high speeds in land and water and can transition easily from water to land- vise versa. But are not large enough to hold the package, crew and equipment needed for our journey. Lager amphibious vehicle are quite theoretical. We would have to design a vehicle that could hold the required weight, design a propulsion system suitable to a larger vehicle. We would also need a suspension mechanism for the tire, which will make the vehicle amphibious.

Designing our own amphibious vehicle, gives us the opportunity to make a vehicle which is cost effective, environmental friendly and specific to our purpose. It overcomes the barrier of land to sea travel.

Propulsion Systems

Our Plan

The two main propulsion systems that could be used for the marine aspect of our amphibious vehicle include a Water Jet Propulsion System or a Propeller System. A propulsion system produces thrust to enable the vehicle to move forward. Propulsion work on Newton's Third Law, for every action there is an opposite and equal reaction.

Details

- Water Jet Propulsion System

  In a water jet propulsion system works the propelling force is generated by adding momentum to the water by accelerating a certain flow of water in the direction of the stern. The water from under the vessel is fed through an inlet duct to a precision inboard pump, usually mounted at the transom (horizontal beam reinforcing the stern of a boat) adding head (pressure) to the water. This head is then applied to increase the velocity when the water passes through an outlet nozzle into the ambient atmospheric pressure. This thrusts the boat forward, giving us a propulsion System.

- Propeller System

  A propeller works by thrusting a column of water away from the main body of the ship, thereby producing a reactive force that moves the boat forward (Newton's third Law). Propeller blades rotate downward while water rushes in to fill the space left behind to create a pressure differential. Water accelerates from the front of the propeller towards the back, creating a column of water slightly bigger than the propeller itself. Higher velocity creates a water jet out of the rear of the propeller, which adds momentum and thrust to the water. This thrust moves the boat forward.

- Basic components
  - Hub-Solid cylinder located at the centre of the propeller to which each propeller blade is attached.
  - Blades- Shape and number of blades affects the speed of the blade and the effect on the engine. Having more than 3 blades increases drag, therefore the optimal number of blades for our medium sized vehicle is 3, as we don't need to reach excessive speeds.
  - Aluminium vs Stainless Steel propellers- Aluminium propeller are an affordable option for small to medium-sized boats. Aluminium absorbs impact energy to help protect drive component. Under load, aluminum props bend when spinning. Stainless Steel propellers are a more expensive option that delivers increased rigidity and performance, especially on heavier boats. Because Stainless Steel propellers don't flex under power, they are also available in larger pitch sizes.

AMPHIBIOUS BOATS

Our amphibious vehicle has been based of some real-life boats we have researched such as:

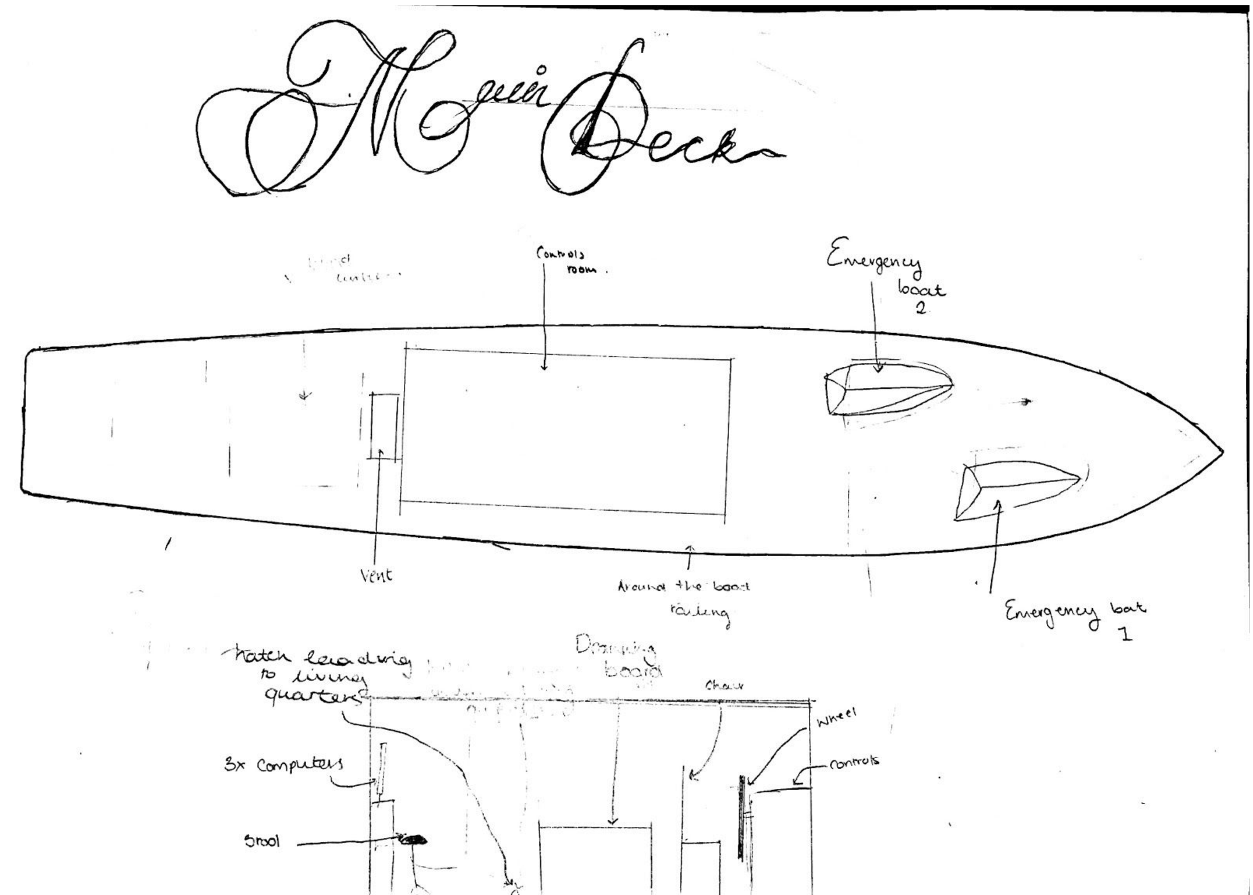
- Tamar class lifeboat (general shape) : [21]
  - Self-righting with 44 people on board so a stable design
  - 20m length 5m beam

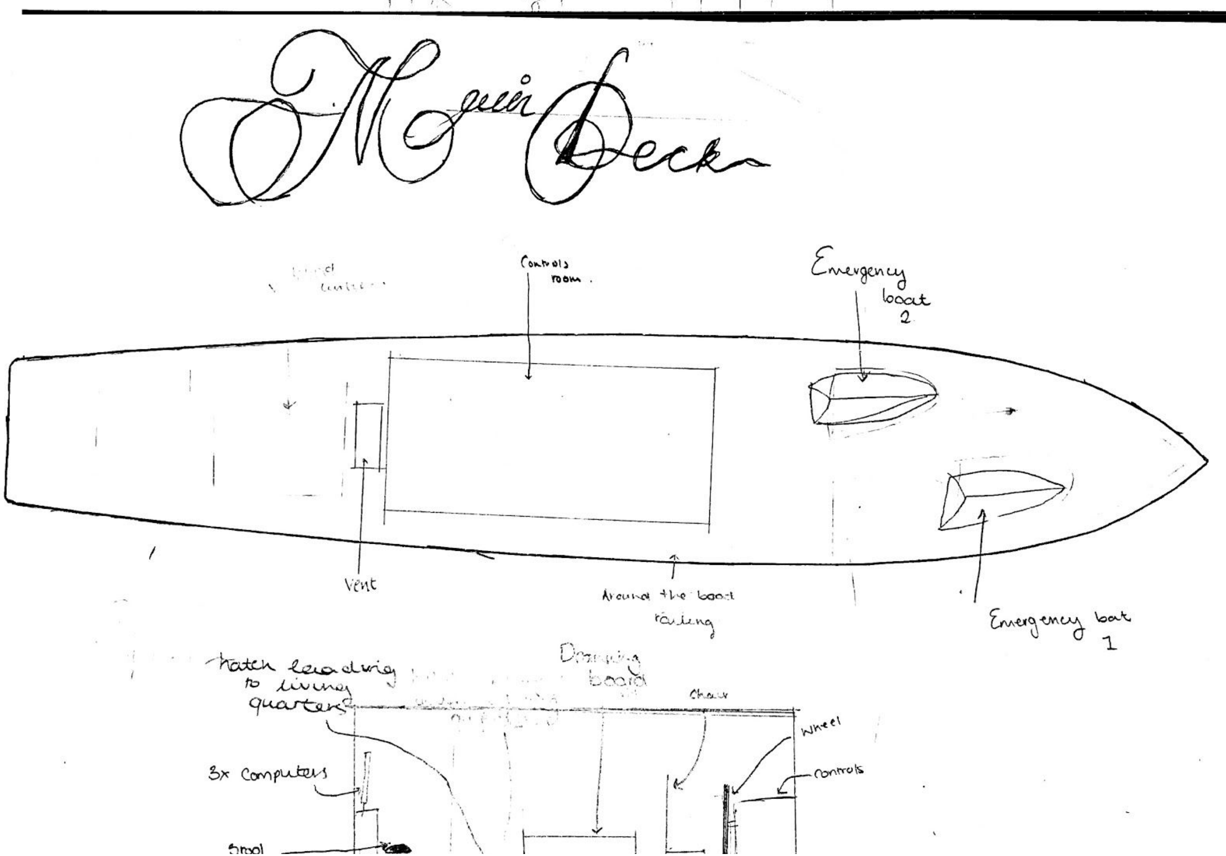
- Iguana yachts (tracks) : [22]
  - an amphibious motorboat that's got all terrain tracks

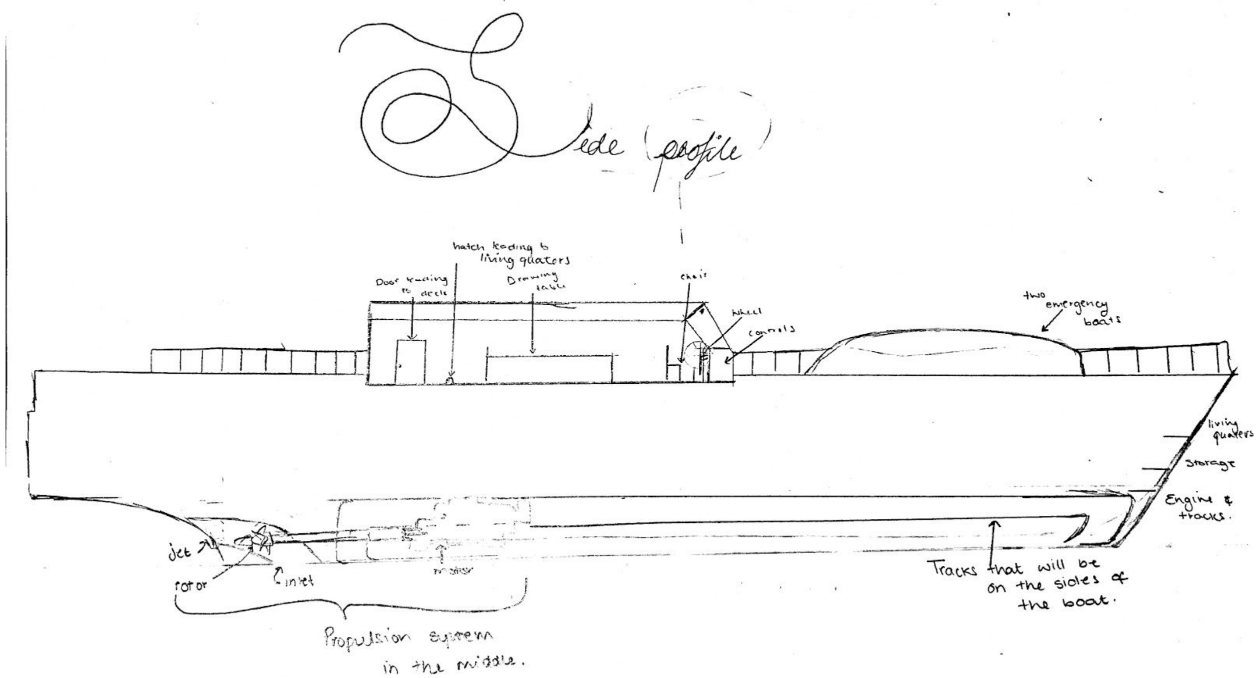
- DT-30PM amphibious terrain (tracks) : [23]
  - Being a mass of 31000 kg proves that tracks can hold up a 30-tonne boat
  - Overall Mass of the boat is 30,000kg (see appendix 3)

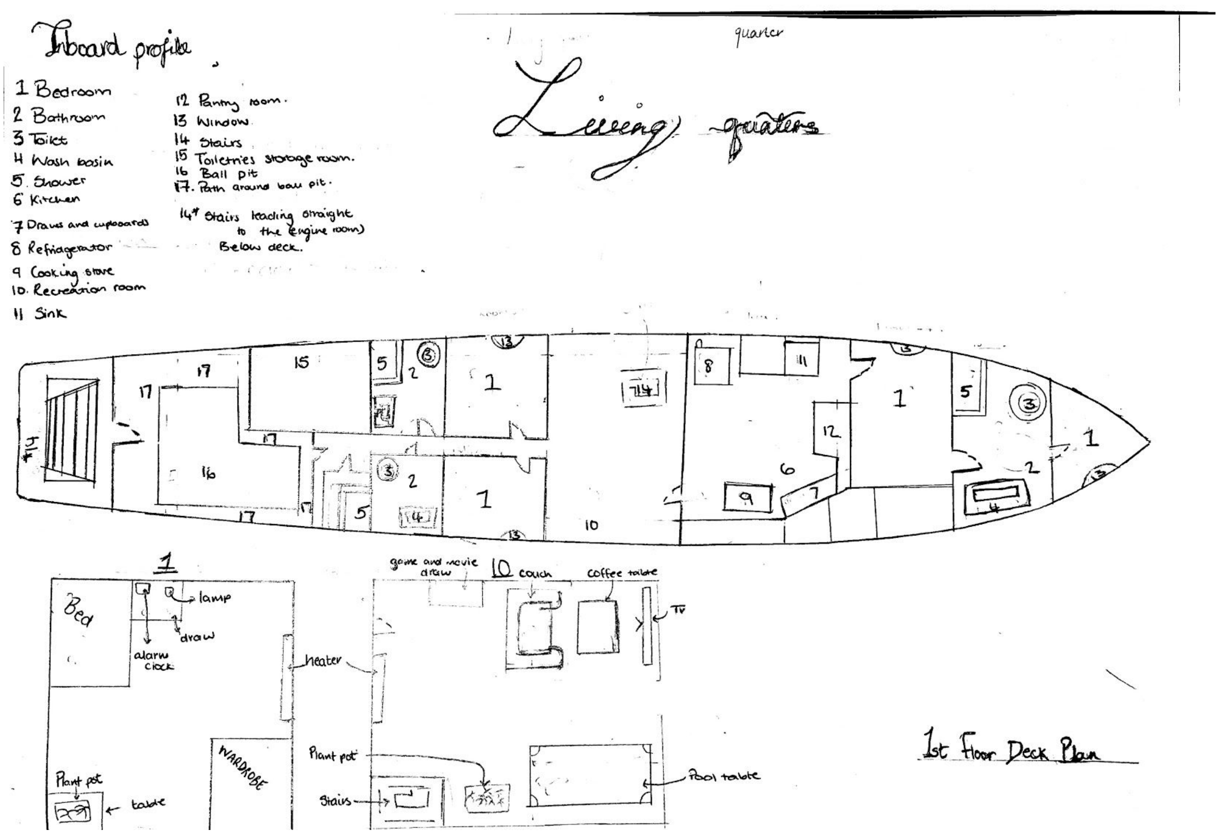
From researching these vehicles we have estimated that our vessel will be 55ft by 15ft by 24ft.To accommodate our cargo each floor have been designed to be 10ft in height.

Blueprints for our amphibious boat






Side profile
hatch leading to living quaters
Door leading to deck
Drawing table
chair
wheel
controls
two emergency boats
living quaters
storage
Engine & tracks.
Tracks that will be on the sides of the boat.
jet
rotor
inlet
Propulsion system in the middle.


Inboard profile
1 Bedroom
2 Bathroom
3 Toilet
4 Wash basin
5 Shower
6 Kitchen
7 Draws and cupboards
8 Refrigerator
9 Cooking stove
10 Recreation room
11 Sink
12 Pantry room.
13 Window.
14 Stairs
15 Toiletries storage room.
16 Ball pit
17. Path around ball pit.
14* Stairs leading straight to the engine room) Below deck.
Living quaters
Bed
lamp
draw
alarm clock
heater
WARDROBE
Plant pot
table
game and movie draw
10 couch
coffee table
TV
Plant pot
Stairs
Pool table
1st Floor Deck Plan

AI Vs. HUMAN

Our Plan

We as a team decided to implement AI into our plan, but also have humans onboard our amphibious ship. The idea initially, was to have majority of our ship controlled by AI but have a feed sent to a base on land so someone could keep an eye on all the systems. All data sent to the feed will be done via satellite. We then investigated the legality of this, but then decided it would be better to have humans onboard as well. The base will still be sent information but a crew member onboard will be checking all data runs occurring. We estimated the running costs of this and in the end decided it was best to hire university students. We would hire 3 or 4 students, and then the person in our base which could be set up anywhere, potentially.

Regulation and Liability of Running an AI Ship

The existing regulatory regime does not allow unmanned or AI-enabled ships. A captain or Master of the ship is necessary as he or she would have many duties to manage ship in terms of safety, crime and how its running. Safe manning levels are required for a ship to be considered seaworthy under key regulations, such as the UNCLOS and SOLAS Conventions. However, safe manning levels are subjective under the UNCLOS and SOLAS Conventions. This allows different jurisdictions the discretion to stipulate different manning requirements. To facilitate the development of unmanned/AI-enabled shipping, the regulatory regime will need to be updated to provide more certainty about risk, responsibility and liability. Shipping is an international business, so updating legislation needs to be on an international level (through the International Maritime Organisation (IMO)) as well as at a national level. This process has already started following the meeting of the IMO in June 2017, where it agreed to commence a regulatory scoping exercise for unmanned/AI-enabled ships. However, it is anticipated that an updated international regulatory framework is unlikely to be in place until at least 2028. AI is considered dangerous due to hackers having the opportunity to hijack the system and overtake the ship. This could be extremely dangerous and unsafe. [24][25][26]

Hiring Students

The cost of hiring a student or several students to work on the vehicle whilst it operates depends on their age and how long they will be working. Hiring 3 students to work 8-hour shifts per day so that the full 24 hours is covered would cost anywhere between £51,684 and £64,648.80 annually.

Details

The average student studying at university is between the ages of 18 and 22, the minimum wage for 18 to 20-year-olds is currently £5.90, and the minimum wage for 21 to 24-year-olds is £7.38.

Advantages and Disadvantages

Advantages	Disadvantages
Hiring university students would be cheaper than hiring people already with degrees	University students are more likely to make mistakes than people already with degrees
University students have a high level of education in specific fields	University students may not want to take part as they could want to focus on their education

Summary

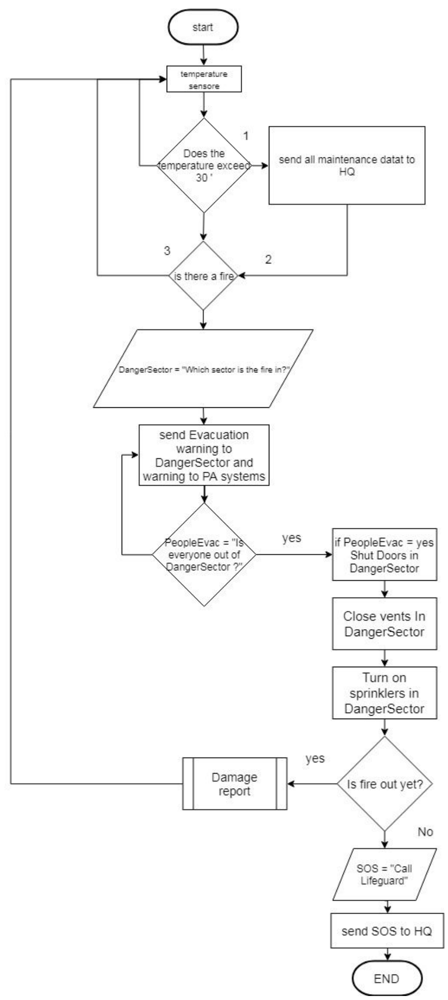
To summarise it would be best to hire university students at age 20 because at this point they have had several years education in their specific field so they are less likely to make mistakes, and they can be paid less than if they were further into their education. [29][30]

Flow charts

AI is a key concept of our amphibious boat, therefore we created flowcharts of some systems we had created and designed.

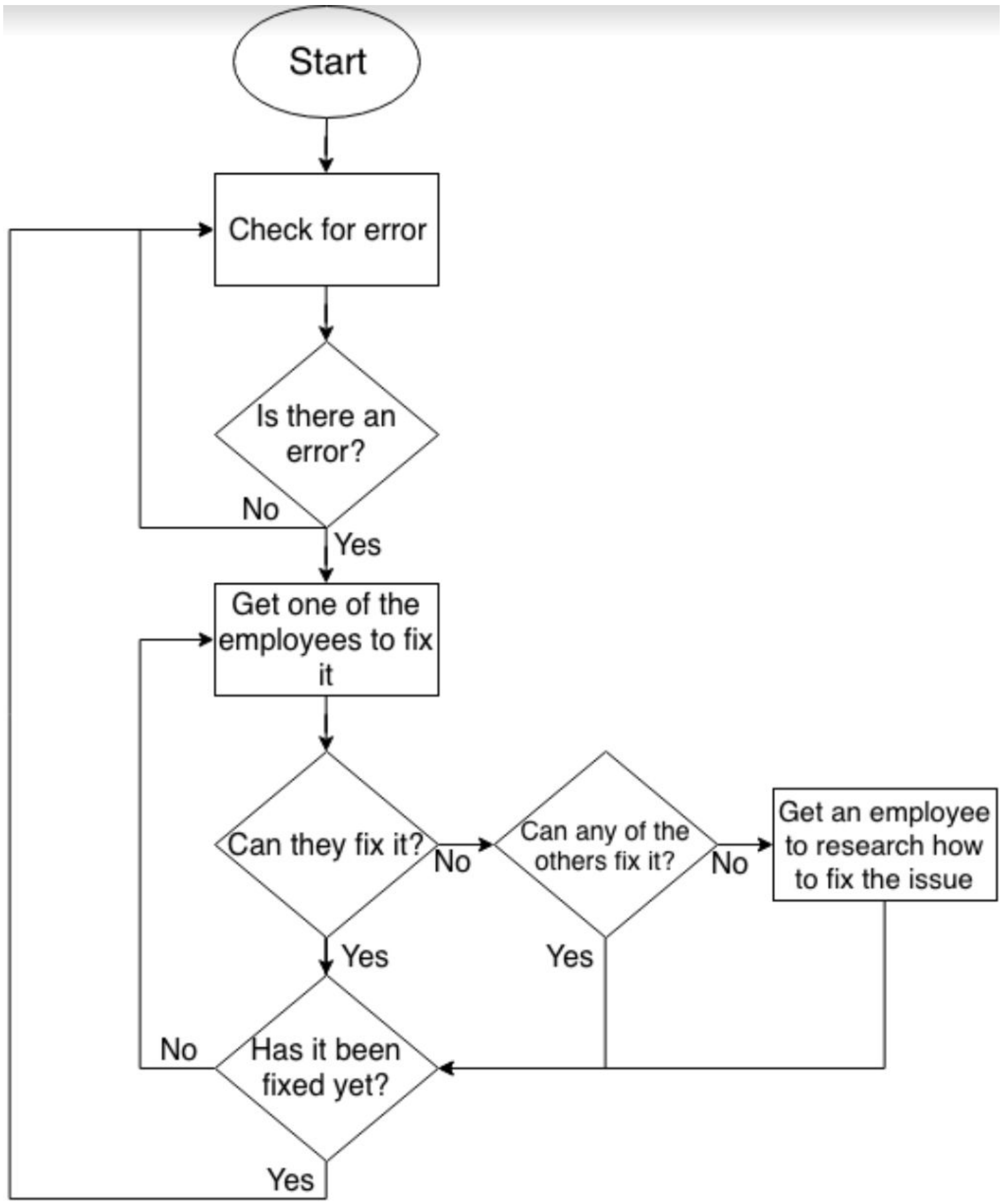
Fire

The flowchart below is of a code that would be written into our system. The flowchart shows what would happen in the event of a fire; our system is designed to act when a fire has been detected by staff or by the system itself. It would close off vents seal off a sector of the boat and flood the sector affected with CO_2.



Maintenance

The flowchart below shows what the AI would do to check for any need of maintenance, and then what it would do if maintenance was required.



EMERGENCY PLAN

CODES

In case of an emergency of any sorts there is a code to be projected throughout the vessel

- IGNIS = FIRE
- INFIRMUM = SYSTEMS BUGS/CRASH
- IMPERIUM = POWER FAILURE

STAGE 1

The code for the emergency recognised, will be projected throughout the ship and stage 1 will commence. In stage 1 of an emergency all personnel will go to their stations outlined in the event of an emergency. By the emergency exit of their station there will be a button which will be pressed and in doing so this will alert command that there is a member of the ship ready. Then a systems check will proceed in finding out the source of the problem. If everything works out, then the ship will not go into stage 2.

STAGE 2

In stage 2 the systems check done by the captain on the bridge and the staff member on land will have done a data analysis of the entire ship. The ship will then go into the following emergency procedures.

IGNIS (Fire)

In our AI section we have outlined the procedure in case of a fire, and in short it is as follows:

1. We check where the rooms have risen above 30°C (to allow for any room for errors)
2. We seal off that area by closing all doors to the room
3. All ventilation systems are closed of oxygen is siphoned out and the room is flooded with carbon dioxide
4. This goes on a loop until the fire is out

Then we do a check of the damages to all computer, electrical systems and physical systems. With a fire the emergency procedures end at 2 unless extensive damage is caused by said fire. Then we repair any damages we can or end the journey for the safety of all the crew.

INFIRMUM (Systems Bug)

In case of a code INFIRMUM the boat will send a report back to base just in case they have not picked up on it. The base and captain will then decide how to proceed whether to dock at the nearest port if available. Although this goes against the requirements in the guidelines we do believe the life of the crew overrules the project at hand.

IMPERIUM (Power Shortage)

In the event of a power shortage we will wirelessly charge our vessel as a backup. It is our idea to have a wireless charging port for our vessel powered by wind.

STAGE 3

Stage 3 is when all crew members leave the ship via one of two lifeboats on the main deck, and return to shore safely.

APPENDICES

Appendix 1: The Route

$2 * 10^7$ m is the total journey distance needed to travel. The following calculations below show the average velocity of our mode of transport.

- This equates to $2 * 10^7/365$ = 54794.5 m per day.
- 54794.5 / 24 = 2283.1 M per hour.
- 2283.1 / 60 = 38.05 M per minute
- 38.05 / 60 = 0.63m/s

- This means to transport our cargo the distance required in a year we would have to be traveling at the minimum average velocity of 0.63 ms-1.

- With our 3 month time frame the transport would have to travel, (0.63 * 2) * 2 = 2.52 m/s
- 2.52 * 4 = 10.08 m/s, this is the overall average velocity we would have to travel.

Appendix 2: ENERGY

Hydrogen Energy

The price:

1. Compressed hydrogen cylinder - 200 cu.ft of hydrogen (NTP) or 5667.37 Litres.
2. Cost of hydrogen cylinder is $100 + $14/month (rental) +$20 (delivery)
3. 1kW fuel cell system with a hydrogen consumption rate of 13 Standard Litre/min.
4. Number of hours of operation at 1kW = 5667.37/13 = 7.26 hours

Example 1:

The cost of operating a 1kW fuel cell for 7.26 hours when only one cylinder is purchased per month is $134. This is equivalent to $18.40 per hour to operate at one kilowatt.

Example 2:

When the number of hydrogen cylinders used is increased, then the cost is reduced. Assuming 5 cylinders of hydrogen are consumed in one month, this gives 7.26 x 5 = 36.33 hours of operation. The cost of the cylinders is (5 x $100) + (5 x $14) + $20 = $590. This is equivalent to $16.24 per hour to operate at one kilowatt. Roughly £12.50 per hour for 1 kilowatt. [8]

Solar Panel System cost

100kw =$130,000 (£100,100) - $200,000 (£154,000) [10]

The costs of different energy types

Biomass [16]

- Woodchip-2 or 3 p per kWh
- If bought in bulk is 5p per kWh (a pallet of around 100 x 10 kg bags = 1 tonne)
- 1 tonne bag of wood chip= 5 p per kWh
- 1 tonne contains 4800 kWh of energy
- £215/£240 per tonne

Wind [17]

- Large scale onshore wind =3 or 4 p per kWh

Wave [18]

- 35-40p per kWh

Hydrogen [19]

- £10 - £15 per kilo

Solar [20]

- 100kw =$130,000 (£100,100) - $200,000 (£154,000)

Appendix 3 Transport

- Overall Mass of the boat:
    - Payload to carry 1000 kg
    - Hydrogen Fuel 1064 kg [28]
    - Tanks 5000 kg [27]
    - Fuel cell 500 kg [32]
    - Motor 200 kg [33]
    - Food 200 kg
    - People 400 kg
    - Drinking water 3000 kg [34]
    - Accommodation 8300 kg [31]
    - Rest of boat 10336 kg

      = 30000 kg

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