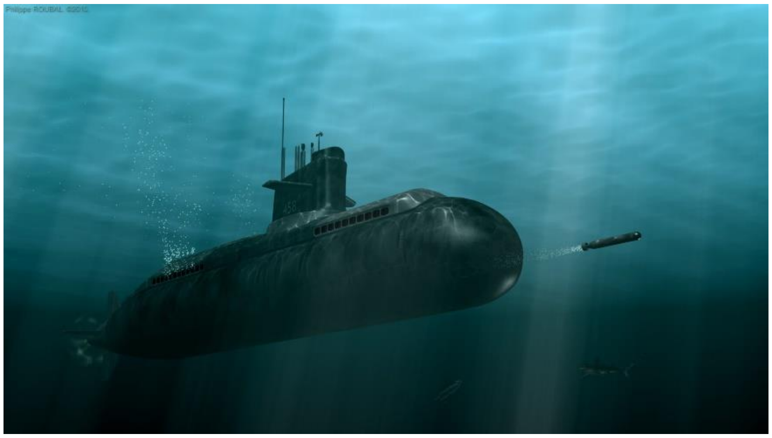
Portsmouth College

Pole to Pole

Autoblotts

2018/2019

Contents



A submarine (A24)

About us

The College *Ben Searle, Lead Science Learning Technician*

Portsmouth College remains an independent FE college in a time of cuts, mergers, and academization. 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.

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.

Charlie Foord *Project Manager/Transport*

I am studying A levels in Maths, Physics, Architecture and Further maths. This project has helped me to develop my team work and problem solving skills. I feel that, while working on this years Blott Matthews project, I have learnt essential skills about formulating a report and time management for a project/design.

Alex Morey *Report Editor/AI vs Human*

I study Biology, Chemistry and Maths. I have chosen to take part in the Blott-Matthews challenge as I thought it would be a fun challenge, and a fantastic opportunity to collaborate with lots of different people. I hope to attend a medical school at a Russell Group University.

Amber Murray *Concept Artist/Transport*

Next year I will be studying animal care as I admire the animal kingdom and hope that this will help me to pursue a career as a zoo keeper. At the moment, I'm studying AS levels in chemistry, biology and maths. My favourite of these is biology and is the one I can really get stuck into.

Max Waller *Finance Manager/AI vs Human*

I'm taking Physics, Mathematics, History and an AS-Level in further maths. I heard about the Blott-Matthews Challenge through my physics teacher and I thought it would be great opportunity.

Salihah Begum *Concept Artist/Energy*

My name is Salihah Begum in the project I was concept artist and part of the energy team I chose to take part in the Blott-Matthews competition as it will increase my awareness and knowledge in engineering; having also gained interest in this area. This has been a great experience and I have enjoyed it.

David Jones *AI vs Human*

Hi I'm David, I'm studying a levels in biology maths chemistry and being cool. I feel I bring a sense of humour to the group and have had plenty of fun creating the team name. Transformer Roblotts in disguise.

Muhmammad Malik *Energy*

I'm Muhammad and I study Chemistry, Physics and Mathematics at Portsmouth college. My personal aspirations for the future is to study Engineering at a Russel group university. I would strongly recommend all students to consider getting involved in extra curricular activities like this one. The challenge emphasizes the importance of research within the STEM subject. The Blott Matthews has enabled me to develop my academic and social skills by challenging my independent skills.

Owen Stark *Transport*

I'm a first year student; currently studying Biology, Chemistry, and Maths (pure). I think this project has helped me develop a keen aptitude for design and team working. I one day hope to pursue a career in medicine, post-college.

Harry Aylward *Energy*

I am in my first year of college, studying physics, chemistry and maths (pure). In the future I would like to go into mechanical engineering because I like the idea of creating something that contributes to the world around us. Over the course of the Blott Matthews challenge I have improved upon my team working skills and problem solving abilities.

The Brief

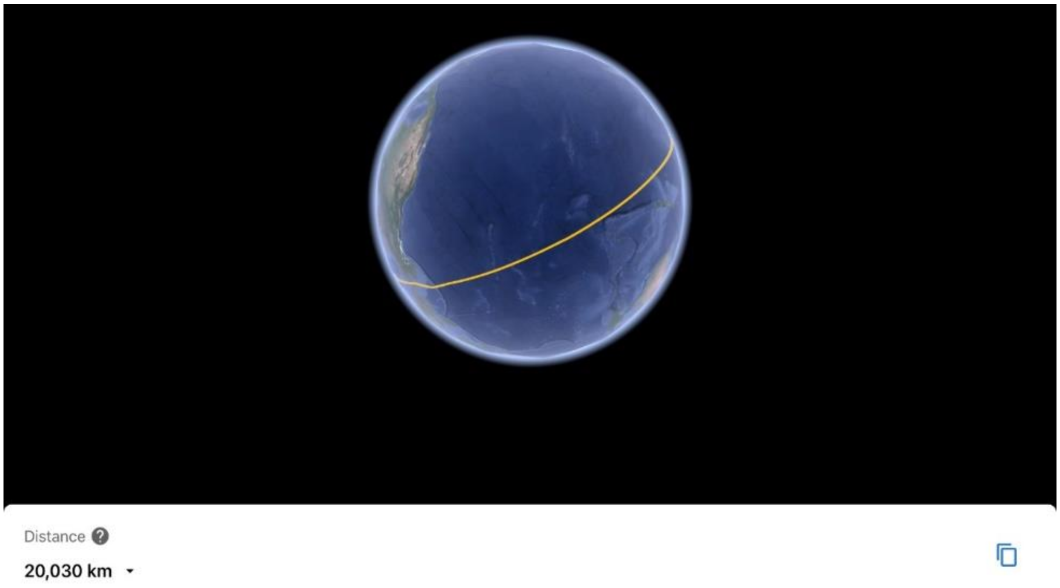
Travel from Pole to Pole

We have been tasked with transporting a 1 ton load from the geographic North Pole to the South Pole. This presented a variety of challenges, including finding the shortest passable route that our craft was able to achieve, then finding the appropriate vehicle to make the final section of the journey over Antarctica, alongside the pressing issue of ensuring the suitability of the vehicle in transporting such a heavy load. We had to consider a wide variety of variables and scenarios

The Route

Our route is 20,030 km (12,450 miles) long. The submarine will depart from the Geographic North Pole (90 degrees north) and cross the Arctic Ocean, followed by the Pacific Ocean after passing through the Bering Strait between Russia and the USA. Upon reaching the coast of Antarctica, the vessel will make landfall approximately 1,700 km from the Geographic South Pole, where our land based vessel (a Ford EcoLine) will make the final part of the voyage. We have selected this route because it is significantly more direct when compared to heading north first, then crossing the Atlantic. We have also decided on this route because it is predominantly open sea – meaning our main method of transport – the submarine, will be able to travel more quickly, meaning our voyage

Figure 1: The route our vessel will take across the Pacific: (Credit: Google Earth)



Transport

Introduction

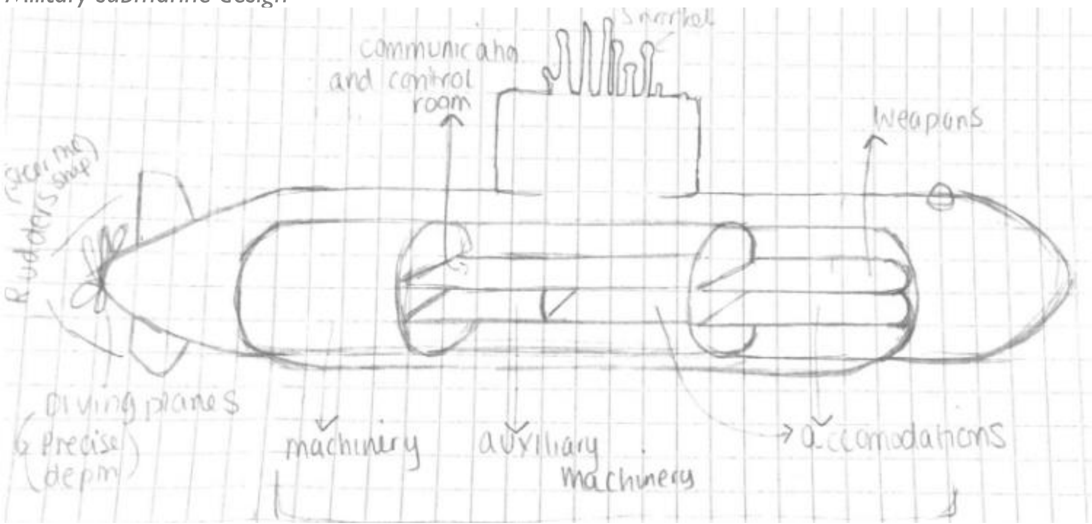
The transportation of this journey is a fundamental part of the project as it will entail the system, we will use to take the one-ton load from the geographical North Pole to the geographical South Pole.
We have decided to use a submarine to complete that sea portion of the journey. The circumference of the earth is approximately 40,000km however when we consider the route we are taking and the fact we will not be travelling in a straight line the journey will most probably last 25,000-30,000km. Through the calculations (appendix A) we know that the journey will take us approximately 12-16 days and so, with thinking about stops to solve errors that may or may not occur, we have allocated the total journey a time of a month.
We considered using a ship for the transport however we decided against this due to the fact we would have to fact in trade routes and existing ship passages. Also, using a submarine would make the journey more effective and efficient (A13). The average cargo ship can travel around 18-20 knots whereas a submarine can travel up to around 25 knots on average. Although this is not a drastic difference, there are many other advantages of using a submarine that will be explained further in this chapter.
If we are using a submarine, we will need to carefully consider how to get across the land aspect of the route; as we need to start at the geographical North Pole and end at the geographic South Pole. This means we will require the use of tracks on the submarine to power the vehicle to the water. The tracks have been analysed to be a better choice over wheels and will be brought up after diving has begun. Our original idea for land transport at the South Pole, to complete the journey, was an Earth Rover. After research we found that this mode of transport would take weeks to complete and would require extra design and testing whereas current research facilities in Antarctica already use transport such as the Ford e-series van; that we know will be reliable as it is the latest useful transport used in the conditions that it will be undergoing. The designs we have looked at will only require a specific adjustment and that is the wheels. The van we are using for the snow will need much larger tyres.
It was important that we carefully analyse each part of the project individually and have considered alternatives to many of the components of transportation and have reached a design that we believe will be the optimum solution to submarine cargo transportation.

Submarine or boat?

As we have chosen a route that uses mainly water our two options for transportation are a submarine or a boat. While a submarine is more expensive is has many more advantages such as being able to avoid storms that could cause serious damage and easily avoiding shipping routes which would add time to our journey. There are also some disadvantages to using a submarine, from being underwater for so long the outer layer is likely to be damaged so we may have to add a secondary layer to the outside to ensure that it will survive the journey. We will also be less likely to use renewable energy, which will cause a small amount of damage to the environment. However even with these disadvantages we have chosen to use a submarine as it is less likely to get so damaged that we cannot continue the journey.

Design

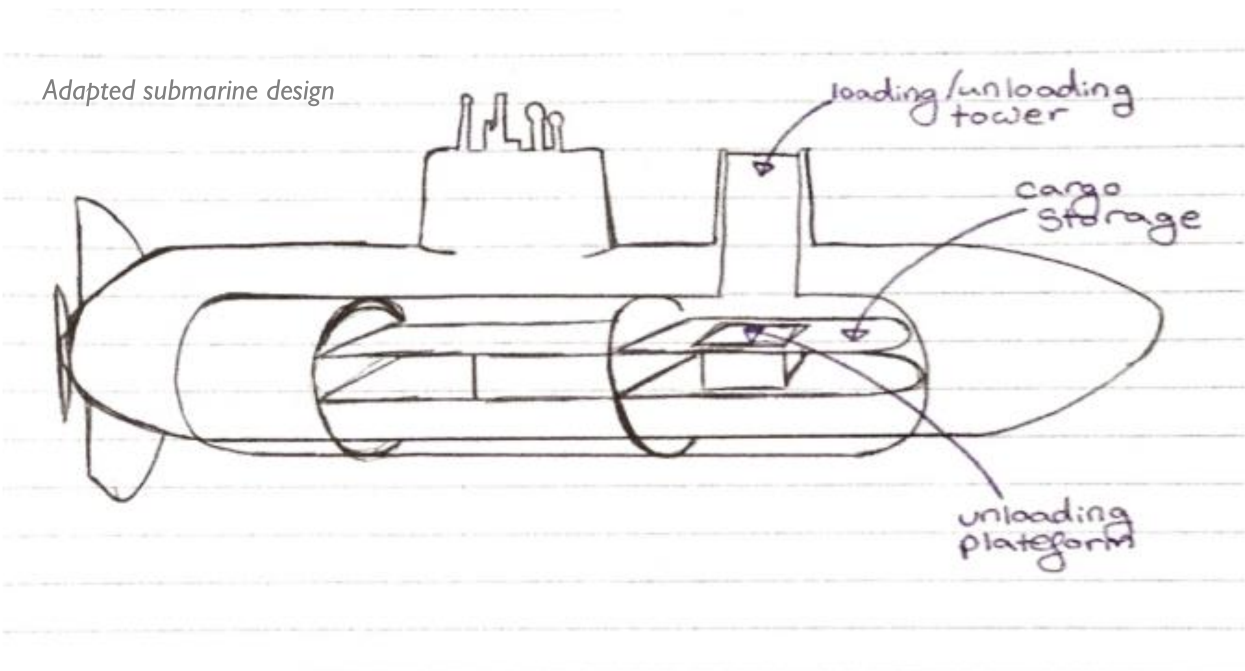
Military submarine design



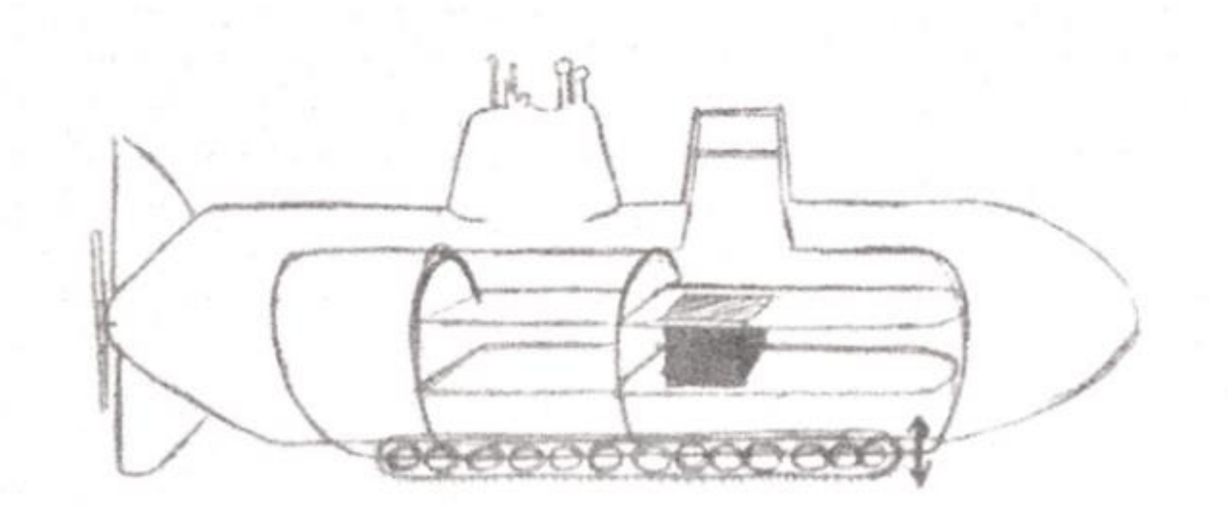
Many designs we have found for submarines are for military use, many of our designs are based off these and so the layout is relatively the same, however, the applications of the rooms are different. Where the weapons are stored is where the cargo is, also as we will need to easily get the van, and the 1 tonne load, off of the submarine when arriving at the South Pole there will be a loading and unloading tower that pushes objects up until it is level with land. This will enable unloading with minimal effort from the crew. For more on these adjustments see our modification designs below.

The drawings attached are our teams' sketches of technical submarine drawings; these are the basis of our own submarine sketches (shown below):

Adapted submarine design



Adapted submarine design - showing tracks



Features of a submarine and how they work (A15)

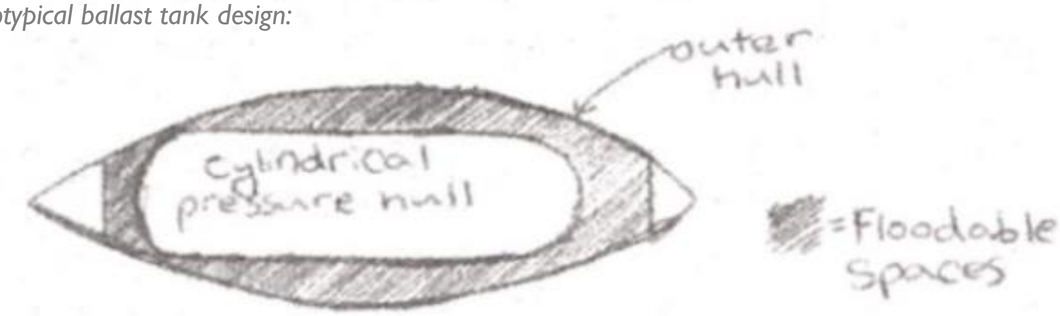
With submarine designs it has two hulls, an outer hull and a pressurised hull. The pressurised hull is the cylindrical inside that holds the accommodation, machinery, cargo and control room. This is the part of the vessel that the crew can access and move about. The outer hull houses the pressurised hull and is not pressure tight. This is because when in submerged conditions the space between the outer hull and pressurised hull is filled with water; this is covered more when we discuss ballast tanks.

The bridge fin is essential for any submarine design as it has a special shape that reduces drag and provides vertical stability underwater to the vessel (A14). The submarine we are designing is unique from others as it will have two bridge fins; one for normal use and the second for unloading the one tonne load of cargo along with the land vehicle. These bridge fins also use hydroplanes that are mounted either side of them.

Hydroplanes are generally mounted on the bridge fin and in front of the propellers. These hydroplanes are an essential part of the stability of a submarine (A16). They help to maintain a balance under completely submerged conditions and operate best under high speed conditions.

Ballast tanks are important for submerging and surfacing in submarines as a key principle in the diving of a submarine is Archimedes principle (A17). This states that the upward buoyancy force is equal to the weight of the displaced fluid. When a submarine is surfaced its weight is less that the water weight displaced therefore there is a greater upward buoyancy force that downwards buoyancy force. To dive down to a depth the vessel needs to take in water; in order to increase its weight. This water is taken in in the ballast tanks. Which are evenly dispersed around the submarine. These 'floodable spaces' are often located between the pressurised hull and the outer hull. The ballast tanks weight will also be monitored by the AI system and all the crew will need to do is decide on an appropriate depth to dive to. Below is a diagram we have pieced together for a stereotypical ballast tank:

Stereotypical ballast tank design:

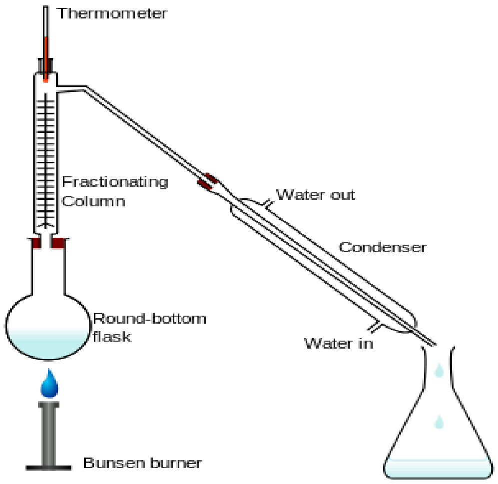


This is only a rough sketch and more accurate depictions of ballast tanks can be found in the appendix. However, submarines cannot dive with ballast tanks alone as they need to reach neutral buoyancy. When a submarine is surfaced it is in positive buoyancy as it's upwards force is greater than the downwards force. When diving it is in negative buoyancy due to the fact that they are moving downwards. However, to reach neutral buoyancy the upwards force needs to equal its downwards force. To be in neutral a submarine has to use the hydroplanes we mentioned earlier. These are movable (controlled in the control room) and these are angled to determine the angle of the dive. This is important because it means the submarine can dive at a safe argument to sea level. In appendix A you can find the angle calculations for the dives and surfacing.

To surface compressed air is forced into the ballast tanks and therefore water is forced out of them. To control the ascent, water is forced over the hydroplanes and this pushes the stern down; angling the whole submarine upward.

The design of our submarine uses both case studies and unique features for a cargo vessel. Merchant submarines are traditionally used in blockade runs, however, they are also used for dives under arctic ice (A1). This would be incredibly useful for us as we will be travelling through icy waters. Due to the structure of glaciers and icebergs, two thirds submerged under water, we will need to use a sonar system [see transport appendix for research] in order to locate the safe routes. An AI operated system (A2) will work alongside the sonar system and will automatically avoid the problem by calculating the most appropriate course to take; going around or diving to a lower depth. This will eliminate human error as it will operate around the clock to keep crew members and the cargo safe. In case of a flaw in this AI system, the submarine will also include a damage assessment device that will locate and assess the severity of damages to the submarine. This is important because it will help the crew to prioritize what needs doing and inform them of what needs solved by certain times. This will affect the cost of the submarine as we will need to both design the system and hire an AI specialist, however, it will be worth it for the purpose of efficiency.

Fractional distillation (A21)

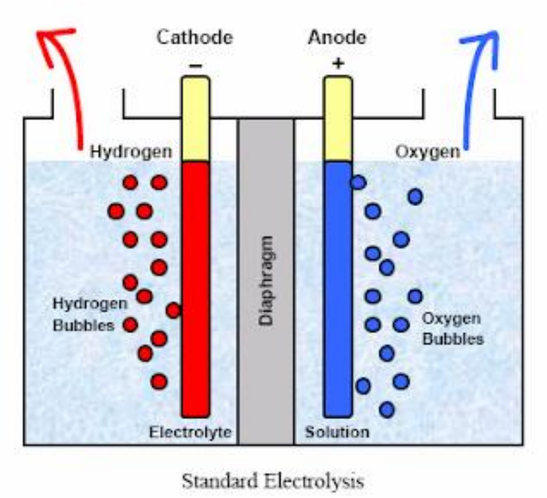


Other systems the submarine will need to use will mostly be run through the AI system but will still need to function on their own. The optimum temperature on board the submarine needs to be 18 Degrees Celsius for an appropriately dressed crew member. To avoid issues to people with allergies and people who fall ill the temperature should only range between 18 and 21 degrees Celsius (A3).To maintain this we are going to use both heaters and coolers stationed at regular points on the submarine. This will be monitored by the AI device and inform crew when the temperature is too high or too low. Thermistors in the system will either

increase or decrease their resistance to maintain a temperature of around the suggested (A4).
The air in which the crew is living needs to be monitored as well for two very important things;

- Oxygen levels
- Carbon dioxide levels

There are many gases that need to be monitored and censored on board to avoid problems occurring.



Electrolysis of water to gain oxygen (A22)

Oxygen is, of course, one of the most fundamental components for life to survive. A submarine experiences a dive can have varied fluctuations in oxygen levels and there for the volume of oxygen needs to be monitored and kept at a constant 21% (A5). This can be done via electrolysis of salt water. This is a simple system but we also need to consider when oxygen levels get too high; which could be dangerous. Therefore the system will only work when the AI system monitors an oxygen level of around 20% and get it back up to 21%, optimum for human life. Carbon dioxide is produced by humans and burners; however the carbon dioxide in the air must stay at around 0.5% to be safe. It is monitored by chemical scrubbers, which use soda lime which trap carbon dioxide.

This is a feature not required to be monitored by the AI as it will need to be in use for the whole journey, however, the chemical scrubbers will need to be monitored in case there is a fault with the system (A6).
Due to the fact we are using a crew for some uses on board, an essential part of human life is drinkable water. This isn't something easily accessible on a submarine vessel however submarines can use a water filtration system which converts the saltwater in the surrounding ocean to water for everyday use. Vessels like this use a distillation process (A7); this is when saltwater can be heated till the water's boiling point, which will condensate separately to the salts. The average submarine can produce up to 40,000 gallons of water a day. For more requirements on this see the AI vs Humans chapter.

Van or Rover

Our first thought for transporting the load off the submarine and on to the ice was using a rover. We researched the mars rover because there will be limited energy availability, on the mission, so our transport has to be efficient and sustainable. A rover would also be easily customizable to the specific needs of our journey. We would be able to use lightweight materials and adapt the wheels for maximum traction on the ice. The rover we need will not need all of the features on a planetary rover so it will be more cost effective. The Mars Rover costs £1.935 billion (A8) including the launch equipment without these features the rover would cost approximately £774 million. The advantages of using a rover is that they are sturdy, can be remotely operated so we would not need to hire a driver that would be necessary for any other form of transport. Rovers are also able to travel over many types of terrain which is important as conditions of the poles change constantly. However there are couple of disadvantages. Such as the Curiosity rover moves at a maximum speed of 0.14km/h (A9). If a crew member was required to control/oversee the operation, this would mean significantly increased outlay than we originally planned, and as a result we are looking into using faster equipment. The cost of the rover itself is also a significant outlay, especially when we consider that there is equipment that is better value for money. Whilst looking into alternative options for transporting the load onto the ice we found the Ford e-series van, which we learnt had been used before on expeditions to the poles. This option is considerably less expensive than using a rover, and also be able to carry the load also faster as we would travel at an average speed 25mph. Although we would need to make extensive modifications to the suspension & the wheels and add a form of security mechanism (such as heavy duty straps) in order to increase the suitability of the vehicle, we believe that the cost to the project would be significantly lower than using the rover. The only disadvantage is that the van will require a driver, but we can bring the crew members who travelled on the submarine. In addition, we could draw from their experience if something was to go wrong. After considering all these options we have decided

A ford e-series E-450 dual rear wheel cutaway (A23) to use the ford e-series van to transport our load on to the ice as it is more cost effective and can move faster so this will cut down on the time it takes to unload the box.

The type of van we use is essential and we have opted for a ford e-series E-450 dual rear wheel cutaway. This is because it has plenty of space for the cargo load on the back and is strong enough to carry ten times the mass of the 1 ton load (A10). This class of vehicle is already used at various research facilities across Antarctica and was capable of crossing the entirety of the mass South Pole in 24 days (A11). Due to this data we can be sure of its reliability under the conditions of the South Pole. It is capable of carrying a load of 22000 lbs. (=9970.9kg). A key thing that you must consider when operating heavy loads in a vehicle, such as the ford e-series cutaway, is torque; the engines rotational force. The engine with enough torque required is the 6.8L Triton V10.

AI vs Human

Would humans be more suitable?

Although the potential of robots/AI is extremely high, the suitability of humans must be considered. Although the cost of employing a form of human crew will be higher, especially if the journey does end up being close to a year. However, the initial cost could be returned, as the problem solving ability of a highly trained engineer could solve problems that arise with the craft, where the AI may be unable to.

Crew Requirements

We realized that by law, maritime craft requires at least one crew member (even if the vessel is autonomous) to be present onboard and to take control in the event of something untoward happening. As a result, we require 2 crew as a minimum. We need someone with submarine experience to take command of the vessel when underway, and someone with engineering and mechanical knowledge to ensure the craft can continue. To keep costs down, it may be better to pay someone extremely qualified (as no outlay will be required when ensuring they meet the desired standards) - despite the higher salary that will inevitably have to be paid. The minimum cost for a Navy Captain (who is qualified to command a submarine) is £88,000. The average salary for a qualified engineer is £40,000, but we may need to employ a more qualified naval engineer (£60,000 – 80,000.) However, this initial higher offset will be displaced as the crew will be more equipped to deal with any situation that would arise.

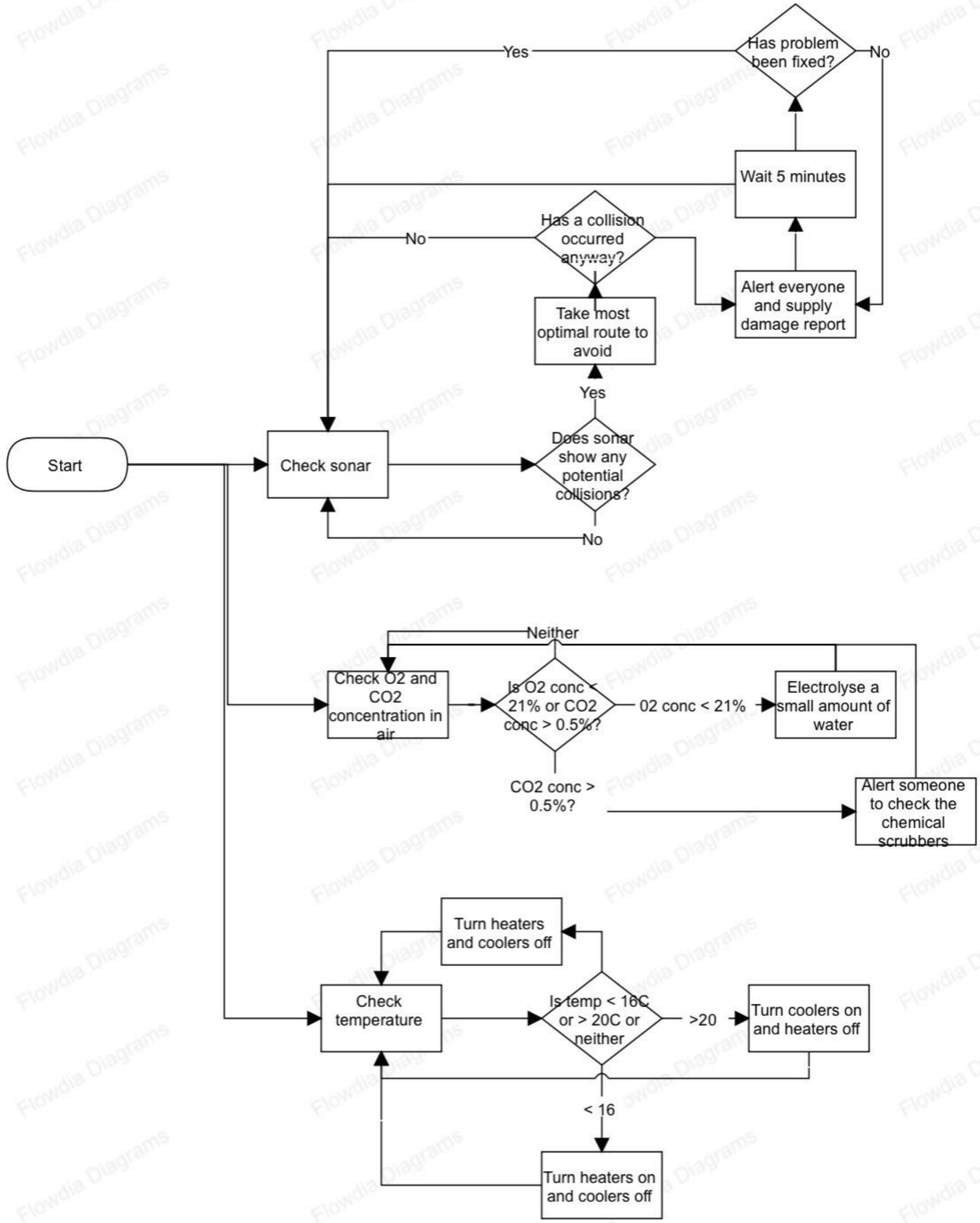
Conditions for the crew: Hazards

We aim for crew conditions to easily surpass working conditions as set out by most international governments - this is a key priority as the route will not always be in the, and despite being in international waters for most of the journey we must ensure that crew needs are met. There is the potential for illness to occur, which could prove problematic if a crew member does catch something contagious. Norovirus could have massive implications for our crew, as news reports of larger cruise ships (that do carry significantly more people) having major quarantine issues involving the virus. Cruise ships also have more advanced medical facilities with trained professionals, who can deal with a problem more effectively. The size constraints of our submarine mean we can't afford to have such sophisticated facilities and as a result illness could halt the journey entirely. It would be our responsibility to ensure that we hire crew members who are in peak health to reduce the risk of illness having an adverse effect on the voyage. In addition, the likelihood of issues with food are low as a result of long life food (similar to what is already used in exploration industries such as astronauts) which would be sealed in a vacuum environment until it is required. In contrast to naval submarines (which can afford more cooked meals (B1),) the inability to stop for any extra provisions on the way means we have to use this type of food. Illness caused as a result of the submarine's design is extremely rare, with the most prolific case occurring in the 1950s as a result of asbestos poisoning, although a scenario like this is unlikely now as all materials used in any form of building are thoroughly tested to ensure they meet international regulations. We will have to ensure more stringent tests are carried out as a result of the brief - as we are unable to stop on the way, the submarine's design must be a minute risk to the crew. Where possible, we'd aim to eradicate such a risk completely.

The most risk that faces the crew is the nuclear reactor we are using for the submarine. As mentioned above, this is because a nuclear reactor has the potential to fail, which would release toxic radiation, and the effects would be quickly felt as the size of the submarine would allow the radiation to circulate the cabin quickly. However, we feel this is unlikely, as there have been no major incidents of nuclear meltdown in submarines whilst on voyage. Another scenario of failure is where the method of propulsion fails and the craft could sink - in a similar scenario to the USS Thresher in 1963 (B5), however, we are confident that this will not happen; the technology has advanced significantly, and the most recent submarine accident with fatalities was the sinking of the ARG San Juan, which was incidentally a diesel-electric submarine.

The need for AI

Despite our provision for highly trained crew, the assistance of AI will prove invaluable for our journey, allowing our submarine to be more self-contained and reduce a reliance on the crew, as they will be able to focus on other areas of the craft and the voyage. We have created a flow chart.



Has problem been fixed?
Yes
No
Wait 5 minutes
Has a collision occurred anyway?
No
Alert everyone and supply damage report
Take most optimal route to avoid
Yes
Start
Check sonar
Does sonar show any potential collisions?
No
Neither
Check O2 and CO2 concentration in air
Is O2 conc < 21% or CO2 conc > 0.5%?
02 conc < 21%
Electrolyse a small amount of water
CO2 conc > 0.5%?
Alert someone to check the chemical scrubbers
Turn heaters and coolers off
Check temperature
Is temp < 16C or > 20C or neither
>20
Turn coolers on and heaters off
< 16
Turn heaters on and coolers off

Energy

Nuclear in a submarine

Nuclear power is particularly appropriate for being in the sea for an extremely long period without refueling. The Virginia Class Submarine has an unlimited range in theory, however this is limited by food & supplies. In our scenario, however Although nuclear power is not renewable, it provides us energy that can last for decades and a benefit is it has no harmful effect on our atmosphere, being more efficient than burning fossil fuels as the amount of energy released is approximately 8,000 times more. Having nuclear power will be very effective and significantly more environmentally friendly as it has minimal greenhouse gas emissions, as nuclear power plants do not burn fuel being the most appealing benefit of nuclear power. There are other methods of energy generation for the use in submarines however nuclear power suits our needs and is more plausible offering a number of benefits, regarding efficiency. An average capacity factor of 91 percent, beats other energy forms by a substantial margin.

Pressurized Reactors/Electric motors

Our initial idea for energy consisted of using multiple energy sources which can be used for different purposes in the submarine.
Pressurized reactors will be used along with steam turbines, which will turn to generate electrical energy that provides the forward and backwards thrust for the submarine.

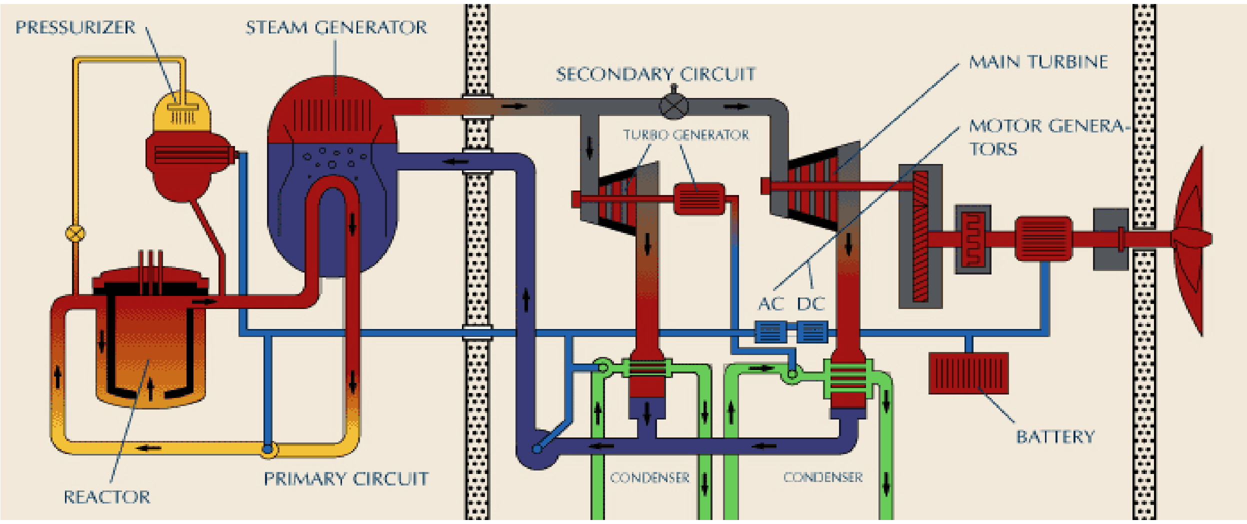


Diagram of a naval pressurized reactor ()

Basic operation of pressurized reactors

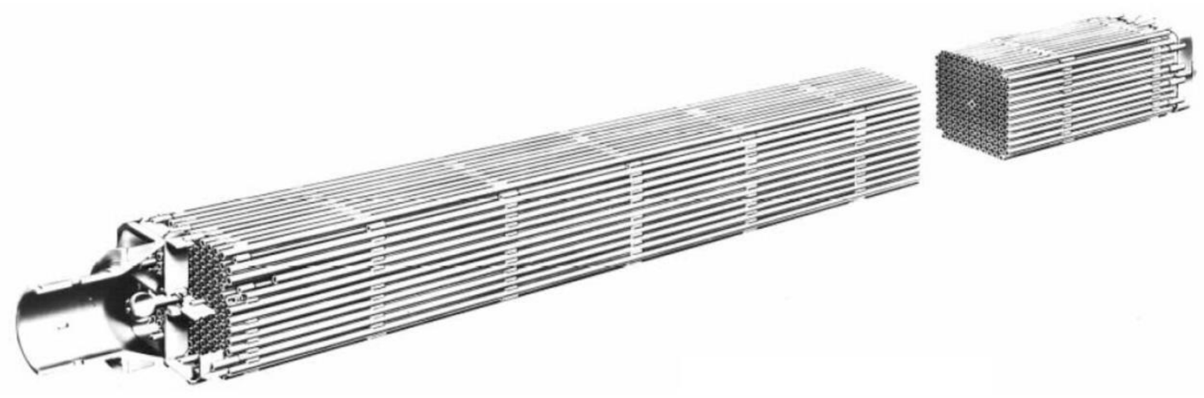
The nuclear reactor as seen in the Figure above will generate heat or the steam generator in our primary circuit. The nuclear reactors undergo Nuclear Fission which involves the breaking of atoms that allows lots of energy to be released in the reactor. As uranium fissions, more energy is released in the form of heat that turns the hot water to steam. As the water goes through the steam generator it turns to steam by losing its heat. This steam flows through the secondary circuit to the propulsion system where the steam drives the turbine to generate power for the submarine. As the water is cooled, it condenses and turns to water and it is pumped back to the primary water circuit. The reason for using a pressurizer is to keep the water from boiling.

The main job of the primary circuit is used to circulate water in a closed loop to maximize the yield of the successful energy produced. This is achieved by a two way system which consists of the steam to be condensed so it can be reused as water. The primary circuit operates in optimum conditions at a temperature of about 260 °C and a set pressure.

In the secondary circuit, the steam rotates the propellers of the turbine which is connected to an electrical generator and the electric power is used by one of the main propellers of the submarine. The secondary circuit is involved in the propulsion of the submarine by the use of electric motors and the steam that turns the turbine. The generated steam also provides electricity for their auxiliary system within the submarine as well as the energy needed for the propulsion systems.

Difference between 235U and 238U

A more enriched fuel element will contain a high concentration of 235U than 238U therefore it increases the probability of a Fission reaction. A higher enriched fuel is more sustainable because it has a larger power density and therefore it will produce energy at a more reliable rate. The enrichment of 235U varies from 20% to 96% in modern fuel elements.
A typical marine reactor produces energy up to 100 MW which can be produced at a high efficiency.



Above: A common nuclear fuel element ()

Reprocessing of Uranium

The used fuel of Uranium will still contain about 96% of its original content of which the 235U content will have been reduced to under 1%. Reprocessing involves the separation of Uranium and Plutonium from the waste products by dissolving pieces of the fuel rods and dissolving them in acid. This enables recycling of Uranium to reduce the amount of waste the element significantly. The remaining 3% of high-level radioactive wastes can be stored in liquid form and subsequently solidified. This can be 75 kg of useful product per year from a 100 MW reactor.

Furthermore, the uranium recovered from reprocessing, which typically contains a slightly higher concentration of U-235 than U-238, can be reused as fuel after conversion and enrichment. This will improve the overall efficiency of using Uranium as our main fuel element. In conclusion, due to our 10,000 km trip, the reprocessing of fuel will be significant if all of the Uranium is used. (C1)

Electric motors

Electric motors work on the fundamentals of Alternating Current (AC) or Direct Current (DC). A simple electric motor will consist of the following:

- Armature
- Split ring Commutator
- Brushes
- Axle
- Field magnet
- DC power supply

A motor makes use of electromagnets and permanent magnets (North and South Pole) to create rotation. Inside an electric motor, the armature will be the electromagnet while the magnetic field will be permanent, these attracting and repelling forces create rotational motion.

The use of three poles in the motor instead of two poles can enhance the performance of the motor. For example, in a two poles motor, it is likely for the motor to get stuck while rotating if the electromagnet is horizontally balanced between the North and South Pole.

Furthermore, another advantage of using a three pole motor is its higher efficiency of energy conservation. In a two pole motor, when the commutator gets to the point where it flips, there is a temporary attraction which connects the positive and negative terminal. This results to the drainage of battery and a waste of energy. However, a three pole motor can be an alternative substitute due to its performance.

Diesel-electric propulsion

A diesel engine has air which is more compressed allowing the engine to get greater efficiency from the fuel because of its higher compression ratio within the cylinder to heat the air inside. This means that the diesel engine is around 20% more efficient than an equivalent petrol engine.it has a lower fuel consumption and emissions due to the possibility to optimize its loading of diesel engines. The engines in operation can work effectively on high loads with high engine efficiency.

Also diesel-electric propulsion has a high reliability due to its multiple engine redundancy, meaning if an engine malfunctions there will be sufficient power to operate the vessel-reducing the vulnerability of failure.

In addition, because of its efficient performance and high motor torque, it has an advantage in icy conditions as the electrical system can provide maximum torque at even slow speeds.

As well as having a slow speed e motor which allows it to avoid the gearbox and propulsion like pods that keep the structure noise giving diesel engine reduced vibration and low propulsion noise ,diesel engines have a reduced life cycle cost, resulting in lower maintenance and operational costs.

Likelihood of failure

Nuclear submarines don’t use diesel generators as conventionally as propelled vessels to the same extent. There is a requirement on the diesel generator to remain idle for a considerable length of time as well as being immediately available when required with a high reliability factor.

There could also be a nuclear meltdown, but diesel generators do run the risk of implosion, as seen in the sinking of the ARG San Juan in 2017.

Appendix A: Transport

Submarine or Boat?

As we have chosen a route that uses mainly water our two options for transportation are a submarine or a boat. While a submarine is more expensive is has many more advantages such as being able to avoid storms that could cause serious damage and easily avoiding shipping routes which would add time to our journey. There are also some disadvantages to using a submarine, from being underwater for so long the outer layer is likely to be damaged so we may have to add a secondary layer to the outside to ensure that it will survive the journey. We will also be less likely to use renewable energy, which will cause a small amount of damage to the environment. However even with these disadvantages we have chosen to use a submarine as it is less likely to get so damaged that we cannot continue the journey.

Climate and Storms

Violent storms can be felt up to 400ft deep, but the average submarine can reach depths around/deeper than 800ft, which for the most part completely eliminates the worry that the submarine may be destroyed before the journey is complete. Mega storms such as hurricanes can be felt further than 400ft and often roll a submarine by 5 degrees, which would be unpleasant but tolerable experience for the crew and would not damage the submarine.

Materials

The common materials for many modern-day vehicles are different Metal polymers and various alloys (e.g. high strength alloyed steel). Due to the fact our team is aiming to do our project using a submarine, I have looked into how these are made in various ways. The high strength alloyed steel that I mentioned earlier, is the most common material used in submarines. This alloy can go up to a limit of 250-300 meters. We believe this will be a good depth to reach as the route we are taking may be prone to storms and so our submarine would need to be kept safe.

Rovers

We have also investigated the use of Rovers to get the One-ton load across land and so we researched the mars rover. We did this because it was a mission that required limited energy availability and had to be a sustainable and efficient mode of transport. A rover would be beneficial for us as it can be built for our desired needs, which means we can make it adaptable for the cold weather and the pressure under sea, which is more effective as it would not need many of the features of planetary rovers used by NASA, and we could use materials best for the ice and securing the load.

Tracks or Wheels

To get our craft from the center of the pole to the water we need to use either tracks or wheels. There are several key factors that will influence our decision including; traction, ground pressure, suspension and steering. While tracks exert less ground pressure it is more complicated to build the suspension then it is for wheels. Wheels also provide easier steering and are more lightweight. However tracks can move over obstacles and on ice with a lot more ease than wheels. The main issue with using tracks is that rubber tracks tend to have a shorter running time than wheels, so we will need to use a more hardy material that we can use. Overall, we have chosen tracks to use on the craft as they have more traction on ice and snow and exert less ground pressure PSI than wheels.

Uses of Electromagnets

The main use of electromagnets in modern day transportation is for maglev (magnetic levitation). These are often used in trains and we are unsure how this would work but the main way the operate is using repelling magnets to levitate an object. A benefit of this is that there is a reduced frictional force; therefore, there would be less energy transferred to the thermal energy store.

Water Purification

Submarines do not carry all the water needed from the start of the journey, they use a thermal distillation method that can produce 10,000- 30,000 gallons a day. Tubing coiled into cones acts as a heat exchanger, sea water is pumped into the bottom and heated outside of the tubing then compressed. After this the vapor travels down inside of the tubing being cooled along the way and flows into a storage tank. The weekly need for water on our submarine is approximately 3,000 gallons or less including showers 4 times a week and water to cool down any reactors if necessary.

Density and volume

For a submarine to stay level it must have a weight equal to the upthrust force to prevent an acceleration upwards or downwards. Due to case study research the dimensions of nuclear size submarine are; length-175m, beam-23m, and draught-12m. From this data we can approximate the volume of the submarine to be 727708.23498m^3.

According the research the same 175x23x12m submarine has a mass of 43544868kg and therefore a weight of 427175155.1N.

Water has a density of 997kg/m∃ and using the equation;

Mass= 997 x 727708.23498

=14115948.03kg

=138477450.1N of water is displaced.

Therefore, accounting for the weight of the submarine, it would need to take in an appropriate amount of water weight to make the downwards acting force (weight) equal to the upwards upthrust force (weight of water displaced.

427175155.1N – 138477450.1N = 288697704.9N

= 29428919.97kg of water intake.

29428919.97kg ÷ 997 kg/m∃ = 29517.47239m∃ of water intake.

Therefore, there needs to be approximately 29517.47239m∃ of space in the ballast tanks which leaves the submarine with 43190.76259m∃. To control the ballast tanks [see transportation for more information] we would use an AI system [see AI vs Humans for more information].

Speed and Time

The Russian Typhoon submarine could travel up to 22.22knots, around 41.15km/hr, and this is the submarine we did our case study for the dimensions and weight from. We know that the circumference of the earth is 40Mm and, therefore, the distance that we need to travel is 20Mm. Around 89% of this journey will be done by submarine and the rest will be done via an earth rover. Using basic equations like

41.15 (km/hr) =17800 (km) ÷ time (hrs)

Time (hrs) = 17800(km) ÷ 41.15 (km/hr)

Time (hrs) = 432.5637911hrs

=18days at sea, round up to approximately 20 days.

The average earth rover is extremely slow, 0.1mph, and so we have decided on a popular choice of transport across Antarctica; Ford E-Series Vans [see the transportation chapter]. According to [https://jalopnik.com/5379341/the-land-vehicles-of-antarctica/] the vehicle can go from the coast of the south pole to the geographical south pole in 69hours. This would bring an approximate travel time to a month.

Power

According to case research done in the energy chapter, a uranium powered nuclear generator can produce approximately 1650MW of power. Using the equation, we can work out the energy transferred to be 1.6x10^15J.

Loading calculations

The van we are using will carry the load on the back part of the van and therefore the mass of the entire body is increased. The average van will have a mass of about 15,000-16,000kg. Including the ton load and people it will come to approximately 17,000kg. Using W=mg we can work out the force required to push the van up the second bridge fin (= 166770N). this force is negligible compared to the driving force from the motors; therefore, there will be no issues with unloading.

Appendix B: Energy

Electric motors

Electric motors work on the fundamentals of Alternating Current (AC) or Direct Current (DC). A simple electric motor will consist of the following:

- Armature
- Split ring Commutator
- Brushes
- Axle
- Field magnet
- DC power supply

A motor makes use of electromagnets and permanent magnets (North and South Pole) to create rotation. Inside an electric motor, the armature will be the electromagnet while the magnetic field will be permanent, these attracting and repelling forces create rotational motion.

The use of three poles in the motor instead of two poles can enhance the performance of the motor. For example, in a two poles motor, it is likely for the motor to get stuck while rotating if the electromagnet is horizontally balanced between the North and South Pole.

Furthermore, another advantage of using a three pole motor is its higher efficiency of energy conservation. In a two pole motor, when the commutator gets to the point where it flips, there is a temporary attraction which connects the positive and negative terminal. This results to the drainage of battery and a waste of energy. However, a three pole motor can be an alternative substitute due to its performance.

Diesel-electric propulsion

A diesel engine has air which is more compressed allowing the engine to get greater efficiency from the fuel because of its higher compression ratio within the cylinder to heat the air inside. This means that the diesel engine is around 20% more efficient than an equivalent petrol engine.it has a lower fuel consumption and emissions due to the possibility to optimize its loading of diesel engines. The engines in operation can work effectively on high loads with high engine efficiency.
Also diesel-electric propulsion has a high reliability due to its multiple engine redundancy, meaning if an engine malfunctions there will be sufficient power to operate the vessel-reducing

the vulnerability of failure.
In addition, because of its efficient performance and high motor torque, it has an advantage in icy conditions as the electrical system can provide maximum torque at even slow speeds.
As well as having a slow speed e motor which allows it to avoid the gearbox and propulsion like pods that keep the structure noise giving diesel engine reduced vibration and low propulsion noise ,diesel engines have a reduced life cycle cost, resulting in lower maintenance and operational costs.

Appendix C: Costs

AI vs Human:

The salary for a submarine captain varies, as we want a more experienced captain we would be willing to pay the higher fees. For a submarine captain of upward of 20 years' experience, it would take £7306.20 a month. The journey will take approximately 18 days at sea, and filtering in any problems faced this could take up to a month, so the salary would be £7306.20.

As well as a captain there'll need to be a naval engineer. The salary of a naval engineer is £38,997, so that equivalates to £3249.75 for the journey. We think due to sleep scheduling, that it would be appropriate to have 3 marine engineers, so the total would be £9749.25 for the journey.

Among the crew we would need an AI specialist to ensure that it is actually working,. The AI specialist actually has the highest salary, being around £131010 a year, so that would be £10917.50 for the journey.

The last of the crew members would be the nuclear specialist. Considering that we are using nuclear energy to power the submarine this is essential. The average annual income of a Nuclear Power Reactor Operator is £62,184.00, meaning that for the journey they would cost £5182.00.

The total wages for the crew would cost: £7306.20 + £9749.25 + £10917.50 + £5182.00 = £33,154.95

<u>Cost analysis for Transport</u>

The submarine	This is the main mode of transport and will be the bulk of our expenses	Virginia class submarine	£1.6 billion	A18
Modifications	because our submarine will need tracks and specific parts for the journey it will require modifications	tracks, cargo area (in second tower) and implanting AI	£1.5million	
Land vehicle	when we get to the South Pole we will need a vehicle to go the remainder of the journey	Ford E-Series E-450 Van	£20,000	A19

Land modifications	the van we will use will need specific tires for the cold weather	NOKIAN HAKKAPELIITTA 44	£1,000	A20

These are only approximate values as there are certain things we cannot predict with accuracy; for example, there are no submarines in use with tracks. A way of reducing a cost was buying an existing Virginia class submarine instead of building one, which would've come to around £75 billion. However, by doing this we will need to increase modification costs as it will be more challenging to implant things like the tracks in this. Therefore, we have concluded as a team that the tracks will be attached below the submarine and once submerged can be deployed in the ocean.

Motor & Propulsion Costs

Rolls Royce PWR3 Nuclear Turbine: (C4)
£3,000,000,000 for entire contract to the Ministry of Defence with 4 submarines being built.

£3,000,000,000/4 = £750,000,000 for the motor.

Turbine and Pump Jet Propulsion: (C5)

Approximately £125,000,000

It is worth noting that these figures are only estimates, and based on the cost analysis for the transport team (see above), these costs may be mitigated depending on the condition of the submarine we would purchase. If the motors and generators were in good condition then it would not be a necessity to purchase such equipment, which would case

Appendix D: AI vs Human

Why use highly qualified staff over graduates?

As stated above, we have elected to use highly qualified staff as crew members. We have reached this decision, despite increased outlay over a significantly higher pay range, we believe more qualified staff will be better equipped to deal with any serious problems that arrive in conjunction with the AI. Although graduates may be similarly equipped to deal with such problems, there is a higher potential for mistakes to be made that could lead to the end of our voyage prematurely.

Do we need the AI at all?

Something we had to consider throughout the project was whether AI was actually required at all. We believe it is necessary to have AI in order to assist and be of a tangible benefit to the crew.

It has been concluded that 61% of human errors are skill based. (C6) This furthers our point above that having highly skilled crew will be beneficial as they will have a broader knowledge of how to solve problems; if they were to arise. The AI, however, would be able to assist in solving any problem if it were to occur, and potentially be able to avert a problem that could have been instigated by human error.

Final Summary

In conclusion, to transport our 1 ton load within 20 days using the geographic North Pole to South Pole route which is 20,030 km as this is the shortest and most easiest considering the weather conditions; we have decided to transport this load by a merchant submarine made up of high strength alloyed steel being the most suitable and effective transport ,this will include having tracks making it stronger and therefore less likely to get damaged in storms and withhold icy conditions to power the vehicle to the water safely. To ensure safety as we encounter icebergs, we would use the sonar system working alongside an AI operated system that's going to help control the temperature of the submarine to be approximately 18 degrees. To monitor the fundamental gases we will be using chemical scrubbers for carbon dioxide and for oxygen levels the electrolysis of seawater as this is very important ,as well as to provide drinkable water for the crew members we'll be using a water purification system with thermal distillation. The crew members will have sufficient amount of food sealed in a vacuum environment.

Considering many factors, we have opted to go with ford series E-450 dual rear wheel cutaway that will travel at an average speed of 25mph for transporting the load off the submarine. For our journey we will have the assistance of an AI with 6 professional healthy naval engineers of board the submarine to ensure the best and to eradicate any risks.

For the energy the submarine will be using nuclear power as it's more efficient and environmentally friendly. Submarines need electrical power to operate the equipment on board. To supply this power, submarines are equipped with diesel engines that will use reactors. Submarines also have batteries to supply electrical power. After carefully assessing what's best and efficient we have decided that the engine will consist of pressurized nuclear reactors to power the submarine by nuclear fission. In the reactor mainly consisting of 235 Uranium will be assembled to undergo a fission chain reaction; the heat created by the uranium is used to make steam to turn the turbines. Furthermore, this will then drive the electrical generators which will provide power to the motors. The most suitable motors to use will be electric with three poles as it has a higher conservation of energy and provides better performance. The motors will then drive the propeller shafts. The generators, in addition to supplying powers to the main motors it also charges the main storage batteries- this will be lithium ion batteries being sustainable for long journeys and charges quickly. The power is distributed through the main propulsion control cubicle sent to the motors, the lithium ion batteries will provide the power to drive the motors also giving power to the auxiliary and lighting needed. In addition to providing enough power there will be diesel electric propulsion to operate the vessel in case of engine malfunction and to reduce the vulnerability of failure. As a team we have done a lot of research to ensure we transport the load safely and effectively.

References

References Set A: Transport

A1: https://en.m.wikipedia.org/wiki/Merchant_submarine

A2: https://www.bbc.co.uk/news/av/technology-46350188/the-ferry-using-rolls-royce-technology-that-sails-itself

A3: https://www.first-utility.com/the-blog/ideal-room-temp

A4: https://en.m.wikipedia.org/wiki/Room_temperature

A5: https://www.space.com/17683-earth-atmosphere.html

A6: https://biology.stackexchange.com/questions/16741/what-is-the-minimum-air-pressure-the-human-body-can-tolerate-if-oxygen-supply-is

A7: https://wonderopolis.org/wonder/how-does-a-submarine-work-2

A8: https://www.space.com/10762-nasa-mars-rover-overbudget.html

A9: https://www.space.com/22226-mars-rover-curiosity-time-lapse-video.html

A10: https://www.ford.com/commercial-trucks/e-series-cutaway/

A11: https://jalopnik.com/the-land-vehicles-of-antarctica-5379341

A12: https://simple.m.wikipedia.org/wiki/Fractional_distillation

A13: https://www.extremetech.com/extreme/188752-chinas-supersonic-submarine-which-could-go-from-shanghai-to-san-francisco-in-100-minutes-creeps-ever-closer-to-reality

A14: https://en.wikipedia.org/wiki/Sail_(submarine)

A15/A16: https://www.marineinsight.com/naval-architecture/introduction-to-submarine-design/amp/

A17: https://en.wikipedia.org/wiki/Archimedes%27_principle

A18: https://en.m.wikipedia.org/wiki/Virginia-class_submarine

A19: https://jalopnik.com/the-land-vehicles-of-antarctica-5379341

A20: https://www.googleadservices.com/pagead/aclk

A21: https://simple.wikipedia.org/wiki/File:Fractional_distillation_lab_apparatus.svg

A22: http://stray-ideas.blogspot.com/2007_09_01_archive.html

A23: https://www.ford.com/commercial-trucks/e-series-cutaway/features/

A24: http://3d-synthesis.com/37-Submarine.html

References Set B: AI vs Human

B1: https://www.military1.com/navy/article/571315-fully-submerged-what-its-like-to-live-on-a-submarine/

B2: https://edition.cnn.com/2016/05/06/politics/life-on-uss-missouri-nuclear-submarine/index.html

B3:https://www.iwm.org.uk/history/life-on-board-a-british-nuclear-submarine

B4: https://en.wikipedia.org/wiki/ARA_San_Juan_(S-42)

B5: https://en.wikipedia.org/wiki/USS_Thresher_(SSN-593)

B6: https://mars.nasa.gov/mer/mission/tl_surface_nav_hazard.html

References Set C: Energy

C1: http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/nuclear-fuel-cycle-overview.aspx

C2: https://electronics.howstuffworks.com/motor6.htm

C3: https://en.wikipedia.org/wiki/ARA_San_Juan_(S-42)

C4:https://web.archive.org/web/20110722100732/http://www.defencemanagement.com/news_story.asp?id=16337

C5:http://mragheb.com/NPRE%20402%20ME%20405%20Nuclear%20Power%20Engineering/Nuclear%20Marine%20Propulsion.pdf

C6: https://commons.wikimedia.org/wiki/File:Nuclear_fuel_element.jpg