Department of Mechanical and Industrial Engineering
Faculty of Engineering and Architectural Science

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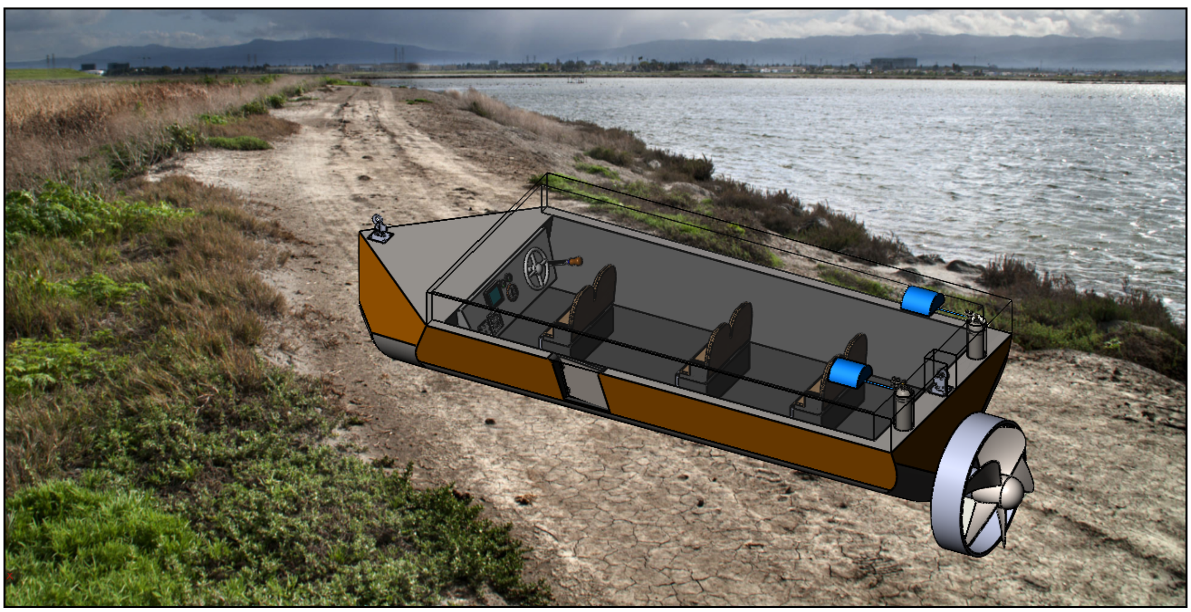
MEC325: INTRODUCTION TO ENGINEERING DESIGN
FINAL DESIGN PROJECT REPORT



THE PACIFIC 11 MARITIME ESCAPE SYSTEM

TEAM 1206

team declaration

We, the undersigned members of Team 1206 in MEC325, agree that:

- all team members have abided by all Ryerson Policies and course rules, and
- one of our members has shared a properly completed Workload Distribution Form with our Teaching Assistant and our instructor.

We furthermore accept that any violation of Ryerson Policy or course rules will lead to a grade penalty or charges of academic misconduct.

Table 1: Team Members Names and Student Numbers

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[1] Only the last 5 digits of the student number are required.

executive summary

The DMMMR team has designed a maritime escape and life-support system called the Pacific 11 Escape System. There are several types of maritime escape and life-support systems for different types of vessels, but our design was mainly focused on smaller vessels. Through extensive research on the review of existing liferafts for smaller vessels, it seemed that most of the products could only function if they were inflated, let alone the limited features provided on board. We figured this as a dissatisfaction for the consumers and took promising opportunities to innovate a satisfactory product.

Based on consumer reviews from various websites like Amazon, Alibaba, and Ocean Safety, we noted and assessed the design failures and shortcomings of the liferafts. Many of the customers complained that the liferafts are too small for six people to sit with comfort and are less stable in rough water conditions. They take a maximum of 30 seconds to inflate, which can be the difference between life and death [30]. Customers also complain about the difficulty in boarding the life rafts and the lack of safety features on board. So, our design team focused on targeting these issues specifically as well as covering all the specific goals in our design.

In the early part of the design process, we figured that our product has to accommodate different age groups with different physical characteristics, be eco-friendly, and affordable. For smaller vessels, many of the life rafts in the market can only operate after being inflated. This can be a devastating issue for the passengers, if the inflation system takes time or fails to work. So, our product is designed in such a way that it is attached to the side of the small vessel and can be easily deployed using an on-load mechanism without any inflation system required. We designed a maritime escape system that includes 3 comfortable bench seats that hold 2 people each with 3-point seat belts to secure the passengers during propulsion. If the system capsizes, then an inflation bag self-righting system will be enabled automatically. Our eco-friendly ducted propulsion system with an user-friendly navigation and communication system will ensure that the passengers on board safely reach land and get rescued.

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introduction

design brief

design brief addenda

Design Brief E:

Maritime Escape/Life-Support System

Overview

A conventional "life-boat" has many problems: they capsize, they can become waterlogged, they cannot move quickly, its occupants remain exposed to the elements, and they often lack supplies or means of communicating distress to rescue agencies, to name a few. Large and complex solutions already exist, but they are all basically "scaled-down ships". **Design an innovative system to help at most six people per unit escape** from the most common maritime accidents and disasters safely and quickly, such that they can survive until they are rescued, subject to reasonable limits.

Background and Details

Figure 1: Lifeboat of the Titanic.

Lifeboats have come a long way since the Titanic (see Figure 1; source), although simple wooden "mini-boats" remain the norm, especially in economically depressed regions, and for smaller vessels.

Expensive, powerful, robust designs already exist for large ships such as ocean liners and military ships.

However, there remains a “gap” in maritime escape and life-support systems for smaller vessels.

An NGO, working in conjunction with a large consortium of small and medium Caribbean fishing/tour operators, is looking for a new design intervention in the area of maritime escape and life-support systems for smaller vessels. Specific goals include:

1. Ensure the safety, comfort, and dignity of users and co-users.
2. Each instance of the system should accommodate up to six persons (including any crew).
3. Be usable within a range of 50 km from major bodies of land, gale-force winds, and waves up to 3m.
4. Ensure ethical practices at every stage of the product life cycle.
5. All relevant maritime regulations and standards are observed and followed.
6. The deployment must be possible by untrained users; however, measures must be in place to prevent accidental deployment (by, for instance, a drunk tourist on a fishing tour).

Other Notes

- Preference is given to innovative solutions, so long as the safety, comfort, and dignity of users and co-users are maintained or improved.
- Preference is given to solutions that have a low environmental impact.
- Preference is given to solutions that address all relevant sources of waste, including noises, smells, etc.
- Project scoping must include specifying the level of perceptual, cognitive, and physical ability required to use the intervention.

current situation

Situation Scan

❖ **Goals:**

- What does the design brief expect you to do?
    - The expectation is to come up with an innovative design regarding lifeboats.
    - Our design will focus more on lifeboats for smaller and medium-sized vessels; it should hold no more than six people.
    - This design brief is specifically for Caribbean fishing and tour operators companies that require the use of a smaller vessel.

❖ **Users:**

- What are the key human factors that could impact or be impacted by the situation?
    - The human mental state of mind.
    - Human perception is also impacted in times of danger.
    - Human motor control is critical due to the reflexes and movement involved during the usage of a lifeboat.
- What distinguishing characteristics do your principal/target users exhibit?
    - The design brief states, "small to medium-sized vessels". This suggests that our users include fishermen, tour operators, and tourists.
    - The lifeboat can only hold 6 people which means that there might be 1 or 2 crewmembers. If a situation arises where the crewmembers are not available or cannot do their job then the co-users (tourists and other passengers) would need to use the lifeboat, which turns them into a user.
    - Our target audience would be the companies that are operating the tour boats and fishing boats.
- What impact may users' backgrounds and histories have on their interactions with your intervention?
    - There may be a language barrier as the users come from different countries.
    - Tourists tend to lack the knowledge needed to operate a vessel.
- Are there any particular abilities/disabilities evident in the users within the current situation?
    - The users that we've listed above are in different age groups and may come from all over the world.

    - This means that our users are extremely diverse and have varying levels of abilities/disabilities. We need to therefore adhere to their needs when designing the product.
    - The users could be: deaf; blind; pregnant; experience autism; experience dwarfism; have mental disorders; experience aging; have phobias; experience back problems.
  - In what kind of mood or emotional/psychological state will users be?
    - Users will be in a fearful and panic state of mind due to the emergency situation.
  - What impact will co-users have on the situation?
    - All co-users which are the passengers on board, must cooperate with the crew members (users) operating the raft and follow proper instructions; otherwise, the situation could worsen.
  - What could other “agents” besides the users and co-users benefit from achieving a better situation?
    - The Caribbean company that is operating the vessel
    - Life insurance companies
  - What could other agents be adversely affected by a change to the current situation? What situational changes should you avoid to ensure non-user agents will not be harmed?
    - Associations that make regulations for lifeboats
    - Users that are not used to the new regulations provided in the lifeboat
    - Investors and sponsors that have invested money into the boat touring company.
- **Circumstances:**
  - What environmental/sustainability concerns exist?
    - Diesel is often used for several lifeboats, and it is not sustainable and expensive; it is also terrible for the environment.
    - A modern-day lifeboat is usually steel-hulled and “double-skinned.” Steel production is known to have harmful impacts on the environment
    - The effects of steel on the environment include air emissions (CO, SOx, NOx, PM2), wastewater contaminants, hazardous waste, and solid waste.
  - How is the economy?
    - The lifeboat economy is essential for cruise ships, and large ship corporations purchase the majority of them.
  - Is the regional society stable?
    - Yes, the regional society is stable because the Caribbean gets a lot of its GDP from water-related tourism.
  - What industries/businesses are typical in those areas?
    - A significant factor in the Caribbean economy is tourism; therefore, businesses set up in those regions will be centered around the tourism industry. For example, people often take cruises around the islands of the Caribbean, and it is a hotspot for cruise ships.

    - Another Caribbean Islands' primary industry is sugarcane; the climate allows for the ideal growing conditions for sugarcane.
    - The economy of the Caribbean depends heavily on natural resources, agriculture and travel, and tourism.
  - Is there a client that is different from the end-user? Are there any goals set by the client that conflict with the goals you set for your intervention?
    - Cruise Ship companies and other large ship oriented companies buy lifeboats for their users in emergency scenarios.
    - No, all goals set by the client should match with the goals set by us because the number one priority for both is the user's safety.

- **Competition:**
  - What are the existing interventions used in the current situation? What will your intervention have to compete against?
    - Fully enclosed lifeboats:
      - Enclosed lifeboats completely cover passengers and crew members from weather and rough water conditions, since it consists of a permanent non-removal rooftop and sides.
    - Partially enclosed lifeboats:
      - The sides of the lifeboat can be opened and closed with a foldable cover.
    - Fully open lifeboats:
      - No enclosures from top and sides.
    - Coastal/inshore rafts:
      - Used within 20 miles or 32 km of land [56].
    - Offshore/ocean rafts:
      - Used within 150 miles or 241 km of land [56].
  - Who (what type of person) uses each of the existing interventions?
    - Potentially anyone that boards a ship can use the lifeboat in the time of an emergency.
  - What do users think about existing products and technologies?
    - Lifeboat manufacturers have been tackling the issue of "Too many compact lifeboats that don't hold enough passengers" by manufacturing larger sized lifeboats.
    - An example of this is the Norwegian company Harding's double-decker lifeboat that could accommodate 440 people.
    - Lifeboat personnel and other manufacturers have pointed out that this creates a problem when it comes to evacuation.
    - Evacuating that many people and ensuring their safety and well-being would be a near-impossible task, especially considering the time constraints during an emergency.
    - These existing solutions are good enough and can help people survive; however, there is a market gap for more compact-sized lifeboats.

- What functions and characteristics are familiar (or unique) to the different existing interventions?
    - All modern lifeboats have a radio and radar to navigate through the body of water.
- What environmental impacts do current interventions have?
    - Current designs are causing pollution to the bodies of water due to gas and oil emissions.
- What do users dislike or find problematic about the current situation?
    - In current designs, users find the embarkation errors that occur during the launching procedure problematic.
    - Lifeboat release mechanism failure is also a common issue.

❖ **Environment: (Refer to Table 42 in the appendix for more details)**

- What is the geography or setting of the initial situation?
    - The lifeboat would be somewhere in the ocean near the Carribeans for an unknown period of time.
    - The lifeboat people must have access to fresh water, food, medication, navigation, and other vital resources for human survival for an extended period of time.
- What's the weather like?
    - There are often rainstorms, high-speed wind, and low visibility.
    - Our design must be able to accommodate those conditions so that the people on board could survive.
    - The Caribbean sea temperatures vary from 24°C to 30°C [2] (the average being 27°C), so our design must be ready to handle those different temperatures
- How many hours of daylight does the area get?
    - The hours of daylight in the ocean are approximately 12 hours a day [8].
- Are there any particular outlier circumstances that are important? (Examples: earthquakes, armed conflict, drought or flood, etc.)
    - The outlier circumstances could include tsunamis, hurricanes and thunderstorms.
    - The link below shows the “Beaufort Wind Scale,” which we could use to help design our lifeboat to handle the most extreme conditions [9].
- How sensitive is the environment to pollution and other impacts that might accrue through product use?
    - Lifeboats have a negative impact on the environment and cause pollution. This includes but is not limited to oil and carbon dioxide emissions, garbage, noise pollution, wastewater, and physical damage to sea life due to the excretion of harmful metals and chemicals from the lifeboat during its lifecycle.
    - Our design must adhere to those environmental issues to have an environmentally friendly product or a product that causes the least amount of pollution possible.

- **Strategy:**

- Market Segment:
    - We're targeting our product to small fishing and tour operators in the Caribbean.
- Degree of Innovation:
    - We would like to expand on the existing model of the lifeboats and rafts. We would like to incorporate new safety features and technologies, which would make the overall product safer and more efficient.
    - Combine the designs of lifeboats and rafts mentioned above in the competition to produce an innovative end product that consists of advanced technologies and a feasible design for tour operators and fishing companies.
    - Keeping in mind that the target is for smaller tour operators and fishing companies, the product must be designed that is reasonably priced.
- Time to Market:
    - The design is anticipated to be released to the market in 1 year.
        - Approximately four months for the final report to be approved and marked by the boss.
        - Approximately a month to edit the report based on the boss's comments and to start the manufacturing process.
        - Approximately seven months to manufacture and market the product.
    - Suppose any new technologies are invented in the future. In that case, we will try to incorporate it as a side feature if applicable and added to the design add-ons for feature purchases.
- Production:
    - When looking at fishing and tour operators that run a smaller business, it can be seen that the vessels are generally smaller compared to more prominent business operators. The average capacity of a smaller vessel made for fishing or touring depends on the size of the boat. A general rule on determining a smaller vessel's capacity is taking the vessel's length, multiplying it to the vessel's width, and then dividing it by the number 15; this will give the boat's capacity. Smaller tour operators have smaller sized vessels with smaller caps ranging from 15-20 people [10].
    - According to the SOLAS requirement, the number of lifeboats required on a vessel is determined by the particular boat's max human capacity. There should be enough lifeboats to accommodate at least 125% of the max capacity of the ship. According to our design brief, the lifeboat must carry a minimum of 6 passengers comfortably. The smaller vessel will be required to have 4-5 lifeboats active and ready to use at all times [11].
    - It is possible that a lifeboat could be maintained for a very long period of time as the parts to the overall system can be repaired, replaced, or maintained. But, as the lifeboat gets outdated by newer iterations, it would be wise to invest in a more modern lifeboat system.
- Environmental Concerns:
    - We are implementing solar power into our design to reduce emissions, which prolongs the use of products, making it suitable to use in the long term.

- We will focus on making the product for long-term use, and most parts would be repeatable. If our product is maintained appropriately, it could be usable for 10+ years.
- Cost:
  - A D class inshore lifeboat costs around £52,000 but when reduced to a smaller size can go from $4000-$8000 [12].
  - An inflatable life raft with the capacity of 30 can cost $5000 [12].
  - It costs £1,527 a year to train one lifeboat crew member [12].
- Customization:
  - The number one priority of our lifeboat design will have safety in mind, and all of our lifeboats will have all the necessary components of our design. Still, if a customer wants a specific feature to be added to the lifeboat as an extra feature or functionality, we will assess their needs. If our assessment is deemed viable, we will accommodate it.

Reference Design

Coastal Commander 2.0 Liferaft 6-Person Valise [13]:

- Functionality:
  - Type of Lifeboat:
    - This lifeboat is fully enclosed, which means that it can protect its passengers from the weather at sea.
    - It also holds no more than six passengers, which is listed in the design brief as the main feature.
  - Propulsion:
    - There is no engine on this liferaft and can only be paddled.
  - Release Mechanism (Launch Type):
    - The launch type is that the cylindrical container is thrown into the water and then a string is pulled, which then allows the liferaft to inflate.
    - This process takes a maximum of 30 seconds [13].

Figure 2: Image of Coastal Commander 2.0 Liferaft

- Year Built:
  - No specific date provided
- Cost:
  - US $1799.99
- Environmental Impacts [14]:
  - There is no direct negative impact on the environment when the liferaft is operating, since there is no engine in the liferaft.
  - However, during production and manufacturing, electricity and other types of energy sources are used which can negatively impact the environment.

- User Needs
    - Safety is the number one need for tourists and crew on board.
        - Hence, lifesaving equipment must be provided for the users on the lifeboat, such as:
            - Comprehensive medical equipment
            - This includes oxygen and full resuscitation kit, Entonox for pain relief, a large responder bag, and three different stretchers.
            - Fully insulated liferaft, which provides protection against harsh weather conditions.

B-Class Lifeboat - Atlantic 85 [15]:
https://rnli.org/what-we-do/lifeboats-and-stations/our-lifeboat-fleet/b-class-lifeboat

Figure 3: Image of B-Class Lifeboat (Atlantic-85)

- The second lifeboat chosen is the B-Class Lifeboat. It is the closest to the modern-day lifeboat in terms of looks and compatibility.
    - Below are some critical points regarding objective measures and user needs [16].
- Functionality
        - The fastest lifeboat in the RNLI fleet, with a top speed of 35 knots powered by two 115hp 4-stroke engines.
        - A rigid inflatable raft that can be quickly implicated onto the side of a small vessel due to its compact size and agility
        - Capable of being beached in an emergency without sustaining damage to its engines.
    - Release Mechanism (Launch Type)
        - It can use a davit system to lower the lifeboat into the water, which will be applied for our design.
        - It can also be launched into the ocean from a carriage.
    - Range/Endurance:
        - The range is 3 hours maximum until it runs out of fuel.

- Cost:
    - The B-Class Lifeboat is priced between the other two designs; we've shown $367K, which is still very expensive compared to the Freefall Lifeboat.
- Year Created and Last Built:

    - This boat was introduced in 1993 and was last built in 2003, which means that the design, the technology used, and the build quality might be somewhat outdated.
- Environmental Impacts [18]:
    - Air pollution:
        - The gasoline engine that this lifeboat uses releases pollutants such as carbon dioxide and other toxic gases into the air.
        - However, because it runs on gasoline and not diesel, it does release less carbon dioxide and is, therefore, somewhat more environmentally friendly.
    - Noise pollution [19]:
        - The noise produced by ships and lifeboats can harm many sea creatures that rely on sound to communicate.
        - These species' survival relies on the ability to communicate and orientate themselves correctly, and the noise pollution we emit is a severe threat to their delicate acoustic habitat.

- User needs:
    - The user's safety is the most critical need to be taken into consideration during rescue operations.
        - Hence Atlantic 85 provides safety equipment such as:
            - Searchlight and parachute illuminating flares.
            - Medical equipment with oxygen and full resuscitation kit, responder bag, multi-purpose ambulance pouch, and stretcher.
        - If the Atlantic 85 capsizes, it consists of a manually operated righting mechanism, in which a bag needs to be inflated on top of the roll bar. (US diagram)
    - Communication and navigation systems are provided, which includes:
        - VHF (very high frequency) radio
        - Intercom
        - GPS
        - Radar
        - VHF direction-finding equipment
        - Electronic chart

Free-fall Lifeboat - (JY-FN-4.90) [20]

- The third lifeboat that was chosen is a freefall lifeboat called JY-FN-4.90.
    - Below are points that will describe the lifeboat's objective measures.

- Cost is a significant factor as it allows the company to decide its budget for the actual design and market price to beat.
    - On Alibaba.com, these lifeboats cost between US$36,900-US$63900.00, which is CAD$49182.17 - CAD$85169.12.
        - Compared to Trent and B class lifeboats, the cost is much cheaper.

Figure 4: Image of Freefall Lifeboat

- Functionality
        - Fully enclosed free-fall lifeboat equipped with diesel engine BUKH DV29 RME.
        - 29 hp with a max speed of 6 knots.

    - Release mechanism:
        - The freefall hook is located at the stern of the boat, in which the helmsman controls the release device.
        - The emergency release system is included along with the release device; these two systems operate independently.
        - The hoisting and gravity lowering are both operated by two double wire ropes attached to three lifting eyes mounted on top of the superstructure.
    - Range/Endurance:
        - It consumes fuel at 7.8 litres per hour with a fuel capacity of 180 litres.
            - In total, the freefall lifeboat will last for about 23 hours before running out of fuel.
- Environmental Impacts
    - The Freefall Lifeboat is equipped with an inboard diesel engine.
        - This could cause pollution of air and water, reductions in invisibility, and global climate change.
    - Also, Freefall lifeboat is very loud. Its propellers are powerful; therefore, it can disturb local ecosystems by causing noise pollution and killing fish that get caught in its blades.
    - A significant effect of lifeboats on wildlife also comes from the contaminants used to disinfect, protect, and operate watercraft that also leach into the water, has severe environmental impacts, and weakens or destroys wildlife.
- User Needs
    - Safety is a number one priority for people on board; hence lifesaving equipment must be provided for the users in need of the lifeboat.
        - The Free-Fall Lifeboat (JY-FN-4.90) provides the following standard lifesaving equipment, according to SOLAS (Safety of Life at Sea) [20]:
            - 2 x Rowing oar (wood)
            - 1 x Survival manual English/ flag state language
            - 1 x Magnetic compass fitted on the hull (with illumination)

- 1 x Sea anchor
- 2 x Painter, synthetic rope (20mm Dia. .x 50m)
- 1 x Freshwater 3ltr /person
- 1 x Drinking cup with graduate (plastic)
- 1 x Emergency food ration 10000 KJ/ Person
- 4 x Signal rocket (parachute)
- 6 x Hand flare
- 1 x Waterproof electric torch with one spare bulb and 1 set of spare batteries
- 1 x Daylight signal mirror with instructions
- 1 x Lifesaving sin. table waterproof paper
- 1 x Whistle or equivalent (plastic)
- 1 x First aid kit in plastic waterproof container or bag
- 1 x Anti-seasickness medicine 12 doses / person
- 1 x Seasickness bags 1 pcs / person
- 1 x Jackknife with lanyard
- 3 x Tin opener galvanized steel
- 2 x Buoyant rescue quoit with polypropylene rope (4mm dia.x30m)
- 1 x Manual pump fitted on the hull
- 1 x Fishing tackle
- 1 x Portable extinguisher of the dry powder type (oil extinguishing)
- 1 x Searchlight of the portable type, fitted on the hull
- 1 x Radar reflector
- 1 x Thermal protective aid 15% of lifeboat capacity
- 1 x Rainwater tank with a 5-litre capacity
- 1 x Boarding ladder, wood with synthetic rope

Chosen Reference Design:

- Three different types of lifeboats were researched that are currently in the market: Inflatable liferaft, Atlantic 85, and Freefall lifeboat. So, based on the requirements of the design brief, we have decided to choose the Atlantic 85 lifeboat as our reference design due to the following reasons:
    - Type of lifeboat:
        - The liferaft and Freefall are both fully enclosed lifeboats, while Atlantic 85 is entirely open.
            - Fully enclosed lifeboats can cause anxiety and panic attacks to people with claustrophobia and also limit people on board to get fresh air.

            - On the other hand, open lifeboats like Atlantic 85 expose people on board to dangerous weather and the environment.
                - However, this issue may be solved with a convertible roof design.
        - Out of the three lifeboats, only the liferaft needs to be inflated for usage.
            - Inflatable lifeboats can save lots of space when they are not required in action.
                - However, it can take up to 30 seconds to inflate the liferaft fully [13]. These 30 seconds could be dangerous for passengers, since passengers will have to wait until it opens. So, waiting for about 30 seconds can be a difference in between life and death for an individual during the emergency situation.
        - The design brief requires a lifeboat for small vessels up to 24 m in length and 150 gross tons.
            - The liferaft has dimensions of 27” length X 10.5” width X 17.5” height. This size is way too small for passengers to even fit properly, let alone not being able to sit with comfort [13].
            - The freefall lifeboat is 4.90 m in length and 2.25 m in width. Even though they can be attached to small vessels, this size will be relatively narrow, bulky, less spacious, and uncomfortable for the people on board [15].
            - Atlantic-85 has a length of 8.44 m and a width of 2.85 m. This is a perfect size for a lifeboat since it’s not narrow like the liferaft and freefall lifeboat [14].

    - Speed:
        - The Atlantic-85 lifeboats' stand-out features are its speed and maneuverability. In many cases, rescues can involve being dangerously close to human-made structures, caves, and cliffs. These key features allow the lifeboat to complete these rescues while preventing damage to its components and while keeping its passengers safe.

    - Range/Endurance:
        - In terms of how fast the fuel is consumed:
            - Atlantic-85 consumes it the fastest, which is 3 hours maximum going at 35 knots (64.82 km/hr).
            - The liferaft has 0 range in terms of how many kms it can travel due to no propulsion system.
            - The freefall lifeboat consumes fuel in 23 hours with a speed of 6 knots (11.112 km/hr).

        - The design brief requires the range of the lifeboat to be 50 km. Even though the Atlantic 85 consumes fuel the fastest, it can easily cover the 50 km range since it can go at 64.82 km/hr.

    - Cost:
        - The Atlantic-85 is the most expensive between the liferaft and freefall lifeboat.
            - However, quality of comfort, spaciousness, and safety features are way more important for passengers' safety, which we feel lacks quite a bit in the liferaft and freefall lifeboat.
            - Our goal in pricing would be to come up with a more affordable product for tour operating companies while maintaining the quality of the lifeboat and its vital safety features.

    - Release Mechanism:
        - The launch type for the liferaft is that the cylindrical container is thrown into the water and then a string is pulled, which then allows the liferaft to inflate. This process takes a maximum of 30 seconds [13].
            - We feel that this release mechanism isn't safe at all for the passengers because not only they have to wait for the liferaft to inflate, but also would have to jump into the water to access the liferaft and board it.
        - Atlantic 85 and Freefall are both capable of using the davit system.
            - However, the Atlantic 85 can also be launched into the waters by on-load mechanism, carriage, and be kept in floating boathouses.

    - Environmental Impacts:
        - Atlantic-85 operates on Yamaha 4-stroke engines, which uses gasoline to function. The Freefall lifeboat uses engines that run on diesel, MAN 2840 marine, and BUKH DV29 RME.
        - It is known that diesel engines are more efficient than engines that run on gasoline.
            - Diesel engines emit less carbon dioxide since diesel fuel contains about 12 percent more energy per gallon than ordinary gasoline.
            - It also contains about 16 percent more energy than gasoline that contains ethanol.
        - The liferaft has no engine, so it won't negatively affect the environment.

So, overall we feel that the Atlantic-85 is a good reference design, even though it does have drawbacks to it regarding the environmental impact and cost. When it is time for us to come up with our own design, we will focus on how to make this reference design better by making it eco-friendly and affordable for the fishing/tour operators.

Situated Use Cases

Table 2: Mohsan Raza's SUC (Johnny McDonnel)

Team member	Mohsan Raza
SUC 1	A user is scared of the rough sea waters.
	On a stormy mid-day, with the waves bouncing up to 10ft high, Johnny, a young teenager, is forced to evacuate his cruise tour and board the safety lifeboat. He is shivering from the breeze and scared by the constant bouncing of the cold waters. He is unsure of what to do next because of his inexperience and age. He needs assistance boarding the lifeboat.

Table 3: Rufat Akhmetov's SUC (Alexander Bushmelov)

Team member	Rufat Akhmetov
SUC 2	An elderly person fails to comprehend the functionality of the release mechanism.
	In an evacuation, the user must lower the lifeboat using the release mechanism. The 74 year old man fails to understand the release mechanism and therefore finds issues operating the machinery which further increases the severity of the situation.

Table 4: Dirgh Desai's SUC (Sheela Stanley)

Team member	Dirgh Desai
SUC 3	Eight months pregnant woman boarding and exiting the maritime escape system
	During an evacuation of the vessel in an emergency, users would want to board and exit the lifeboat quickly. This can be problematic for a 32-year-old pregnant woman who can't move fast enough and have agility issues during the rescue operation.

Table 5: Mohammed Khan's SUC (Emma Jafari)

Team member	Mohammed Khan
SUC 4	User is intoxicated
	On a blistering summer day in the Caribbean, where the temperature is 35°C, a 23-year-old female enjoys several alcoholic drinks and gets tipsy. This prompts the client to have a negative behavioral impact on travelers and crew members. This behavior impacts the crew individuals' capacity to perform significantly as the weight of being answerable for many lives is already there.

Table 6: Mohamed Ismail's SUC (Fatima Abdullah)

Team member	Mohamed Ismail
SUC 5	A safety pin/release handle has been accidentally removed/moved.
	A 12-year-old teenager who is relatively unfamiliar with the controls has removed/moved a crucial safety pin/release handle at the wrong time and has therefore risked the lives of everyone else on board. Doing so during the lifeboat release process while passengers are still boarding could result in injury or death. Activating specific commands in the lifeboat should be a multistep process to avoid accidental activation.

usage scenario

Figure: Usage Scenario

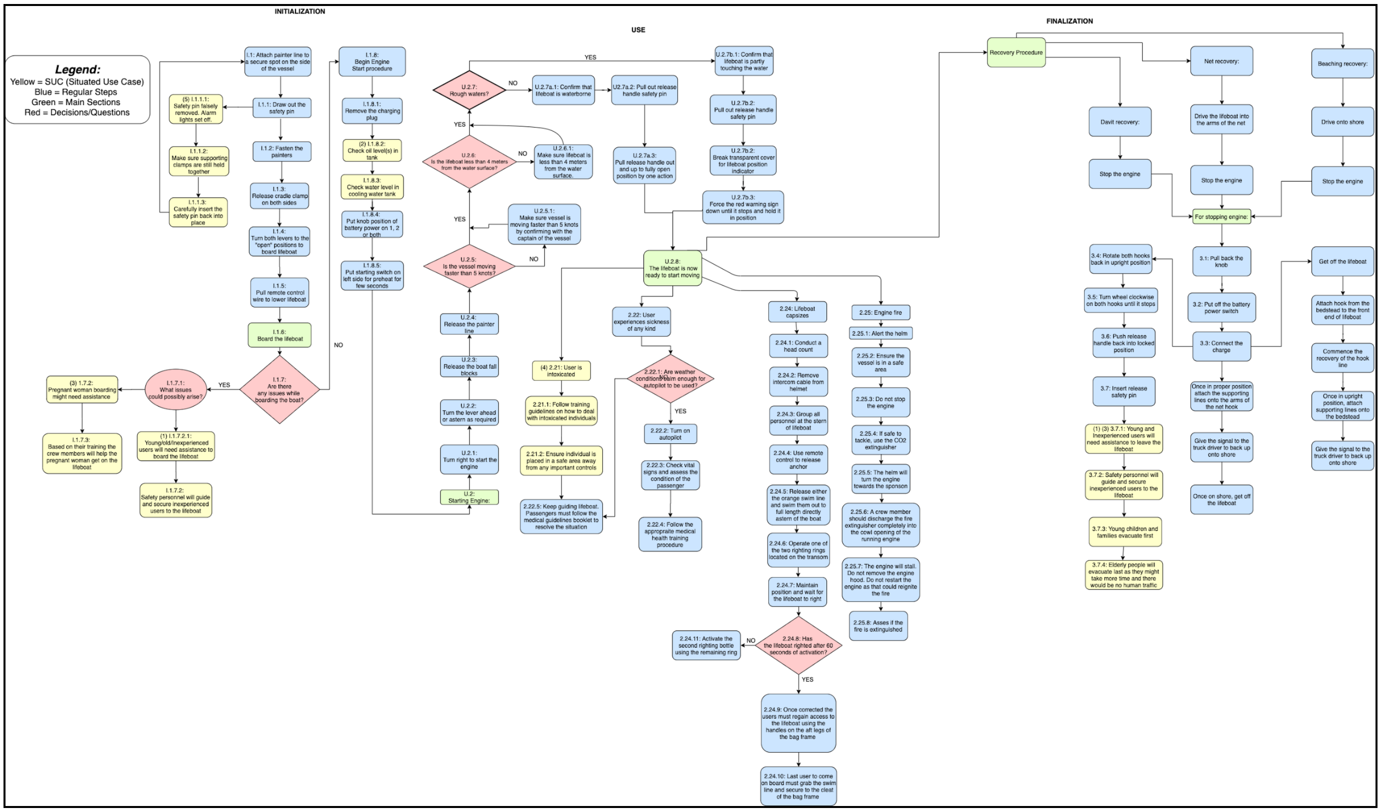


Figure 5: Usage Scenario

hf demands

Table 7: Human Factors Demands and Personas Chart

HUMAN FACTORS AND PERSONAS CHART							
	PRODUCT:	LIFEBOAT					
HUMAN FACTORS		PERSONA NAME:	Emma	Alexander	Fatima	Sheela	Johnny
		TEAM MEMBER RESPONSIBLE:	Mohammed Khan	Rufat Akhmetov	Mohamed Ismail	Dirgh Desai	Mohsan Raza
		MINIMUM REQUIRED CAPABILITY FOR USE					
PERCEPTUAL	VISION	20/160					
	HEARING	-10 to 25 dB loss					
	SMELL	2.20%					
	TOUCH	2.20%					
	BALANCE	6.20%					
	TEMPERATURE	-					
COGNITIVE	MEMORY	5.00%					
	REASONING	5.00%					
PHYSICAL	STRENGTH	8%M 11.6%F					
	(BODY) MOBILITY	6.20%					
	DEXTERITY & PRECISION	9.80%					

product strategy

Situation Scan:
This was the first step of project initialization where research was conducted on the basic information on our product including: the competition; the users; our goals; the circumstances that we have to consider when designing; the environment of the area we're targeting; our production strategy. Developing the situation scan provided the team members with a clearer understanding of the system we're creating as a whole as well as a general idea of what the aspects the team needs to focus on throughout the project. The information collected in the situation scan was discussed by all the team members and utilized to choose a reference design in the second step.

Reference Design:
Following the initial research phase the team explored the existing market and the different types of vehicles used to rescue people. Fully enclosed, partially enclosed and hyperbaric were the 3 main types of systems available in the market today. After conducting substantial research and looking at a number of different options the group decided to focus on 3 main products which are the Atlantic-85 (B-Class Lifeboat), Free-fall Lifeboats and The inflatable liferaft. The advantages and disadvantages of each were then weighed and analysed in a group discussion which led to the chosen reference design being the Atlantic-85 (B-Class Lifeboat).

Situated Use Cases:
Each of the group member's personas were involved in a situation where they would face a problem in that particular situation. The situation is an environment where the user will use and intervene with the product created. Each team member came up with a distinct situation in which the user will encounter interaction failures during the usage of the product. By using the SUCs, it will allow us to design a product that provides a solution for the respective user interaction problems in a specific environment.

Usage Scenario:
As a team we produced one usage scenario diagram that each team member worked on by being the representative of each of their personas respectively, and developed SUCs from looking at the potential failures in the product's usage scenarios. We made sure to accurately describe each situation by adding annotations and descriptive text where necessary so that if a reader who is unacquainted with our project can still make sense of it. The usage scenario was done on draw.io because of how functional it was with google docs.

Human Factor Demands:
The last step needed to complete the project initialization stage of the project was the human factor demands. The table of human factor demands is based on the usage scenario and each team member's situated use case. After identifying and discussing the worst-case scenarios on the usage scenario diagram for each human factor the exclusion calculator was utilized to fill in the table and find all the values necessary.

problem analysis

preferred situation / expectations

relevant human factors & personas

Persona 1: Johnny McDonnel (Mohsan Raza):

- Age: 12
- Sex/Gender: Male
- Ethnicity: Caucasian
- Level of education: Middle School (Grade 7)
- Relationship status: None
- Height: 1.35m (4'4 ft)
- Weight: 72lbs (32.5kg)
- What connects their life to the scope of this project:
    - Johnny is young and careless; he often wanders away from his parents to look for mini-adventures to occupy his time with. He has trouble listening to his parents' orders and usually dismisses them the first few times he is told to do something. He is young, so he does not yet have a sense of endangerment when he thinks of a cruise tour, so he runs freely around the vessel. Once safety staff makes the call to gather people to board the lifeboats, Johnny will be scared and not have the cognitive ability to sense the situation's danger and eventually take longer to board the lifeboat.

Persona 2: Alexander Bushmelov (Rufat Akhmetov)

- Age: 74 (Elderly)
- Sex/Gender: Male
- Ethnicity: European
- Height: 1.83m (6'0ft)
- Weight: 243lbs (110kg)
- Level of education:
    - Completed HS
    - Institute graduate
- Relationship status: Has a wife and two children.
- What connects their life to the scope of this project:
    - Alexander, born and raised in eastern Europe, is a retired metal worker. He has been dealing with diabetes since his adolescent years. Following his post-secondary education, he entered the metal works industry and went on to work overseas. The numerous years of labour have enabled Alexander to freely communicate in the English, Polish, and Russian language. However, the time he spent working with metals left his vision and hearing ability slightly damaged due to the unsafe working environment he was exposed to. Additionally, his diabetes

has led to the development of sensorimotor polyneuropathy. Following his retirement, he spends most of his time helping around the house and indulging in personal matters such as reading and playing bingo, but his poor eyesight requires him to wear reading glasses.

Persona 3: Sheela Stanley (Dirgh Desai)

- Age: 32
- Sex/Gender: Female
- Height: 1.65m (5’5”)
- Weight: 137 lbs (62 kg)
- Ethnicity: South Asian
- Level of education: Bachelors in Geography
- Relationship status: Married
- What connects their life to the scope of this project:
    - Sheela was born in Mumbai, India, in a middle-class family. She has a huge passion for travelling around the world and learning about diverse geologies and topographies. Everything in life was going well until, at the age of 20, she damaged her eardrums in a car accident, causing her to be partially deaf, and since then, she wears hearing aids to listen. At that time, she was in her second year of university and became very depressed until she met the love of her life. When she was 26, they both decided to get married and spend their lives with each other, and now at the age of 32, she is 7.5 months pregnant. Even though she has mobility issues due to her pregnancy, they decided to go on a one week vacation to the Caribbean Islands to celebrate their eighth wedding anniversary.

Persona 4: Emma Jafari (Mohammed Khan):

- Age: 23
- Sex/Gender: Female
- Height: 1.83m (5’10”)
- Weight: 160 lbs (72.5 kg)
- Ethnicity: African American
- Level of education: High school graduate
- Relationship status: Newly married
- What connects their life to the scope of this project:
    - Emma was born and raised in New York City. At the age of six, her father was charged with first-degree murder and sentenced to life in prison. She spent most of her teen years living with her alcoholic mother. At the age of 18, she was kicked out of her mother's house and forced to live on the streets. After spending four months homeless, she found a well-paying job as a stripper at a nightclub in times square. After finding success at her new job, she moved into a lovely looking apartment in downtown Manhattan and lived the dream life. She

develops a drinking problem down the line from attending multiple parties. Her crazy personality attracts many rich guys, and at the age of 23, she decides to settle down and get married. On her honeymoon, she decides that this will be the last time she consumes an alcoholic beverage.

Persona 5: Fatima Abdullah (Mohamed Ismail)

- Age: 13
- Sex/Gender: Female
- Ethnicity: Middle Eastern
- Height: 1.49m (4’10”)
- Weight: 90 lbs (40 kg)
- Level of education: Just entered elementary school (delayed education)
- Relationship status: None
- What connects their life to the scope of this project:
    - Fatima is a young girl from Syria. She fled the war when she was just seven years old after her parents were killed in an airstrike. After spending multiple years in an orphanage in Germany, she was adopted by a German couple. She wasn’t able to receive a proper education, so she struggles to speak proper English or German; however, she has recently started elementary school. Due to the environment that she has grown up in, Fatima never learned how to swim correctly and fears swimming. After being adopted, her parents took her to a psychiatrist who diagnosed her with post-traumatic stress disorder (PTSD), which she developed due to her childhood experiences in the war. Being in a lifeboat may trigger flashbacks and an anxiety attack. Despite her lack of education, she is a very curious individual and likes to take devices apart in her spare time to find out how they work and put them back together.

hf capabilities

Table 8: Human Factors Capabilities and Personas Chart

HUMAN FACTORS AND PERSONAS CHART								
	PRODUCT:	LIFEBOAT						
HUMAN FACTORS		PERSONA NAME:	Emma	Alexander	Fatima	Sheela	Johnny	
		TEAM MEMBER RESPONSIBLE:	Mohammed Khan	Rufat Akhmetov	Mohamed Ismail	Dirgh Desai	Mohsan Raza	
		MINIMUM REQUIRED CAPABILITY FOR USE						
PERCEPTUAL	VISION	20/160	20/60	20/140	20/20	20/70	20/20	
	HEARING	-10 to 25 dB loss	30 dB	40 dB	25 dB	30 dB	25 dB	
	SMELL	2.20%	0.10%	0.10%	0.10%	0.10%	0.10%	
	TOUCH	2.20%	0.1%	2.20%	0.10%	0.10%	0.10%	
	BALANCE	2.20%	25%	5.00%	2.20%	6.10%	15.80%	
	TEMPERATURE	-	-	-	-	-	-	
COGNITIVE	MEMORY	5.00%	15.80%	2.20%	2.20%	2.20%	15.80%	
	REASONING	5.00%	15.80%	5.00%	15.80%	15.80%	15.80%	
PHYSICAL	STRENGTH	8%M 11.6%F	11.6%F	8.0%M	11.6%F	11.6%F	5% M	
	(BODY) MOBILITY	2.20%	15.80%	2.20%	2.80%	7.50%	2.20%	
	DEXTERITY & PRECISION	2.20%	15.80%	15.80%	2.20%	5.25%	2.20%	

Justification for changes to minimum required capability for use percentages:

Balance, (Body) Mobility, and Dexterity and precision were changed from 6.2% to 2.2%, 6.2% to 2.2% and 9.8% to 6.2% respectively. This is because it is absolutely vital that our personas are able to balance, move and perform tasks precisely in our system. The design brief clearly states that the deployment must be possible by untrained users and this cannot be done if the percentages stay as they are. A 6.2 percentage would exclude a significant portion of the population and would impact the usability of our product so we therefore had to decrease the minimum required capability for use to 2.2%.

interaction errors

Table 9: Mohsan Raza's Initialization Interaction Error

<table>
<tr><td>IE</td><td colspan="3">IE.I.1.7.2.1.1</td></tr>
<tr><td>Context</td><td colspan="3">Johnny tries to find his way to board the lifeboat.</td></tr>
<tr><td>Impact</td><td colspan="3">Overall Impact: 6 (See Appendix 2 for details.)</td></tr>
<tr><td rowspan="2">SII 1</td><td rowspan="2">Alarm Noise</td><td>Low unidentifiable noise</td><td>Loud recognizable noise</td></tr>
<tr><td>Johnny may not recognize what type of alarm it may be due to the alarm being low pitch and unidentifiable and carry on with his fun.</td><td>Johnny hears a loud noise and recognizes the alarm sound as an evacuation alarm as the P.A. is restating to get to the lifeboats.</td></tr>
<tr><td rowspan="2">SII 2</td><td rowspan="2">Visual Indicators</td><td>Few</td><td>Many</td></tr>
<tr><td>Johnny does not see the visual indicators of where the lifeboat is located and how to board and may result in him getting lost.</td><td>Johnny sees that many signs and signals pointing where he should go to get on the lifeboat in time.</td></tr>
</table>

Table10: Mohsan Raza’s Use 1 Interaction Error

<table>
<tr><td>IE</td><td colspan="3">IE.U.1.17a.1.3</td></tr>
<tr><td>Context</td><td colspan="3">Johnny tries to turn on the lifeboats autopilot.</td></tr>
<tr><td>Impact</td><td colspan="3">Overall Impact: 3(See Appendix 2 for details.)</td></tr>
<tr><td rowspan="2">SII 1</td><td rowspan="2">Knowledge of autopilot controls</td><td>Little</td><td>Some</td></tr>
<tr><td>Johnny knows the meaning autopilot and knows that some vessels have the option to use autopilot but does not know how it works</td><td>Johnny can attempt to turn on the lifeboat’s autopilot feature by reading the user manual</td></tr>
</table>

Table11: Mohsan Raza’s Use 2 Interaction Error

<table>
<tr><td>IE</td><td colspan="3">IE.U.1.6.1.2</td></tr>
<tr><td>Context</td><td colspan="3">Johnny tries to see if the lifeboat is less than 4 meters from the water surface.</td></tr>
<tr><td>Impact</td><td colspan="3">Overall Impact: 5(See Appendix 2 for details.)</td></tr>
<tr><td>SII 1</td><td>Depth Perception</td><td>Not good</td><td>Good</td></tr>
</table>

		Johnny is unsure how high he is from the water surface and tries his best to estimate	Johnny looks over the hull of the lifeboat and checks if it is near the water. If so, then Johnny could release the lifeboat.

Table 12: Mohsan Raza's Finalization Interaction Error

IE	IE.F.1a.8.2		
Context	Johnny tries to push the release handle back into the locked position.		
Impact	Overall Impact: 5(See Appendix 2 for details.)		
SII 1	Grip Type	One-hand	Two hands
		Johnny can only use his dominant hand to pull back the release handle into the locked position, which is good enough to do the task but requires all his strength.	Johnny uses both his hands to shift the release handle back into the locked position, which has more than enough force to do the task and reliefs half the pressure on his dominant hand, which would make it easier for Johnny.
SII 2	Lock click noise	Unidentifiable	Identifiable
		Johnny tries to push the release handle back into position and assumes that he did so after testing, but he does not hear or feel it clicking into place.	Johnny pushes the release handle back enough so that he hears an audible indicator and feels a click that the handles have been locked into place.

Table 13: Mohamed Ismail’s Initialization Interaction Error

IE	IE.I.1.6.2		
Context	Fatima is evacuating and needs to know what to do.		
Impact	Overall Impact: 7 (See Appendix 2 for details.)		
SII 1	Amount of users able to fully understand the emergency announcement	some	most
		The instructions being voiced on the loudspeaker during the emergency evacuation are in English only. Some users may not understand English very well. There is also no screen with written text so that people could read the instructions.	The instructions are voiced on a loudspeaker by the crewmembers. The passengers have booklets that they can read with instructions and protocols in multiple languages.
SII 2	The volume of loudspeaker	100 dB	70 dB

	announcement and alarms	The volume is too loud; it triggers this persona's PTSD, causing more panic and putting her in a shocking state.	The volume is loud enough to be heard and alert the passengers but not too loud to the point where it would put them in a state of panic and worry.

Table 14: Mohamed Ismail's Use 1 Interaction Error

IE	IE.U.1.17a.2.4		
Context	Fatima needs to check the vital signs of a passenger and assess their condition.		
Impact	Overall Impact: 5 (See Appendix 2 for details.)		
SII 1	Amount of users with the appropriate knowledge on how to check for vital signs and assess a passengers condition	low	high
		Fatima is a young girl with little education and would not understand how to do these tasks if she is required to. The lifeboat does not contain any instructions on how to handle these situations.	Fatima knows what to do as she has read the safety manual under her seat that is available in several languages.

Table 15: Mohamed Ismail's Use 2 Interaction Error

IE	IE.U.1.9.3

Context	Fatima's seat is too big for her size and therefore she keeps swaying from side to side as the boat moves.		
Impact	Overall Impact: 6 (See Appendix 2 for details.)		
SII 1	The level of comfort of the user and the level of danger the design puts the user in	Low comfort and high danger	High comfort and low danger
		Some seats may be too large or certain users and too big for other users, which decreases the user's comfort level and may put the user in danger as they are not secure.	Seats should be made of a material that is waterproof and comfortable to all users. They should also have some sort of restraint to secure them.

Table 16: Mohamed Ismail's Finalization Interaction Error

IE	IE.F.1c.7.1		
Context	Fatima is getting off the lifeboat but she is scared of the water she keeps slipping on the ramp.		
Impact	Overall Impact: 8 (See Appendix 2 for details.)		
SII 1	Type of Flooring	Slippery Floors	Non-slippery floors
		Fatima is slipping on the ramp due to its poor design and she is really scared of the water causing stress to her and the other passengers. The worst case scenario would result in her getting seriously injured.	The slip-resistant flooring allows Fatima to exit the boat safely and with no complications.

Table 17: Mohammed Khan's Initialization Interaction Error

IE	IE.I.1.6		
Context	Emma tries to open the hatch to the lifeboat.		
Impact	Overall Impact: 6 (See Appendix 2 for details.)		
SII 1	Users not able to grasp complicated instructions	Some	Most
		The instructions on opening the door are written in a disorderly manner and require multiple steps; an intoxicated user gets confused and cannot open the hatch to the lifeboat.	The instructions on opening the lifeboat's hatch are shown using action symbols and have one clear step allowing the intoxicated user to understand visually how to enter the lifeboat quickly and easily.

Table 18: Mohammed Khan's Use 1 Interaction Error

IE	IE.U.1.6.1		
Context	Emma tries to predict the distance between the boat and the water.		
Impact	Overall Impact: 6 (See Appendix 2 for details.)		
SII 1	Impaired Vision	low	high
		Emma tries to predict the distance but is unable to so correctly as being intoxicated is affecting her eyesight.	Emma is able to use sensors on the bottom of the boat, which tells her precisely how far the ship is from the water.

Table 19: Mohammed Khan's Use 2 Interaction Error

IE	IE.U.1.15		
Context	Emma is asked to make sure the fuel tank is full.		
Impact	Overall Impact: 3(See Appendix 2 for details.)		
SII 1	Basic Knowledge	Not good	Good
		Emma is not able to understand the readings on the fuel tank and makes an assumption.	Emma is easily able to understand the fuel tank readings and is able to give an educated answer.

Table 20: Mohammed Khan's Finalization Interaction Error

IE	IE.F.1c.6		
Context	Emma is told to put the boat's electric engine on charge.		
Impact	Overall Impact: 6(See Appendix 2 for details.)		
SII 1	Safety knowledge	low	High
		Emma grabs the wire and decides to insert it into the charging port.	Emma has had previous experience with electricity and makes sure to wear protection before putting the electric engine on charge.

Table 21: Rufat Akhmetov’s Initialization Interaction Error

<table>
<tr><td>IE</td><td colspan="3">US.I.1.8.2</td></tr>
<tr><td>Context</td><td colspan="3">Alexander attempts to read the current oil levels of the engine in the lifeboat.</td></tr>
<tr><td>Impact</td><td colspan="3">Overall Impact: 6 (See Appendix 2 for details.)</td></tr>
<tr><td rowspan="2">SII 1</td><td rowspan="2">The contrast of dipstick and liquid level</td><td>low</td><td>high</td></tr>
<tr><td>Alexander may not easily recognize the current level of oil in the engine.</td><td>Alexander clearly sees the contrast of the dark liquid on the stick and proceeds with the engine commencing procedure.</td></tr>
</table>

Table 22: Rufat Akhmetov’s Use 1 Interaction Error

<table>
<tr><td>IE</td><td colspan="3">IE.U.1.7a.3</td></tr>
<tr><td>Context</td><td colspan="3">Alexander fails to grasp the lever and pull it up in one motion.</td></tr>
<tr><td>Impact</td><td colspan="3">Overall Impact: 3 (See Appendix 2 for details.)</td></tr>
<tr><td rowspan="2">SII 1</td><td rowspan="2">Grip Type</td><td>One-hand</td><td>Two hands</td></tr>
<tr><td>Due to the numbness in his hand, he is not able to properly grasp the lever</td><td>Alexander would have a more straightforward approach to capturing the lever with the support of both of his hands</td></tr>
</table>

SII 2	Force required	high	low
		If the force Alexander is required to exert may be over his physical ability.	A low force requirement would enable Alexander to pull up the lever with no difficulty quickly.

Table 23: Rufat Akhmetov’s Use 2 Interaction Error

IE	IE.U.1.11:		
Context	Grab the steering wheel and hold a steady course		
Impact	Overall Impact: 4(See Appendix 2 for details.)		
SII 1	Stability of steering wheel	low	high
		Low stability would require Alexander to operate the steering wheel with his condition for an extended period of time.	The steering wheel’s high stability would only require the user to the right direction of the lifeboat if it goes off course and does not require the user to fully grasp the steering wheel for excessive time periods.

Table 24: Rufat Akhmetov’s Finalization Interaction Error

IE	IE.F.1b.7		
Context	Attaching supporting lines onto the net hook arms		
Impact	Overall Impact:4 (See Appendix 2 for details.)		
SII 1	Type of support	Rope lines	Hooked lines

		Alexander would have to tie the rope lines securely, but due to his diabetes's effect on his motor ability, he wouldn't secure the cables with proper strength.	Alexander would not have to worry about tightly securing the lines and would simply attach the hooks onto each other with great ease

Table 25: Dirgh Desai's Initialization Interaction Error

IE	IE.1.7.2		
Context	Sheela is boarding the lifeboat.		
Impact	Overall Impact: 6 (See Appendix #2 for details.)		
SII 1	Mobility	No separate entrance.	Organized separate entrance.
		Sheela may not be able to rush boarding along with everyone due to her low agility and reflexes because of her massive body.	Sheela will be able to carefully and calmly board the maritime escape system without risks of tripping or falling.

Table 26: Dirgh Desai's Use 1 Interaction Error

IE	IE.1.16.9a.1
Context	Sheela is accessing the lifeboat using the handles on the aft legs of the bag frame.

Impact	Overall Impact: 6 (See Appendix #2 for details.)		
SII 1	Grip type	Weak	Moderately strong
		Since Sheela is in the third trimester, she will experience fatigue, which will reduce her grip strength.	Sheela will need to use two of her hands to grip properly while someone pushes her up.

Table 27: Dirgh Desai's Use 2 Interaction Error

IE	IE.1.16.6		
Context	Sheela is swimming out of the lifeboat due to a capsize.		
Impact	Overall Impact: 6 (See Appendix #2 for details.)		
SII 1	Stamina to swim	Swimming by herself.	Someone helping her to swim.
		Sheela may not be able to swim by herself since she would be in low energy and stamina.	Sheela will be able to swim safely with assistance.

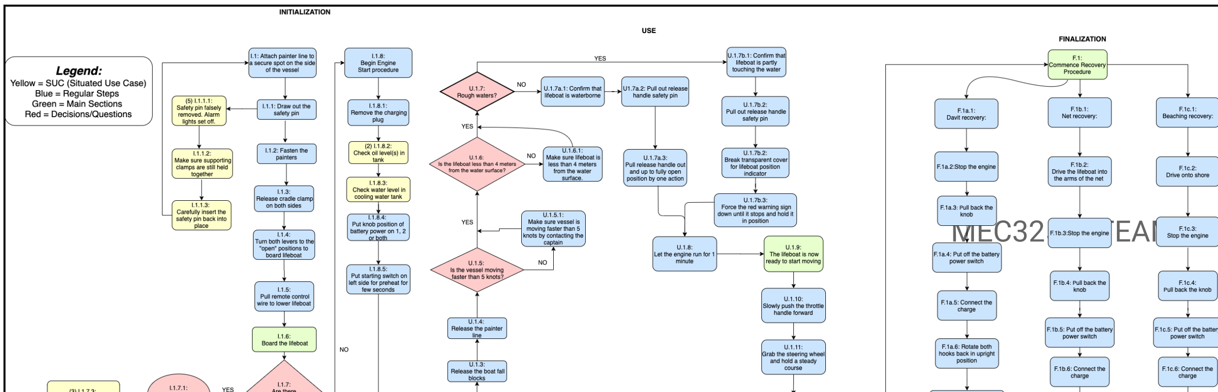
Table 28: Dirgh Desai's Finalization Interaction Error

IE	IE.1.2.4
Context	Sheela is exiting the lifeboat.

Impact	Overall Impact: 5 (See Appendix #2 for details.)		
SII 1	Leg strength	Weak	Moderately Strong.
		Sheela may not be able to stand up from the seat by herself due to numbness in thighs.	Sheela can use her two hands to get up by pushing up on the seats next to her.

revised usage scenario

You can view the revised usage scenario in more detail here.



requirements

1. Functionality Requirements
    a. FR: Materials used in the product must resist corrosion
        i. C: no more than level 2 over 10-15 years [21],
            1. Flaking corrosion could fall into machinery and cause damage, and so it must be avoided.
            2. Maintenance over its life cycle would be costly, so we design this to not corrode over its operating life.
    b. PC: Must be of adequate strength [22]
        i. C: The lifeboat must securely and safely launch and handle twice the lifeboat's total mass when completely loaded with its full load of individuals and equipment of about 850kg.[25]

Figure 6: Revised Usage Scenario

            1. Each lifeboat that is launched from a free-fall state must have sufficient strength to withstand a load without residual deflection on the removal of that load.
        ii. C: Be fit for being deployed and towed when the vessel is moving at a speed of 5 knots on steady waters.
            1. Must abide by SOLAS Regulation No.16 and No.17[23]
        iii. C: The product must be able to operate at a minimum speed of 8 knots while taking into account all persons and equipment.
            1. Must abide by SOLAS Regulation No.29 - Steering Gear[23]
    c. FR: The product must protect the passengers from the elements [22]

        i. C: The exterior components must be able to operate throughout sea temperatures of -1°C to +30°C
            1. If the exterior structure does not withstand these temperatures then this could have an effect on the functionality of the product and the safety of the passengers.
        ii. C: Product's internal contents must be capable of operating within 0°C to +55°C
            1. The prime operating cabin temperature is around room temperature and the internal components must operate within the stated temperature ranges.
    d. FR: The product must have seats capable of supporting users weight [25]
        i. C: Each seat must support up to a load of 100 kg in any single-seat location.
            1. Because any higher of a load per seat will break or deform the seat, and 100kg is a reasonable weight for most users.
    e. PC: The product must be compatible with small vessels [22].
        i. C: Small vessels are 24 m in size, and so the lifeboat must be compact and be easily installed on its sides.
            1. According to SOLAS and LSA codes, the lifeboat should not be less than 7.3 m in length.
2. Safety Requirements
    a. FR: The product must carry multiple persons
        i. C: Passengers must not exceed six individuals, including crew members.
            1. This is a requirement based on the design brief.
    b. PC: The product must be equipped with life jackets or PFDs (personal floatation device)
        i. C: Life jackets must accommodate all body types.
            1. Passengers come in all different shapes and sizes, so the product must accommodate their physical needs, especially when it comes to life jackets because that is a crucial aspect of their safety.
    c. FR: The product must provide a signalling mirror.
        i. C: The signalling mirror must have a retro-reflective surface with a hole in the center.
            1. This specific design of the signalling mirror would allow individuals to reflect light onto a passing vessel or rescue plane.
    d. FR: The product must provide a properly adjusted magnetic compass.
        i. C: This compass must be independent of any power supply.
            1. A compass is crucial to stay on course during rescue operations.
    e. FR: The product must provide a first aid kit.

i. C: It must contain the necessities such as medications, bandages, disposable gloves, tweezers, and other items.
    1. This is important as accidents could occur, and immediate response is needed to treat any injuries.

ii. C: It must be easily accessible whilst a passenger is seating him his or her's seat
    1. A user of the product should not have to get up and retrieve a first aid kid, as it should be near them while they are seated because of safety reasons.

f. FR: The product must provide flares [24]
    i. C: It must contain one hand-held red flare, two parachute flares (day and night), one hand-held orange smoke signal, two floating orange smoke signals (day), and one electric distress light (night)
        1. Flares produce an intensely bright light that can be used as a distress signal and are therefore very important in emergency scenarios.
    ii. C: Flares must be under 42 months of age [24]
        1. This rule is to ensure that the product does not have any bad flares aboard; however, flares can last for more than 42 months.

g. FR: The product must provide food provisions for the users [22].
    i. C: Provisions must contain a minimum of 10kJ (2390 Calories) per person.
        1. To accommodate the users appropriately through the entirety of their journey.

h. FR: The product must provide the users with seatbelts.
    i. C: Seatbelts must be designed for all sizes of humans.
        1. Passengers come in all different shapes and sizes, so the product must accommodate their physical needs, especially when it comes to seatbelts because that is a crucial aspect of their safety.

i. PC: The product must be durable[26].
    i. C: The body of the product must be of fibre-reinforced plastic nature.
        1. This material must be used since it is a better option than other metals, mainly due to its ability to resist corrosion, its durability and its possession of high tensile strength.
        2. It also has high tensile strength, lasts longer and has a higher performance.
    ii. C: Fibreglass used must be crack proof to prevent the degradation of fibreglass material.
        1. If the fibreglass is cracked during operation, it could cause leaks and the product's overall performance to decrease.

3. User/lifeboat Requirements
    a. PC: The product must be ergonomic
        i. C: The product must have sufficient space for users to freely move around onboard the product.
            1. The cabin must be of adequate width to fit and accommodate the components and passengers located inside the cabin.
    b. PC: The product must be user friendly
        i. C: The product must not have any sharp edges.
            1. Due to the nature of the product, it may be moving and swaying in different directions. Although the users would be secured in by their seatbelts, sharp edges should be avoided when designing to prevent any injuries.
    c. PC: The product must be easy to learn and use.
        i. C: The product's instructions must be written in at least size 14 points.
            1. This is to reduce the number of excluded users and make sure instructions are clear and readable.
        ii. C: The product's instructions must be written in English, Spanish, Mandarin, Hindi, Arabic, and French.
            1. The most popular language in the Caribbean is Spanish [26]
            2. The other languages were chosen because they are the five most spoken languages in the world [26].

4. Economical Requirements
    a. PC: The product should be affordable to purchase for tour operators and fishing companies.
        i. C: The product must be cheaper than the reference design
            1. The reference design costs $367k and we hope to cut that price down by at least 1/3 .
    b. PC: The product should be affordable to reuse
        i. It should cost no more than $1500 peruse.
            1. The cost of usage must account for the fuel, emergency supplies and electricity costs of recovering the lifeboat after use.
    c. PC: The cost of repair of the product should be reasonable
        i. The cost should not exceed the original value of the product
            1. The maintenance costs, on average, must be less than the yearly cost of replacing the product.
5. Maintenance Requirements:
    a. FR: The product must account for the maintenance and be tended to on regular intervals as per SOLAS requirements.

i. C: Maintenance must be done every at most three months. [31]
    1. This is done to avoid ruptures and damage to the product, and also it is done so ship staff can repair cracks.
    2. Ship staff must check the hull for any cracks or drills before every deployment.
    3. Ship staff must check if the valve works correctly and is not frozen or harmed, the sprinkler mechanism mounted in lifeboats should be monitored before every deployment.

ii. C: Air support system and pressure of air bottles must be verified and checked every 5 years. [31]
    1. The full cylinder of oxygen must read 2000 PSI and the pressure must be tested to 1.5 times the working pressure.

iii. C: The product's battery must be changed every 2-3 years. [31]
    1. Lifeboat battery supplies power for the lighting as well as for starting the lifeboat engine.
    2. The battery must be able to start the lifeboats engine multiple times, so many companies have a policy in place to reinstate batteries every 2-3 years.

iv. C: The product's engine must be tested every week [31]
    1. This must be done for 3 minutes, detail as that is the optimal testing time. Any issues with the engine should appear within those 3 minutes.

6. Environmental Requirements:
    a. PC: The product must be sustainable
        i. C: The product must be durable enough to last up to 10-15 years and still be in decent condition.
            1. If the product is in good condition for longer than that, fewer products would have to be made resulting in less expense and fewer materials thrown into landfills which will eventually decrease our product's impact on global warming.
    b. FR: Engines must meet International emission standards. [28]
        i. C: NOx limits range from 3.4 to 1.96 g/kWh
            1. The emission standards are placed to limit greenhouse-gas pollution and reduce emissions.
        ii. C: CO standard of 5.0 g/kWh
            1. For the most part, CO emission standards are intended to accomplish air quality and protect human life.
    c. FR: The product must account for the surrounding environment [29].

i. C: Chemicals used to disinfect, protect and run watercraft are often leached into the water, seriously affecting the ecosystem and weakening or destroying wildlife. The product must be FRP.
   1. FRP composites are fully recyclable and therefore have no harmful impact on the marine environment [30].

discussion

There is a gap in the market for maritime escape systems specifically for smaller sized vessels and current designs and solutions have their flaws and shortcomings. A large portion of the population is excluded from using a lot of these designs which do not appeal to people with certain disabilities. To tackle this we developed multiple different personas that cover a wide range of users from different backgrounds and highlighted their different abilities. After conducting a further analysis of our human factor capabilities and our personas we were able to use our revised usage scenario to develop interaction errors that displayed instances where the product would fail in engaging with the user. Using all the previous steps mentioned we were able to develop a set of requirements for our product that included functional requirements, product characteristics and constraints. These requirements were based on the human factor capabilities, the personas and the interaction errors. This section of our design project allowed us to establish a deeper, thorough, and more mature understanding of our product, users and the things we need to take into consideration when producing our designs.

product architecture

system identification matrix

Table 29: Subsystems with its functional requirements

Functional Requirement	**Subsystems**								
	Navigation & Communication System	Deployment System	Propulsion System	Passenger Securing System	Passenger Seating System	Passenger Access System	Self-righting System	Emergency Aid System	Structural System

Resist Corrosion			x		x	x			x
Withstand operating temperature range	x		x						x
Support users of different physical characteristics	x	x		x	x	x		x	x
Compatible with small vessels		x							x
Accommodate six users			x	x	x	x			x
Secure passengers				x	x	x			x
Protect passengers from elements									x
Operate 50 km from land	x		x					x	

Withstand waves up to 3 m and gale-force winds			x			x			x
Provide an alternative method(s) of power	x		x						x
Easily Recyclable			x	x	x	x			x
Preserve the surrounding environment			x					x	x
Follow SOLAS Rules	x	x	x	x	x	x	x	x	x

system diagram

1. Navigation and Communication System
    - This system will provide a visual guide on the screen, which would enable users to guide the lifeboat towards the desired waypoint.
        - Withstand operating temperature range:
            - Electronic components of the vehicle could heat up, and that could disable the components from functioning correctly.
        - Operate 50 km from land:

            - The navigation and communication system should operate within the 50km range so that the passengers do not lose contact with the rescue team onshore.
        - Provide an alternative method(s) of power:
            - If the maritime escape system's battery dies/fails to work, alternative energy methods such as solar power or a second battery could be used instead [31].
        - Follow SOLAS Rules & Regulations:
            - The SOLAS document referenced states the specific navigation and communication systems requirements for different types of water vehicles. Our final product should adhere to those regulations [31].
        - Support users of different characteristics:
            - The way the buttons and controls are structured should accommodate the physical anthropology of each user.
    - This may include a compass, GPS, helm, crew intercoms, and radar.
    - Quantification of interfaces:
        - User Commands [31]:
            - Move helm to direct vehicle
            - Power GPS on or off
            - Power Radar on or off
            - Power deck light on or off
            - Activate/deactivate Intercom
            - Power Navigation light on or off
            - Ballast control
            - Power couple batteries on or off
            - The power propulsion system on or off
        - Electricity:
            - (12 / 24 / 35) V
        - Feedback to users:
            - Port engine overheat warning light
            - Boat speed in MPH (Knots)
            - The Revolutions per minute of the engines
            - Indication of fuel level in the tank
            - Man overboard warning light
            - Propulsion system overheat warning light
            - Propulsion system malfunction warning light
            - Location of incoming distress signal
            - Orientation relative to the North Pole
            - GPS virtual assistant
            - Incoming radio distress signals

        - Light and sound energy:
            - (30 / 60 / 90) dB
            - (360 / 750 / 950) nm
        - Propulsion system turned on:
            - 102 dB (engine at full power)

2. Deployment System
    - This system is responsible for safely lowering the maritime escape system from the side of the vessel. This system enables users to lower and deploy the product in the time of need.
        - Support users of different physical characteristics:
            - The deployment system (davit release mechanism) should operate and withstand a load of all the users seated on board the maritime escape system.
        - Compatible with small vessels:
            - This deployment system should be operable and compatible with small-sized vessels.
            - This system secures the maritime escape system to the vessel's side and holds it in place while the vessel is sailing across the waters.
        - Follow SOLAS Rules & Regulations:
            - This system should be checked upon, and follow up repairs must be done annually to abide by the SOLAS requirement on the davit release system [31].
    - This may include Davit release mechanism, frapping lines, gripes, tricing pendants, and falls [32].
    - Quantification of interfaces:
        - User Commands:
            - Pulling or pushing the operating lever
            - Removal of the locking pin
            - Securing painter line
        - Passengers:
            - Six Users
        - Release of vehicle:
            - Greenlight unlocked symbol indicating that the device has been released.
            - Red lock light symbol indicating that the product is still secured on the system.

3. Propulsion System

- This system provides the product with the transportation ability. This will interact with the water surface and provide the necessary propulsion force, which allows the product to move or sail across the waters.
  - Support users weight on board:
    - The propulsion system must have enough force to propel forward, backwards, and sideways by taking into account the passengers' weight on board.
  - Withstand operating temperature range:
    - The engine used in the maritime escape system should withstand high and low temperatures to avoid overheating or overcooling, potentially impacting the engine's performance.
  - Operate 50 km from land:
    - The propulsion system should be able to operate at this distance because the design brief requires it to do so. For example, the fuel in the tank should last until the maritime escape system reaches land.
  - Withstand waves up to 3 m and gale force winds:
    - The engine and propellers must be designed in a way that can operate in these rough conditions.
  - Provide alternative method(s) of power:
    - In case the power runs out on the lifeboat and is unable to move, a portable generator must be incorporated into the maritime escape system.
    - Feet and wooden paddles could be incorporated into the design as an alternative for users to move the product physically.
  - Easily Recyclable:
    - After the maritime escape system reaches the end of its lifespan, its components could be recycled. Therefore the materials used to manufacture the specific parts of the propulsion system should be recyclable.
  - Preserve surrounding environment:
    - Noise levels of the propelling engines should be minimal to prevent increase in noise pollution.
    - The engines used should reduce the emissions of CO_2, SO_2 NO, CO, and hydrocarbons emissions.
  - Follow SOLAS Rules & Regulations:
    - The SOLAS document referenced states the propulsion system's specific requirements, specifically the engines used and the fuel consumption, for different types of water vehicles. Our final product should adhere to those regulations. [31]

        - Accommodate six users:
            - The propulsion system should provide the escape system with enough power to move while the passengers are on board.
    - This may include diesel engine, electric engine, fuel tank, deck fill, etc.…
    - Quantification of interfaces:
        - Energy:
            - 105 litres/tank [31]
            - 35 A of power [33]
        - Debris:
            - Obscure items that may interfere with the system: plastic waste, fishing nets, and small rocks
        - Energy consumption:
            - At full throttle, it will last for 2 hours and 30 minutes [31]
        - Movement of vehicle:
            - A maximum speed of 35 knots [31]
        - Pollution:
            - Noise pollution - up to 102dB from engine [31]
            - 5- 30 g/KW/Hr of HC and NOx emissions [34]
        - Propulsion system malfunction:
            - Red malfunction signal on the navigation panel

4. Passenger Securing System
    - This system will ensure that all the passengers are safely and comfortably secured to their seats and don't end up with any injuries due to the lifeboat's rapid movement. To avoid negatively impacting the user's performance, safety and comfort, the system could give users the freedom to adjust the straps and seat alignments to cater to their different physical characteristics and needs, but that depends on the individual design concepts that we come up with.
        - Support users of different physical characteristics:
            - The securing system should accommodate all the passengers on board with different heights and weights.
        - Accommodate six users:
            - The securing system should be available for six people on board.
        - Secure passengers:
            - The securing system should secure users and co-users on board to prevent them from falling or moving around during propulsion and rough waters.
        - Easily Recyclable:
            - After the maritime escape system reaches the end of its lifespan, its components could be recycled. Therefore the materials used to

manufacture the specific parts of the securing passenger system should be recyclable.

- Follow SOLAS Rules & Regulations:
  - The SOLAS document referenced states the specific requirements for the securing system, which includes the seat belts for different types of water vehicles. Our final product should adhere to those regulations. [31]

- This may include Seat belt, seat harness, and seat restraint.
- Quantification of interfaces:
  - Passengers:
    - Six users
  - User interaction:
    - Pull strap/securing mechanism towards the buckle.
    - Inserting belt into the buckle
    - Adjusting strap/securing mechanism
    - Unbuckling the belt

5. Passenger Seating System
   - This system will ensure that all the passengers are safely and comfortably seated and don't end up with any injuries due to the lifeboat's rapid movement.
     - Support users of different physical characteristics:
       - The seating system should accommodate all the passengers on board with different heights and weights.
     - Accommodate six users:
       - The seating system should be available for six people on board.
     - Secure passengers:
       - The seating system should provide proper seating for users and co-users to prevent them from moving around while on board.
     - Easily Recyclable:
       - After the maritime escape system reaches the end of its lifespan, its components could be recycled. Therefore the materials used to manufacture the specific parts of the passenger seating system should be recyclable.
     - Follow SOLAS Rules & Regulations:
       - The SOLAS document referenced states the specific requirements for the seating system. Our final product should adhere to those regulations. [31]
   - This may include: seats (six precisely), and benches
   - Quantification of interfaces:
     - User interactions:

        - Adjustment of the seat
    - Passengers:
        - Six Users

6. Passengers Access System
    - Enables passengers to board in and out of the maritime escape system.
        - Resist corrosion:
            - Corrosion will negatively affect the passenger's access system's performance, and the materials used to manufacture this system should resist corrosion.
        - Support users of different physical characteristics:
            - The access system must accommodate all users of different weights and heights to enter and exit the maritime escape system.
        - Accommodate six users:
            - The access system must be easily accessible for all six passengers.
        - Secure passengers:
            - Locking and unlocking of the access system which will secure the passengers.
        - Withstand waves up to 3 m and gale force winds:
            - The access system must be adequately dimensioned and shall be watertight not to let any water in.
        - Follow SOLAS Rules & Regulations:
    - This may include: sliding doors, hinged doors or no doors (opened design)
    - Quantification of interfaces:
        - User interaction:
            - Open/close the hinged door.
            - Slide open/close the horizontal door.
            - Hop over the side of the system
        - Passengers:
            - Six passengers will enter and exit the access system.

7. Self-righting System
    - The self-righting system has gas cylinders that are made from steel construction and contain a combination of CO_2 and nitrogen under pressure in liquid form.
    - When the righting system is operated, the acting/release knife will puncture a diaphragm inside the cylinder head, allowing it to release the pressure and turn the liquid mix to gas. Then the gas flows through the supply hose to the inflation bag. The hose is fitted with a non-return valve at the bag end [32].
    - Follow SOLAS Rules & Regulations:

            - This system should also have suitable handholds for the users to cling onto the product in time of capsize. Additionally, they should be held in such a way that when subjected to an impact sufficient to cause them to break away from the lifeboat, they break away without damaging the product to abide with the SOLAS regulation [35].
            - This system should be tested, checked up on and follow up repairs must be done annually to abide by the SOLAS requirement on the davit release system [31].
    - This may include two gas bottles, two supply hoses, inflation bag, and an anchor [31.
    - Quantification of interfaces:
        - User interaction:
            - Activate self-righting (Pull string/Press button)
        - Gas:
            - 2 x (12 / 15 / 18) Litre compressed gas cylinders
            - Mixture of carbon dioxide and nitrogen [32]
        - Inflation bag:
            - Activation time 12 - 20 Seconds
        - Vehicle upright:
            - Reorientation time 30 - 45 Seconds

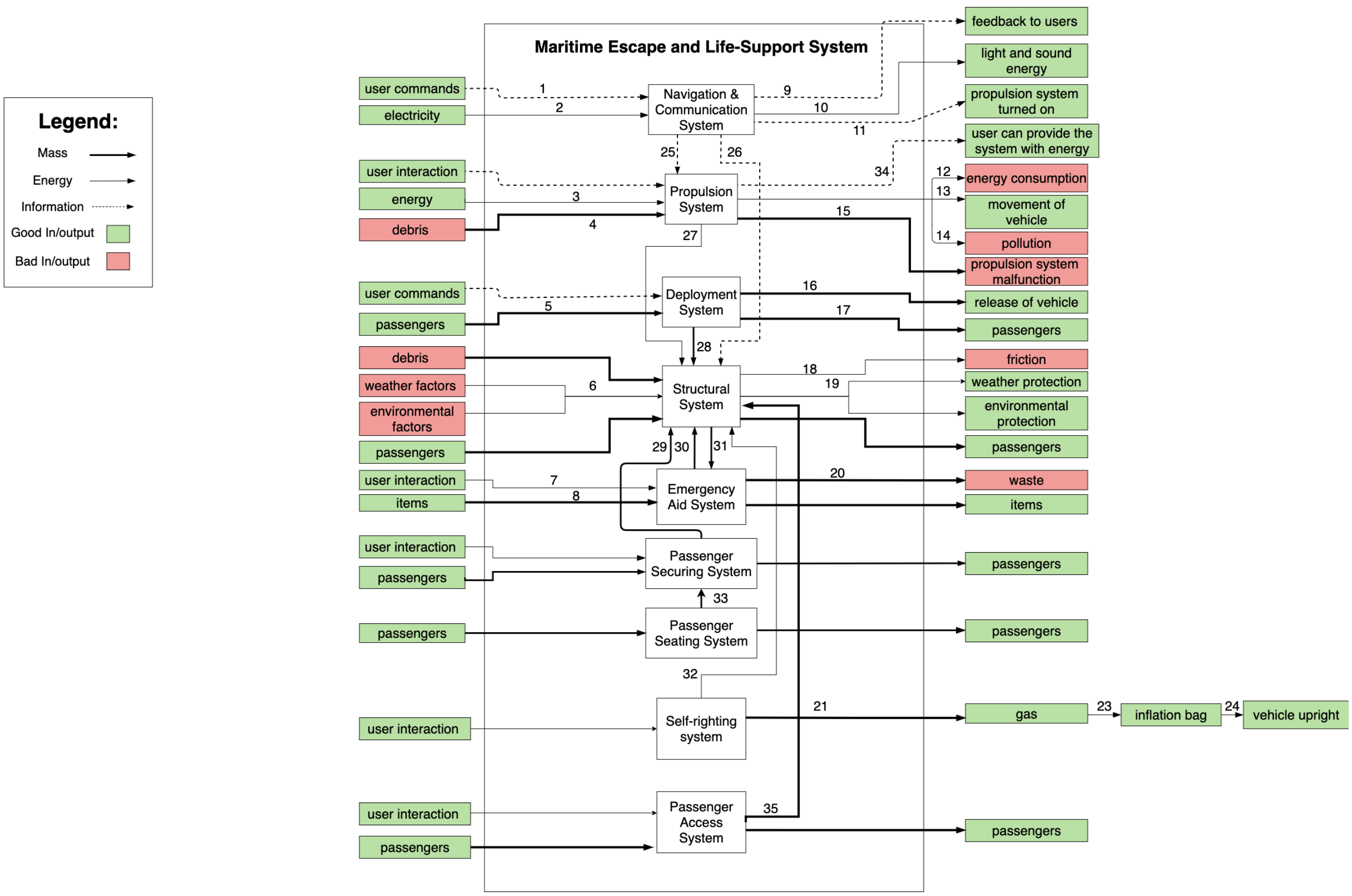
8. Emergency Aid System
    - This system will provide aid to the passengers and crewmate and cases of emergencies. This system is vital in time of need and must be preserved over long periods when the lifeboat is not in use.
        - Support users of different physical characteristics:
            - An example of this would be the lifejackets provided. They need to be able to fit a wide range of people so that no one is excluded.
        - Operate 50km from land:
            - The components of the emergency aid system listed below must be enough for passenger consumption throughout the period of time they spend at sea, which relates to the distance from land and therefore relates this functional requirement to the subsystem.
        - Preserve surrounding environment:
            - Using the emergency aid system leaves the passengers with a lot of waste which may include plastic bottles from water bottles. The maritime escape system should provide a waste compartment for the passengers.

        - Follow SOLAS Rules & Regulations:
            - The SOLAS document referenced requires different types of water vehicles to have specific emergency aid components and so our maritime escape system must adhere to the specifications listed in the document. [37]
    - This may include a First Aid Kit, food supply, water, flare, lifejackets, etc...
    - Quantification of interfaces:
        - User interaction:
            - Open bag/box/compartment
            - Use the items inside based on their required functionality.
        - Items: First Aid Kit, food supply, water, flare, lifejackets, and etc...
        - Waste: Food ration wrapping, bandages, and bandage/first aid kit wrapping.
        - Minimum of six plastic garbage bag(s), one for each passenger.

9. Structural System
    - This system will serve as the exoskeleton and interior of the product. This system will provide the product with a rigid structure where other systems can be mounted onto. The structure system will encounter a force of impact upon release from the vessel and must withstand the impact force.
        - Resist Corrosion:
            - Corrosion often negatively impacts the performance of water vehicles during their lifetimes. The materials used to manufacture our maritime escape system should try to resist corrosion as much as possible to avoid any issues with regards to the overall performance of the vehicle.
        - Withstand operating temperature range:
            - The structure, specifically the exo-skeleton, will experience a wide range of temperatures, so therefore, the materials used should be able to withstand those temperatures and operate correctly.
        - Support users of different physical characteristics:
            - The structure of the maritime escape system should be able to withstand the weights of passengers on board.
        - Compatible with small vessels:
            - The size and shape of the structure should be within 24 m for small vessels [38].
        - Accommodate six users:
            - According to the design brief, the size and shape of the structure should be able to accommodate up to six users comfortably and safely.

        - Protect passengers from elements:
            - The structure should either be partially or fully enclosed to provide the passengers with protection from the harsh weather conditions at sea.
        - Withstand waves up to 3 m and gale force winds:
            - The structure should be able to withstand forces and pressure from waves and strong winds that may cause the system to bend or break.
        - Provide an alternative method(s) of power:
            - If needed, the structure could potentially provide a renewable source of energy. If this is incorporated into the design, it will provide the users with an alternative method of power in case the maritime escape system runs into failure.
        - Easily Recyclable:
            - After the maritime escape system reaches the end of its lifespan, its components could be recycled. Therefore the materials used to manufacture the structure should be recyclable.
        - Preserve surrounding environment:
            - The materials used in the structural system should not have an effect on the surrounding ecosystem.
        - Follow SOLAS Rules & Regulations:
            - The SOLAS document referenced provides specific requirements for the structure of the water vehicle. Therefore our maritime escape system must adhere to the specifications in the document. [32]
        - Secure passengers:
            - The seats should connect securely to the structure so that they don't move out of place when the system is operating.
    - This may include: The body of the maritime escape system, hooks for the release system, storage compartments and seating for the users.
    - Quantification of interfaces:
        - Debris: Obscure items that may interfere with the system: plastic waste, marine life and rocks
        - Weather and environmental factors: seawater, rain, winds and sea waves.
            - Resistance to corrosion refer to requirements (1a)
        - Passengers:
            - Six Users
            - Max weight capacity for 6 passengers is 900 Lbs [39]
        - Friction:
            - The tensile strength of FRPs is typically upto 6000 MPa [40]
        - Weather and environmental protection:

- The structure to be coated with Nyalic.
- What material could the structure be made out of to resist weather conditions?
    - If Inflatable, then plastic polymers (Polyvinyl Chloride fabric) [41]
    - If open/partially closed/ fully closed then, steel, aluminum, fibre-reinforced plastic and polyethylene. [42]



Full system diagram can be viewed here.

Figure 7: Flow chart of the inputs and outputs for systems of Maritime Escape System

system interfaces

Inputs:

1. **User Commands -** This is when the user provides information to the system to perform a good input task. This input would be part of the navigation & communication system used by crewmembers to turn the propulsion system on.

2. **Electricity -** This input would provide power to the navigation & communication system, making it a good input and an energy input as it allows for energy to the system. This electricity could possibly be generated from a battery and renewable energy resource.

3. **Energy -** This input gives force and energy to run the general system. This is a good input as it provides the energy needed for the propulsion system to apply force and move the vehicle. The framework is intensely dependent upon the input and is a part of the propulsion system.

4. **Debris -** These are any objects that may negatively impact the product's functionality as they may get lodged into the propulsion system causing it to malfunction; therefore this is a bad input. Debris can be many different things including small particles, pebbles, small fish or others and thus, this input is categorized as a mass.

5. **Passengers -** The maritime escape system is designed to carry no more than six people. This input is considered to be a mass, and the passengers would be seated in the passenger securing system, which would secure them in place and keep them safe. Passengers are also involved in the deployment system as they would have to be in the structure and activate the deployment. It is a good input as it does not cause any harm to the product and users itself.

6. **Weather and environmental factors** - The hull of the maritime escape system should be able to withstand the elements outside its hull. Also, the structure of the system should be able to resist environmental factors such as corrosion over its lifecycle. This input is considered to be associated with energy because of the energies of wind and waves, as well as the energy required to corrode the material of the hull. It is a lousy input because

if the tides, wind, and temperature conditions worsen, then it can put passengers' lives in danger, and if the corrosion is severe enough, it can ruin the integrity of the vessel as a whole.

7. **User Interaction -** This is considered physical interaction with the securing passenger system as users would have to secure themselves in and the propulsion system when users need to refill the propulsion system with eItAlso, it is also a physical interaction for the passenger access system because the passengers will have to operate the access system by opening, closing, locking, or unlocking.

8. **Items -** These are considered crucial for the passengers' survival and safety during their utilization of the maritime escape system. This includes but is not limited to life-vest, food rations, flares, flare-gun, first aid kit, instructions kit, repair kit, one buoyant rescue quoit with 30m lively line, copy of lifesaving signals in waterproofed cards, and radar reflector [43]. This list of items would be stored in the emergency aid system. As these items are crucial to the survival of the passengers in desperate times, this input would be in a good category [43].

Outputs:

9. **Feedback to users -** This is a good output. The navigation and communication system would provide feedback to the users, which falls under the information category. This feedback would update the users about the status of the maritime escape system.

10. **Light and sound energy -** This is a good output. The navigation and communication would provide this output in energy form, which would supply lighting for the users in order to receive feedback on the navigation panel or screen. The sound energy would also be audio feedback cues or an incoming radio frequency response from the Navigation and Communication systems.

11. **Propulsion system turned on -** After the 'user commands' input enters the Navigation & Communication system as information, it leaves as an output where the propulsion system turns on. This is an exemplary output as the user has activated an essential part of the system that will allow it to move.

12. **Energy consumption -** This is a bad output. The propulsion system needs fuel utilization, which requires a ton of fuel to be burned and releasing more pollutants into the atmosphere. This system conveys the output in the form of energy.

13. **Movement of vehicle -** This is a good output. The energy applied from the fuel consumption from the propulsion system will give the energy required for the product to move in waters with various conditions. The development and movement of the product will lead the clients to safety.

14. **Pollution -**The consumption of fuel discharges pollutants into the environment. This is a bad output. The propulsion system is intensely founded on fuel consumption that is needed for the product to have the energy to perform its required functions.

15. **Propulsion system malfunction -** If the debris input is large enough, it could potentially cause the propulsion system to malfunction and stop functioning properly. This would be considered a bad output as it would render the system useless; passengers on board will not be able to reach a safe area.

16. **Release of vehicle -** This output is a mass because the release is a physical activity where the system is lowered into the water. It is also considered a good output because this is an essential part of the rescue so that the passengers can get to safety. The input related to this output is the user commands. The users would launch the davit release mechanism, which would release the vehicle.

17. **Passengers -** This is not an information or energy output, so it must be a mass output. The passengers enter the structural system, deployment system, securing passenger system, and passenger access system and will exit those subsystems by the end of the rescue process. This is a sound output as it suggests that the passengers have completed the rescue process.

18. **Friction -** This output occurred when the debris rub against the exo-skeleton of the structural subsystem. Debris would cause conflict, which might damage the structural subsystem over time and therefore, it is a bad output.

19. **Weather and environmental protection -** This output is a good output as it keeps in mind that we need to have protection against the elements and resistance against any external factors that can degrade our structural system.

20. **Waste from Items -** The items input used in the emergency aid system, such as water or food may have plastic components categorized as waste material. This is bad output that leaves the emergency aid system and should be recycled or stored in a dedicated portion of the structural subsystem until the passengers can dispose of it appropriately and adequately.

21. **Gas** - This is considered a good output since the gas as a mass into the inflation bag during the utilization of the self-righting system. It is an essential output for the activation of the self-righting system.

22.

23. **Inflation bag** - This falls under good output. The inflation bag stores the mass of the gas that flows into it and is a component of the self-righting system which is responsible for the vehicle to return into an upright position.

24. **Vehicle upright -** This is a good output because once the gas, and inflation bag outputs have appropriately proceeded, the mass will upright and allow the passengers to get back on board.

34. **Users can provide the system with energy** - This is a good output as it provides the propulsion system with energy. If we use an engine as our propulsion system, for example, when that engine runs out of fuel, a user would have to interact with the engine by opening up the refill valve and physically pouring the fuel in, which therefore justifies the existence of this output.

System Interaction:

25. The **Navigation & Communication System** interacts with the **Propulsion System** and tells the system what speed and direction it needs to go , which is **information** transfer. It sends commands to the propulsion system and receives feedback allowing the propulsion system to be turned on and off and providing warning signs to the users.

26. The **Navigation & Communication System** interacts with the **Structural System** due to the control panels set-up within the structural system's interior, which is a mass.

27. The **Propulsion System** causes the **Structural System** to move as it provides the structure with a forward force from the engine, which is considered an **energy** transfer.

28. The **Deployment System** is connected to and holds the **Structural System** when the maritime escape system is not needed or used. It then allows the system to be lowered into the water when an emergency occurs; this causes this interaction to be a **mass** transfer due to the structure's movement aspect.

29. The **Passenger Securing System** is part of/connected to the **Structural System,** so a **mass** arrow attaches those two systems together.

30. & 31. **Structural System** and **Emergency Aid System** are connected because the Emergency Aid System consists of a mass (first aid kit, flares, food, water, etc..) that is stored inside the structural system of the product.

31. The **Self-righting System** interacts with the **Structural System** because the components of the self-righting system contain mass such as inflation bags, hoses, and gas bottles are directly attached to the system's structure.

32. The **Passenger Securing System** is part of/connected to the **Passenger Seating System,** so a **mass** arrow attaches those two systems.

35. The **Passenger Access System** connected to the **Structural System,** so there is a **mass**

An arrow that links these two systems together.

discussion

In stage 3, we recognized all the subsystems that we incorporated into our design. We created a System Identification Matrix, which indicated subsystems related to specific functional requirements by placing an “X” into each of their respective boxes. We then justified how each subsystem related to each functional requirement. The following step was to produce a system diagram which required us to create valid inputs and outputs and identify which ones were acceptable and which ones were terrible. To make our system diagram we utilized the suggested decision on the wiki by Sulustri himself, which was Diagrams.net. We then moved on to the next step that explained all the subsystems, inputs, outputs and how each subsystem related to each other and added quantifications to all of our subsystems. We faced a problem because the flowchart software did not update frequently enough, so some team members had an older version of the flowchart while others had a more updated version, which caused confusion and a lot of mistakes. We overcame this issue by delegating one individual as the flowchart supervisor while the remainder of the group clarified what they should add or eliminate to the flowchart.

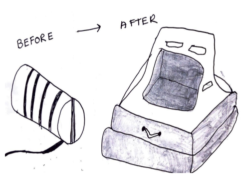
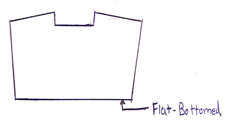
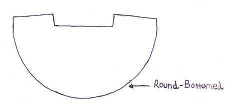
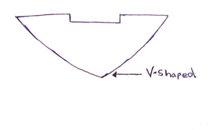
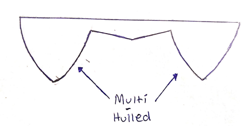
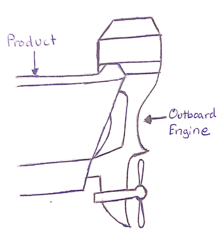
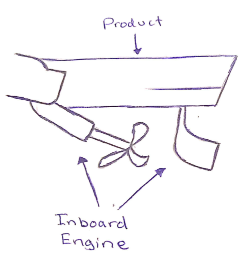
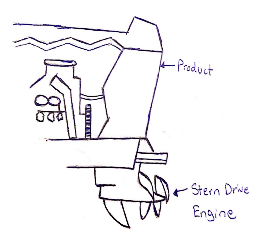
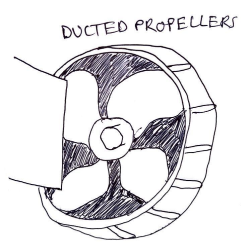
Some noteworthy aspects of the system design of our product include:

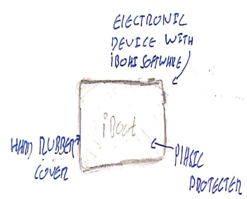
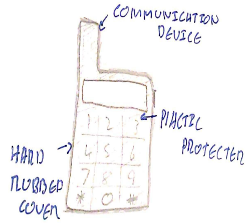
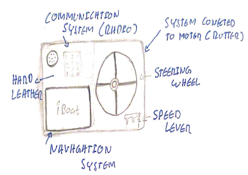
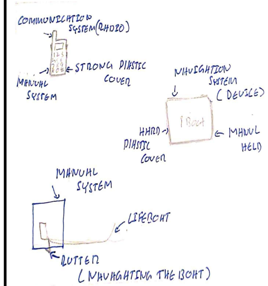
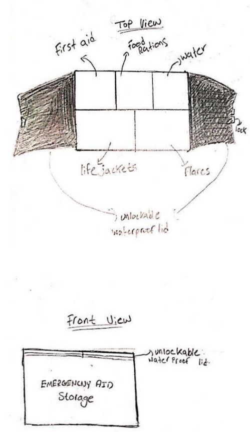
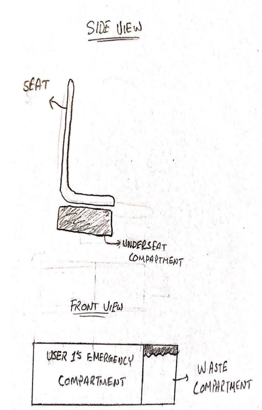
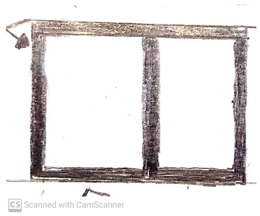
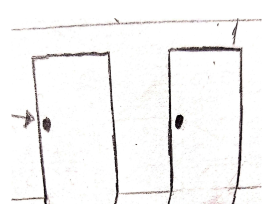
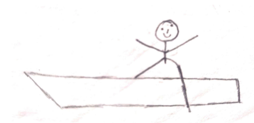
- ❖ We chose to incorporate the effects that the elements and the environment could have on our product’s overall structure in our system diagram. This is essential so that our design does not fail when used in practice.
- ❖ We added a subsystem called a self-righting system in case our product capsized, and this consists of some sort of inflation bag that is designed to reorient the system if it is not faced upwards.

concept design

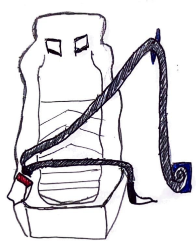
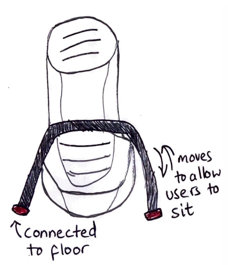
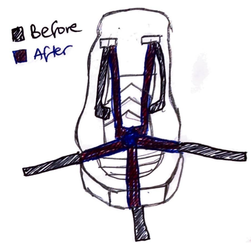
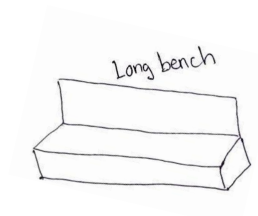
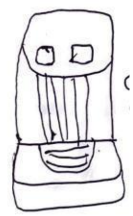
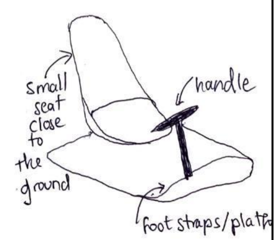
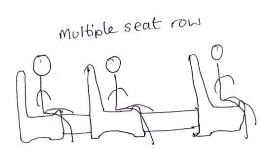
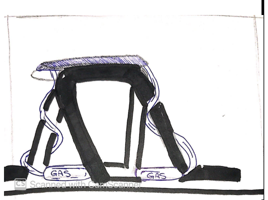
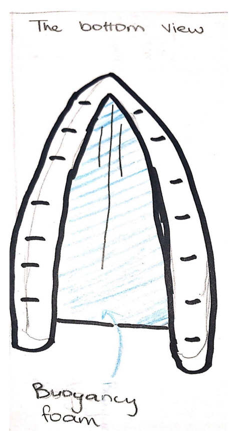
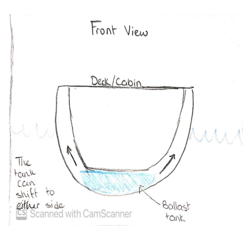
ideation

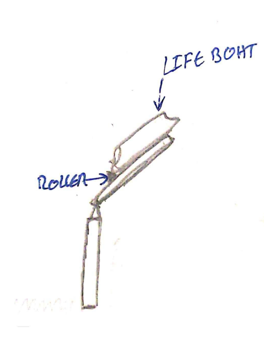
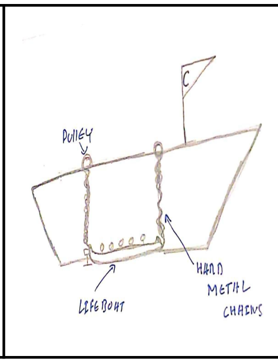
Table 30: Design concepts for each subsystem and their respective drawings

Subsystem	Design Concept #1	Design Concept #2	Design Concept #3	Design Concept #4	Design Concept #5
Structural System	Inflatable convertible Cabin	Flat-bottomed hull	Round-bottomed hull	V-shaped hull	Multi-hulled
					
Propulsion System	Outboard engine	Inboard engine	Stern drive engine	Ducted propellers	Paddles
					
Navigation & Communic	Navigation and communication system device 1	Navigation and communication system device 2	Components are installed onto one panel and display the system for one	Separated components used manually and kept in storage for	N/A

ation System			user.	different users	
					N/A
Emergency Aid System	Personalized first aid bag	Large storage container split into multiple sections.	Underseat compartment	N/A	N/A
				N/A	N/A
Passenger Access System	Door sliders	Hinge doors	No doors (Open design)	N/A	N/A
				N/A	N/A
	3-point seatbelt	Lap bar restraint	5-point harness	Roller coaster restraint	N/A

Passenger

Securing System					N/A
Passenger Seating System	Long bench	Traditional seating	Low to the ground seating	Multiple connected seats in a row	
					
Self-righting System	Inflation bag	Buoyancy foam	Movable ballast tank	N/A	N/A
				N/A	N/A
***Deployment System**	Free-fall mechanism	Onload mechanism			

			N/A	N/A	N/A

*Notice: Free-fall mechanisms require the maritime escape system's structure to be fully or partially enclosed while Onload mechanisms allow the structure to be either open or closed. This is important in understanding our concepts.

1. **Structural System**
    a. Functional Requirement:
        i. Resist corrosion
        ii. Withstand temperature range
        iii. Support users weight
        iv. Protect passengers from elements
    b. Embodiments:
        i. ***Inflatable convertible cabin:*** The exoskeleton of the product is designed so that when the product is inflated, the cabin can be covered with a thin sheet of material that would provide cover from incoming waves and splashing waters.
        ii. ***Flat-bottomed hulls***: The bottom (hull) of the maritime escape system is flat. This type of hull design is very stable for fishing and other uses on small and calm water bodies [44].
        iii. ***Round-bottomed hulls***: are also known as displacement hulls designed to move smoothly through the water with minimum or little effort. However, this design concept is found to be less stable and can quickly capsize [44].
        iv. ***V-shaped hulls***: Also known as planing hulls and are known to be the most common in powerboats. The deep v-shaped hulls can plane on the water

at higher speeds and provide a smoother ride through choppy water. V-shaped hull designs are usually equipped with larger engines than round or flat-bottomed hulls [44].

v. ***Multi-hulled:*** Depending on the hull's engine and shape size, this design concept can either have displacement or planing hulls. This hull design is known to have the most stability on water but requires more room to steer and turn [44].

c. How the embodiments relate to the personas:

i. Since the round-bottomed hull design is less stable, it will be difficult for Alexander and Sheela to board and exit the maritime escape system due to their low mobility. They would both have to be extremely careful. Otherwise, they can lose their balance and fall.

ii. Alexander and Sheela would have difficulty trying to get in and out of the inflatable cabin due to its lack of stability.

2. Propulsion System

a. Functional Requirement:

i. This system enables the product to move on the surface of the water by using the necessary propulsion force

b. Embodiments:

i. ***Outboard engine:*** An engine that is mounted on the transom of the maritime escape system and outer part of the system's hull [34].

1. In order to use this engine, a hand tiller is used to power and steer the product.

ii. ***Inboard engine:*** This engine is located inside the hull, consisting of a four-stroke automotive engine that powers a drive shaft connected to a propeller [44] .

1. Includes a rudder that is located behind the propeller and is controlled by a steering wheel.

iii. ***Stern drive engine:*** A combination of inboard and outboard engine, which uses a four-stroke automotive engine attached to the inside of the hull to power the maritime escape system [44].

1. A steering wheel is used to determine the direction of the product.

iv. ***Ducted propellers:*** This consists of a tunnel-like construction on the backside of the hull with a propeller inside the duct's end has a smaller diameter than the front, which allows the water to be pushed through at a higher force, causing the vehicle to move with more power [45].

v. ***Paddles:*** These are the most simple form of propulsion and would work pretty well in calm waters. However, It may be hard for some users to use paddles efficiently, and it would be very hard using them if there is a storm of some sort.

c. <u>How the embodiments relate to the personas:</u>

i. Alexander is an older man, Johnny and Fatima are very young, and Sheela is a pregnant woman. All these people will have an extremely hard time using the paddles to push the maritime escape system.

3. Navigation & Communication System

a. <u>Functional Requirement:</u>

i. Navigation

1. Pinpoints the vessels current location
2. Suggest the user faster route options

ii. Communication

1. Alert nearby vessels
2. Communicate with offshore help services

b. <u>Embodiments:</u>

1. **Rubber cover:** Protective layer of hard rubber that will keep dust and small particles out of the system and is a good insulator if the system malfunctions.
2. **Plastic layer:** Provides a protective layer of hard plastic that will keep the system waterproof in case of any outside rain or accidental spillage.
3. **System on one panel:** This layout of the navigation and

communication system will allow the user to have everything in clear view and will only require one user to use the whole system.

4. **Manual usage:** The system is broken up into three components and will require the use of a minimum two users to utilize the system’s functions. The devices will be packed away in the storage system.

ii. Navigation

1. **TZ iBoat:** An advanced software that is made easy to use and provides safe navigation to the user. Some features include weather forecast, worldwide map navigation, maritime traffic display, and this can all be done offline [46].
2. **Open CPN:** This software features live traffic updates, multiple route options, voice navigation and requires a stable internet connection.

iii. Communication

1. **ICOM M802 SSB radio:** The radio system allows the user to communicate with nearby vessels and allows the user to communicate with offshore stations [47].
2. **Iridium Satellite Phone**: Allows communication through internet connection worldwide. Communication connection varies on the weather.
3. **Iridium Go**: An advanced software that allows the user to text and send voice messages using an internet connection. This software also can come connected with the navigation system.

c. <u>How the embodiments relate to the personas:</u>

i. Johnny and Fatima will both will experience difficulty utilizing the navigation and communication system as the two of them are very young and have relatively little involvement in innovation

ii. Emma will encounter haziness and absence of concentration when attempting to utilize the system as it requires the client's complete consideration and clear vision.

4. **Emergency Aid System**
    a. Functional Requirement:
        i. This system will provide aid to the passengers and crewmate in cases of emergencies.
    b. Embodiments:
        i. ***Personalized first aid bag:*** Simple and effective. A small bag that all users can carry for all required items in case of an emergency requires first aid administration. This type of system would expect the users to already come with equipment such as life vests and food rations.
        ii. ***Large storage containers split into multiple sections:*** This is where we would keep the emergency items such as the food and water supply, first aid, lifejackets, and flares. A large storage container is effective to keep the majority of essential equipment in one area. Also, splitting up the container sections is effective for accessibility and ease of finding the correct equipment or items.
        iii. ***Underseat compartment:*** Accessible and effective. This would be a personalized compartment under each user's seat. Users wouldn't have to get up to use any of the emergency aid items. Also, there would be a waste compartment next to the first aid compartment if needed to get rid of any waste users create. This will save space in the already crowded maritime escape system.
    c. How the embodiments relate to the personas:
        i. Alexander is old. Therefore he will have trouble disposing of his waste if the waste compartment is not near him, so if the under-seat waste compartment is there it will make it easier for Alexander to access.
        ii. Since the compartments are organized into their respective sections, it will make it easier for all personas to differentiate the items, making it accessible.

5. **Passenger Access System**
    a. Functional Requirement:

   i. Provides passengers with an easy, safe and secure way to enter and exit the maritime support system.

b. <u>Embodiments:</u>
   i. ***Door sliders (horizontal):*** These doors would only work on a fully enclosed or partially unclosed system. Depending on the system and its design, these doors could either be made of thin breathable material that is still rigid enough to protect against the elements or solid metal or plastic design. The sliding doors should automatically open up when the maritime escape system is capsized to allow passengers to leave the system if needed.
   ii. ***Hinge doors:*** These doors will include ramps, which can only work on a fully enclosed or partially unclosed system. The doors should automatically open up when the boat is capsized to allow the passengers freedom to leave the system if needed.
   iii. ***No doors:*** This system would work with fully open systems as they wouldn't need a door in order to enter.

c. <u>How the embodiments relate to the personas:</u>
   i. It may be hard for Sheela to get into a fully open system with no doors because she is pregnant and the side of the boat might be too high for her to step over.
   ii. It may be hard for Alexander to get into a fully open system with no doors because he is old and the side of the boat might be too high for him to step over.
   iii. It may be hard for Johnathan and Fatima to get into a fully open system with no doors because they are young and somewhat short, and the side of the boat might be too high for them to step over.

6. **Passenger Securing System**
   a. <u>Functional Requirement:</u>
      i. Secure passengers in place so that they are safe while also being comfortable.

b. Embodiments:

i. ***Three-point seat-belt:*** Very simple, yet very effective. It has some adjustability and protects the user very well. It fits a range of different people; however, might not be good for smaller users. The users would have to manually open up this seatbelt in order to release themselves if the maritime escape system capsizes.

ii. ***Lap bar restraint:*** This would be a rubberized moveable bar that the users can pull down and position close to their body. Compared to seat belts, the general public might find this option somewhat uncomfortable. Despite this, due to its mechanics, it usually fits a wide range of users. This design could automatically open up using perhaps a mechanical mechanism or a hydraulic mechanism that would allow users to escape if the maritime escape system capsizes easily.

iii. ***Five-point harness:*** This type of harness would provide extra safety as it secures the user in place at different points in the body. It is also adjustable, so it would accommodate many other users. The users would have to manually open up this seatbelt in order to release themselves if the maritime escape system capsizes.

iv. ***Roller coaster restraint:*** This restraint supports the rider's upper body and limits the movement of the user within the seat. It would fit sideways to avoid taking up too much space if it came down from above the head. It is the safest and most secure option; however, it would take up more space than traditional seat belts, increase production costs, and be quite uncomfortable after a while and has limited adjustability. This design could automatically open up using perhaps a mechanical mechanism or a hydraulic mechanism that would allow users to escape if the maritime escape system capsizes easily.

c. How the embodiments relate to the personas:

i. Johnny McDonnel and Fatima Abdullah may have some troubles with embodiment i. and iv. due to the lack of adjustability. They are both young, short and small so embodiments ii. and iii. might be better for them as they can adjust the straps and the bar to fit right up against their bodies.

ii. Sheela Stanley is a pregnant woman so the securing system must allow her to sit down freely and not feel restricted. Therefore embodiments ii. and iv. Would probably not work well with her when compared to the other two embodiments that are made out of flexible straps and not hard/rubberized bars of plastic/metal

iii. Embodiment ii. may sometimes add pressure to the user's thighs and knees, Alexander Bushmelov is an older man who might have some muscular or joint issues so this might not be the greatest option for him.

7. **Passenger Seating System**
   a. Functional Requirement:
      i. Support users of different physical characteristics
      ii. Accommodates six users
      iii. Secure passengers
   b. Embodiments:
      i. ***Long bench:*** This is a simple method of seating that is currently used in existing water vehicles. If it is designed properly, this type of seating could be very safe and comfortable for the users. However, there is a lack of personalized space for each person.
      ii. ***Traditional seating:*** This is the most well-known type of seating that is found on all types of transportation. It performs the functional requirements properly. An issue with this would be how we would implement it in the structure without taking too much space and increasing the overall weight significantly.
      iii. ***Low to the ground seating***: This type of seating has been inspired by the following design here. We would have to somewhat alter the design in order to accommodate all people. It can be used with various types of securing methods and would not take much space on the maritime

escape system.

iv. ***Multiple connected seats in a row***: This is similar to the long bench; however, in this design, the users would have personalized seating and would be organized differently.

c. How the embodiments relate to the personas:

i. Sheela and Alexander would have a hard time using the low to the ground seating due to pregnancy and age. The other seating embodiments would work much better with those personas.

8. Self-righting System

a. Functional Requirement:

i. Reorient the product into the upright position in case of capsizing.

b. Embodiments:

i. ***Inflation bag:*** Simple, compact, and effective for the unenclosed maritime escape system. It can be folded and does not take up much space. It is designed to be inflated by a gas that is supplied through a hose line connected to the gas cylinders. In the event of a capsize, this system will reorient the product into an upright position while the passengers are safely holding onto the supporting lead line.

ii. ***Buoyancy foam:*** It is injected into the space between the inner and outer shells of the product. It effectively provides stability and safe self-righting ability on fully enclosed marine escape systems without requiring the users to get off the vehicle.

iii. ***Movable ballast tank***: It is a compartment within the product that holds water, the water moves in and out of the product and provides balance and stability to the product. It is designed to change the centre of the vehicle's mass to bring it back into the upright position and is an effective self-righting method.

c. How the embodiments relate to the personas:

i. Inflation bags in combination with the supporting lead line, will help Johnny, Alexander and Fatima hold onto the product while the self-righting system is in action.

ii. Similarly, the buoyancy foam and ballast tank will assist in keeping all the personas in a steady equilibrium on the cabin while the vehicle is in use.

9. **Deployment System**
   a. Functional Requirement:
      i. It allows the lifeboat to be deployed into open waters safely and quickly.
   b. Embodiments:
      i. ***Free-fall mechanism***: The lifeboat is deployed from a mechanism that is installed on the vessel. The mechanism is installed at the side of the boat at a high level compared to the water. The lifeboat is released from this mechanism into the water and the self-writing system plays a role in this deployment.
      ii. ***Onload mechanism:*** The lifeboat is lowered till it reaches the water with a pulley system installed on the vessel. The pulley is connected on both sides of the lifeboat with rigid metal chains. As the lifeboat is near the vessel, a lever is pulled within the lifeboat that releases it into the water.
   c. How the embodiments relate to the personas:
      i. Johnny, Emma, Alexandra, Fatima, and Sheela will not have the option to work these systems as just clients with experience and training ideally, and crewmembers will control the utilization of this system.
      ii. This system includes a lot of movement, and Sheela being pregnant, will find it challenging to support the crewmembers. Johnny and Fatima are small children who can't completely handle guidelines unmistakably and can not uphold the crew members.

TOTAL CONCEPTS: 5 x 5 x 4 x 3 x 4 x 3 x 3 x 4 x 3 = 129,600 CONCEPTS

inconsistent embodiments

Inconsistent embodiments happen when two embodiments from different subsystems are not compatible. This, therefore, eliminates any concepts that might include those two embodiments as they would not work. We were able to identify 29 inconsistent embodiments. Since we were left with hundreds of possible design concepts, we decided to use the hill-climbing method to determine which concepts would go through instead of using brute force. Below you will find a screenshot of the inconsistent embodiment chart. The inconsistent embodiments chart can be found here and the justifications chart can be found here.

Subsystem	***Embodiment Name***		A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D1	D2	D3	E1	E2	E3	E4	F1	F2	F3	G1	G2	H1	H2	H3	H4	I1	I2	I3
Structural	Inflatable Convertible Cabin	A1	-					X	X	X					X						X		X		X	X	X		X	X			X	X	
	Flat-Bottomed Hull	A2	-	-								X														X	X								
	Round-Bottomed Hull	A3	-	-	-							X																							
	V-Shaped Hull	A4	-	-	-	-						X																							
	Multi-Hulled	A5	-	-	-	-	-					X															X								
Propulsion	Outboard Engine	B1	-	-	-	-	-	-																											
	Inboard Engine	B2	-	-	-	-	-	-	-																										
	Stern Drive Engine	B3	-	-	-	-	-	-	-	-																									
	Ducted Propellers	B4	-	-	-	-	-	-	-	-	-																								
	Paddles	B5	-	-	-	-	-	-	-	-	-	-						X															X	X	
Navigation and Communication	Navigation and communication syst	C1	-	-	-	-	-	-	-	-	-	-	-																						
	Navigation and communication syst	C2	-	-	-	-	-	-	-	-	-	-	-	-																					
	Components are installed onto one	C3	-	-	-	-	-	-	-	-	-	-	-	-	-																				
	Separated components used manua	C4	-	-	-	-	-	-	-	-	-	-	-	-	-	-																			
Emergency Aid	Personalized first aid bag	D1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																		
	Large storage container split into mu	D2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																	
	Underseat compartment	D3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			X							X		X	X			
Passenger Securing	3-point seatbelt	E1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-															
	Lap bar restraint	E2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-														
	5-point harness	E3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-													
	Roller coaster restraint	E4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						X						
Self-righting	Inflation bag	F1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-											
	Buoyancy foam	F2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-										
	Movable ballast tank	F3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-									
Deployment	Free-fall mechanism	G1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						X		X
	Onload mechanism	G2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-							
Passenger Seating	Long Bench	H1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
	Traditional Seating	H2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-					
	Low to the ground seating	H3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
	Multiple connected seats in a row	H4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Passenger Access System	Door Sliders (Horizontal/Vertical)	I1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	Traditional door	I2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	No doors (Open design)	I3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Figure 8: Inconsistent embodiments chart

initial concepts

When developing our design concepts, we decided that it would be suitable to use the hill-climbing method as opposed to the brute force method. This is because our morphological chart has more than 200 concepts, even after removing the inconsistent embodiments.

Concept #1: **Original Sketch:**

- ***Structural:*** V-Shaped Hull
- ***Propulsion:*** Outboard Engine
- ***Navigation & Communication:*** Components are installed onto one panel and display the system for one user
- ***Emergency Aid System:*** Underseat compartment
- ***Passenger Securing:*** Lap bar restraint
- ***Passenger Seating:*** Traditional Seating
- ***Self-righting:*** Inflation bag
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** No doors (open system)

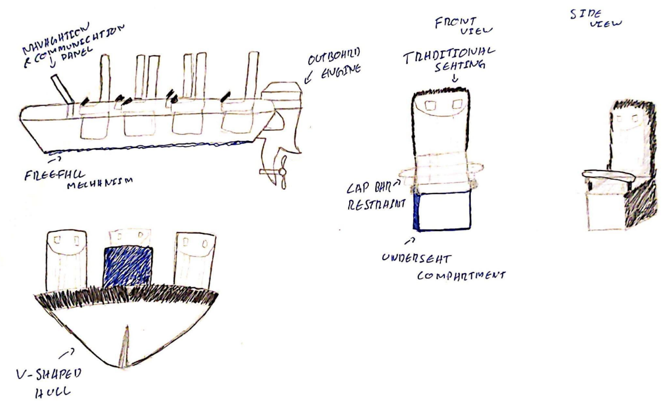


Figure 9: Original sketch of concept #1

The issue distinguished in this design concept is ergonomic. The lap bar constraint is intended to protect the client when the item is being utilized in awful climate conditions as the bar keeps the user locked in one place, yet this likewise eliminates the client's capacity to twist or reach compartments under the seat for the medical aid pack in the event of crises. This causes an issue in light of the fact that the lap bar requirement is secured once positioned in position and must be opened by a mechanical system that opens all the client's lap bars and causes a hazardous climate for all clients. This issue identifies with the requirement (2e.ii), which expresses that the emergency treatment kid must be effectively accessible for the clients. This issue can be settled by utilizing the three-point safety belt which gives the client movability and easy access to the under-seat compartments without placing the client in a dangerous circumstance.

Final List of Embodiments:

- ***Structural:*** V-Shaped Hull
- ***Propulsion:*** Outboard Engine
- ***Navigation & Communication:*** Components are installed onto one panel and display the system for one user
- ***Emergency Aid System:*** Underseat compartment
- ***Passenger Securing:*** 3-Point seat belt
- ***Passenger Seating:*** Traditional Seating
- ***Self-righting:*** Inflation bag
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** No doors (open system)

Final Sketch:

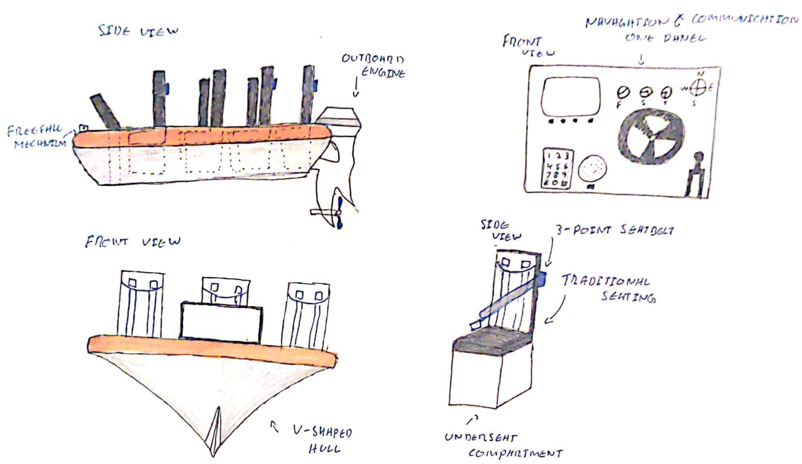


Figure 10: Final concept 1 sketch

Brief verbal description of design concept 1:

This design includes a V-shaped hull that is intended to plane on top of the water at higher speeds and give a smoother ride through rough waters. This design is propelled by an onboard motor on the backside of the system. The seating framework comprises four rows; the first and last rows have one seat while the second and third-rows have two seats making a total of 6 seats meaning six users. Every one of the six seats will incorporate a 3-point seatbelt to ensure the passenger is secure. Under each seat, there will be a compartment conveying emergence aid kits and personal protective gear. The deployment system will be a freefall system that will drop the maritime escape system into the water. The self-righting system is an inflation bag situated on each side of the boat. The navigation and communication system will be found at the front of the framework and will be controlled by the pilot from one control board. Lastly, this design will be a no door design that permits the user to enter and leave the framework rapidly and proficiently in the event of crises.

Concept #2: **Final Sketch:**

- ***Structural:*** Round-bottomed hull
- ***Propulsion:*** Ducted Propellers
- ***Navigation & Communication:*** Separated components used manually and kept in storage for different users
- ***Emergency Aid System:*** Large storage container split into multiple sections
- ***Passenger Securing:*** 5-point harness
- ***Passenger Seating:*** Multiple connected seats in a row
- ***Self-righting:*** Movable ballast tank
- ***Deployment:*** Onload Mechanism
- ***Passenger Access:*** Hinge Door

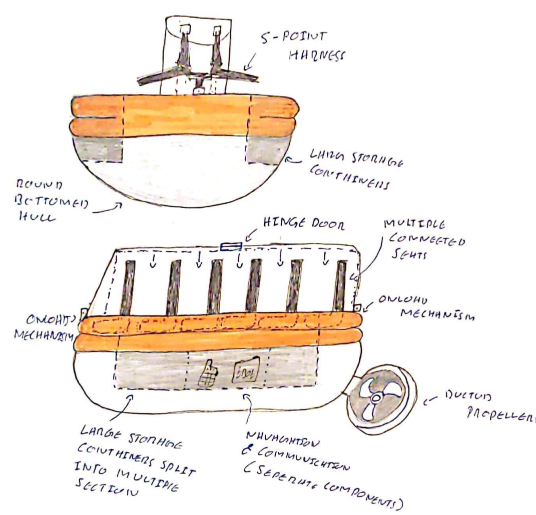


Figure 11: Final sketch for concept 2

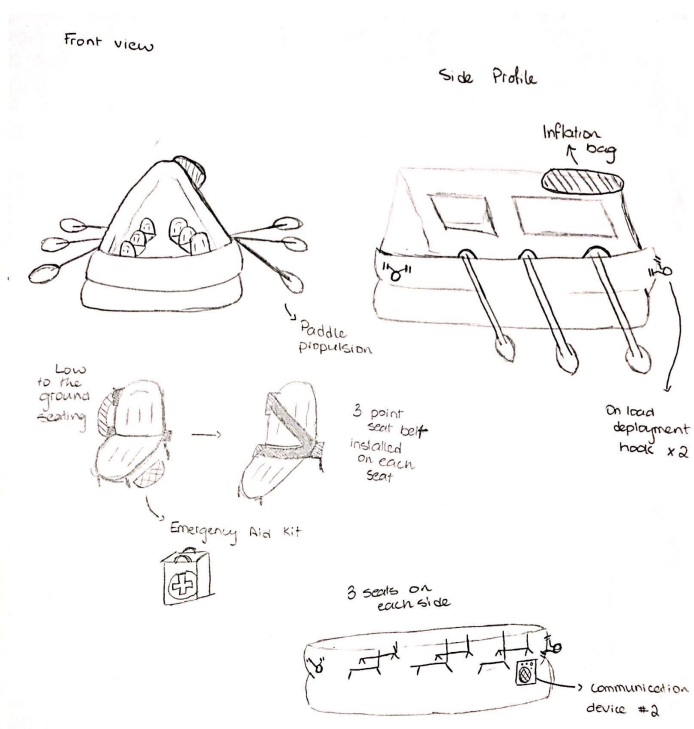
For this design idea, there weren't any issues distinguished, therefore we decided to move it onto the final design concepts where we will be evaluating the design in the concept evaluation section of this report.

Brief verbal description of design concept 2:

This design has a round-bottomed hull that is intended to move smoothly through the water with little effort . This design is propelled by a ducted propeller that is located on the backside of the system. The seating framework consists of one row which has a total of six seats back to back meaning six users. Every one of the six seats will incorporate a 5-point harness to make sure the passenger is secure. On each side of the boat , there will be a large storage compartment conveying emergence aid kits and personal protective gear. The deployment system will be an on-load mechanism to lower the maritime escape system into the water. The self-righting system is a movable ballast tank situated on each side of the boat. The navigation and communication system will be found in the large storage compartments and the system will be navigated by the pilot from the front navigation panels connected to the ducted propellers. Lastly, this design will be a hinge door design that permits the user to stay safe from the surrounding environment such as bad weather or bad water conditions.

Concept #3: **Original Sketch:**

- ***Structural:*** Inflatable convertible cabin
- ***Propulsion:*** Paddles
- ***Navigation & Communication:*** Navigation and communication system device 2
- ***Emergency Aid System:*** Personalized first aid bag
- ***Passenger Securing:*** 3-point seatbelt
- ***Passenger Seating:*** Low to the ground seating
- ***Self-righting:*** Inflatable bag
- ***Deployment:*** Onload Mechanism
- ***Passenger Access:*** No doors (Open



system)

Figure 12: Original sketch of concept 3

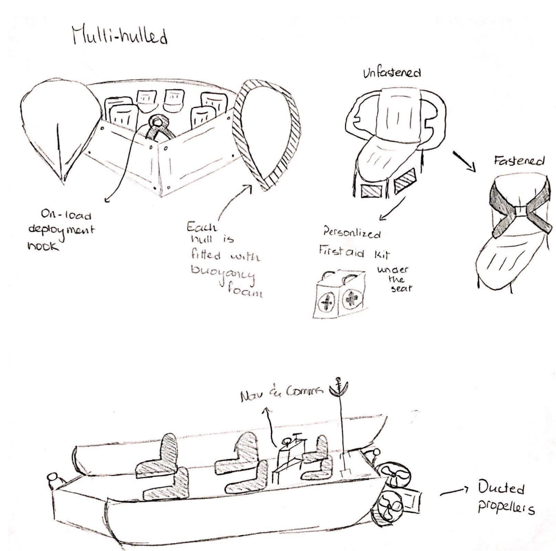
For this design concept, there weren't any problems identified by all group members. The embodiments do function together and no issues were identified; therefore we carried onto the final design concepts where we will evaluate the design in the concept evaluation section.

Brief Verbal Description of design concept 3:

This concept design consists of an inflatable structural system, the hull and body of this design is entirely inflatable. This design is propelled by 6 paddles located at every seat. The navigation and communication system consists of a portable device that is brought on board upon inflation of the maritime escape system. The seating system consists of 3 rows of 2 separated low to ground seats equipped with a 3-point seat belt which will secure the passengers onto their seats. There is no passenger access system since it is a partially enclosed design where the users can hop on over into the inside and take their seats. There are 2 compartments under each seat, one of which is the emergency aid component and the other is a waste compartment. The self-righting system used for this design is the inflation bag which is located at the rear end on top of the partial enclosure. The structural system is also equipped with on-load release mechanism hooks on the product's front and back end.

➔ Concept #4:

Original Sketch:



Original Embodiments:

- ***Structural:*** Multi-hulled
- ***Propulsion:*** Ducted Propellers
- ***Navigation & Communication:*** Navigation and communication system device 1
- ***Emergency Aid System:*** Underseat compartment
- ***Passenger Securing:*** Roller coaster restraint
- ***Passenger Seating:*** Traditional seating
- ***Self-righting:*** Buoyancy foam

- ◆ ***Deployment:*** Onload mechanism
- ◆ ***Passenger Access:*** No doors (Open system)

Figure 13: Original Sketch of Concept 4

Brief Verbal Description of design concept 4:

This design is multi-hulled, which means there are two hulls supporting the product, the middle platform is where the passengers will be seated. This design concept is propelled with ducted propellers at the rear end of the product. The navigation and communication system consists of a panel located in front of the rear seats. The seating system comprises 3 rows of 2 traditional seats equipped with a roller coaster constraint to secure the passengers in their seats. There are two compartments under each seat, one of which is the emergency aid component and the other is a waste compartment. For the self-righting system, both the hulls are fitted with buoyancy foam. The structural system is also equipped with on-load release mechanism hooks on the product's front and back end. Lastly, this design is a fully open maritime escape system, which means the product will not have any doors, and the users can enter the product by going over either hull to go onboard.

The problem identified would be ergonomic. The rollercoaster constraint would hold the users tightly to the seat, and it would be somewhat challenging for the users to reach down into the under-seat storage compartment to access the first aid kit. If the user cannot reach down to the compartment, they would have to unfasten the seat belt to access the first aid kit, unsafe while the vehicle is in motion. This relates to the requirement (2e.ii), which states that the first aid kid must be easily accessible for the users. This situation can be avoided by switching out the roller coaster constraint with the 3 point seat belt, which would give some room for the users to move around in their seats and enable them to reach down and grab any emergency aid components provided in the under-seat storage compartment.

***For the final sketch just swap the roller coaster restraint with the 3-point seat belt in the sketch above**

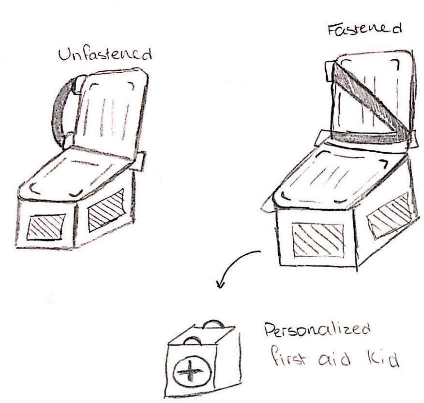


Figure 14: Final sketch of concept 4

Final Embodiments:

- ***Structural:*** Multi-hulled
- ***Propulsion:*** Ducted Propellers
- ***Navigation & Communication:*** Navigation and communication system device 1
- ***Emergency Aid System:*** Underseat compartment
- ***Passenger Securing:*** 3 point seatbelt
- ***Passenger Seating:*** Traditional seating
- ***Self-righting:*** Buoyancy foam
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** No doors (Open system)

Concept #5:

- ***Structural:*** Flat-bottomed hull
- ***Propulsion:*** Inboard engine
- ***Navigation & Communication:*** Components are installed onto one panel and display the system for one user
- ***Emergency Aid System:*** Large storage container split into multiple sections
- ***Passenger Securing:*** Lap bar restraint
- ***Passenger Seating:*** Long bench
- ***Self-righting:*** Buoyancy foam
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** Door sliders (horizontally)

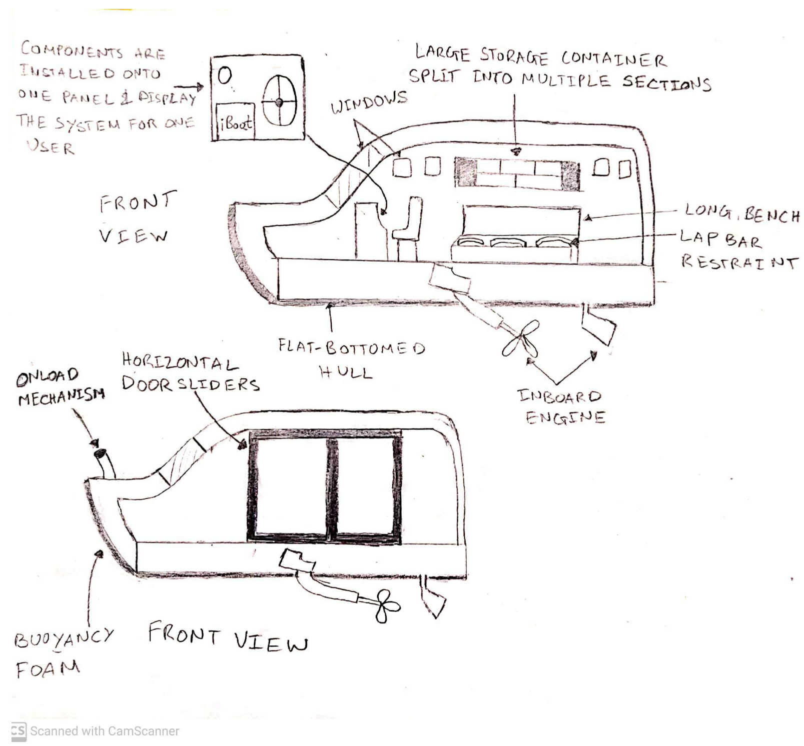


Figure 15: Final sketch for concept 5

For this design concept, there weren't any problems identified by all group members. The embodiments do function together, and no issues were identified; therefore we carried onto the final design concepts where we will evaluate the design in the concept evaluation section.

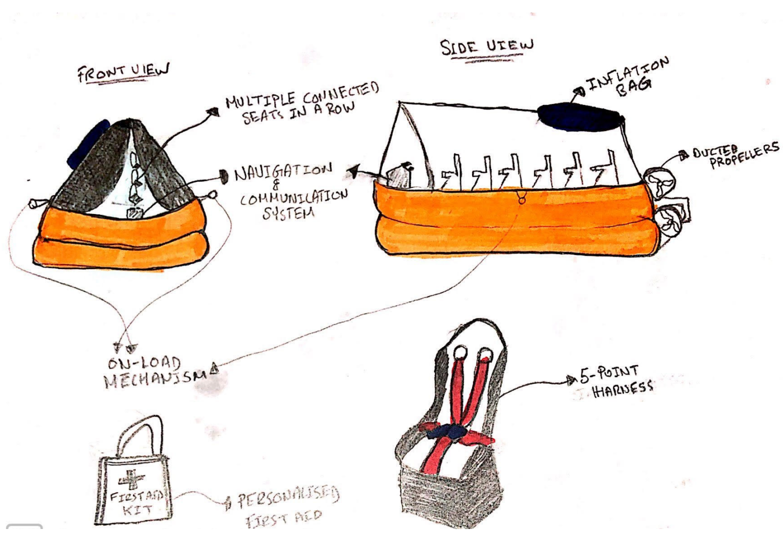
Brief verbal description of design concept #5:

Concept #5 has a flat-bottomed hull structure, in which the bottom of the lifeboat is flat. It contains an inboard propulsion system for which the engine is inside the hull. In terms of navigation and communication systems, it is situated on one control panel that includes everything and is used by one user. The emergency aid system, which is a large container in sections, is on the walls of the lifeboat; that way, it is easier for passengers to access it. There is a long bench for passengers to sit on with a lap bar restraint to secure themselves. This lifeboat will use an onload mechanism to deploy and a buoyancy foam in case of a capsize. Horizontally sliding doors are used in this design to minimize energy to open and close the access system.

Concept #6:

Original List of Embodiments

- ***Structural:*** Inflatable convertible cabin
- ***Propulsion:*** Ducted Propellers
- ***Navigation & Communication:*** Separated components used manually and kept in storage for different users
- ***Emergency Aid System:*** Personalized first aid bag
- ***Passenger Securing:*** 5-point harness
- ***Passenger Seating:*** Multiple connected seats in a row



- ***Self-righting:*** Inflation bag
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** No Door (Open Design)

Figure 16: Original sketch for concept 6

The problem identified in this design is ergonomic. The inflatable cabin's room would be extremely tight as the 5-point harness requires a large seat to incorporate in the design. Having six seats with the 5-point harness would cause the room inside the inflatable cabin to be very tight and hard to move around. This could have negative impacts on users who are claustrophobic. This relates to requirement (3a), which states that the maritime escape system must have space to move around inside its hull. The situation can be avoided by switching out the 5-point harness constraint with the 3-point seatbelt, which does not require the seat to be as large, allowing for more space to be freed up inside the maritime hull escape system.

***For the final sketch just swap the 3-point seatbelt for the 5-point harness used in the sketch above**

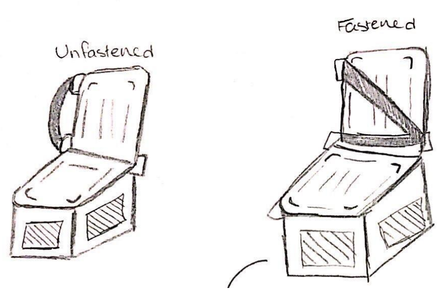


Figure 17: Final sketch for concept 6

Brief verbal description of design concept 6:

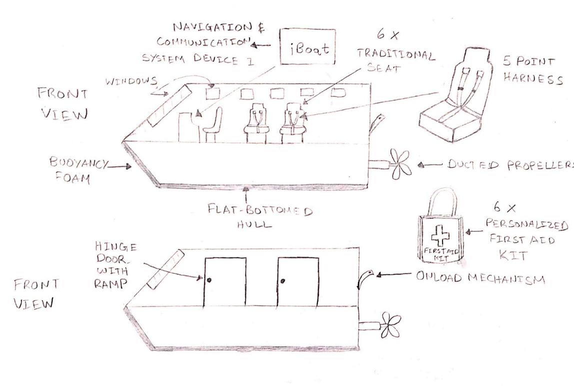
The design is an inflatable convertible cabin, so the hull is inflatable and it is covered by a convertible covering to shield the system from the elements. This design is propelled by ducted propellers that are attached to the back of the system. Navigation and communication comprise the front panel where the overall system can be operated and multiple components kept in other compartments on the system. The seating system will be one row of six seats through the front of the system till the back of the system. Each seat will have a backrest where a 3-point seatbelt will extrude from and secure all passengers per seat. The emergency aid system will be a personalized first aid bag that will be given to each user after they board the system. The self-righting system is an inflation bag that is located on top the covering used to shield the users from the elements. The deployment system will be an on-load mechanism to lower the maritime escape system into the water. The hooks for the on-load mechanism are located at the left and right side of the product. Lastly, this design will be a no door design, which means users can enter our product by going over the design side, rather than opening some sort of door.

Final List of Embodiments

- ***Structural:*** Inflatable convertible cabin
- ***Propulsion:*** Ducted Propellers
- ***Navigation & Communication:*** Separated components used manually and kept in storage for different users
- ***Emergency Aid System:*** Personalized first aid bag
- ***Passenger Securing:*** 3-point harness
- ***Passenger Seating:*** Multiple connected seats in a row
- ***Self-righting:*** Inflation bag
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** No Door (Open Design)

Concept #7:

- ***Structural:*** Flat-bottomed hull
- ***Propulsion:*** Ducted propellers
- ***Navigation & Communication:*** Navigation and communication system device 1
- ***Emergency Aid System:*** Personalized first aid bag
- ***Passenger Securing:*** 5-point harness



- ***Passenger Seating:*** Traditional seating
- ***Self-righting:*** Inflation bag
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** Hinge doors

Figure 18: Final sketch for concept 7

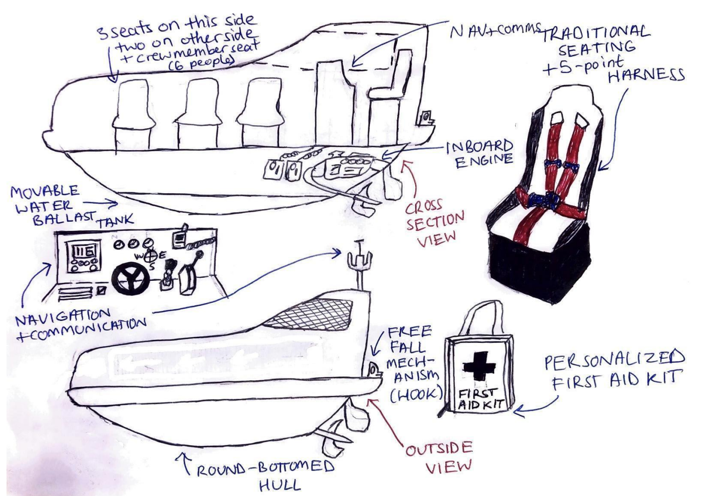
For this design concept, there weren't any problems identified by all group members. The embodiments do function together and no issues were identified, therefore we carried onto the final design concepts where we will evaluate the design in the concept evaluation section.

Brief verbal description of design concept 7:

Concept #7 has a flat-bottomed hull structure, in which the bottom of the lifeboat is flat. It contains a ducted propulsion system for which the propellers are outside the hull. In terms of navigation and communication system, it uses one device called TZ iBoat that controls and includes everything that the product must use to navigate and communicate. The emergency aid system, which is a personalized first bag, will be given to each passenger after boarding. There is a traditional seat for passengers to sit on with a five-point harness to secure themselves. This lifeboat will use an onload mechanism to deploy and a buoyancy foam incase of a capesize. Hinge doors with ramps are used in this design to allow ease of access to all passengers.

Concept #8:

Original Sketch:



- ***Original List of Embodiments:***
- ***Structural:*** Round-bottomed hull
- ***Propulsion:*** Inboard Engine
- ***Navigation & Communication:*** Components are installed onto one panel and display the system for one user
- ***Emergency Aid System:*** Personalized first aid bag
- ***Passenger Securing:*** 5-point harness
- ***Passenger Seating:*** Traditional seating

- ***Self-righting:*** Movable ballast tank
- ***Deployment:*** Free-fall mechanism
- ***Passenger Access:*** Hinge doors

Figure 19: Original sketch for concept 8

The problem identified in this design is environmental. Engines usually run at 140 to 160 degrees celsius. Since, the inboard engine and the ballast tank are very close together, the engine could potentially heat up the water in the moveable ballast tank, which would have to go back into the ocean. Small sea creatures could also get stuck inside and die [48]. This problem relates to requirement 6.d, which clearly states that the product should not have harmful impacts on the surrounding environment. In this case, the movable ballast tank could be replaced with an inflatable self-righting system that would not interfere with the other embodiments and form a better overall concept. The final edited concept design sketch can be seen below.

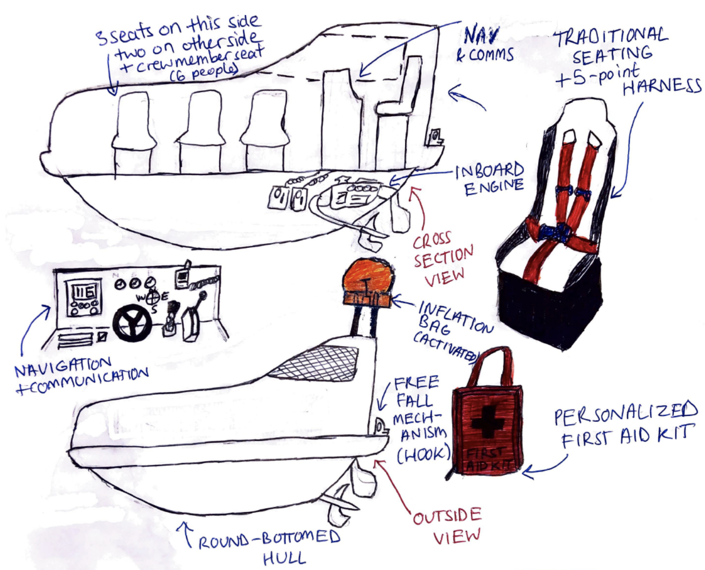


Figure 20: Final sketch for concept 8

- ***Final List of Embodiments:***
- ***Structural:*** round-bottomed hull
- ***Propulsion:*** Inboard Engine
- ***Navigation & Communication:*** Components are installed onto one panel and display the system for one user
- ***Emergency Aid System:*** Personalized first aid bag

- ***Passenger Securing:*** 5-point harness
- ***Passenger Seating:*** Traditional seating
- ***Self-righting:*** Inflation Bag
- ***Deployment:*** Free-fall mechanism
- ***Passenger Access:*** Hinge doors

Brief verbal description of design concept 8:

This design is a round-bottomed hull, allowing the boat to get through the water easily at slower speeds [49]. This design is propelled by an inboard engine, which is integrated into the hull. Navigation and communication is compressed into a panel that has all the controls needed. The seating system will be six traditional seats 3 being on either side or 3 on one side, 2 on the other, and 1 for the crewmember. We used a 5-point harness in this design, which will secure passengers in place. The emergency aid system is a personalized first aid kit for each passenger; this can be held by the passenger or placed on the side of the seat. This concept uses an inflation bag for its self-righting system, which is integrated on top of the structure. The deployment system will be a freefall mechanism that will allow for a quick release in emergency situations. The hooks for the freefall mechanism are located at the back of the product. Lastly, this design will have a traditional door on the back to make it easy for passengers to enter and leave the maritime escape system and works with the freefall mechanism.

Concept #9: **Original Sketch:**

- ***Structural:*** V-Shaped Hull
- ***Propulsion:*** Stern drive engine
- ***Navigation & Communication:*** Navigation and communication system device 1
- ***Emergency Aid System:*** Large storage container split into multiple sections
- ***Passenger Securing:*** Lap bar restraint
- ***Passenger Seating:*** Multiple connected seats in a row
- ***Self-righting:*** Movable ballast tank
- ***Deployment:*** Onload mechanism

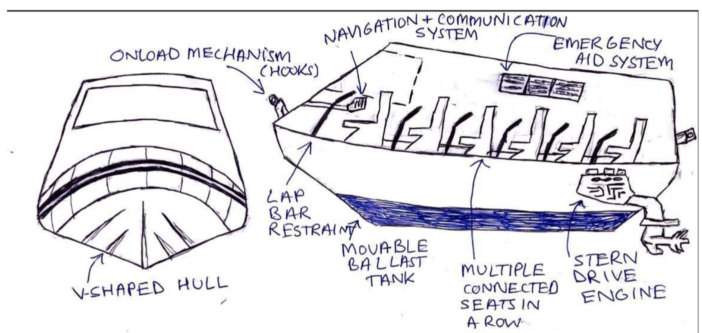


Figure 21: Original sketch for concept 9

- ***Passenger Access:*** Sliding doors

The problem identified in this design is functional. Ballast tanks are usually made of steel which tends to rust when it is not protected properly and especially in salt water. This causes the ballast tank to be a highly corrosive environment. Therefore, this would increase maintenance costs, reduce the lifetime of the vessel and harm the environment due to materials that leave the ballast tank. This problem relates to requirement 6.d which states that the product should not have harmful impacts on the surrounding environment and requirement 1.a which states that the materials used in the product must resist corrosion. In this case, the movable ballast tank could be replaced with buoyancy foam as the self righting system which would not interfere with the other embodiments and would form a better overall concept. The final edited concept design sketch can be seen below.

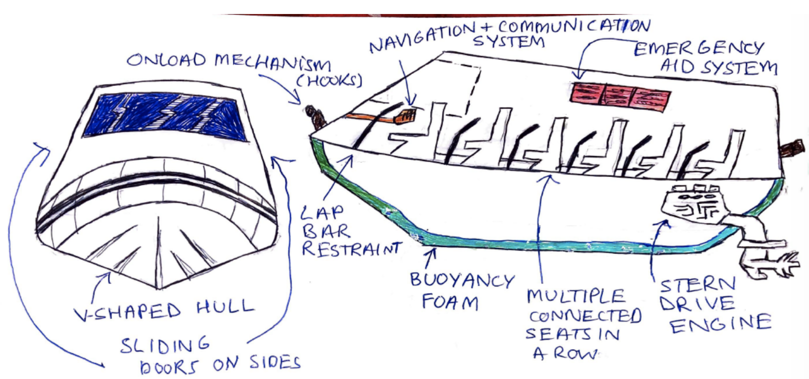


Figure 22: Final sketch for concept 9

Brief verbal description of design concept 9:

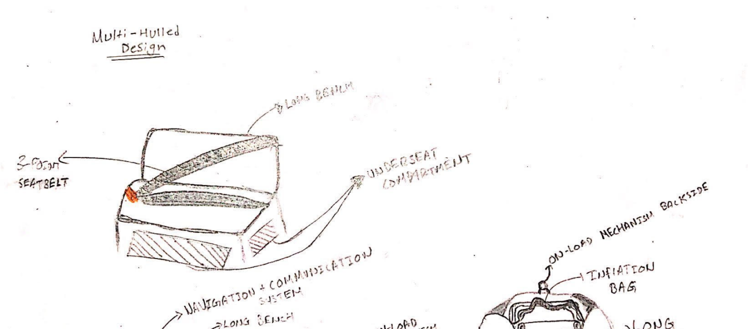
This design is a V-shaped hull that helps the system cut through the water and is way more suitable for open water than other hulls [40]. This design is propelled by a sterndrive engine, which is integrated into the hull. Navigation and communication are compressed into a simple easy to use system called TZ iBoat that has all the controls needed. The seating system will be six seats connected in a row with lap bar restraints for each person that will secure them in place. The emergency aid system is a compartment that is divided into different parts. In this concept, this can be integrated into the floor or on the sidewall of the structure. This concept uses a buoyancy foam for its self-righting system, which is integrated into the design. The deployment system will be an on-load mechanism to lower the maritime escape system into the water. The hooks for the on-load mechanism are located at the front and back of the product. Lastly, this design will have sliding doors on the side of the structure to make it easier for users to enter and leave the maritime escape system.

- ***Final List of Embodiments:***
- ***Structural:*** V-Shaped Hull
- ***Propulsion:*** Sterndrive engine
- ***Navigation & Communication:*** Navigation and communication system device 1
- ***Emergency Aid System:*** Large storage container split into multiple sections
- ***Passenger Securing:*** Lap bar restraint
- ***Passenger Seating:*** Multiple connected seats in a row
- ***Self-righting:*** Buoyancy Foam
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** Sliding doors

Concept #10:

Original/Final List of Embodiments

- ***Structural:*** Multi-hulled
- ***Propulsion:*** Outboard Engine
- ***Navigation & Communication:*** Separated components used manually and kept in storage for different users
- ***Emergency Aid System:*** Underseat compartment
- ***Passenger Securing:*** 3-point seatbelt
- ***Passenger Seating:*** Long bench
- ***Self-righting:*** Inflation bag
- ***Deployment:*** Onload mechanism
- ***Passenger Access:*** No door design



For this design, there wasn't a problem that me and my group could identify. Therefore we decided to move it onto the final design concepts where we will be evaluating the design in the concept evaluation section of this report.

Figure 23: Final sketch for concept 10

Brief verbal description of design concept 10:

This design is multi-hulled, so there are multiple hulls beneath the vessel; the middle area is where the passengers will be located. This design is propelled by an outboard engine on the rear of the system. Navigation and communication comprise the front panel where the overall system can be operated and multiple components kept in other compartments on the system. The seating system will be three rows on long benches where two users can be seated per bench to accommodate all six users. Each bench will have a backrest where a 3-point seatbelt will extrude from and can secure both passengers per bench. Under each bench will be two under-seat compartments, one for each user that consists of a waste component and an emergency aid component. The self-righting system is an inflation bag which is located above the middle bench. The deployment system will be an on-load mechanism to lower the maritime escape system into the water. The hooks for the on-load mechanism are located at the front and back of the product. Lastly, this design will be a no door design, which means users can enter our product by going over the side of the design rather than opening some sort of door.

concept evaluation #1

This is the overall DM (Decision Matrix) for our concepts. The individual DMs for each team member along with the justifications can be found in the appendix.

Table 31: Concept Evaluation #1 Decision Matrix

	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	4	0	0	0	0	0
CONCEPT 1	0	4	1	1	-1	-1	0
CONCEPT 2	0	4	2	-2	-1	-1	2
CONCEPT 3	-6	11	-1	-2	-1	-1	-1
CONCEPT 4	1	3	1	1	-1	-1	1
CONCEPT 5	2	1	2	2	-2	-1	1
CONCEPT 6	-3	9	-1	-2	-1	-1	2
CONCEPT 7	-4	10	1	-2	-1	-1	-1
CONCEPT 8	-2	8	2	-2	-2	-1	1
CONCEPT 9	2	1	2	2	-2	-1	1
CONCEPT 10	0	4	1	1	-1	-1	0

*The justification for individual personas can be found in appendix 2

Key justifications (for overall DM Evaluation #1):

Concept 1:

1. Functionality:

   a. Score: 1
      i. Concept 1 includes seats and a lap bar restraint for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off-balanced situations. Therefore, functionality was given a score of 1. It does not get a score of 2 as it does not protect the passengers from elements since it is an open structure.

2. Usability:
   a. Score: 1
      i. Users will experience the same amount of difficulty boarding the system as the reference design because they both require the passenger to maneuver over the side of the structure. But since the seats have a 3-point seatbelt, the passengers will be safer and more secure than if they were on the reference design. Also, there is an under-seat compartment which makes it easier for them to access anything they may need during their use without having to move that much. Therefore, usability was given a score of 1.
3. Producibility:
   a. Score: -1
      i. Most of our personas required proper seating due to their physical handicaps. While the reference design did not have proper seating for its passengers, concept 1 increased production cost and required more work to be done during manufacturing. Therefore, concept 1 got a score of -1 for producibility as it would be harder to produce the product.
4. Maintainability:
   a. Score: -1
      i. This concept includes a 3-point seatbelt which is an essential component for the safety of the passengers. This would require frequent check-ups to make sure the 3-point seatbelt works properly and does not malfunction during an emergency. These checkups and the maintenance needed (if the seatbelt were to break) would increase the maintenance

cost making it harder to maintain this concept. Also, the under-seat compartment would have to be restocked after every use, which would increase the cost to maintain the design concept compared to the reference design. Therefore, maintainability was given a score of -1.

5. Sustainability:
    a. Score: 0
        i. The propulsion system used in this design concept is an outboard engine which is the same as our reference design, we as a group decided the score to be 0 since the engine is neither better nor worse than that used in the reference design. Also, the system is an open structure, which is the same as the reference design.

Concept 2:

1. Functionality
    a. Score: 2
        i. This concept incorporates a 5-point harness and a proper seating system that is more secure than the reference design, which does not have a seating system. Our design concept is enclosed; therefore it shelters its users from the elements which the reference design does not offer. Due to these reasons, the functionality was scored a 2 as it is much better when compared to the reference design.
2. Usability:
    a. Score: -2
        i. Users will experience more difficulty in entering and exiting the system due to the hinge door system because it requires physical strength and dexterity to open up. The storage systems are larger compartments on the side of the system and are much harder to access without leaving the seat. The 5-point harness would be harder to put on in an emergency situation especially for some of the personas that could include children, pregnant women and the elderly. Therefore, concept 2 got a score of -2 for usability as it would be harder to use the product.

3. Producibility:
    a. Score: -1
        i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers, concept 2 did, increasing production cost and requiring more work to be done during manufacturing. Therefore, concept 2 got a score of -1 for producibility as it would be harder to produce the product.
4. Maintainability
    a. Score: -1
        i. This concept includes a door and a 5-point harness that are essential components for the passengers' safety. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. This design includes a ballast tank that is much more difficult to maintain than an inflation bag on our reference design. Therefore, maintainability was given a score of -1.
5. Sustainability
    a. Score: 2
        i. The ducted propellers used in this concept are very efficient to the environment because they reduce noise pollution. The reduced noise levels will help the passengers sit in the lifeboat without a problem. In the reference design, an outboard engine is used which makes a significant amount of noise compared to concept #2, thus increasing noise pollution in the environment. Concept #2 has an enclosed design that protects the passengers on board and the lifeboat's interior from weather elements like rain. However, the reference design is fully open which leaves the passengers and interior of the lifeboat completely open. Therefore, sustainability was given a score of 2 for concept 2.

Concept 3:

1. Functionality:
    a. Score: -1
        i. This concept incorporates a 3-point seat belt and low to the ground seating system which is more secure when compared to the reference design which does not have a seating system. Additionally, the structure of this concept is not rigid and won't provide protection to the users from exterior elements. Also, if the vehicle was to impact an unknown debris at sea, the whole integrity of the inflatable structure would be affected. Due to these reasons the functionality was scored a -1 as it is much more fragile when compared to the reference design.
2. Usability:
    a. Score: -2
        i. Users will experience the same amount of difficulty boarding the system as the reference design because they both require the passenger to maneuver over the side of the structure. But since the seats have a 3-point seatbelt, the passengers will be safer and more secure than if they were on the reference design. Also, the personalized first aid bag would be useful as each user will have access to one without having to move around the lifeboat. The paddles as the propulsion system would require knowledge and physical strength from the user to be able to use it appropriately, so it would be much more difficult compared to the reference design. Therefore, usability was given a score of -2.
3. Producibility:
    a. Score: -1
        i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers, concept 3 did, increasing production cost and requiring more work to be done during manufacturing. Therefore, concept 3 got a score of -1 for producibility as it would be harder to produce the product.
4. Maintainability
    a. Score: -1

i. This concept includes an open system and a 3-point seat belt which is an essential component for the safety of the passengers. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. This design includes an inflatable bag which is what the reference design has. Therefore, maintainability was given a score of -1.

5. Sustainability
    a. Score: -1
        i. This concept design uses paddles to propel instead of an engine, which reduces pollution in the environment. However, using paddles in rough waters is not ideal for the passengers because they won't be able to sustain enough energy to go to shore just by paddling. Therefore, sustainability was given a score of -1.

Concept 4:

1. Functionality:
    a. Score: 1
        i. Concept 4 includes seats and a 3 point seat belt as a restraint for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off balanced situations. The structure of the vehicle consists of 2 hulls both fitted with buoyancy foam to provide stability and buoyancy while in use. Additionally, buoyancy foam is a self-righting mechanism that does not require user interaction when the vehicle capsizes. Therefore, functionality was given a score of 1. It does not get a score of 2 as it does not protect the passengers from elements since it is an open structure.

2. Usability:
    a. Score: 1
        i. This design concept has traditional seating and a roller coaster restraint which most users are familiar with. However, just like the reference design users are required to maneuver their way onto the structure which can be quite difficult for some people. This concept also comes with an underseat compartment that makes it easier for users to access items during their time using the product. Therefore this concept gets a score of 1 for usability as it is only slightly better than the reference design.
3. Producibility:
    a. Score: -1
        i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers, concept 4 did which increases production cost and requires more work to be done during manufacturing. Therefore, concept 4 got a score of -1 for producibility as it would be harder to produce the product.
4. Maintainability
    a. Score: -1
        i. This concept includes an open system and a 3-point seatbelt which is an essential component for the safety of the passengers. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. This design includes a buoyancy foam self righting system which is harder to maintain when compared to an inflation bag on our reference design. Therefore, maintainability was given a score of -1.
5. Sustainability
    a. Score: 1
        i. The ducted propellers used in this concept are very efficient to the environment because they reduce noise pollution. The reduced noise

levels will help the passengers sit in the lifeboat without a problem. In the reference design, an outboard engine is used which makes significant amount of noise compared to concept #2, thus increasing noise pollution in the environment. Concept design #4 has an open structure design which leaves the passengers and the interior of the lifeboat to be affected from weather elements like rain. The reference design is also fully open which leaves the passengers and interior of the lifeboat completely open. Therefore, sustainability was given a score of 1 for concept #4.

Concept 5:

1. Functionality
    a. Score: 2
        i. Concept 5 includes seats equipped with a lap bar as a restraint for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off balanced situations. Additionally the design structure of this vehicle is enclosed, and will serve as protection to the users from exterior elements while in use. It is also equipped with buoyancy foam as a self righting mechanism which does not require users to unboard the vehicle when it capsizes and can self-reorient itself whilst keeping the passengers safe inside. Therefore, functionality was given a score of 2.

2. Usability
    a. Score: 2
        i. The sliding doors make exiting and entering the lifeboat really easy for most people, on the other hand, the reference design does not have an access system and requires people to hop on which would be difficult for a significant portion of the population. The lap bar restraint is fairly simple to use for all people while securing the passengers very well. Due to these reasons concept 5 received a score of 2 for its usability.
3. Producibility:

a. Score: -2
   i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers, concept 5 did which increases production cost and requires more work to be done during manufacturing. This concept also has an inboard engine which would be harder to manufacture as it is embedded into the structure unlike the reference design which has an outboard engine that could just be installed at the rear end of the lifeboat. Therefore, concept 5 got a score of -2 for producibility as it would be harder to produce the product.

4. Maintainability
   a. Score: -1
      i. This concept includes a closed system with horizontal sliding doors and a lab bar restraint which is an essential component for the safety of the passengers. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. This design includes a buoyancy foam self righting system which is harder to maintain when compared to an inflation bag on our reference design. Therefore, maintainability was given a score of -1.

5. Sustainability
   a. Score: 1
      i. For design concept 5, the inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and the interior of the lifeboat so it can be used in the future again. The reference design uses an outboard engine which has higher noise levels and consists of an open design

which exposes the interior to the harsh weather. Therefore, sustainability for concept 5 was given a score of 1.

Concept 6:

1. Functionality:
    a. Score: -1
        i. This concept incorporates a 5-point seat belt installed onto each seat which is more secure when compared to the reference design which does not have a seating system. Additionally, the structure of this concept is not rigid and won't provide protection to the users from exterior elements. Also, if the vehicle was to come to an impact with an unknown debris at sea the whole integrity of the inflatable structure would be affected. Due to these reasons the functionality was scored a -1 as it is much more fragile when compared to the reference design.
2. Usability
    a. Score: -2
        i. Users do not have a proper access system which is similar to the reference design so they would have to hop onto the structure which could be difficult. The 5 point harness would be hard to put on by some of the users and can be quite uncomfortable. The separated components of the navigation and communication systems would work pretty well on a hull system but in the inflatable cabin, due to some lack of stability, these components could fall or get scattered or lost. Due to all these reasons concept 6 gets a score of -2 for usability.
3. Producibility:
    a. Score: -1
        i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers, concept 6 which increases production cost and requires more work to be done during manufacturing. Therefore, concept 6 got a score of -1 for producibility as it would be harder to produce the product.
4. Maintainability

a. Score: -1

i. This concept includes an open system and a 5 point harness which is an essential component for the safety of the passengers. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. This design includes an inflation bag self righting system which is what the reference design has. Therefore, maintainability was given a score of -1.

5. Sustainability

a. Score: 2

i. For concept 6 the ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Also since it can be enclosed the elements don't have effect on the users and equipment inside, therefore it will prolong the lifetime of the lifeboat. Therefore, sustainability was given a score of 2.

Concept 7:

1. Functionality

a. Score: 1

i. Concept 7 includes seats equipped with a 5 point harness as a restraint for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off balanced situations. Additionally the design structure of this vehicle is enclosed, and will serve as protection to the users from exterior elements while in use. It is also equipped with buoyancy foam as a self righting mechanism which is outperformed by the inflation bag self-righting system used in the reference design. Therefore, functionality was given a score of 1.

2. Usability

a. Score: -2
   i. The hinge doors require physical strength to open that some users may not have. This is not convenient in an emergency situation as it could waste a lot of precious time. The reference design does not have a door mechanism so entering and exiting the structure is faster than using the hinge door. The 5-point harness can be difficult to put on and take off for some users such as children, it can also be somewhat uncomfortable if worn for longer periods of time. Due to these reasons we can say that design concept 7 is less suitable than the reference design and so it gets a score of -2 for its usability.

3. Producibility:
   a. Score: -1
      i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers, concept 7 did which increases production cost and requires more work to be done during manufacturing. Therefore, concept 7 got a score of -1 for producibility as it would be harder to produce the product.
4. Maintainability
   a. Score: -1
      i. This concept includes a closed system with hinge doors and a 5-point harness which is an essential component for the safety of the passengers. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept This design includes an inflation bag self righting system which is what the reference design has. Therefore, maintainability was given a score of -1.

. Sustainability
   b. Score: -1
      i. The flat-bottom hull can only be used on calm bodies of water because if

used on rough bodies of water it can capsize easily due to it being less stable and this can cause damage to the lifeboat so the lifeboat to be unusable therefore users will not have a lifeboat to use in the future. Therefore, sustainability was given a score of -1.

Concept 8:

1. Functionality
    a. Score: 2
        i. Concept 8 includes seats equipped with a 5 point harness as a restraint for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off balanced situations. Additionally the design structure of this vehicle is enclosed, and will serve as protection to the users from exterior elements while in use. Therefore, functionality was given a score of 2.
2. Usability
    a. Score: -2
        i. Users will experience more difficulty in entering and exiting the system due to the hinge door system because it requires physical strength and dexterity to open up. The 5-point harness would be harder to put on in an emergency situation especially for some of the personas that could include children, pregnant women and the elderly. Therefore, concept 8 got a score of -2 for usability as it would be harder to use the product.
3. Producibility:
    a. Score: -2
        i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers, concept 8 did which increases production cost and requires more work to be done during manufacturing. This concept also has an inboard engine which would be harder to manufacture as it is embedded into the structure unlike the reference design which has an outboard engine that could just be installed at the rear end of the lifeboat. Therefore, concept 8

got a score of -2 for producibility as it would be harder to produce the product.

4. Maintainability
    a. Score: -1
        i. This concept includes a closed system with hinge doors and a 5-point harness which is an essential component for the safety of the passengers. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. This design includes a Movable ballast tank self righting system which is harder to maintain when compared to an inflation bag on our reference design. Therefore, maintainability was given a score of -1.
5. Sustainability
    a. Score: 1
        i. For concept 8 the Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again. Therefore, sustainability was given a score of 1.

Concept 9:

1. Functionality
    a. Score: 2
        i. Concept 9 includes seats all equipped with a lap bar as a restraint for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off balanced situations. Additionally the structure of the product is enclosed and provides protection for the users from exterior elements. Therefore, functionality was given a score of 2.

2. Usability
    a. Score: 2
        i. This design concept is equipped with multiple connected seats in a row which has a lap bar constraint which a majority of users would be familiar with. However, when compared to the reference design which lacks a passenger access system, this concept has a sliding door which would provide an exit/entry point to the users. Additionally this design is enclosed which would provide users with an easy access to the other systems located inside the vehicle. Also, the vehicle has a large storage container that can be accessed by the users while the vehicle is in motion. Therefore, this concept received a score of 2 for usability.
3. Producibility:
    a. Score: -2
        i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers, concept 9 did which increases production cost and requires more work to be done during manufacturing. This concept also has a stern-drive engine which would be harder to manufacture as it is embedded into the structure unlike the reference design which has an outboard engine that could just be installed at the rear end of the lifeboat. Therefore, concept 9 got a score of -2 for producibility as it would be harder to produce the product.
4. Maintainability
    a. Score: -1
        i. This concept includes a closed system with sliding doors and a lap bar restraint which is an essential component for the safety of the passengers. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. This design includes a Movable ballast

tank self righting system which is harder to maintain when compared to an inflation bag on our reference design. Therefore, maintainability was given a score of -1.

5. Sustainability
    a. Score: 1
        i. Stern drive engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again. Therefore, sustainability was given a score of 1.

Concept 10:

1. Functionality:
    a. Score: 1
        i. Concept 10 includes long benches for seats and a 3 point seat belt as a restraint for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off balanced situations. Additionally, since the design is an open one, the passengers are not protected from exterior elements. Therefore, functionality was given a score of 1.
2. Usability:
    a. Score: 1
        i. Users are required to maneuver their way onto the structure just like the reference design which can be quite difficult for some people. However, the securing system is a 3-point seatbelt which completely secures the user and is familiar with most users. The storage system is placed under the seat and is very convenient for the users to access when the product is in use. Therefore, concept 10 got a score of 1.
3. Producibility:
    a. Score: -1
        i. Most of our personas required proper seating due to their capabilities. While the reference design did not have proper seating for its passengers,

concept 10 did which increases production cost and requires more work to be done during manufacturing. Therefore, concept 10 got a score of -1 for producibility as it would be harder to produce the product.

4. Maintainability:
    a. Score: -1
        i. This concept includes an open system and a 3-point seat belt which is an essential component for the safety of the passengers. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. This design includes an inflation bag self righting system which is what the reference design. Therefore, maintainability was given a score of -1.
5. Sustainability:
    a. Score: 0
        i. The propulsion system used in this design concept is an outboard engine which is the same as our reference design, we as a group decided the score to be 0 since the engine is neither better nor worse than that used in the reference design. Also, the design is an open structure which is the same as the reference design.

<u>This is the cluster chart that shows all our initial concept designs:</u>

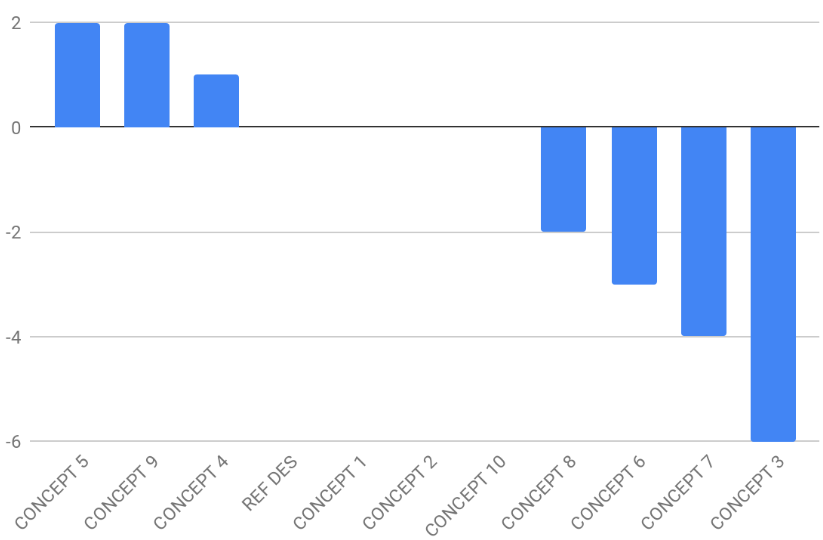


Figure 24: Cluster Chart for Concept Evaluation #1

concept refinement

Our designs that survived the concept evaluation stage were concept 5, concept 9 and concept 4. These concepts had scores of 2, 2 and 1 respectively. We then decided to add two more concepts. Concept 11, which is an entirely new concept that consisted of the best aspect of the worst concepts and concept 59, which is a blend of the top two concepts we had after the evaluation stage which were concept 5 and concept 9. These two new concepts and their list of embodiments are explained below.

➔ NEW Concept #11

- ***Structural:*** V-shaped hull
- ***Propulsion:*** Ducted Propellers
- ***Navigation & Communication:*** Components are installed onto one panel and display the system for one user
- ***Emergency Aid System:*** Underseat compartment
- ***Passenger Securing:*** 3-point seatbelt
- ***Passenger Seating:*** Long bench
- ***Self-righting:*** Inflation bag
- ***Deployment:*** Onload Mechanism
- ***Passenger Access:*** Sliding door

Explanations of how you generated the new concepts:

For concept 11, our group decided to create an entirely new concept keeping in mind the best aspects of the worst concepts. We decided to take the V-shape hull from concept 1 because

V-shaped hulls are the best option for open waters as they reduce drag and provide a smoother ride even at high speeds[50] . From concept 2 we decided to incorporate the ducted propellers because they are more efficient in producing thrust when compared to a traditional propeller [51]. After conducting the concept evaluation we concluded that, because ducted propellers produce less noise pollution it is a better propulsion system to use as some of our personas have things such as PTSD, hearing loss and pregnancy so therefore the less noise the propulsion system produces the better. Ducted propellers are also more efficient and environmentally friendly. From concept 3 we decided to use the 3-point seat belt because it's the perfect middle ground between safety and comfort. It protects users from bouncing around and secures them to their seats while also allowing them to adjust and slightly move around unlike the roller coaster restraint, lap bar restraint or 5 point harness. 3-point seatbelts are also very common and familiar so there is no learning curve when it comes to using them. From concept 6 we took the inflation bag as it is the most efficient and best option out of the 3 embodiments for the self righting system. It is also easier to manufacture as you wouldn't have to install it within the actual structure of the lifeboat. The navigation and communication system was taken from concept 8, we decided to implement the components that are installed onto one panel because it's accessible, organized and easy to use. When it comes to the access system for concept 11 we decided to go with the sliding doors as they were the best option. Hinge doors require a lot of physical strength which our personas do not have and the no door embodiment is the worst option for our personas as it is unsafe and not practical in dangerous emergency situations. Sliding doors would allow for a quick, safe and comfortable entry and exit for all passengers. For deployment we decided to use the onload mechanism instead of the freefall mechanism because the freefall mechanism is more dangerous. The lifeboat would plunge down into the water which could damage the structure and risk the lives of the passengers. On the other hand, the onload mechanism is way safer when used properly as it is lowered down into the water and users can safely enter it. We decided to use the long bench and the underseat emergency aid compartment from concept 10. This is because the long bench would take up less space in the structure making it suitable for smaller vessels and the underseat compartment is easy to access in emergency situations and would not cause much difficulty when combined with the 3-point seatbelt.

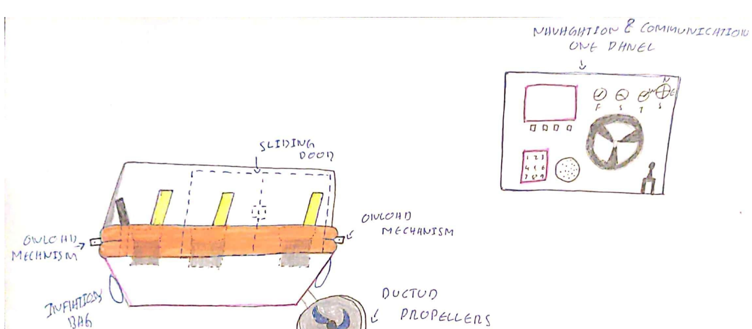


Figure 25: Final sketch concept 11

Brief verbal description of design concept 11:

This design is a V-shaped hull which allows the system to cut and glide through the water and is considered more suitable for open water when compared to other hulls [52]. This design concept is propelled by ducted propellers which are installed at the rear end of the hull. The navigation and communication system is compressed into one panel that is equipped with all the necessary controls. The seating used for this design are 2 sets of long benches that can seat 6 users. The 3 point seat belt is installed into each designated section of the bench for each user to fasten themselves. The emergency aid system is located in a compartment under each seat, that every user has easy access to. This concept uses an inflation bag for its self righting system which is integrated on top of the structure. Additionally, the release mechanism used in this design is the onload mechanism, the vehicle is equipped with two onload mechanism hooks located at the front and rear ends of the hull. Lastly, this design will have a sliding door on the side of the structure to make it easier for users to enter and leave the lifeboat.

<u>**NEW Concept 59:**</u>

- ***Structural:*** V-shaped hull
- ***Propulsion:*** Stern drive engine
- ***Navigation & Communication:*** Components are installed onto one panel and display the system for one user
- ***Emergency Aid System:*** Large storage container split into multiple sections

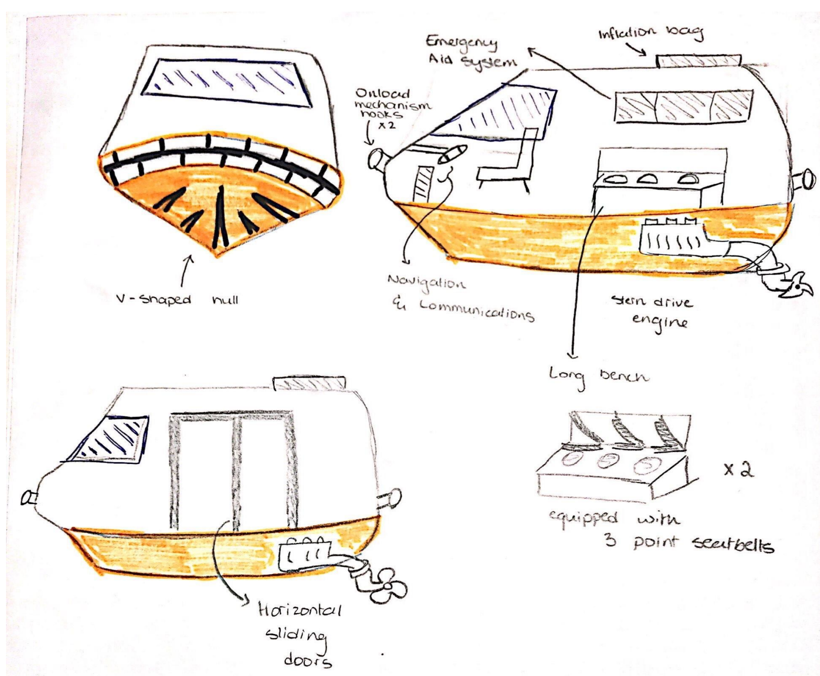
- *Passenger Securing:* 3-point seatbelt
- *Passenger Seating:* Long Bench
- *Self-righting:* Inflation bag
- *Deployment:* Onload Mechanism
- *Passenger Access:* Sliding door

Explanations of how you generated the new concepts:

For concept 59, our group decided to blend concept 5 and 9 together since they were the highest ranking concepts in evaluation #1. From concept 5, we decided to keep the Navigation & Communication system where all the Components are installed onto one panel and display the system for one user since it would be the most simple and accessible design out of the two. Also, from concept 5 we decided that the long bench design would be cost efficient and cover the needs of all our personas. From concept 9, we chose to keep the V-shaped hull and the stern drive engine because V-shaped hulls are the best option for open waters as they reduce drag and provide a smoother ride even at high speeds. For stern drive engine, the reason wasthate it would be easier to maintain than an inboard engine since an inboard engine would be further inside the lifeboat structure. Lastly, we kept the rest of the design features the same that both concepts had in common, such as, the lap bar restraint, the large storage container split into multiple sections, buoyancy foam, onload mechanism, and sliding doors.

Brief verbal description of design concept 59:

This design is a V-shaped hull that allows the system to cut and glide through the water and is considered more suitable for open water than other hulls [40]. This design concept is propelled by a stern drive engine which is installed into the hull of the product. The navigation and communication



system is compressed into one panel that is equipped with all the necessary controls. The seating used for this design are 2 sets of long benches that can seat 6 users. Figure 26: Final sketch for concept 59

The 3 point seat belt is installed into each designated section of the bench for each user to fasten themselves. This concept uses an inflation bag for its self righting system which is integrated on top of the structure. The emergency aid system consists of a large storage container that is split into multiple sections. Additionally, the release mechanism used in this design is the onload mechanism, the vehicle is equipped with two onload mechanism hooks located at the front and rear ends of the hull. Lastly, this design will have a sliding door on the side of the structure to make it easier for users to enter and leave the lifeboat.

concept evaluation #2

Table 32: Concept Evaluation #2 Decision Matrix

	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	6	0	0	0	0	0
CONCEPT 4	1	5	1	1	-1	-1	1
CONCEPT 5	2	3	2	2	-2	-1	1
CONCEPT 9	2	3	2	2	-2	-1	1
CONCEPT 11	4	1	2	2	-1	-1	2
CONCEPT 59	3	2	2	2	-1	-1	1

*The justification for individual personas can be found in appendix 2

Key justifications (for overall DM Evaluation #2):

Concept 11:

1. Functionality
    a. Score: 2
        i. Concept 11 includes seats and 3-point seatbelts for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off balanced situations. This concept also has an enclosed design unlike the reference design so it would protect the users from any elements that could potentially harm them. Therefore, functionality was given a score of 2.
2. Usability
    a. Score: 2
        i. The 3-point seat belt is well known and familiar to most people so there wouldn't be a learning curve when using it. The reference design does not have any seats,so the users might be confused about where they should sit and may feel unsafe. Also, there is an under seat compartment that makes it easier for them to access anything they may need during their use without moving that much. The sliding door system would also make it easier and safer for users to enter and exit the lifeboat unlike the reference design. Therefore, usability was given a score of 2.
3. Producibility
    a. Score: -1
        i. Most of our personas required proper seating due to their physical disabilities. While the reference design did not have proper seating for its passengers, concept 11 does which increases production cost and requires more work to be done during manufacturing. Also, the sliding doors in concept 11 would also have to be manufactured, but there is no need for that due to its opendesign in the reference design. Therefore, concept 11 got a score of -1 for producibility as it would be harder to produce the product.
4. Maintainability

   a. Score: -1
      i. This concept includes a 3-point seatbelt which is an essential component for the safety of the passengers. This would require frequent check ups to make sure the 3-point seatbelt works properly and does not malfunction during an emergency. These check ups and the maintenance needed (if the seatbelt were to break) would increase the maintenance cost making it harder to maintain this concept. Also, the underseat compartment would have to be restocked after every use which would increase cost to maintain the design concept compared to the reference design. Therefore, maintainability was given a score of -1.

5. Sustainability
   a. Score: 2
      i. The ducted propellers used in this concept are very efficient to the environment because they reduce noise pollution. The reduced noise levels will help the passengers sit in the lifeboat without a problem. In the reference design, an outboard engine is used which makes a significant amount of noise compared to concept 11, thus increasing noise pollution in the environment. Concept 11 has an enclosed design that protects the passengers on board and the lifeboats interior from weather elements like rain. However, the reference design is fully open which leaves the passengers and interior of the lifeboat completely open. Therefore, sustainability was given a score of 2 for concept 11.

Concept 59:

1. Functionality
   a. Score: 2
      i. Concept 59 includes long bench seats and a 3 point seat belt restraint for each passenger which is more secure and safer when compared to the reference design which does not have proper seating and would therefore put the passengers in danger during off balanced situations. Additionally, since the design is enclosed it protects the users from exterior elements

which the reference design fails to do. For these reasons, functionality was given a score of 2.

2. Usability
    a. Score: 2
        i. The sliding doors make exiting and entering the lifeboat really easy for most people, on the other hand, the reference design does not have an access system and requires people to hop on which would be difficult for a significant portion of the population. The three point seatbelt is widely known and is fairly easy to use while also securing passengers in their seats very well. Due to these reasons concept 59 received a score of 2 for its usability.
3. Producibility
    a. Score: -1
        i. Most of our personas required proper seating due to their physical disabilities. While the reference design did not have proper seating for its passengers, concept 59 increased production cost and required more work to be done during manufacturing. Also, the sliding doors in concept 59 would also have to be manufactured, but there is no need for that due to its opendesign in the reference design. Therefore, concept 59 got a score of -1 for producibility as it would be harder to produce the product.
4. Maintainability
    a. Score: -1
        i. This concept is a closed system equipped with horizontal sliding doors and a 3 point seat belt restraint, an essential part of all passengers' safety. All these different components would require frequent check ups to make sure they work properly and do not malfunction during an emergency. These check ups and the maintenance needed (if the components were to break) would increase the maintenance cost making it harder to maintain this concept. Therefore, maintainability was given a score of -1.

5. Sustainability
    a. Score: 1
        i. Stern drive engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and the systems in the interior of the cabin to be used in the future again. Therefore, sustainability was given a score of 1.

This is the cluster chart that shows all our final concept designs:

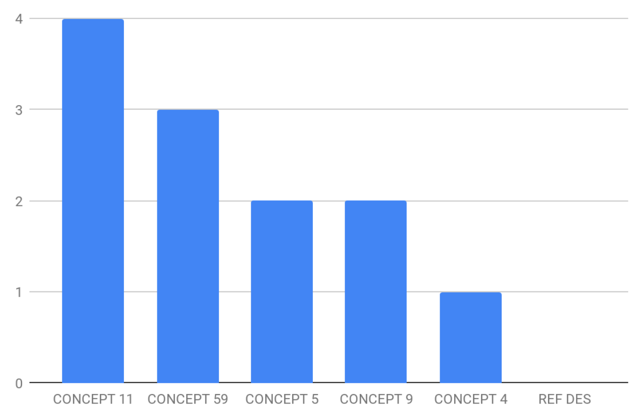


Figure 27: Cluster Chart for Concept Evaluation #2

final concept validation

After conducting the previous 3 stages of the design project which were concept evaluation 1, concept refinement and concept evaluation 2, we concluded that the best and final design would be concept 11. This concept fulfills most, if not all, of the requirements and satisfies nearly all of our personas needs. When considering the PRS, the product should provide a first aid kit and other emergency items such as flares, lifejackets, food and water rations. By including an emergency aid compartment under each seat, users will have all the items they may need during the use of our product and it will also be more accessible for each user.

Furthermore, the PRS requires our design to incorporate seatbelts, which we decided to do by using a 3-point seat belt system which is commonly used in cars and is very simple to use. The

PRS also states that our product should be ergonomic and user-friendly. We incorporated this by making a one panel where all the displays and controls are located and easy to use so the user doesn't struggle when using our product. When we incorporated the long bench design into our final design we had ergonomics and cost to manufacture in mind, because we not only wanted the inside of our lifeboat to be comfortable but cost efficient as well.

In our PAS we had a functional requirement for our propelling system to be able to preserve the surrounding environment, we decided to go with ducted propellers because they provide the least noise pollution compared to all other engines we looked at and also ducted propellers was the only propelling system which used electricity to run rather than diesel or gasoline mentioned in the other engines. The noise pollution will benefit not only the marine life but also the passengers on board.

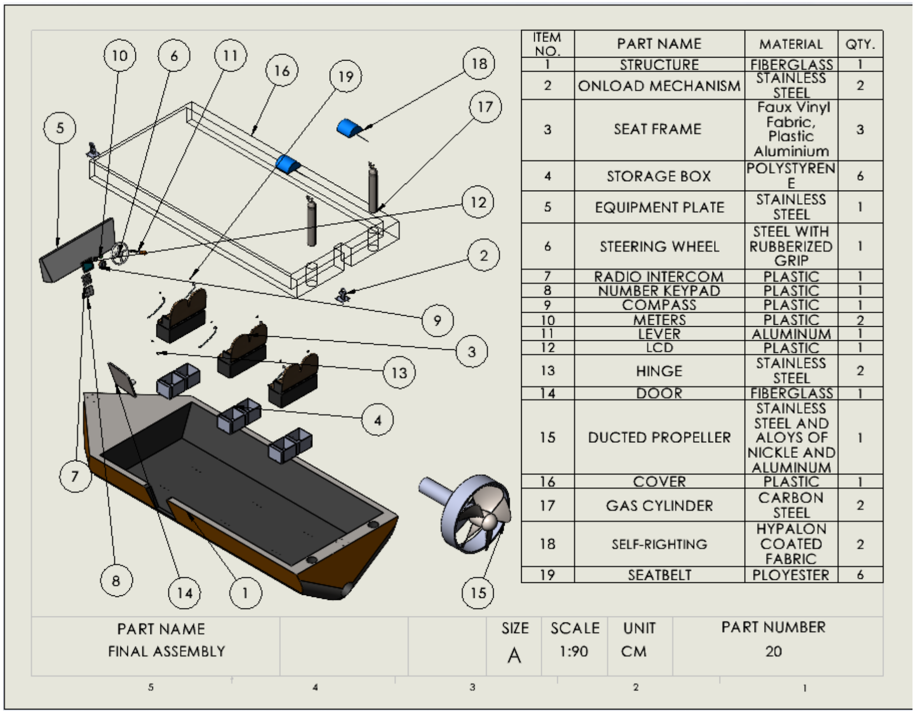
Moreover, we went with sliding doors for the passenger access system because we wanted our product to not be too taxing on the user's physical capabilities which we mentioned in our PSS when we talked about the human factor demands and capabilities. The sliding doors were just what we needed in our final design as they provided our personas with a safe and secure way to enter and exit the structure. The V-shaped hull we used for different concepts were beneficial because when it is used on top of the water at higher speeds, it provides a smoother ride through choppy and wavy water. For our deployment and self-righting system we chose to do an onload mechanism and inflation bag respectively, we did this because in our PRS we wanted our product to be reusable, and by using the two design features mentioned above we can do just that.

Overall we are confident in our design and we believe that we've improved from our reference design.

discussion

We started off stage 4 by identifying what subsystem we would like to implement into our design and what functional requirements are needed in the system identification matrix. The next step was to design 2 to 5 embodiments per subsystem and produce a system diagram with explanations of the system interfaces, all the inputs and outputs as well as the subsystems themselves while relating these explanations to our personas. We had 129,600 concepts, some of which we needed to eliminate, we did so by identifying pairs of inconsistent embodiments that helped us eliminate a significant portion of the concepts. The next step was to produce 10 initial concepts at random, as recommended by Dr. Salustri in the Wiki, and use the hill climbing method for each of those concepts in order to improve them. A decision matrix and cluster then needed to be put together. This was done by looking at the functionality, usability, producibility, maintainability and sustainability of each of the concepts and relating them to the personas, SUCs and requirements and then numbering them based off of a 5 point grading scale. Aftering justifying all our numbers for the decision matrix we then had to look at the cluster and identify which designs were good enough to move onto the next section and which concepts needed to be scrapped. We were left with 3 concepts and decided to add 2 more in the concept refinement stage. This was done by creating a new concept and combining two of our best ones. The concept evaluation then needed to be done again which allowed us to pinpoint exactly which concept was our final and best one, which was concept 11.

detailed design



ITEM NO.	PART NAME	MATERIAL	QTY.
1	STRUCTURE	FIBERGLASS	1
2	ONLOAD MECHANISM	STAINLESS STEEL	2
3	SEAT FRAME	Faux Vinyl Fabric, Plastic Aluminium	3
4	STORAGE BOX	POLYSTYRENE	6
5	EQUIPMENT PLATE	STAINLESS STEEL	1
6	STEERING WHEEL	STEEL WITH RUBBERIZED GRIP	1
7	RADIO INTERCOM	PLASTIC	1
8	NUMBER KEYPAD	PLASTIC	1
9	COMPASS	PLASTIC	1
10	METERS	PLASTIC	2
11	LEVER	ALUMINUM	1
12	LCD	PLASTIC	1
13	HINGE	STAINLESS STEEL	2
14	DOOR	FIBERGLASS	1
15	DUCTED PROPELLER	STAINLESS STEEL AND ALOYS OF NICKLE AND ALUMINUM	1
16	COVER	PLASTIC	1
17	GAS CYLINDER	CARBON STEEL	2
18	SELF-RIGHTING	HYPALON COATED FABRIC	2
19	SEATBELT	PLOYESTER	6

Figure 28: Final Assembly and Bill of Materials

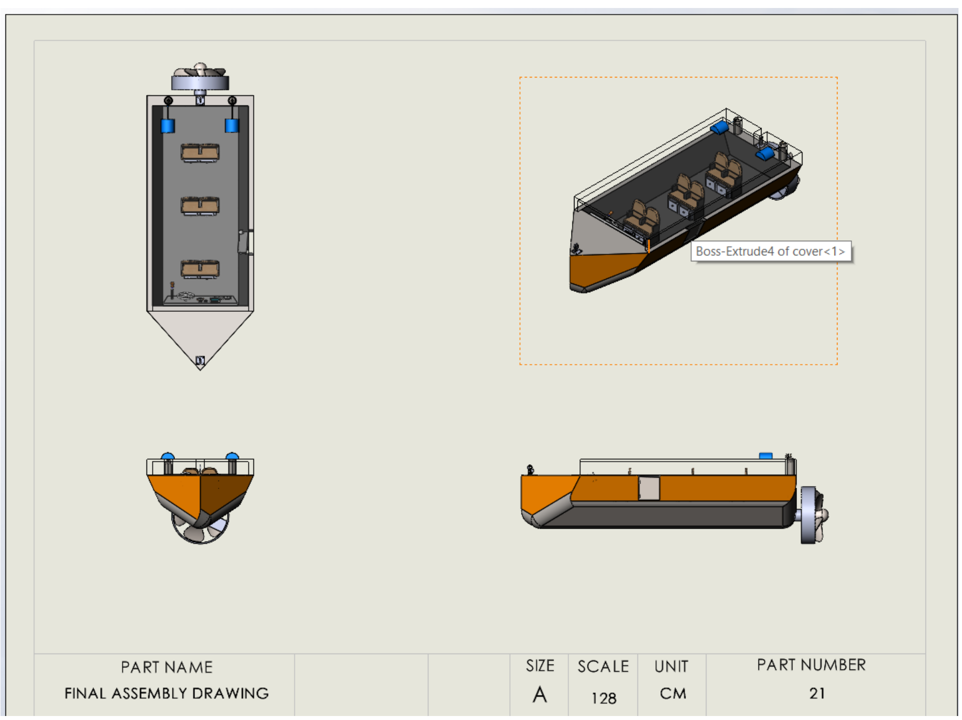


Figure 29: Final Assembly Drawing

Table 33: Detail Design rationale for Navigation and Communication System

<table>
<tr><th colspan="2">Navigation and Communication System</th></tr>
<tr><td>Part: Components are installed onto one panel and display the system for one user</td><td>Material: Stainless Steel, Plastic, Rubber</td></tr>
<tr><td colspan="2">Rationale:
● The component itself will be made of stainless steel.
    ○ Stainless steel is one of the stronger materials in terms of metals
    ○ Its corrosion resistance, this will increase the life time of the component
● The LCD, Meters, Compass and number pad will all be made from plastic
    ○ Plastic is a very strong material
    ○ Plastic is also waterproof, in many of these cases electric wires are involved within the specific component.
    ○ A very cheap and cost effective material easy to replace
● All the elements being installed onto one component is much easier to access in comparison to separate elements kept in storage.
● The use of Plastic and Stainless steel will reduce the weight and cost of the lifeboat.</td></tr>
</table>

Table 34: Detail Design rationale for Deployment System

<table>
<tr><th colspan="2">Deployment System</th></tr>
<tr><td>Part: Onload Mechanism</td><td>Material: Stainless Steel</td></tr>
<tr><td colspan="2">Rationale:
● Onload mechanism can release the lifeboat from a wire, with the boat above water level and with all crewmembers and passenger safely inside the boat
● Unlike the freefall mechanism, the onload mechanism release the boat from a height of about 1 m so that the fall is smooth and does not damage the hull of the vessel or the crew and passengers inside
● Onload mechanism is lever operated therefore you can release the boat without having to go outside or in case there is a fire on the ship where the lifeboat is released from
● Onload mechanism is best used when there are rough waters since other methods are unable to deploy in rough waters.
● End-of-life of the onload mechanism is very high due to the materials used in this part being very strong, durable, and resilient to multiple factors like weather and environment. [53]
● Maintenance is fairly easy as all you need to do before releasing the lifeboat is making sure that the pin is in place and functional
● Stainless steel is easily obtainable from online manufacturing like alibaba.com, therefore the manufacturing of this part will be relatively easily</td></tr>
</table>

Table 35: Detail Design rationale for Propulsion System

<table>
<tr><th colspan="2">Propulsion System</th></tr>
<tr><td>Part: Ducted Propeller</td><td>Material: Stainless Steel, Alloys of Nickel, Aluminum and Bronze (NAB)</td></tr>
</table>

Rationale: ● The propeller itself would be made of Stainless Steel. ○ Stainless Steel is more durable than the other common materials used in the marine industry. ○ Stainless steel propellers have stiffer blades making them less likely to bend or brake when in contact with physical debris or objects in bodies of water. ○ The high strength of the material provides a high hydrodynamic efficiency [54]. ● The part that connects the propeller to the vehicle would be made of an alloy of Nickel, Aluminum and Bronze. ○ NAB alloy propellers have reasonable durability with low replacements costs. ■ The low replacement cost makes the use of this material in the design economical and affordable. ○ The parts made of NAB can be easily replaced and repaired. ○ The aluminum alloys are lighter in weight and reduce the overall weight of the product [55].

Table 36: Detail Design rationale for Passenger Securing System

Passenger Securing System	
Part: 3-point seat belt	Material: Polyester
Rationale: ● This is an off-the-shelf part that we will use from this manufacturer. The CAD file was obtained from the grabCAD website. ● 3-point seat belts are readily available and can easily be attached onto the seating, we therefore do not need to manufacture this product as we can buy it from a supplier. ● At the end of the product's life these seat belts can easily be removed and repurposed or sold as spare parts. ● Most commonly used seat-belts and are therefore familiar and easy to use. ● In some cases the buckle can get stuck in between the seats, in order to avoid this our buckle would be protruding outwards to avoid issues with putting on the seat belt.	

Table 37: Detail Design rationale for Passenger Seating System

Passenger Seating System	
Part: Long Bench, Frame	Materials: Faux Vinyl Fabric, Plastic (Polypropylene), Aluminium
Rationale: ● The long bench would be made of faux vinyl fabric for the seating and polypropylene plastic for the arm rests and bottom portion [57]. ○ Faux vinyl fabric is a soft and high-quality material that is much cheaper when compared to the other options on the market [58]. ○ The fabric is easy to clean and requires low maintenance due to its quality and durability [58]. ● The frame that connects the seating system to the structure of the lifeboat will be	

manufactured out of an aluminium alloy [59]. ○ Aluminum is highly ductile and malleable which allows it to be precision machined easily. ○ This is needed in our design as the frame's shape is quite intricate. ○ This saves time during manufacturing making it a more efficient option. ○ This metal is also widespread and readily available in the market. ○ For the end of the product's life the frame can easily be detached from the structure and recycled. ● The armrests and the structure of the long bench will be made out of a hard plastic such as polypropylene. ○ Polypropylene is recyclable and does not release as many toxins as other plastics [60]. ○ It is relatively inexpensive and has a high stiffness and strength which is needed to ensure the structure is rigid. ● The dimensions used in the passenger seating system was based on this website as well as Dr. Neumann's Chapter 8 Lecture, Slide no. 26.

Table 38: Detail Design rationale for Passenger Access System

Passenger Access System	
Part: Sliding door	Material: Fiberglass
Rationale: ● The process of producing a fiberglass isn't too complicated, since glass is heated until its molten and then forced through fine holes. This produces glass filaments which are very thin and light [62]. It is extremely versatile and cheap to make compared to other composites [63]. ● In terms of usability, it's quite light which means that our lifeboat can be attached to the side of small vessels. Also, it can be propelled, maneuvered, and handled easily because of the lightweight. ● The main source of ingredient in a fiberglass is glass, which is made out of sand. Sand is an abundant, natural, non-depleting resource, and therefore is a highly sustainable material [63]. ● Fiberglass requires maintenance every three months or so, since it can start oxidizing in 4-12 months if not maintained properly [64]. ● Fiberglass can be recycled using three methods: grinding, incineration, and pyrolysis. Grinding is the easiest and most eco-friendly [65].	

Table 39: Detail Design rationale for Self-righting System

Self-righting System	
Part: Inflation bag and gas cylinders	Material: Hypalon coated (inflation bag), carbon steel (gas cylinders)
Rationale: ● Hypalon fabric has many useful applications due to its durability and great ability of	

holding air . ○ UV light and extreme temperatures have little to no effect on the integrity of the material [66]. ○ Does not get brittle over its lifetime. ○ Low maintenance costs since a patch can be applied onto any puncture. ● Carbon steel packs the gas quite well because it is strong and shock resistant [67]. ● Carbon steel is also safe to handle and work with [67].

Table 40: Detail Design rationale for Emergency Aid System

Emergency Aid System	
Part: Underseat Compartment	Material: Plastic (Polystyrene) [61]
Rationale: ● Easy to install (shape of the compartment is perfect for the space that is under each bench) ● Easy to manufacture (plastic is one of the most manufactured materials in the world) ● Easily accessible for all users (each compartment is directly under each users seat) ● Maintenance would just be the contents inside the compartment and not the compartment itself. ● End-of-life is very long as plastic(Polystyrene) is known to be very hard to decompose ● Provides great amount of storage for items used on the product ● Includes a waste compartment on the side of the product where users can dispose of garbage or any waste they accumulate during their use.	

Table 41: Detail Design rationale for Structural System

Structural System	
Part: V-shaped Hull	Material: Fiberglass(hull) and cover(plastic)
Rationale: ● The process of producing a fiberglass isn't too complicated, since glass is heated until its molten and then forced through fine holes. This produces glass filaments which are very thin and light [62]. It is extremely versatile and cheap to make compared to other composites [63]. ● In terms of usability, it's quite light which means that our lifeboat can be attached to the side of small vessels. Also, it can be propelled, maneuvered, and handled easily because of the lightweight. ● The main source of ingredient in a fiberglass is glass, which is made out of sand. Sand is an abundant, natural, non-depleting resource, and therefore is a highly sustainable material [63]. ● Fiberglass requires maintenance every three months or so, since it can start oxidizing in 4-12 months if not maintained properly [64]. ● Fiberglass can be recycled using three methods: grinding, incineration, and pyrolysis. Grinding is considered to be more eco-friendly than the other two methods [65].	

design discussion

As a team, we decided that our product should be designed in a way that it does not require inflation to operate the lifeboat. Inflating a lifeboat takes several seconds and so during an evacuation from the vessel, those couple of seconds could be lethal for a person, not taking into account the dangerous situation that could occur if the inflation system does not inflate the lifeboat due to technical issues. The reference design uses a deployment system called the davit-release. We figured that this type of deployment system is dangerous for passengers because the lifeboat will be dropped, which can injure the passengers on board. Hence, for our Pacific 11 design, we used an on-load mechanism. Our product will be attached to the side of the small vessel, and so the on-load mechanism will safely lower the lifeboat gently into the water after the passengers have boarded the Pacific 11.

Many of the products, including our reference design involves no proper seating arrangement and passenger securing like seatbelts. This is a major design issue that we solved in our design because during harsh water conditions the passengers on board can be thrown around. Our design has six seats for six passengers with 3-point seatbelts, so they can sit with comfort during the rescue operation. Under each seat, there is an underseat compartment which contains an emergency aid system that includes first aid kit and other emergency items such as flares, lifejackets, food and water rations. In terms of the navigation and communication system in our product, we designed one panel where all the displays and controls are located and easy to use so the user doesn't struggle when using our product.

For our propulsion system, we decided to go with ducted propellers because they provide the least noise pollution compared to all other engines we looked at. Also, ducted propellers was the only propelling system which used electricity to run rather than diesel or gasoline mentioned in the reference design. The noise pollution will benefit not only the marine life but also the passengers on board.

For the passenger access system, our design contains sliding doors with a rooftop because we wanted our product to be easily accessible by just sliding the door open or close with minimal energy from the user. The sliding doors with rooftop was needed in our final design as they provided our personas with a safe and secure way to enter and exit the structure.

project discussion

Time management, coordination, and feedback amongst team members were critical factors that affected the report as a whole. Managing time is a huge factor in completing this design project due to the limited time available throughout this semester. As a group, we tried our best that we were on the correct pace in completing each task from the design roadmap by a specific period of time. However, we still came across the pressure of not finishing a task on time, especially the day before MS1 and MS2 were due. In terms of coordination, our group did not have a formal leader per say, but there were many moments where a specific group member stepped up and took lead of what the group will be doing, or what needed to be focused on during a certain meeting. Also, they would outline all required things that needed to be completed by a specific date and how we were going to complete them. Constantly, throughout the design project, we were giving each other feedback on our respective tasks. In addition, all five members of the group made important contributions during the whole process.Together, we worked efficiently and effectively in our group meetings due to our entire group having the desire to put in good work for this project.

In terms of the procedural problems, the main problem we encountered was understanding the design roadmap, which we were able to solve through group discussions. Technical problems arose when we were using the SolidWorks software, since many of our group members were inexperienced in using the software. Due to our inexperience, we ran into multiple issues like mating the different parts that were made by each group member into one final part, let alone the drawing complexity of the subsystem part. Another technical problem that we encountered was the difficulties in quantifying particular interfaces with the correct quantifications using online references and equations. This was very hard as it was incredibly difficult finding the correct references and equations required for our particular lifeboat design so we can make sure that there were no technical issues with our design. There was also a period during the project where one of our group members had to travel for a family emergency to africa where he did not have stable access to the internet. The other team members were very understanding and divided the workload evenly and appropriately for those 2 weeks so that the team does not fall behind.

Whilst doing this project, we encountered scheduling problems with some group members because we had some group members who were situated outside the country with different time zones, which resulted in issues with holding group work sessions/meetings. This problem was resolved by having each group member present a time for every day of the week where they were free and able to work on the project together, and from there we choose two days where everyone could join said session/meeting.

There were instances in the later half of the project where the group felt that we could have added a certain feature or design detail which may have made our design better. However, we were too far into the design process in which we could not afford making a change in an earlier part of the project, because it would have a significant impact on the report as a whole. Not to mention that making such a change would require lots of hours of work which we ran out of coming into the close of the semester due to other courses workload and exams. Ultimately, we feel that our group did the best job that we could have done given our circumstances and time given to work on this project. We are satisfied with our design and believe that it is a significant improvement from our reference design, since we added a rooftop, passenger seating and securing systems, a user friendly navigation and communication system, and an eco-friendly ducted propulsion system.

conclusion

The main objective of this design report was to come up with an ergonomic, ethical, and practical design of a maritime escape/life-support system that is suitable for smaller vessels and six passengers with different physical capabilities. Our design contains all the best features of the many designs created and were combined into our final design, to produce a safe, comfortable, and cost effective product.

Areas we could improve on:

Possible areas where our design could be improved in the future include: ventilation and a more efficient propulsion system. Incorporating a ventilation system for our passengers will help the passengers feel more comfortable as there is fresh oxygen flowing inside the enclosed system. If there are six users inside our enclosed system then all the CO_2 which is being exhaled by the users will eventually accumulate to where users will start to have trouble breathing. Therefore, for future design solutions for our product we can improve on the air circulation inside our product. Also, for future design models we can include propulsion systems that can operate entirely on batteries, which are a lot cheaper to use and quite efficient for the environment.

In conclusion, there have been many concepts that our group generated during this long design process. However, most concepts were not cost effective, practical or suitable for our personas. By using our personas, we assessed a wide demographic of users when designing our product. Each change in our product was done in order to expand the user population of our product. Using a lifeboat should not be a physical or mental burden on any user, and every maritime escape system should cater to its user as they are the ones that it is intended for. All factors in the design process that were thought to be burdens on the users were eliminated throughout each step of the design roadmap. We also took many other factors into consideration like cost to produce, eco-friendliness, product maintenance/sustainability, and user experience. Hence, we came up with our design.

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scientific and practical sources

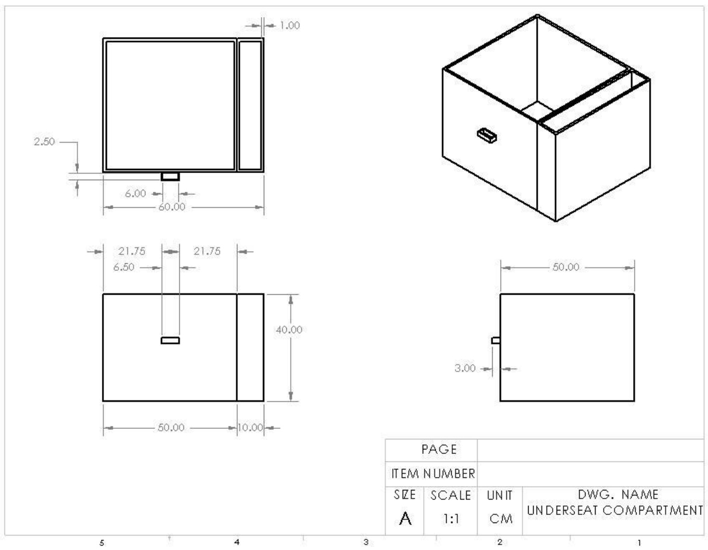
[USE ASME REFERENCE STYLE]

All of our sources are in the references section.

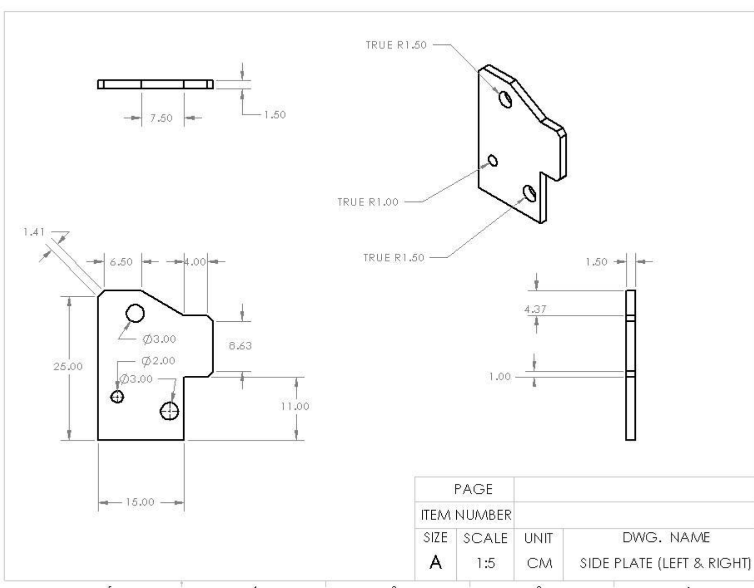
appendix 1: drawings

Mohsan's Drawings:

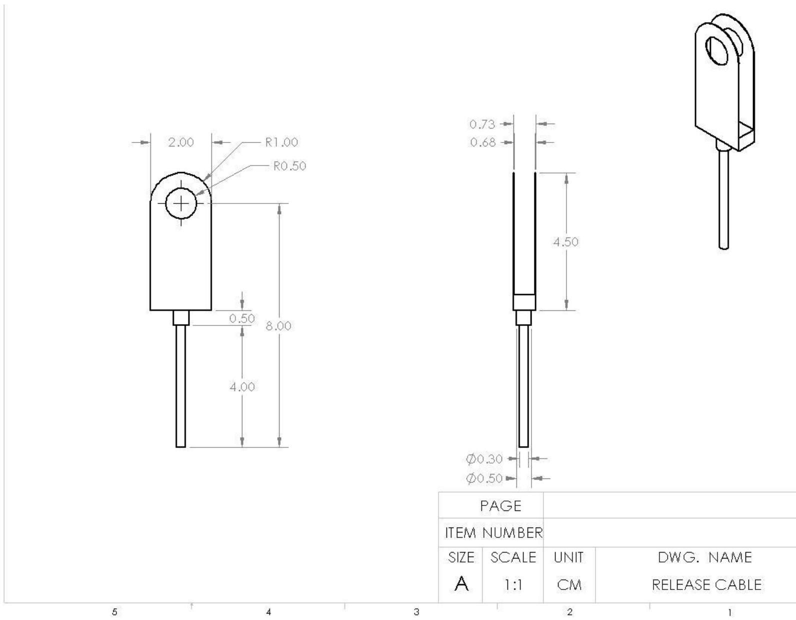
1. Underseat Compartment



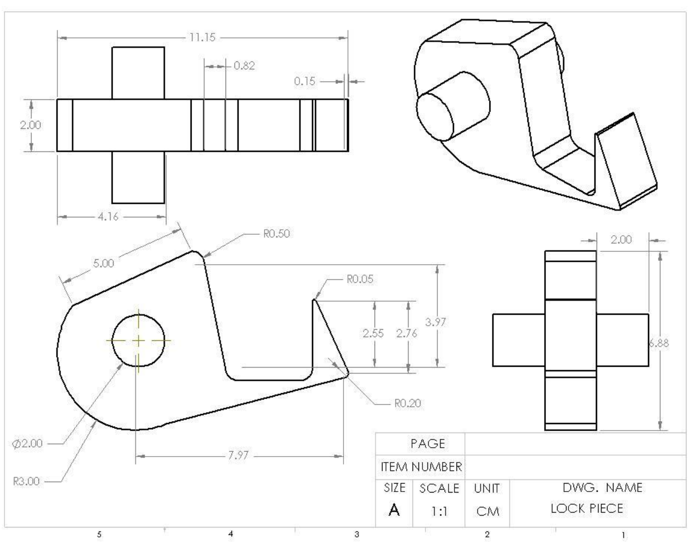
2. Side Plate (Left and Right)



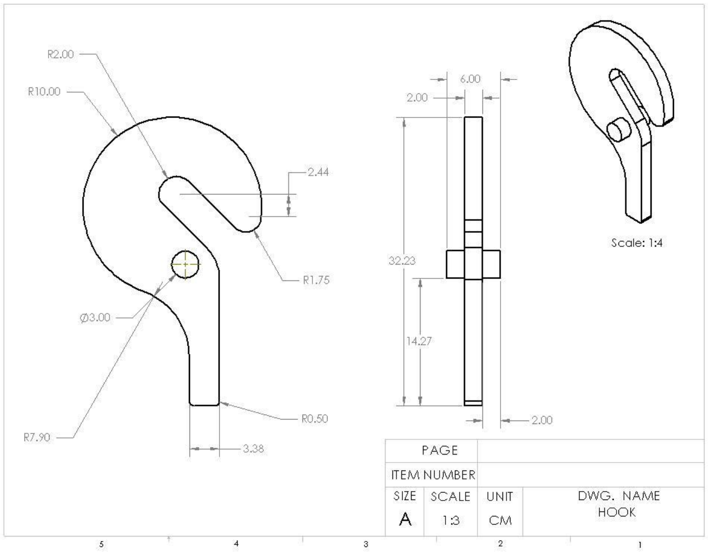
3.Release Cable



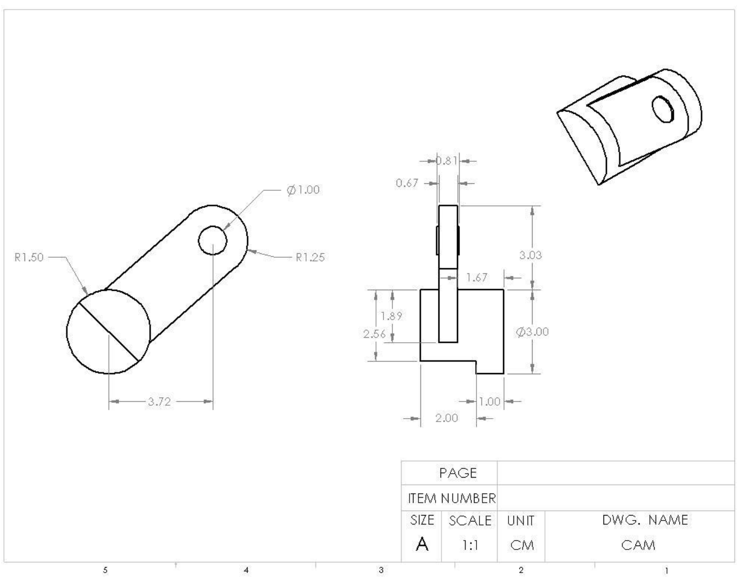
4. Lock piece



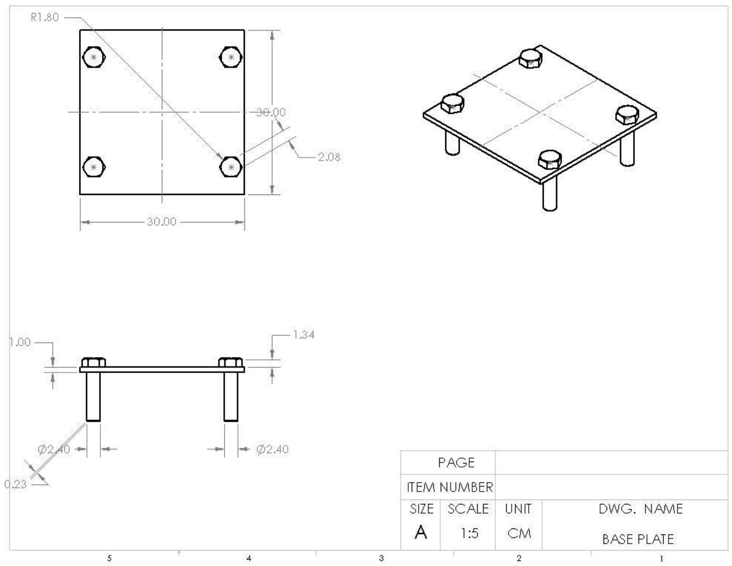
5. Hook



6. Cam

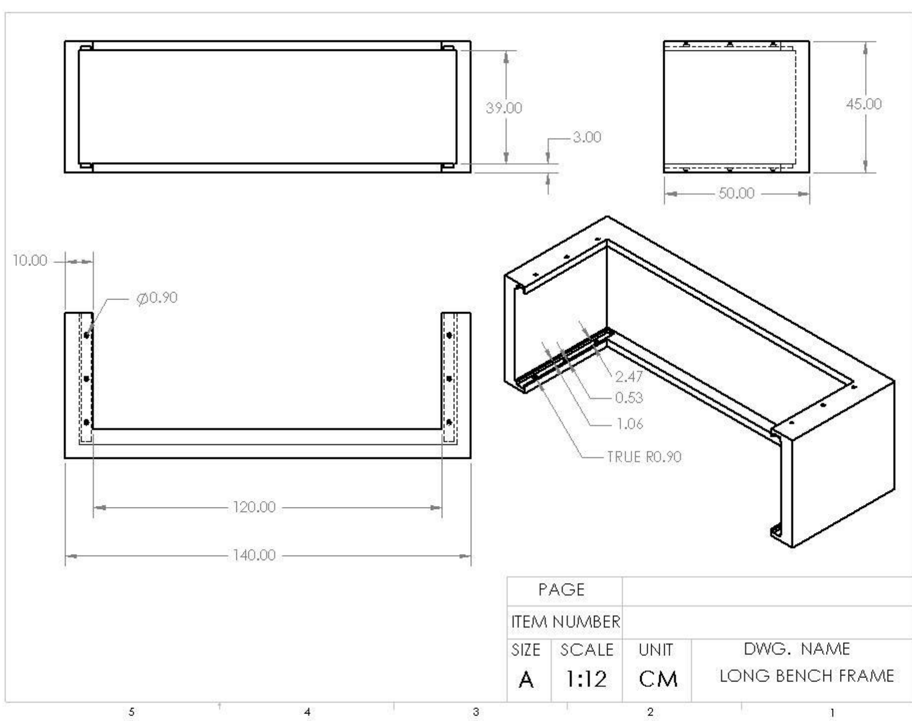


7. Base plate

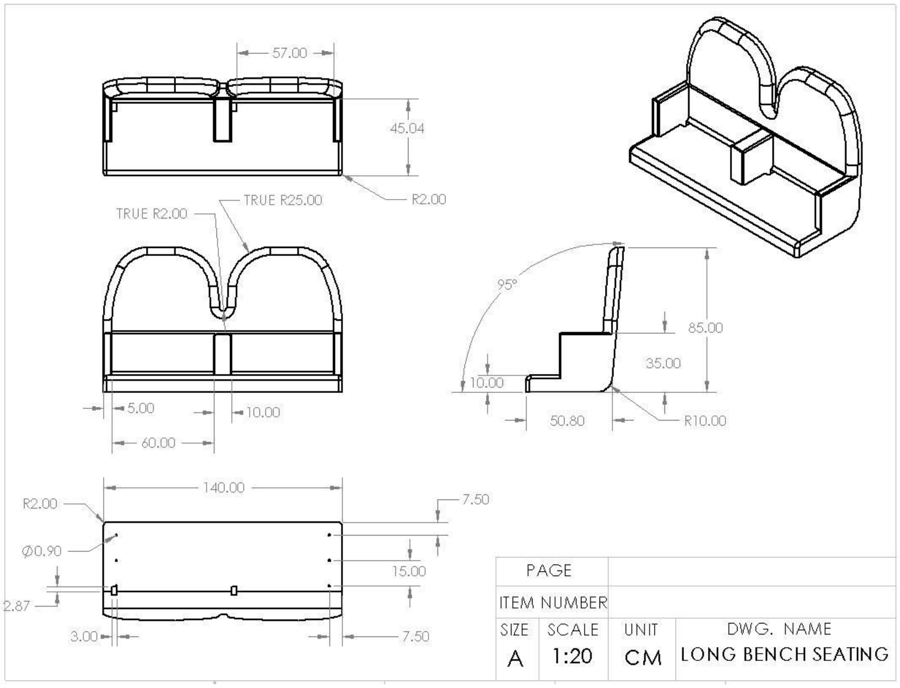


Mohamed Ismail's Drawings:

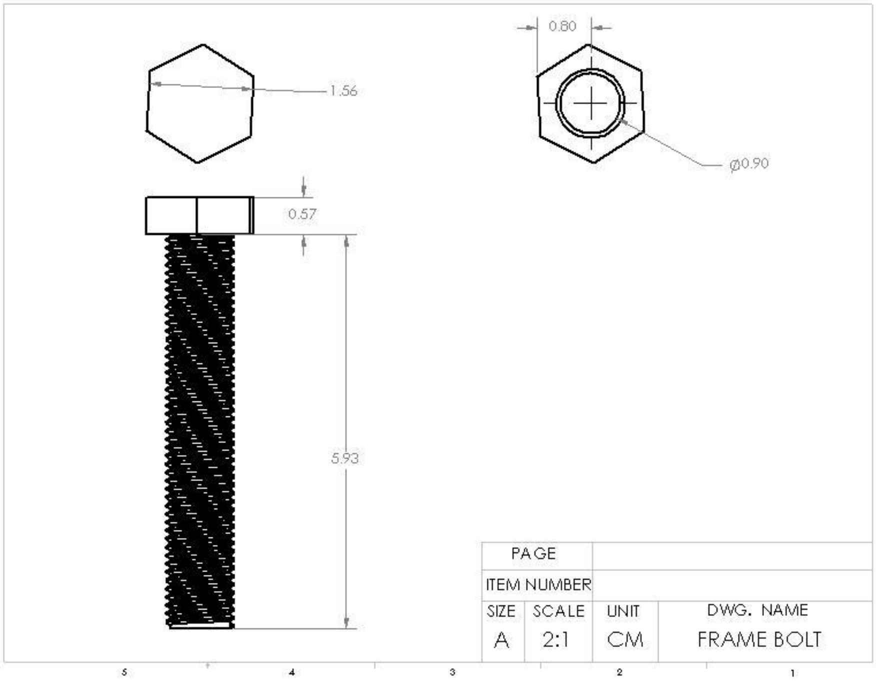
1. Long Bench Frame



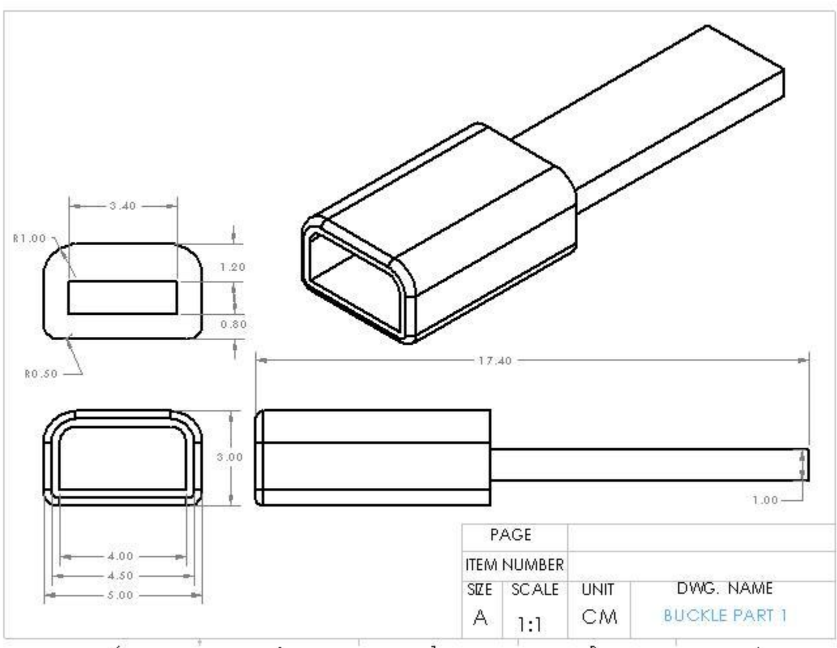
2. Long Bench Seating



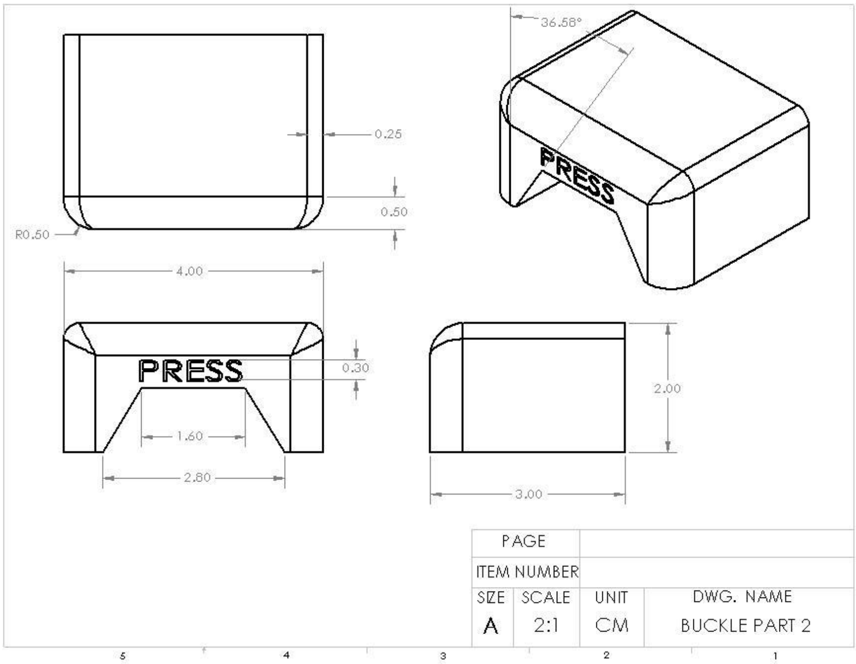
3. Frame Bolt



4. Buckle Part 1

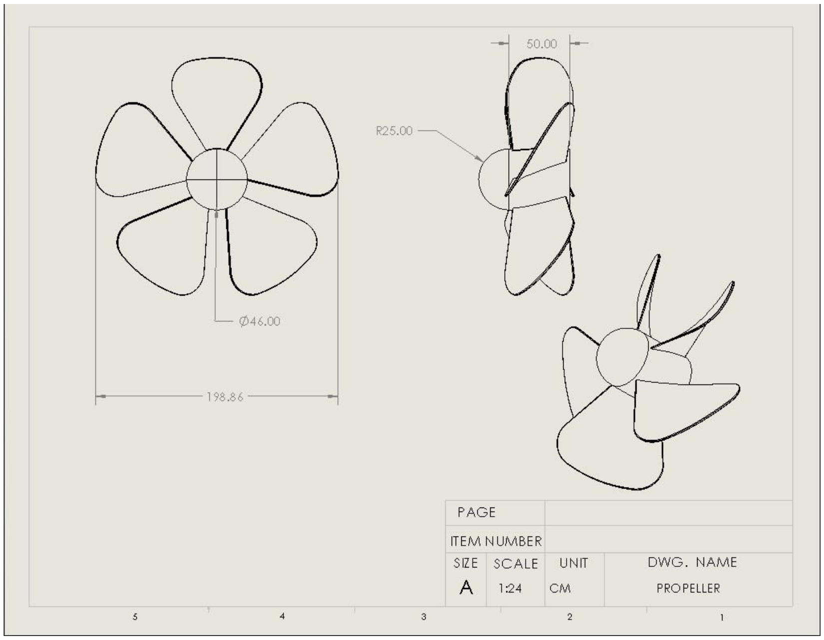


5. Buckle Part 2

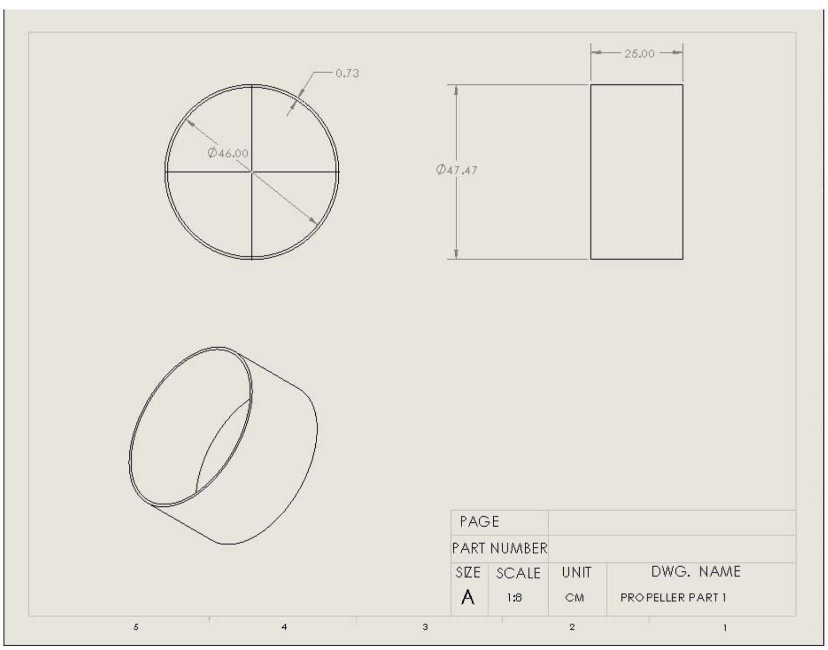


Rufat Akhmetov’s Drawings:

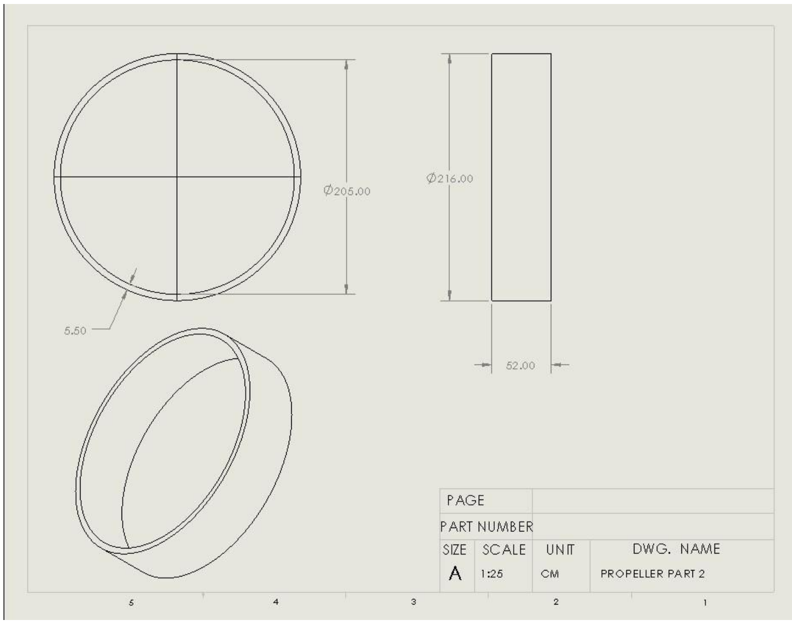
1. Propeller



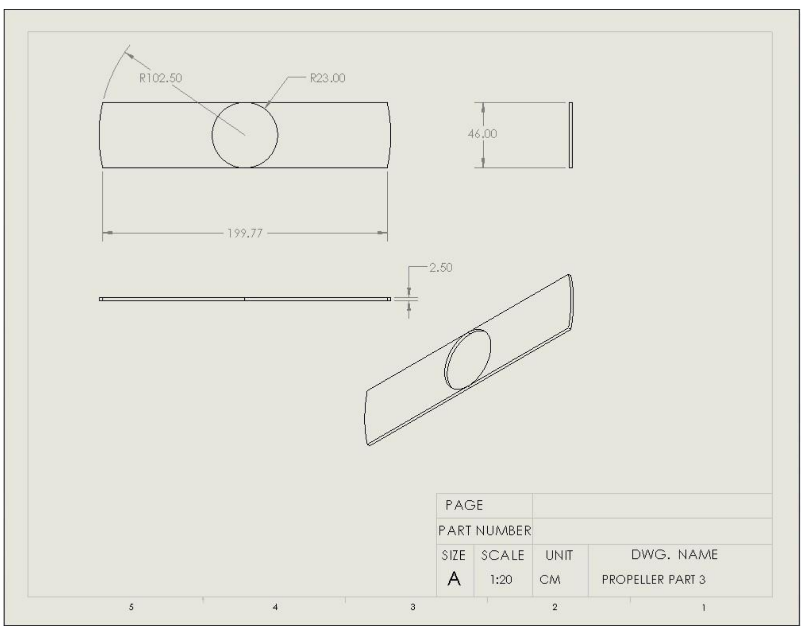
2. Propeller Part 1



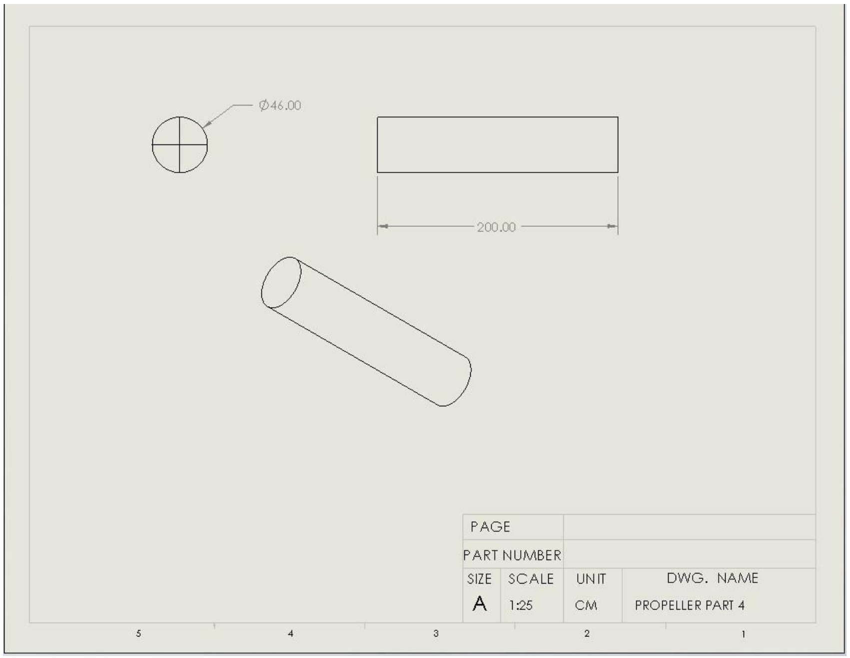
3. Propeller Part 2



4. Propeller Part 3

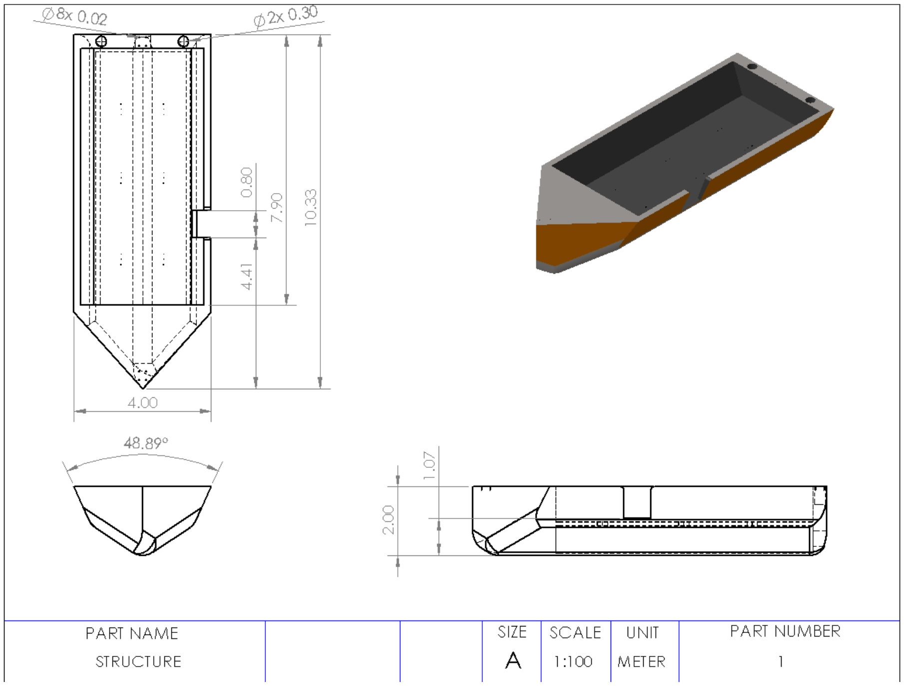


5. Propeller Part 4

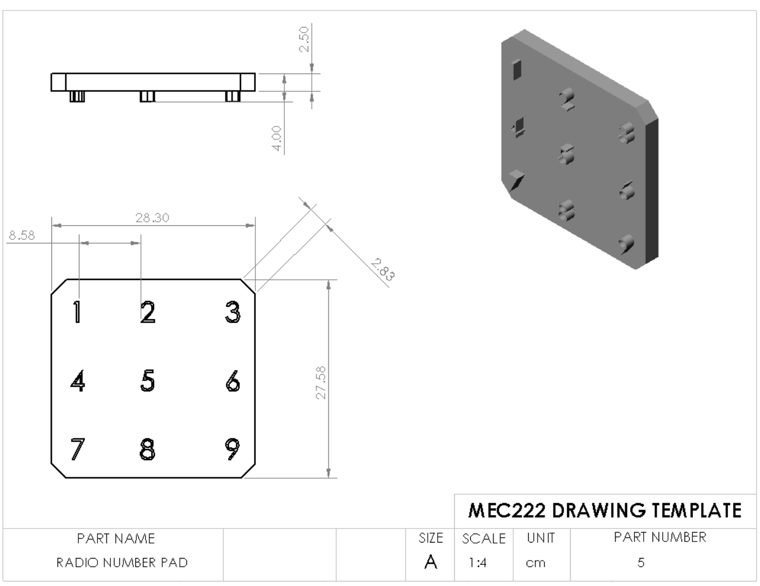


Mohammed Khan’s Drawings

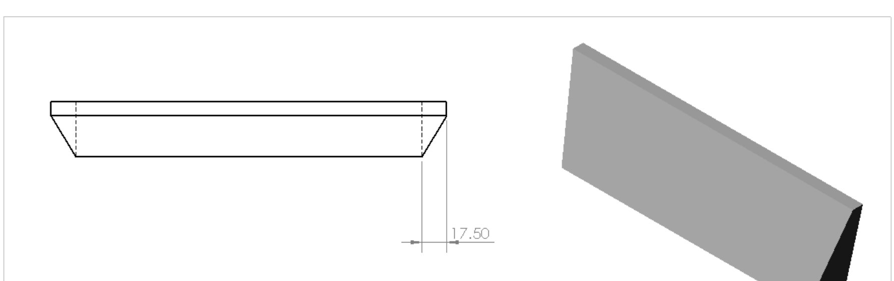
Part 1 - Structure



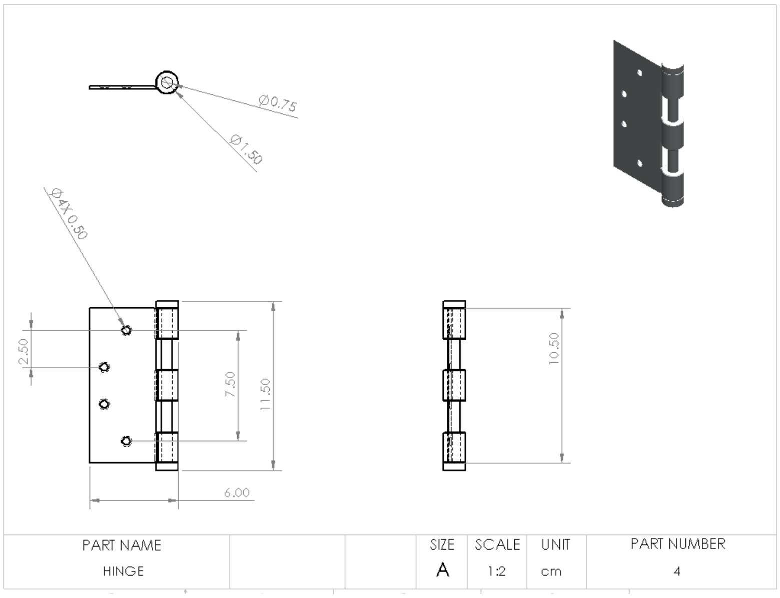
Part 2 - Door



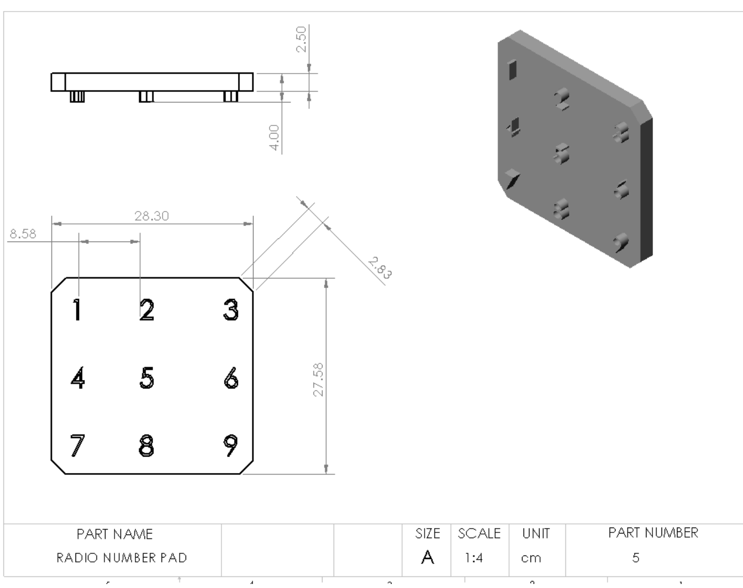
Part 3 - Components Plate Part



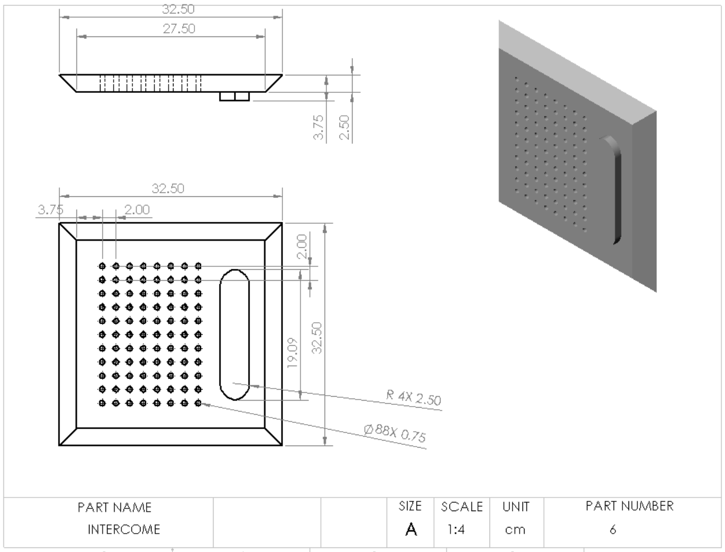
Part 4 - Hinge



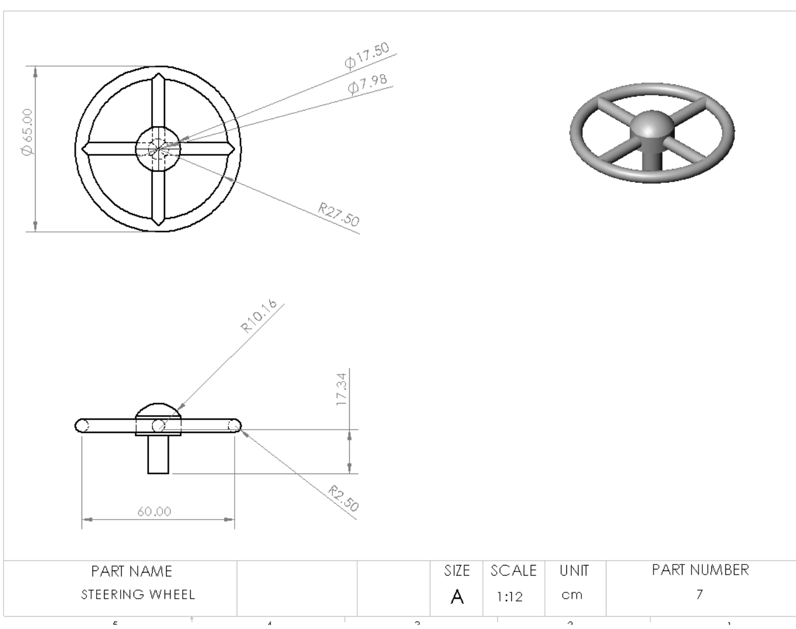
Part 5 - Number Keypad



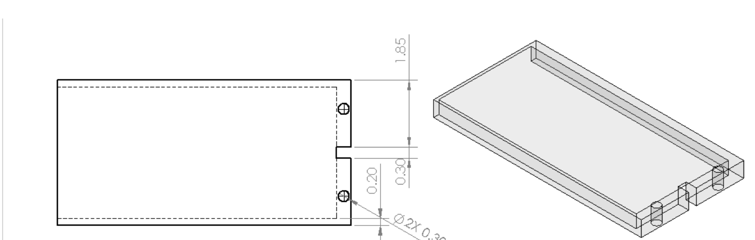
Part 6 - Radio



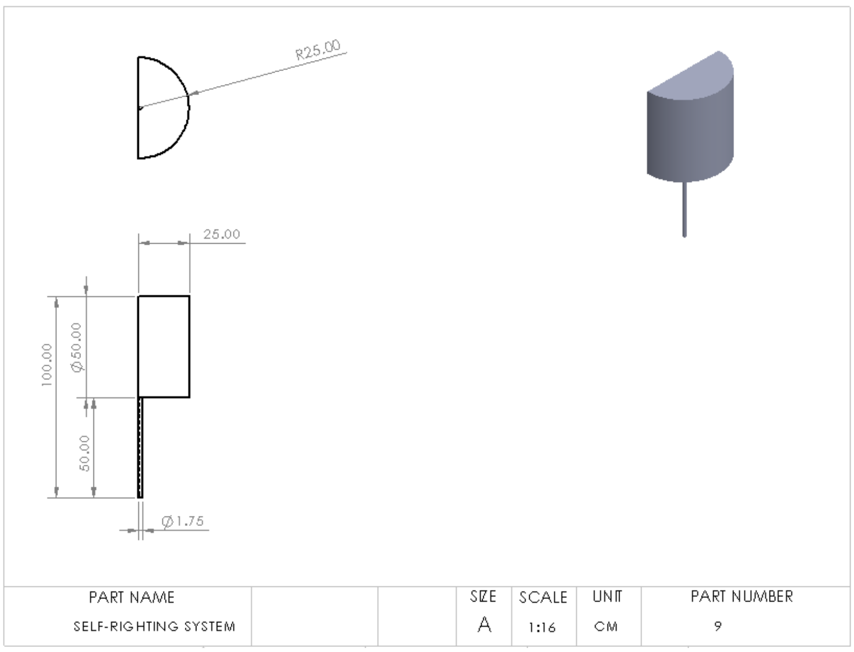
Part 7 - Steering Wheel



Part 8 - IN CLOSED SYSTEM



Part 9 - self-righting system



appendix 2: decision matrices

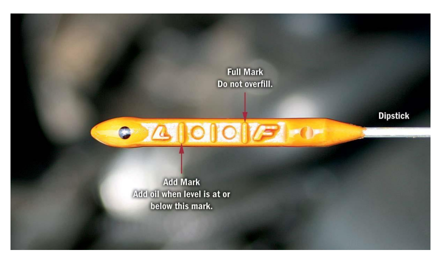
Table 42: Environmental/weather conditions in the caribbean

Weather Element	Characteristic	Value	Link
Temperature	Maximum	30°C	[3]
	Minimum	3°C	
	Average	27°C	
Snow	Maximum	Non-existent	N/A
	Minimum		
	Max Snow Depth		
Rain	Average annual	1150mm	[4] [5]
	Average days per year	149 days	
	Least days per year	40 days	
	Max days per year	225 days	
Wind	Max gust	130 mph	[6]
Hail	Largest (diameter)	Very rare. 0.5 inch	[7]
	Heaviest	N/A	
Daylight	Average Hours	12 hours a day without significant fluctuation	[8]

Explanations of Human Factor Demands Chart (In order of impact)

1. **Vision**
   - Worst Case for this HF based on our US:
     - 1.9.2/1.9.3: Checking oil/water level(s) in the tank
   - Rationale: Checks must be conducted prior to the ignition of the engine; if a user misreads the oil level(s), the machine would malfunction and leave all the users stranded at sea.
   - The population included: Normal Vision, Visually Impaired and Low Vision
     - 20/20 to 20/160
   - Prioritization List:
     - Severity: 2
     - Likelihood: 2
     - Frequency: 2
     - Overall Score: 6

Table 43: Vision justification for Human Factor Demands Chart

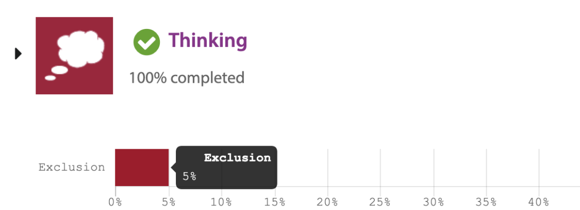
SUC	2	Checking oil/water level(s) in the tank
Variable	Value	Justification
Task	1.9.2 1.9.3	Checks must be made on the oil/water level(s) before the engine's ignition population to avoid any malfunction during the lifeboat usage.
Font Size	12 pt or under	According to the picture attached, we can conclude that the font size would be 12 pt or less. The numbers on the dipstick are usually minimal. 
Contrast	low	The oil/watercolour will be blended into the metals that are usually dark in colour, so there would be little to no difference.

Glare	low	Most of the materials used in the engine are hard plastic and metal. When checking the water and oil levels, there would be low glare because of the materials used. The only glow that the user could shine a flashlight onto specific parts of the engine's particular features.
White Space	low	There is usually little to no white space in the engine portion, especially while checking the oil and water levels.
Conclusion		
Population Included	20/20 to 20/160	TOTAL EXCLUSION: 0.9% SIZE OF TARGET POPULATION: 43,306,997
% Population Excluded	0.9%	

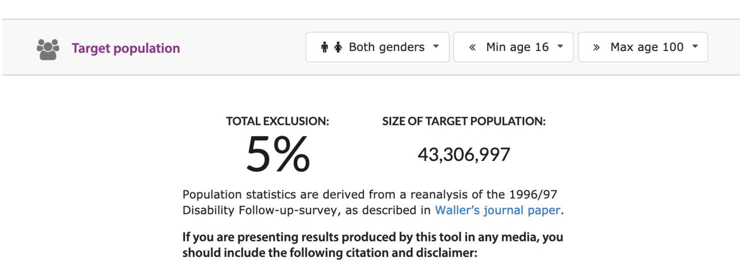
Table: Vision analysis of HF Demands and Capabilities

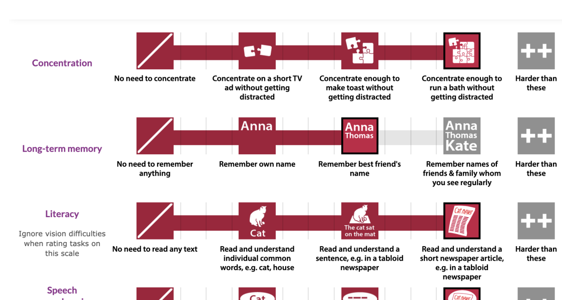
2. **Memory**
   - Worst Case for this HF based on our US:
     - 1.9: Follow Engine Start procedure
     - Rationale: Having the ability to recall orders given by the crew members is significant as commands cannot be repeated on various occasions in crisis circumstances. Not having the option to recollect explicit orders in the cases can put numerous lives in danger.
   - The population included: 95%
   - Prioritization List:
     - Severity: 2
     - Likelihood: 2
     - Frequency: 2
     - Overall Score:6

3. **Reasoning**
   - Worst Case for this HF based on our US:
     - 2.6: Is the lifeboat less than 4 meters from the water surface?
   - Rationale: The user must have a general understanding of lengths and others to be able to assess specific situations
   - Population included: 95%
   - Prioritization List:
     - Severity: 2
     - Likelihood: 2
     - Frequency: 2
     - Overall Score: 6



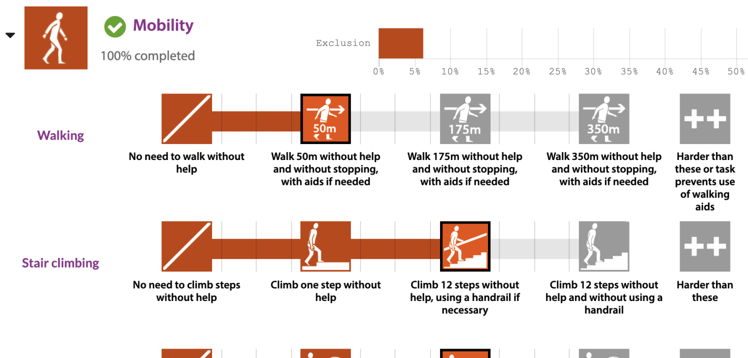
Exclusion Calculator for Memory and Reasoning:

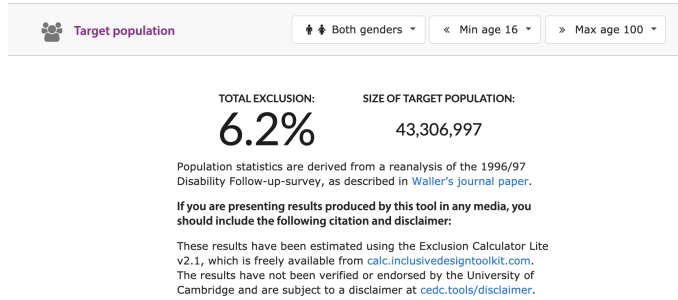




4. **Balance**
    - Worst Case for this HF based on our US:
        - 1.6: Entering the lifeboat
    - Rationale: Entering a freefall lifeboat requires some balance as the lifeboat is not steady. Also, entering the lifeboat is one of the initial steps of evacuating the vessel. On the off chance that the client has no balance and struggles to enter the lifeboat or needs help from the crew members, this causes a postponement in deploying the lifeboat.
    - The population included: 93.8%
    - Prioritization List:
        - Severity: 1
        - Likelihood: 2
        - Frequency: 2
        - Overall Score: 5
5. **Mobility**
    - Worst Case for this HF based on our US:
        - 1.1: Deploying the lifeboat as fast as possible.
    - Rationale: Being able to move rapidly, openly, and bend downwards and reach upwards is significant in crisis circumstances. The user's ability to move freely and work rapidly will influence the rate of deployment greatly.
    - The population included: 93.8%
    - Prioritization List:
        - Severity: 2
        - Likelihood: 1
        - Frequency: 1
        - Overall Score: 4

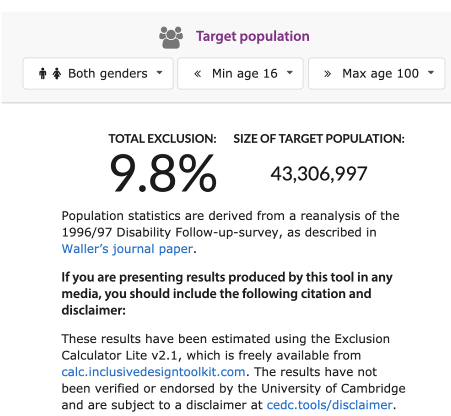
Exclusion Calculator for Balance and Mobility:

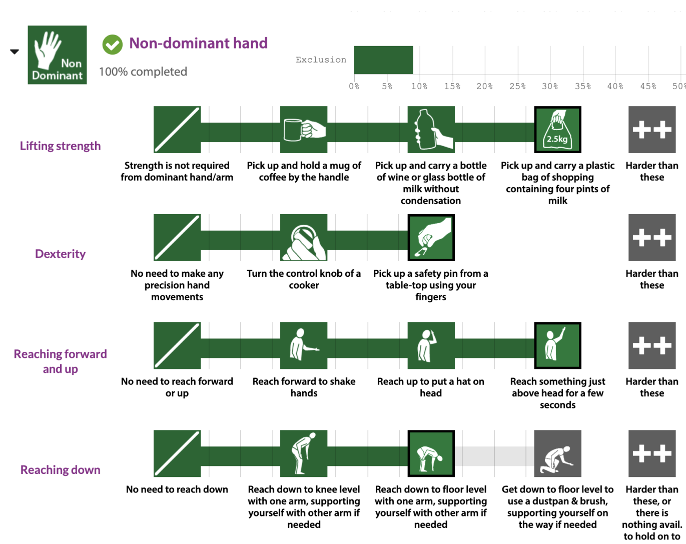


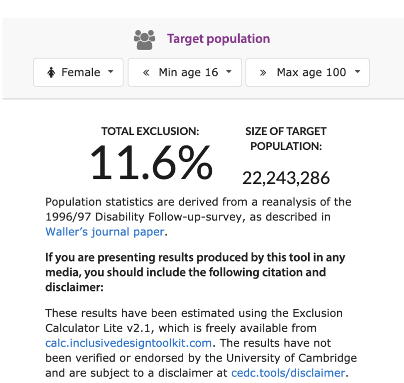


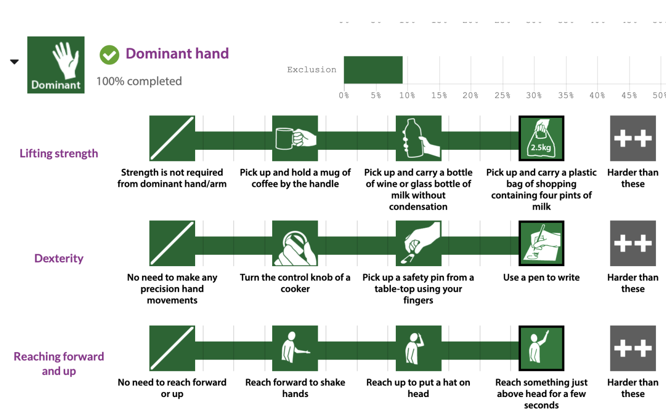
6. **Dexterity and Precision**
   - Worst Case for this HF based on our US:
     - 2.25.6: A crew member should discharge the fire extinguisher completely into the cowl opening of the running engine
   - Rationale: In using the fire extinguisher, the user will need to use his/her hands to operate it. The crew member will have to use high precision to point the extinguisher into the cowl opening to put out the fire.
   - Population included: 90.2%
   - Prioritization List:
     - Severity: 2
     - Likelihood: 1
     - Frequency: 1
     - Overall Score: 4

Exclusion Calculator for Dexterity, Precision, Touch and Strength:









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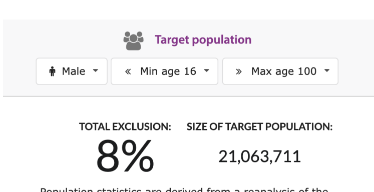

7. Hearing

- Worst Case for this HF based on our US:
  - 1.6: Hearing instructions from crew members while boarding the lifeboat
- Rationale: Not being able to hear the crew members' orders will impact the user's knowledge of the giving situation. Entering the lifeboat is a crucial stage of initialization; this causes a postponement in deploying the lifeboat.
- Population included:
  - -10 to 25 dB loss
- Prioritization List:
  - Severity: 1
  - Likelihood: 1
  - Frequency: 1
  - Overall Score: 3
- **Exclusion Calculator for Hearing:**

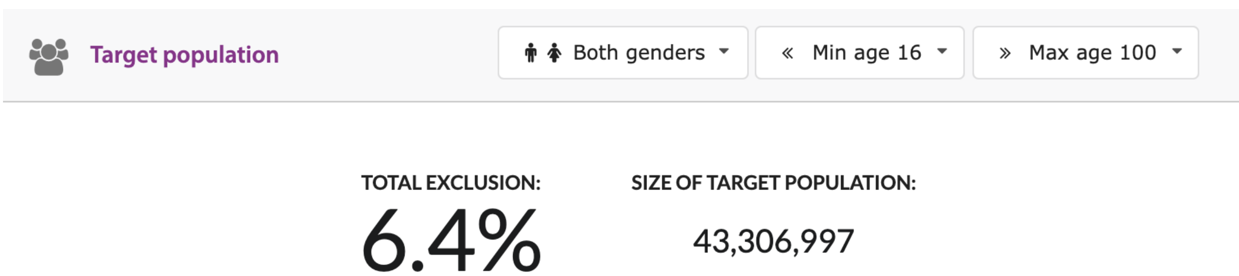

Table 44 : Hearing justification for Human Factor Demands Chart

SUC	3	Eight months pregnant woman boarding the lifeboat
Variable	Value	Justification
Task	1.6	Many tasks require the sense of hearing during the installation, use and finalization of the reference design. Task 1.6 was chosen because it is the most likely and the most critical situation where hearing is required. The lifeboats passengers must be able to hear the safety instructions given by the crew members during evacuation. If a user has difficulty hearing, that might negatively impact their understanding of vital instructions.

Volume (dB)	80-89 dB	According to My Health Alberta Website the volume level while at a noisy restaurant would be 80-89dB which is quite a similar environment to boarding a lifeboat in an emergency. https://myhealth.alberta.ca/Health/Pages/conditions.aspx?hwid=tf4173#:~:text=A%20sound's%20loudness%20is%20measured,concert%20is%20about%20120%20dB.&text=Hearing%20protectors%20reduce%20the%20loudness,sounds%20for%20a%20longer%20time.
Conclusion		
Population Included	-10 to 25 dB loss	
% Population Excluded	6.4%	
Notes	We could reduce the population excluded to provide crewmembers with loudspeakers near the entrance of the lifeboat.	

8. Smell

- Worst Case for this HF based on our US:
  - 2.25: Smelling any smoke or fumes coming from the engine that could alert a fire
- Rationale: The inability to smell the fumes or smoke coming from the engine could result in the lifeboat catching fire, and the users would be helplessly swimming in the middle of the sea.
- The population included: 97.8%
- Prioritization List:
  - Severity: 2
  - Likelihood: 0
  - Frequency: 0
  - Overall Score: 2

9. Strength

- Worst Case for this HF based on our US:
  - 2.19: Moving release handle and up to the fully open position when releasing the lifeboat
  - 1.1.1: Safety pin falsely removed. Alarm lights set off.

- Rationale: The lifeboat's release procedure requires the user to use some force to release the lifeboat off of the vessel properly. Not moving the lever in one motion would impact the launch system's integrity and lifeboat itself.
- Population excluded Male: 8%
- Population excluded Female: 11.6%
- Prioritization List:
  - Severity: 2
  - Likelihood: 0
  - Frequency: 0
  - Overall Score: 2

Table 45: Strength justification for Human Factor Demands Chart

SUC	5	A safety pin/release handle has been accidentally removed/moved to an inexperienced teen's open position in the lifeboat's release process. It needs to be put back in place correctly before the finalization process.
Variable	Value	Justification
US Task	2.19 and 1.1.1	Moving the release handle and up to the fully open position when releasing the lifeboat and the safety pin falsely removed would be the worst-case scenario for strength and was chosen to demonstrate this table.
Weight (kg)	5 kg	We could not find the specific mass of the release handle or safety pin used in the lifeboat on the internet, so we considered a similar mechanism used on airplanes, which could weigh anywhere from 3kg to 7kg.
Force Required (N)	49 N	According to the Aviation Safety website, the approximate force required to move the exit control handle from closed/locked position to open position is anywhere from 3kg to 7kg, which is 29 N to 69 N. This is most likely similar to the force required on the lifeboat. https://aviation-safety.net/airlinesafety/exits/exit.php?type=103-4#:~:text=Approximate%20weight%20of%20overwing%20exits,(15%20lbs.) https://aviation-safety.net/airlinesafety/exits/exit.php?type=022-0#:~:text=*%20Approximate%20force%20required%20to%20move,(32.5%20lbs.)%22

<table>
<tr><td>Chart from Data</td><td>Grip with hand strength.</td><td colspan="3">Based on the reference design, moving the release handle and up to full position or taking out the safety pin would require grip with hand strength.</td></tr>
<tr><td>Age Range</td><td>11-15</td><td colspan="3">Given that we are analyzing the reference design based on the safety pin or being falsely removed or activated by a teen user, this age range was chosen. Younger users wouldn't have the strength to do the task, and older users would have the reasoning not to remove the safety pin or move the release handle at the wrong time.</td></tr>
<tr><td colspan="5">Conclusion</td></tr>
<tr><td>Percentiles Included for someone-handed handed grip strength</td><td rowspan="2">Males</td><td>95th %ile to 99th %ile</td><td rowspan="2">Females</td><td>Not Included 0%</td></tr>
<tr><td>Percentiles Included for two-handed grip strength</td><td>50th %ile to 99th %ile</td><td>75th %ile to 99th %ile</td></tr>
</table>

Inputs	
Male	
Mean	30.2
SD	11.87
Female	
Mean	23.14
SD	7.03

Male Percentiles		Female Percentiles	
Percentile	Max Force Applied (N)	Percentile	Max Force Applied (N)
99.9	65.81	99.9	44.23
99.5	60.77712	99.5	41.24928
99	57.80962	99	39.49178
97.5	53.3465	97.5	36.8485
97	52.5156	97	36.3564
95	49.7855	95	34.7395
90	45.3936	90	32.1384
85	42.5448	85	30.4512
80	40.1708	80	29.0452
75	38.1529	75	27.8501
50	30.2	50	23.14
25	22.2471	25	18.4299
20	20.2292	20	17.2348
15	17.8552	15	15.8288
10	15.0064	10	14.1416
5	10.6145	5	11.5405
3	7.8844	3	9.9236
2.5	7.0535	2.5	9.4315
1	2.59038	1	6.78822
0.5	-0.37712	0.5	5.03072
0.1	-5.41	0.1	2.05

Figure 8: Screenshot of Percentile Data for 1 Handed Grip Strength.

Inputs	
Male	
Mean	49.18
SD	15.2
Female	
Mean	40.53
SD	12.99

Male Percentiles		Female Percentiles	
Percentile	Max Force Applied (N)	Percentile	Max Force Applied (N)
99.9	94.78	99.9	79.5
99.5	88.3352	99.5	73.99224
99	84.5352	99	70.74474
97.5	78.82	97.5	65.8605
97	77.756	97	64.9512
95	74.26	95	61.9635
90	68.636	90	57.1572
85	64.988	85	54.0396
80	61.948	80	51.4416
75	59.364	75	49.2333
50	49.18	50	40.53
25	38.996	25	31.8267
20	36.412	20	29.6184
15	33.372	15	27.0204
10	29.724	10	23.9028
5	[illegible]	5	[illegible]

Figure 9: Screenshot of Percentile Data for 2 Handed Grip Strength.

10. Temperature

- Worst Case for this HF based on our US:
    - 2.22.1: Are weather conditions calm enough for an autopilot to be used?
- Rationale: The user's ability to sense temperature is essential as the raft is dealt with differently as per the climate conditions. The client's users to detect temperature can likewise be fundamental in cases, for example, little small engine flames.
- The population included: 97.8%
- Prioritization List:
    - Severity: 1
    - Likelihood: 0
    - Frequency: 0
    - Overall Score: 1

11. Touch

- Worst Case for this HF based on our US:
    - 2.22: User may lose their sense of touch
- Rationale: A user losing their sense of touch or becoming numb is very dangerous and could be a sign that that person has damaged their sensory pathways.
- The population included: 97.8%
- Prioritization List:
    - Severity: 0
    - Likelihood: 0
    - Frequency: 0
    - Overall Score: 0

Changes to the Human Factors and Personas Chart:

We changed the Mobility, Dexterity & Precision and Balance minimum required capability for use. For Mobility the value was changed from 6.2% to 2.2%. For Dexterity the value was changed from 9.8% to 2.2%. For Balance the value was changed from 6.2% to 2.2%. This is because these key aspects are essential to be able to use the lifeboat properly and avoid serious injuries. The larger the percentage of exclusion indicates that not everyone is accommodated in the design which means that its a poor design.

Mohsan Raza's Interaction Error Descriptions

Initialization:

Likelihood: 3, because alarm and visual indicators should always go off when trying to board a lifeboat, especially for people like Johnny, who needs assistance in locating the lifeboat.

Exclusion: 1, because most users at Johnny's age would be able to hear and understand the instructions given, but some may have visual and or hearing impairment and will be excluded.

Severity: 2, because some people may find their way to the lifeboat without either SII, but others will not. Therefore, given the importance of locating the lifeboat in a time of panic is vital for the user's safety.

Overall Impact: 6

Use 1:

Likelihood: 0, because Johnny, who is a young teenager, would never be the first option to control the autopilot of the lifeboat as he is just a child and inexperienced

Exclusion: 3, because most if not all users except the operator of the lifeboat will not be in control of the autopilot; therefore, many of the users (including Johnny) of the lifeboat will be excluded

Severity: 0, the lifeboat can operate without the use of autopilot

Overall Impact: 3

Use 2:

Likelihood: 0, because Johnny is too young to be able to be the one who determines whether the lifeboat is less than 4 meters from the water surface.

Exclusion: 2, because many users like Johnny will not have the depth perception ability to judge whether or not the lifeboat is 4 meters from the water surface by just looking at it.

Severity: 3, because if the lifeboat were to be dropped at the height of greater than 4 meters from the water surface, it could damage the hull and extreme harm to its users.

Overall Impact: 5

Finalization:

Likelihood: 0, because a young child would not be in the position to be the one to lock the life back into position to be reused.

Exclusion: 2, because most people would have the strength to push the handle back into place as it is not that demanding, but for people who do not have the physical strength, then it can't be done.

Severity: 3, because if the lifeboat is not locked into place, then it may collapse and cause significant harm to its user, so the lifeboat must be secure during the exit procedure.

Overall Impact: 5

Mohamed Ismail's Interaction Error Descriptions

Initialization:

Likelihood: 3. Emergency announcements would always occur whenever the lifeboat is used.

Exclusion: 2. A significant number of people would be excluded as the lifeboats are meant to be on tour operators and fishing boats that likely have people from different countries that speak different languages.

Severity: 2. If users don't understand instructions properly (SII 1), that might cause miscommunication and have negative consequences for their safety and well-being. The users would be in a state of panic, worry, or stress, which would be emphasized by the alarms' volume.

Overall Impact: 7

Use 1:

Likelihood: 0. Fatima is a young inexperienced girl. The possibility that she has to do this task is low as the other passengers would probably have more experience to perform the tasks effectively and efficiently.

Exclusion: 2. Most of the passengers might not know how to perform the task; however, some might know due to past knowledge and experience or by carefully watching/reading the instruction video/manual provided by the lifeboat.

Severity: 3. Suppose none of the passengers know how to perform this task, and the lifeboat's design does not do an excellent job of making the safety instructions clear and accessible. In that case, the sick passenger's condition could potentially get significantly worse.

Overall Impact: 5

Use 2:

Likelihood: 3, Using the seat in the lifeboat is something that occurs during every use of the lifeboat so the likelihood of this happening is high. The design of these seats must be really good.

Exclusion: 1, Normal seats usually fit most users. The only users that would probably find it uncomfortable includes but is not limited to: overweight people; people with back problems; people with dwarfism; children.

Severity: 2, If the user does not fit well in their seat then they could get injured due to the movement of the lifeboat, therefore this causes harm to users and has a severity of 2.

Overall Impact: 6

Finalization:

Likelihood: 3, Getting off the lifeboat is a process that occurs during every use of the lifeboat so the likelihood of this happening is high.

Exclusion: 2, If the ramp isn't slip-resistant a lot of users would find it hard to get off the lifeboat.

Severity: 3, If someone slips and falls due to the poor design then that might result in serious injuries.

Overall Impact: 8

Mohammed Khan's Interaction Error Descriptions

Initialization:

Likelihood: 1. In most emergency cases, the crew member will be responsible for opening the lifeboats entryway, which they are trained to do. Still, In some cases, the crewmembers will not open the door, in which case the passenger is looking to open the hatch.

Exclusion: 2. The user being intoxicated on a tour boat is highly possible. Taking into consideration the age of passengers of tour boats the child and teenage passengers are excluded from this scenario.

Severity: 3, Not being able to open the door to the lifeboat is critical, especially in times of emergency

Overall Impact: 6

Use 1:

Likelihood: 1, since is Emma is an adult, she will be looked at as an option to help the crew members in times of emergency

Exclusion: 2, Most users have good vision or modification like contacts or glasses that give them a clear vision, but some users have terrible eyesight and will be excluded.

Severity: 3, if the distance from the boat to the water is not measured correctly, the boat's launch can fail.

Overall Impact: 6

Use 2:

Likelihood: 0, As Emma is a passenger is very unlikely that she will be asked to check the readings of the fuel tank

Exclusion: 1, most of the passengers are included as most likely they cannot understand the fuel tank's readings.

Severity: 2, if the reading of the fuel tank is taken incorrectly, the boat will sooner run out, keeping the users stranded

Overall Impact: 3

Finalization:

Likelihood: 0, Emma being a passenger, will not be told to do this task as crew members will be trained.

Exclusion: 3, only knowledgeable users will include as the task will require training

Severity: 3; if the lifeboat is not charged and put back on to the tour boat without checking, this can be a severe problem of an emergency where the lifeboat is required for use again.

Overall Impact: 6

Rufat Akhmetov's Interaction Error Descriptions

Initialization:

Likelihood: 2, since people of old age have a worsened vision ability, other elderly or visually impaired users could encounter the same issue.

Exclusion: 2, since people of older ages like Alexander, usually over the age of 50, have worsened eyesight. Several older users would find themselves in the same situation.

Severity:2, this is mainly because the engine has the possibility of malfunctioning while in use. The malfunction would lead to the possibility of an engine fire; additionally, it would leave the users stranded on the lifeboat in the middle of the sea.

Overall Impact: 6

Use 1:

Likelihood: 1, since people of old age have weakened muscles and joints, they are unable to perform the movement in one motion without injuring themselves.

Exclusion: 1, since most people can perform the task, it is disabling a small percentage of users.

Severity: 1, the improper performance of the task could result in an injury to the user.

Overall Impact: 3

Use 2:

Likelihood: 1, in the chance of improper steering, another physically healthy user would take control of the steering wheel and navigate the lifeboat.

Exclusion: 1, since the elderly tend to have motor limiting diseases they are the main exclusion of the user population.

Severity: 2, since the navigation of the lifeboat to a safe destination is a crucial part of proper utilization of the product, failure to correctly steer would jeopardize the lives of the other users.

Overall Impact: 4

Finalization:

Likelihood: 2, since a user of old age would find it hard to secure even if they have no signs of mobility degradation over their lifespan.

Exclusion: 1, since the development of sensorimotor polyneuropathy is rare but it is more common amongst the elderly.

Severity: 1, since the failure of securing the lines tightly would lead to the lifeboat falling off the truck bed that is attempting to retrieve it, causing product damages.

Overall Impact: 4

Dirgh's Interaction Error Descriptions

Initialization:

Likelihood: 2 - Most lifeboats should have a separate entrance for people with disabilities and that require extra assistance in boarding.

Exclusion: 1 - The Cambridge Exclusion Calculator suggests that 7.5% of pregnant women (like Sheela) that have low mobility and need special assistance are excluded.

Severity 3 - If a 7.5 months pregnant woman is rushed into boarding, then she is at higher risk of tripping or falling on the ground due to her low mobility and agility.

Use 1:

Likelihood: 2 - If the lifeboat does indeed capsize, then she will have to grip the handles herself in addition to receiving help.

Exclusion: 2 - This case can also apply for elderly and disabled people that are not able to grip firmly.

Severity: 3 - This is very severe since if she is not able to get back on the lifeboat using those handles, she can possibly get injured.

Use 2:

Likelihood: 1 - A crew member or Sheela's husband will help out knowing a 7.5 months pregnant woman is going to struggle swimming.

Exclusion: 2 - This will apply to people with disabilities and elderly.

Severity: 3 - If she gets no help, Sheela will have a very tough time swimming against the waves and could lose even more stamina.

Finalization:

Likelihood: 2 - Sheela's husband will most likely help her get up from her seat.

Exclusion: 2 - This case can also apply to elderly and disabled people.

Severity: 1 - It won't be that severe, since no injury can be caused by getting up from the seat.

Justifications for Personas in the Decision Matrix (Evaluation 1):

Table 46 : Decision matrices for Fatima

EVALUATION FOR PERSONA:			Fatima				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	10	0	0	0	0	0
CONCEPT 1	1	9	1	1	-1	0	0
CONCEPT 2	2	6	2	-1	-1	0	2
CONCEPT 3	-1	11	1	-2	1	0	-1
CONCEPT 4	3	2	1	1	0	0	1
CONCEPT 5	3	2	2	2	-2	0	1
CONCEPT 6	4	1	2	1	-1	0	2
CONCEPT 7	2	6	2	2	-1	0	-1
CONCEPT 8	3	2	2	2	-2	0	1
CONCEPT 9	3	2	2	2	-2	0	1
CONCEPT 10	2	6	1	1	0	0	0

Table 47 : Decision matrices for Johnny

EVALUATION FOR PERSONA:			Johnny				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	8	0	0	0	0	0
CONCEPT 1	2	4	1	1	0	0	0
CONCEPT 2	2	4	2	-2	0	0	2
CONCEPT 3	0	8	1	-1	1	0	-1
CONCEPT 4	3	3	1	1	0	0	1
CONCEPT 5	5	1	2	2	0	0	1
CONCEPT 6	2	4	1	-1	0	0	2
CONCEPT 7	-1	11	2	-2	0	0	-1

CONCEPT 8	0	8	2	-2	-1	0	1
CONCEPT 9	5	1	2	2	0	0	1
CONCEPT 10	2	4	1	1	0	0	0

Table 48 : Decision matrices for Emma

EVALUATION FOR PERSONA:			Emma				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	10	0	0	0	0	0
CONCEPT 1	3	2	2	2	-1	0	0
CONCEPT 2	2	5	2	-1	-1	0	2
CONCEPT 3	0	10	1	-1	1	0	-1
CONCEPT 4	2	5	1	1	-1	0	1
CONCEPT 5	3	2	2	2	-2	0	1
CONCEPT 6	1	8	-1	1	-1	0	2
CONCEPT 7	1	8	1	2	-1	0	-1
CONCEPT 8	2	5	2	1	-2	0	1
CONCEPT 9	4	1	2	2	-1	0	1
CONCEPT 10	3	2	1	2	0	0	0

Table 49 : Decision matrices for Alexander

EVALUATION FOR PERSONA:			Alexander				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	7	0	0	0	0	0
CONCEPT 1	0	7	1	1	-1	-1	0
CONCEPT 2	3	1	2	1	-1	-1	2
CONCEPT 3	-5	11	-1	-1	-1	-1	-1
CONCEPT 4	1	6	1	1	-1	-1	1
CONCEPT 5	3	1	2	2	-1	-1	1
CONCEPT 6	2	4	1	1	-1	-1	2
CONCEPT 7	0	7	2	1	-1	-1	-1
CONCEPT 8	2	4	2	1	-1	-1	1
CONCEPT 9	3	1	2	2	-1	-1	1
CONCEPT 10	0	7	1	1	-1	-1	0

Table 50 : Decision matrices for Sheela

EVALUATION FOR PERSONA:			Sheela				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	6	0	0	0	0	0
CONCEPT 1	1	3	2	1	-1	-1	0
CONCEPT 2	1	3	2	-1	-1	-1	2
CONCEPT 3	-1	8	1	-1	1	-1	-1
CONCEPT 4	1	3	1	1	-1	-1	1
CONCEPT 5	3	1	2	2	-1	-1	1
CONCEPT 6	-1	8	1	-2	-1	-1	2
CONCEPT 7	-2	11	2	-1	-1	-1	-1
CONCEPT 8	-1	8	2	-2	-1	-1	1
CONCEPT 9	3	1	2	2	-1	-1	1
CONCEPT 10	0	6	1	1	-1	-1	0

Concept 1:

6. Functionality
    a. Fatima: 1 - Fatima has a seat and seat belt so she's more secure when compared to the reference design but it doesn't protect her against elements so it doesn't get a 2.
    b. Sheela: 2 - Concept #1 and reference design both use outboard engines which cause more noise and that will be a problem for her due to her damaged ear drums. Both designs use V-shaped hulls which are good for stability for Sheela. However, in concept #1, the navigation and communication system is composed into one panel which is a good thing if Sheela has to ever use it due to its simplicity.
    c. Johnny: 1 - Our design Concept includes comfortable seats and lap bar restraint which is more secure than the reference designs'. But doesn't provide protection from the elements for Johnny.
    d. Emma: 2 - This design has a much better securing system than the reference

design and is much better for securing Emma. The navigation and communication is also together and fairly simple for Emma to use.

e. Alexander: 1 - This concept design is fairly similar to the reference design, his seat has a seat belt that will hold him in place. The seatbelt used will provide Alexander accessibility into the other systems while he is seated inside the vehicle.

7. Usability
    a. Fatima: 1 - Fatima is safer because of the seats and seat belts so this gets a 1. There is no proper entrance so she would have to hop on which is inconvenient and might be hard due to her age and size just like the reference design.
    b. Sheela: 1 - The concept allows Sheela to sit on a traditional seat and secure herself with lap restraints, which is good since she's pregnant. However, in the reference design there are no seats. Both designs are open, which won't protect her from harsh weather. Also, both designs don't have an access system which will make it difficult for Sheela to hop on into the lifeboat due to her baby bump.
    c. Johnny: 1 - Johnny will experience the same amount of difficulty boarding the system as the reference design. But since the seats only have a lap bar restraint it will be easier for him to secure himself into the system. Also, since there is an under seat compartment it makes it easier for him to access anything he may need during his use without having to move.
    d. Emma: 1 - This design is very similar in terms of accessing the system to the reference design. Emma will find the controls of the system easier to use.
    e. Alexander: 1 - Alexander will have the same experience using the systems in the vehicle when compared to the reference design. This design having no doors enables him to quickly step into the vehicle and fasten himself into his seat which is safer because of the type of seat and seatbelt used.
8. Producibility
    a. Fatima: -1 - Fatima would need seating to make sure she stays safe and secure however, producing lightweight seats that are also safe and implementing it into the manufacturing of the inflatable cabin would be difficult.
    b. Sheela: -1 - In this concept, it requires Sheela to have a seat and seat belt due to

her pregnancy. This will increase the production cost compared to the reference design.

c. Johnny: 0 - This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
d. Emma: -1 - Emma needs to be secure while the product is in use this will add the 3-point seatbelt system adding an extra element in production.
e. Alexander: -1 - In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.

9. Maintainability
    a. Fatima: 0 - Fatima wouldn't need to do any work to maintain it compared to the reference because she is young and does not have the knowledge or education background to do so. Therefore we can say that this design would be just as maintainable as the reference.
    b. Sheela: -1 - The lap bar restraint and seats required for Sheela must be maintained properly, which will increase maintenance cost compared to the reference design.
    c. Johnny: 0 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
    d. Emma: 0 - The maintenance of the lifeboat is fairley the same as the reference design.
    e. Alexander: -1 - The lap bar restraint and seats required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.
10. Sustainability
    a. Fatima: 0 - When comparing this design to the reference design we can say that sustainability does not change in Fatima's view.
    b. Sheela: 1- This design is no more or no less sustainable in the perspective of Sheela to the reference design.
    c. Johnny: 0 - This design is no more or no less sustainable in the perspective of

Johnny to the reference design.

d. Emma: 0 - The sustainability is fairly the same as the reference design. The systems are similar to the reference design.
e. Alexander: 0 - This design is no more or no less sustainable in the perspective of Alexander to the reference design.

Concept 2:

1. Functionality
   a. Fatima: 2 - Fatima has a seat and seat belt so she is more secure when compared to the reference design and it protects her against elements so it gets a 2.
   b. Sheela: 2 - This concept uses ducted propellers that are known to make less noise while functioning. This is very good for Sheela because her eardrums are partially damaged and it could hurt her ears if the propulsion system is too loud. The reference design uses an outboard engine that is known to be noisy and hence not ideal for Sheela. Also, concept 2 is fully enclosed, while reference design is fully open. Fully opened reference design is bad for Sheela, since it will expose her to harsh weather like storms.
   c. Johnny: 2 - Our design concept includes comfortable seats and 5-point harness which is more secure than the reference designs'. Also, it does provide good protection from the elements
   d. Emma: -1 - Emma is required to be secured on the product while in use and the 5-point harness will perform that task.
   e. Alexander: 2 - This design has a five point seat belt which secures Alexander into the seat better than traditional seatbelts and additionally it provides protection to him from the exterior elements at sea.

2. Usability
   a. Fatima: -1 - Fatima might experience trouble putting on the 5 point seat belt due to her young age and lack of experience.

b. Sheela: -1 - The 5-point harness will be too tight for her, since she has a big baby bump.
c. Johnny: -2 - Johnny will experience the greater amount of difficulty boarding the system as the reference design as he has to use a hinge door to board. The seats have a 5-point harness which will be harder for him to secure himself into the system.
d. Emma: -1 - This design is very similar in terms of accessing the system to the reference design. Emma will find it harder to use the navigation and communication system as the systems are stored in the storage compartments.
e. Alexander: 1 - Alexander will have better ability to use the systems within the confines of the vehicle since he is protected from exterior elements. Therefore, the protection that is provided will not give him trouble seeing while using the other systems.

3. Producibility
    a. Fatima: -1 - Fatima The enclosed design and seats would increase manufacturing time and be more expensive compared to the reference.
    b. Sheela: -1 - In this concept, it requires Sheela to have a seat and seat belt due to her pregnancy. This will increase the production cost compared to the reference design.
    c. Johnny: 0 - This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
    d. Emma: -1 - Emma will find it harder to enter and exit the system efficiently in times of emergency.
    e. Alexander: -1 - In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.
4. Maintainability
    a. Fatima: 0 - Fatima or the crewmembers wouldn't need to do any more work to maintain it compared to the reference so we can say that this design would be just as maintainable as the reference.
    b. Sheela: -1 - The 5-point harness and seat required for Sheela must be maintained

properly, which will increase maintenance cost compared to the reference design.

c. Johnny: 0 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
d. Emma: -1 - The maintenance of the lifeboat will be harder for Emma as the navigation and communication systems are not clear sight but stored away in storage.
e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.

5. Sustainability
    a. Fatima: 2 - Ducted propellers are more environmentally friendly and make less noise for Fatima while on the lifeboat compared to the reference design which uses an outboard. Also, since it is enclosed the elements don't have an effect on Fatima and equipment inside, therefore it will prolong the lifetime of the lifeboat. However, the reference design is fully opened, which is bad for Fatima and the interior of the lifeboat.

    b. Sheela: 2- Ducted propellers are more environmentally friendly and make less noise for Sheela while on the lifeboat compared to the reference design which uses an outboard. Also, since it is enclosed the elements don't have an effect on Sheela and equipment inside, therefore it will prolong the lifetime of the lifeboat. However, the reference design is fully opened, which is bad for Sheela and the interior of the lifeboat.

    c. Johnny: 2 -Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Also since it can be enclosed the elements don't have effect on the users and equipment inside, therefore it will prolong the lifetime of the lifeboat.

d. Emma: 2 - Ducted propellers are more environmentally friendly and make less noise for Emma while on the lifeboat compared to the reference design which uses an outboard. Also, since it is enclosed the elements don't have an effect on Emma and equipment inside, therefore it will prolong the lifetime of the lifeboat. However, the reference design is fully opened, which is bad for Emma and the interior of the lifeboat.

e. Alexander: 2 - Ducted propellers are more environmentally friendly and make less noise for Alexander while on the lifeboat compared to the reference design which uses an outboard. Also, since it is enclosed the elements don't have an effect on Alexander and equipment inside, therefore it will prolong the lifetime of the lifeboat. However, the reference design is fully opened, which is bad for Alexander and the interior of the lifeboat.

Concept 3:

1. Functionality
    a. Fatima: 1 - Fatima has a seat and seat belt so she's more secure when compared to the reference design but it doesn't protect her against elements so it doesn't get a 2.
    b. Sheela - 1: The propulsion system is only the paddles, which is good for her ears, since there won't be any noise from the engine like the one used in the reference design. However, she won't have enough strength to paddle continuously, which is a negative functionality of concept 3. The inflatable convertible cabin will protect Sheela from harsh weather, unlike the reference design which is fully open.
    c. Johnny: 1 - Our design concept includes comfortable seats and with a 3-point seat belt which is more secure than the reference designs'. The design does provide protection from the elements but is not as good as it is not very strong protection.
    d. Emma: 1 - Emma will be kept secured when the product is in use but will not be secured properly as the 3-point seatbelt system is not the best secure option.

The emergency aid system is also designed for each user in the system.

e. Alexander: -1 - While being seated inside, the propulsion system used in this design will require Alexander to constantly paddle the product with the other users. Due to his old age and health he might encounter difficulties while using the paddles therefore a grade of -1 was selected.

2. Usability
    a. Fatima: -2 - The design requires Fatima to hop on and paddle which is not convenient and could be hard due to her age and size.
    b. Sheela: -1 - Sheela won't have continual strength and keep paddling with the paddles. Also, low to the ground seating system will be hard for her due to her big baby bump. The reference design has an engine that could propel, which doesn't require any strength to be used.
    c. Johnny: -1 - Johnny will experience the same amount of difficulty boarding the system as the reference design. But since the seats have a 3-point seat belt it will be easier for him to secure himself into the system since he is familiar with this seatbelt. The paddles require require knowledge and physical strength from the user to be able to use it appropriately and Johnny is quite young so he will have difficulty
    d. Emma: -1 - The paddling system will be much harder for Emma and take much more energy in comparison to the reference design.
    e. Alexander: -1 - The paddle system will require Alexander to constantly paddle which would consume much of his energy and due to his age and health a grade of -1 was chosen.
3. Producibility
    a. Fatima: 1 - This is a simpler design than the reference so it'll be easier to produce.
    b. Sheela: -1 - In this concept, it requires Sheela to have a seat and seat belt due to her pregnancy. This will increase the production cost compared to the reference design.
    c. Johnny: 1 -The reason I put a point here is because this design is the simplest design out of all of them compared to the reference design therefore it would

cost less to produce.

   d. Emma: Emma will need the securing system installed and that will add to the production.
   e. Alexander: -1- In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.

4. Maintainability
   a. Fatima: -1 - The inflatable cabin is more susceptible to cutting open when compared to the reference design so that would increase maintenance costs.
   b. Sheela: -1 - The 3-point seat belt and seats required for Sheela must be maintained properly, which will increase maintenance cost compared to the reference design.
   c. Johnny: 1 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
   d. Emma: 1 - Emma will be able to maintain the system with more ease because of the paddles in comparison to an engine.
   e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.
5. Sustainability
   a. Fatima: 2 - Paddles produce nearly no environmental problems so they're very sustainable despite the fact that they require a lot of energy by the user. The paddles must be secured to the boat so they don't fall into the water.
   b. Sheela: -1 - This design is better than the reference design because it does not harm the surrounding environment at all due to Sheela using paddles to steer the lifeboat. But it gets -1 points because Sheela may get tired from using the paddles as they require lots of energy to consistently use therefore.
   c. Johnny: 1 - This design is better than the reference design because it does not harm the surrounding environment at all due to Johnny using paddles to steer the lifeboat. But it gets -1 points because Johnny may get tired from using the

paddles as they require lots of energy to consistently use therefore.

d. Emma:-1 - Inflatable convertible cabin is much more likely to get damaged
e. Alexander: -1 - This design is better than the reference design because it does not harm the surrounding environment at all due to Johnny using paddles to steer the lifeboat. But it gets -1 points because Johnny may get tired from using the paddles as they require lots of energy to consistently use therefore.

Concept 4:

1. Functionality
    a. Fatima: 1 - Fatima has a seat and seat belt so she's more secure when compared to the reference design but it doesn't protect her against elements so it doesn't get a 2.
    b. Sheela: 1 - In this concept the ducted propellers are good for her since low noise levels and it won't cause further harm to her already damaged ear drums. In reference design, an outboard engine is used which has a higher noise level.
    c. Johnny: 1 - Our design concept includes comfortable seats and the roller coaster restraint which is more secure than the reference designs'. But doesn't provide protection from the elements
    d. Emma: 1- Emma will be secure when the product is in use. And will have access to the emergency aid below her at all times.
    e. Alexander: 1 - This concept design is fairly similar to the reference design, his seat has a seat belt that will hold him in place. The seatbelt used will provide Alexander accessibility into the other systems while he is seated inside the vehicle.
2. Usability
    a. Fatima: 1 - Fatima is safer because of the seats and seat belts so this gets a 1. There is no proper entrance so she would have to hop on which is inconvenient and might be hard due to her age and size just like the reference design.
    b. Sheela: 1 - The traditional seating in concept 4 is good for Sheela, since she needs to sit on a seat due to her baby bump. In the reference design, there are no seats.
    c. Johnny: 1 - This design will be easier for Johnny as it has an under seat

compartment so it's easier to access items. And it has traditional seating and a roller coaster restraint which Johnny is familiar with.

d. Emma:1- Emma will have an easier time entering and exiting the system in times of emergency while also have an easier time accessing the emergency aid system under her seat storage compartment.

e. Alexander: 1 - Alexander will have the same experience using the systems in the vehicle when compared to the reference design. This design having no doors enables him to quickly step into the vehicle and fasten himself into his seat.

3. Producibility
    a. Fatima: 0 - This design has roughly the same producibility as the reference design.
    b. Sheela: -1 - In this concept, it requires Sheela to have a seat and seat belt due to her pregnancy. This will increase the production cost compared to the reference design.
    c. Johnny: 0 - This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
    d. Emma: -1 - Emma is required to be secure and will need the securing system to be installed this will increase the production.
    e. Alexander: -1- In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.
4. Maintainability
    a. Fatima: 0 - Fatima or the crewmembers wouldn’t need to do any more work to maintain it compared to the reference so we can say that this design would be just as maintainable as the reference.
    b. Sheela: -1 - The roller coaster restraint and seats required for Sheela must be maintained properly, which will increase maintenance cost compared to the reference design.
    c. Johnny: 0 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix

d. Emma: 0 - Emma will have a similar experience in maintaining the system in comparison to the reference design.
e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.

5. Sustainability
    a. Fatima: 1 - Ducted propellers are more environmentally friendly when compared to the diesel engines used in the reference design so sustainability gets a higher score.
    b. Sheela: 1 - Ducted propellers are more environmentally friendly and make less noise pollution for Sheela on the lifeboat compared to the reference design which uses an outboard.
    c. Johnny: 1 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard.
    d. Emma: 1 - Emma will find the system more sustainable as she will be able to use the system without making any errors or causing damage to the system in any way.
    e. Alexander: 1 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard.

Concept 5:

1. Functionality
    a. Fatima: 2 - Fatima has a seat and seat belt so she is more secure when compared to the reference design and it protects her against elements so it gets a 2.
    b. Sheela: 2 - Due to the inboard engine being used in concept 5, the noise levels will be low because the engine will be inside the hull. This is good for Sheela due to her damaged ear drums. In reference design, an outboard engine is used which has a higher noise level. This design is enclosed, which means it will protect

Sheela from dangerous weather conditions, unlike reference design that is fully open. Also, all the navigation and communication system components are onto one panel which is a simplistic design for Sheela to use in case she has to use it.

c. Johnny: 2 - Our design concept includes comfortable seats and lap bar restraint which is more secure than the reference designs'. And also provides protection from the elements
d. Emma: 2 - Emma will be secured properly when the product is in use and will be able to access all the navigation and communication systems on one panel.
e. Alexander: 2 - This design has a lap bar restraint which secures Alexander into the seat, and additionally it provides protection to him from the exterior elements at sea. Also the lap bar restraint enables Alexander to reach down into the underseat compartment in time of need.

2. Usability
    a. Fatima: 2 - Fatima is secured into her seat and has a proper entrance and exit which makes it safer and easier to enter and leave the system.
    b. Sheela: 2 - There is a long bench that Sheela can sit on with lap restraint to secure herself. In the reference design, there are no seats and a securing system which is bad for Sheela due to her pregnancy. The door sliders can be easily used by Sheela, since they require very minimal energy to open and close them.
    c. Johnny: 1 - For this design it will be easy to board the system as the doors slide open and close. Also, the seating and securing system are quite easy for a child to use.
    d. Emma: -1 - Emma will not be able to enter and exit the system with ease in times of emergency while also not being able to use the navigation and communication system.
    e. Alexander: 2 - Since the design is enclosed, Alexander will easily access the other systems inside the vehicle.
3. Producibility
    a. Fatima: -2 - The enclosed design, seats and inboard engine would increase manufacturing time and be more expensive compared to the reference.

b. Sheela : -1 - In this concept, it requires Sheela to have a seat and seat belt due to her pregnancy. This will increase the production cost compared to the reference design.
c. Johnny: 0 - This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
d. Emma: -2 - Emma is required to be secured and the addition of the lap restraint will add to production while also the horizontal opening doors will add to production.
e. Alexander: -1- In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.

4. Maintainability
    a. Fatima: -1 - This design has more components which requires more maintenance checks and increases the likelihood of faults so it gets a score of -1.
    b. Sheela: : -1 - The lap bar restraint and seat required for Sheela must be maintained properly, which will increase maintenance cost compared to the reference design.
    c. Johnny: 0 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
    d. Emma: -1 - Emma will have more components to maintain and will be much more harder in comparison to the reference design.
    e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.
5. Sustainability
    a. Fatima: 0 - The type of propulsion system used here is very similar to the reference it does not increase nor decrease the sustainability.
    b. Sheela: 1 - Inboard engine will decrease noise pollution for Sheela onboard and the environment. Also, it is enclosed so it protects the users from weather

elements and also the interior of the lifeboat so it can be used in the future again.

c. Johnny: 0 - Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.
d. Emma: 1 - Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.
e. Alexander: 1 - Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.

Concept 6:

1. Functionality
    a. Fatima: 2 - Fatima has a seat and seat belt so she is more secure when compared to the reference design and it protects her against elements so it gets a 2.
    b. Sheela: 1 - The ducted propulsion system used in concept 6 has a low noise level, which is good for Sheela due to her damaged ear drums. In the reference design an outboard engine is used which has a higher noise level. Also, concept 6 has an inflatable convertible design which is needed in order to protect Sheela from harsh weather like storms. In the reference design, it has a completely open design.
    c. Johnny: 1 - Our design concept includes comfortable seats and 5-point harness which is more secure than the reference designs'. But only provides slight protection from the elements
    d. Emma: -1 - This design concept consists of a 5-point harness securing system which is much more secure in comparison to the reference design.
    e. Alexander: 1 - This design has seats with a 5 point harness which is relatively more secure when compared to the reference design. Therefore, Alexander will be more secure in his seat which is safer.

2. Usability

a. Fatima: Fatima is safer because of the seats and seat belts so this gets a 1. There is no proper entrance so she would have to hop on which is inconvenient and might be hard due to her age and size just like the reference design.
b. Sheela: -2 - The 5-point harness will be quite difficult for Sheela to use due to her big baby bump. The no door access system will be tough for Sheela to use since she will have to use her legs and hop on into the lifeboat, which can be difficult for her also due to the big baby bump. Also, the multiple connected seats might be a little uncomfortable for her because she will require some space to sit.
c. Johnny: -1 - This design would make it more difficult for Johnny to use because it has a 5-point harness which is very complicated for a child to use and also uncomfortable. Johnny will experience the same amount of difficulty boarding the system as the reference design.
d. Emma: 1 - Emma will find it easier in entering and exiting the system with the closed system in comparison to the reference design.
e. Alexander: 1 - Alexander will have better ability to use the systems within the confines of the vehicle as he is protected from exterior elements. Therefore, the protection that is provided will not give him trouble seeing while using the other systems.

3. Producibility
    a. Fatima: -1 - Lightweight seats may be hard to produce and put on the inflatable cabin.
    b. Sheela: -1 - In this concept, it requires Sheela to have a seat and seat belt due to her pregnancy. This will increase the production cost compared to the reference design.
    c. Johnny: 0 -This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
    d. Emma: -1 - Emma is required to be secure when the system is in use and will need a securing system that will increase the production cost.
    e. Alexander: -1- In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.

4. Maintainability
    a. Fatima: -1 - The inflatable cabin is more susceptible to cutting open when compared to the reference design so that would increase maintenance costs.
    b. Sheela: -1 - The 5-point harness and multiple connected seats in a row will require frequent maintenance, which is not needed in the reference design.
    c. Johnny: 1 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
    d. Emma: 0 - The reference design is very similar in terms of maintainability.
    e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.
5. Sustainability
    a. Fatima: 2 - Ducted propellers are more environmentally friendly when compared to the diesel engines used in the reference design so sustainability gets a higher score.
    b. Sheela: 2- Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Also since it can be enclosed the elements don't have effect on the users and equipment inside, therefore it will prolong the lifetime of the lifeboat
    c. Johnny: 2 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Also since it can be enclosed the elements don't have effect on the users and equipment inside, therefore it will prolong the lifetime of the lifeboat.
    d. Emma: 2 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Also since it can be enclosed the elements don't have effect on the users and equipment inside, therefore it will prolong the lifetime of the lifeboat.

e. Alexander: 2 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Also since it can be enclosed the elements don't have effect on the users and equipment inside, therefore it will prolong the lifetime of the lifeboat.

Concept 7:

1. Functionality
    a. Fatima: 2 - Fatima has a seat and seat belt so she is more secure when compared to the reference design and it protects her against elements so it gets a 2.
    b. Sheela: 2 - The ducted propulsion system used in concept 6 has a low noise level, which is good for Sheela due to her damaged ear drums. In the reference design an outboard engine is used which has a higher noise level. Also, concept 6 has an enclosed design, which is needed in order to protect Sheela from harsh weather like storms. In the reference design, it has a completely open design.
    c. Johnny: 2 - Our Design Concept includes comfortable seats and 5-point harness which is more secure than the reference designs'. And also provides protection from the elements
    d. Emma: 1 - In comparison to the reference design the securing system and seating system have been added to secure emma.
    e. Alexander: 2 - This design has a five point seat belt which secures Alexander into the seat better than traditional seatbelts and additionally it provides protection to him from the exterior elements at sea.
2. Usability
    a. Fatima: 2 - Fatima is secured into her seat and has a proper entrance and exit which makes it safer and easier to enter and leave the system.
    b. Sheela: -1 - The 5 - point harness will be tough for Sheela to use due to her big baby bump.
    c. Johnny: -2 - This design would make it more difficult for Johnny to use because it has a 5-point harness which is very complicated for a child to use and also uncomfortable. Johnny will experience more difficulty boarding the system as the

reference design, due to their being hinge doors because it requires knowledge to open them and physical strength to open them.

   d. Emma: 1 Emma will be able to enter and exit the system safely and will be secured when the system is being used.
   e. Alexander: 1 - Alexander will have better ability to use the systems within the confines of the vehicle since he is protected from exterior elements. Therefore, the protection that is provided will not give him trouble seeing while using the other systems.

3. Producibility
   a. Fatima: -1 - The enclosed design and seats would increase manufacturing time and be more expensive compared to the reference.
   b. Sheela: -1 - In this concept, it requires Sheela to have a seat and seat belt due to her pregnancy. This will increase the production cost compared to the reference design.
   c. Johnny: 0 - This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
   d. Emma: -1 - Emma is required to have a securing system that will increase the production cost.
   e. Alexander: -1- In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.
4. Maintainability
   a. Fatima: -1 - This design has more components which requires more maintenance checks and increases the likelihood of faults so it gets a score of -1.
   b. Sheela: -1 - In this concept the seats and seat belts would need regular maintenance checks, since Sheela will be using them.
   c. Johnny: 0 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
   d. Emma: 0 - In comparison to the reference design maintainability will be the same as emma is in a state of intoxication and cannot maintain.

e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.

5. Sustainability
    a. Fatima: -1 - Ducted propellers are more environmentally friendly when compared to the diesel engines used in the reference design so sustainability gets a higher score.
    b. Sheela: -1 - The flat-bottom hull can only be used on calm bodies of water because if used on rough bodies of water it can capsize easily due to it being less stable and this can cause damage to the lifeboat so the lifeboat to be unusable therefore users will not have a lifeboat to use in the future
    c. Johnny: -1 - The flat-bottom hull can only be used on calm bodies of water because if used on rough bodies of water it can capsize easily due to it being less stable and this can cause damage to the lifeboat so the lifeboat to be unusable therefore users will not have a lifeboat to use in the future
    d. Emma: -1 - The flat-bottom hull can only be used on calm bodies of water because if used on rough bodies of water it can capsize easily due to it being less stable and this can cause damage to the lifeboat so the lifeboat to be unusable therefore users will not have a lifeboat to use in the future
    e. Alexander: -1 - The flat-bottom hull can only be used on calm bodies of water because if used on rough bodies of water it can capsize easily due to it being less stable and this can cause damage to the lifeboat so the lifeboat to be unusable therefore users will not have a lifeboat to use in the future.

Concept 8:

1. Functionality
    a. Fatima: 2 - Fatima has a seat and seat belt so she is more secure when compared to the reference design and it protects her against elements so it gets a 2.
    b. Sheela: 2 - The inboard engine that is used as a propulsion system has a low noise level which is good for Sheela due to her partially damaged ear drums.
    c. Johnny: 2 - Our Design Concept includes comfortable seats and 5-point harness

which is more secure than the reference designs'. And also provides protection from the elements

d. Emma: 2 - This design concept has a very good securing system, the 5-point harness, and protects her from elements.
e. Alexander: 2 - This design has a five point seat belt which secures Alexander into the seat better than traditional seatbelts and additionally it provides protection to him from the exterior elements at sea.

2. Usability
    a. Fatima: 2 - Fatima is secured into her seat and has a proper entrance and exit which makes it safer and easier to enter and leave the system.
    b. Sheela: -2 - The round bottomed hull will be little unstable for Sheela to use and also the 5-point harness will be tough for Sheela due to her big baby bump.
    c. Johnny: -2 - This design would make it more difficult for Johnny to use because it has a 5-point harness which is very complicated for a child to use and also uncomfortable. Johnny will experience the same amount of difficulty boarding the system as the reference design.
    d. Emma: 1 - Emma will find the Navigation and communication system much easier to use in comparison to the reference design.
    e. Alexander: 1 - Alexander will have better ability to use the systems within the confines of the vehicle since he is protected from exterior elements. Therefore, the protection that is provided will not give him trouble seeing while using the other systems.
3. Producibility
    a. Fatima: -2 - The enclosed design, seats and inboard engine would increase manufacturing time and be more expensive compared to the reference.
    b. Sheela: -1: In this concept, it requires Sheela to have a seat and seat belt due to her pregnancy. This will increase the production cost compared to the reference design.
    c. Johnny: 0 - Freefall mechanism would cost more than the davit release mechanism from reference design, and due to the fast/abrupt nature of the freefall mechanism it could scare Johnny.

   d. Emma: -2 - Emma is required to have a very secure system that will increase the production cost.
   e. Alexander: -1- In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.
4. Maintainability
   a. Fatima: 0 - Fatima or the crewmembers wouldn't need to do any more work to maintain it compared to the reference so we can say that this design would be just as maintainable as the reference.
   b. Sheela: -1 - In this concept, it requires Sheela to have a seat and seat belt due to her pregnancy. This will increase the maintenance cost compared to the reference design.
   c. Johnny: 0 - Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.
   d. Emma: 0 - This design is very similar to the reference design in terms of maintainability.
   e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.
5. Sustainability
   a. Fatima: 1 - The type of propulsion system used here is very similar to the reference; it does not increase nor decrease the sustainability.
   b. Sheela: 1 - Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.
   c. Johnny: 1 - Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.
   d. Emma: 1 - Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather

elements and also the interior of the lifeboat so it can be used in the future again.

e. Alexander: 1 - Inboard engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.

Concept 9:

1. Functionality
    a. Fatima: 2 - Fatima has a seat and seat belt so she is more secure when compared to the reference design and it protects her against elements so it gets a 2.
    b. Sheela: 2 - The inboard engine used to propel the lifeboat is noise efficient for Sheela due to her damaged ear drums.
    c. Johnny: 2 - Our design concept includes comfortable seats and lap bar restraint which is more secure than the reference designs'. And also provides protection from the elements
    d. Emma: 2 - Emma is required to have a securing system and this design has a secure system in comparison to the reference design.
    e. Alexander: 2 - This design has a lap bar restraint which secures Alexander into the seat, and additionally it provides protection to him from the exterior elements at sea. Also the lap bar restraint enables Alexander to reach down into the underseat compartment in time of need.
2. Usability
    a. Fatima: 2 - Fatima is secured into her seat and has a proper entrance and exit which makes it safer and easier to enter and leave the system.
    b. Sheela: 2 -
    c. Johnny: 2 - For this design it will be easy to board the system as the doors slide open and close. Also, the securing system is just a lap bar restraint so Johnny could easily figure how to secure himself.
    d. Emma: 2 - The system has an easy concept for navigation and communication and is easier for Emma to use.
    e. Alexander: 2 - Since the design is enclosed, Alexander will easily access the other systems inside the vehicle.

3. Producibility
    a. Fatima: -2 - The enclosed design, seats and inboard engine would increase manufacturing time and be more expensive compared to the reference.
    b. Sheela: -1 - The seats and seat belt will increase the production cost.
    c. Johnny: 0 - This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
    d. Emma: -1 - Emma will find it much harder in entering and exiting the system as the system is closed.
    e. Alexander: -1- In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.
4. Maintainability
    a. Fatima: -1 - This design has more components which requires more maintenance checks and increases the likelihood of faults so it gets a score of -1.
    b. Sheela: -1 - The seat and seat belt will require frequent maintenance, which will increase the maintenance cost.
    c. Johnny: 0 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
    d. Emma: 0 - This design concept is the same as tehr reference design in terms of maintainability.
    e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.
5. Sustainability
    a. Fatima: 1 - The type of propulsion system used here is very similar to the reference; it does not increase nor decrease sustainability.
    b. Sheela: 1 - Stern drive engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.
    c. Johnny: 1- Stern drive engine will decrease noise pollution for the users onboard

and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.

d. Emma: 1 - Stern drive engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.

e. Alexander: 1 - Stern drive engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.

Concept 10:

1. Functionality
    a. Fatima: 1 - Fatima has a seat and seat belt so she’s more secure when compared to the reference design but it doesn’t protect her against elements so it doesn’t get a 2.
    b. Sheela: 1 - The multi-hulled structure of this concept is quite stable for functionality.
    c. Johnny: 1 - Our Design Concept includes comfortable seats and with a 3-point seat belt which is more secure than the reference designs'. The design does not provide protection from the elements.
    d. Emma: 1 - Emma will require the seating system and the 3-point seatbelt to keep her secure while the product is in use. This is much better than the reference design.
    e. Alexander: 1 - This concept design is fairly similar to the reference design, his seat has a seat belt that will hold him in place. The seatbelt used will provide Alexander accessibility into the other systems while he is seated inside the vehicle.
2. Usability
    a. Fatima: 1 - Fatima is safer because of the seats and seat belts so this gets a 1. There is no proper entrance so she would have to hop on which is inconvenient and might be hard due to her age and size just like the reference design.
    b. Sheela: 1 - The 3-point seatbelt is good for Sheela because it enables her to

secure herself. Also, the long bench can be used by her to sit on.

c. Johnny: 1 - This design is similar to the reference design in the sense that to board the system you have to go over the side. The reason I added a point here is because the seating and securing system are quite easy for a child to use.
d. Emma: 2 - This design is a lot easier for emma to use as the seating system requires users to be seated next to each other and can assist emma if she is in need of help.
e. Alexander: 1 - Alexander will have the same experience using the systems in the vehicle when compared to the reference design. This design having no doors enables him to quickly step into the vehicle and fasten himself into his seat which is safer because of the type of seat and seatbelt used.

3. Producibility
   a. Fatima: 0 - This design has roughly the same producibility as the reference design.
   b. Sheela: -1 - The seats and seat belts will be required to be produced. This increases the production costs.
   c. Johnny: 0 - This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
   d. Emma: 0 - This design has roughly the same producibility as the reference design.
   e. Alexander: -1- In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.
4. Maintainability
   a. Fatima: 0 - Fatima or the crewmembers wouldn't need to do any more work to maintain it compared to the reference so we can say that this design would be just as maintainable as the reference.
   b. Sheela: -1 - The seats and seat belts require maintenance that will be part of maintenance cost.
   c. Johnny: 0 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a

lifeboat based on his human capabilities located in the appendix

d. Emma: 0 - This design is just as maintainable as the reference design as many of the subsystems are the same as the reference design.
e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.

5. Sustainability
   a. Fatima: 0 - The type of propulsion system used here is very similar to the reference it does not increase nor decrease the sustainability.
   b. Sheela: 0 - This design is no more or no less sustainable in the perspective of Sheela to the reference design.
   c. Johnny: 0 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard.
   d. Emma: 0- This design is more environmentally friendly in comparison to the reference design.
   e. Alexander: 0 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard.

Justifications for Personas in the Decision Matrix (Evaluation 2):

EVALUATION FOR PERSONA:			Fatima				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	6	0	0	0	0	0
CONCEPT 4	3	3	1	1	0	0	1
CONCEPT 5	3	3	2	2	-2	0	1
CONCEPT 9	3	3	2	2	-2	0	1
CONCEPT 11	6	1	2	2	0	0	2
CONCEPT 59	5	2	2	2	0	0	1

EVALUATION FOR PERSONA:			Johnny				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	6	0	0	0	0	0
CONCEPT 4	3	5	1	1	0	0	1
CONCEPT 5	5	2	2	2	0	0	1
CONCEPT 9	5	2	2	2	0	0	1
CONCEPT 11	6	1	2	2	0	0	2
CONCEPT 59	5	2	2	2	0	0	1

EVALUATION FOR PERSONA:			Alexander				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	6	0	0	0	0	0
CONCEPT 4	1	5	1	1	-1	-1	1
CONCEPT 5	3	2	2	2	-1	-1	1

CONCEPT 9	3	2	2	2	-1	-1	1
CONCEPT 11	4	1	2	2	-1	-1	2
CONCEPT 59	3	2	2	2	-1	-1	1

EVALUATION FOR PERSONA:			Sheela				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	6	0	0	0	0	0
CONCEPT 4	1	5	1	1	-1	-1	1
CONCEPT 5	3	3	2	2	-1	-1	1
CONCEPT 9	5	1	2	2	-1	1	1
CONCEPT 11	4	2	2	2	-1	-1	2
CONCEPT 59	3	3	2	2	-1	-1	1

EVALUATION FOR PERSONA:			Emma				
	TOTAL	RANK	Functionality	Usability	Producibility	Maintainability	Sustainability
REF DES	0	6	0	0	0	0	0
CONCEPT 4	2	5	1	1	-1	0	1
CONCEPT 5	3	4	2	2	-2	0	1
CONCEPT 9	4	2	2	2	-1	0	1
CONCEPT 11	5	1	2	2	-1	0	2
CONCEPT 59	4	2	2	2	-1	0	1

Concept 11:

11. Functionality
    a. Fatima: 2 - This concept provides seating and a 3-point seatbelt which secures Fatima. It is also an enclosed design unlike the reference design and so it protects Fatima from any elements that could potentially harm her. Winds, rain and a lot of loud noises could trigger Fatima's PTSD, the enclosed design limits

that from happening.

b. Sheela: 2 - This concept provides seating and a 3-point seatbelt which secures Sheela. It is also an enclosed design unlike the reference design and so it protects Sheela from any elements that could potentially harm her. Winds, rain and a lot of loud noises could damage Sheela's ear drums even more, so the enclosed design limits that from happening.
c. Johnny: 2 - Our design concept includes comfortable seats and 3-point seat belts which are more secure and easy to use compared to the reference designs'. And also provides protection from the elements
d. Emma: 2 - This design concept has a long beach seating system which will be convenient for Emma while the 3-point securing system will keep her secure on the seat while the system is in use. This system is also a closed system which will keep Emma safe from the outside environment.
e. Alexander: 2 - This design has a 3 point seat belt restraint which secures Alexander into the seat, and additionally it provides protection to him from the exterior elements at sea. Since the design is enclosed Alexander can safely unbuckle his seat belt and access the emergency aid compartment located inside the cabin.

12. Usability
    a. Fatima: 2 - The 3-point seatbelt is familiar and it would be easy for Fatima to use as well as adjust. The emergency aid underseat compartment is easily accessible in case an emergency happens.
    b. Sheela: 2 - The 3-point seatbelt is familiar and it would be easy for Sheela to use as well as adjust. The emergency aid underseat compartment is easily accessible in case an emergency happens.
    c. Johnny: 2 - For this design it will be easy to board the system as the doors slide open and close. Also, the seating and securing system are quite easy for a child to use.
    d. Emma: 2 - Emma will find the emergency aid compartment under the seat very accessible in times of emergency in comparison to the reference design. The sliding door system will make it easier for Emma to enter and exit the system.

e. Alexander: 2 - Since this concept is enclosed, Alexander is enabled to easily access the other systems located within the cabin. Additionally the sliding door would provide an easy access point into the vehicle without which he can use it with ease when compared to the hinged door and no door (open design).

13. Producibility
    a. Fatima: 0 - This design would have the same producibility as the reference design so it would not have an effect on Fatima and therefore it was scored a 0.
    b. Sheela: -1 - The seats and seat belt will increase the production cost compared to the reference design.
    c. Johnny: This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
    d. Emma: -1 - Emma is required to have a 3-point seat system for securing her when the system is in use and will increase the production cost.
    e. Alexander: -1 - In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.
14. Maintainability
    a. Fatima: 0 - Fatima would not be able to maintain this design in any way because of her age and lack of knowledge and so this concept is similar to the reference design and maintainability gets a score of 0.
    b. Sheela: -1 - The maintenance cost of sit and seat belts would increase due to frequent maintenance checks required for it.
    c. Johnny: This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
    d. Emma: 0 - This design is similar to the reference in terms of maintainability as Emma will be in a state of intoxication and will not be able to maintain the lifeboat.
    e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the reference design.

15. Sustainability
    a. Fatima: 2 - The ducted propellers cause less noise pollution which is good for Fatima because she has PTSD. They are also more environmentally friendly. The less noise she's exposed to the better as she would feel safer. If she were to go on the reference design she might have an episode due to the noise of the engine and the visual disturbances from the open structure design.
    b. Sheela: 2 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Also since it can be enclosed the elements don't have effect on the users and equipment inside, therefore it will prolong the lifetime of the lifeboat.
    c. Johnny: 2 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Also since it can be enclosed the elements don't have effect on the users and equipment inside, therefore it will prolong the lifetime of the lifeboat.
    d. Emma: 2- Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Additionally the structure is enclosed and exterior elements will have no effect on the systems located inside the cabin while also providing a prolonged lifetime to the vehicle.
    e. Alexander: 2 - Ducted propellers are more environmentally friendly and make less noise pollution for the users on the lifeboat compared to the reference design which uses an outboard. Additionally the structure is enclosed and exterior elements will have no effect on the systems located inside the cabin while also providing a prolonged lifetime to the vehicle.

Concept 59:

6. Functionality
    a. Fatima: 2 - This concept provides seating and a 3-point seatbelt which secures

Fatima. It is also an enclosed design unlike the reference design and so it protects Fatima from any elements that could potentially harm her. Winds, rain and a lot of loud noises could trigger Fatima's PTSD, the enclosed design limits that from happening.

b. Sheela: 2 - This concept provides seating and a 3-point seatbelt which secures Fatima. It is also an enclosed design unlike the reference design and so it protects Sheela from any elements that could potentially harm her. Winds, rain and a lot of loud noises could damage eardrums, the enclosed design limits that from happening.
c. Johnny: 2 - Our Design Concept includes comfortable seats and 3-point seat belts which are more secure and easy to use compared to the reference designs'. And also provides protection from the elements
d. Emma: 2 - This design concept has a closed system and will protect Emma from the outside environment. The system also has the 3-point securing system which will secure Emma and keep her in her seat when the system is in use.
e. Alexander: 2 - This design has a 3 point seat belt restraint which secures Alexander into the seat, and additionally it provides protection to him from the exterior elements at sea. Since the design is enclosed Alexander can safely unbuckle his seat belt and access the emergency aid compartment located inside the cabin.

7. Usability
    a. Fatima: 2 - The 3-point harness is familiar and it would be easy for Fatima to use as well as adjust. The emergency aid storage unit is easily accessible in case an emergency happens.
    b. Sheela: 2 - The 3-point harness is familiar and it would be easy for Sheela to use as well as adjust. The emergency aid storage unit is easily accessible in case an emergency happens.
    c. Johnny: 2 - For this design it will be easy to board the system as the doors slide open and close. Also, the seating and securing system are quite easy for a child to use.
    d. Emma: 2 - The securing system is very familiar with Emma and she will be able to

secure herself correctly while the product is in use. While also the emergency aid system is very accessible unlike the reference design.

e. Alexander: 2 - Since this concept is enclosed, Alexander is enabled to easily access the other systems located within the cabin. Additionally the sliding door would provide an easy access point into the vehicle without which he can use it with ease when compared to the hinged door and no door (open design).

8. Producibility
    a. Fatima: 0 - This design would have the same producibility as the reference design so it would not have an effect on Fatima and therefore it was scored a 0.
    b. Sheela: -1 - The production cost of seats and seat belts will increase the production costs.
    c. Johnny: 0 - This design is very similar in terms on producibility to the reference design therefore it would not have a effect on the fitness of Johnny
    d. Emma: -1- The concept will have to have a 3-point securing system which will increase the production cost.
    e. Alexander: -1 - In this concept, it requires Alexander to have a seat due to his age and health condition. This will increase the production cost compared to the reference design.
9. Maintainability
    a. Fatima: 0 - Fatima would not be able to maintain this design in any way because of her age and lack of knowledge and so this concept is similar to the reference design and maintainability gets a score of 0.
    b. Sheela: -1 - The seats and seat belts will require frequent maintenance.
    c. Johnny: 0 - This design is just as maintainable as the reference design because Johnny is a child and does not have the iq or strength in order to maintain a lifeboat based on his human capabilities located in the appendix
    d. Emma: 0 - This design is similar to the reference in terms of maintainability as Emma will be in a state of intoxication and will not be able to maintain the lifeboat.
    e. Alexander: -1 - The seat and seat restraint required for Alexander must be maintained properly, which will increase maintenance cost compared to the

reference design.

10. Sustainability
    a. Fatima: 1 - Stern drive engines make less noise pollution as it is incorporated within the structure. Noise pollution is harmful for the environment and sea life. The reference uses an outboard engine which makes way more noise. Fatima has PTSD so the less noise she's exposed to the better as she would feel safer.
    b. Sheela: 1 - Stern drive engines make less noise pollution as it is incorporated within the structure. Noise pollution is harmful for the environment and sea life. The reference uses an outboard engine which makes way more noise. Sheela has a problem with the ear drums, so the less noise she's exposed to the better as she would feel safer.
    c. Johnny: 1 - Stern drive engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.
    d. Emma:1- Stern drive engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.
    e. Alexander: 1 - Stern drive engine will decrease noise pollution for the users onboard and the environment. Also, it is enclosed so it protects the users from weather elements and also the interior of the lifeboat so it can be used in the future again.