Sea Level Enclosure

Preliminary Report

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DISCLAIMER

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1 BACKGROUND

1.1 Introduction

This project is to design a sea-level enclosure. This means that an enclosure is completely sealed from the outside atmospheric pressure and has its own custom pressure inside. This project focuses on getting the enclosure to exactly sea level condition (elevation = 0). The sponsor for this project is the head coach of the NAU women's swimming and diving team. He would like this enclosure to help train his athletes with the swimming skills. Once completed, he would like to continue to use it for years and even let some international teams try out the enclosure. The major difficulties with this project are the large volume that will be covered, a 3rd party company suppling the sea-level atmospheric gases, and making and testing a prototype to see if an enlarged idea will work.

1.2 Project Description

The team did not know much about the project when first begun other than it was an enclosure over a pool. It was not until the team met with client, Andy Johns, the head coach of the women's swimming and diving team, for a meeting to discuss the project. After the meeting the team had learned that the main plan for the enclosure is to cover two lanes of the pool on the deep end of the swimming pool in the Aquatic Center here in NAU while also covering some land by the pool, so a coach can be inside and talk to his athletes. The design must be easy to set up/take down, be safe, take up minimal space while stored, and most importantly keep sea-level conditions inside the enclosure.

1.3 Original System

"There was no original system when this project began."

2 REQUIREMENTS

2.1 Customer Requirements (CRs)

The purpose of this project is to create a sea level environment enclosing two lanes of the NAU Aquatic Center swimming pool. To determine customer requirements the client Andy Johns, the NAU women's swimming and diving head coach, was interviewed by the team. Through this discussion, it was found that setup/breakdown time and storage were the most important needs that must be met. Along with the design being compact to store, its weight must be taken into consideration so that it can easily be moved to and from the pool/storage areas. Also, the client wants the final design to be durable, being able to last for many years and be transparent for safety reasons. Finally, this projects goal is to create a sea level atmospheric environment, meaning that the final build will need to be airtight, this will be one of our primary requirements. Being airtight we will need strong seals and meshing's, at any airlock or entrance that the final concept may have.

2.2 Engineering Requirements (ERs)

Setup/Breakdown time will require a 5 min tolerance due to the uncertainties that the user will encounter during the assembly/disassembly process (Table 1). For example, if the air pump under performs, it will have a negative impact on the setup time. If setup/breakdown time exceeds 35 mins, the design will be considered a failure. Since the system will be enclosing a large amount of space, pressure may vary within the enclosure. However, a two kPa pressure difference will not result in a significant difference in a pressure-based altitude change. Next a tolerance of 10% was set on transmittance, which will allow a multitude of different materials to fall within this specification. Target limits have been set for cycles, area, and collapsed volume to accurately reflect on the customers needs. Finally, weight set at 136kg for the whole design, should be able to be carried by two or four adults to achieve portable criteria.

Table 1: Engineering requirements

Engineering Requirement	Target Value	Tolerance
Setup/Breakdown time	30 mins	+/- 5min
Pressure	78.2 kPa	+/- 2kPa
Transmittance	80%	+/- 10%
Cycles	240 times	> 240 times
Area	$280m^2$	$< 280m^2$
Collapsed	$28\ m^3$	$< 28m^3$
Weight	136 kg	+/- 5kg

2.5 House of Quality (HoQ)

Based off the customer needs given by the client our team determined appropriate engineering requirements. This was then added into a house of quality for further analysis (Figure1). The primary need for this design was to create a sea level environment, we determined the best way to measure this criterion was the pressure that the enclosure can reach. Our target for this will be a 78 kPa gauge pressure in Flagstaff to achieve a sea level pressure condition. Next, the client needs a fast setup and breakdown time so that the structure can be opened when needed and out of the way when not in use. This we directly used as a requirement and for the time limit for setup and breakdown, we set our benchmark at 30 minutes or less. Along with time, the design must be reasonably light for easy maneuverability we set an engineering requirement for this to be 136 kg, so that two to four people could set it up. Another client need that must be satisfied is have the enclosure compactable so that it can be stored in a small storage room with the approximate dimensions of 3x3x3 meters, this means the design must be very compactible. For this requirement, the collapsed volume we are setting a target goal of $28m^3$, so the design will easily fit within the allotted space. Lastly our client needs the final build to last, he would like for it to function for multiple years without maintenance. The requirement we selected for this need was number of cycles before system failure we set this limit at 240 cycles.

	Setup/breakdown time	Pressure	Transmittance	Cycles	Area	Collasped volume	Weight
Setup/breakdown time							
Pressure	--						
Transmittance							
Cycles		+					
Area	--	--					
Collasped volume	-			+	+		
Weight	-		-	+	+	+	

A	Fabrico Sun Domes
B	Yolloy

Customer Needs	Customer Weights	Technical Requirements: Setup/breakdown time	Pressure	Transmittance	Cycles	Area	Collasped volume	Weight	Customer Opinion Survey: 1 Poor	2	3 Acceptable	4	5 Excellent
Quick assembly/dissembly	4	9			3		3	6	A	B			
Sea level altitude	5		9		6				A			B	
Clear design	3			9							B		A
Longevity	4		6		9						AB		
Compact space	3	6				9	9	6		B	A		
Weight	4	6				6	6	9	B		A		
Technical Requirement Units		min.	kPa	%	#	m2	m3	kg					
Technical Requirement Targets		30	78.2	80	240	280	28	136					
Absolute Technical Importance		78	69	27	78	51	63	78					
Relative Technical Importance		17.6%	15.5%	6.1%	17.6%	11.5%	14.2%	17.6%					

Figure 1. House of Quality

3 EXISTING DESIGNS

Chapter 3 will focus on research done for our project and explain existing designs that relate similarly. This was done by searching for designs with similar requirements and seeing if anything can be learned. Unfortunately, this project seems to be unique.

3.1 Design Research

After researching for designs similar to this project it was found that the information was very scarce. Enclosures were found over pools covering them completely. Even inflated enclosures were found covering the pools. None, of which, had to keep a certain pressure inside other than keeping the enclosure from collapsing. The gas supplier, Altitude Control Technologies, has their information on their projects very hidden, the team is still waiting to hear back from this company. Based on this the team has been coming up with new ideas for this enclosure without necessary information.

3.3 Functional Decomposition

The functional decomposition for this project consisted of constructing a black box model and either a Functional Model, Work-Process Diagram, or a Hierarchical Task Analysis. The Black Box Model is very simple. It is one box with the name of the device being designed inside and arrows pointing in on the left side and out on the right side to show inputs into the system and the outputs returned. For this project, we chose, a Hierarchical Task Analysis, because it is a very helpful tool to see what steps go into take to a certain design. This is very beneficial to this project considering every time it is going to be used it will have to be set up, used, taken apart, and then stored away until next time it will be used, which, will not be for weeks at a time during certain parts of the year.

3.3.1 Black Box Model

A black box model is a concept that engineers use to show the inputs and outputs from a system (Figure 2). A human will start an electrically powered air pump to allow air to enter the system. The air that enters must be calibrated to a specific ratio so that sea-level condition can be simulated. This can be accomplished with a computer system supplied by Altitude Control Technologies. The air that enters the system will not result in the output end of our black box, because our main goal is to hold the air within our design. The whole system operates based on computer control, human interaction is only involved at initial startup and shut down. The black box model helped team to understand what our design needs to take in and give out. It also was helpful in setup and building the hierarchical task analysis.

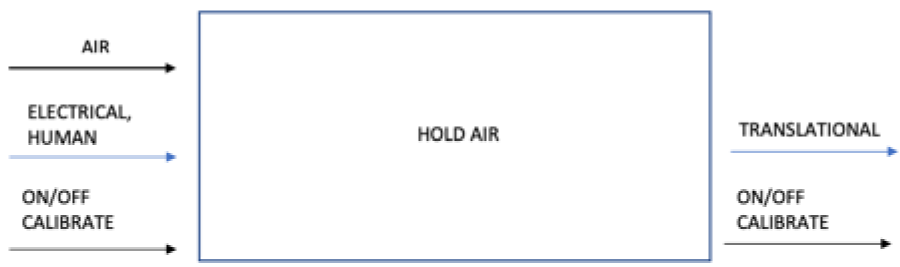

Figure 2: Black Box

3.3.2 Hierarchical Task Analysis

A hierarchical task analysis model was made to deconstruct the individual tasks that the sea level enclosure will perform (Appendix A). This was started with the basic functions including setup, usage, breakdown, and storage. These were then expanded upon in detail to fully understand what tasks go into each aspect of the project. First breaking down setup, the enclosure must be removed from storage and put in place by the pool. Then, if assembly is need this must be performed. Once all components are in place the pumps or pressurization system can be turned on filling the enclosure with appropriate levels of air. Once properly controlled to ideals ranges of air and pressure usage may begin. The enclosure may be entered either through the water or an airlock system. At this point the coach and/or athlete may begin with their sea level experience. After use, the disassembly branch starts, with evacuating all persons from the enclosure. Once everyone is out, the pump/pressurization system can be turned off and decompression can begin. Break down of components starts once all air has been removed. Enclosure will then be properly compacted to prepare for storage. Finally, the project and all pieces will be placed within storage area until next use.

3.4 Subsystem Level

The system must be able to hold sea level atmospheric pressure in Flagstaff. To achieve this goal, each subsystem must fulfill specific design requirements. The system must be able to be assembled and disassembled in a timely manner. The whole structure needs to be waterproof and be under desired weight limitation for portability. The system will be stored in storage area for most of its life since customer will only be using it twice a week during swimming season. The subsystems we will be evaluating are an airlock for the coach to enter into the enclosure, different pumps for pressurization of a larger system, and different sealing methods to ensure that design stays at required pressure.

3.4.1 Subsystem #1: Airlock

The airlock subsystem of this project is very important when it comes to the coach entering and leaving the enclosure. This needs to be done for the coach to communicate with his athletes to ensure they are doing their training properly. An airlock is a small room before entering a larger enclosure. Airlocks are used for various applications including, entering a clean room or a pressurized chamber. The point of the airlock is to sterilize the person entering and/or matching the pressure in the airlock to the enclosure being entered. This is crucial to this project because little to no pressure should be lost while being used.

3.4.1.1 Existing Design #1: Modular Airlock Clean Rooms

Modular Airlock Clean Rooms are made by Clean Room Depot (1). This design is important to the team because this design is portable with fast set up times. This will give ideas on how to properly seal an airlock if the final design incorporates one. With minimum tools and less than one hours' time this can be made into an airtight clean room for temporary or permanent applications. This design uses a clear lightweight vinyl and an anodized aluminum frame. The vinyl locks into the frame and uses foam gaskets to seal the room. The frame attaches together with knock-together corners, this makes it possible for individual parts to be replaced. Unfortunately, the price and pressure capabilities for this design were not given.

3.4.1.2 Existing Design #2: bioBUBBLE

The bioBUBBLE is another airlock with soft walls and can convert between many pressures to adapting to a changing environment (2). This company offers to build airlocks for customers to any size they desire. Using similar framework used by Clean Room Depot the vinyl is attached with a hoop an loop system and states that the blowers used are very efficient using 99.99% HEPA filters. Information on this design is limited as well but it does state they are affordable airlocks and easily change the conditions inside to whatever pressure is needed for a certain application.

3.4.1.3 Existing Design #3: Modular Airlock Clean Rooms

This design is from Terra Universal Critical Environment Solutions and they have pressurized and non-pressurized versions of their airlock (3). The non-pressurized airlock is simple as it just provides a neutral air zone. This helps minimize disturbances and air turbulence when entering or leaving controlled environments. These airlocks come fully assembled and range from $7,427-$8,572 for sizes 1321 x 1118 x 2286 mm - 1321 x 1829 x 2286 mm. For this project a non-pressurized airlock may be considered because the lower cost and if it does not affect the pressure in the enclosure drastically.
Pressurized airlocks come with a EC fan/filter unit with HEPA filters. This stops cross contamination when going in between 2 rooms because inside the airlock changes the pressure, using 2 x 4 ft fan, to match the room being entered. Though, these are more expensive ranging from $10,062-$11,208 for the dimensions of 1321 x 1118 x 2717 mm - 1321 x 1829 x 2717 mm.

3.4.2 Subsystem #2: Pressurization Pumps

This subsystem is also important to consider because pumps and other devices from Altitude Control Technologies will be filling up/pressurizing the enclosure which has a large volume. The volume of the enclosure was roughly calculated to be 934 m^3 (33,000 ft^3) and the time it takes to pressurize the designed enclosure will also be included in the setup time marked at 30 minutes. Looking into different pump and their flow rates will give the team and Altitude Control Technologies an idea on what size and how many pumps will be needed to reach the setup mark.

3.4.2.1 Existing Design #1: Mounto 3-Speed Air Mover Blower Monster Carpet Dryer

The Mounto air mover blower is designed for drying carpets (4). This design shows that it is very possible to fill a large volume in a short amount of time. This pump uses a one HP motor and can blow 4030 CFM. This would roughly feel up the enclosure purposed in approximately eight minutes. This design also can stack up to three in series which would then fill the enclosure in less than three minutes. These models run for around $210.00. It also has a five-year warranty.

3.4.2.2 Existing Design #2: Huawei Air blower 330W - Model W-2E

This blower is cheaper at $122.51 but is much lighter and is used for things like inflating bouncy houses (5). This design shows a more practical kind of blower seen by almost everyone. This design though only pushes 176.55 CFM which is low, but it is also stackable. Using only one of these blowers it would take over 3 hours to fill the enclosure.

3.4.2.3 Existing Design #3: 3HP Inflatable Fan Blower Vortex Pump

This pump is made by Manvac and runs from $373-$533 (6). This pump alone is capable to fill the enclosure in about 24 minutes, which is within the needed range. More efficient and high CFM models of this blower are made and could fill up the enclosure in just over 10 minutes. Unfortunately to view these pumps one must contact the supplier.

3.4.3 Subsystem #3: Sealing Method

The sealing method is one of the most crucial requirements within this project. This subsystem is the key component that holds the gases provided by Altitude Control Technologies, the gases in the enclosure must meet the requirements of a sea-level atmosphere. To keep the enclosure at sea-level conditions proper sealings must be in place to hold the gases within. Without proper sealing the gases will escape and deflate the enclosure.

3.4.3.1 Existing Design #1: Structure Sealing

The Wyoming McMurry High Altitude Performance Center, is an example of a completely sealed structure (7). This allows the building to vary between different pressure/elevations levels within for training, recovery, and any other experiments that require different altitude conditions. Common paths for air leaks that must be taken in consideration for this structure to be completely sealed include around and through windows and doors, through gaps at transitions between the walls, floors, and ceilings. This method would meet the requirements for this project if the budget allowed for such a large cost factor.

3.4.3.2 Existing Design #2: Membrane Air Separation Technology

Looking at the Smithsonian Museum of American History, the Star-Spangled Banner is enclosed in a fire proof environment holding extremely low levels of oxygen. This enclosure was created by Altitude Control Technologies using a completely redundant oxygen control system utilizing membrane air separation technology (8). This form of sealing doesn’t allow for any air to escape the environment meeting the requirements for the enclosure but isn’t a viable option due to high cost factors and precise set-up procedures.

3.4.3.3 Existing Design #3: Heat-sealing

Inflatable Pool toys today are heat pressed to allow for a complete seal from any water entering the air chamber (9). This sealing method will allow the design “Floaty” to achieve the sealed air chambers that surround the base of the enclosure.

4 DESIGNS CONSIDERED

This section will introduce different design concepts that fulfill our customer/engineering requirements. All the subsystems that contributes to our design, each design has its own focus. All the design concepts and subsystems will mostly likely be changed around as the team narrows down the final design. However, all the concepts introduced here will provide some ideas or directions for our final team design. All designs that are introduced in this section have rough sketches that can be found in Appendix B.

4.1 Design #1: Floaty

The design, Floaty, uses a bubble themed structure with an inflatable pool toy like base. Attached to the base of the enclosure will be small weights that will be evenly spaced along the bottom of the air chambers base. The concept is aired up by a compressor, this should make for quick assembly times. Once the base is aired up the base is then laid across the lanes of the pool and attached to the sides of the hoods along the short wall of the pool. The air pumps provided by Altitude Control Technologies will be attached to the corresponding attachment points, then the system will be turned on and the enclosure will be ready once the signal is given by the system. Some pros for this design is the quick assembly time and the ease of use. While some cons are the difficult collapsing methods including the complex folding of the enclosure to allow for increased longevity.

4.2 Design #2: PVC

The second design uses PVC as the main structure for the enclosure. The PVC will use a house driven design layout for the frame structure. The assembly will include putting the large set-up pieces together to create a frame. The frame will include four set post that will be the main supporting area for the entire cover. The cover will be set across the top of the frame with weights along the edges of the cover which will create the seal between the air and water. Some pros for this concept include a much higher factor of safety for the users and ensures for a large work space for the coach to walk and help train athletes. The cons for this design include, assembly/disassembly will take much longer due to the many pieces that will comprise the frame. Also, the frame elements will increase the amount of space the design will take up in storage compared to some other designs.

4.3 Design #3: Roller

The roller design is based loosely off a pool cover that is rolled onto a spindle at one end of the pool. This concept will dispense the enclosure out and then be inflated into a dome shape enclosure. When not in use this provides easy storage because the entire enclosure will be rolled up and will be moveable with wheels fixed on the frame holding the spindle. Pros of this concept are the weight would no longer be a factor because the design wouldn’t have to be picked up and storage space would be minimized. Cons of this would be an extremely long spindle holder are needed and would be costly.

4.4 Design #4: 2 Lands

2 lands design uses the concept of storing the enclosure under the water on or near the bottom of the pool. This would eliminate the need for storage space except for the pump/pressurization system. When needed air would be pumped into enclosure raising it from the bottom. After fully ascended the swimmer would be able to enter from underneath and train within the environment. After use the air could then be pumped out and the enclosure would naturally sink back to the bottom. Some pros of this idea are that storage space and weight of enclosure wouldn't be a factor, also the cost would be minimal as just the enclosure material and pump are needed for this design. The cons of this concept are that have the enclosure stored near the bottom of the pool could be a safety concern. Also, with having the design stored in the water it would be constantly exposed to the chemicals in the water possibly causing it to deteriorate at a rapid rate.

5 DESIGN SELECTED – First Semester

After considering many designs only one can be selected to begin making models or prototypes. This chapter focuses on how and why one certain design was selected. The first section starts with stating what methods, calculations, and rationale were used to select a final design. Lastly, the chapter will go in-depth on describing the selected design. Focus will be on calculations, parts/materials, 3D models, a prototype, and any other relevant material for the selected design.

5.1 Rationale for Design Selection

The decision matrix shows the top four designs, the design Floaty was the highest contender coming in a weighted total of 88.23 (figure 3). These results were found and calculated from the values determined on the pugh chart giving the Floaty design a plus on the criteria of cost, weight, compatibility, longevity, and assembly time. The disadvantages for this design are mainly focused on the disassembly time because the enclosure would need to be folded up for storage.

		Roller			2 Lands			Floaty			PVC		
Criteria	*Weight*	Raw	-	Weighted	Raw	-	Weighted	Raw	-	Weighted	Raw	-	Weighted
Assembly Time	0.154	90.00	-	13.86	80.00	-	12.32	80.00	-	12.32	70.00	-	10.78
Sea Level Altitude	0.193	95.00	-	18.34	95.00	-	18.34	95.00	-	18.34	95.00	-	18.34
Clear Design	0.115	90.00	-	10.35	90.00	-	10.35	90.00	-	10.35	90.00	-	10.35
Longevity	0.154	75.00	-	11.55	10.00	-	1.54	80.00	-	12.32	75.00	-	11.55
Compactibilty	0.115	50.00	-	5.75	97.00	-	11.16	90.00	-	10.35	80.00	-	9.20
Weight	0.154	50.00	-	7.70	95.00	-	14.63	90.00	-	13.86	75.00	-	11.55
Cost	0.115	69.00	-	7.94	50.00	-	5.75	93.00	-	10.70	88.00	-	10.12
	1.000			75.48			74.08			88.23			81.89

Figure 3: Decision Matrix

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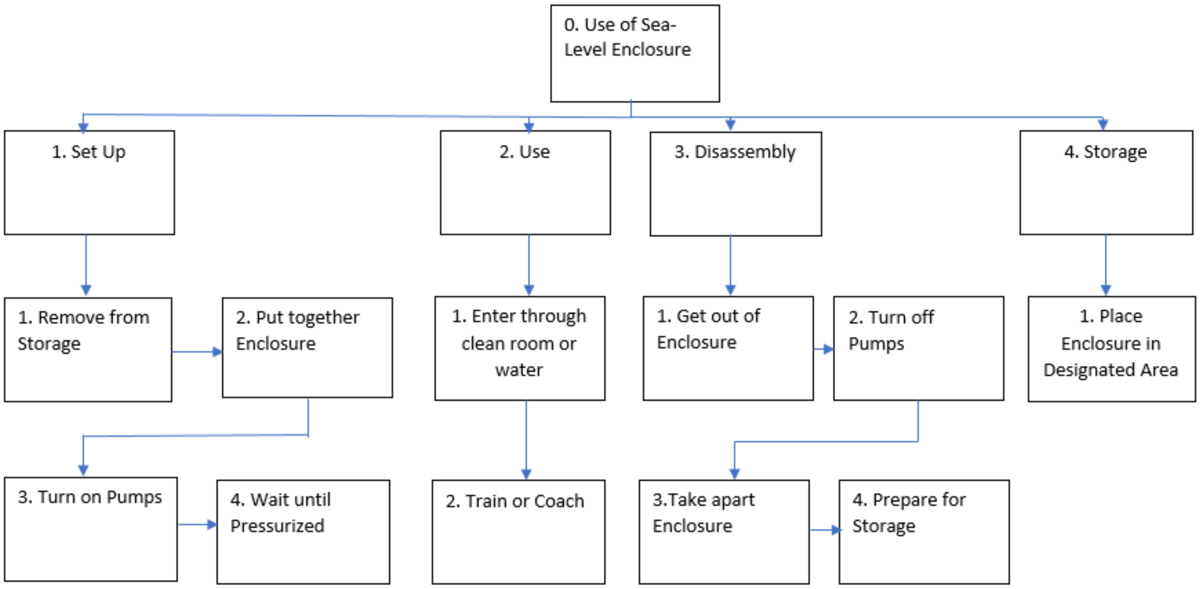
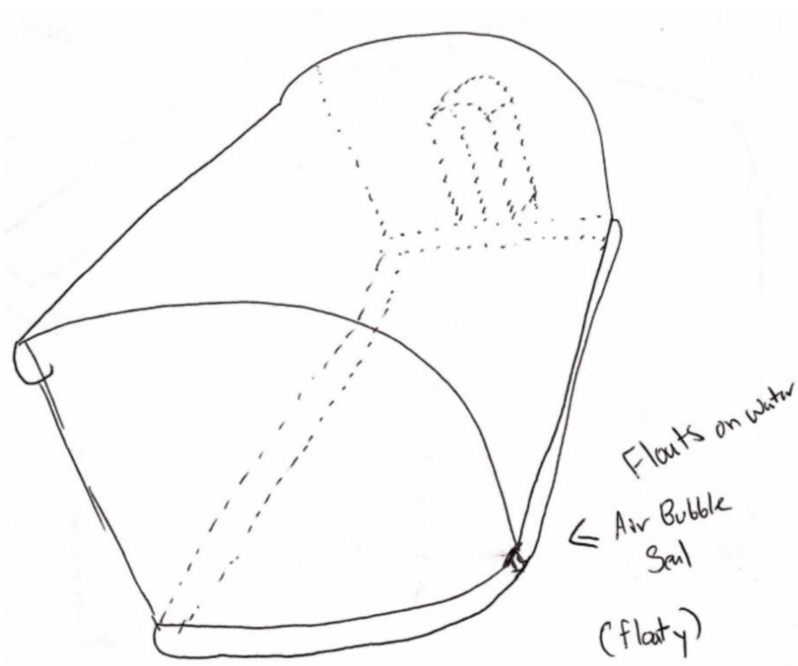
7 APPENDICES

7.1 Appendix A: Hierarchical task analysis

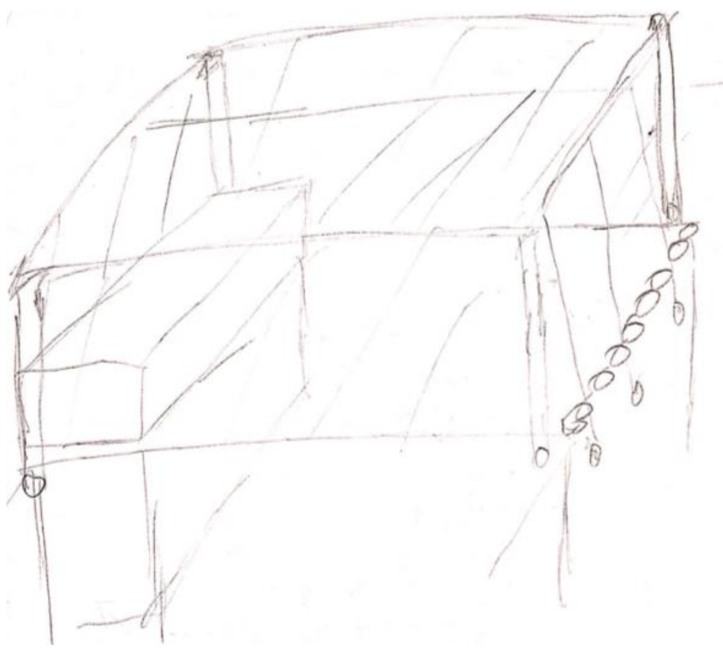


A1: Hierarchical task analysis

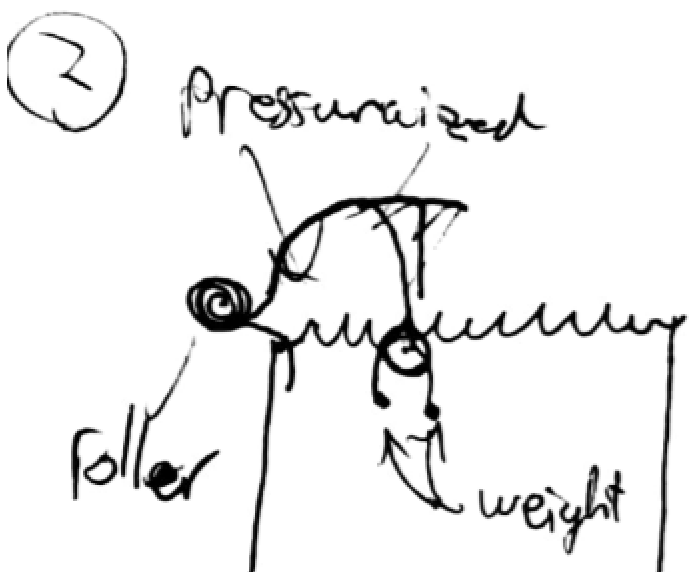
7.2 Appendix B: Design Sketches



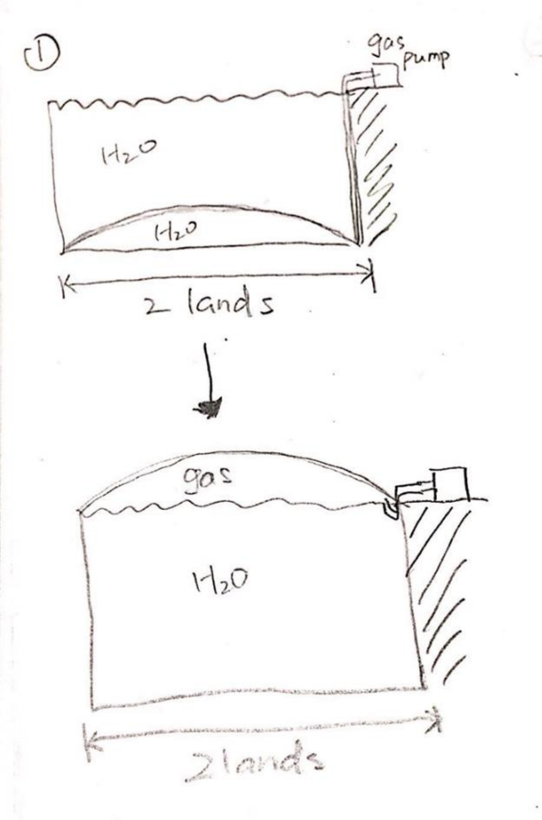
B1: Design 1-Floaty



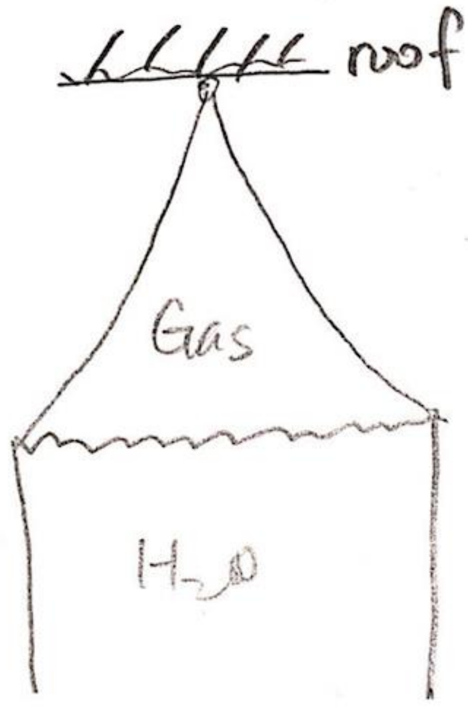
B2: Design 2-PVC



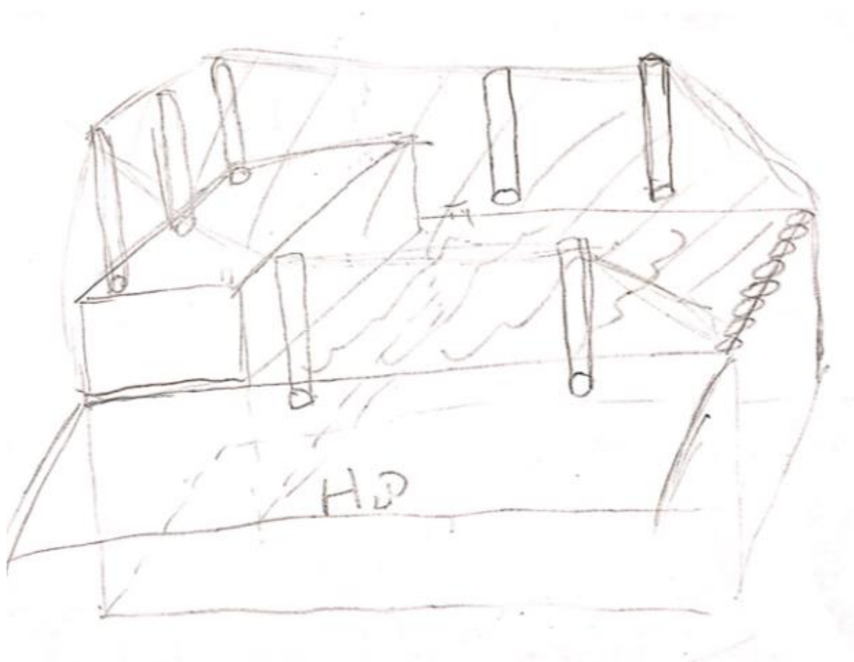
B3: Design 3-Roller



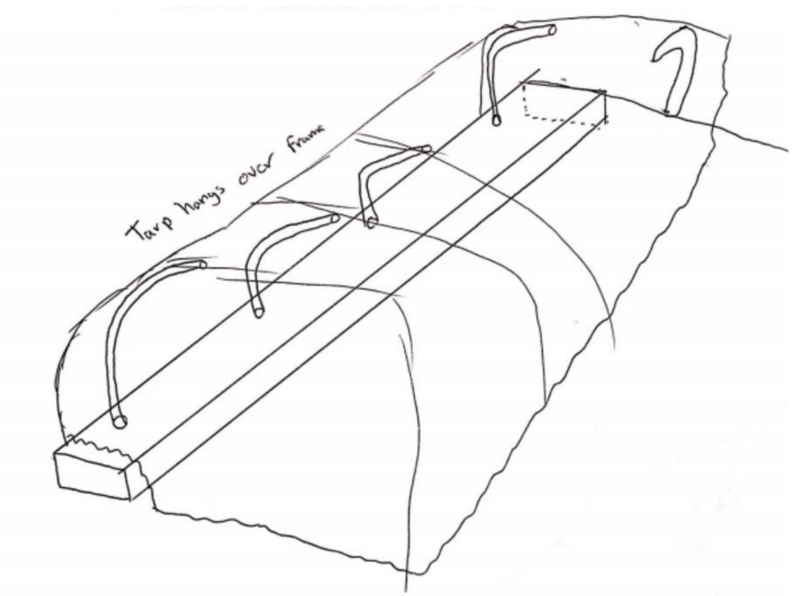
B4: Design 4-2 Lands



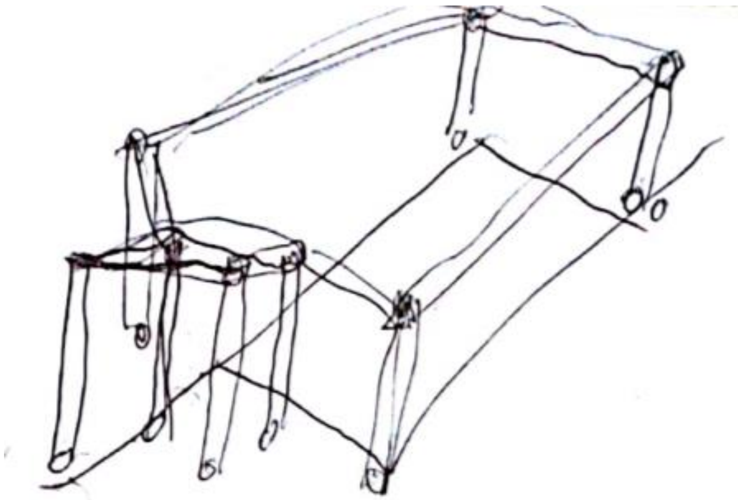
B5: Design-Circus



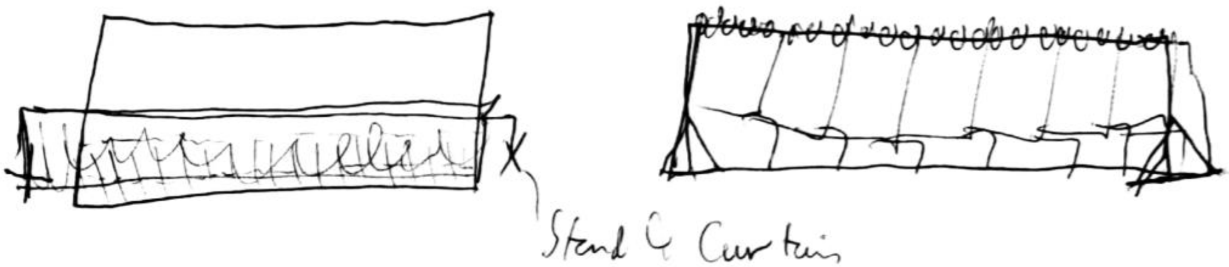
B6: Design-7 beams



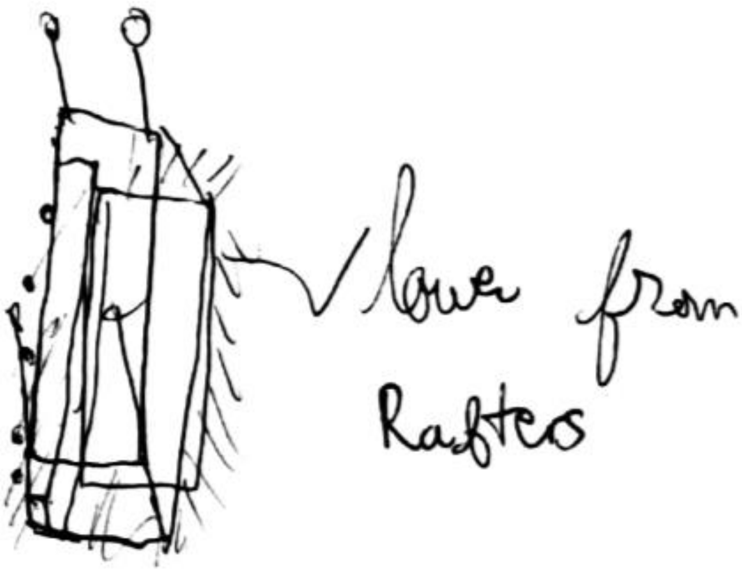
B7: Design-Hangover



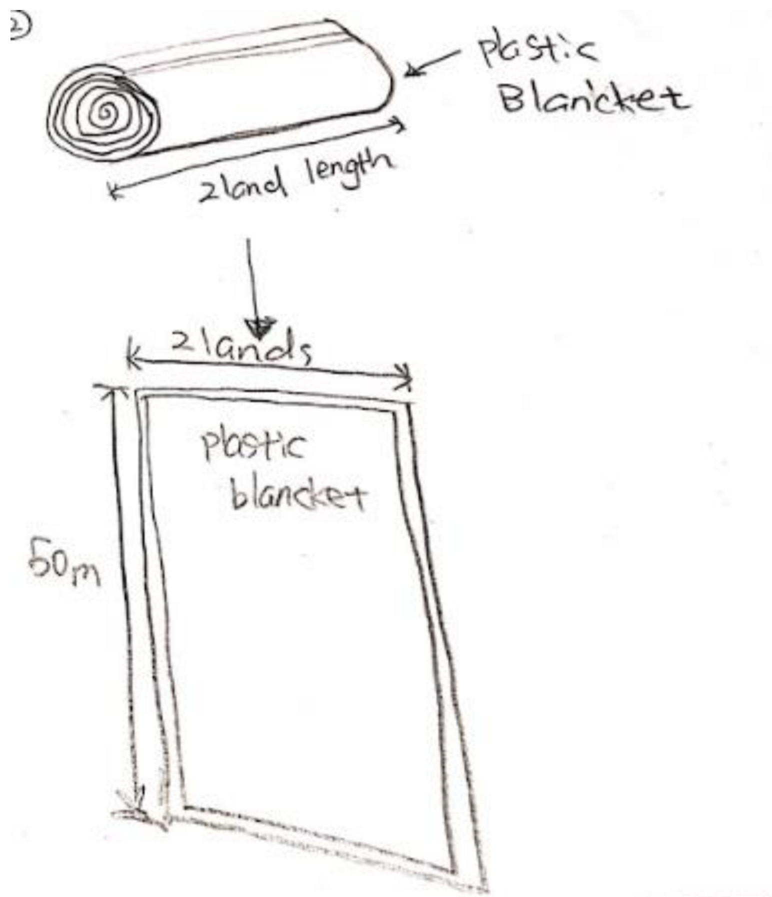
B8: Design-Spider



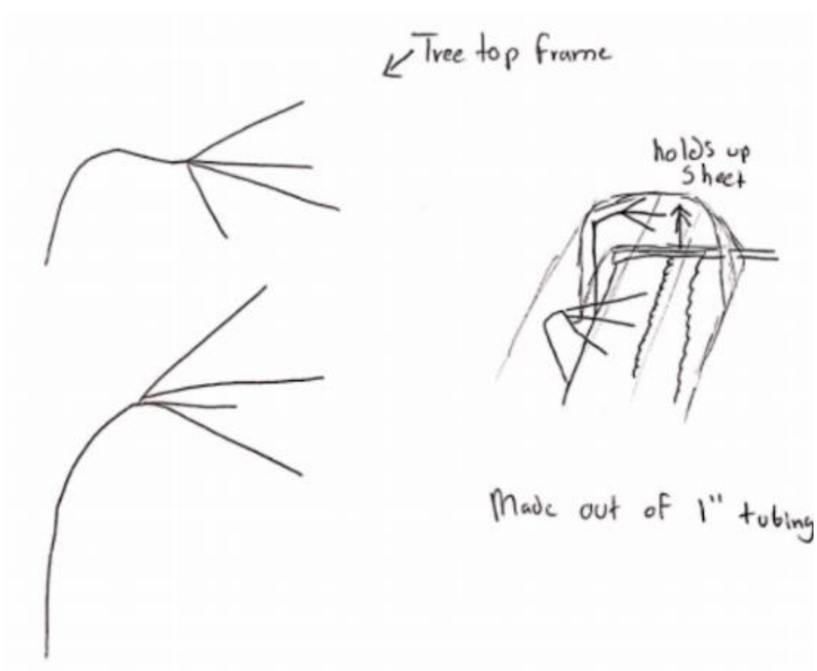
B9: Design-Curtain



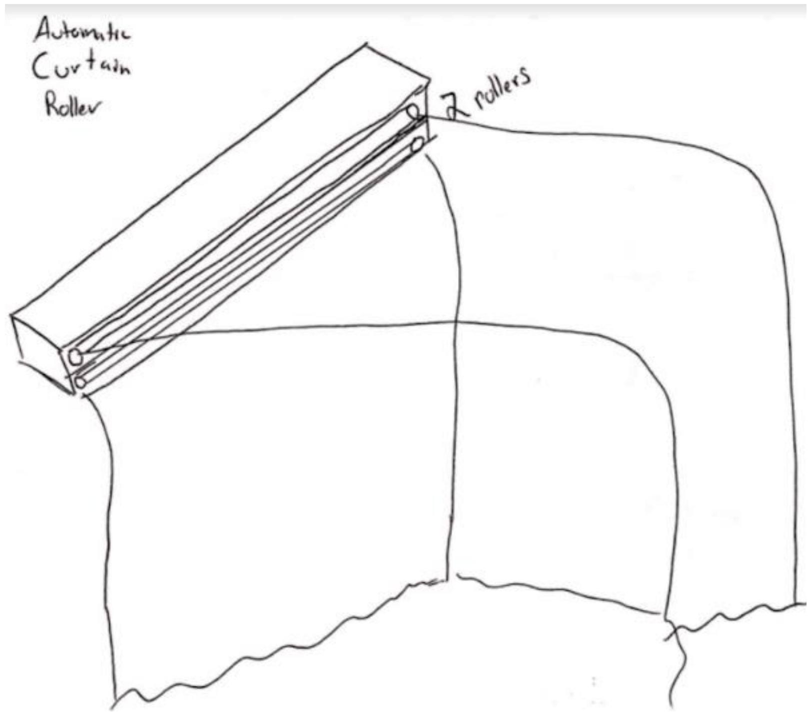
B10: Design-Descender



B11: Design-2 Lands



B12: Design-Tree Friend



B13: Design-plastic wrap