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August 2nd, 2024

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RE: MSE411 Capstone final report for *Breeze* portable toilet

Dear Dr. Golnaraghi:

This report, titled "Final Report: Breeze Portable Toilet," presents a summary of eight months of work on a revolutionary design that disrupts the traditional portable toilet industry. Our proposed design prioritizes user comfort while addressing common concerns surrounding cleanliness and odor. Drawing inspiration from the first portable toilets, the Breeze features innovative elements such as a vacuum flush system, heating and ventilation, a dedicated storage compartment, running water, a scent diffuser, touchless controls, and interior lighting.

The report aims to conclude the project by summarizing the first four months of research and design work and the last four months of manufacturing the proof-of-concept prototypes. It describes in detail the methodology and execution of prototype manufacturing. Finally, the report wraps up by providing personal takeaways and reflections from the team members on the work accomplished and the challenges faced.

At the end, our team expresses gratitude for your support and guidance over the past eight months.

Sincerely,

Rustem Ismagilov
President, Relieve

R E L I E V E

Final Report
Breeze Portable Toilet

02-August-2024
Submitted to - Dr. Farid Golnaraghi

RELIEVE

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Executive summary

Relieve is poised to revolutionize the portable sanitation industry with the introduction of the *Breeze* portable toilet, an innovative solution designed to address widespread dissatisfaction with traditional portable toilets, especially on construction sites. Despite numerous public campaigns and government initiatives, such as British Columbia's "Get Flushed" movement, current efforts fail to address the fundamental design flaws of existing portable toilets. A study by Hong Kong Polytechnic University revealed that over 82% of users are dissatisfied with current portable toilet solutions, highlighting significant issues such as unpleasant odors, lack of user comfort, and overall unhygienic conditions—concerns that are equally relevant in North America, especially in the post-COVID era where sanitation expectations have heightened.

The *Breeze* portable toilet by *Relieve* directly addresses these issues by prioritizing user comfort, hygiene, and dignity through a comprehensive redesign. Our commitment to disruptive innovation is reflected in our focus on three key pillars: superior user experience, energy and water efficiency, and cost competitiveness.

The design features an ergonomic circular structure for maximum comfort and efficient use of space, integrated climate control to ensure optimal temperature and comfort in various environmental conditions, and a vacuum flushing system to reduce odors and significantly improve sanitation standards. Sustainability is a core aspect, with the design minimizing water usage while maintaining high hygiene standards, incorporating greywater recycling to enhance efficiency, and utilizing energy-efficient components to reduce environmental impact.

The portable toilet market in North America, valued at approximately $11.85 billion USD in 2022, is projected to reach $20.43 billion USD by 2028, highlighting significant growth potential. By addressing critical issues related to cleanliness and comfort, *Relieve* not only mitigates health risks associated with bacterial contamination and exposure to low temperatures but also capitalizes on a substantial business opportunity. Our solution exemplifies a harmonious blend of profitability and social responsibility.

Relieve is set to redefine the portable sanitation landscape with the *Breeze* portable toilet. By prioritizing user comfort, hygiene, and sustainability, we offer a groundbreaking solution to a long-standing problem. With successful proof-of-concept demonstrations, incorporation of user feedback, and securing necessary funding, *Relieve* is well-positioned to establish the *Breeze* portable toilet as the new standard in portable sanitation. We invite investors to join us in this transformative journey, ensuring a future where portable toilets are synonymous with comfort and cleanliness.

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Introduction

Since portable toilets were introduced, there haven't been many improvements to the standard "blue" porta-potties. These toilets are only portable, but people use them reluctantly. Users often feel disgusted when they must use them. That's why our team at Relieve is working on a project to create cleaner and fresher portable toilets for construction workers. We want to make a portable toilet that doesn't smell bad, stays clean, feels like a real toilet, and improves user comfort with features like lighting, ventilation, heating, and touchless operation. There are about 3.6 million portable restrooms worldwide. The market for portable toilets was valued at around 11.85 billion USD in 2022 and is expected to grow to about 20.43 billion USD by 2028 [1]. Our team has set the following goals for our portable toilet: it should be odor-free, hygienic, comfortable, and as energy-efficient as possible.

The team believes in delivering an innovative, easily transportable, sustainable alternative to conventional “blue cabin” toilets. The pain points of the users of the portable toilet are addressed through our design [1], which are:

1. Water all around the pit and sink.
2. There is no storage space for the user’s belongings, (e.g. handbags and backpacks).
3. Negative user experience due to lack of cleanliness.
4. Smell due to non-flush ability and improper waste disposal.
5. Too much physical contact creates a sense of insecurity and instability in users.

Due to these points, the survey conducted in the case study [1] has given a rating of 1.6 out of 5 for current portable toilets.

In the following sections, we will discuss our idea and design methodology, outlining how we created a solution that incorporated advanced features like a vacuum system, climate control, touchless actuation, and lighting. We will explain our proof-of-concept implementation strategy, including visual demonstrations which includes Virtual reality and Augmented reality. Moreover, the feedback from the demo day event is shared along with key takeaways from our project. Finally, we'll conclude with the potential impact and future directions for our innovative portable toilet.

Goals and Objectives

The goal of the project is to create a portable toilet that satisfies the following requirements:

1. Making the design as compact as possible for less space consumption and easier transportation but keeping enough room inside for user comfort.
2. High water and energy efficiency.
3. Durable and robust to withstand weather conditions and vandalism.
4. Flushable, odor-free, warm, and has hand washing and drying capabilities.
5. The design of the toilet should be ergonomic by meeting the following standards:
    1. Spacious.
    2. The internal layout should not be congested.
    3. Ample storage space for personal goods.

    4. Aesthetically pleasing internal components with smooth contours.
6. Contactless actuating mechanisms (either pedal or IR actuated).
7. Accumulation of water around the pit and the sink should be minimized or eliminated.
8. Meeting the safety standards of the construction industry.
9. The storage capacity of human waste should be sufficient to accumulate human waste for the typical working site.
10. Maintenance of the toilet should be convenient and quick.

The team lists the objectives achieved during the last 8 months, as follows:

1. Completed market research and defined functional specifications:
    - Get information about portable toilet manufacturing and price margins.
    - Interviewed 1 and collected feedback from 14 potential users from construction and agricultural industries.
    - Contacted and interviewed 1 stakeholder.
2. Selected a design configuration and did the design specifications:
    - Estimated manufacturing/assembling costs of a portable toilet in Canada based on a simplest toilet topology.
    - Brainstormed several design options and selected the best candidate.
    - Brainstormed several options for each subsystem and selected the best candidate for each.
    - Developed BOM for final design.
3. Developed proof-of-concept for:
    - The scaled down vacuum pump operation: assembled, debugged, and tuned a scaled-down subsystem.
    - The vacuum toilet system.
    - The cabin structure.
    - Features placement.
4. Actual prototype:
    - Virtual-reality prototype for highlighting the interior features of the product.
    - Augmented-reality prototype to visualize the actual size of the toilet.
5. Spark – coast capital venture connections:
    - Finished Module 1 and Module 2 of Spark foundational program.
    - Scheduled and attended Mentor meet with venture connections.
6. Business plan formulation in MSE405 course
    - Business model:
        - Customer.
        - Value proposition.
        - Differentiation & control.
        - Scope activities & products.
        - Value capture for profit.
        - Organizational design.
    - Marketing plan
        - Target customer segments.
        - Objectives.
        - Marketing mix.
    - Location selection.
    - Outsourcing.

- Goals.
- Organizational structure.
- Risks & Rewards.
- Profit & Loss.

Idea

The idea originated while brainstorming different technologies that team Relieve may work on for their 8-month capstone. Then, some advice from supervisor Dr. Amr Marzouk ignited the idea to look for problems rather than solutions. After digging deeper, we have discovered that the most potential is housed in those problems which are not so pleasant to work on, and people are shy or hesitant about the implementation. The nastiest problems have biggest perspectives. With the mindset of doing something for the community, "*We are committed to enhancing the lives of those who build the world around us*". We have realized how millions of construction workers must go through using unhygienic, unpleasant, and disease prone toilets daily. With this spark, we have ignited the idea through the following design methodology.

Design methodology

To design the solution to the above problem, thorough market research is conducted to gain insights on the root problem, and users' feedback on the optimal solution. To achieve this valuable data, we have conducted a survey for construction workers which provides following understanding:

1. 69.2% users have non-flushable porta-potty at their workspace.
2. About 70% of users use the washrooms at their workspace while rest refrain from using any.
3. An estimated 60% of users are dissatisfied with their current washroom solutions, and 30% are neutral about it, with only 8% liking them.
4. The top features that users want to see in their portable toilet cabins are Sanitation, Odorless, Sink, and lighting at night.
5. Users are so frustrated, that about 53.8% users may even pay for high-end washroom use.

In addition to the users, the stakeholders such as construction companies, procurement officers, trade unions, and established manufacturers also play an important role in the design process. These stakeholders are contacted to achieve insights into what the product may be lacking from their perspective and what must be done to solve the problem itself.

Moreover, the technology used to operate the toilet has also its limitations, which are considered during building of solution. These limitations are:

1. Energy consumption of the ventilation, heating, drying, illumination, and flushing mechanism systems.
2. Maximum capacity of the storage systems: freshwater, greywater, and solid waste.
3. Minimum of 500 [mbar] pressure level for vacuum flush.
4. Installed equipment must support 110VAC-60Hz (standard in Canada).

Keeping note of all the above criteria, a solution is proposed as highlighted in the next section, whose proof-of-concept and prototype is demonstrated on demo day of July 26th.

Proposed Solution

The current section overviews external and internal features of the portable toilet. The external appearance of the cabin is depicted in Figure 1: the cabin looks like a cylindrically shaped compartment elevated above earth level with a sliding door and transparent dome for natural lighting during daytime. As seen behind the door, there is a self-draining and slip resistant floor to prevent accumulation of water and slippage respectively. The sliding door has foot actuation to enhance sanitary conditions. Moreover, enough movable room is visible for one person to comfortably use the *Breeze.*

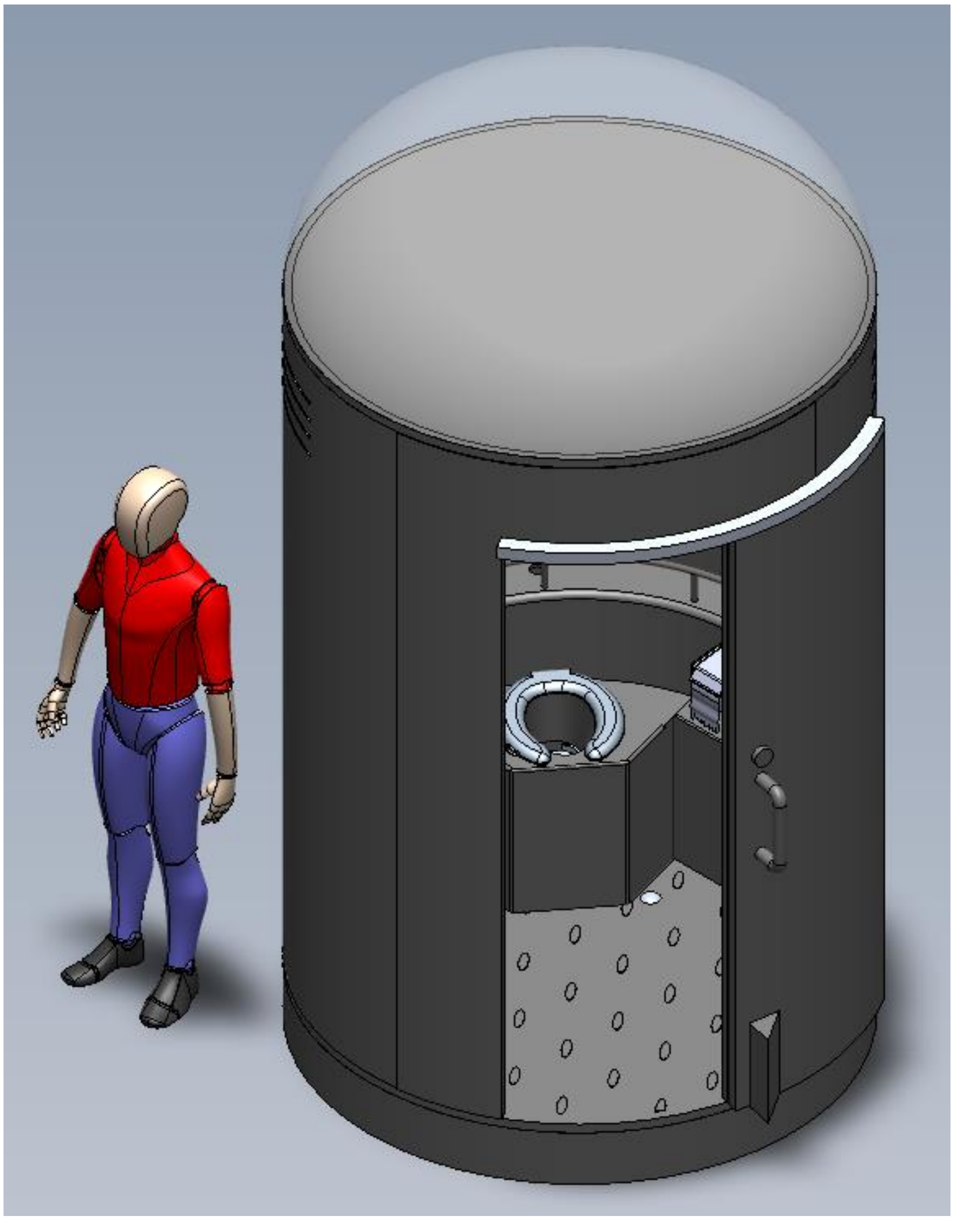


Figure 1: External isometric view of the cabin without walls

Internally, upon entry to the cabin user might see a vacuum toilet in front of them, a sink, and a urinal from left and right, respectively (shown in Figure 2).

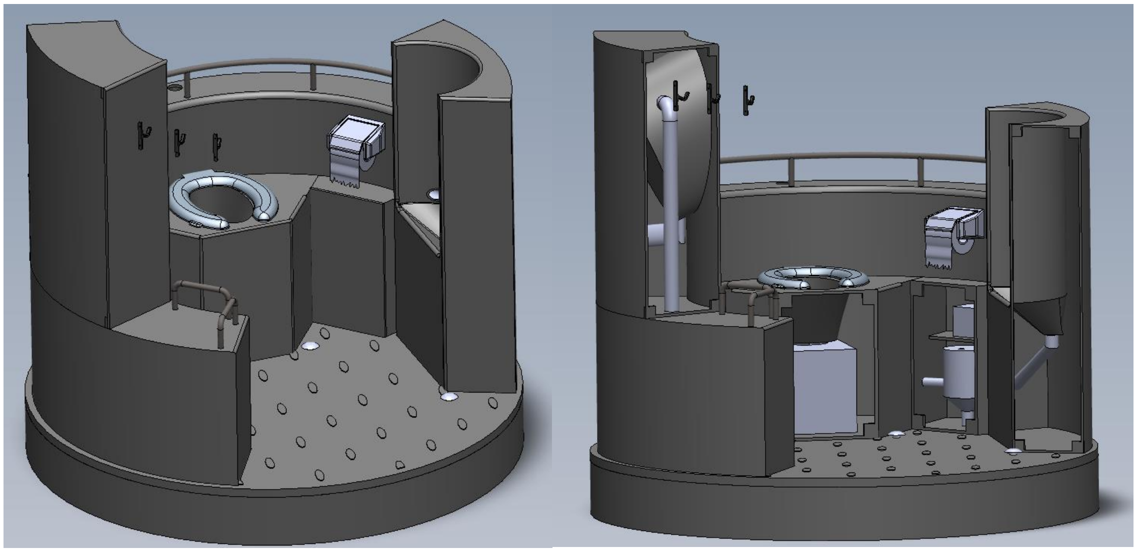


Figure 2: Layout of the cabin

The design features two types of water tanks: a freshwater tank for handwashing and a greywater tank for storing used water from the sink for flushing. Both tanks have a sector-like shape and are mounted along the cabin walls. The freshwater tank is located beneath the sink faucet, while the greywater tank is positioned above the vacuum toilet. A vacuum pump, hidden between the urinal and toilet, operates the vacuum system, and a waste compartment is placed beneath the floor. The toilet's exhaust pipe is directed away from the entrance. To meet functional requirements, the design includes an infrared heater suspended from the ceiling to provide instant warmth, a water-heating faucet for comfortable handwashing, hooks for clothes above the freshwater tank to the left of the entrance, and LED lighting for illumination.

Main structure:

1. A cylindrically shaped cabin
2. Manually opened sliding door
3. Air exhaust for ventilation

Roof:

1. A transparent dome

Interior:

1. A vacuum toilet
2. Urinal
3. Sink with water-heating faucet
4. Storage compartment: hooks for clothing and place to leave construction worker bag (on the top of the hood of the freshwater tank)
5. IR heater suspended from the roof
6. Fresh- and greywater tanks and a vacuum pump embedded into the structure of the walls

Base:

1. Waste containment
2. Exhaust to empty waste containment

Implementation

While the product design was specified, the prototype couldn't be realized at full scale. Considering the project's scale, the team size, and its self-funded nature, the scope of the deliverables was constrained to three key elements:

Proof of concept	Demonstration method
Compressor operation	• Scaled down subsystem
Design/internal layout	• VR simulation • AR simulation

Each listed deliverable serves as a proof of concept addressing the key components of the system. The following sections discuss these subsystems, their methodologies, and the challenges encountered.

Vacuum system

Objective

The objective of the vacuum system (vacuum toilet) lies in its ability to process human waste from the toilet bowl into the waste containment in a reasonable amount of time repeatedly. The realization of this objective depends on several factors: the ability of the system to create sufficient negative and positive pressure in the intermediate vacuum tank, the ability to control swiftly the solenoid valves in compressed air and human waste piping, and the ability to manage effectively energy consumption of the system.

Architecture of the system

The vacuum system could be divided into two parts: mechanical and electrical ones. The former includes tanks/reservoirs (toilet bowl, intermediate vacuum tank, and human waste containment), valves (controlling compressed air and human waste pipes), venturi vacuum generator, and piping. The latter – Arduino Nano 33 IoT and four interface boards that facilitate control of valves with the mentioned MCU. The total schematic of the system is shown in Figure. 3.

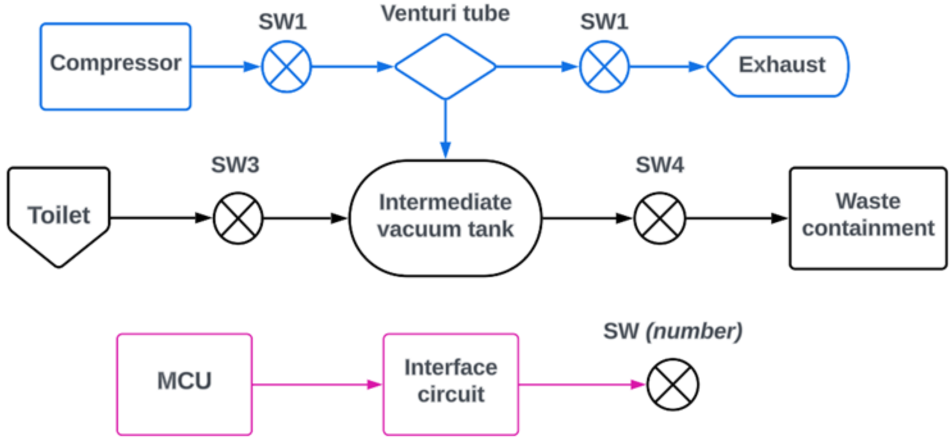


Figure 3: Principle of Vacuum system

In Figure 3 blue color designates components that pass through compressed air, black color – the components that carry human waste, while purple color displays electrical components.

The principle of operation could be described as follows. The flushing cycle of the vacuum toilet consists of 4 stages.

Stage 1: Vacuum creation

Valves SW1 and SW2 are open. Valves SW3 and SW4 are closed. Compressed air is supplied by compressor and exhausted from exhaust. Air is evacuated from the intermediate vacuum tank by venturi effect.

Stage 2: Suction

Valves SW1 and SW2 are closed. Valve SW3 is open, valve SW4 is closed. Human waste is transferred from the toilet bowl into the intermediate vacuum tank.

Stage 3: Compression

Valves SW3 and SW4 are closed. Valve SW1 is open, valve SW2 is closed. Human waste is compressed by the means of compressed air from the compressor.

Stage 4: Exhaust

All valves except SW4 and SW1 are closed. Human waste is exhausted into waste containment.

Mechanical design

Valves

For the physical setup, the following valves were selected.

Table 1: Valve selection

Designation	Manufacturer	Model	Power Supply	Thread type
SW1	China SNS Pneumatic Co., Ltd	2W025-08/AC110V NPT	110VAC/60 Hz	NPT ¼" (F)
SW2	RIH	2WSeries	110VAC/60 Hz	NPT ¼" (F)
SW3	RIH	2WSeries	110VAC/60 Hz	NPT ½" (F)
SW4	Electric Solenoid Valves	PSL-25	110VAC/60 Hz	NPT 1" (F)

The selection of the valves was governed by two considerations: their power supply, type, and size of thread. The power supply has been set to be 110 VAC/60 Hz for all four valves for the sake of compatibility with the Canadian grid. The thread type is supposed to be of NPT type adopted widely in North America for plumbing applications. To ensure that the size of the thread of the valves is compatible with the size of the Venturi tube thread, the size of thread for SW1 and SW2 has been selected to be ¼". The thread size for two valves passing through human waste (SW3 and SW4) has been initially selected to be 1" but has been reduced to ½" due to the problems with procurement of the valve SW3. This problem explains why the thread sizes of SW3 and SW4 differ.

Venturi tube

The selection of the venturi tube has been governed by the amount of negative pressure it could provide for the compressed airflow of the following characteristics: 4 [cfm] under 90 [PSI] (typical characteristics of a commercially available 20 [L] compressor), and the speed of evacuation. The vacuum toilet system shall guarantee 0.5 [bar] of pressure to transfer human waste effectively. The characteristics of the selected venturi tube are displayed in the table below.

Table 2: Venturi tube characteristics

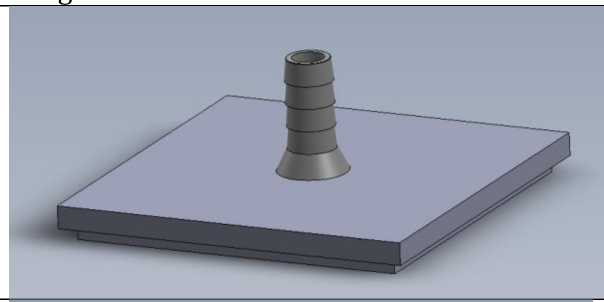
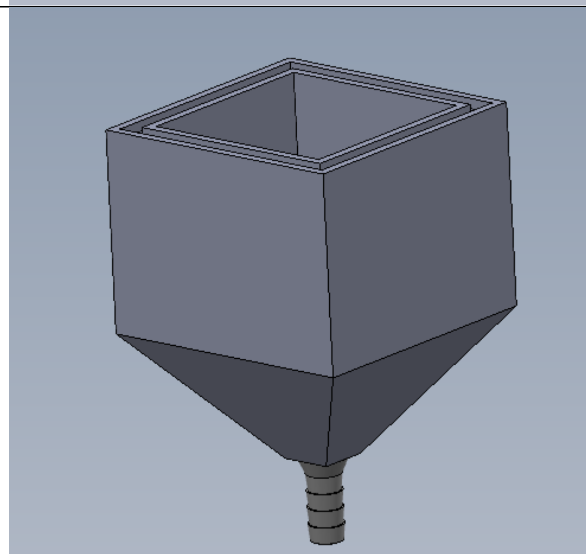
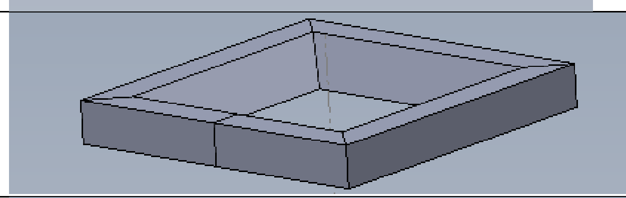
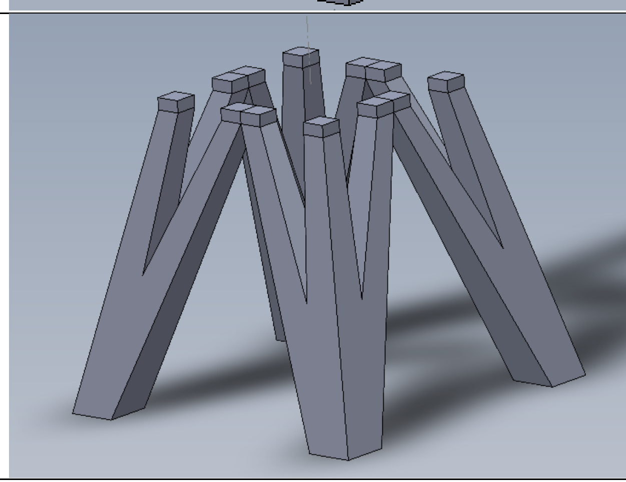
Characteristic	Value
Manufacturer	ASHATA
Model	CV-15HS
Working pressure (bar)	1-6
Rated pressure (bar)	5
Thread type and size of 3 ports	BSPT (F), ¼"
Negative pressure (bar)	-0.92
Suction flow rate (L/min)	63

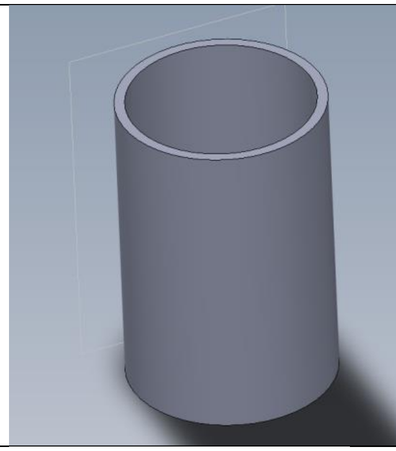
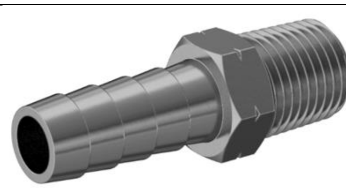
According to the table, the selected venturi tube could guarantee 0.08 [bar] pressure within a 2-second timeframe for a 2 [L] volume intermediate vacuum tank.

Printed components

The vacuum system included a set of 3D printed components. They are listed in the following table:

Table 3: Vacuum system 3d-printed components

Part	Qty	Image
Vacuum chamber lid	1	
Vacuum chamber	1	
Vacuum chamber base	1	
Vacuum chamber standoffs	4	

"Toilet" tank	1	
½" Hose – ½ NPT adapter	2	
½" Hose – 1 NPT adapter	2	
3/8" Hose – 1/4 NPT adapter	2	
3/8" Hose – 1/4 BSPT adapter	3	

The following figure depicts the assembled vacuum chamber on its standoffs

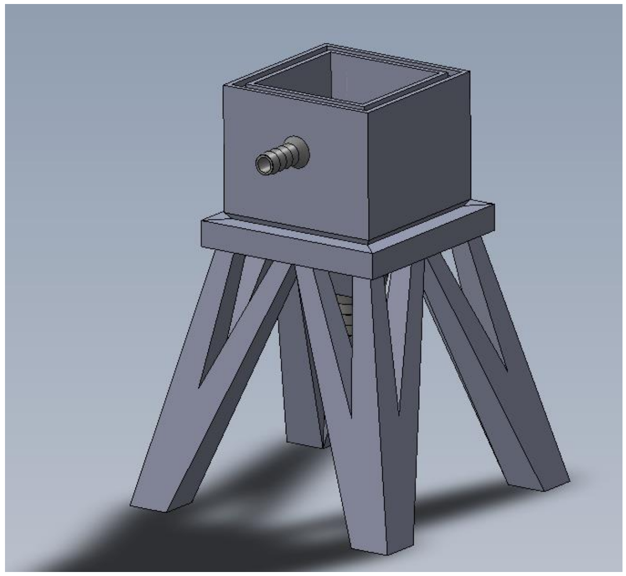


Figure 4: Assembled Vacuum chamber with standoff

Electrical design

Power flow

Achieving the ability to control the valve with MCU has been one of the project's main challenges. The core of the challenge is that the MCU could provide sufficient power to operate the relay. Also, the MCU digital pin and relay control port require different voltage levels: 3.3 VDC vs 5 VDC. These two challenges have led to the following architecture of the interface board (Figure 5). The black boxes designate functional components of the circuit, while the red ones – power ones. The number above the link identifies the voltage level of the electrical link.

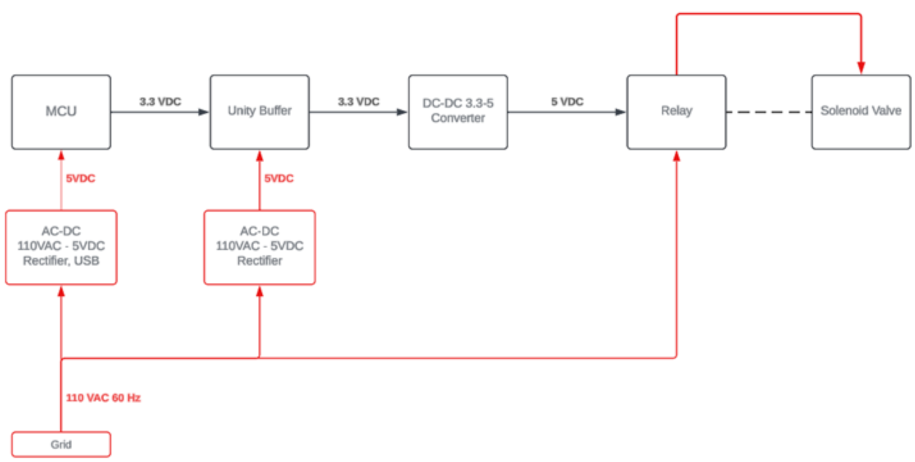


Figure 5: Interface Board architecture

According to Figure 5, the unity buffer copies the voltage from the digital pin of the MCU and transfers it to the DC-DC converter. The latter converts 3.3 VDC to 5 VDC and passes it to the relay that activates the solenoid valve. A separate AC-DC rectifier (from the grid AC voltage to 5 VDC) powers the unity buffer and provides power to the relay.

Since relay and solenoid valves had been selected in the first place, their power ratings have defined the selection of the unity buffer (op-amp with negative feedback) and DC-DC converter. In Figure 6, the power flow diagram is displayed. Note that the violet arrow designates power flow in the link while the thinner green arrow designates current in the link. Therefore, for example, the product of the green number and the voltage level of the link should give us the violet number. A slanted box connected with a dotted line shows the rated power of the device. Power flow in the system incorporates a Factor of Safety equal to 5 and efficiency of the DC-DC converter that is equal to 70 %. Based on the diagram, both the unity buffer and DC-DC converter shall be rated at 2578 [mW].

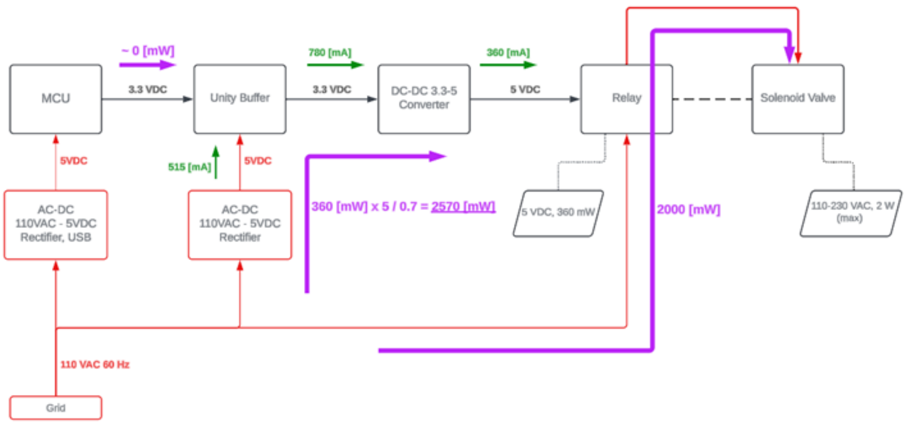


Figure 6: Power flow diagram

Power requirements

Since relay and solenoid valves have been selected in the first instance, the relay's power requirements define the selection of the unity buffer op-amps and DC-DC converter. In the table below, rated power of the selected components is listed and compared against the required level of 2570 [mW].

Table 4: Power components selection

Component	Manufacturer	Model	Maximum power, [mW]
Unity Buffer	Microchip	LMC7101	3600
DC-DC 3.3-5 Converter	Texas Instruments	TPS61023	7500
AC-DC 110VAC-5VDC Rectifier	MW MEAN WELL	RS-15-5	15000

According to the table, the selected components satisfy the power draw of the relay.

Solution 1: Printed PCB

The interface circuit has been implemented in the PCB form using Altium. The 3D view of the PCB is displayed in Figure 7. The PCB has two layers: the upper signal layer and the bottom ground layer. Two layers are displayed in Figure 8. Several features of the board should be mentioned. Starting with UX/UI ones, two sets of testing ports have been added: **TEST** port is used to check the integrity of external electrical connections (power and digital connections), while **TEST INT** -- to test electrical continuity within the board (connection between the unity buffer and DC-DC converter, and between DC-DC converter and the relay). Also, digital and 2 power terminals of the PCB to from the left side are separated to avoid short circuits.

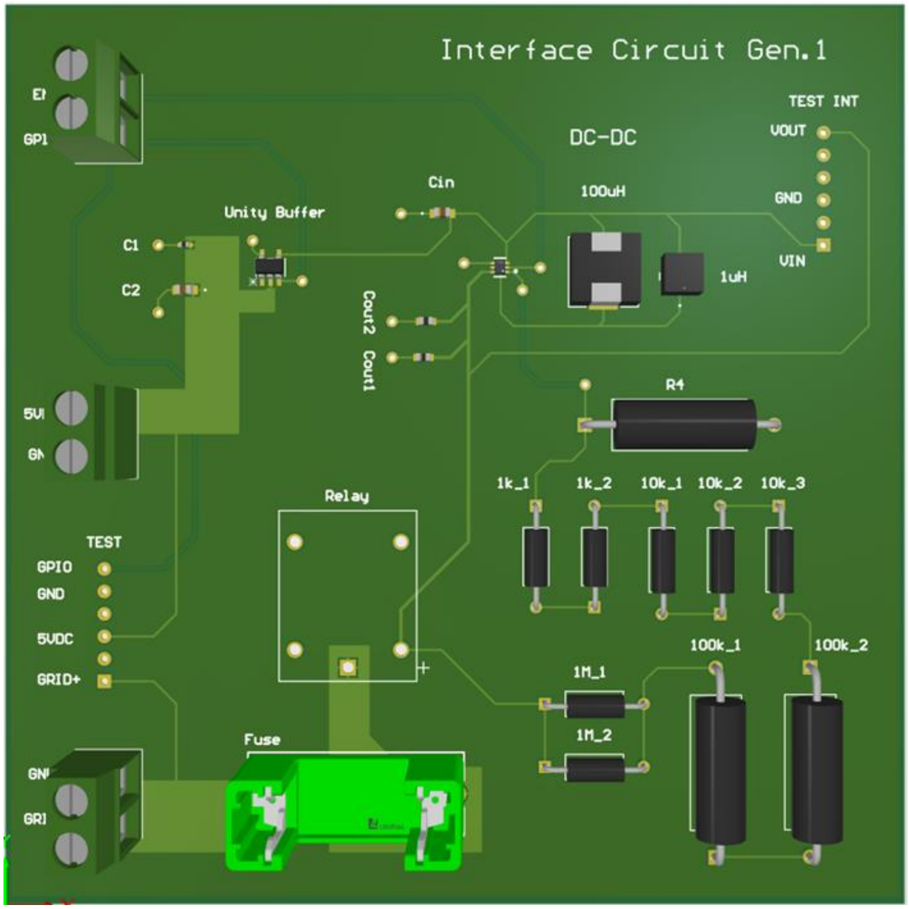


Figure 7: 3D view of Interface Board

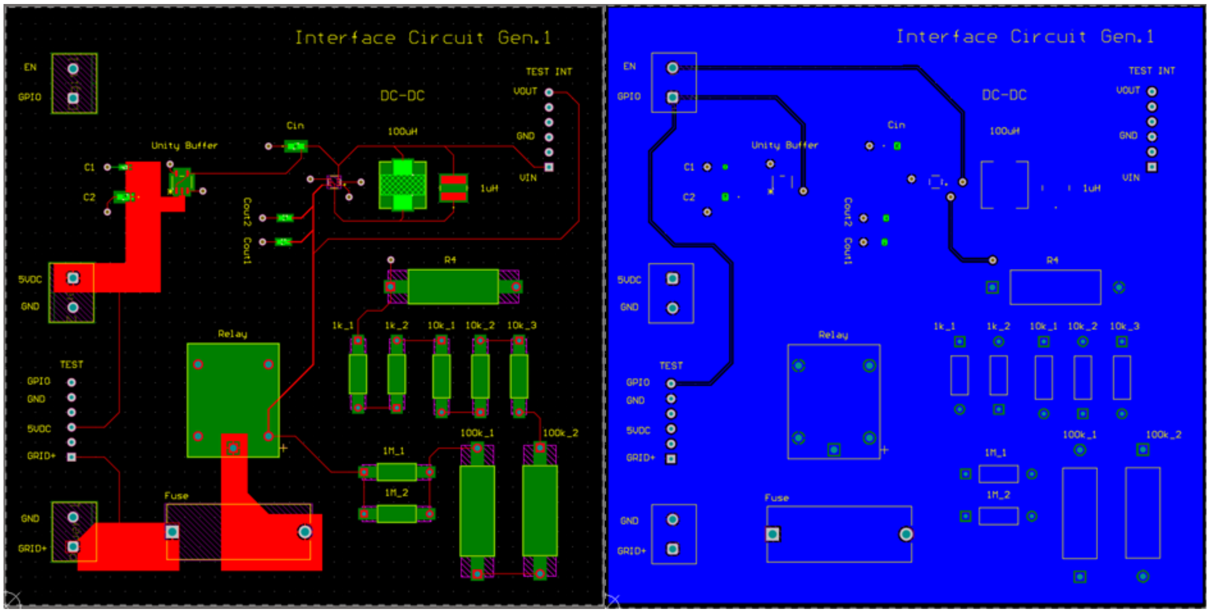


Figure 8: The two signal layers of the Interface Board (upper signal – to the left, ground one – to the right)

Design features of the PCB are demonstrated using the layer view (Figure. 8). First, the relay is connected to the positive terminal of the grid (**GRID+** port) via spacious polygons to ensure that the trace could sustain power draw of the solenoid valve. Secondly, the positive power supply pin of the unity buffer op-amp is decoupled using 10 and 0.1 [uF] capacitors (designations C2 and C1, respectively) to filter out the noise from the **5VDC** power supply and ensure stability of the op-amp. Additionally, the positive power supply pin of the op-amp is connected to the **5VDC** port via a wide polygon located over a continuous ground layer, enhancing stability of the power rails. Finally, almost the entire lower signal layer (the reason why it is called ground layer) is allocated for **GND** node to damp signal distortions.

Solution 2: Arduino relays

Interface Board has a serious drawback: its manual soldering is time consuming and is prone to unintentional damage of the components. These issues happen because capacitors and DC-DC converters are tiny and highly susceptible to the heat from the soldering iron. Due to the limited amount of time, 2 of the 4 Interface Boards have been replaced with readily available relay board from Huayao manufacturer tailored for Arduino Nano 33 IoT.

Integration and testing

Testing of the Interface Board

Testing of the operation of the Interface Board involved the following steps.

1. Imitation of the solenoid valve with a 1M Ohm resistor connected to the grid.
2. Testing of the Interface Board with GPIO = HIGH (3.3 VDC).
3. Testing of the Interface Board with GPIO = LOW (0 VDC).
4. Connection of the real solenoid valve (SW1, to be specific) instead of a dummy resistor.
5. Steps 2 and 3 are repeated.
6. Steps 4 and 5 are repeated for SW2, SW3, and SW4.

It should be noted that to provide a pathway for induced negative current during the switching-off of solenoid valves, each of them was connected in parallel to a huge resistor (100k Ohm).

During tests, several results have been obtained.

1. Each valve has been opened when GPIO = LOW and closed when GPIO = HIGH.
2. DC-DC converter has failed to convert 3.3 VDC into 5 VDC.
3. Despite point 2, the relay is still operational.

Testing of the assembled system

Testing of the assembled system has consisted of the following steps.

1. Connection of the compressor to the system.
2. Pouring colored liquid into the tank imitating the toilet bowl.
3. Turning on the control software.
4. Gradual increase of pressure during the 1st stage of the flushing cycle.
5. Observation of the change of the colored liquid level during the 2nd stage of the flushing cycle.

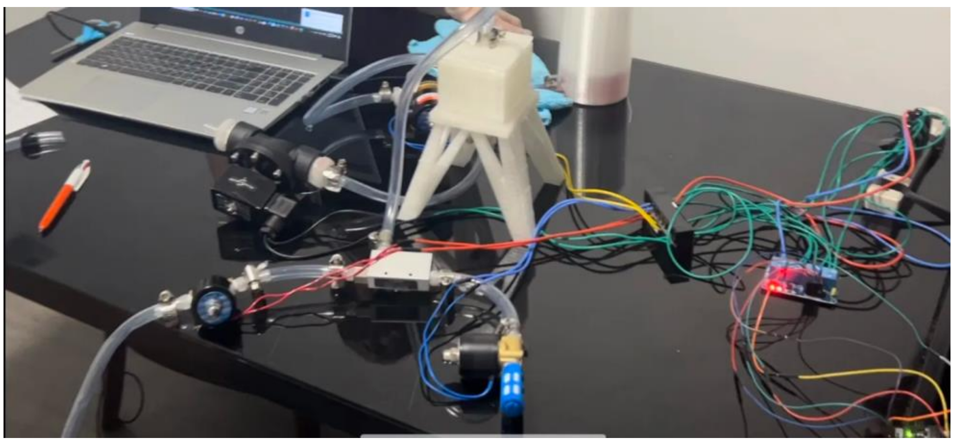


Figure 9: Testing of Vacuum chamber on standoff along with valves.

Figure 10: Air compressor used as Air source

Figure 11: Chamber used to resemble the toilet.

During tests, several results have been obtained.

1. Barbed connectors are unable to contain airflow of pressure greater than 20 [PSI]. In other words, barbed connectors are unsuitable for any compressed air applications.
2. Printed barbed connectors cause such huge leakages of compressed air that the compressor becomes unable to provide output pressure greater than 15 [PSI]. In this case, no observable negative pressure is attainable in the intermediate vacuum tank.
3. When barbed connectors are reinforced with ultra-fast glue (the hose is glued to the barbed connector), the output pressure level of 45 [PSI] is attainable. In this case, some negative pressure is created in the intermediate vacuum tank that causes the level change in the tank imitating the toilet bowl. The repetition of the flushing cycle under 40 PSI input pressure causes breakage of the ultra-fast glue seal.

From the tests the following lessons have been derived.

1. Compressed air connections require special vacuum to thread adapters rather than barb to thread adapters. It automatically means that plastic hoses are not suitable for compressed air lines and should be replaced with metal ones.
2. The minimum pressure in the compressed air line shall be at least 90 PSI to ensure sufficient negative pressure in the intermediate vacuum tank and evacuation flow rate from it.

Virtual demonstration

Due to financial and manufacturing limitations, the real scale cabin could not be assembled. Instead, the second-best option for delivering the experience was selected – a set of virtual simulations. The objective of this demonstration was to provide an interactive experience of the Breeze cabin design, layout, and interior. This set included the following parts:

1. SolidWorks model
2. VR demonstration
3. AR simulation

The following sections discuss each of the above deliverables:

SolidWorks model

The SolidWorks model was the key component of the project as it was a main platform to visualize the proposed design. The work on the model was started back in January and underwent a few iterations since then.

The following figures demonstrate the final version of the design:

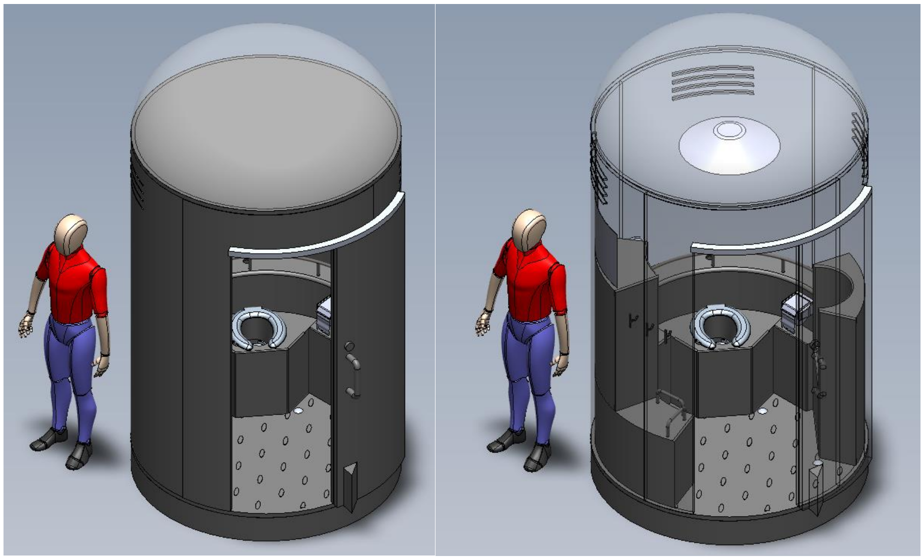


Figure 12: Outside view of the Solidworks model

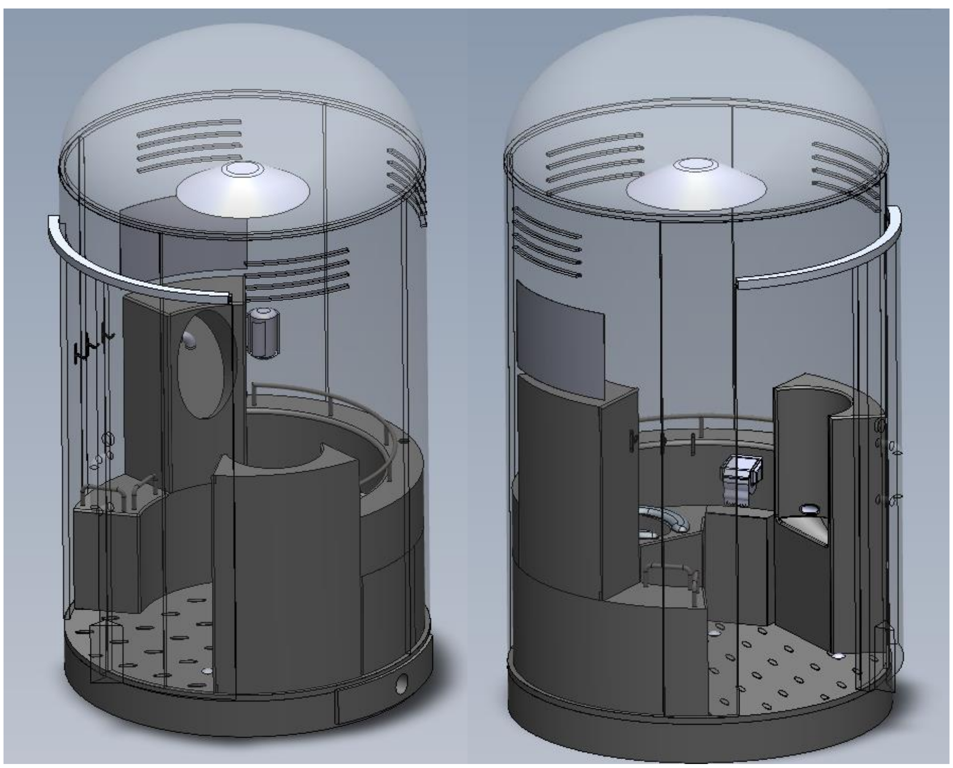


Figure 13: Interior of the Solidworks model

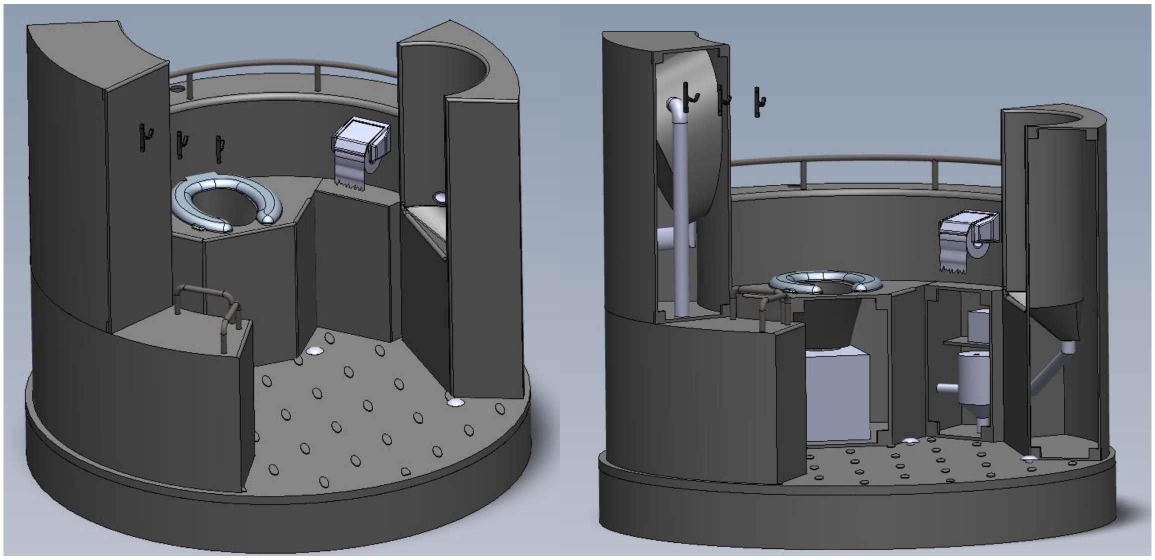


Figure 14: Layout of the Cabin

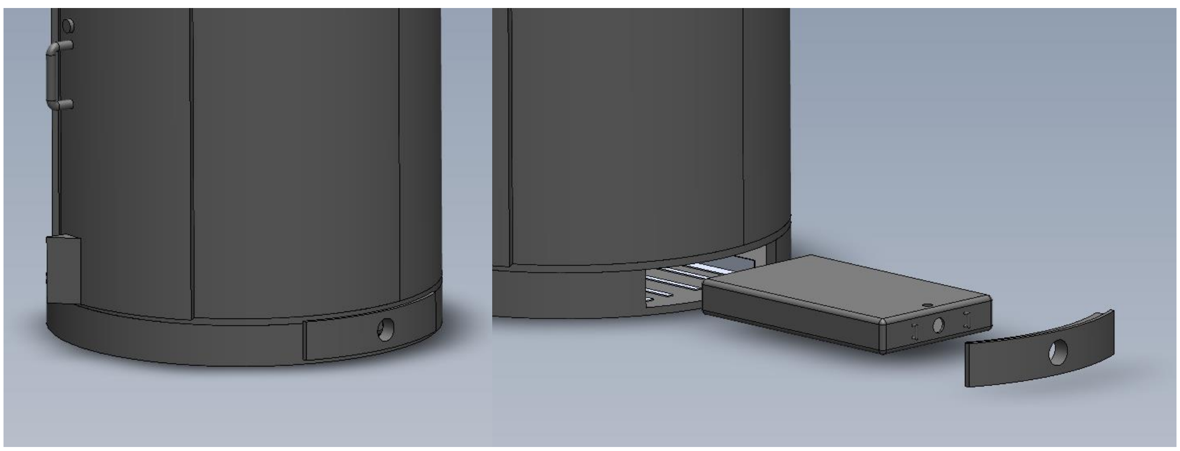


Figure 15: Waste cartridge system functionality

VR demonstration

To effectively deliver an experience of the interior, the VR setup was implemented. The approach included the following steps:

1. The completed SolidWorks model was imported in SolidWorks Visualize 2022
2. Using SolidWorks Visualize 2022 toolbox, the model was rendered with 6000 layers (4 hours) into a 360 degrees skybox image.
3. The rendered skybox was imported to the VR-Photo phone app that enabled its VR helmet compatibility
4. The phone with the running app was inserted into the Samsung Gear VR thus completing the VR simulation

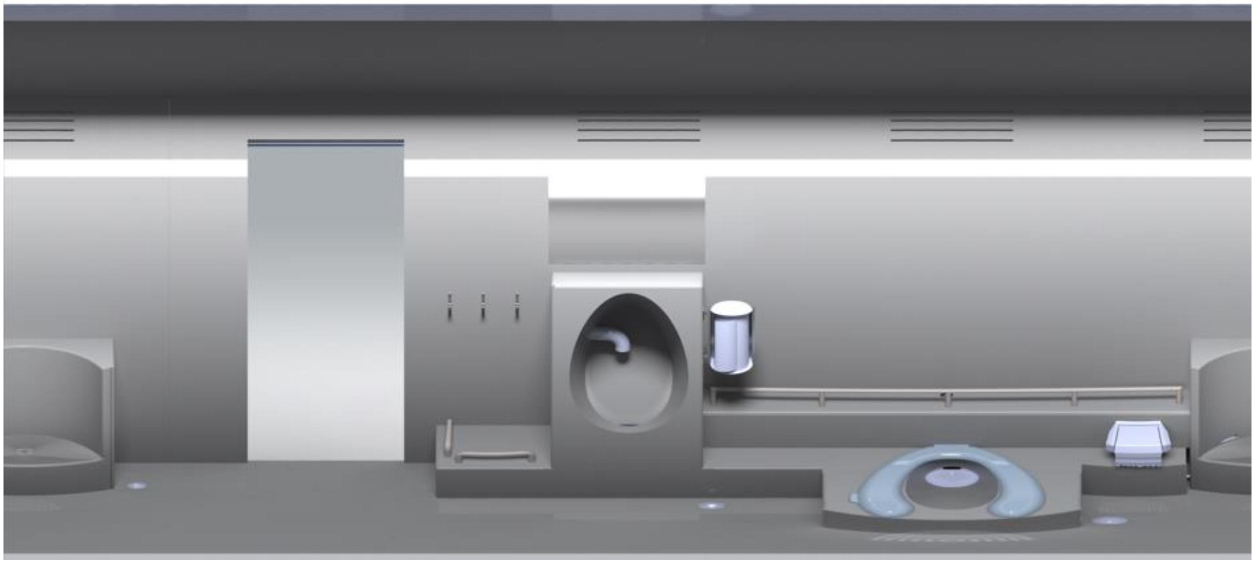


Figure 16: VR demonstration Solidworks photo experience 360

AR demonstration

If the VR portion of the demonstration aimed to deliver a realistic image of the cabin, the AR was developed to demonstrate the real scale model thus replacing an initially planned prototype.

The approach included the following steps:

1. The completed SolidWorks assembly model was converted to GLB format
2. The GLB model then was imported to the Adobe Aero
3. Using the Adobe Aero AR toolbox, the model was uploaded to the Adobe cloud and made accessible with a VR code

Figure 17: Augmented reality QR code

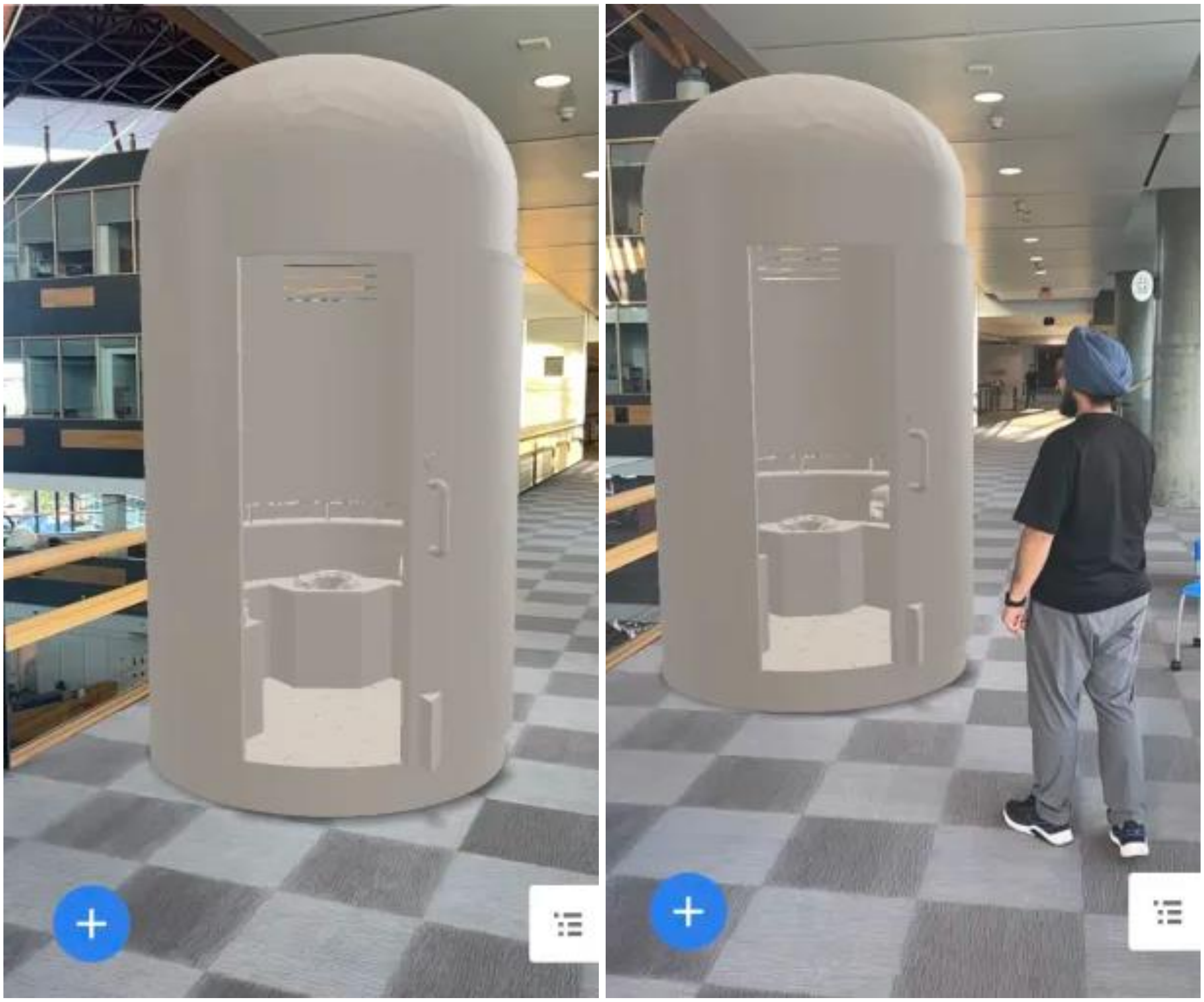


Figure 18: Augmented reality demonstration

Demo day review

On the demo day our team presented all three deliverables: vacuum pump system, VR setup, and AR demonstration. The required for the pump system air compressor was rented from Home Depot thus enabling the team to actuate the setup and save money on purchasing the equipment. Although the setup was prepared to be actuated, the execution was limited by the SFU security due to safety concerns.

Throughout the 4 hours of the project showcasing all three team members were given plenty of opportunity to attempt and perfect their presentation skills.

Key takeaways

Being a summary of the 8 months of work, this section includes the team members' reflection on the accomplished work, as well as individual lessons learnt and takeaways, both technical and general.

Rustem

- Although Relieve was positioned as an entrepreneurial opportunity from day one, it failed to meet the Capstone format plan. Adherence to the capstone outline limited the project's flexibility. In situations where the real business initiative would have required more time for research, a sudden pause, or even a rapid pivot, the team prioritized following the curriculum and the linear development of the project.
- Communication and outreach are continuous, time-consuming processes that require dedicated time or a person focusing on those particular tasks.
- It was surprising to see that the least time-consuming part of the project—VR and AR—grabbed the most public attention, while the most challenging and effort-intensive part—the pump system—attracted less interest.

Saranpreet

- Keeping and maintaining the budget is a crucial part of any engineering project. There are unforeseen circumstances which may plummet the budget from dark and it must always be accounted for on every stage of any design project.
- This project even though was more inclined towards the entrepreneurial side, but nevertheless the technical side was very intensive as we tried to debug the vacuum system until the very night before. Which even piques more interest in this project as whole.
- There is no doubt that a bigger team means more help, more skillset, and less burden, but nonetheless even a team of three with focus, determination, and passion can produce outstanding results which are evident from the report above.

Artem

- Any electronic project should involve at least 2 generations of the design to reduce the risk of design error.
- The procurement of the electronic components and order of the PCB should be done by local manufacturers to eliminate custom broker payments and reduce delivery time.
- In the design of complex electronic boards, practical tests should be preceded by Spice simulations to reduce the cost of PCB manufacturing.
- When PCB are procured, both their printing and assembly should be ordered to reduce the risk of mechanical, electrostatic or heat damage during assembly.

Conclusion

In conclusion, in the span of 8 months our team went through the early-stage startup development process that included: determining a real and practical problem, collecting firsthand feedback, using it to drive the design, setting up the prototype objectives, manufacturing the system, and presenting the product on the demo day trade show. The main challenges faced by our team were the rigidity of the course curriculum, absence of funding, and the reduced size of the team. Nevertheless, we agree that this ambitious venture granted us valuable experience of product development and entrepreneurial pursuit [2].

References

[1] T.-Y. Yeh and Y.-T. Shih, "DS 123: Proceedings of the International conference on Engineering and Product Design Education (E&PDE 2023)," Hong Kong, 2023.

[2] Open AI, "ChatGPT," [Online]. Available: https://chat.openai.com/. [Accessed 09 02 2024].