SHOVEL

MAKING GARDENING MORE ACCESSIBLE

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Design 1
EDNS151

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

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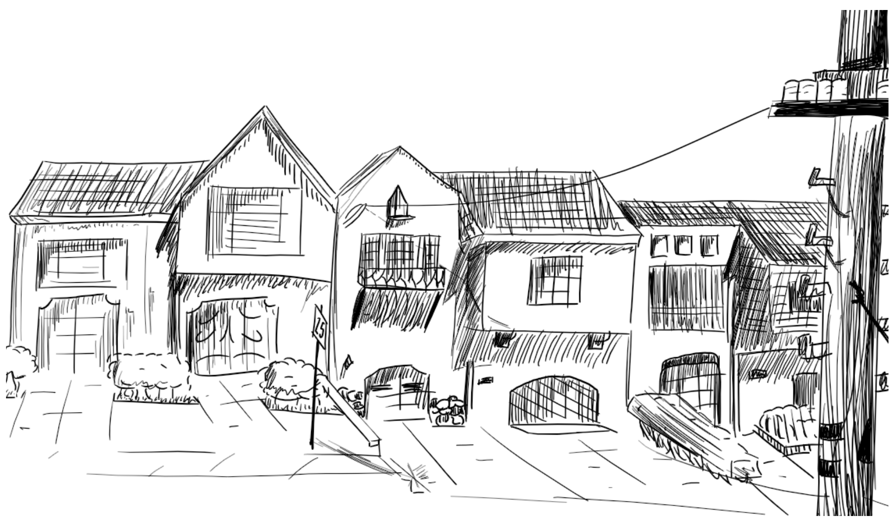
Introduction

Problem Statement

How can we make gardening more accessible in urban areas?

Background

The idea of accessibility and nature is very broad, and can be applied to nearly every aspect of day to day human life. It seems the great outdoors is accessible to every person, this is simply not the case. There is more to The Great Outdoors than simply taking a step outside. Transportation, money, and time are all constraints that make gardening less accessible, particularly in heavily populated areas. Sometimes it can be hard to escape the city and enjoy nature.



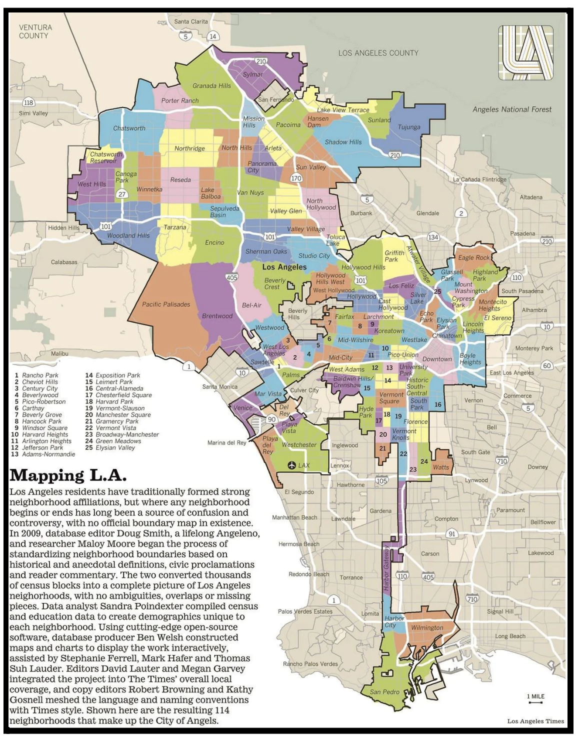
People have done this for centuries in the form of gardens. Individuals in urban areas are able to maintain both indoor and outdoor gardens in order to get a daily taste of nature in an every busy city. However, this does not come without its problems. The standard for living in the city are apartments or small houses. These can often hold live plants, but the space for maintaining an outdoor garden in these spaces are limited. Keeping indoor plants or patio planters can be expensive and time consuming, especially for beginner gardeners. Owning a garden is not the sole outlet for people to access greenery in urban areas. Parks of all shapes and sizes can be found in every single city. Parks are free and public, which makes them seem like they solve the issue. Unfortunately, this is not the case either. Parks do exist in every city, but they do not exist equitably to all people.

Los Angeles is the second most populated city in the United States. The following table displays data taken in Los Angeles and different demographics based on the acreage of parks in the area [3]. Each of these areas are very densely populated, and located throughout the city. Next is a map of each different Los Angeles area [4]. The neighborhoods that are in more central and urban parts of the city tend to contain less parks.

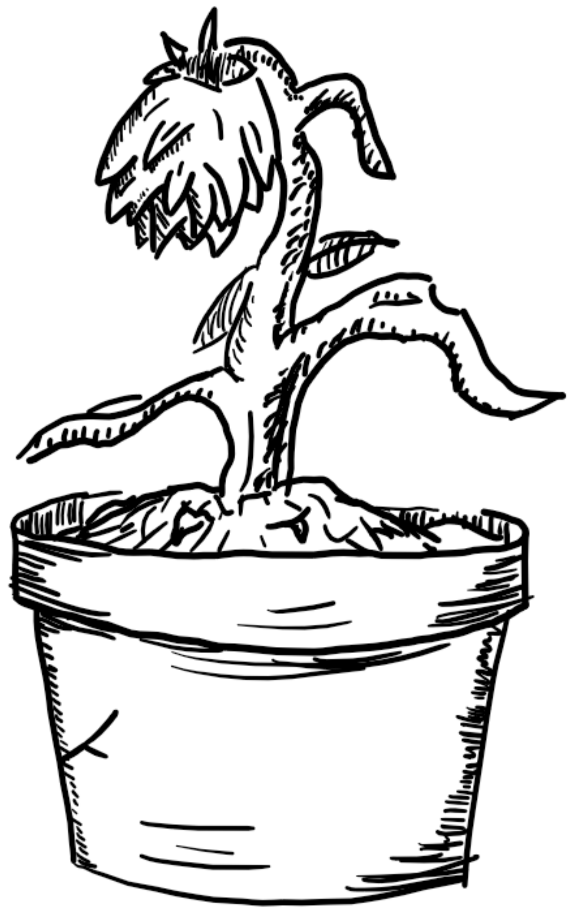
Table 1

Park and Neighborhood Characteristics

	Acres	# of facilities	% White	% Latino	% Black	% Asian	% Households in poverty (1999)	% < 18	% > 60
Algin Sutton Park	16.0	17	2	65	31	2	44.3	42.2	6.3
Green Meadows	9.0	17	0	65	34	0	36.1	38.1	10.7
Costello	3.4	8	1	95	0	4	54.9	38.0	8.0
Pecan	4.2	7	5	80	2	12	35.6	25.8	15.8
St. Andrews	8.5	12	0	11	88	0	16.6	26.3	21.8
Van Ness	8.1	16	1	21	75	1	16.3	28.8	16.6
Evergreen	6.4	11	2	94	0	3	31.9	31.7	14.0
Wilmington	6.9	11	5	86	5	2	41.2	41.9	6.8
Bellevue	9.0	10	26	52	3	17	23.9	21.3	10.9
Fernangeles	10.0	9	27	55	1	11	9.8	29.7	14.6



Denver is ranked number one nationally for highest accessibility to local parks. On average, an individual has to walk 3 to 6 blocks to get to their closest park. However, recent studies have shown that Americans today are “rarely willing to walk more than a block or two” [5]. The lack of wanting to walk places stems from physical disability, fear of crossing neighborhood lines, and general unwillingness. Even being ranked highest for accessibility, many people in Denver will not want to walk the three blocks or more to a park. With yards becoming more infrequent due to the demand in larger housing, access to nature in urban areas in becoming smaller and smaller.



Many people across America do not have easy access to parks. While gardens can be a solution, these too come with many headaches. It can be fulfilling, but it is not realistic for all Americans in city spaces to maintain yards or indoor gardens. Busy schedules and lack of time makes it so people cannot sustain plant life.

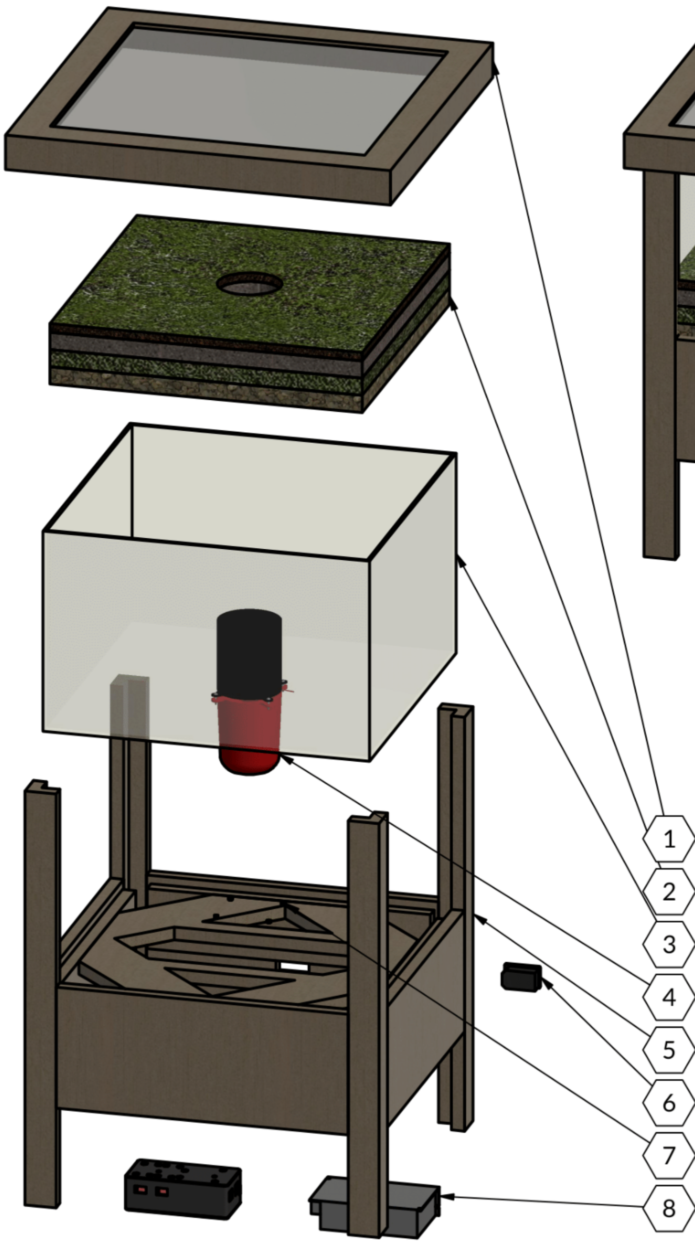
Studies have proven that 21-40 year olds would spend more time gardening if they had more breaks from the hussle of everyday life [6]. Busy working schedules in the modern era do not allow for this. Here at Shovel, we want to address this problem. Maintaining houseplants can be time consuming, and take up a large amount of space. People often do not have time, resources, nor the desire to maintain house plants or a small yard. This inspired us to build a noninvasive and functional greenhouse table, the Eden Table.

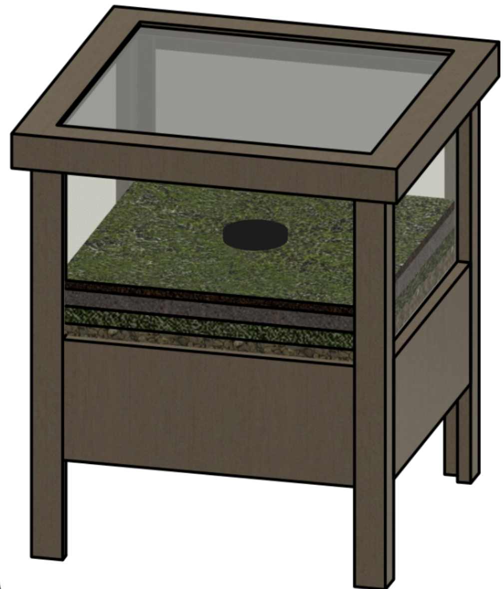
Our Solution:

The Eden Table

The Eden Table is a miniature greenhouse inside a functional, modern piece of furniture. Inside the biosphere, a wide range of mosses, ferns, and other plants thrive. Lighting and watering is handled automatically, making gardening easy for those with busy schedules. An engineered distribution of soil, sand, peat moss, and gravel make up the substrate, ensuring the system stays mold and algae-free passively over time.

This table allows for plant growth with minimal efforts or space. The system for the most part maintains itself, and is aesthetically pleasing without requiring a large amount of human interaction.

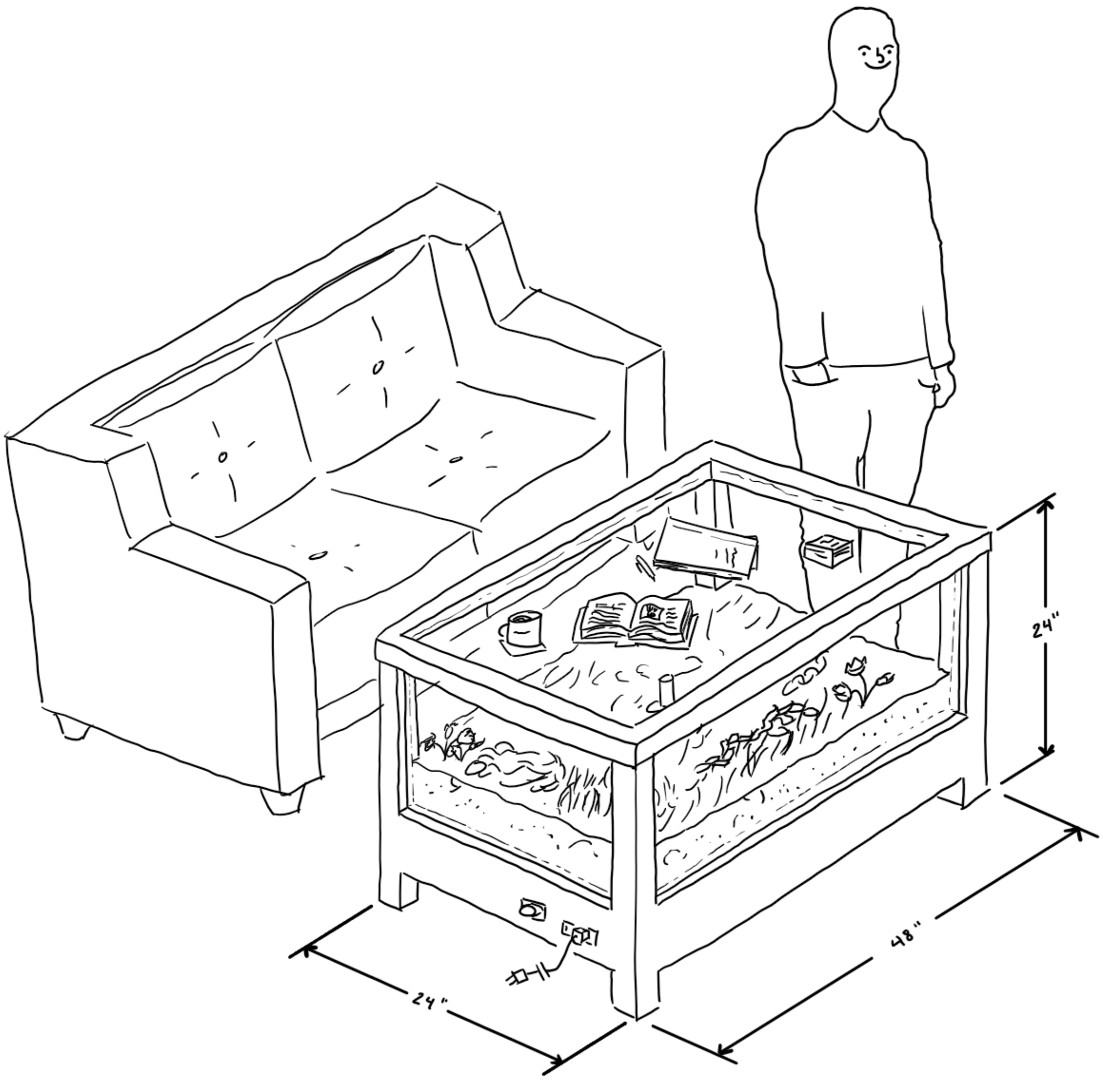




PARTS LIST	
ITEM	PART NUMBER
1	Lid
2	Substrate
3	Biosphere
4	Watering System
5	Frame
6	3-Prong Inlet Socket
7	Electronics
8	Power Supply

COLORADO SCHOOL OF MINES	EDNS151 DESIGN 1 SECTION W TEAM SHOVEL	DRAWN BY BRENT WERDER	DRAWING TITLE Eden Table Exploded View
		2021.05.02	
		SCALE: 1 / 8	
		MMGS	

The prototype Eden Table is sized as a bedside table. The frame is constructed out of reclaimed ghostwood, which not only keeps it rugged and durable, but lends it the rustic, homely feel that makes it so effective as a centerpiece to a room. The full-spectrum plant lighting in the biosphere also acts as a soothing source of ambient light. The final version of the Eden Table will be scaled up to a coffee table.



Alternative Analysis

Before selecting the Eden Table as our final design, the team considered a number of alternative solutions, using stakeholder feedback, research, and analysis to make our decision.

Stakeholders

The affected parties for our problem statement are:

- Urban inhabitants
- City & state governments
- Physically disabled
- Menally disabled
- Low-income groups
- Apartment tenants
- City planners
- Garden centers
- Gardeners
- People interested in gardening
- Gardening-oriented manufacturers
- Landlords

Existing Alternatives

Many solutions have already been developed to solve this problem, including:

- Community gardens
- Potted plants
- Raised garden beds
- Hanging plants
- Glass watering bulbs
- Soil moisture monitors
- Zen gardens
- Succulents & other houseplants

Because people still struggle with keeping gardens in urban areas, the problem persists despite all these solutions.

Specifications

The focus of this design was being accessible to all people, regardless of living locations, physical ability, or financial ability. In order for the design to be accessible, the following specifications need to be met:

CONSTRAINTS & REQUIREMENTS

Cost	Below $400/un mfg. cost *Consult mfg. for per-unit cost*
Durability	Must survive rigorous daily use for at least 1yr *Product abuse tests in variety of conditions*
Size	Should be able to fit through an average front door *(36" x 80" max)*

The cost of the table is higher, however, very sensitive and high quality products must be used. Since the product being manufactured will be novel, using pre existing products may be difficult, meaning more raw materials are needed and production will take longer, thus being more costly. However, as will be discussed in Value Proposition, the value of this table far outweighs the costs for our stakeholders.

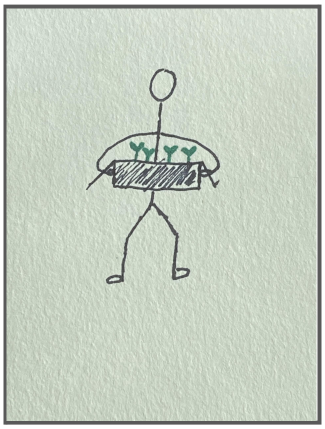
Alongside with the price, the product should last longer than a year. If it is not durable, it would have to be replaced often, which can be costly. On top of cost, a product that is not durable and needs to often be replaced would cause a large amount of waste.

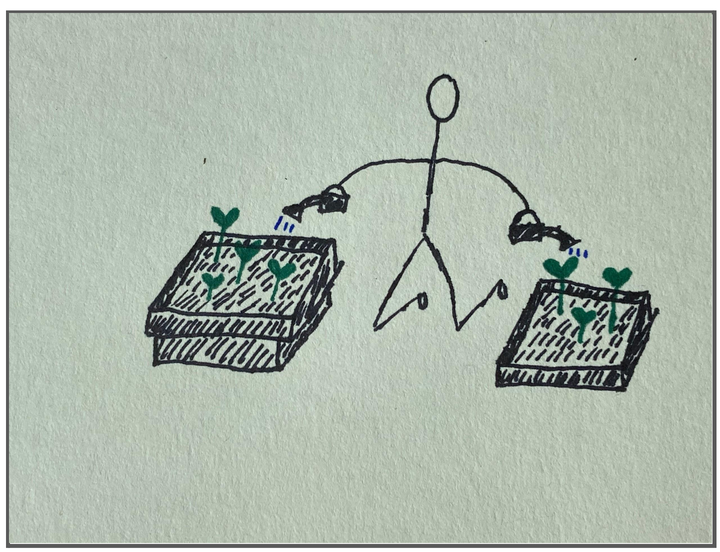
Finally, it needs to be accessible in all city areas. It should fit through the average door, so it may be placed in an apartment or small house without any extra struggle of the user.

Decision

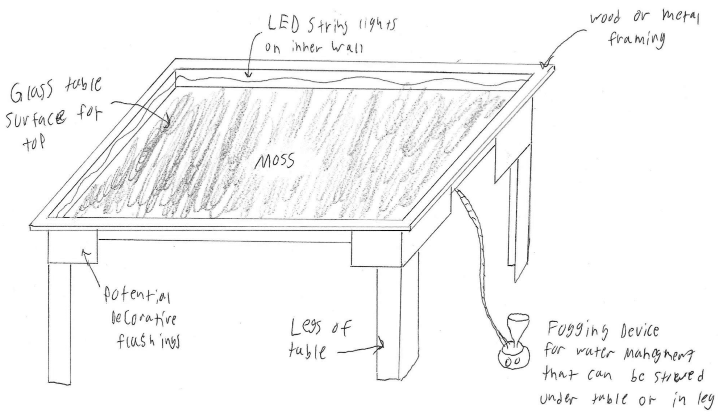
Our group used an unweighted decision matrix using five concepts from the brainstorming process to assist in making our decision. The concepts we evaluated are as follows:

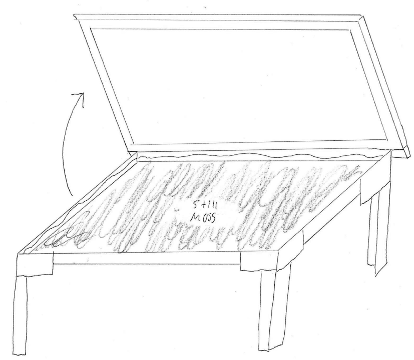
- ❖ Box Garden
  - ➢ Compact gardening unit that is easy to transport and can be arranged for the needs of the user.

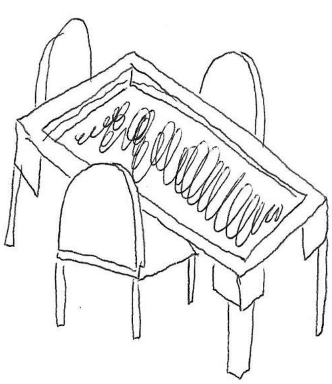


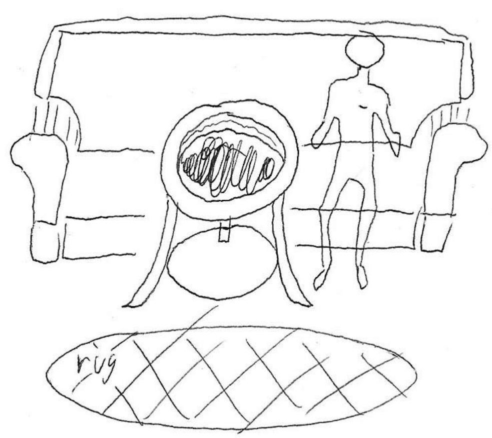



- ❖ Moss Table
    - ➢ Table with self-contained moss biosphere and built-in plant maintenance systems.

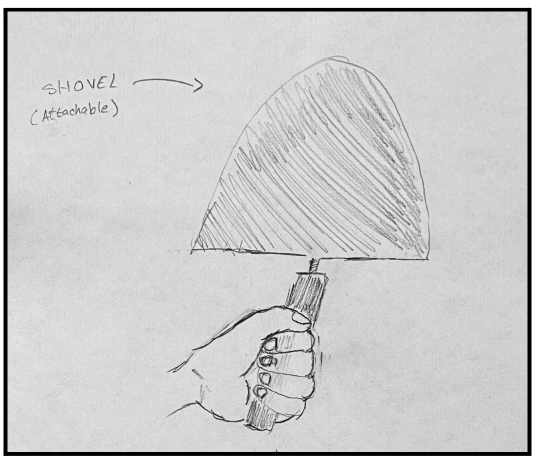


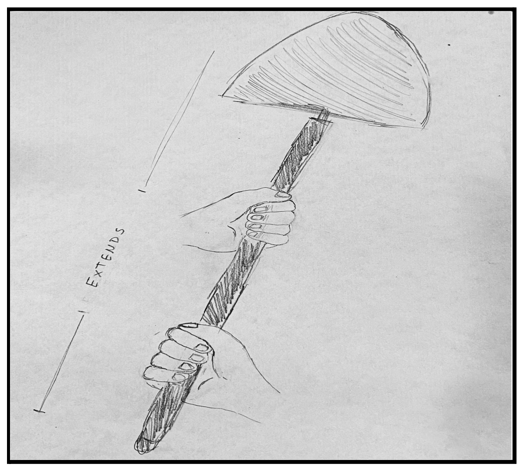




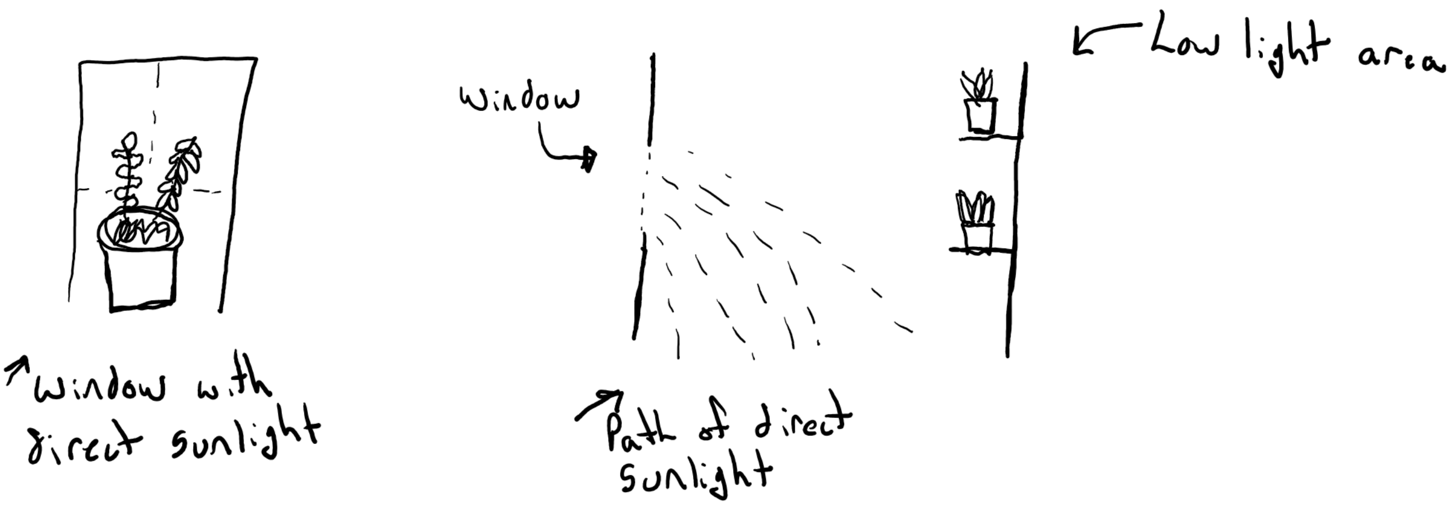


❖ Multitool
  ➢ Compact “Swiss army knife” specifically built for gardening.

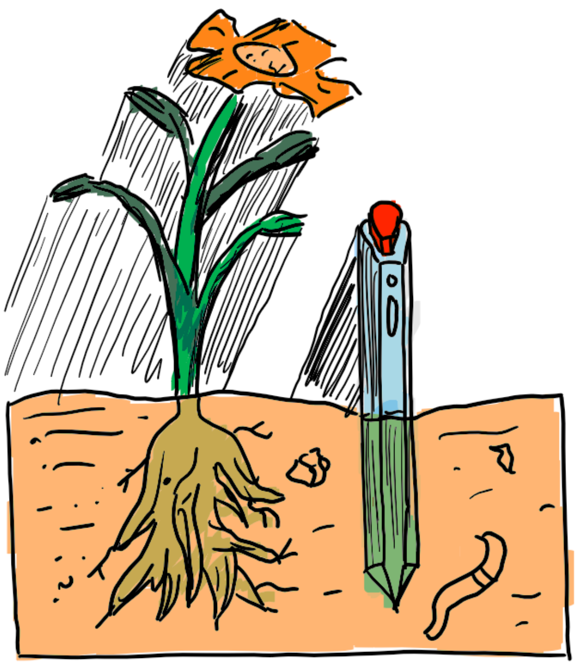


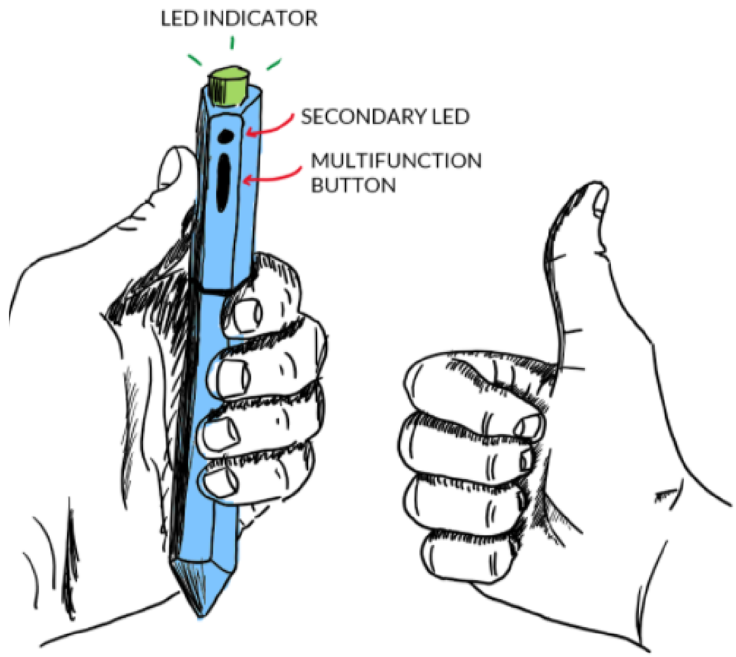


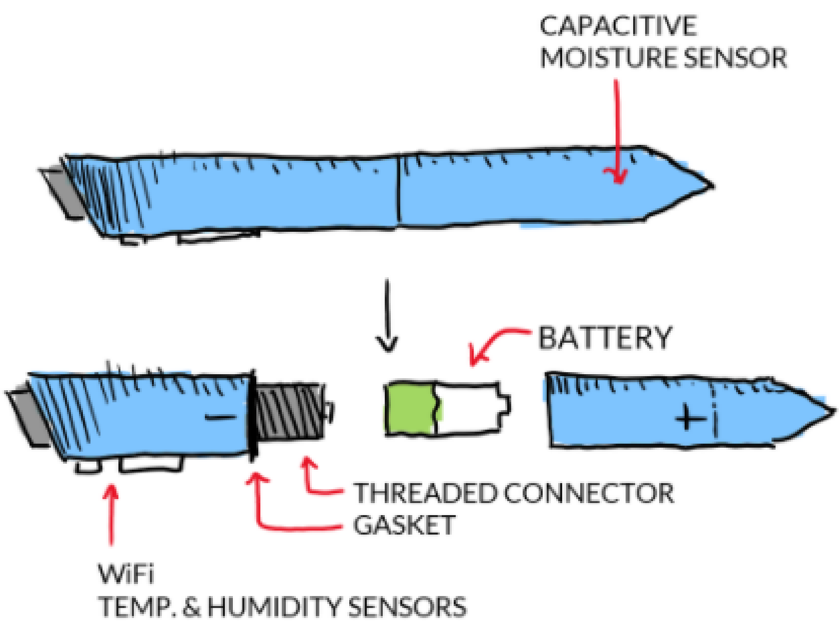
- Gardening Subscription Box
    - Starter gardening kit sent by mail.



- Soil Probe
    - Small electronic device inserted into soil to provide data about plant wellness.







(Higher points are better.)

DECISION MATRIX	Cost vs. Value	Durability	Size	Energy	Sustainability	Demographic	
Box Garden	4	3	5	4	4	3	23
Moss Table	4	4	5	3	5	3	24
Multitool	5	4	5	5	4	2	25
Gardening Subscription Box	5	4	5	1	3	4	22
Soil Probe	5	4	5	4	2	4	24

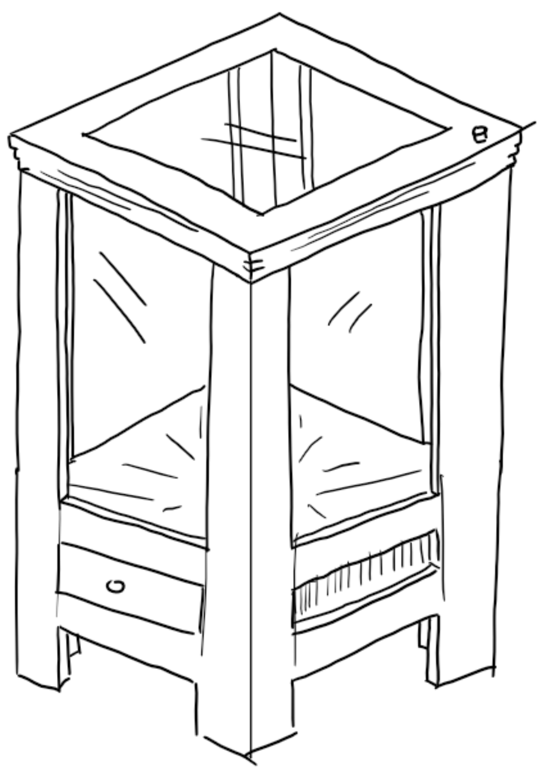
Included in the matrix are a few factors included from our stakeholder specifications (incl. cost, durability, size), as well as some ancillary factors which our group considered for the final impact of the design:

- Cost vs. Value
  - Does the value of the product exceed its cost?
    High points mean the solution has a high value-cost ratio.
- Durability
  - Is the solution relatively durable for its cost?
    High points mean the solution has an appropriate level of durability.
- Size
  - Is the solution reasonably large for its value?
    High points mean the solution is space efficient.
- Energy
  - How much energy does the solution use?
    High points mean the solution is energy efficient.
- Sustainability
  - What is the relative environmental impact of the solution?
    High points mean the solution has a low impact on the environment.
- Demographic
  - How many people does the solution apply to?
    High points mean the solution applies to a large demographic.

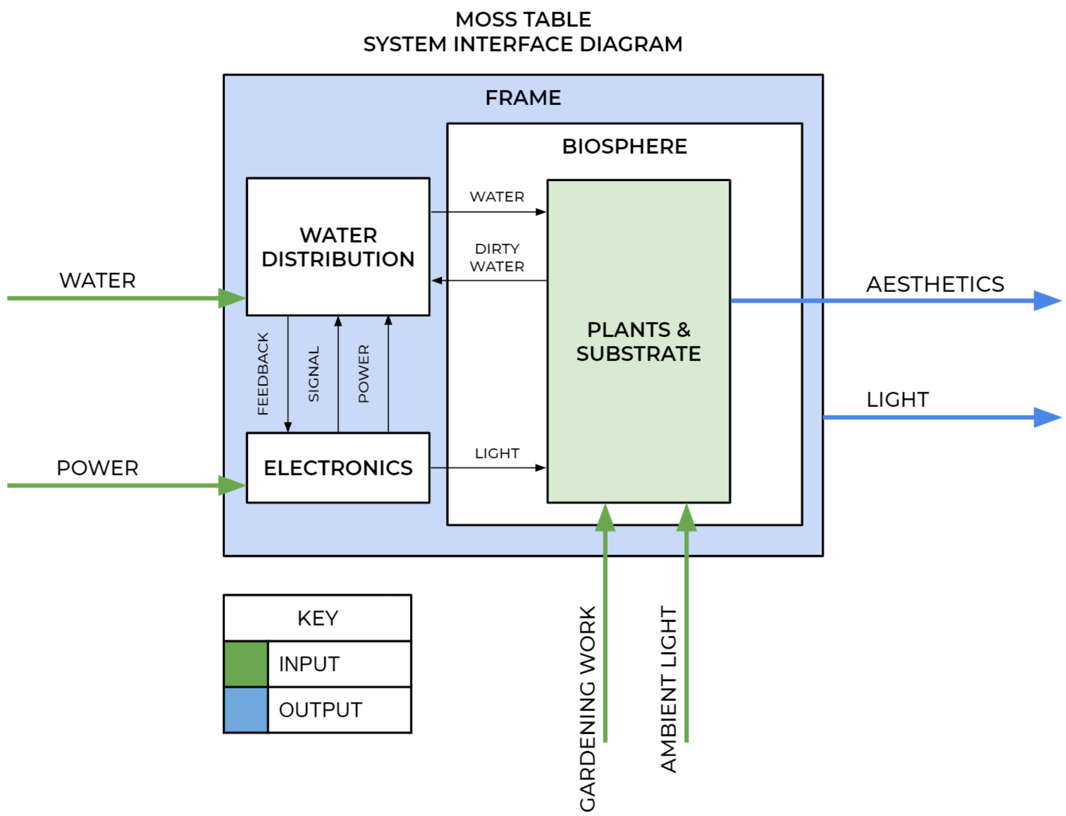
Final Design

While the multitool scored highest on the decision matrix, the team will be proceeding with the idea of the moss table. The concept is a self-sustaining garden contained within a normally functioning table

The concept of a green-house table is somewhat novel, and cannot be found on the market. This table will ideally have internal watering and lighting systems. This means that it will require minimal human interaction, and will primarily be for aesthetics and functionality. The versatility of the design means that it can be made in various different sizes. This will allow it to fit into almost every space and fit the user's needs. This product can be used by gardeners at every different level of experience. A challenge this group may face is trying to lower the cost. A lower cost will make this product more accessible to people of every demographic. However, furniture is often expensive, so a higher price could very well be justified.



Subsystem Report



System

The above figure shows the inputs and outputs of the design. Overall, there are four inputs and two outputs:

In:

- ➢ Water
- ➢ Power
- ➢ Gardening Work
- ➢ Ambient Light

Out:

- ➢ Aesthetics
- ➢ Light

Five main subsystems comprise the system: the frame that houses all other subsystems and makes up the actual table, the biosphere which contains the plants and their growth substrate, and a watering system with its accompanying electronics.

Interfaces

The electronics group is categorized by the subsystems of watering and light. Both of these two components work with a power source. They needed to work with each other in order to make sure that a power source could be shared. More importantly, the lighting the water subsystems need to work together, but if the lighting system gets wet it could compromise the lighting.

They further consulted the substrate and plant subsystem. The plants have certain water and lighting requirements. The electronics will be on a timer in order for the plants to grow and sustain themselves. They have strict lighting and water requirements. Too much or too little of both can be detrimental to plant growth. The plant substrate will be internally filtered so the water pump does not become damaged or dirty.

The biosphere has very strict sizing requirements. Sized improperly, the biosphere would not have fit in the table space. The frame and the subsystem are dependent on one another. These subsystems sit together like a puzzle, and are size dependent on one another's dimensions.

The plants fit within the biosphere. The choice of the plants are dependent on the size of the biosphere. The plants make up the largest aesthetic component of the system, they are selected and arranged based on visual interest.

The frame is the subsystem that accommodates the others the most. It not only holds the biosphere, but it will need to conceal the electronics so that it is visually pleasing. It is sized in order to meet these requirements. Moreover, the materials are waterproof, so that the watering system does not corrode or otherwise damage the frame.

Frame

Abdullah Khawaji

This subsystem provides the framing of the table where multiple components connect and function together. The design of the framing will also make it easy to access all the different components to either clean or perform maintenance such as repairing or replacing certain components that need attention.

It is a wooden frame that has four legs that uniformly sits on the floor, and the legs that hold and connect the different pieces together.

Functionality and Components

The overall objective of this subsystem is to provide the space and assign the placements of all the other subsystems while the frame holds it all in place. Another key objective is the aesthetic. In order to give the table a pleasing look, many of the components of the other subsystems will be concealed through using the frames.

Operation

The subsystem needs to achieve the following:

- It provides a stable structure to hold all other subsystems together
- It provides adequate space and places to interconnect the other components
- It enables any other external systems to integrate through.

In order for it to achieve these objectives, the subsystem will be designed with strong ghostwood that provides stability and durability. This kind of wood is also water-resistant that can cater for the nature of plantation function within. It was also designed with interconnectivity places for all the components, such as water distribution, biosphere, plant substrates, and electronics. The integration of each one of these components were considered in the design of the frame to enable it to perform as expected.

Inputs

The required inputs for the framing is the other subsystems which are: biosphere, plant substrate, electronics, and water distribution. All these subsystems will be placed at their appropriate places with the sufficient space that is required and having the frames to support them. For each other subsystem, the following input are needed:

1. The exact sizes and dimensions
2. The weight
3. The type of material used
4. The places where they connect with the frame, and the type of connection
5. The other accessories associated with other subsystems that require space to be designed in the frame
6. The overall product desired size and features including durability, appearance, etc.

Components

The key components needed to accomplish the output function is the wood and glass. The wood is for the framing where all the subsystems will be placed at while having a large space in the middle for the glass. The frame itself has four wooden legs, a frame for space in the middle, and a frame on the top.

For off-the-shelf components, the subsystem is basically composed of ghostwood that is cut in different shapes to achieve the desired design. This kind of wood is versatile and also works well with the plant substrate.

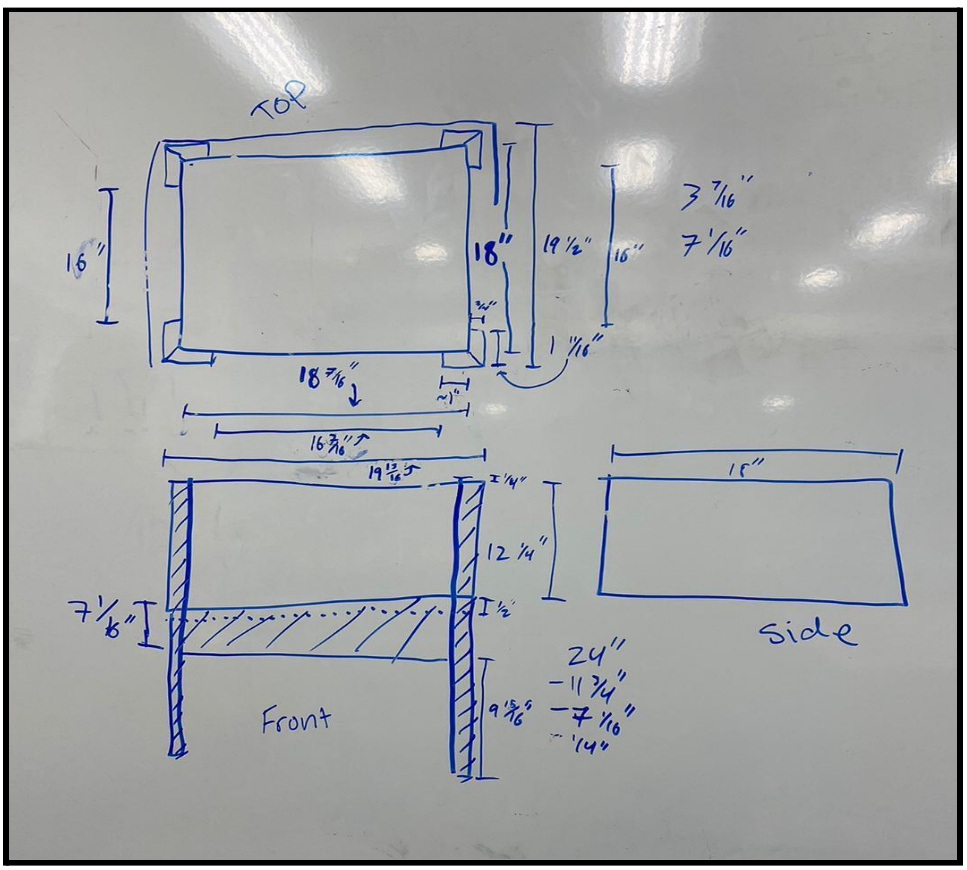
Physical Properties

The chosen material was ghostwood because it is affordable, has a pleasing aesthetic, and is a great material to be used for aquariums [7] meaning it has a fine resistance to water which would help support the water distribution as well as giving it an overall pleasing look for the table that was initially imagined.

The overall dimensions for the works-like prototype are shown in the following table:

	Dimension (in)
Length	18
Width	18
Height	24

The following is the sketch of the frame:



Decision Making

Different alternatives were explored to figure out the best material to be used that can achieve the objective. The following shows the idea generation summary that was used to make the decision for the design of the frame.

Validation

Test Results

Multiple testing was conducted inside the Digger Design Workshop to see if the moss table frame meets the required objectives. The following are the findings:

	Test/Pass Test (Yes/No)
Holds the weights of other systems	Yes
Stable on the ground	Yes
Provides sufficient space for other subsystems	Yes
Provides placements for other subsystems	Yes
Withstands water	Yes
Affordable	Yes

Analysis

Following the standard dimensions of a bedside table [8], the chosen dimensions were 24X18X18 inches. Using these dimensions will make it a reasonable size for a bedside table where the table aligns exactly or closely with a standard bed.

Stakeholder and expert feedback

One of furniture stores salesmen, Nazir Zuhair, was contacted to show this design, and obtain his feedback. He provided the following: “This is a very brilliant design. I like the integration of sustainability, green and environmental solutions into daily required pieces of furniture and amenities. I understand from you that you are also going to use ghostwood as a frame of this design and it will be integrated also with glass light and sufficient circulation in network. I found it very creative and innovative and I would probably give some recommendations to improve it further. I would keep in mind that the shape of this design can be in the future as a circular shape or something that can have a variety of different shapes that can fit in different parts of the room.”

Another interior designer was asked, Bader Saleh, to share this design with him. He was pleased with bringing environmental solutions into the indoor furniture design. He stated that “I would make sure that I select the proper plants that require less water and can grow indoors despite that the features of this new design includes sufficient light, oxygen, and water. Wish you the best and I will look forward to a successful product.”

Watering System

Brent Werder

This subsystem provides the plants within the biosphere container with water. To keep the biosphere sustainable over time, this system will also include drainage and filtering for the water. The system is closed-loop; water cycles through it regularly, as controlled by the electronics.

Functionality & Components

Key Functionality

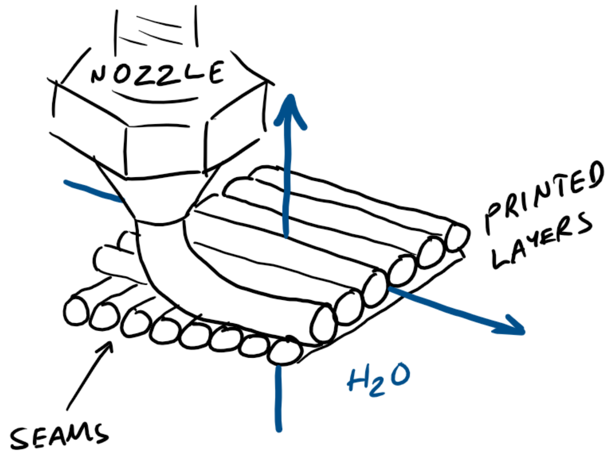
This system moves water around the interior of the table, recirculating it to the plants. It is able to remove some contaminants from the water, though the bulk of contaminants are filtered by the plant growth substrate.

Key Components

- Water Input / Output
  - Allows owner to add / remove water from system.
- Reservoir
  - Tank of reserved water.
- Drainage
  - Allows water to drain from biosphere.
- Filter
  - Removes contaminants from water.
- Fogger
  - Creates fog that distributes water to plants.

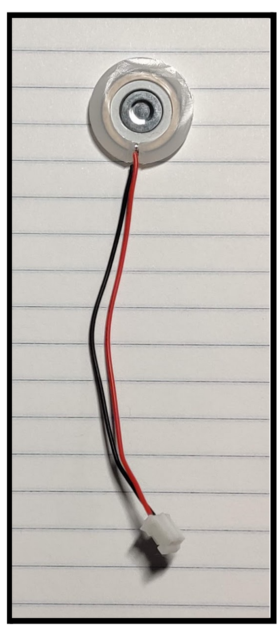
Physical Properties

Because this subsystem deals with the distribution and treatment of water, all elements included within it are designed to be watertight. The main structural components of the system are designed to be 3D printed in PETG plastic, then coated with a watertight acrylic coat for extra protection. FDM 3D prints are naturally porous because of the nature of the printing. Prints are layer-based, and composed of cylinders squished together. The microstructure of the part, therefore, has many holes through which water can flow, both laterally and vertically.



To solve this issue, the prints will be intentionally overextruded. This means more plastic will be printed than necessary to “squish” the layers together more compactly. Although this helps prevent leaks, this method of printing adversely affects the precision of the part. To mitigate this, the reservoir--the part with the least complex structure which holds water for the longest time--is designed with loose tolerances. Other parts of the system do not need these measures for watertightness as they only allow water to pass through them. Additionally, the final version of this product would use injection molded plastic parts, which do not suffer from the same issues as 3D printed prototypes.

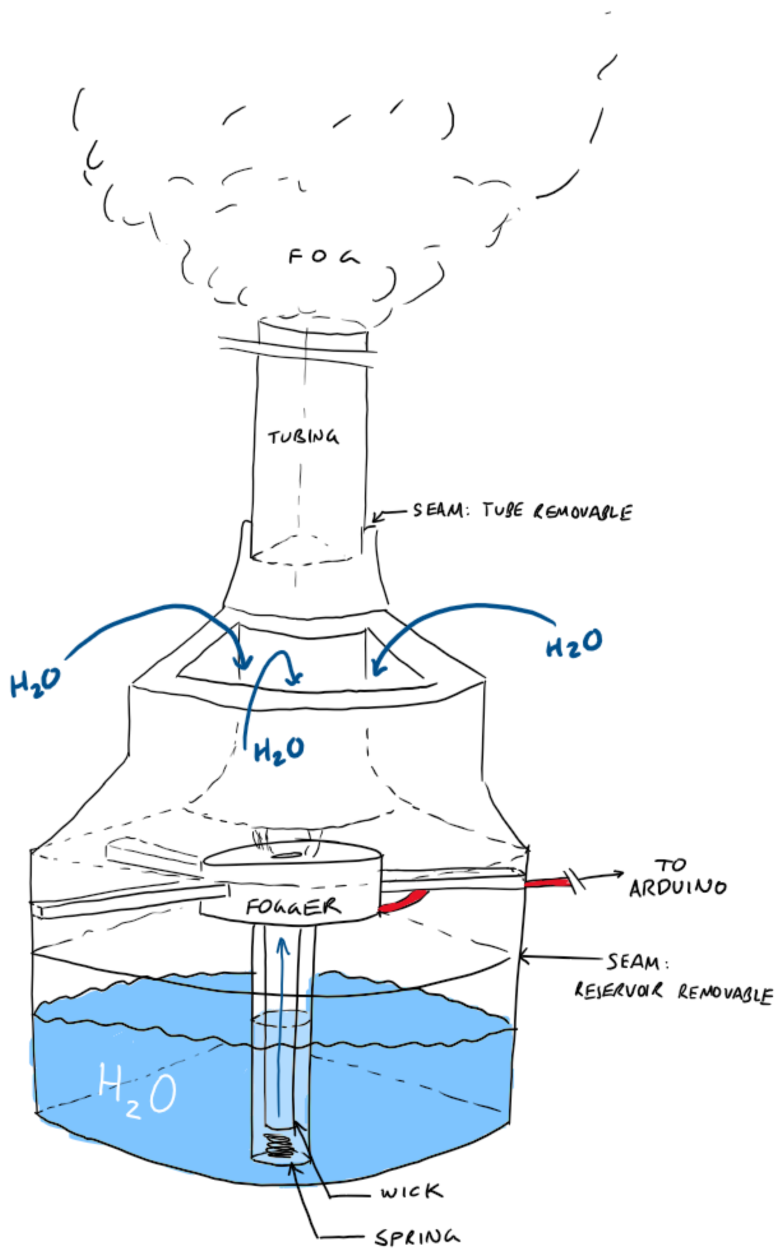
The fogger in use is a 16mm ultrasonic disc that aerates fog through the piezoelectric effect. It drives water through an array of 740 5um holes which create an extremely fine mist. It operates on 5V, which is easily supplied by the Arduino in use for the electronics. The manufacturer states that it has a service life of roughly 3000hrs, and produces 30-50mL of fog per hour.



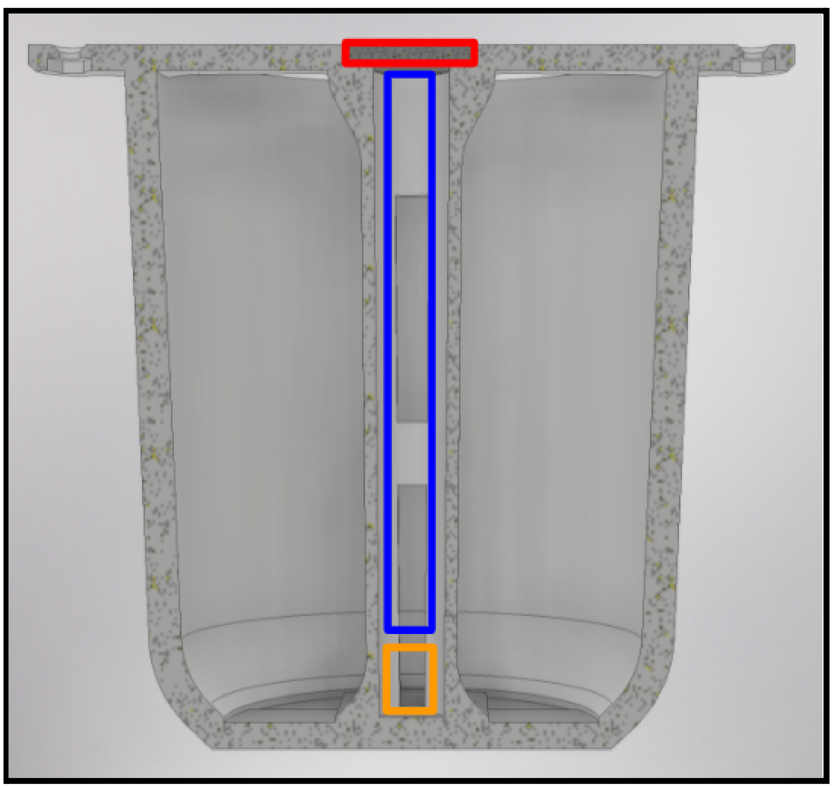
The filter used in the design serves two purposes--it ensures no dirt reaches the fogger, and wicks water from the reservoir up to the fogger. For convenience and affordability, a commonly available cylindrical cotton humidifier filter is used. These filters operate using capillary action, a force resulting from the strong cohesive forces present in water [9]. It drives the water upwards into the fogger, which takes care of filtration and supplying the fogger in one step. A small spring is employed to make sure the filter is always pushed against the fogger.

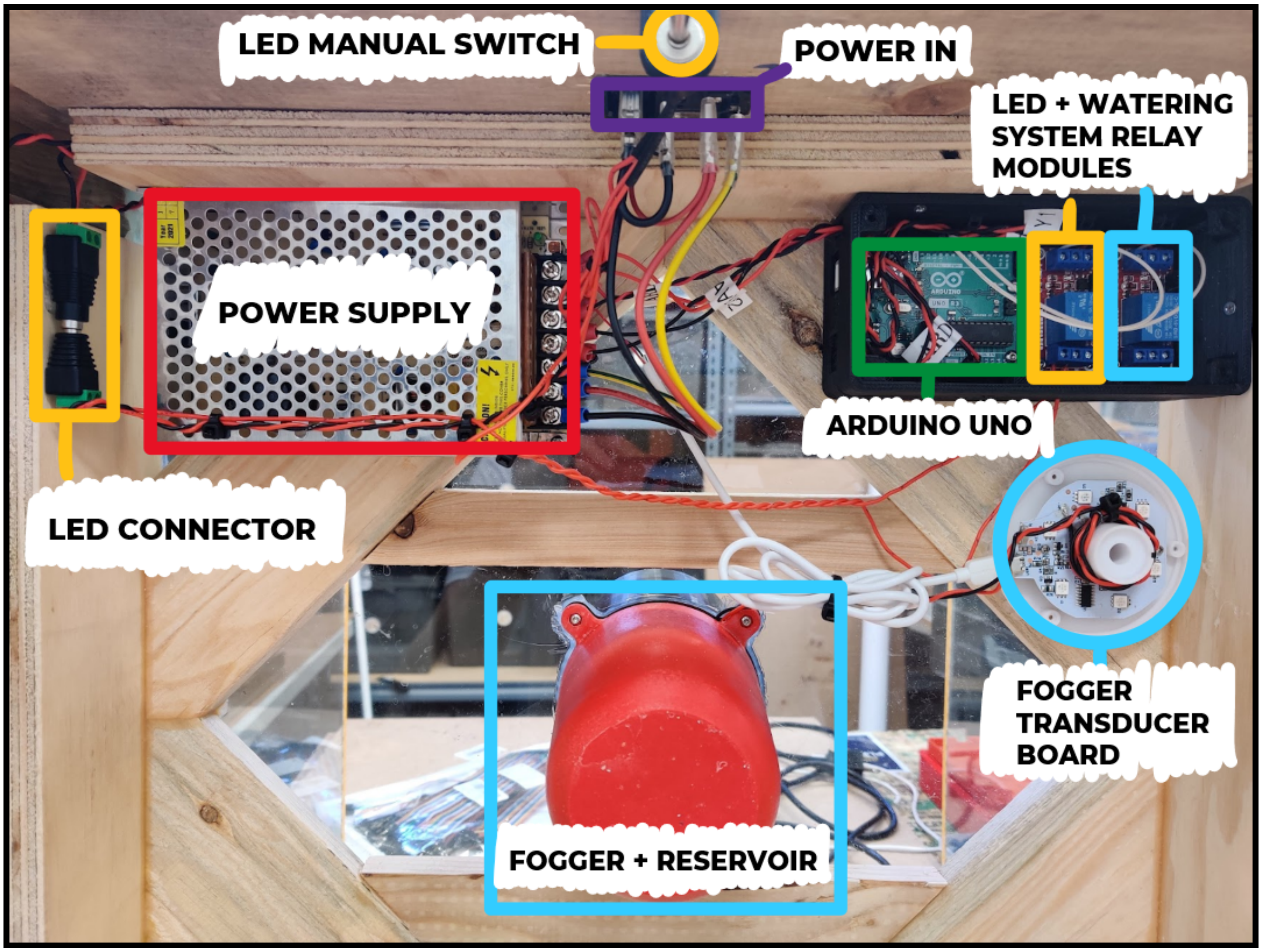
Implementation

The fogger design is relatively simple--the geometry is the most complex part. The fogger sits in the center, with the wick dipped into the reservoir underneath. A funnel allows the fogger to pull air from the surroundings, and its funnel shape allows condensed water to roll away from the fogger. Included in this implementation are return areas for the water, which allows it to run continuously as water flows back from the biosphere into the reservoir. The fogger system is designed to fit into the corner of the frame.



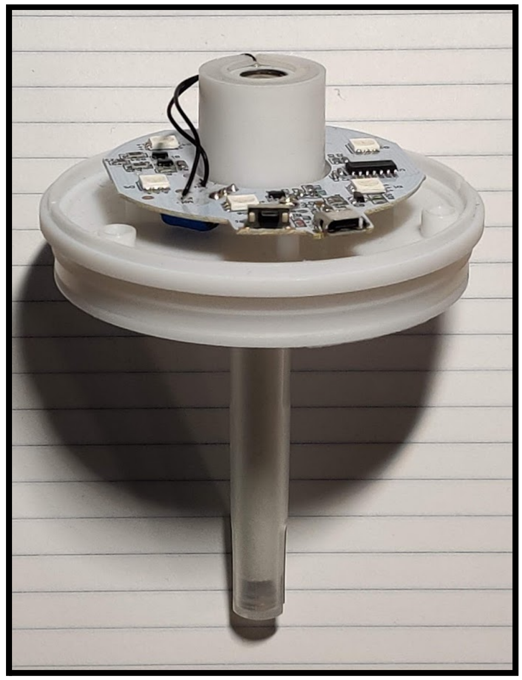
Inside the reservoir, a long perforated tube extends into the water, allowing the cotton wick (blue) to pull water to the fogger (red). A small spring (orange) is used to ensure the wick makes consistent contact with the fogger during operation.





As shown in the above photo, the electronics and watering system share the same housing underneath the frame. The reservoir and fogger unit attaches directly to the acrylic of the biosphere, with holes to allow water to flow back into the system. A transducer board that provides the 113KHz output the fogger needs to operate. This board connects to a relay module operated by an Arduino Uno R3, which provides the logic for the rest of the components. This relay allows the Arduino to switch the fogger on and off on a schedule, while allowing the transducer board the ~300mA at 5V it requires to operate.

Also pictured is the lighting system, which similarly runs on a schedule set by the Arduino. A manual switch is placed in parallel with the relay switch to allow the user to turn the LEDs on manually. Turning the switch off returns the system to scheduled operation.

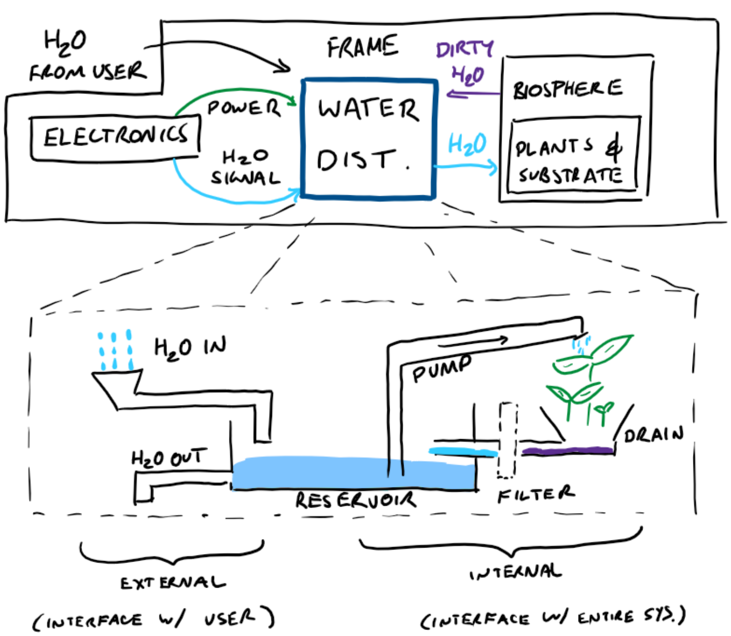


The fogger design is heavily inspired by small, personal humidifiers. One such example is above--the left is assembled, and the right is the PCB and mechanical interface between the fogger and wick. This PCB includes the transducer circuit mentioned prior. The basic design of the right image is utilized in the fogger reservoir.

Below is a subsystem diagram detailing the interfaces and components of the water distribution system.

Requirements & Goals

<u>Customer Needs</u>



The water distribution system should be robust enough to last a long time maintenance-free. The user should never need to worry about clogs, leaks, or other errors. If those should occur, the replacement / repair process should be easy.

Constraints

All elements should be easy to remove / replace for maintenance and cleaning. The filtration system and water I/O should be especially easy to reach, without requiring specialized tools to access. Additionally, all elements should be resistant to algae or other contaminants, should the filtration system fail to remove them.

Contextual Specifications

The arrangement of the parts for the system are heavily dependent on the frame and biosphere designs. Therefore, the system should be developed with extremely flexible tolerances that allow for sweeping structural changes in those two systems. For example, the tubing used to route the water across the frame should likely be made of flexible rubber. This allows the tubes to move during assembly (and possibly use) and allows the mfg. tolerances to be far more lenient.

Interfaces & Data Transferred

Interface 1: Frame

The frame is responsible for holding all elements of the table together. The frame will need a physical connection to hold the entire watering system in place. It also needs to be waterproof to ensure any leaks do not propagate to other subsystems.

Interface 2: Biosphere

The watering subsystem is designed to water the plants contained within the biosphere. Therefore, the biosphere will need attachment points that connect to the foggers and tubing so they can provide the plants with water. The drainage system is directly between the two systems, and will require collaboration to design and develop.

Interface 3: Electronics

The electronics are responsible for providing the watering system with a signal to start and stop watering. The watering system may also provide feedback to the electronics such as water level, substrate moisture, biosphere humidity, and other information (though some of these may fall into the purview of other subsystems).

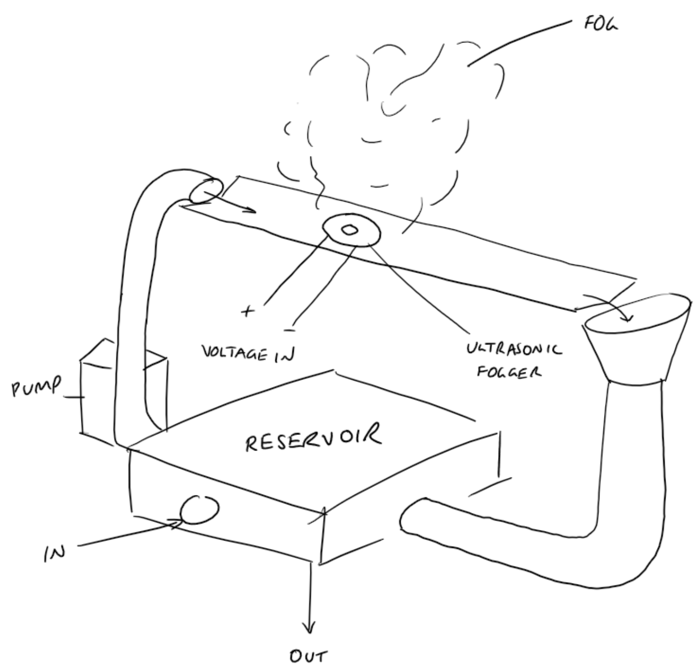
Design Process Tools

Concepts Considered & Decision Tools Used

The team considered removing the entire watering subsystem. Some biosphere terrariums do not require any watering systems to maintain them; they're entirely self-contained [10]. If this option was selected, no watering system would be required. However, using a closed terrarium for this project would limit the plant choices allowable for the table. To keep our options open, and allow the end user more flexibility in their plant choices, a watering system will be developed.

Multiple alternatives to the fog system were also considered. The first concept was a mist-spraying system that would use sprinkler tubing to deliver water to the top of the frame, which would then spray down into the biosphere. This was scratched, as the plants used in the design require very little water. Mist nozzles mounted on the side of the glass would also cause water to condense on the inside panels of the table, which was undesirable for aesthetic purposes.

The fog system was initially designed as shown in the following diagram. A small pump moves water into a channel in the biosphere, which runs underneath the fogger as its water supply. Unused water returns down the drain. This design was especially interesting because it introduced a visually appealing water feature into the biosphere. However, this idea was made obsolete through testing, as the foggers made too much noise and sprayed water somewhat uncontrollably.



Validation

Before proceeding with the final fogger design, three validation steps were taken. First, research was conducted to determine how much water the plants need. Then, a testing rig was constructed to get data on the fogger's capabilities. Finally, the test data was analyzed to determine whether the foggers would hit the specs found in research.

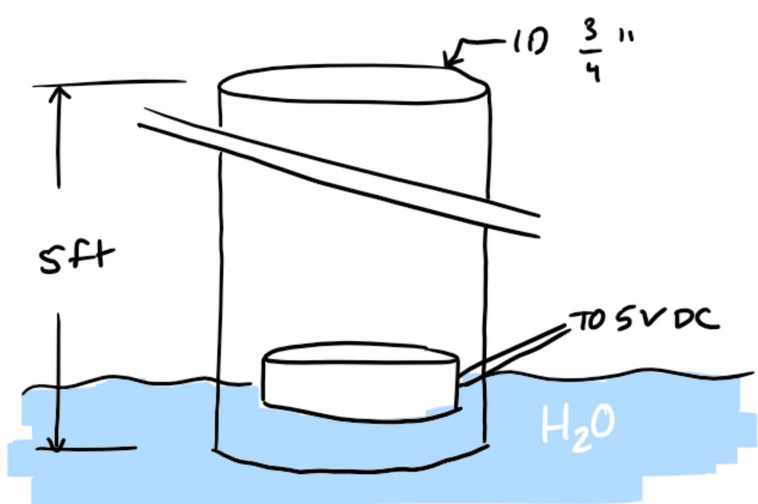
<u>Research</u>

______The plants in use in the biosphere consist of various ferns and mosses. During my research, the team had yet to decide the specific species of plants for the table. To accommodate plants that require a lot of water, the fogger system should be able to meet the specs of plants living in naturally humid environments. This means more arid plants would also survive in the biosphere--the watering cycles would be decreased to ensure they aren't overwatered.

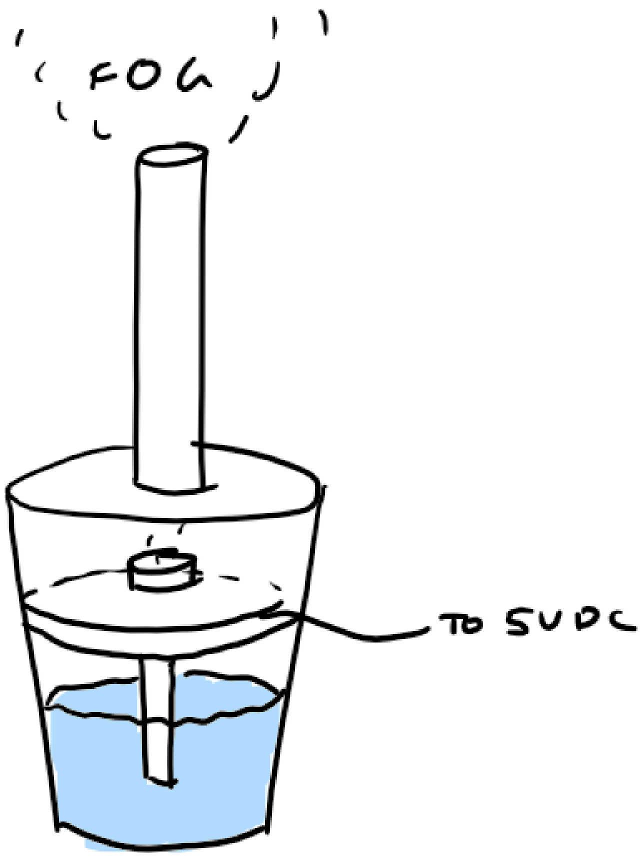
The specification I chose was a 70% humidity maximum. Most ferns and mosses require only 50% relative humidity [11], so the extra overhead would likely be more than enough for any plant chosen for the table.

<u>Test Results & Protocols</u>

The first test was a stress test to see how far the foggers could drive water up a tube. As shown in the following diagram, the fogger was placed inside the tube on the surface of water to ensure no fog was lost to the surroundings. This test failed immediately--the fogger requires air to flow into it to create fog. After adjusting the tube to allow air into the fogger, fog rose roughly 12 inches into the tube before condensing on the sides.



Next, after constructing a new test fixture, the fogger was allowed to run for four hours straight. The water level decreased by 26mm over that period. Occasionally, the fog condensed in the tube and dripped onto the fogger, disabling it for a few seconds. This issue never caused the fogger to go out of service for longer than 45 seconds. In the final design, a funnel-shaped tube is used to direct condensation away from the fogger to get rid of that issue.



Analysis

A few calculations prove that this system is viable for use in the table. First, a few quick calculations determine what volume of water is required to meet the 70% humidity spec. In order for the humidity to be above 70%, there must always be roughly 60mL of water in the biosphere air.

GIVEN

$$HUMID_{\%} = \frac{M_{H_2O}}{M_{AIR}} 100\% \geq \underline{70\%}$$

$$D_{AIR} \approx 0.0012929 \; g/mL$$

$$D_{H_2O} \approx 1 \; g/mL$$

FIND REQD. V_{H_2O}

$$V_{AIR} = 18in \cdot 18in \cdot 12in = 3888\cancel{in}^3 \cdot \frac{16.3871 \; mL}{1\cancel{in}^3} \approx 63713.04 \; mL$$

$$M_{AIR} = V_{AIR} \cdot D_{AIR} \approx 82.37 \; g$$

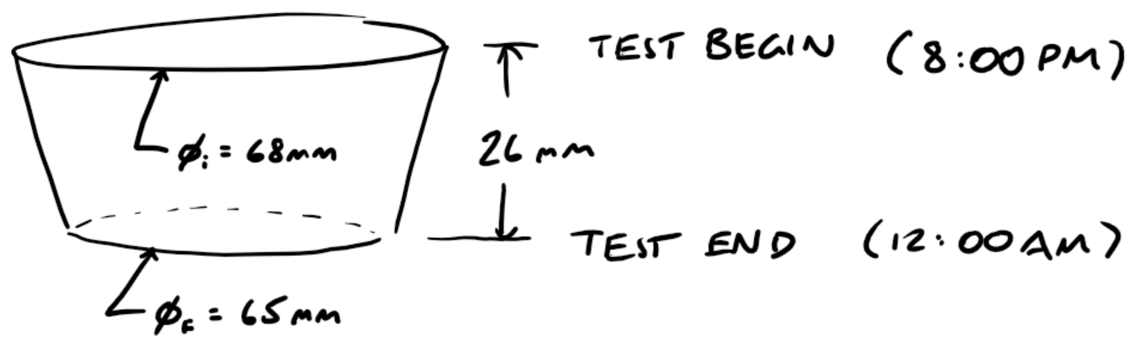
$$\frac{M_{H_2O}}{M_{AIR}} 100\% \geq 70\%$$

$$\left.\begin{aligned} M_{H_2O} &\geq 0.7 \, M_{AIR} \\ M_{H_2O} &= D_{H_2O} \cdot V_{H_2O} \end{aligned}\right\} \quad V_{H_2O} \geq \frac{0.7 \, M_{AIR}}{D_{H_2O}}$$

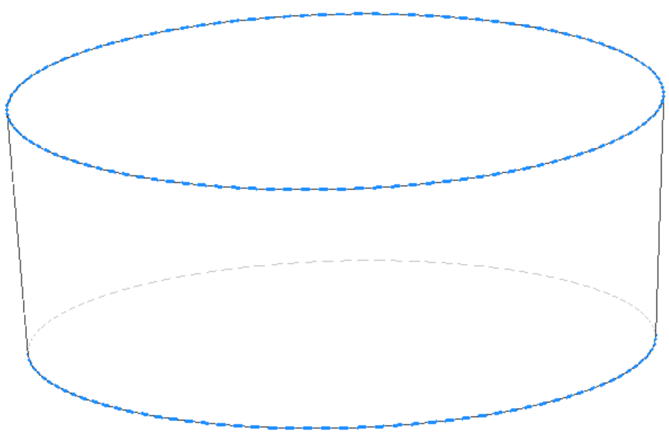
$$\boxed{V_{H_2O} \geq 57.66 \; mL}$$

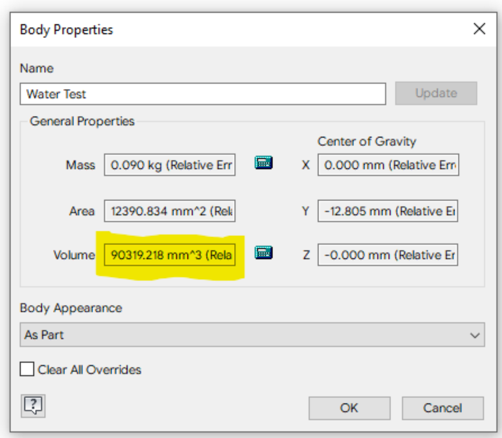
SHOVEL

The test results showed that 4 hours of continuous use decreased the water level by 26mm. The cup used for the test has drafted walls of 68mm diameter at the start point, and 65mm at the end point, as indicated in the following diagram.



Modeling this object in Inventor yields a volume of 90319mm^3. This converts to 90.32mL. That translates to 22.5mL per hour.





Running the fogger for 3 hours leaves the required 60mL of water in the air. Further calculations could determine how often the fogger should operate to combat the rate of condensation inside the biosphere. This can also be done experimentally once the full prototype is constructed.

These test results indicate that the fogger system is indeed effective in hitting, and exceeding, the required specifications for plants inside the biosphere.

Plant Type and Substrate

Guinevere Goltermann

This system will be both the plants and the substrate in which the plants grow in. It will be maintained by the electronics and the watering system, and will be contained within the biosphere. Water will need to drain through the substrate and the substrate will need to sustain plant growth.

Functionality & Components

<u>Key Functionality</u>

This functions as the main purpose of the table. It is most importantly the aesthetic plant piece of the table. Aside from the plant part of the plant table, this system serves as what the plant will be growing in and how it will be able to sustain itself.

<u>Key Components</u>

- Plant that can grow in a closed system
- Plant substrate that maintains water as well as prevents mold.
- Plant fertilizer that is able to keep the plant sustained.

<u>Physical Properties</u>

- High drainage
  - Healthy amount of moisture retention
- Humid
  - Able to maintain plant growth
- Physically layered
  - Layered so that it can drain as well as have systems for roots to grow into

Requirements & Goals

<u>Customer Needs</u>

- Be able to work within a closed system
- Water cannot leak through the biosphere to prevent messes
- Substrate needs to be low maintenance
  - Plants cannot often be distrubed
  - Substrate cannot easily mold
  - Plants should be sustained by substrate

Constraints

- ❖ Mold can develop quickly due to the closed nature of the system
- ❖ Plant cannot have a large/quick growing root system
- ❖ Plants need a very moist environment, but not so moist that it causes root damage

Contextual Specifications

- ❖ These plants typically grow in an open system, such as a forest and need have proper care in order to grow in a closed system
- ❖ The plant needs to be easy to maintain for people of all skill levels.

Interfaces & Data Transferred

Interface 1: Watering System

- ❖ The watering system will provide water to the plants, and the substrate will drain dirty water back into the watering system.

Interface 2: Electronics

- ❖ The electronics will provide the plants with the correct amount of UV light in order for them to grow properly.

Interface 3: Biosphere

- ❖ The biosphere will contain the substrate and the plants. The substrate my supply wears and tears on the biosphere as a whole.

Design Process Tools

Other Concepts Considered

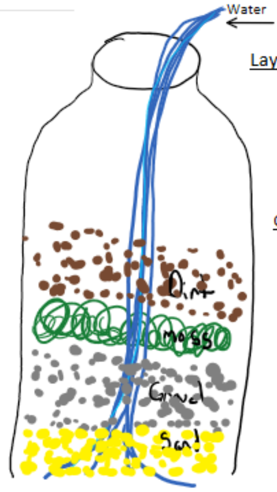
- ❖ Sand, gravel, or pebbles as a base
- ❖ Moss or horticultural charcoal to prevent mold
- ❖ Different plants, such as pepermonias, nerve plants, polka dot plants, and ivy.

Decision Tools Used

Considerations existed around a closed system. These included how well the system would drain and whether or not water would mold the soil or the roots.
The plants need to be able to grow and not outgrow the system. Plants with large root systems or plants that grow tall would not work in this system.
Several different systems were tested to evaluate proper functionality.

1

April 6, 2021 4:16 PM

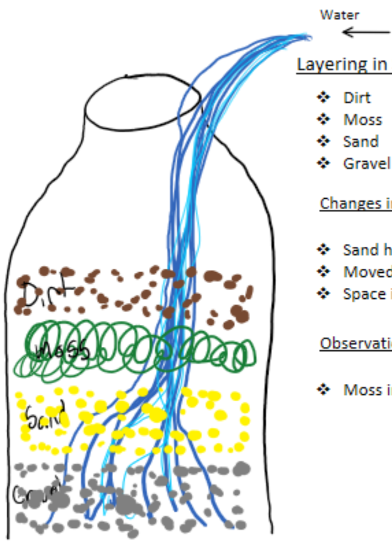


Layering in System: Test 1

- Dirt
- Moss
- Gravel
- Sand

Observation as water is poured in

- Low filtration
- Water does not move through sand; pools at bottom
- Moisture does not stay in dirt



Layering in System: Test 2

- Dirt
- Moss
- Sand
- Gravel

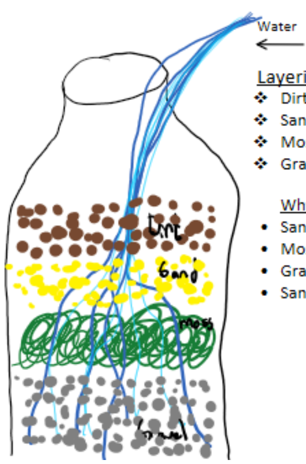
Changes in system

- Sand holds the most water for longest
- Moved sand up for more filtration
- Space in between gravel is good for water retention

Observations

- Moss in this space does not allow for filtration

1:14 PM



Layering in System: Test 3

- Dirt
- Sand
- Moss
- Gravel

Why test 3 was most effective

- Sand disperses water across system
- Moss serves as not only filtration but dries sand as well
- Gravel holds water, similar to real world ground water
- Sand maintains healthy amount of moisture in water

Validation

Test Results & Protocols

- Three or more different iterations of the substrate will be tested
  - 
  - Trials 1, 2, and 3 are shown above
- This will be done in a glass or clear system so drainage issues can be observed.
- The plants were purchased 2 weeks in advance to see how they reacted to the environment outside of the store and were placed in the table to see how they reacted in a closed system.
  - The ferns thrived in the table.
  - The polka dot plants both fainted, and needed to be heavily watered in order to restore health.
  - The spiderwort plant went from standing to growing in more of an outward position, making it a good fit for the table.

Stakeholder Feedback

- Needs to be easy to maintain no matter what the individuals prior experience with plant life.
- Needs to be able to exist in the system for long periods of time, which is to say it should not outgrow the system or the biosphere.
- The system should be low cost to produce, and should not need to be replaced often due to mold.

Analysis

- The interface will need to be able to last for at least a year with little maintenance from the owner. It should be relatively self sustaining as well as able to sustain rapid plant growth.

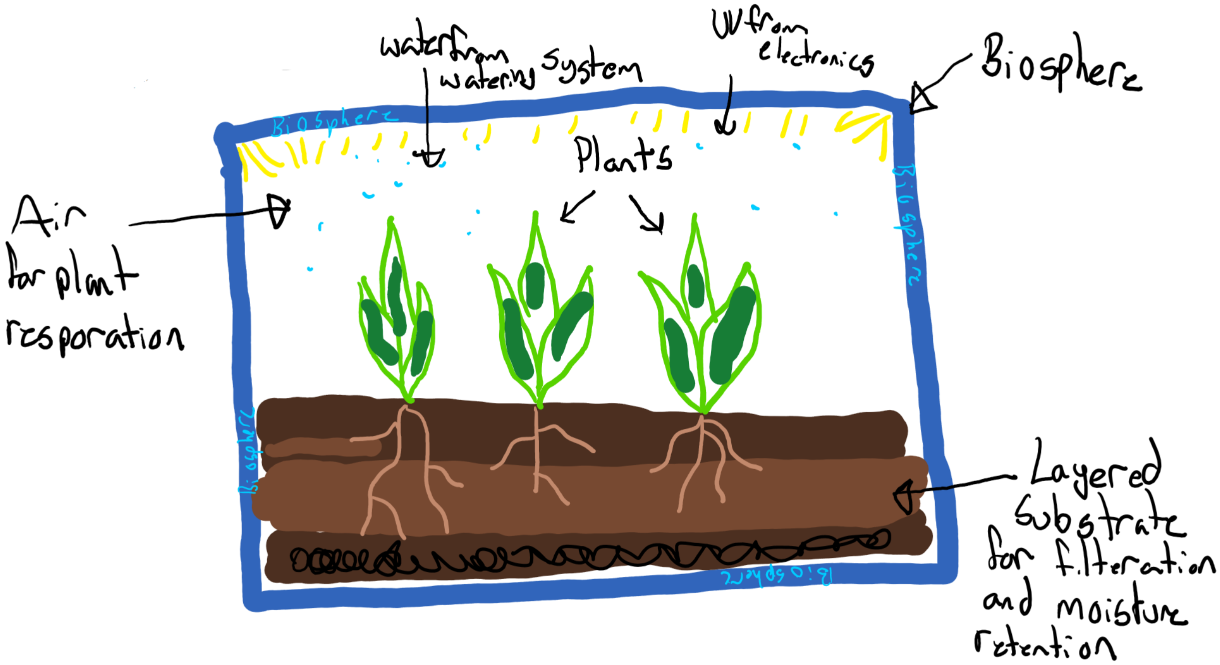
Research

- Mold can develop quickly, typically within 24-48 hours and develops in areas with stagnant water [12].
- The soil will need to be more acidic, within a range of 5 to 5.5 ph [13].

- There are ways to raise the acidity of the soil such as peat moss, shells, and leaf or manure compost [14].

Implementation

- This subsystem will be placed within the biosphere, and will be maintained by the electronics and the watering system.



Electronics

Jayna Roepe

The lights will be inside the table to help with the moss growing but to also provide light to the user. The power source is there to make all the electrical components work. The computer is there so that the lights and mist go on and off at appropriate times. There is also a switch to allow the user to turn on and off the light when they see fit.

Functionality & Components

Key Functionality

The key function is to provide light at appropriate times and supply power to the entire system

Key Components

The Key components are wires, lights, a waterproof box to protect the electronics, a plug that goes into the wall, a power supply that changes the voltage to an appropriate level, and a program for the timer and mister

Physical Properties

It is waterproof to protect the electrical components from water that the mister spurts out.

Requirements & Goals

Customer Needs

Provide light and activate mist for moss at appropriate times and has the user be able to turn on the light when wanted.

Constraints

Can't spend over $100 to build. most protect against coming into contact with water. Has to fit within the frame. Must last for at least 5 years since that is the shortest period of time a typical table will last.

Contextual Specifications

Provide enough power to power the lights and water dispenser and to control when both go on and off.

Interfaces & Data Transferred

Interface 1: Water Distributor

Will send signals to the water distributor to turn on and off the water at appropriate times.

Interface 2: Plants

Will provide light at appropriate times to plants

Interface 3: Frame

Will sit inside and be protected by frame

Design Process Tools

Other Concepts Considered

It was considered to use a plug vs a battery pack, light strips vs light bulbs, LED vs fluorescent vs ect. , and Arduino vs Raspberry pi.

Decision Tools Used

A decision matrix and research was done to decide which of the options was best to use for the moss table.

Validation

Test Results & Protocols

Code test: The code was put through a debugger and no bugs were found. Then it was put through a simulation and worked as intended. Since it worked in a simulation that was the same as the actual thing it should work as planned.

Stakeholder Feedback

Research will be more prevalent than stakeholder feedback because of the amount information needed and the time it would take to find people who could help with specific questions

Analysis

A plug was used instead of a battery pack to provide power because of its easability and longevity. For a battery pack of 10000 mAh to power 10, 60 watt light bulbs it would only last 1.5 hours. While a plug will power it 24/7 with no problem.

When comparing light bulbs to light strips it was deemed that light strips would be better. Since light bulbs are bulky and can not fit nicely inside the frame without some modifications it was deemed a problem. While on the other hand with light strips, they can easily fit into a small space and provide the same amount of light.

When comparing an Arduino to a raspberry pi it was determined that either could be used with no upside or downside to each other and this became more of a manufacturer decision. Both have about the same life expectancy of 10 years so either was viable. It was, in the end, chosen that an Arduino would be used since the manufacturer had more experience with it.

When deciding what voltage to use across all systems it was decided that 5 volts would be used. This is because the Arduino uses 5 volts. So all the electronics that were used to make the light and the mister work were all also 5 volts or converting wall voltage to 5 volts. This will make sure that the system works because as long as the voltage is the same and that voltage is required throughout the system then it will work.

All other products were bought based on how viable and good they were and how expensive they were. It was decided that cost should be as low and possible without losing quality so that the moss table could be offered to more people at a lower cost.

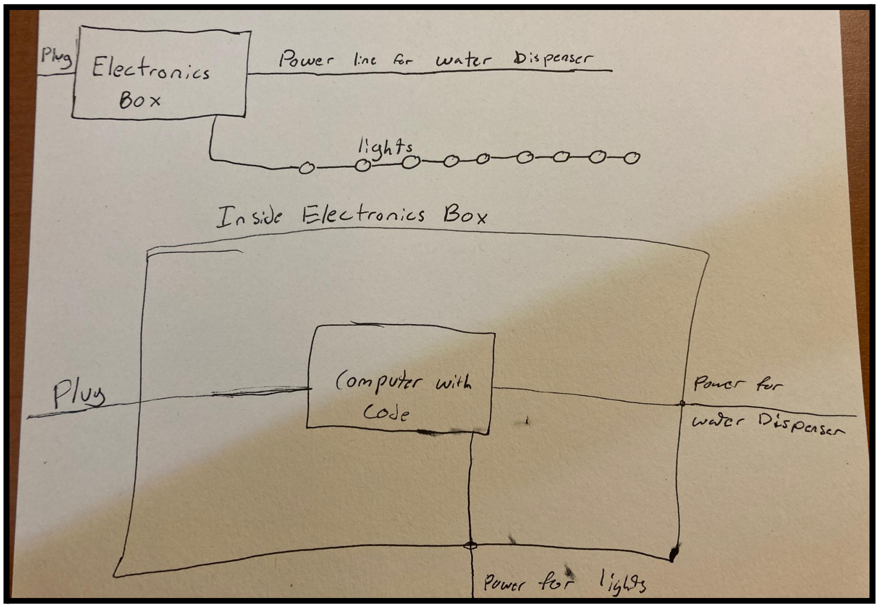
Research

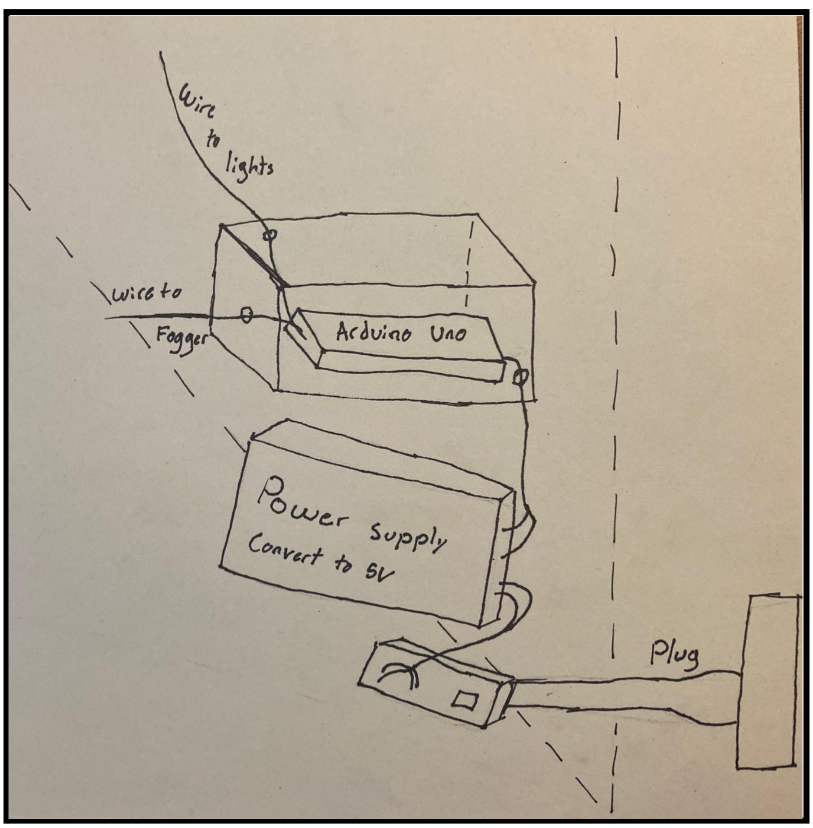
Research was done about what lights, fluorescent vs LED vs ect., would be best suitable for the plants as well as which would last longer. Through this research it was determined that LEDs were good for the plants and also had the longest lasting time, which is why they will be used[15][16].

Research was also done about the different computer chips to use, Arduino vs raspberry pi. A raspberry pi has a better range of use over Arduino, while an Arduino is better for simple circuits and programs[17]. Since the lights and the mister only require simple circuits and programs it was determined that an Arduino would be more effective since it also has a lower cost.

Implementation

The subsystem will be used to power all other parts that need power by being connected to an outlet through a plug. All wires will be hidden as best as possible for the design of the frame. The lights will also be of a temperature appropriate for plants and humans. All the components will sit somewhere inside the frame.





Biosphere

Noah Hollingsworth

The biosphere is the housing vessel of the plant life, soil/substrate, must be a clear and cleanable material for ease of visibility. The goal of this subsystem is to maintain the life within it which is a sturdy structure that can withstand use at a table.

Functionality & Components

Key Functionality

The biosphere is built to be a stationary part which is transparent and stable for optimal viewing, life maintenance, acts as a stable table top surface, funnels recycled water and prevents leaking from the substrate inside.

Key Components

The biosphere will be made out of various thicknesses of acrylic sheets and sealed with a waterproof silicone caulk.

The only thing necessary for full functionality is for the material to be cleaned so viewing is optimal. Unlike other subsystems that require water or power, the biosphere is there to contain the plants and be supported by the frame.

Physical Properties

Materials:

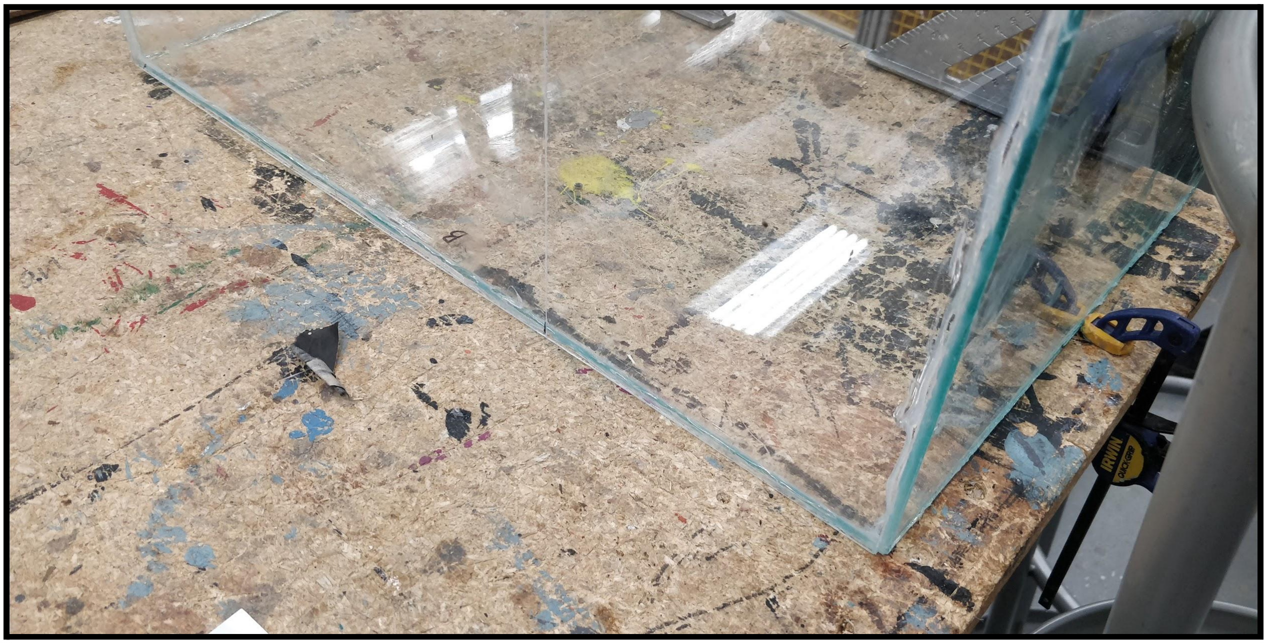
The bottom pane of acrylic is made from a .093" x 18" x 24" piece sheet that was then cut to 18" square.

The top acrylic is a .220" x 18" x 24" piece that will be cut to lay with in the design of the frames lid.

The sides of the biosphere is made out of a .177" x 24" x 36" acrylic sheet that was cut into four 12" x 18" sections

GE waterproof silicone caulk was used to seal all adjacent edges to create a leakless biosphere.

The final biosphere came out so be a rectangular prism that is 12” x 18” x 18 7/16”. The below images are of the sealed biosphere as well as an image of its construction on its side.



Considerations

There are several design features that were taken into account in its construction. First being that of is size so that the container does not compete with its contents and this aids in structural stability. The acrylic sheets are used instead of normal glass due to ease of handling, safety, and cost considerations. The biosphere could have been made out of all of one thinks of plexiglass but again, the different uses of the different parts and cost considerations are taken into account. The bottom is thinner so that it can be more easily molded to act as a funnel for the recycling of water, the sides are of a more standard thickness and the lid is a more considerable size so that it can better withstand being used as a table.

Testing

The caulk can withstand extended periods of applied water based on past anecdotal use in aquariums and also from quick inperson tests. The bottom once supported from the frame will also be able to withstand the pressure exerted on it from the substrate, plants, and water that will be within it.

1.1. The Biosphere successfully contains water without fear of leaking when resting on a surface, i.e. the frame when it is inplace. The test conducted was withstanding 2 inches of water for half an hour, the conclusion being retainment.
1.2. The amount of water that the biosphere will be exposed to is minimal because of the properly timed watering system as well as the implemented drainage system.
1.3. Based on online sources, the caulk will withstand the minute water pressures that will be exerted on it as well as not erode over periods of time. The acrylic sheets will be able to be kept clear by our in person observations of different things that had attached themselves to the surface.

Value Proposition

Garden Table Estimated Cost

Subsystem	Cost
Watering System	25.00
Electronics	110.00
Frame	80.00
Biosphere	200.00
Substrate	60.00
EST. TOTAL (MFG.)	**$505.00**
EST. CONSUMER PRICE	**$800.00**

The goal of our final design was to create a working plant table that is self-sustaining. This table needed to be able to support the weight that comes with use. This includes holding weight, spills, and every day wear and tear over an extended period of time. When scaled to a full production size, different types of tables will need to be produced in order to meet customer needs. The final version of this design--a coffee table--will scale up to a 24” by 48” footprint, at the same 24” height used in the prototype.

A larger table would need to hold more weight, such as the weight of food for a dining room table. Because of this, the wood structure of the table would need reinforcing, and other engineering considerations for long-term use. Other tables would need to meet different sizing requirements, much like fitting in an office, bedroom, or living room. Light coming into different rooms would need to change how long the internal lights are on for.

Benefits of having a plant table that can function on its own is that people who buy it will be able to experience gardening with little to no effort. It takes up little time and does not require much skill. It will be able to bring a natural element to anyone's homes and living spaces. Space or other yard related considerations are not a necessity for this green space.

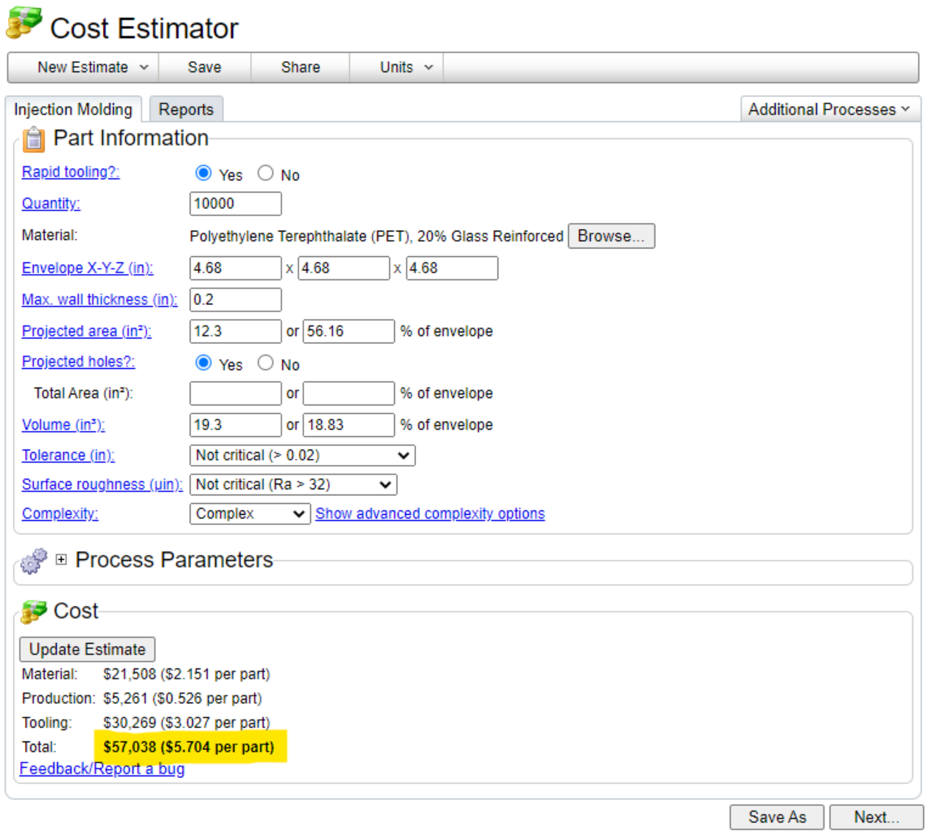
While the overall cost came out a bit higher than anticipated, it still falls well within the budget of a medium to high-end coffee table. Minimalist coffee tables from companies like Williams-Sonoma can range from $400-$4000 and beyond [18], without any significant ancillary features beyond regular table functions. Our design remains competitive within this design space, and manages to deliver far more features than similarly priced competitors.

Watering System

Item	Unit	Unit Cost	Quantity	Total
Fogger	2 pieces	5.99	1	3.00
Cotton Wicks	40 sticks	2.46	1	0.06
Injection Molded Parts	2 parts	8.00	2	8.00
M3 20mm Button Head Hex Machine Screws	50 screws	9.13	4	0.73
M3 Hex Nuts	100 nuts	3.88	4	0.12
M3 Steel Washers	100 washers	3.62	4	0.15
			SUBTOTAL	12.06
			EST. TOTAL	**$25.00**

The watering system is composed of an ultrasonic fogger disk, plastic parts, and fastening hardware. The fogger and wicks in use are standard for a variety of humidifiers and oil diffusers. The consumer-end price goes as high as $3.00 per unit on Amazon, but purchasing in bulk would likely bring the per-unit cost down considerably. The cotton wicks are extremely cheap even on the consumer end, going for roughly 6 cents per unit.

For prototyping, the plastic parts were 3D printed, but the final version would likely use injection molding if demand is high enough. I used the estimate calculator from an online manufacturer to get a rough estimate of the cost, rounded up significantly to account for lower batch sizes than 10,000 [19].



Finally, the hardware estimate came from McMaster-Carr [20]. McMaster is an industry standard for bulk hardware purchases, so that estimate is fairly accurate.

Biosphere

Item	Unit	Unit Cost	Quantity	Total
Acrylic	.093"x18"x24" sheet (needed 18"x18")	8.99	0.75	11.98
Acrylic	.220"x18"x24" sheet (needed 18"x18")	19.94	0.75	26.58
Acrylic	.177"x24"x36" sheet (needed 4x 12"x18")	28.47	1	37.96
Silicone Caulk	1 tube	4.28	3	12.84
Labor	Per hour	20	2	40.00
			SUBTOTAL	129.36
			EST. TOTAL	**$200.00**

The biosphere is constructed almost exclusively out of acrylic sheets of various thickness and then sealed with silicone caulk. These were bought as individual sheets from Homedepot and inturn are marked up in price from what they could be bought as in bulk and same with the caulk. In a more solid production situation, much less caulk will have to be used as precision would increase and the amount used would most likely go down by ⅔. The labor comes from estimates for what carpenters and custom aquarium companies cost and what their national salaries are.

Frame

Item	Unit	Unit Cost	Quantity	Total
Ghostwood Board	¾" x 3 ⅜" x 8'	$12.26	1.95 boards	$23.88
Ghostwood Board	¾" x 7 1/16" x 8'	$25.66	2.58 boards	$66.29
Wood Glue	4 oz	2.97	0.2 bottle	$0.60
Drywall Screws	1-1/8"	3.16	0.1 Bag	$0.32
			SUBTOTAL	$91.09
			EST. TOTAL	**$120**

For the works-like prototype, it was only possible to build a night/bedside table. To build this, ghostwood trims and ghostwood boards were used which were both purchased from HomeDepot. However, for the final design if bought in bulk which ranges from $5.45 to $7.99 per ft^2 according to Rocky Mountain Forest Products [21], only ghostwood boards are needed to build the lid, siding and the legs. To finalize and construct all of the frames, wood glue and screws are needed to assemble all the frames together.

Electronics

Item	Unit	Unit Cost	Quantity	Total
Power Cord	1 cord, 10 feet long	3.52	1	3.52
Power Socket	1 sockets	1.99	1	1.99
Electrical Relays	2 relay	5.98	2	5.98
LED Lights	144 feet	36.89	1	36.89
Silicone Wire	5 feet	2.99	1	2.99
PCB	1 computer	15.00	1	15.00
Assembly-Programing costs	Per hour	25.00	1	25.00
Power Supply	1 power supply	7.80	1	7.80
Breadboard wire	240 pieces	6.99	1	0.03
			SUBTOTAL	99.20
			EST. TOTAL	**$110.00**

The electronics are composed of various wires, LED lights, power cord, power socket, a power supply, and an Arduino Uno. All products were bought from amazon so the end total should be lower when buying directly from a consumer. Also since the Arduino Uno is a one time purchase that will have the program copy onto a board it will become cheaper to make the more that is sold.

Substrate

Item	Unit	Unit Cost	Quantity	Total
Pea Gravel	.5 cubic feet	4.68	1 bag	4.68
Spanish Moss	.145 cubic feet	4.00	2 bags	8.00
Sand	.5 cubic feet	4.50	½ a bag	2.25
Soil	1.67 cubic feet	14.00	1 bag	14.00
Plants	Single Plant	5.00	4 plants	20.00
Assembly	Per hour	10.00	¼ hour	2.50
			SUBTOTAL	51.43
			EST. TOTAL	**$60.00**

The substrate is built of natural materials. The substrate items, pea gravel, sand, dirt, and preserved moss, were purchased at home depot. All of these materials, including plants, can be bought in bulk from wholesalers. The labor cost for the substrate is low. It is easy to make, but requires some heavy lifting. Overall, assembly is not a tremulous job and will be low cost. When purchased in bulk, the most expensive component will be buying unique plants. While this cost can be avoided, uniqueness of plants gives this table a higher selling point.

Risks & Mitigation

Proposal

The final design of this bed side variant moss table will stand approximately 24 ¾” tall with an average side length of approximately 21 ½” based on the lid being the widest part. Our current variant will have moss and four low light and high humidity loving plants. The refilling process for the water reservoir will be easily accessible through a center humidity port.

Frame

The main and most severe risk is the possibility of the electronics or watering system that may catch on fire and damage the frames. Some other risks that can specifically come from the frame are splinters from the wood or certain allergic reactions that can be caused from wood dust. The electronics and watering system must be engineered well enough to not catch on fire and also have the biosphere sealed tight to prevent any leakage.

Biosphere

The primary risk that will be associated with the biosphere is going to leak. I do think however with how the biosphere will be attached to the frame, the risk of occurrence will be unlikely. However, if this does occur, the consumer will have a much harder time fixing it as this pertains to a more structural problem and in turn is a major impact. between these two, it still falls into the acceptable risk region so it will be something that is watched for but still acceptable.

Electronics

The only real risk for the electronics is if water gets on them and they stop working and could possibly create a small fire. This risk is unlikely because of the precautions that we took but is a major risk because it breaks the main function of the table and could burn some stuff. This makes it an acceptable risk at a medium level. The only other risk is that one of the wires or parts stops working. Since it can be replaced it is a moderate risk that is also unlikely so that puts it at an acceptable risk with a low level.

Watering System

The most severe risk with the watering system is a fire. Because we're dealing with 120V AC and water, the risk of a fire is substantial. That's why it's extremely important that the electronics case and biosphere are engineered to be completely watertight. For the prototype, the electronics box will likely be 3D printed, but the final version would likely need a watertight, injection-molded electronics box with rubber gaskets sealing any inlets / outlets. The fogger system is less at risk for fires, as it only operates on 5V at roughly 300mA. The likelihood of a fire here is very low. The most likely risk with the fogger is that one or more elements break, and it fails to deliver water to the plants. In this event, the plants may eventually die. This is a low-cost issue, but would hurt the customer experience.

Plants & Substrates

As I'm sure one could imagine with the substrate/plants the plants may die. However, this is not a severe risk. Plants can be replaced at a relatively low cost. The substrate has a risk in which it won't filter. This is a lower risk however because it has been extensively tested. There is potential for mold to form. While this should be limited due to testing, this does not mean it is impossible.

Conclusion

Next Steps

- Further Testing with other products
    - Testing a different type of watering system for longer durability. This system can run but on low wattage. Another system could prove to be more powerful, however, we had neither the time or resources to test this.
    - Add buttons to the system. This would include a way to turn on the lights from outside. This was a feature that had to be overlooked for timing reasons. This would add another laying of functionality to the table.
    - Adding a secondary timer to both the watering and lighting systems. This timer would need to be more easily adjusted by the user, no matter their computer literacy. This would make it so that the user could change the type of plants in the system and cater to their watering and light needs.
- Table Sizing
    - The table is a smaller size and will be advertised as a bedside table. The next step will be to change the variety of sizes the table is able to come in. This can range from bedside table to dining room table. This will make it so that it can fit into more spaces, and be sold to a wider scope of stakeholders.
- Optimize Prices
    - The main goal of this project was to make a gardening table that is accessible to all groups of people despite their needs. One consideration is a pricing accessible issue. The current items used to are lower cost, but not as price effective as desirable. In the future, this product can be optimized in order to make it more cost effective, therefore, easier to access for all groups. A profit is still made, but more can be sold as it is sold at a lower price.

Over the course of this project, this group learned a lot about the design process, group work, and overall design and engineering. This project included electronics. Several individuals in the group learned basic coding in order to make the computer system run. This code was able to run both the lighting and watering system on a timer. This is what gives the table a self sufficient aspect. The table required building and craftsmanship. A very crucial part of this project involved dimensioning. Careful dimensioning was required. Most members of this group have not done careful field sketches. The ability to express ideas in sketches is crucial to the design process. This skill was honed in over the course of this project.

A key part of this project was learning how to work with other individuals. This includes more than just group members. Over the course of this project, the group's members were able to work in a cohesive way. We were able to become more succinct when it comes to communication with one another was well as meeting deadlines. Each group member was able to do their own work, while making sure it was well communicated with the other team members. This made it so we had to do less catch up work with each other. Working together took time, and is an important skill to know in the engineering design process.

Equally as important, stakeholder communication skills were improved. The vastness of stakeholders was learned. We were able to learn the importance of why stakeholders need to be consulted while designing a project. We had solely focused on our own ideas. While consulting stakeholders, we were able to expand what we could do with our project. Moreover, this was able to help us out of ruts. In places in which our team became lost or confused, we had the ability to consult stakeholders on ways in which we could improve upon pitfalls. This was important in not only the flaring process, but likewise the testing process. Crucial communication skills developed over the course of this project. Skills were improved upon and developed.

However, several aspects of this project could have been changed. The most important of these changes would be in how the materials and material testing would have been changed. Our group would use more premade items. This could have been repurposing a table or another item to use as the biosphere. This would have saved money, and allowed the group more time for testing. Building the biosphere and table has taken up a significant amount of our building time. If repurposed items were used, testing could have been more focused on. Overall, this could have made the project more cohesive.

Appendix

Team Photo and Bios

TEAM SHOVEL!

Left to right:

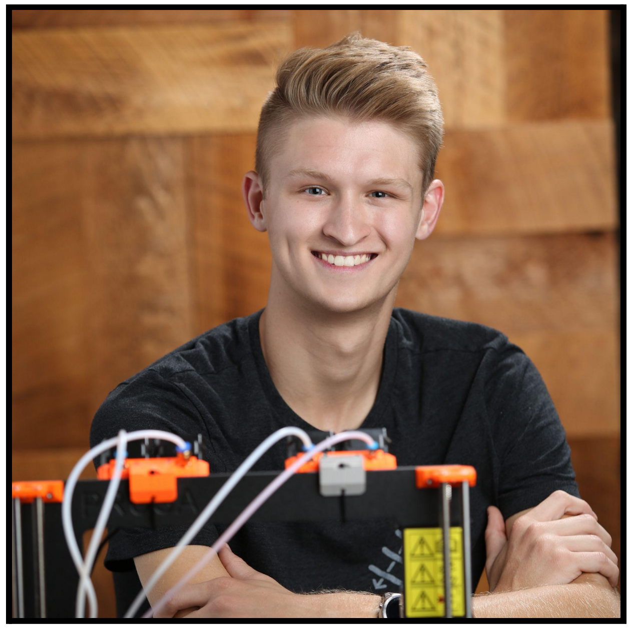
Brent Werder
Abdullah Khawaji
Guinevere Goltermann
Noah Hollingsworth

Not pictured:

Jayna Roepe

Brent Werder

Project Lead,
Electromechanical Engineer



Hey there! I'm Brent. I graduated from Amador Valley High School, and am currently majoring in Mechanical Engineering with an Electrical Engineering minor at Mines. In my free time, I rock climb, mountain bike, and play bass. I also build 3D printers and do other system-level engineering to solve cool (and sometimes important) problems. You can check out some of my other work at https://brentwerder.design.

Guinevere Vigil-Goltermann

Business Coordinator

Hello, my name is Guinevere! I am a graduate of the Denver School of Innovation and Sustainable Design. Here at Mines, I am studying Civil Engineering, with a focus on sustainable infrastructure in marginalized communities. My passion for environmental advocacy has influenced me to work with schools in DPS and international schools in South America in order to make sure people are able to work with their environments. Aside from advocacy, I love to skate, play the bass, and hike with my dog. Pleased to meet you!

Abdullah Khawaji

Frame Structural Technician

Greetings, my name is Abdullah Khawaji and I'm from Saudi Arabia. I graduated from Inspire International Academy and am now majoring in Petroleum Engineering here at Colorado School of Mines. Some of my hobbies are watching movies, playing video games, reading comics and spending time with friends as well as meeting new people.

Noah Hollingsworth

Biosphere Structural Technician

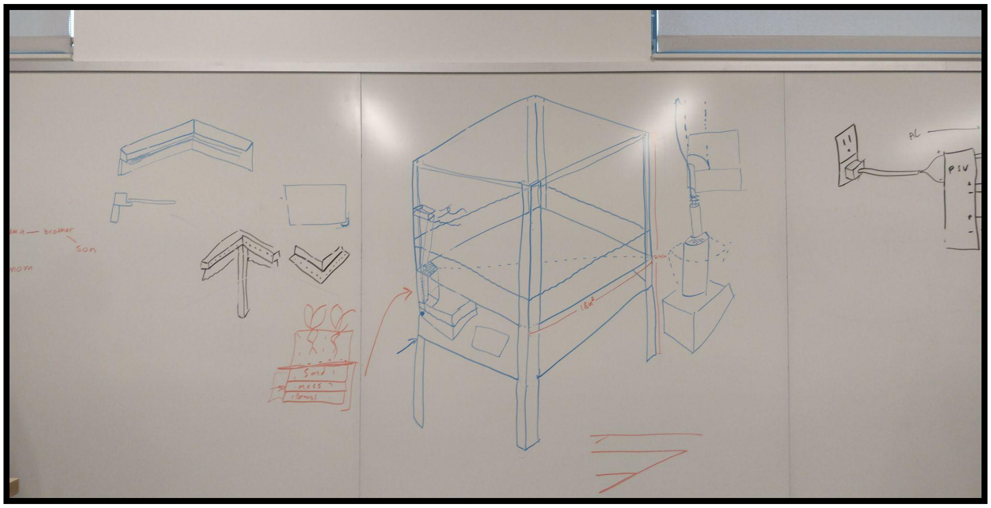
Howdy, I'm Noah Hollingsworth and I'm from Fort Collins, Colorado and attended Rocky Mountain High School. I am here studying Petroleum Engineering here at the School of Mines. My primary pastime is doing research into various realms of knowledge and to learn for the sake of learning. I also play the Tuba and enjoy exploring the worlds of others through video games and stories. But also I must add the joy I get from working with a solid team as they become friends amongst the others in my life.

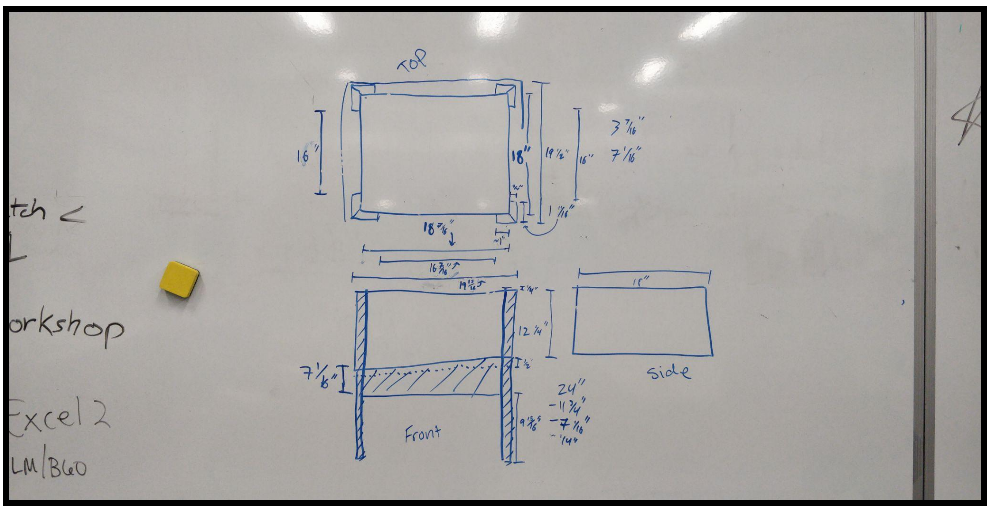
Jayna Roepe

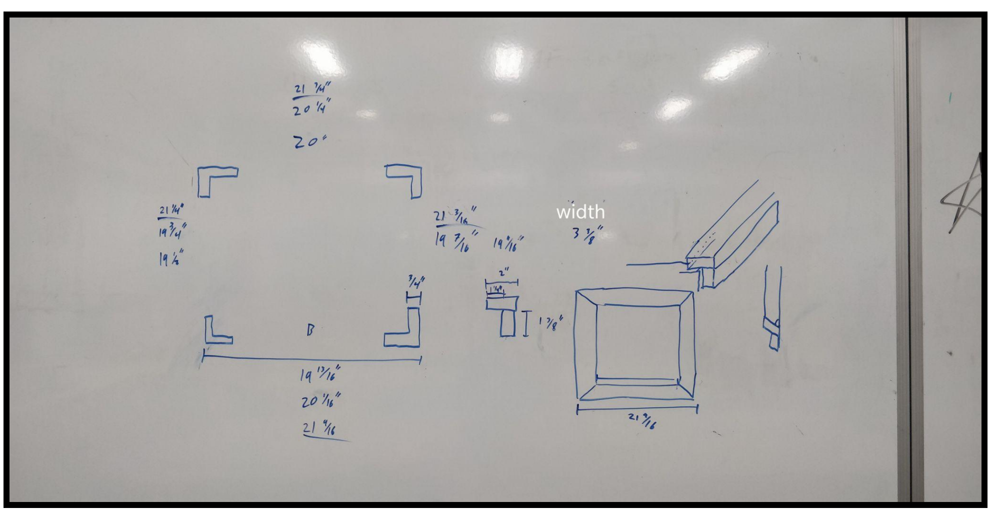
Electronics Documentation

Hey, I'm Jayna. I graduated from Washington-Liberty high school and am majoring in Material Engineering at Mines. I typically spend my free time hanging out with my friends playing D&D, video games, board games, and card games. I also enjoy reading and have been trying to do some creative writing. I am also an avid LEGO fan and have had some of my work put up in a museum.

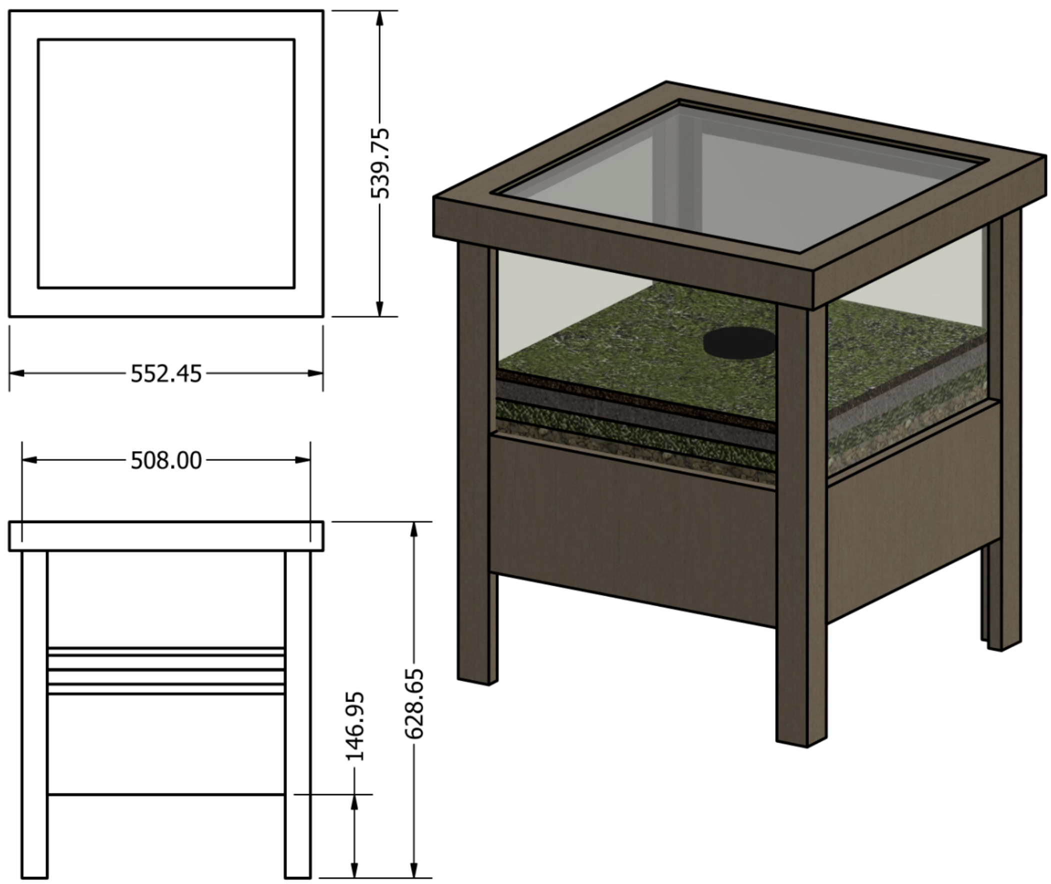
Design Drawings







CAD Drawings



NOTE: Some dimensions omitted for clarity; see individual parts for detailed dimensions.

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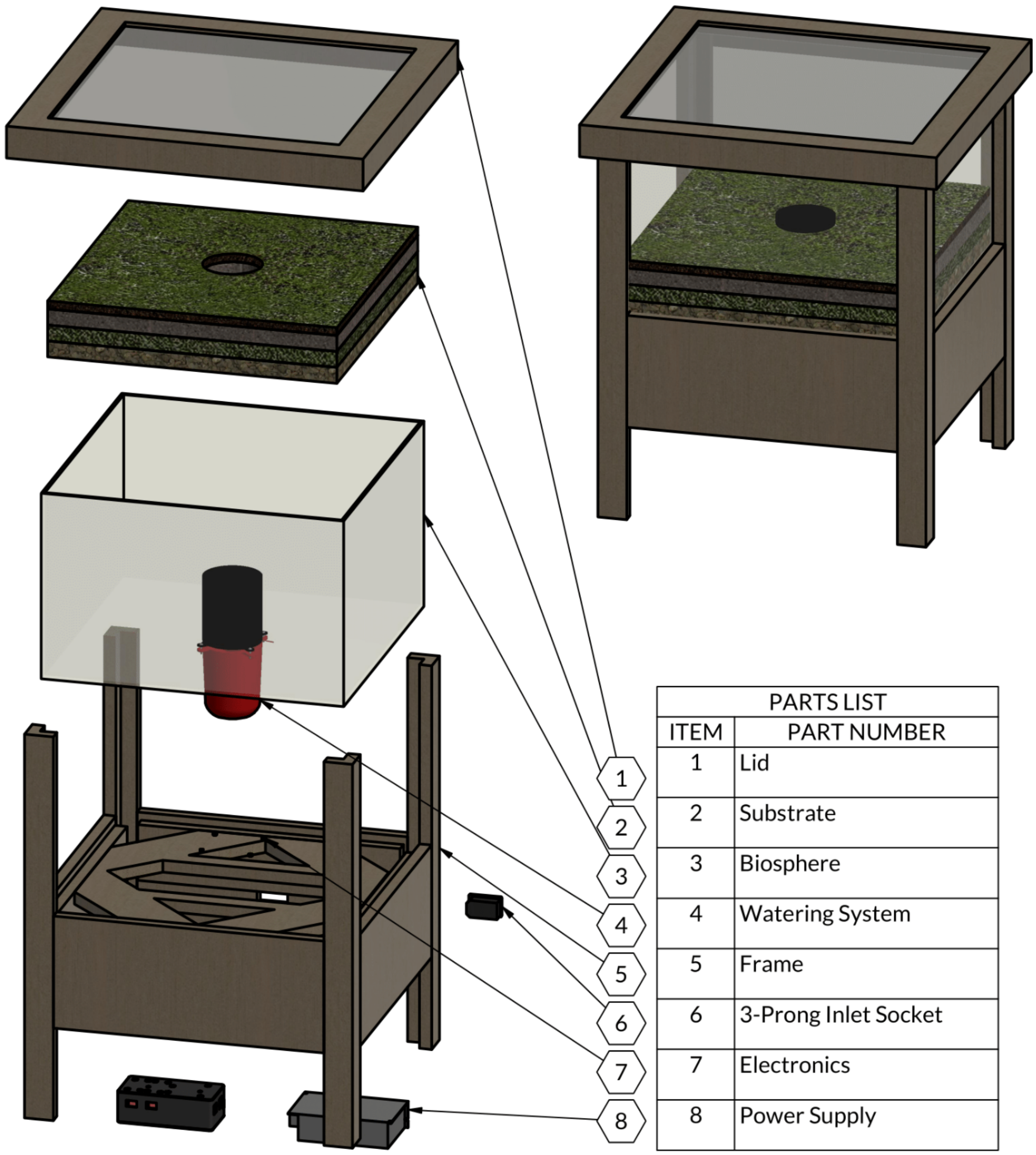
	TEAM SHOVEL	SCALE: 1 / 7	
		MMGS	



PARTS LIST	
ITEM	PART NUMBER
1	Lid
2	Substrate
3	Biosphere
4	Watering System
5	Frame
6	3-Prong Inlet Socket
7	Electronics
8	Power Supply

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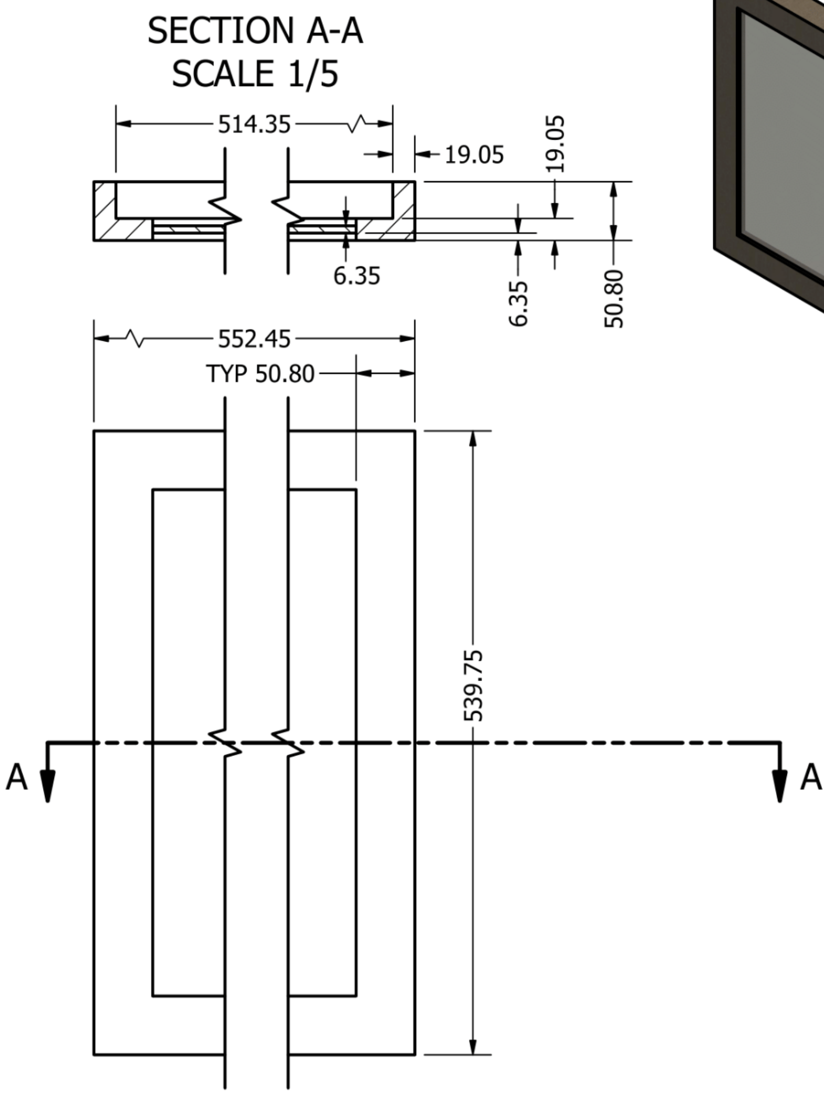

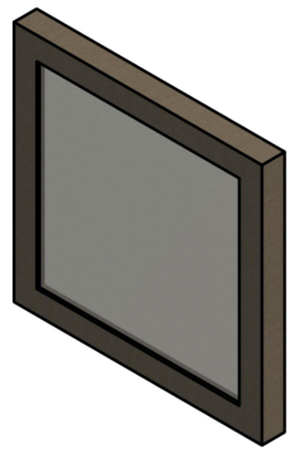

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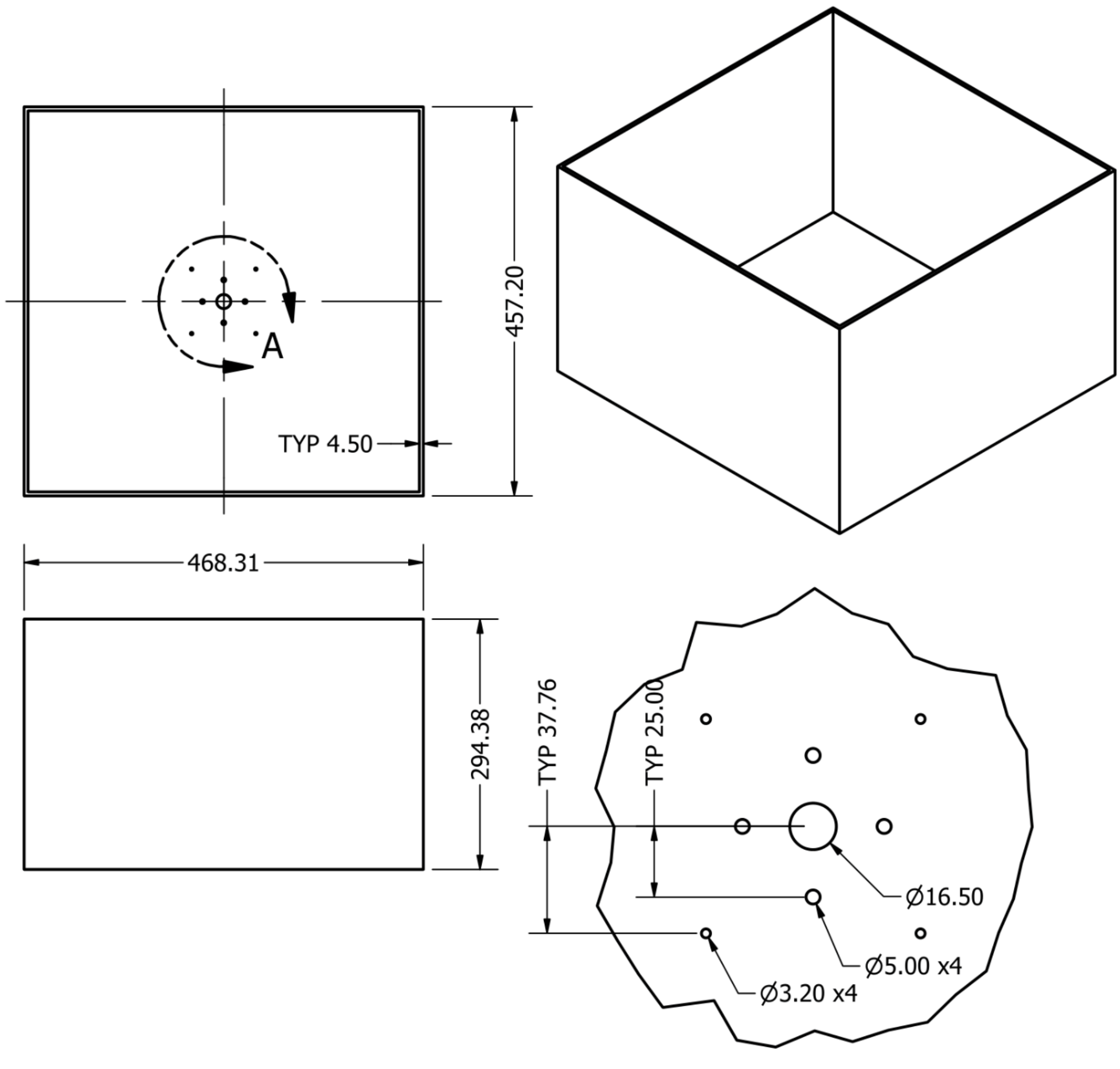
		MMGS	



DETAIL A
SCALE 1/2

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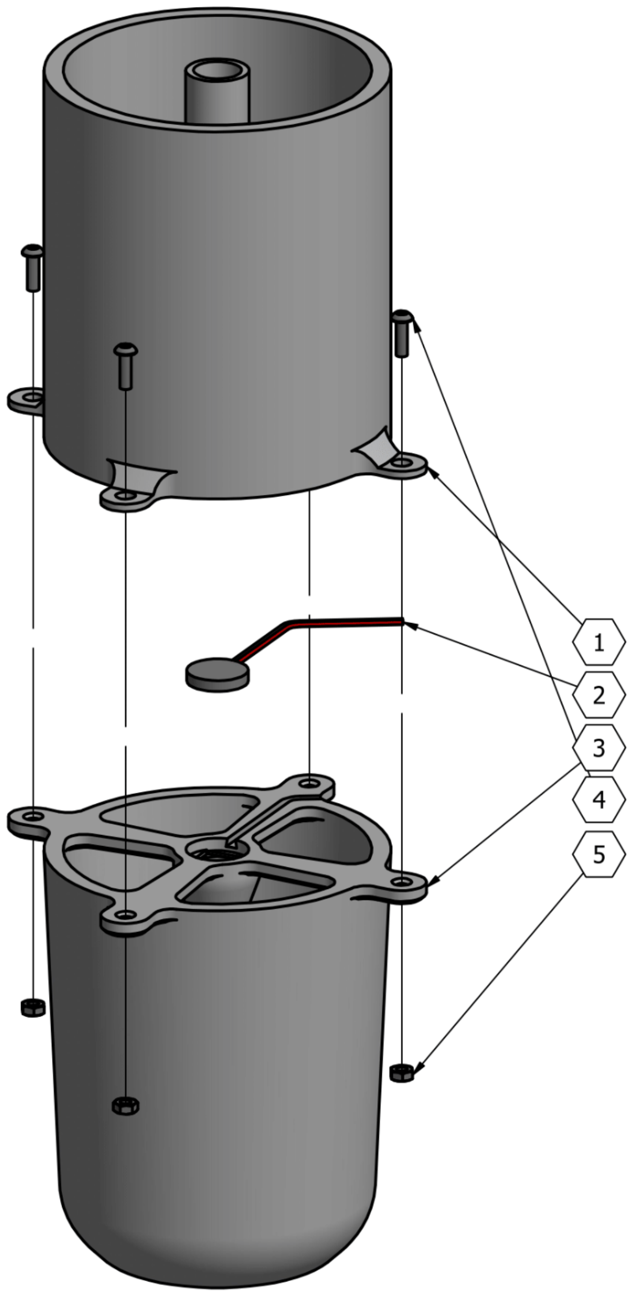
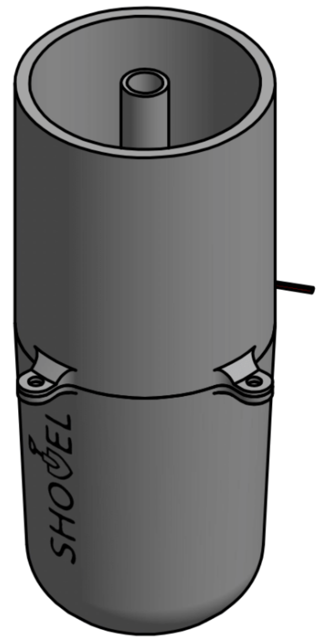
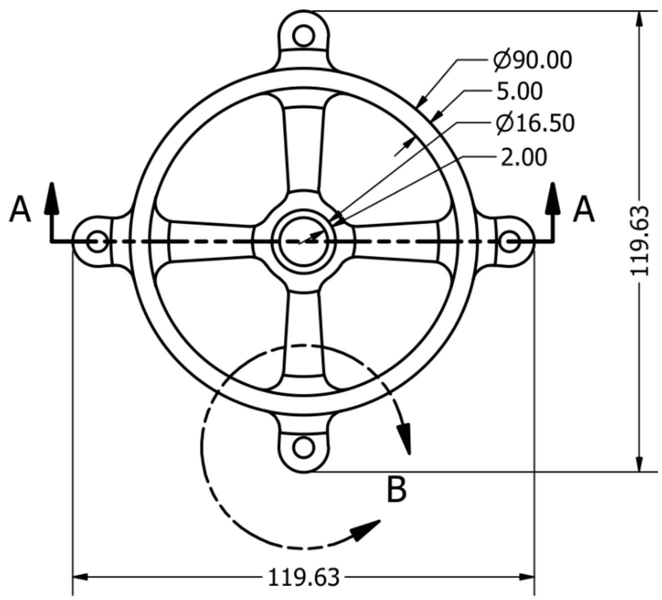
		MMGS	

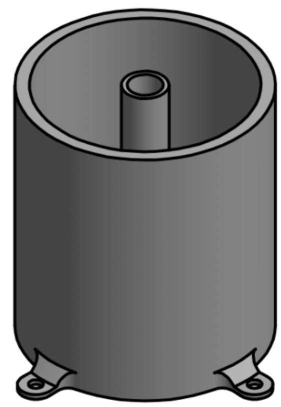


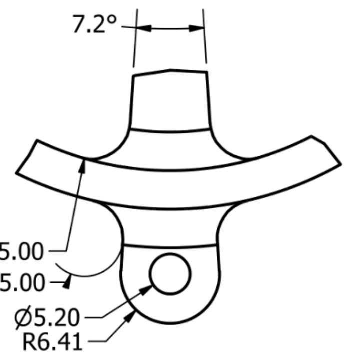


PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Lid
2	1	Fogger
3	1	Cup
4	4	M3 20mm Machine Screw
5	4	M3 Hex Nut

COLORADO SCHOOL OF MINES	EDNS151 DESIGN 1 SECTION W	DRAWN BY BRENT WERDER	DRAWING TITLE
		2021.05.02	Watering System Exploded View
		SCALE: 1 / 2	
	TEAM SHOVEL	MMGS	







DETAIL B
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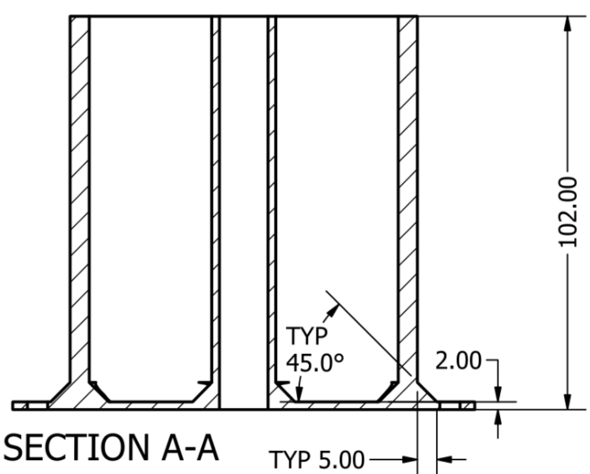
TYP x4



SECTION A-A
SCALE 2/3

NOTE: Some dimensions omitted for clarity; many features are optimized for 3D printing and are not geometrically crucial.

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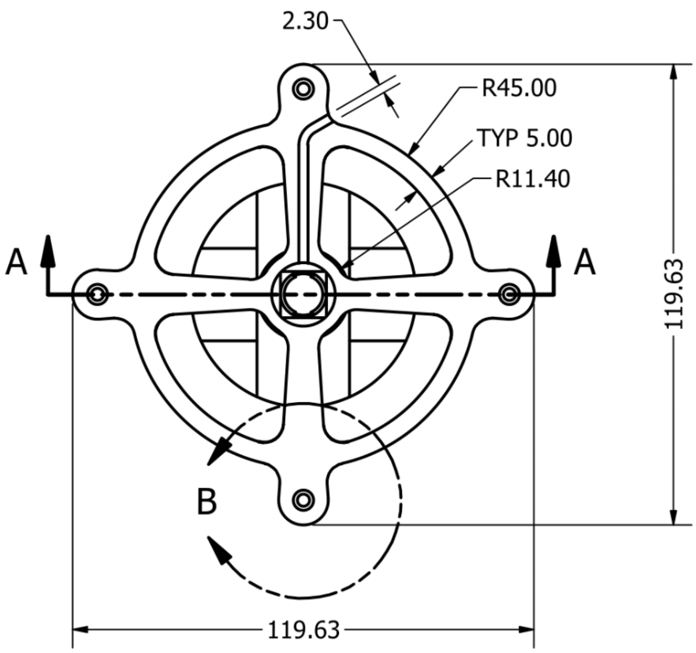
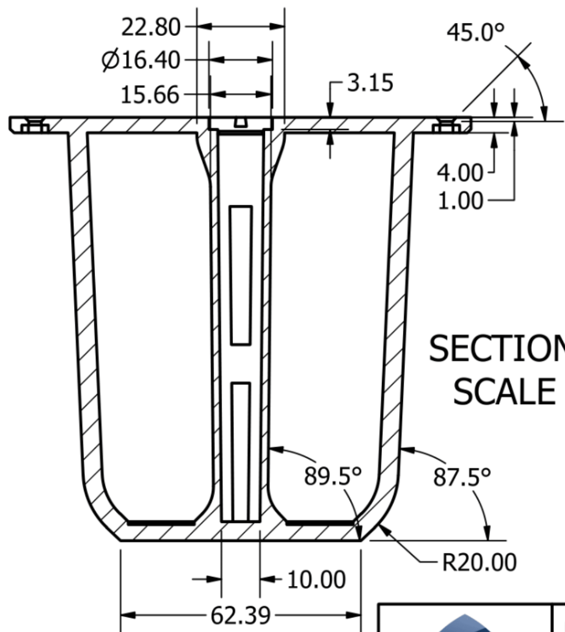
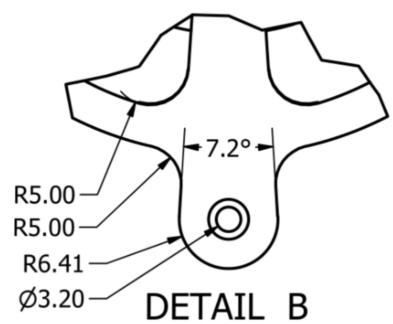
		MMGS	





SECTION A-A
SCALE 2/3

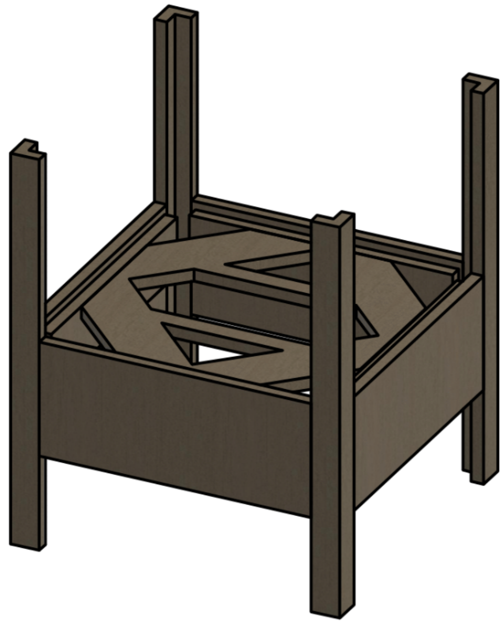


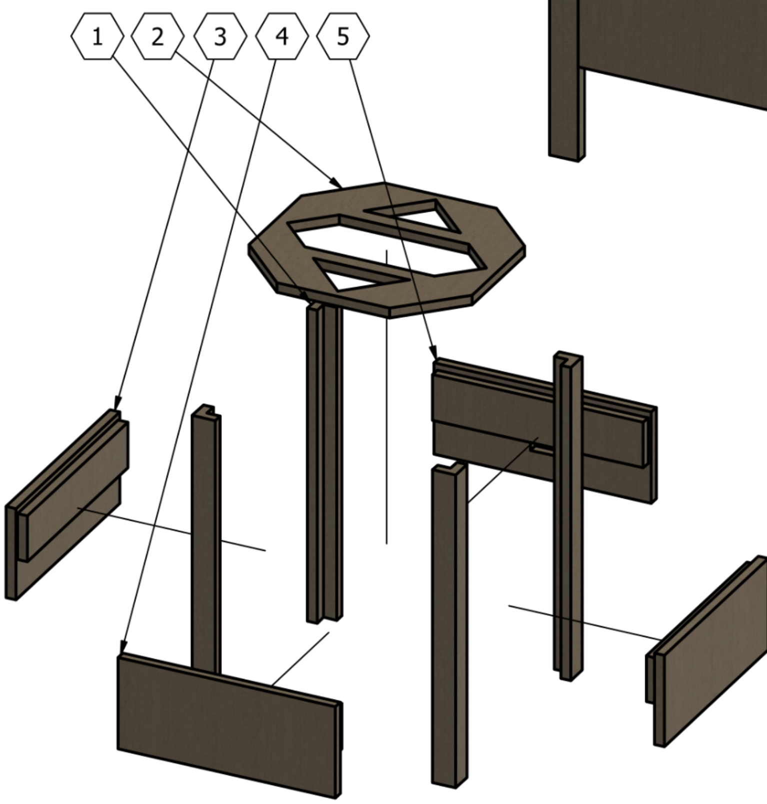
DETAIL B
SCALE 1.33 : 1
TYP x4

NOTE: Some dimensions omitted for clarity; many features are optimized for 3D printing and are not geometrically crucial.

COLORADO SCHOOL OF MINES	EDNS151 DESIGN 1 SECTION W	DRAWN BY BRENT WERDER	DRAWING TITLE Watering System Cup
		2021.05.02	
	TEAM SHOVEL	SCALE: 1 / 2	
		MMGS	

PARTS LIST	
ITEM	PART NUMBER
1	Leg
2	Cross Brace
3	Biosphere Support A
4	Biosphere Support B
5	Biosphere Support C





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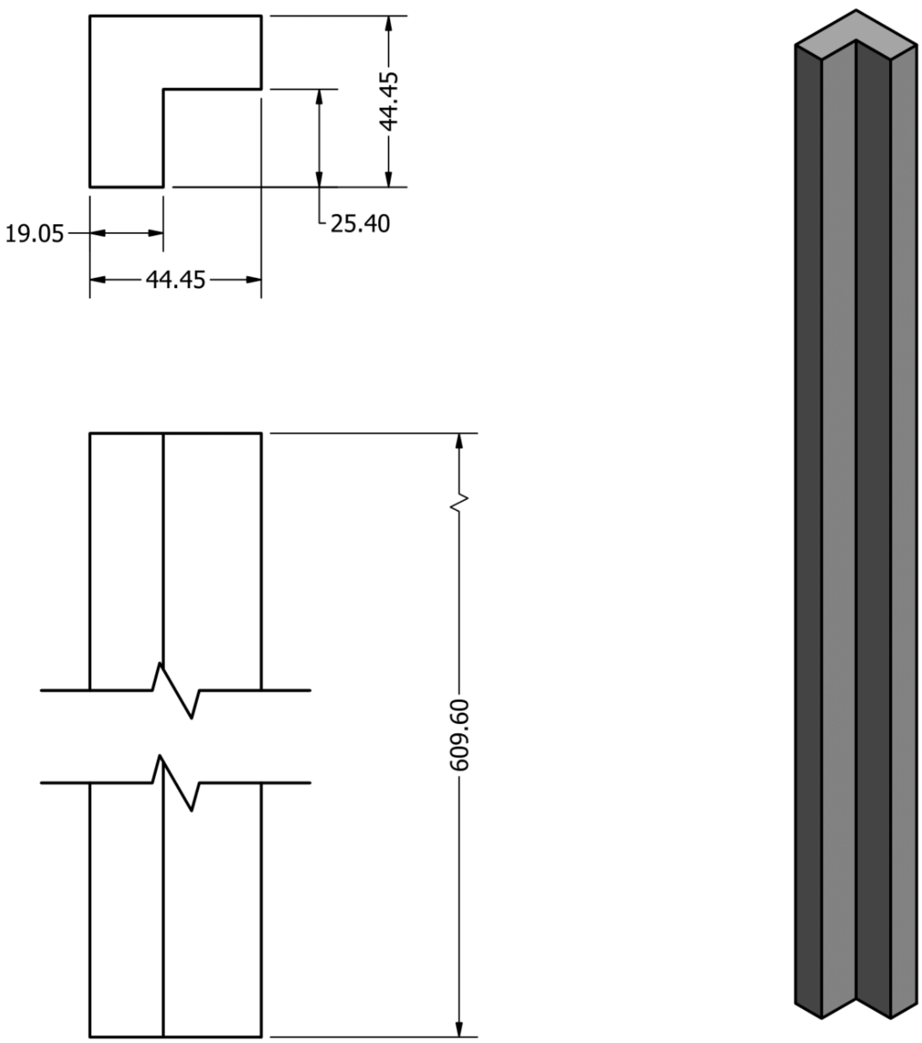
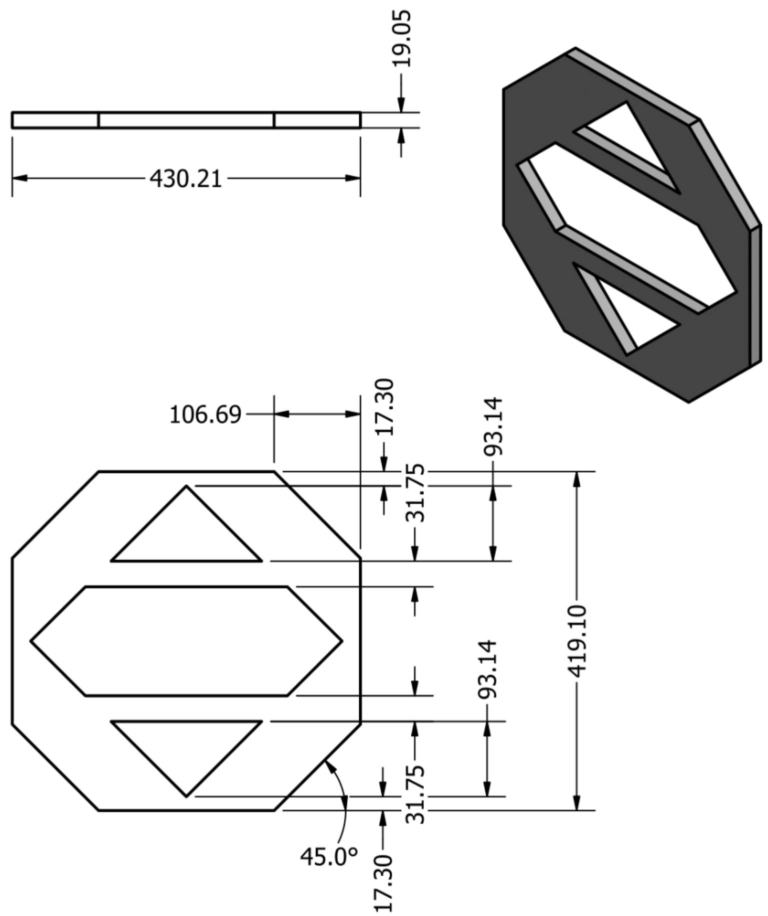
		SCALE: 1 / 10	
		MMGS	



COLORADO SCHOOL OF MINES	EDNS151 DESIGN 1 SECTION W	DRAWN BY BRENT WERDER	DRAWING TITLE
		2021.05.02	Frame Leg
	TEAM SHOVEL	SCALE: 2/3	
		MMGS	



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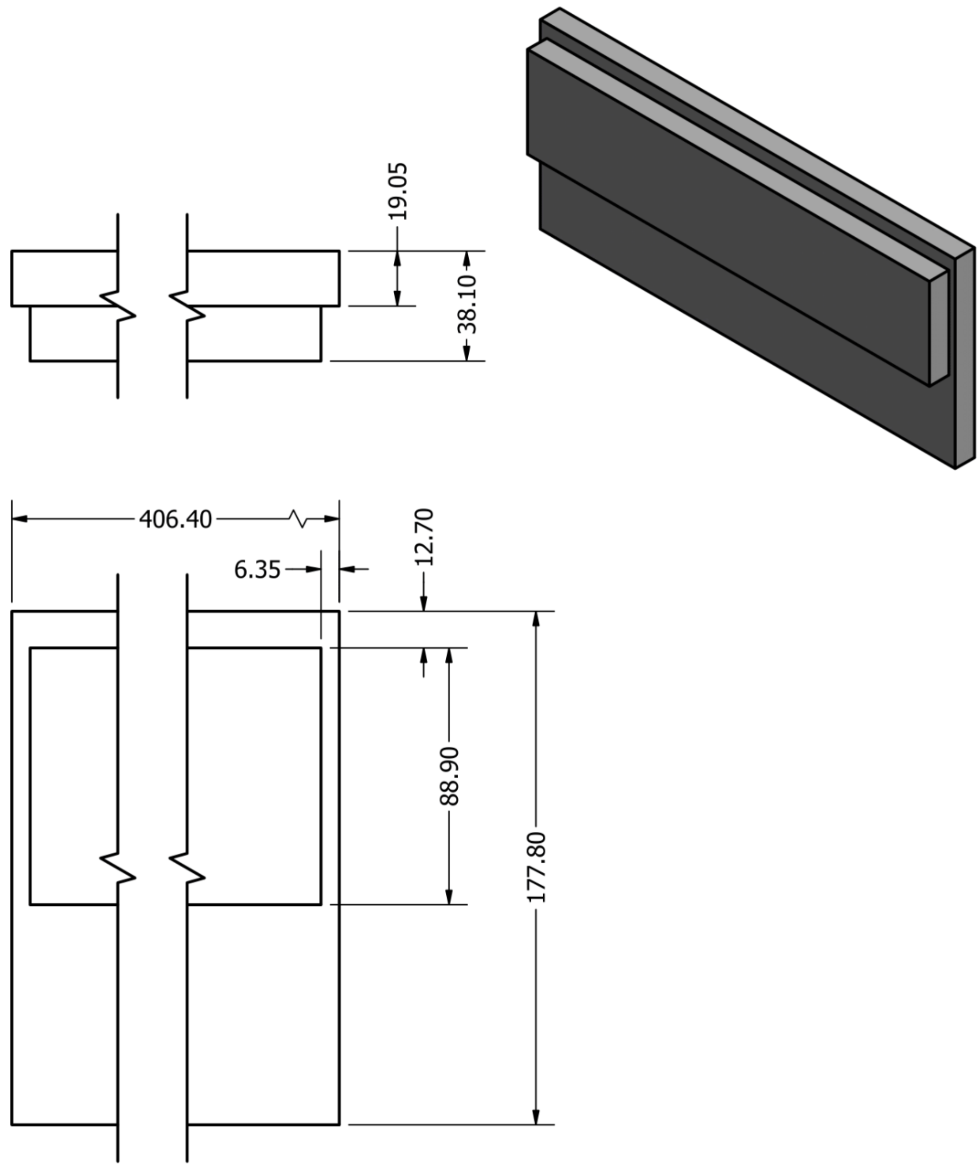
		MMGS	



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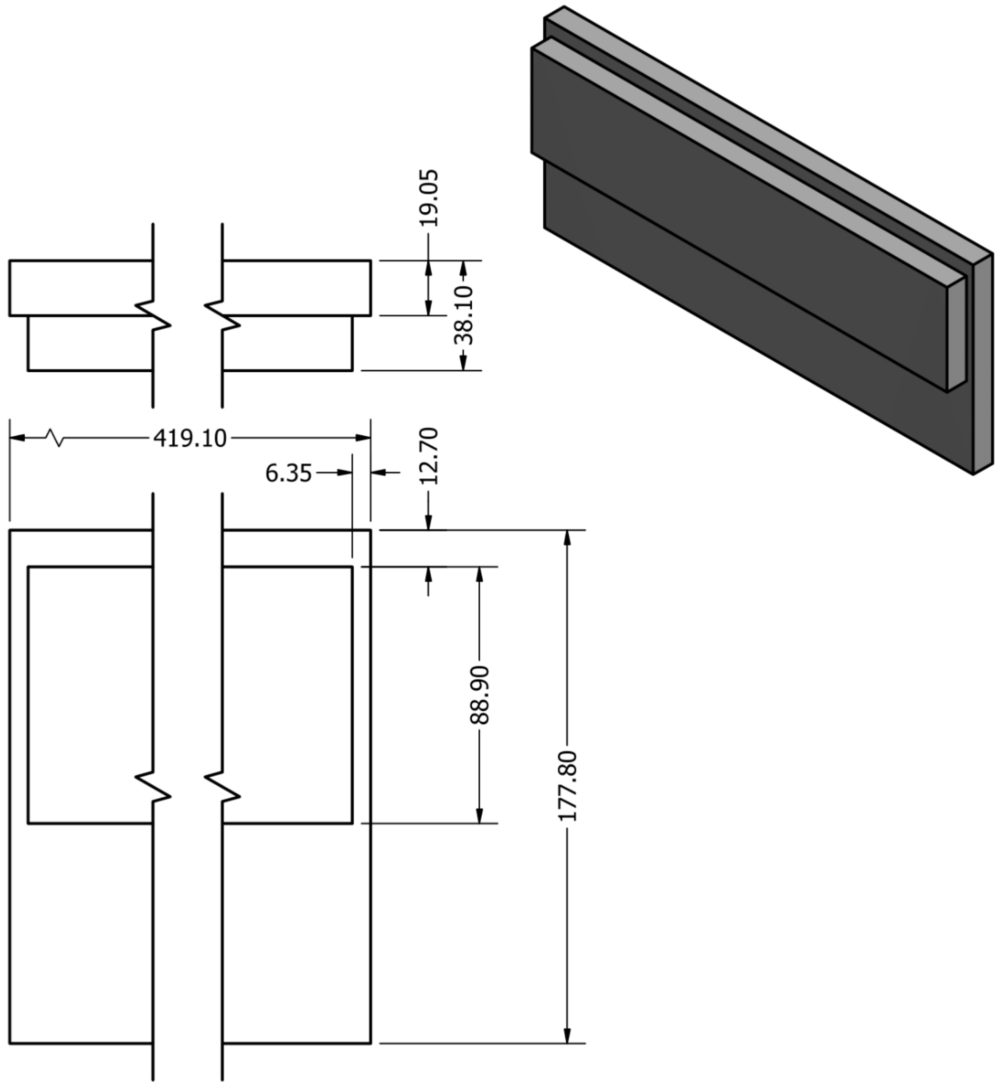
		SCALE: 1/2	
		MMGS	



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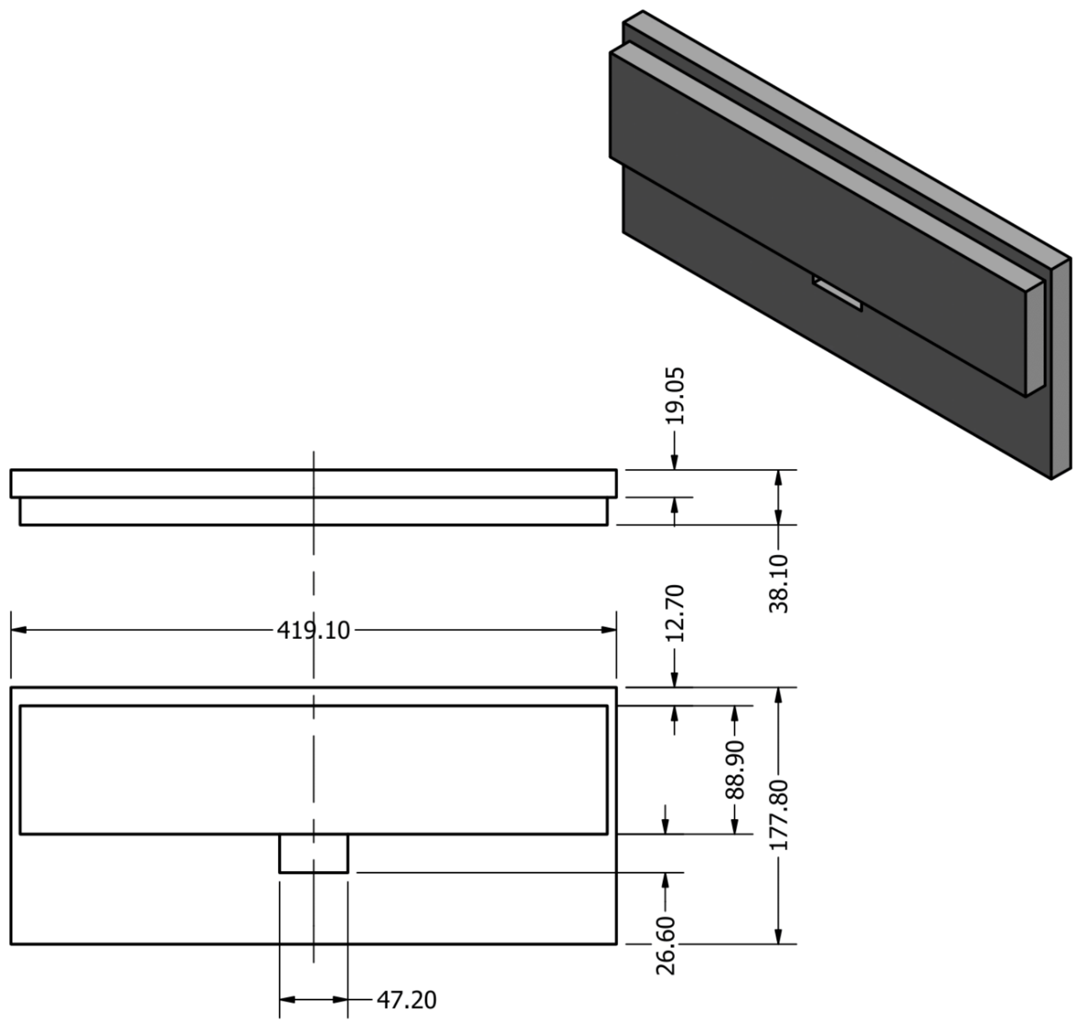
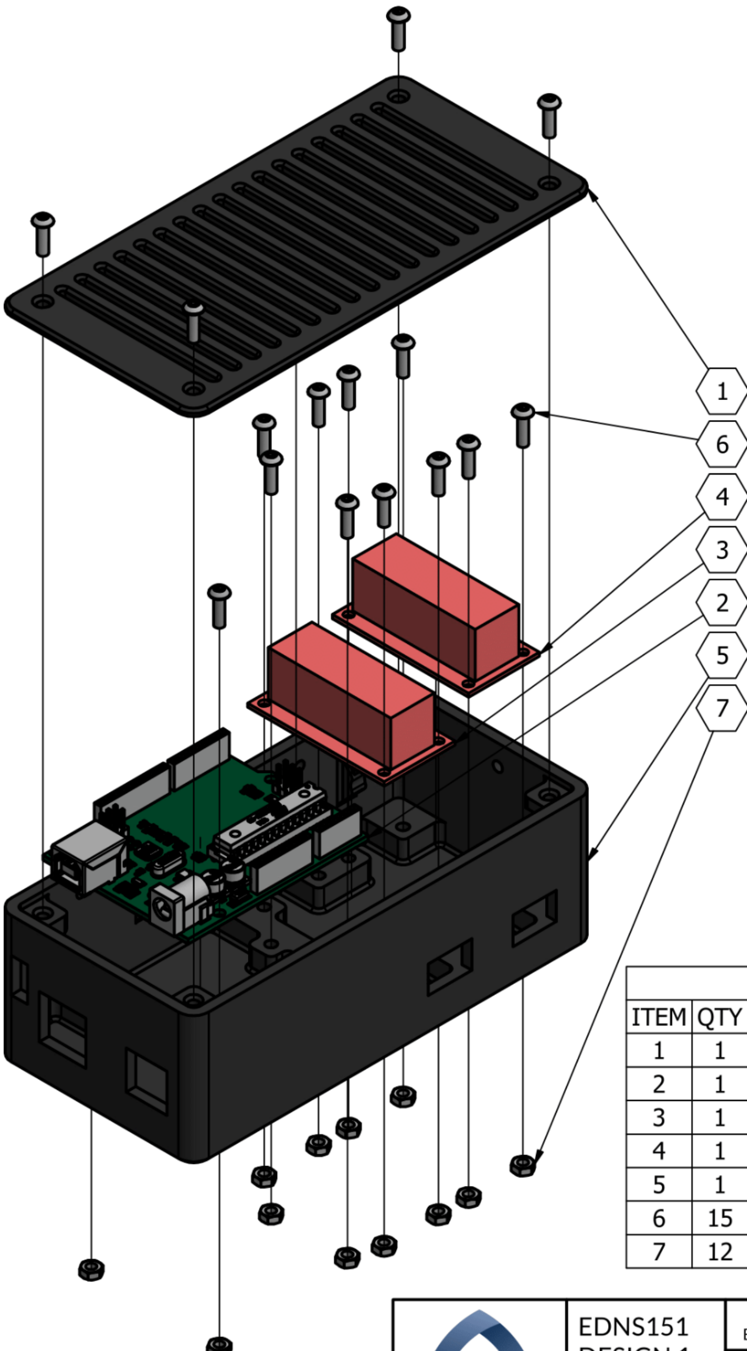
		MMGS	



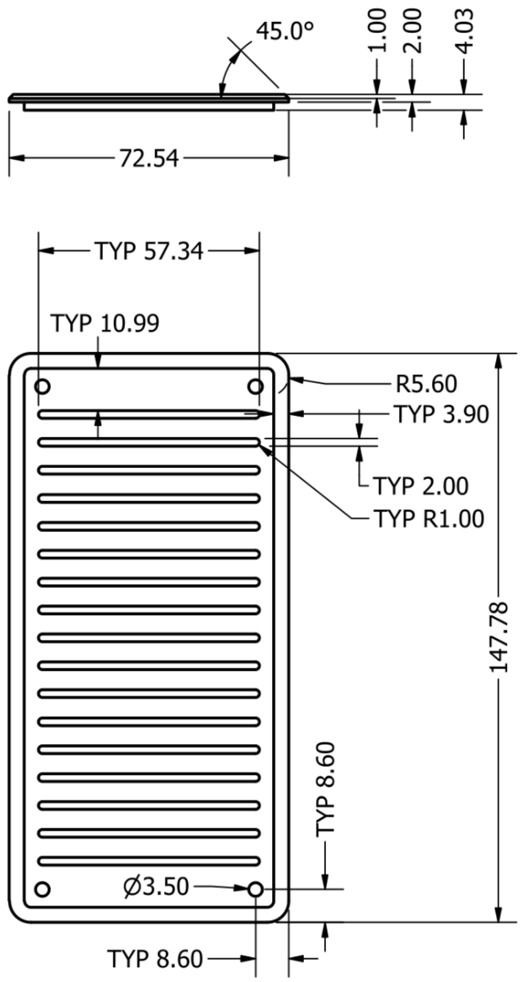
COLORADO SCHOOL OF MINES	EDNS151 DESIGN 1 SECTION W	DRAWN BY BRENT WERDER	DRAWING TITLE
		2021.05.02	Frame Biosphere Support C
	TEAM SHOVEL	SCALE: 1 / 4	
		MMGS	

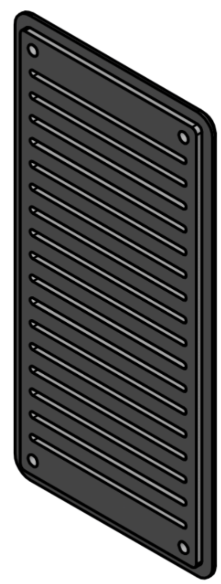
SHOVEL



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Lid
2	1	Arduino Uno
3	1	Relay 1
4	1	Relay 2
5	1	Box
6	15	M3 15mm Machine Screw
7	12	M3 Hex Nut

COLORADO SCHOOL OF MINES	EDNS151 DESIGN 1 SECTION W TEAM SHOVEL	DRAWN BY BRENT WERDER	DRAWING TITLE Electronics Exploded View
		2021.05.02	
		SCALE: 2/3	
		MMGS	





NOTE: Some dimensions omitted for clarity; many features are optimized for 3D printing and are not geometrically crucial.

COLORADO SCHOOL OF MINES	EDNS151 DESIGN 1 SECTION W	DRAWN BY BRENT WERDER	DRAWING TITLE Electronics Lid
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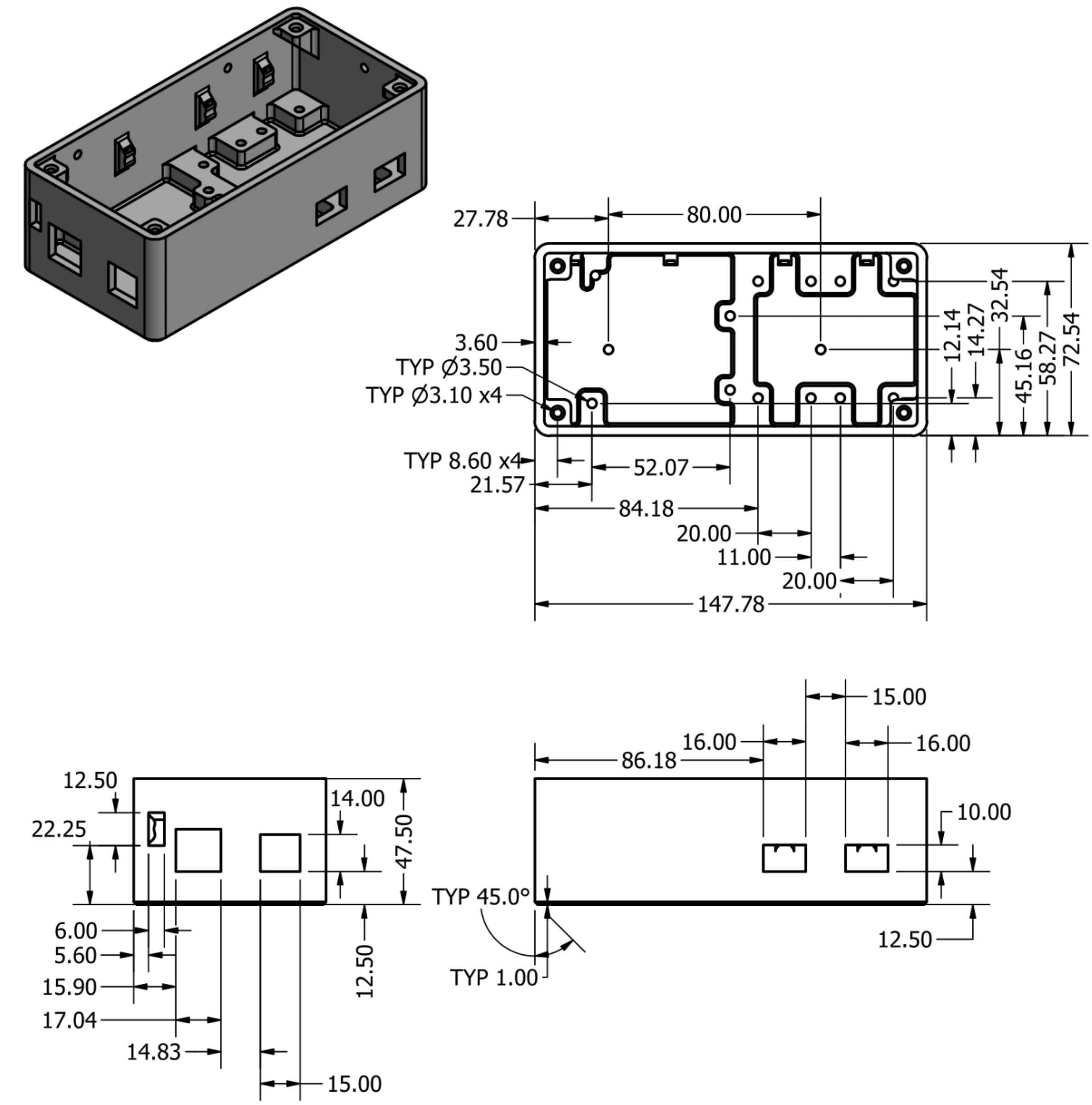
	TEAM SHOVEL	SCALE: 2/3	
		MMGS	



NOTE: Some dimensions omitted for clarity; many features are optimized for 3D printing and are not geometrically crucial.

COLORADO SCHOOL OF MINES	EDNS151 DESIGN 1 SECTION W TEAM SHOVEL	DRAWN BY BRENT WERDER	DRAWING TITLE Electronics Box
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		SCALE: 1/2	
		MMGS	

References

[1] R. Sturm and D. Cohen, "Proximity to urban parks and mental health," *The journal of mental health policy and economics*, Mar-2014. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4049158/. [Accessed: 02-May-2021].

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