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MEMS 411: Safely Capturing Giant African Pouch Rats

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FL21 MEMS 411 Mechanical Engineering Design Project

GIANT AFRICAN POUCH RAT TRAP

We were tasked with designing a trap to safely capture Giant African Pouch Rats in central Africa for Stan Braude - Professor of Biology at Washington University in St. Louis. The interest in Pouch rats stems from their extensive use as bomb-sniffing animals. First generation rats are able to be bred to identify potential landmines for a fifth of the price of a bomb sniffing dog. Pouch rats are much larger than most rats and are a very ferocious species; they will harm themselves if there are any non-smooth surfaces when captured. It is very important that we designed a trap with this safety top of mind.
In the interest of cost savings and ease of manufacturing, the trap is designed to be as simple and durable as possible. The traps are used in both urban and rural environments that include city streets, basements, farms, river beds, and bushes among other locations. The body of the trap is built from 6" PVC, while the tripping mechanism is a mixture of easily worked steel and 3D printed parts. The final design underwent extensive computer modeling and testing as well as 4 complete prototypes builds. Dr. Braude plans to take the completed trap to Africa in the Spring of 2022 for real-world testing. If the prototype is sufficient to Dr. Bruade's needs, the goal is to manufacture about 20 more traps for use in future excursions.

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Contents

List of Figures 2

List of Tables 3

1 Introduction 4

2 Problem Understanding 4
2.1 Existing Devices . . . 4
2.2 Patents . . . 6
2.3 Codes & Standards . . . 8
2.4 User Needs . . . 9
2.5 Design Metrics . . . 10
2.6 Project Management . . . 10

3 Concept Generation 12
3.1 Mockup Prototype . . . 12
3.2 Functional Decomposition . . . 13
3.3 Morphological Chart . . . 14
3.4 Alternative Design Concepts . . . 15

4 Concept Selection 20
4.1 Selection Criteria . . . 20
4.2 Concept Evaluation . . . 20
4.3 Evaluation Results . . . 21
4.4 Engineering Models/Relationships . . . 22

5 Concept Embodiment 24
5.1 Initial Embodiment . . . 24
5.2 Proofs-of-Concept . . . 28
5.3 Design Changes . . . 28

6 Design Refinement 29
6.1 Model-Based Design Decisions . . . 29
6.2 Design for Saftey . . . 30
6.3 Design for Manufacturing . . . 32
6.4 Design for Usability . . . 32

7 Final Prototype 34
7.1 Overview . . . 34

Bibliography 35

Appendix A Parts List 36

Appendix B Build Plans 37

List of Figures

1 Homgarden Live Animal Cage Trap (Source: Amazon.com) 4
2 Z TRAP No.8 Skunk-N-More Standard Live Trap (Source: ZTraps.net) 5
3 Home and Country Humane Mouse Trap (Source: Amazon.com) 6
4 Patent Figures for Folding Trap Door 7
5 Patent Figures for Pivoting Trap Door 8
6 Gantt chart for design project 11
7 Mockups of door-and-pin system to be used in Rat Trap 12
8 Function tree for African Pouch Rat Trap 13
9 Morphological Chart for African Pouch Rat Trap 14
10 Sketches of Pivot Rat Trap concept 15
11 Sketches of "The Pacifist" Trap concept 17
12 Sketches of Deluxe Fat Rat Trap concept 18
13 Analytic Hierarchy Process (AHP) to determine scoring matrix weights 20
14 Weighted Scoring Matrix (WSM) for choosing between alternative concepts 21
15 Diagrams and Calculations Relevant to the Grate Friction 22
16 Diagrams and Calculations Relevant to the Hinge Pin Shear 23
17 Diagrams and Calculations Relevant to the Door Pin Moment 24
18 Assembled projected views with overall dimensions 25
19 Assembled isometric view with bill of materials (BOM) 26
20 Exploded view with callout to BOM 27
21 Blown up view of trigger mechanism operation 28
22 Redesigned Hinge Tab 29
23 Bait Gate inside system 30
24 Heat Map of Risk Assessment 32

List of Tables

1 Interpreted Customer Needs 10
2 Target Specifications 10

1 Introduction

The African Giant Pouch Rat is a species of rat found from central Africa near Sudan all the way down to South Africa. These are some of the largest rodents in the world and can get as large as a household cat. These rats are of special interest because of their acute sensing skills: they are often trained to sniff out landmines. They are much preferred to bomb-sniffing dogs as they are much cheaper to train with a nine-month training costing $7,300 [1]. In contrast, trained dogs can cost north of $30,000. In order to effectively breed these animals into training, they need to be trapped in the wild and taken into captivity of researchers and trainers. Professor of biology, Stan Braude, at Washington University in St. Louis is one of these researchers. After interviewing Professor Braude about current African Giant Pouch Rat traps and his usage of them, we were able to determine that we could develop a new trap that will ease many of his pain points with the traps and provide a finished product that will be better for the rats, researchers, and cheaper to manufacture.

2 Problem Understanding

2.1 Existing Devices

In order to better guide our ideation, we looked at previously designed mechanisms and devices for similar purposes.

2.1.1 Existing Device #1: Homgarden Live Animal Cage Trap

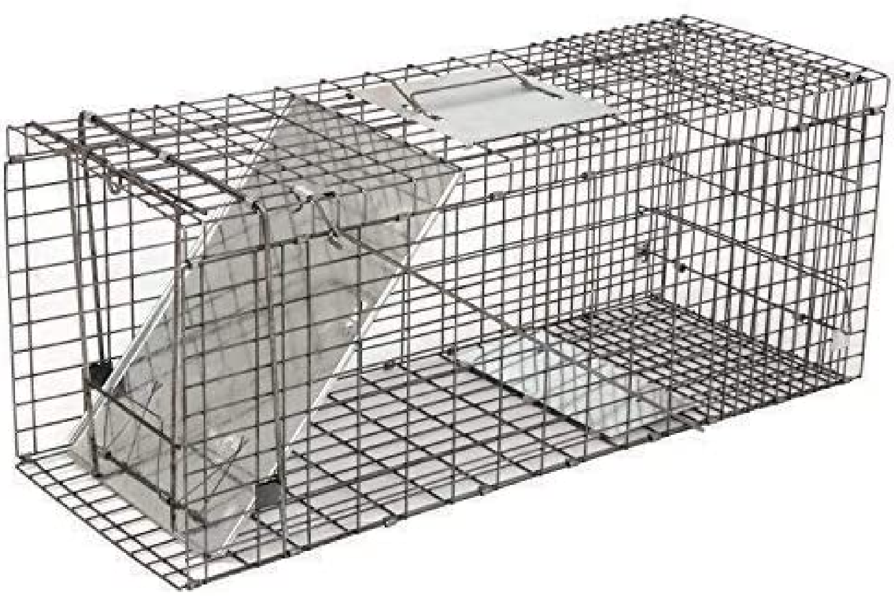


Figure 1: Homgarden Live Animal Cage Trap (Source: Amazon.com)

Link: www.amazon.com/homgarden-live-animal-cage-trap
Description: The Homgarden Live Animal Cage Trap is designed to detain small mammals without harming them. A piece of bait is placed on a pressure plate, which, when stepped on, triggers a

spring loaded system which closes the door of the trap behind the animal. The trap can hold most small mammals, having a length of 32" with an opening of 12" square. The trap is reusable, having a rugged steel wire construction and a solid iron door, and the mechanism is simple and easy to manipulate.

2.1.2 Existing Device #2: Z TRAP No.8 Skunk-N-More Standard Live Trap

Figure 2: Z TRAP No.8 Skunk-N-More Standard Live Trap (Source: ZTraps.net)

Link: www.ztraps.net/no-8-skunk-n-more-live-trap
Description: The Z TRAP No.8 Skunk-N-More Standard Live Trap is designed to detain small mammals without harming them. Made from aluminum, the trap is comprised of a cylinder with bait in a tray on one end behind a grate attached to wire. At the other end a door is held up by the end of this wire. When the animal moves the grate in the act of eating the bait, the wire shifts, dropping the door over the entrance, trapping the animal inside. The trap has an 8" diameter body and is 29" in length. This trap is safer for the animal being made of solid aluminum instead of steel wire. When the animal is caught, it flails in a panic, and the smooth aluminum with be much more gentle than the steel wire frame.

2.1.3 Existing Device #3: Home and Country Humane Mouse Trap

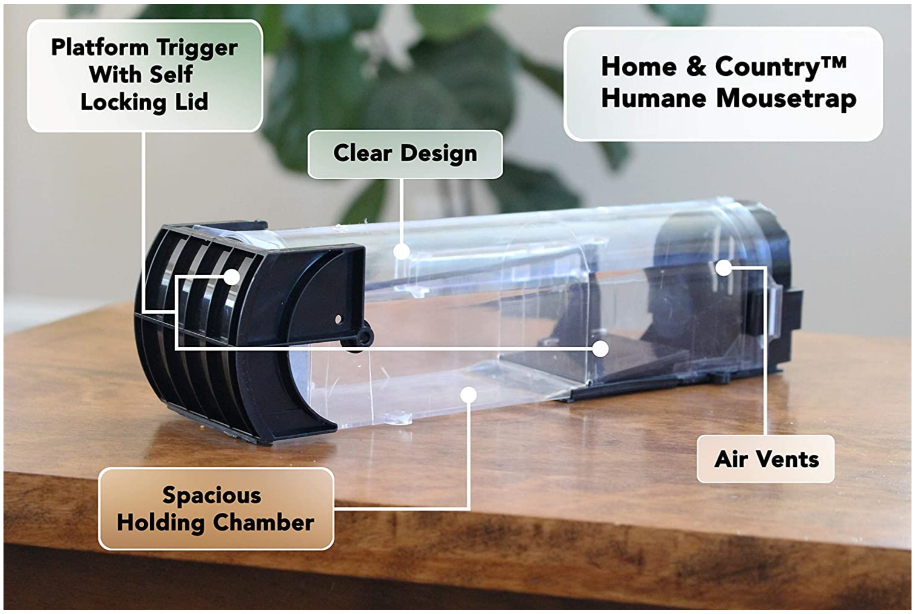


Figure 3: Home and Country Humane Mouse Trap (Source: Amazon.com)

Link: www.amazon.com/home-and-country-Humane-mouse-trap
Description: The Home and Country Humane Mouse Trap is designed to detain small mammals without harming them. This trap is slightly smaller than the previous traps, at 12" long with a 3" square opening. This trap has a pressure plate mechanism triggering an externally mounted door. This trap is made of solid polyurethane and is designed to be comfortable for the animal, with a spacious holding chamber and air holes.

2.2 Patents

2.2.1 Folding Door Animal Trap (US4080749A)

This patent is for a folding door closure mechanism on a humane small mammal cage trap. The door is made of two nearly equal sections, with a hinge in the middle, allowing the door to fold inward. The hinges are spring loaded, which accelerates the rate of closure of the door when the trigger is manipulated. The trigger is a hook-lever combination which is actuated when the animal attempts to claim the bait.

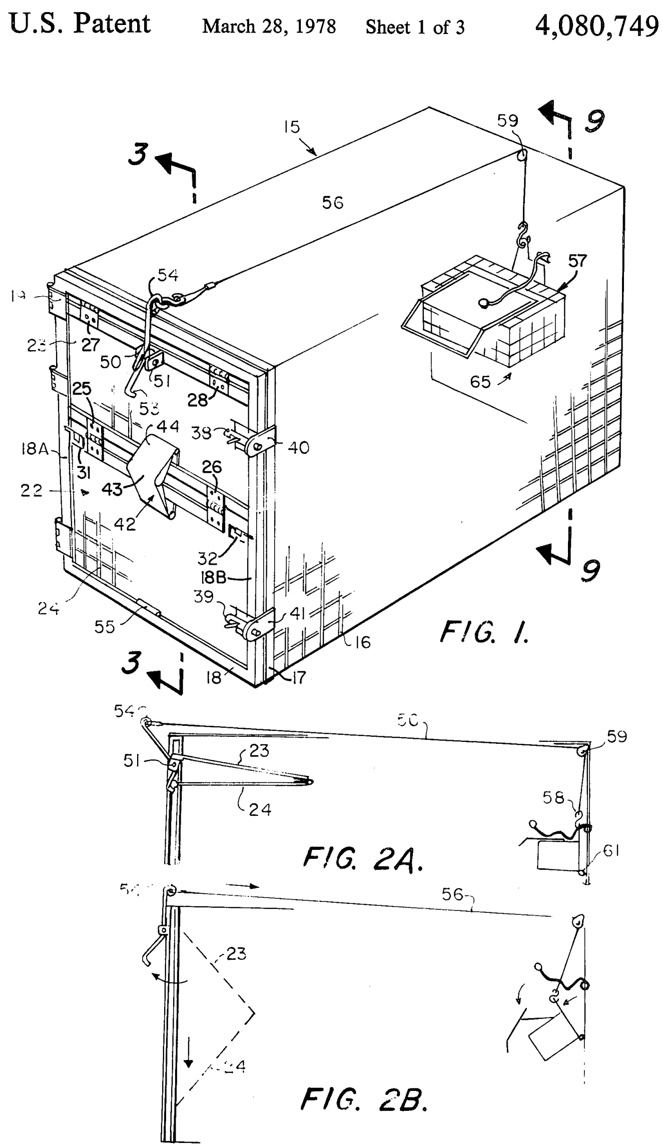


Figure 4: Patent Figures for Folding Trap Door

2.2.2 Pivot Door Animal Trap (US4557067A)

This patent is for a Pivot door closure mechanism on a humane small mammal cage trap. This trap is designed with a door that lies down onto the floor of the trap when set. It is hinged on the bottom lip of the trap entrance, and is spring loaded. The trigger is a pressure plate, which has a tooth on the end which holds down the door of the trap when in the open position. While engaged with the tooth, the door holds the pressure plate in an upward position. When the animal steps on the plate, the plate is pulled down and away from the door, disengaging the tooth, allowing the door to snap upward and trap the animal inside.

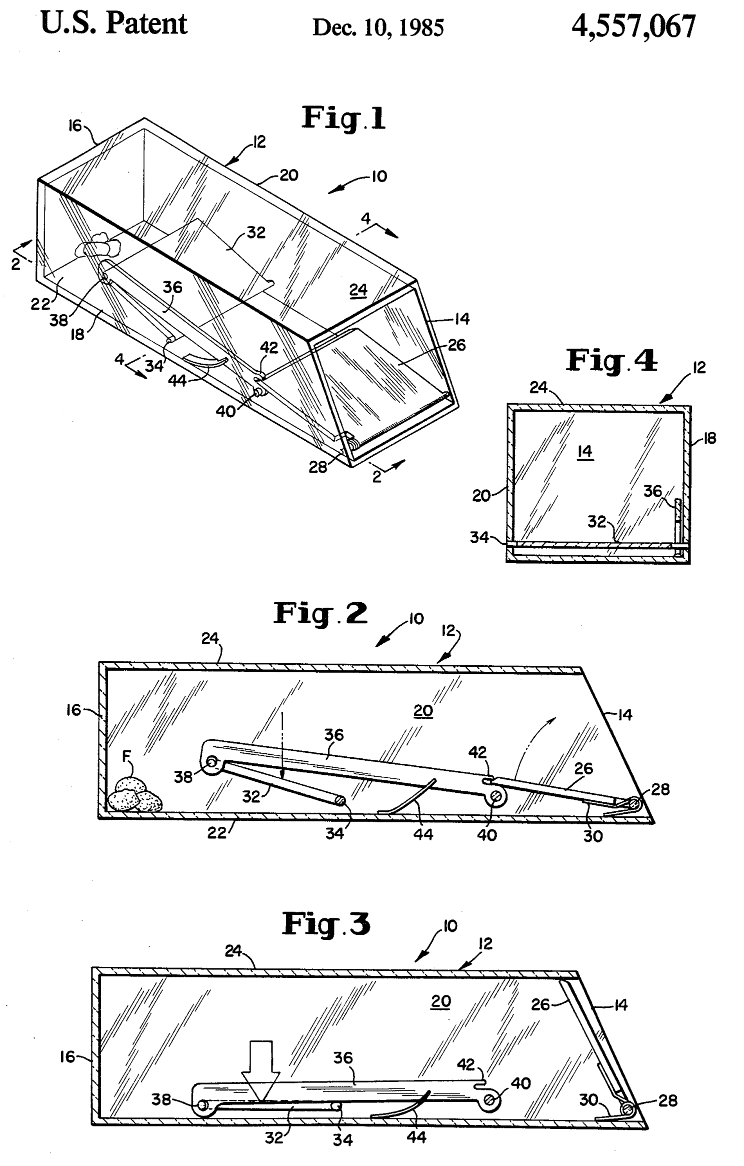


Figure 5: Patent Figures for Pivoting Trap Door

2.3 Codes & Standards

Since the rats are being caught in Tanzania with the purpose of using them to detect land mines, the rats are considered working animals. The next two standards both fall under the Tanzanian government laws for animal cruelty.

2.3.1 Animal Welfare Act of 2008 - Part IV 33-2

To summarize the law, it says that the owner cannot cause any avoidable injury or distress to the animal. This is important to us because the rat will try to gnaw and fight its way out of the trap. We need to ensure that there are no sharp objects or injury prone material that the rat can have access to.

2.3.2 Animal Welfare Act of 2008 - Part IV 33-3

The law states that the animal must be given shelter, adequate space, and a soft lying space for times of rest. If the rat is being left in the trap for an excess duration, we need to make sure that adequate space and shelter are given to it.

2.4 User Needs

To gain further understanding of the fundamental design and purpose of the project, we need to satisfy our user. This section outlines the interaction with the user and its findings.

2.4.1 Customer Interview

Interviewee: Professor Stan Braude
Location: McDonnell Hall 306, Washington University in St. Louis, Danforth Campus
Date: September 9^{th}, 2021
Setting: The interview took place in a conference room, where the customer gave us 2 working prototypes and took ∼40 min.
Interview Notes:
What are the typical uses of the device?

- The device is burrowed into common rat dwellings in Tanzania to catch the rats without causing them harm while in the trap

What are the current likes and dislikes of the product?

- The customer wants the diameter to be slightly larger, approximately 2 inches, and would like the exterior/interior to be sleek in design to eliminate possibility of rat injuring itself. I like the cheap/ lightweight material (PVC) and the overall size.

2.4.2 Interpreted User Needs

We interpreted that the customer is happy with his prototypes but has thoughts for areas of improvement. The customer shows concern for the well being of the rat while in the trap.

Table 1: Interpreted Customer Needs

Need Number	Need	Importance
1	The trap has clear indication of rat occupancy	1
2	The trap has a sleek exterior design	5
3	The trap has a sleek interior design	4
4	The trap has minimal exposed wiring/screws	4
5	The trap needs to be cost effective	1
6	The trap requires a large production amount	3
7	The trap's diameter must be between 4-6 inches	5

The main concern of this project is to have an optimal diameter and length of the trap that allows for rat movement but limits its freedom. Also, there needs to be very few, if any, exposed screws and wiring. Cost is of very low concern because the main material is PVC pipe.

2.5 Design Metrics

After interviewing and creating a table of customer needs, we are able to create a table of design metrics to guide us and give our initial designs structure.

Table 2: Target Specifications

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	7	Interior size	in	6	5
2	6,7	Length	ft	3	2.5
3	2	Simplicity of exterior	protrusions	< 5	< 3
3	3	Simplicity of interior	protrusions	< 3	0
4	4	Rat harming itself	qualitative	Possible concerns	No concerns
5	3	Trap door fit	in	< 1/2"	< 1/8"

2.6 Project Management

The Gantt chart in Figure 6 gives an overview of the project schedule.

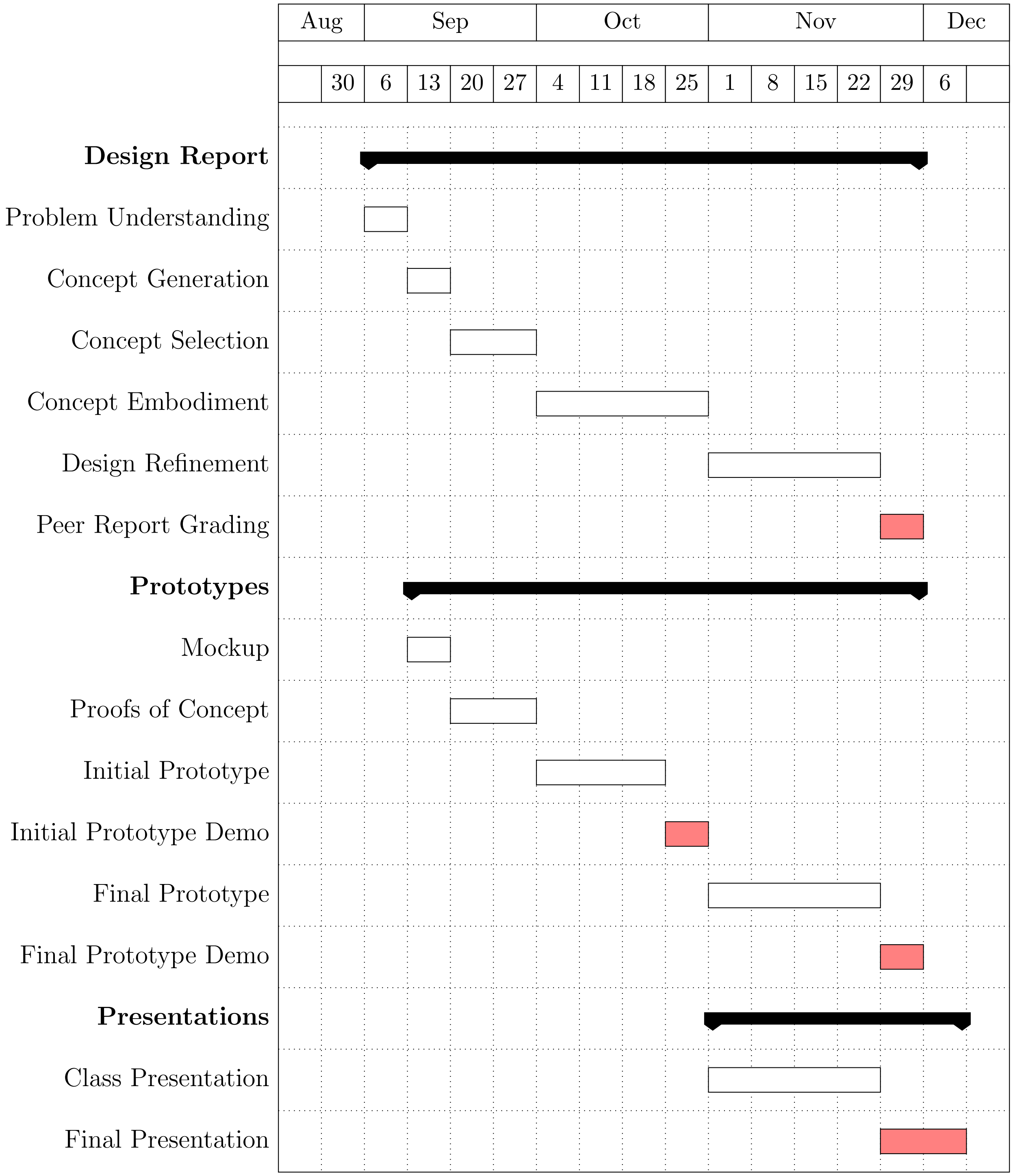


Figure 6: Gantt chart for design project

3 Concept Generation

3.1 Mockup Prototype

While creating this mockup, we were able to finally visualize a lot of the issues we were expecting and begin thinking through them. Since we are working off a design that must be very clean on the inside and out, the way to hold the door/gate up and then cause it to close quickly became our biggest issue. In the photos below, we show the progress we made on the mechanism to hold the door up and then fall once the copper rod is pulled. The rest of the mockup (not included) is a PVC cylinder with a mechanism to push the rod away from the door once the rat goes after the bait.

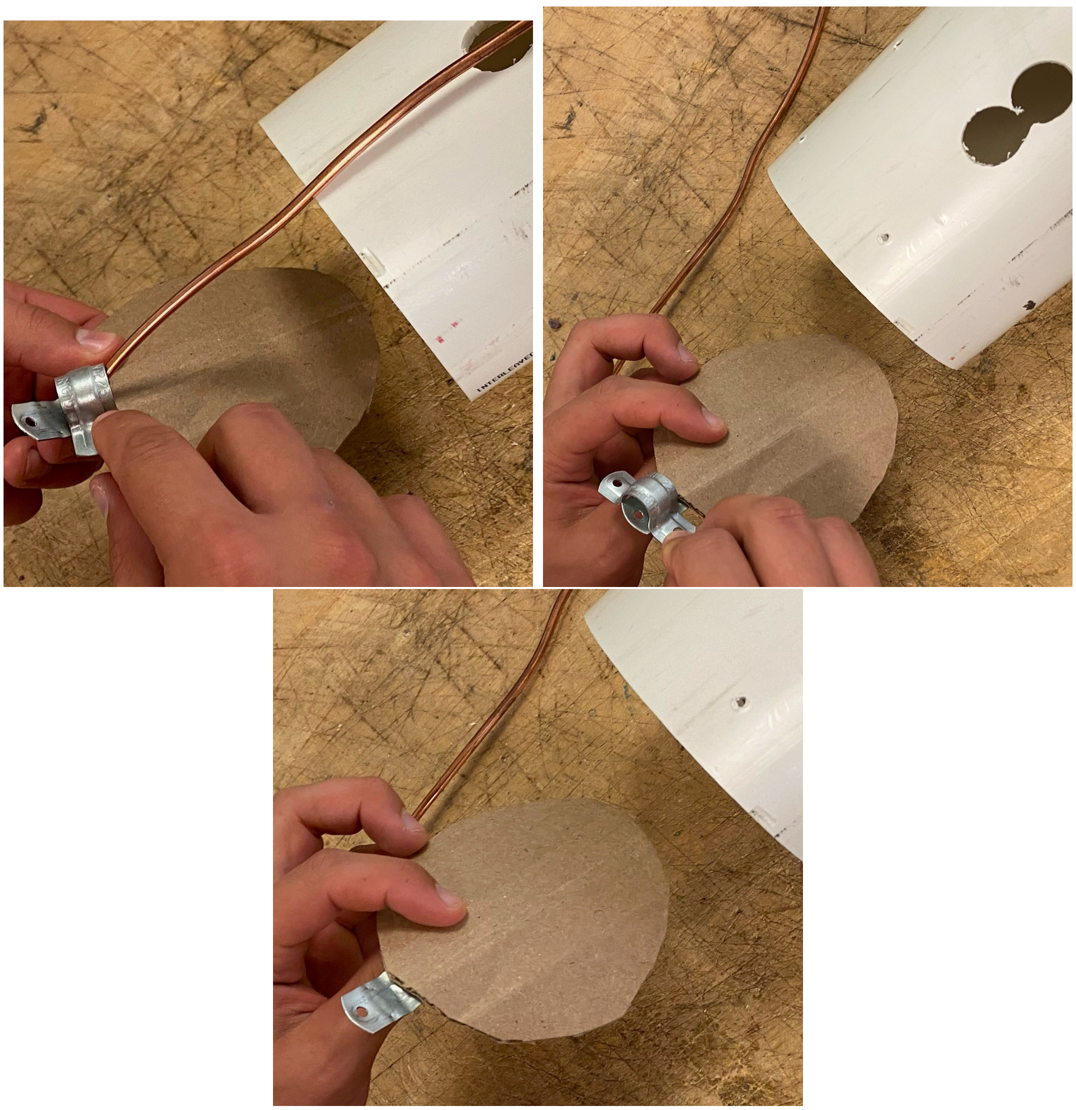


Figure 7: Mockups of door-and-pin system to be used in Rat Trap

3.2 Functional Decomposition

The first step to creating a superior African Pouch Rat Trap was to break down the various functions of the rat trap.

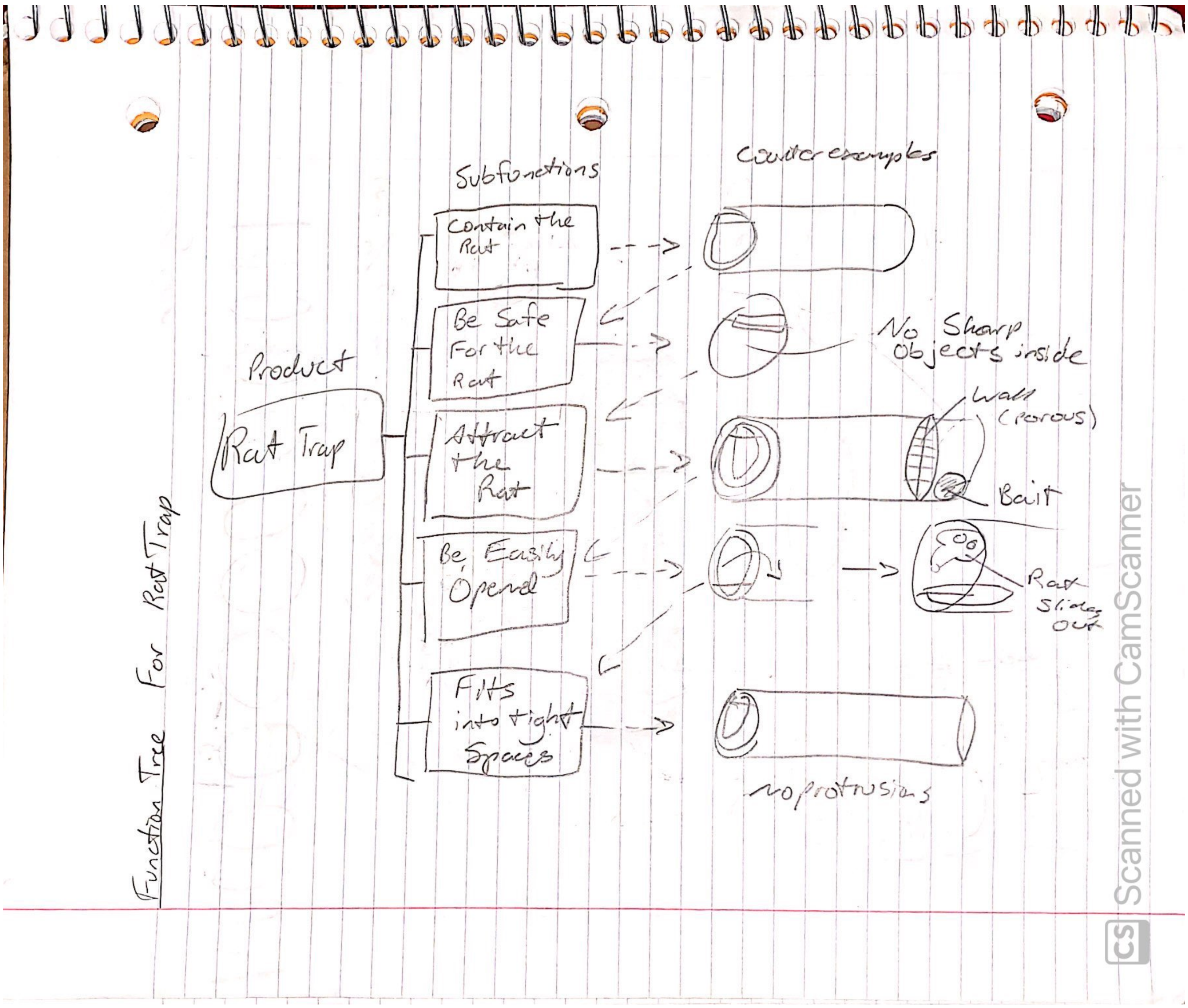


Figure 8: Function tree for African Pouch Rat Trap

3.3 Morphological Chart

With the different functions of the trap defined, several design options were generated to accomplish each.

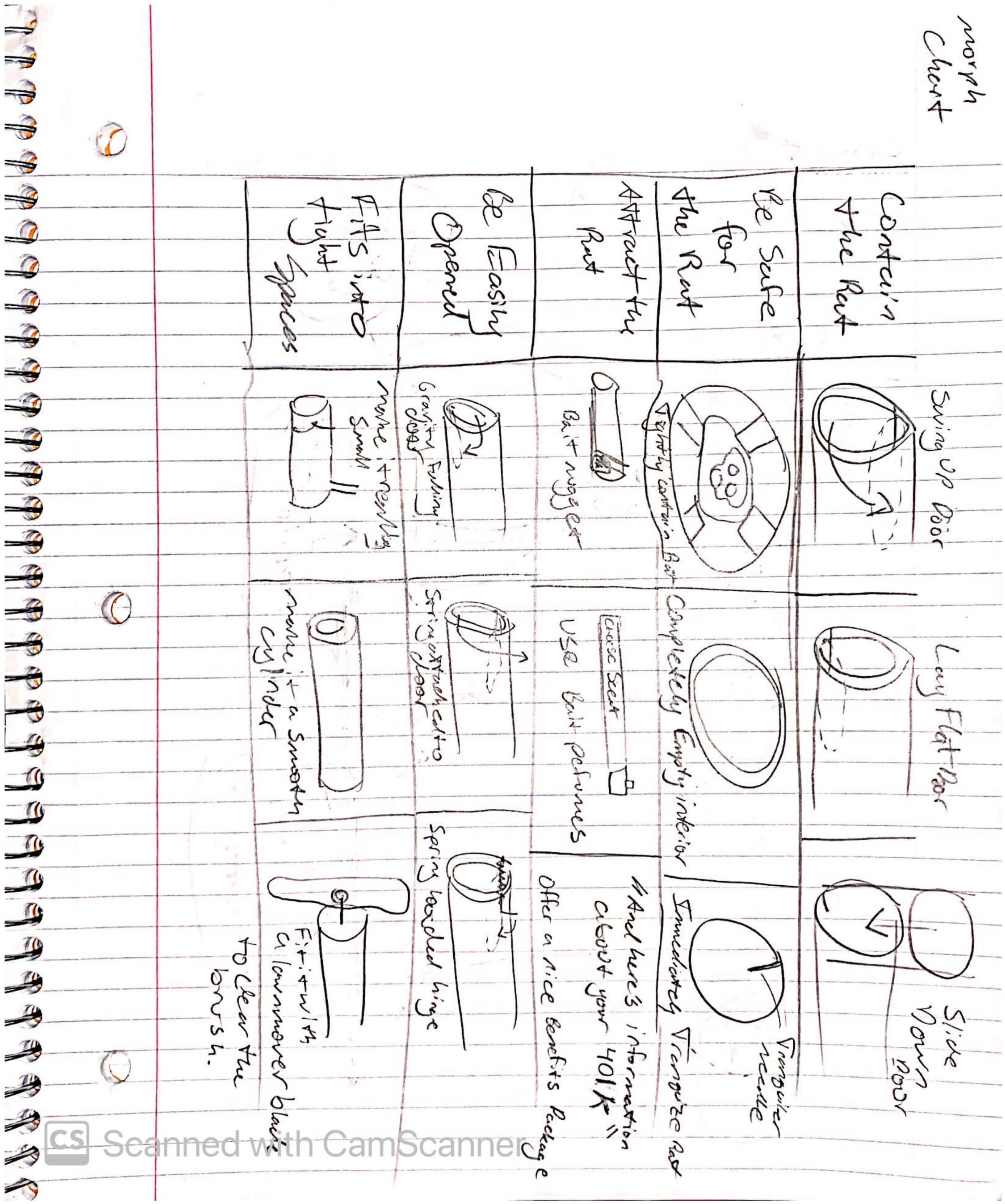


Figure 9: Morphological Chart for African Pouch Rat Trap

3.4 Alternative Design Concepts

3.4.1 Pivot Rat Trap (Anthony Brown)

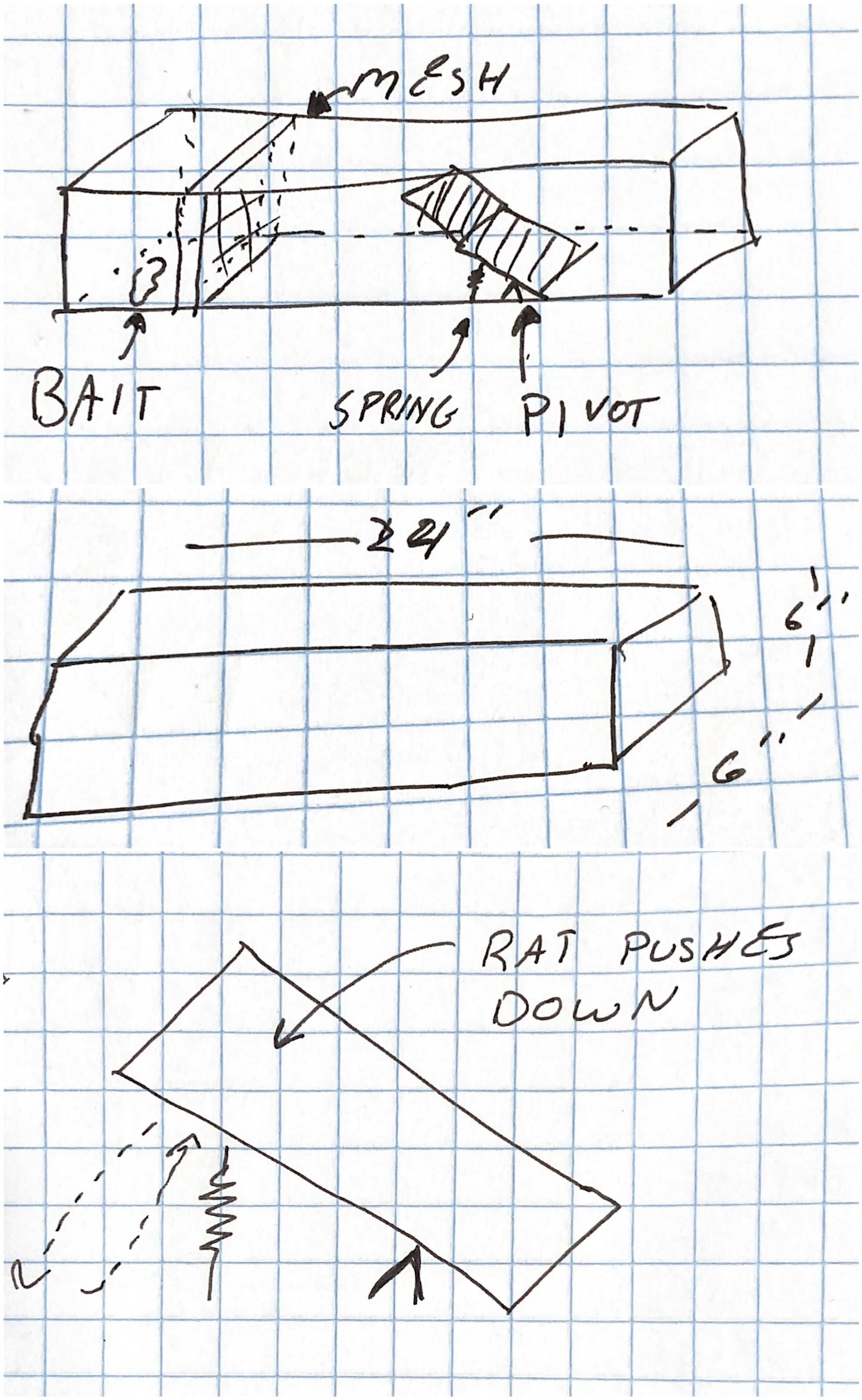


Figure 10: Sketches of Pivot Rat Trap concept

Solutions from morph chart:

1. Unit sits on floor/table
2. Rotational switch
3. Microcontroller
4. Arm on motor
5. Reverse action, actively drive back
6. Battery (or connect to computer using a USB cable)

Description: This trap operates off the premise of the rat walking over a spring-loaded door. Once the rat causes the door to fall over its pivot point, the spring rebounds the door back up, sealing the rat within. The cons to this design are that there are exposed components within – a quality the customer did not want.

3.4.2 The Pacifist (Jared Harrison)

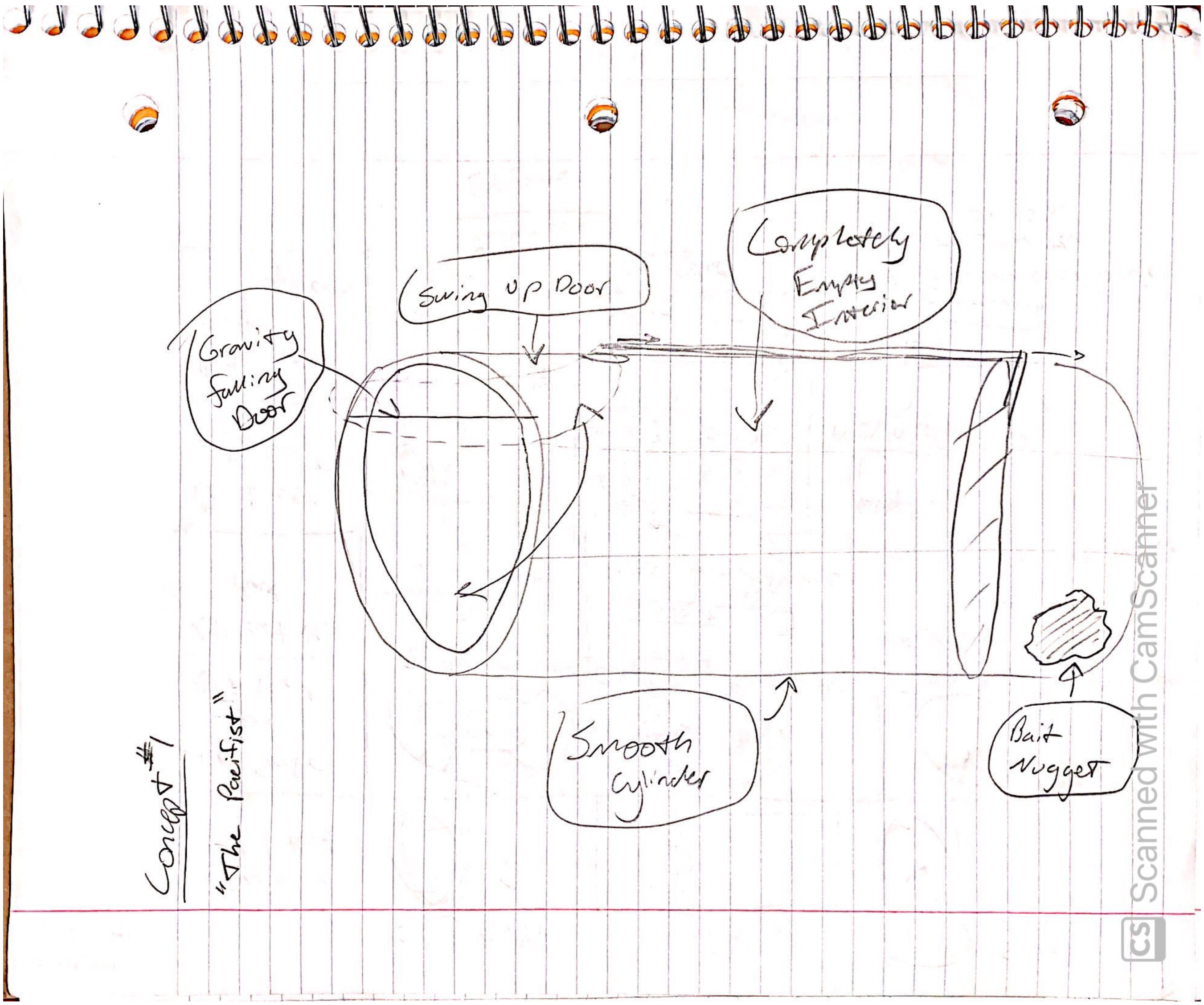


Figure 11: Sketches of "The Pacifist" Trap concept

Solutions from morph chart:

1. The door swings down from above, trapping the rat, which has no capacity to lift it.
2. The interior is completely smooth and empty
3. The Trap attracts the rats with a bait nugget
4. The Trap door is held down only with gravity, so the rat can be removed simply by flipping the trap upside down and sliding the rat over the now fallen door
5. The outside of the trap is smooth and rounded, and can slide into tight spaces under tree roots

Description: This trap is a simple and elegant solution to trapping rats and protecting them from themselves. The door, which swings down from above, is held in place by a wire, which is connected to a grate in front of the bait nugget. When the rat enters and attempts to claim the bait, the grate is pushed back, and the wire is pulled out of the door, which then swings down, trapping the rat. The door is shaped curving away from the rat, so there is no way for it to grab and pull the door. The inside of the trap is completely smooth, and there is nothing the rat can do to hurt itself inside. When the trapper comes to collect the rat, they simply turn the trap over, the door falls, and the rat slides right out of the trap.

3.4.3 Deluxe Fat Rat Trap (John Christensen)

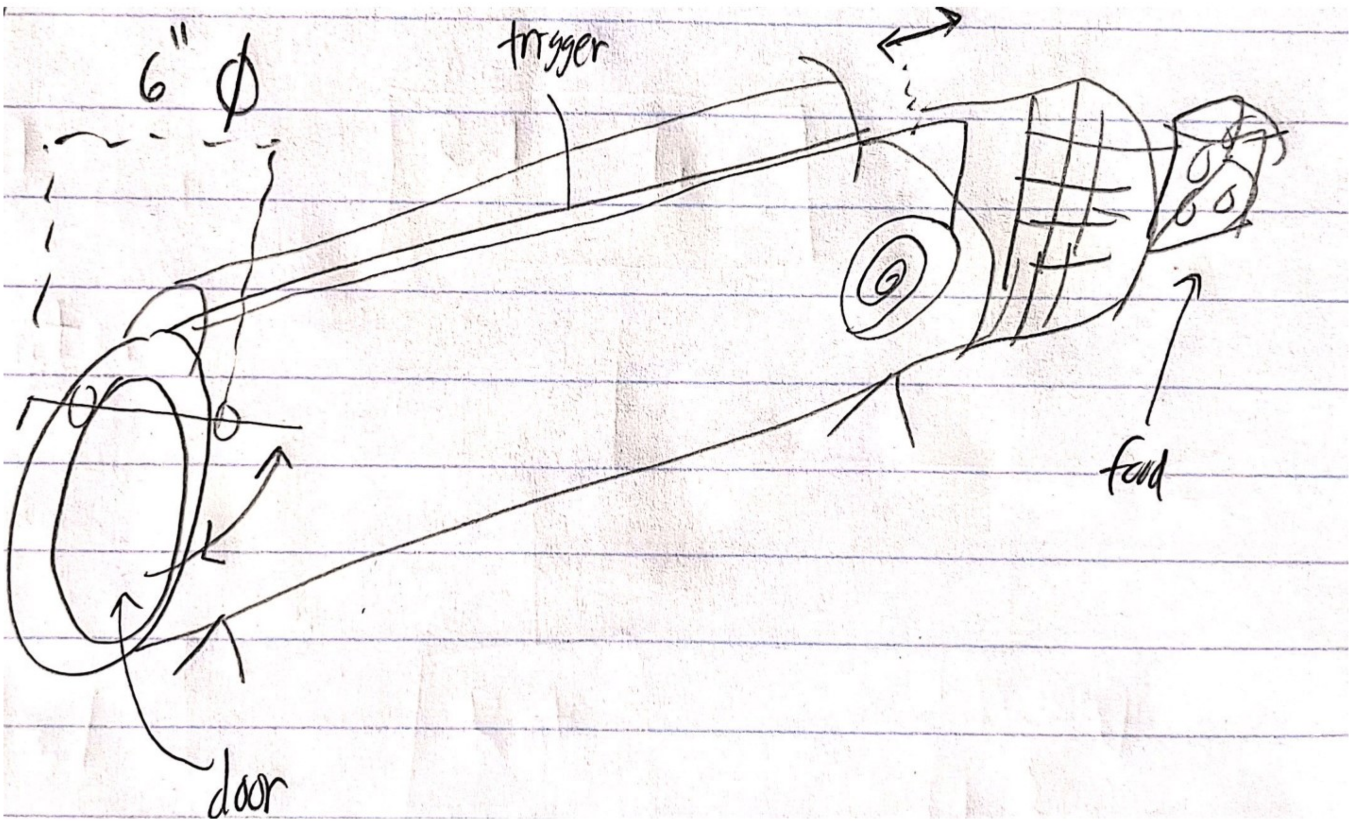


Figure 12: Sketches of Deluxe Fat Rat Trap concept

Solutions from morph chart:

1. The door is a swing up/down door on a hinge that allows for door to rotate and fall once trigger is pressed.

2. The interior is for the most part smooth.

3. The rat is lured in through food, typically corn meal.

4. The door is simply held in place by gravity and can't reopen when standing correctly because the door will be hitting the interior. When flipped upside down, the door follows gravity and opens for the rat.

5. The outside of the trap is very smooth, possibly with another cylinder attached to the exterior cylinder that allows for easy sliding into the tree.

Description: The concept has a PVC outer diameter of 6 inches and a trigger that is enclosed inside a smaller PVC pipe that is attached to the main cylinder. The food lure is set behind the trigger inside the main cylinder, and when the trigger is pushed forward by the rat, the trigger detaches from the door causing the door to fall and trapping the rat.

4 Concept Selection

4.1 Selection Criteria

To select our concept, we first had to weight our various selection criteria in a way that sums to 100%. Below in 13 is the process used to generate these weightings with the corresponding importance of each criteria to one another.

	Cleanliness of Inside	Cleanliness of Outside	Simplicity of Trippping Mechanism	Indication of Rat Caught	Durability		Row Total	Weight Value	Weight (%)
Cleanliness of Inside	**1.00**	3.03	0.33	9.09	2.00		15.45	0.31	31.00
Cleanliness of Outside	0.33	**1.00**	3.03	9.09	3.00		16.45	0.33	33.00
Simplicity of Trippping Mechanism	3.00	0.33	**1.00**	3.03	1.00		8.36	0.17	16.77
Indication of Rat Caught	0.11	0.11	0.33	**1.00**	0.20		1.75	0.04	3.51
Durability	0.50	0.33	1.00	5.00	**1.00**		7.83	0.16	15.71
					Column Total:		**49.85**	**1.00**	**100.00**

Figure 13: Analytic Hierarchy Process (AHP) to determine scoring matrix weights

4.2 Concept Evaluation

Once the weightings were set, we use them in a weighted matrix comparing our various concepts to select the one that best fits what we are looking for. In this case, concept 4 was best suited for the needs of our customer, as shown below in 14.

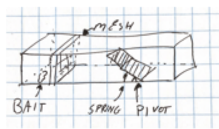
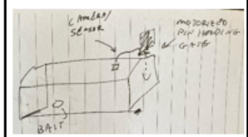
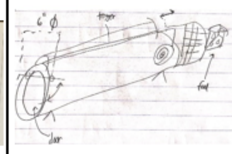
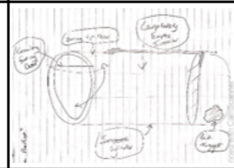
Alternative Design Concepts		Concept #1		Concept #2		Concept #3		Concept #4	
									
Selection Criterion	**Weight (%)**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**
Cleanliness of Inside	31.00	2	0.62	5	1.55	4	1.24	5	1.55
Cleanliness of Outside	33.00	4	1.32	2	0.66	3	0.99	4	1.32
Simplicity of Trippping Mechanism	16.77	4	0.67	1	0.17	3	0.50	3	0.50
Indication of Rat Caught	3.51	3	0.11	3	0.11	4	0.14	4	0.14
Durability	15.71	1	0.16	2	0.31	3	0.47	4	0.63
	Total score	**2.873**		**2.797**		**3.345**		**4.142**	
	Rank	**3**		**4**		**2**		**1**	

Figure 14: Weighted Scoring Matrix (WSM) for choosing between alternative concepts

4.3 Evaluation Results

The five most important factors for the rat trap are displayed in Figure 13 where the weights were calculated. As expected, the cleanliness of the outside of the trap (no excessive protrusions or items that would get in the environment in which the trap is placed) is weighted as most important. The cleanliness of the inside of the trap (no sharp objects inside for rat to injure itself) is just slightly behind the cleanliness of the outside. In total, those two factors account for over 64 percent of the importance of the trap.

The best designed concept is concept 4. It's two highest scores come from the cleanliness of the inside and outside of the trap and did not lack in any category. The biggest improvement for concept 4 compared to the others is that it's built for durability. Concept 4 also provides us with a bait gate that is slotted to slide exactly the amount we want the trigger to slide.

4.4 Engineering Models/Relationships

Essential to the function of the trap is the ability of the rat to actuate the triggering grate in its pursuit of the bait. To move the grate, the coefficient of friction of the grate with the PVC housing and the mass of the grate must both be low enough so that the rat will be able to overcome the friction forces and move the grate to trigger the trap. The mass of the grate will be determined by the density of the material, and the coefficient of friction will be specific to the material, so the material chosen for the grate will be governed by this model.

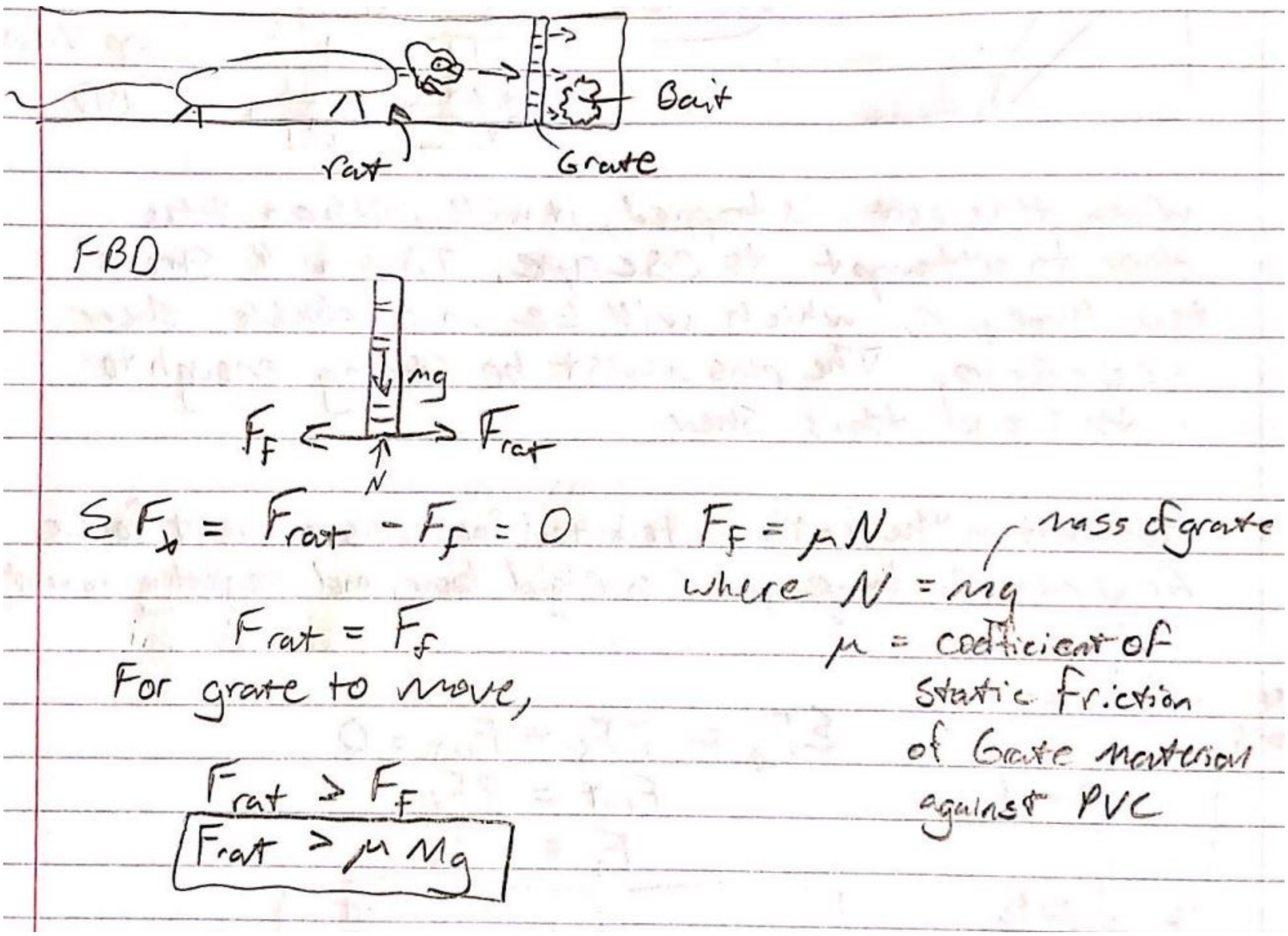


Figure 15: Diagrams and Calculations Relevant to the Grate Friction

Another parameter governing materials selection for the trap components is the shear strength of the trap door hinge pin. Neglecting any moments and assuming the hinge pin is rigid, the forces applied on the hinge pin when the rat is pushing on the door in an attempt to escape can be approximated as double shear with the walls of the trap. The shear stress in the pin can then be approximated as half the force applied by the rat divided by the cross sectional area. The shear strength of the pin must exceed this calculated stress in order to prevent the rat from escaping. The design factors governed by this model are the material choice, which determines the shear strength, and the cross sectional area of the hinge pin, which determines the stress from the applied force.

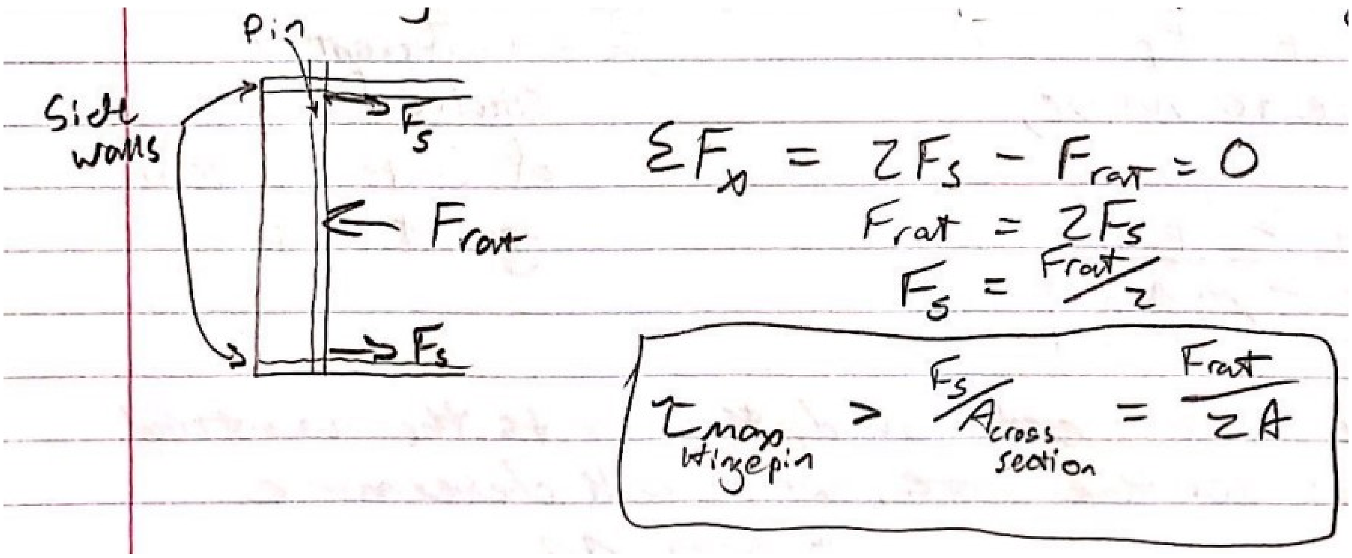


Figure 16: Diagrams and Calculations Relevant to the Hinge Pin Shear

The Door of the trap, which is glued to the hinge pin, is held up by a steel wire which runs along the outside of the trap body, creating interference with a tab extending radially from the hinge pin, preventing its rotation. The moment on the hinge pin created by the weight of the door must be countered by the force applied on the tab by the steel wire for the door to be properly held open. This requirement governs the strength of the steel used, the thickness of the wire, the weight of the door, and the length of the tab.

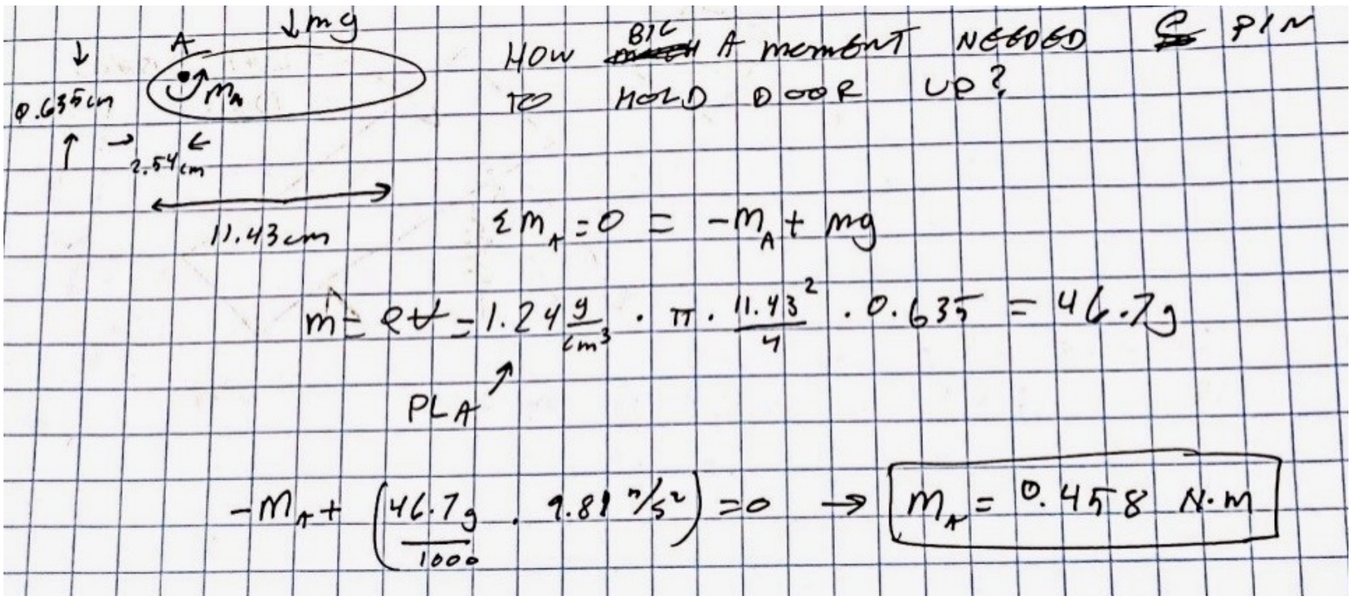


Figure 17: Diagrams and Calculations Relevant to the Door Pin Moment

5 Concept Embodiment

5.1 Initial Embodiment

For our initial embodiment, we began by drafting all of our parts as individual SolidWorks parts and materials [2]. By doing this, we were able to alter our dimensions quickly and effectively while also being able to grasp the true size our prototype would be. Using the parts, we created an assembly within SolidWorks to view tolerances and the motion of all of pieces together. This assembly turned out to be incredibly useful as we were then able to make minute adjustments to the diameters of our parts and study the trigger mechanism closely. The SolidWorks assistance was necessary in our process as we 3D printed some pieces as many as 5 times before completing a working prototype. Below, Fig. 18 shows the overall dimensions of the assembly in isometric form while Fig. 19 contains the bill of materials and Fig. 20 displays an exploded view. All components were held together with either a PVC specific primer and cement or a durable epoxy (hot glue was used for the prototypes). More specifically, Fig. 21 shows the operation of the trigger mechanism.

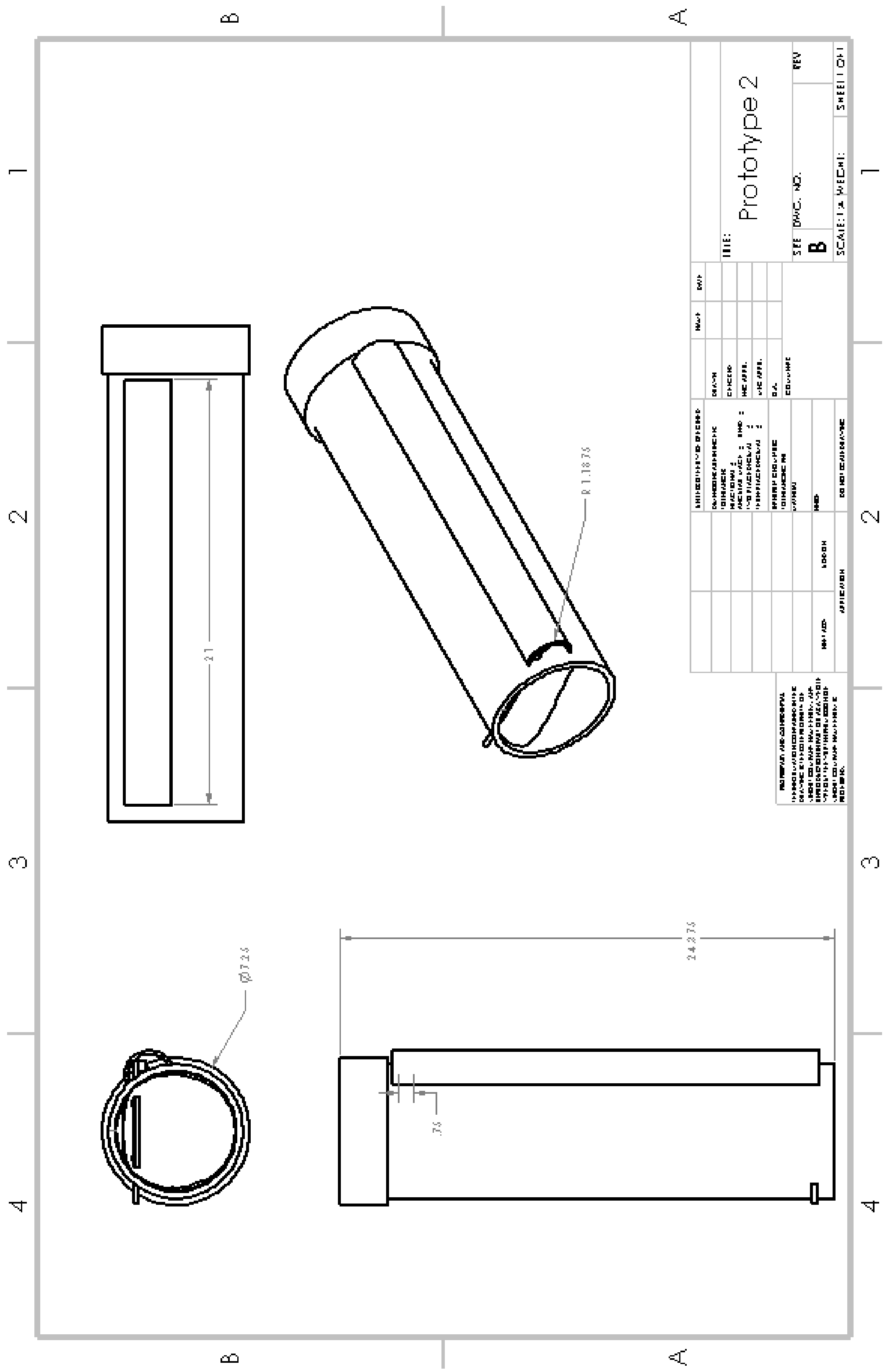


Figure 18: Assembled projected views with overall dimensions

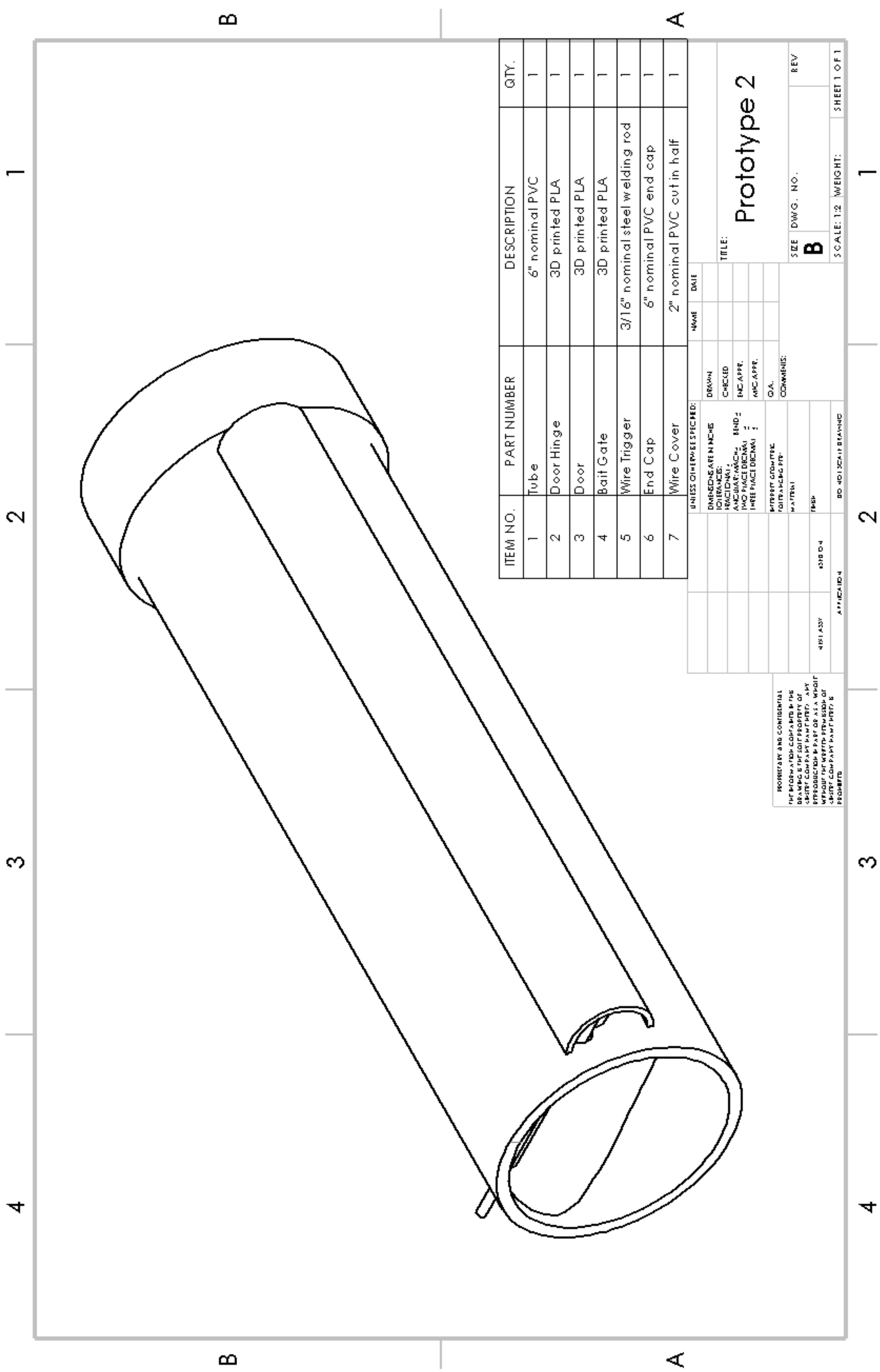


Figure 19: Assembled isometric view with bill of materials (BOM)

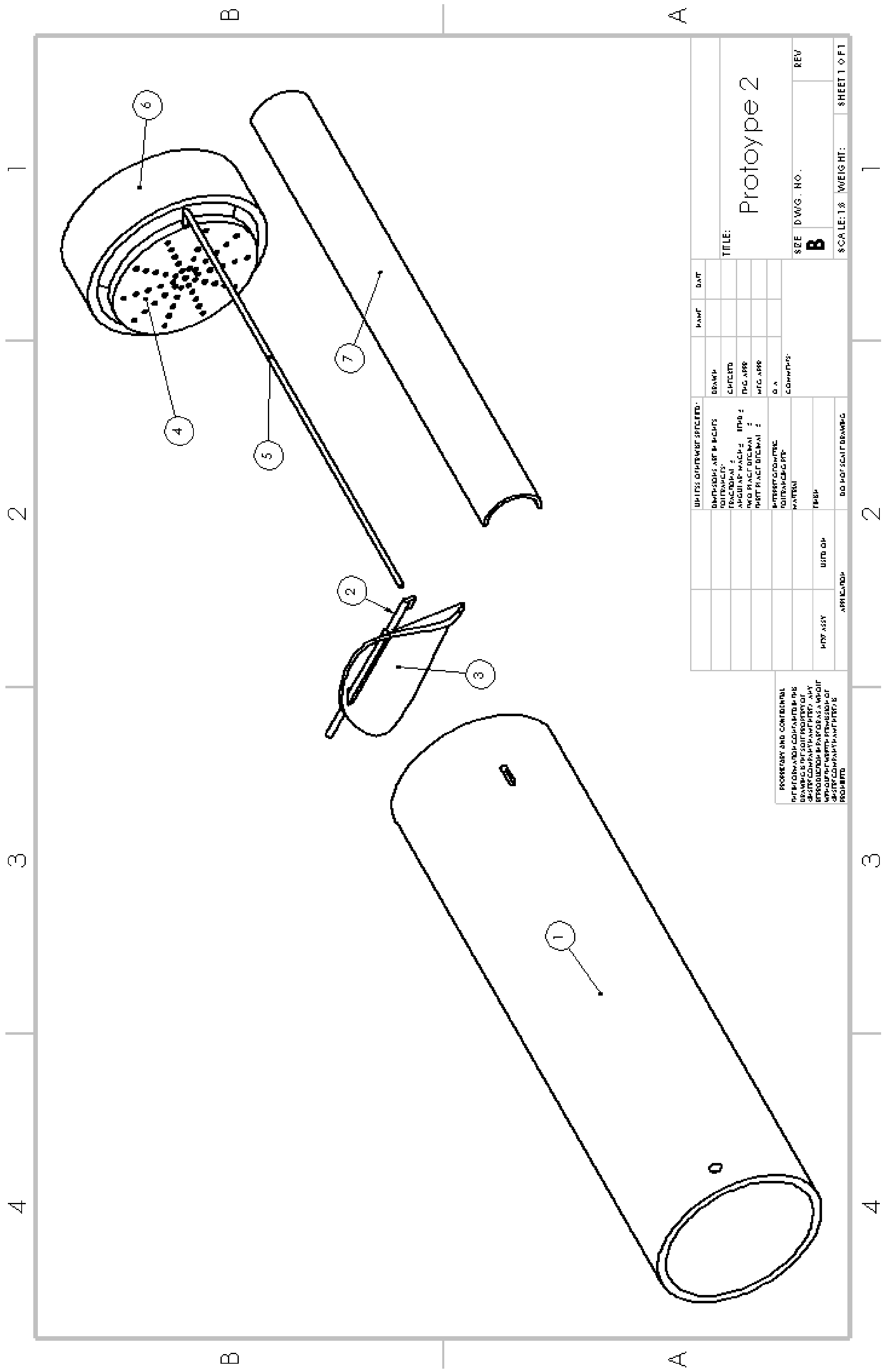


Figure 20: Exploded view with callout to BOM

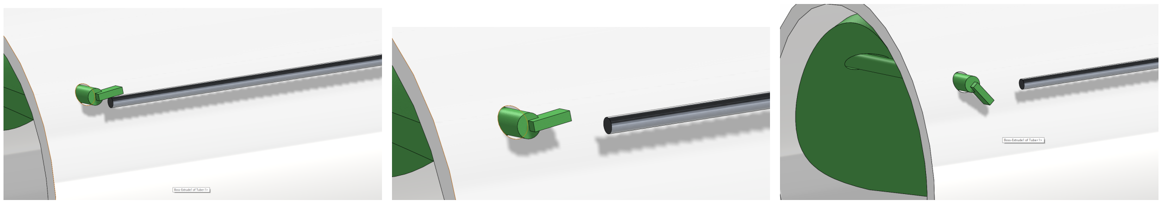


Figure 21: Blown up view of trigger mechanism operation

The first prototype design goal ensures that the prototype is easy to clean. Using the traps in the field in central Africa will involve partially burying them under tree roots, and it is essential that the traps not collect dirt on the inside or outside of the trap. The standard for this goal was to cover and fill the trap with dirt, and then clean it. The PVC body of the trap is very slippery and the trap was very easy to clean. The current prototype easily meets this goal.

The second prototype design goal ensures that the trap works reliably and is easy to set. The standard was to be able to set and trip the trap 20 times within 40 minutes without any repairs. Our prototype is able to complete this task, but we did find a weakness in the trigger system as a result of this test. We found that the current version of the wire rest which holds the trigger wire in place under the hinge pin tab is not sufficient. The wire is free to slide left and right, and even fall off the rest entirely. To solve this problem, we are going to be replacing the rest with a much more secure bracket.

The final prototype design goal tests the durability of the trap. To fulfill this goal, the trap must be able to withstand a rigorous shaking in a variety of orientations without anything breaking off the trap. Our trap, designed with few moving pieces and with rugged durability in mind, passed this test with flying colors.

5.2 Proofs-of-Concept

Through proof-of-concept testing, we discovered a problem with the trigger mechanism. At the point where the wire interferes with the hinge tab, the wire needs to be held in place about a centimeter from body of the trap. If it is not, the wire will be free to move around the inside of the mechanism enclosure, and will move out of position while the trap is not set, making setting the trap more difficult. Alternatively, while set, the hinge pin could slide side to side in its slot, and if the wire is not set in the center of the hinge tab, it could slide off the wire, springing the trap. To solve this problem, we intend to attach a displacement bracket to the body of the trap to keep the wire away from the body, and held in position where the tip of the wire will be reliably set in the center of the hinge tab.

5.3 Design Changes

This section outlines the differences between the initial design seen in Fig. 11 and our final design. The main difference is how the door opens by the connection of the trigger mechanism. The initial design had the trigger on the top going through the door, but the final design had a door with a winged hinge where the trigger mechanism held up the winged part of the hinge on the side of the PVC tube. The hinge changed from circular to square, so the glued connection between the door and hinge was more secure. The "bait gate" (the translation sliding door the rat pushes back to set the trigger off) changed from slotted to a door with a lot of holes. A track was glued around the trigger mechanism to ensure it slides in a straight line and always comes in contact with the wing of the hinge. We also glued little pieces of PVC behind the bait gate, so the door can only slide back a certain distance and doesn't rotate. We added feet to the bottom of the PVC tubing, so the model stands upright and doesn't tip. Our final modification was adding a PVC end cap to enclose the bait (food) and complete the model!

6 Design Refinement

6.1 Model-Based Design Decisions

6.1.1 Component #1: The Hinge

The hinge of our device was specifically manufactured in a way where it could simultaneously function as a hinge for the door and the method by which the trap is actually tripped. The height of the hinge was important so that the door, when set, would rest as high up into the trap as possible so the rats would not interfere with it when entering the trap. The hinge also has a tab on the outside of the body of the device that acts as the tripping mechanism as previously displayed in Fig. 21. The hinge was the final component redesigned after testing to ensure durability when stressed in non-uniform situations. A piece of 1/16" steel was inserted in the hinge tab to increase structural strength and prevent the piece from breaking. Fig. 22 below shows the new tab design of the door hinge.

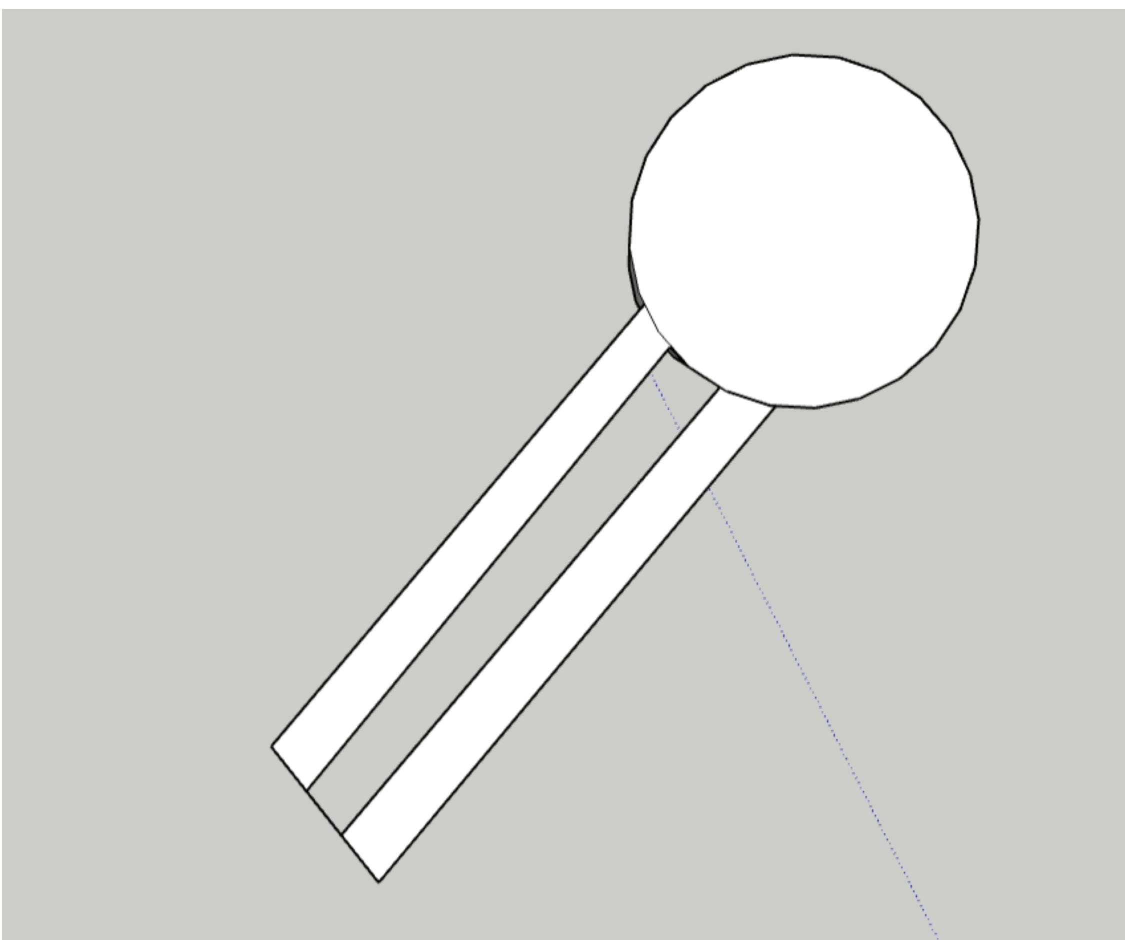


Figure 22: Redesigned Hinge Tab

6.1.2 Component #2: The Bait Gate

The Bait Gate was engineered to be as light as possible while also being strong enough to not allow the rat to push it. To accomplish this, we 3D printed PLA with a hollow inside and with many holes in it. The holes saved weight while also allowing the smell of the bait behind it to waft out and attract the rats. The Bait Gate is shown below in Fig. 23.

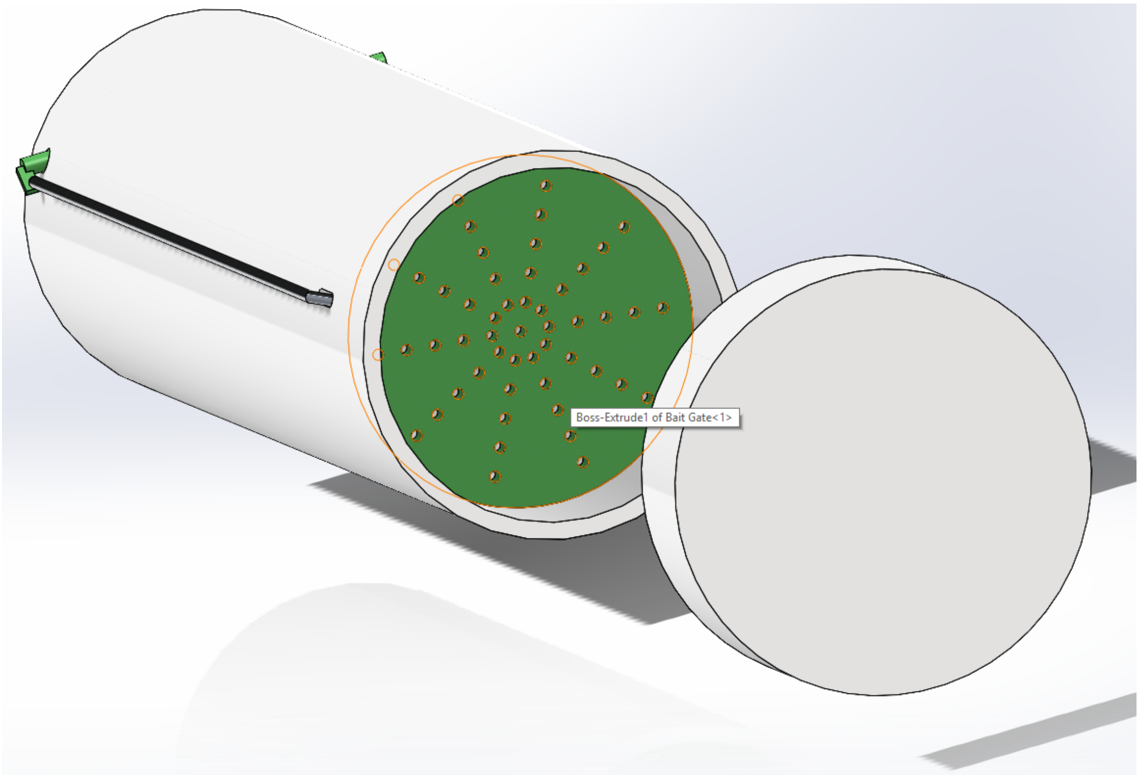


Figure 23: Bait Gate inside system

6.1.3 Component #3: The Door

The door of the trap is perhaps the most important part as it must be functional enough to be open and close when tripped without allowing the rat to escape. Its shape is a unique shape designed specifically to fit to the curvature of the inside of the body when in its "set" position so to be as streamlined as possible. After being tripped, the door falls down and due to its size, it holds itself from pushing back out and pivoting open. The curvature that was required from above also provides the benefit of the rats not being able to reach the front of the door to pull it open if they tried.

6.2 Design for Saftey

To ensure our rat trap was safe for use, we analyzed 5 different risks. The risks were then examined for frequency and severity. Our risks are all well under control!

6.2.1 Risk #1: Wire Cuts User

Description: Metal wire trigger mechanism cuts user when setting or handling the trap.

Severity: Marginal because the wire isn't very sharp.
Probability: Seldom because the trap is easy to set without touching the wire.
Mitigating Steps: Cover the metal wire with a PVC pipe.

6.2.2 Risk #2: Wire Cuts Rat

Description: Metal wire trigger mechanism cuts rat when rat is caught in the trap.
Severity: Marginal because the wire isn't very sharp.
Probability: Unlikely because the rat has minimal access to exposed wire.
Mitigating Steps: Have the wire on the outside of the trap, so the rat can't hurt itself.

6.2.3 Risk #3: User Pinches Fingers in PVC Holes

Description: User pinches their finger in the holes of the PVC body of the trap.
Severity: Negligible because the pinch would have little force behind it.
Probability: Unlikely because the trap is easy to set without touching the holes.
Mitigating Steps: Place PVC coverings over the holes.

6.2.4 Risk #4: User Pinches Fingers in Door/Hinge

Description: User pinches their finger in the holes of the door and hinge.
Severity: Negligible because the pinch would have little force behind it.
Probability: Seldom because the gap between the door and hinge is small.
Mitigating Steps: Make the gap between the door and hinge even smaller, and allow the trap to be set without coming in contact with the gap.

6.2.5 Risk #5: Unsanitary PVC Body of Trap

Description: Unsanitary trap/ risk of infection after releasing rat.
Severity: Critical because the user can become very sick from the diseases of the rat.
Probability: Unlikely because the rat won't be in the trap long.
Mitigating Steps: Ensure the user wears gloves, and make the material easy to clean like PVC.

		Probability that something will go wrong				
	Category	**Frequent** Likely to occur immediately or in a short period of time; expected to occur	**Likely** Quite likely to occur in time	**Occasional** May occur in time	**Seldom** Not likely to occur but possible	**Unlikely** Unlikely to occur
Severity of risk	**Catastrophic**					
	Critical					Unsanitary PVC Body of Trap
	Marginal				Wire Cuts User	Wire Cuts Rat
	Negligible hazard presents a minimal threat to safety, health, and well-being of participants; trivial				User Pinches Fingers in Door/Hinge	User Pinches Fingers in PVC Holes

Figure 24: Heat Map of Risk Assessment

The Heat Map above shows that our risks are completely taken care of. They all fall under the green category of not posing a risk. The most prominent risk is the sanitation of the PVC body of the trap once the rat is released. The rats can carry diseases that the user and the next rat don't want to become infected with. The second most important risk is the wire cuts the user and then the wire cuts the rat. These are important because the wire is mostly covered with a smaller PVC but can still stab the user. The last 2 risks both involve the user pinching oneself on the door/hinge and the holes in the PVC body. The force behind the pinch would be minimal because the sliding parts have minimal weight.

6.3 Design for Manufacturing

Our Current Design has 8 components and 0 threaded fasteners: The trap body, the trap door, the door hinge pin, the end cap, the bait gate, the steel wire, the wire bracket, and the wire cover.

All of the components listed above are theoretically necessary. The trap door must be separate from the door hinge pin for assembly. The pin is inserted through holes in the body and the door itself. Both of these components must also be separate because the door will be 3-D printed, and the pin will be machined from aluminum. The wire must be separate from the bait gate because the bait gate is 3-D printed and the wire is made from steel.

The only components that could be combined would be the wire cover and the wire bracket, which I could combine if I 3-D printed the two as a single piece. This would reduce the number of TNCs from 8 to 7.

6.4 Design for Usability

Our device should be usable for all people regardless of optical capability. The entire device is one color, white, so colorblind people should have no trouble with it at all, and the procedure of setting the trap is performed entirely by touch, so any sort of optical impairment should not impede the use of the trap.

There is no audio component to the setting or use of the trap. The process of setting the trap is done entirely by feeling, and knowing when the trap is occupied could be done by weight up close, and by sight, by whether or not the door is up or down, from far away. Hearing impaired people should have no problem using the trap to its full capacity.

Limb-impaired people or people with weak limbs or arthritis may have trouble setting and using the trap. the trap is slightly heavier than 10 lbs, which could be too much for an weakened individual to safely manipulate and carry. A person without two arms would likely have significant difficulty in setting the trap on their own. A jig which could hold the door up while the bait gate is pushed into place could assist a person with one arm while setting the trap.

People with control impairments should be able to operate the trap, as long as they are able to walk around and use their arms. The operation of setting the trap requires only a force to hold the door up, and a force to push in the bait gate. These do not require any fine motor skills, or attention to detail. A person distracted, or impaired in some way should still be able to operate the trap.

7 Final Prototype

7.1 Overview

Our trap is designed to captured the African Giant Rat in central Africa in a manner that does not harm them. The final design selected underwent many prototypes before working out the bugs and issues that needed to be addressed. Most of these could not be worked out prior to construction and required real-world testing. A complete part listing is included in Appendix A. Detailed build plans are also included in Appendix B. Overall, we are very pleased with out design and hope it greatly assists Dr. Braude with capturing these important rats to be used in extensive landmine detection.

Bibliography

[1] apopo.com. Sept. 10, 2020. URL: apopo.org/en.

[2] Matweb.com. *PVC, Extruded*. URL: http://www.matweb.com/search/DataSheet.aspx?MatGUID=bb6e739c553d4a34b199f0185e92f6f7.

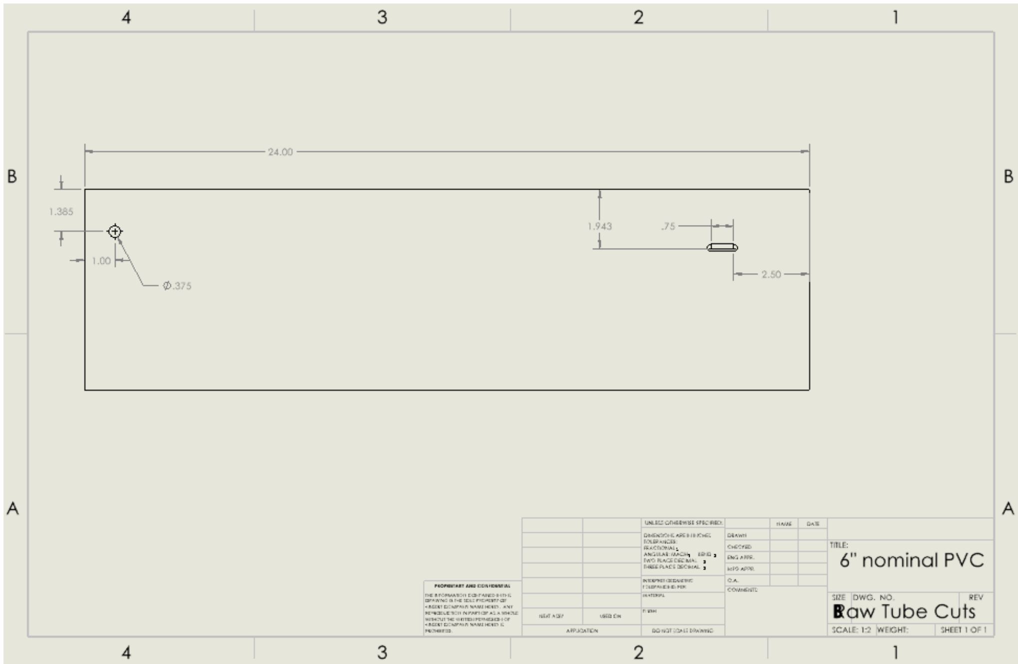
A Parts List

	Part	Source Link	Supplier Part Number	Color, Modifiers, Other ID's	Unit Price	Quantity	Total Price
1	Body	Lowes	#PVC 04600 0600	White, 6" PVC	$ 66.92	1	$ 66.92
2	Door Hinge	3D Printed	N/A	Black, Printed from PLA	$ 1.00	1	$ 1.00
3	Hinge Insert	Lowes	Model #11758	1/16" Steel Sheet Metal	$ 9.82	1	$ 9.82
4	Door	3D Printed	N/A	Black, Printed from PLA	$ 1.00	1	$ 1.00
5	Bait Gate	3D Printed	N/A	Black, Printed from PLA	$ 1.00	1	$ 1.00
6	Wire Trigger	Lowes	Model #11630	3/16" Steel Rod	$ 3.98	1	$ 3.98
7	End Cap	Lowes	#PVC 00116 1400	White, 6" PVC Cap	$ 18.93	1	$ 18.93
8	Wire Cover	Lowes	Model #PVC 07100 0600	White, 1-1/4" PVC	$ 10.96	1	$ 10.96
9	Washers	Lowes	Model #270067	1/2" Flat Washer	$ 0.22	2	$ 0.44
10	Pipe Straps	Lowes	Model #AV301383	4 pack, steel	$ 1.81	1	$ 1.81
11	JB Weld	Lowes	Model #50176H	Quick-setting Epoxy	$ 6.98	1	$ 6.98
12	Spray Paint	Lowes	Model #254146	Flat Black	$ 4.98	1	$ 4.98
TOTAL							$ 127.82

B Build Plans

Giant African Rat Trap Plans

1. Print all 3D parts with the included .stl files from PLA
2. Cut the 6” PVC to the dimensions below



3. Cut the 2” PVC to a length of 21” and cut it in half lengthwise
4. Cut a ½” x ½” piece from the 1/16” steel sheet metal to be used in the tab
5. Cut an additional 2” from the 6” PVC stock and cut into fourths to be used as feet
6. Cut 2” off of the open end of the 6” PVC end cap and use a drum sander to sand the inside surface down to easily slide on and off of the body
7. Insert the steel rod into the bait gate, through the body, and mark where to add a 90º bend and where to cut the end for the door hinge tab and proceed to do both
8. Epoxy the steel insert into the tab portion of the hinge
9. Insert the door and door hinge into the front of the body and line the steel rod up with the hinge so it works properly in both the “set” and “tripped” positions, mark this position
10. Use the JB weld to epoxy the rod into the bait gate and align the rod with the marks made in the above step
11. Place the two washers on the rod and between the two pipe straps so the rod still is aligned with the door hinge properly
12. Epoxy the pipe straps down to the body in the correct positioning
13. Remove the door hinge and add epoxy to the locations where it contacts the door
14. Epoxy the 2” PVC wire cover over the entirety of the rod and hinge-tab locations
15. Epoxy the 4 feet onto the outside of the body on the bottom to stabilize the trap when standing
16. Spray paint the entire trap black