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An Improve Naked Mole Rat Trap, Group III

Spencer Egly
Washington University in St. Louis

Ted Daley
Washington University in St. Louis

Andrew Thompson
Washington University in St. Louis

Washington University in St. Louis
SCHOOL OF ENGINEERING & APPLIED SCIENCE

This project attempts to improve on Dr. Stan Braude's current Naked Mole Rat trap design. Dr. Braude currently uses his trap to catch and tag naked mole rats for his research. While Dr. Braude is happy with his current trap, he designed them himself over twenty years ago, and believes that they can be improved and modernized for increased ease and convenience. The key project goal is to deliver an improved trap to Dr. Braude that will meet his needs. The modifications that this project will attempt to deliver are a repeatable, solar powered trap that is compatible with his current design.

MEMS 411 Design Report

Improved Naked Mole Rat Trap

Ted Daley, Spencer Egly, & Andrew Thompson

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1 INTRODUCTION

1.1 PROJECT PROBLEM STATEMENT

This project attempts to improve on Dr. Stan Braude's current Naked Mole Rat trap design. Dr. Braude currently uses his trap to catch and tag naked mole rats for his research. While Dr. Braude is happy with his current trap, he designed them himself over twenty years ago, and believes that they can be improved and modernized for increased ease and convenience. The key project goal is to deliver an improved trap to Dr. Braude that will meet his needs. The modifications that this project will attempt to deliver are a repeatable, solar powered trap that is compatible with his current design.

1.2 LIST OF TEAM MEMBERS

- Ted Daley, Washington University Class of 2017
- Spencer Egly, Washington University Class of 2017
- Andrew Thompson, Washington University Class of 2017

2 BACKGROUND INFORMATION STUDY – CONCEPT OF OPERATIONS

2.1 A SHORT DESIGN BRIEF DESCRIPTION THAT DESCRIBES THE PROBLEM

> "Naked mole-rats are mouse size rodents that live in underground colonies in East Africa. They are best known for having a queen and workers like bees. I have been studying them in Kenya and Ethiopia for over 25 years and have trapped over 10,000 of these animals and marked and released them. I am the world expert at trapping naked mole-rats and yet I need a better trap. I am looking forward to working with a team of real engineers and designers who can help me in this project." – Dr. Stan Braude

We look to improve the design of Dr. Braude's current naked mole rat trap. The trap should be able to catch multiple rodents and be solar powered. The trap must continue to be modular even with the modifications, and can withstand multiple days of consecutive rodent trapping in the African desert environment.

The trap should be solar powered because currently, the electronic versions run using 4 D-Cell batteries, which are expensive and difficult to transport to various dig sites. Solar energy is very abundant in the African desert, and will be cheaper and more sustainable. The trap being modular and durable is very important for transportation and cost purposes, and our modifications should not change these characteristics of the existing traps.

2.2 SUMMARY OF RELEVANT BACKGROUND INFORMATION

Existing Design 1:

Dr. Braude is currently using two versions of a similar trap: a mechanical version and an electrical version. The electrical version is shown below in figure 1.

Figure 1: Dr. Braude's current electrical trap

The mechanical version is very similar, but works using a lever arm attached to a needle which props up the door, as opposed to an electric motor.

Existing Design 2:

A similar trap that is used to catch other rodents, such as mice or rats, is a ramp based multiple catch trap. It entices the rodents to climb a ramp and descend into a holding area, which they then cannot escape. One such trap is the Tomahawk Multiple Catch Trap, which is picture below in figure 2.

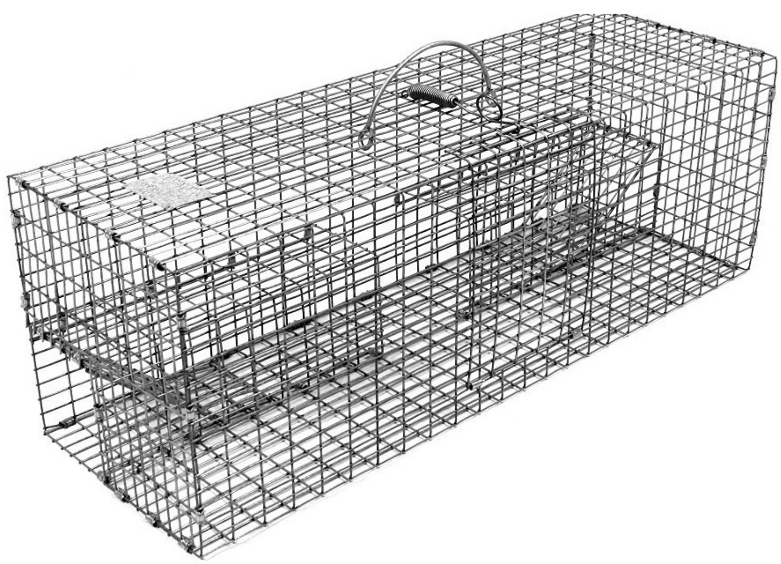


Figure 2: Model MH35 Tomhahawk Multuple Catch Trap

Although this trap is not a direct competitor to Dr. Braude's current trap, because it cannot operate below ground or simulate the feel of a mole rat tunnel like the current trap design does, it does effectively catch other rodents, and it catches multiple rodents without having to be reset, which is a desirable trait for our modifications of Dr. Braude's trap.

3 CONCEPT DESIGN AND SPECIFICATION – DESIGN REQUIREMENTS

3.1 OPERATIONAL REQUIREMENTS ALLOCATED AND DECOMPOSED TO DESIGN REQUIREMENTS

3.1.1 List of identified operational and design requirements

- Trap must have a repeatability element
- Trap must be solar powered
- Trap must be modular

3.1.2 Functional allocation and decomposition

- Arduino needs to power motors for repeatability to work. That means the Arduino is going to needed to be coded with the proper logic. Additionally, the proper circuit system must be set up so the Arduino can work correctly.
    - Motors must rotate enough to raise and lower trap correct amount
    - String must be strong enough to lift the trap
- Solar powered trap means rechargeable batteries must be used. A diode is necessary to control the current flow from the solar panel and the battery to the Arduino.
- Modularity means all current components must be compatible with Dr. Braude's current design.
- Trap must be able to trap multiple naked mole rats without having to be reset each time.
- Trap must be durable enough to be transported from the U.S. to the deserts of Ethiopia, on a plane and in a bumpy car ride.
- Trap must be able to be taken on plane
- Trap must be able to catch both a baby naked mole rat and a queen naked mole rat, so it must be applicable to naked mole rats in a range of sizes

3.2 FOUR CONCEPT DRAWINGS

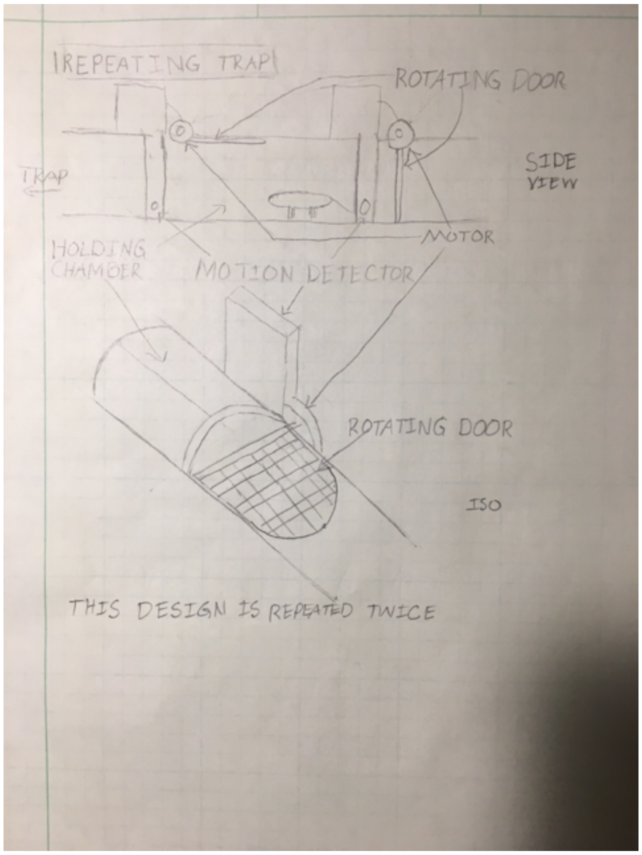


Figure 3: Concept 1

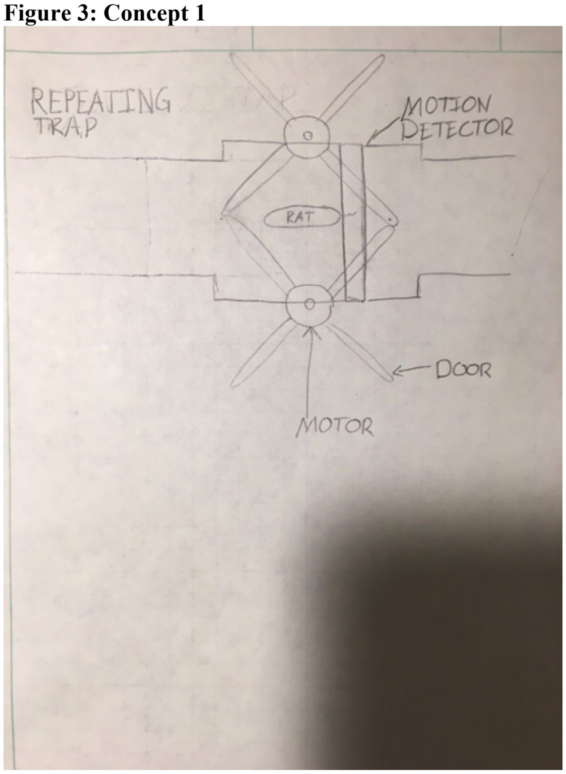


Figure 4: Concept 2

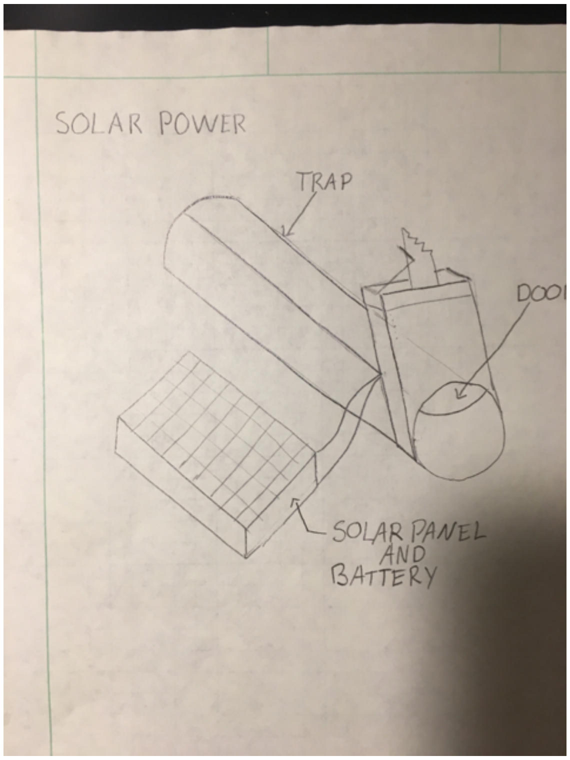


Figure 5: Concept 3

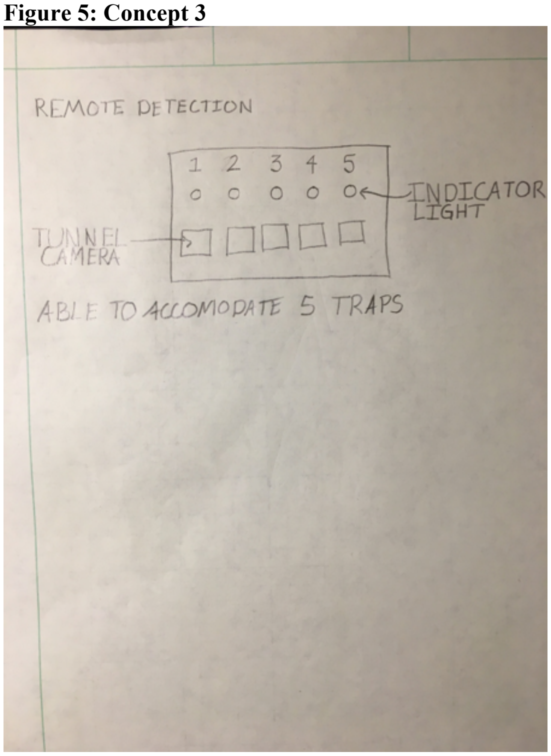


Figure 6: Concept 4

3.3 CONCEPT SELECTION PROCESS

Concept 1: Two-door repeatable trap

This is the more expensive option, because it requires two motors to power the doors. Both motors could be powered by one motion sensor, so that when the inside door closes, the outside door opens, and vice versa, but doubling the parts could be expensive. In addition, there is a risk that if the naked mole rat is held in the back chamber, when another rat enters the trap and the outside door shuts, if the inside door opens, the trapped rat could re-enter the entrance chamber, and then exit the trap if the outside door opens. A fix to this would be writing a code so that once a rat is trapped in the farthest back chamber, the door to that chamber would stay closed. This would reduce the number of rats able to be trapped, but also reduce the chance that they escape the trap. This design requires a motion sensor and two motors (or more for more chambers), as well as a piece of material for the door, likely rubber or some other material that can contour to the shape of the top of the trap, but still keep a naked mole rat trapped once the rat is behind the door.

Concept 2: Revolving door repeatable trap

This concept may be difficult to achieve due to the size of the tunnel in which it would reside in. The trap diameter is only 1.75 inches, which means that the arc length is only ¼ of the circumference of the trap. This means that it may be too small to trap a queen naked mole rat, which can be up to 6 inches long. The trap must be able to catch both babies and queens, so the difficulty with a revolving door idea is that if it is too long, a baby can escape, but if it is too short, trapping a queen might be difficult. This design one motor which is capable of powering two outputs, the revolving doors on each side of the trap. A revolving door on each side of the trap is required to lessen the chance that the rat can escape before the door finishes closing. Having two doors also reduces the likelihood that a rat gets trapped between the door and the wall, as the two doors could push the rat into the next chamber. The doors must be programmed so that once closes slightly after the other, so the doors could be slightly larger than half of the area of the tunnel.

Concept 3: Solar Powered Trap

This design is fairly simple, and can be integrated into any of the other designs that we have created for the repeatable trap. A solar panel is required for this design, and it must be as small as possible in order to be easily transportable and easily mounted onto the trap in the field. The solar panel will also have to be attached to a battery, which will power the trap at night when the sun is down. The power will then run through to the motor (or motors). The risk of this design is that if the solar panel breaks during transportation, it might be expensive and time-consuming to fix and replace. Additionally, it will have to be above ground in order to catch the most sunlight, and could attract larger animals, which could damage the trap or some of its components. However, this design does completely reduce the need to carry external batteries, which should lessen the cost of the trap, the amount of materials which need to be brought on each trapping expedition, and the total cost of an expedition, assuming the solar panel does not get damaged or lost.

Concept 4: Remote Detection

This concept reduces line of sight dependency for Dr. Braude or any other trap user. It adds costs, because each trap needs to have a transmitter and a corresponding receiver on the signal board. A risk for this concept is our group's lack of programming knowledge. It may be hard for us to deliver a product; given that we may struggle to program the system correctly. However, once the system is programmed, it should meet the design requirements. The transmitter would be triggered by the door in the trap closing on a rodent. Additionally, a second transmitter could signal to the trapper if the tunnel had become blocked or obstructed, but that would require a motion sensor or some sort of light detector, which would add more costs. This concept could also be integrated fairly easily into either of the repeating trap designs.

Winner: Concept 1, with concepts 3 and 4 integrated into the design

The two door repeating trap concept has many advantages over the revolving door concept. It is safer for the rats, and can catch either a baby or a queen naked mole rat, while the revolving door concept might sacrifice the ability to catch a rat on either end of the size spectrum. It could also be expanded to be able to catch more rats. The compartments would be modular, which fits with the current design and design requirements, and more compartments with more doors could be added to the end of the trap to catch more rats. This would be especially useful at night, when the trap is not being emptied and reset constantly. This would require the motors that power the door to be easily set and attached to the main logic board, and the logic would have to be able to account for different numbers of holding compartments. Concepts 3 and 4 could easily be integrated into concept 1, to meet all design requirements. The solar panel would charge up a battery for night use, and power the motors connected to each vertically oriented door. The doors could each have a sensor which would transmit a signal to the master switchboard when it closes. The risk for this project is coding and cost: the logic for the doors to close when triggered by a motion sensor will be difficult for our level of coding knowledge, and each motor, sensor, and transmitter will add to the cost of the trap. However, this design meets every design requirement and should keep the trap's current modular status. Transportation should not be an issue as long as the solar panel is handled carefully. The trap may take a bit longer to set up with these modifications, but that negative should be outweighed by the fact that the user will not have to rush to empty and reset the trap, since they will be capable of trapping multiple rats.

3.4 PROPOSED PERFORMANCE MEASURES FOR THE DESIGN

- **Is there a demonstrable repeatability element?**
- **Is there a solar panel that can fully power the trap without battery assistance?**

3.5 DESIGN CONSTRAINTS

3.5.1 Functional

- **Repeatability:** Trap multiple rats at once
- **Modularity:** Design must be able to work with existing design and other groups' designs.
- **Solar Powered:** Incorporate solar power into the design.

3.5.2 Safety

- Trap must not harm the mole rats in any way shape or form.
- All parts must be able to safely be carried on to airplane for transportation.

3.5.3 Quality

- Traps must be able to withstand desert condition. Therefore quality of parts is paramount.

3.5.4 Manufacturing

- Large scale manufacturing is not a concern. Most parts will be 3D printed.

3.5.5 Timing

- Deadlines for prototyping and design must be met as part of the project.
- Timing mechanism in doors must work in order to ensure proper logic when trapping rats. Cannot allow mole rates to escape with bad door timing.

3.5.6 Economic

- Economic constraints are not a large concern for the project.

3.5.7 Ergonomic

- Final design should be simple to assemble and use. "Plug 'n play" is the goal so any person can set the trap.

3.5.8 Ecological

- The mole rate trap with be used directly in the environment. Therefore, no harmful chemicals should be used in its design. All materials should be safe for animals handling.

3.5.9 Aesthetic

- No real aesthetic concerns.

3.5.10 Life cycle

- Design should be durable. A life cycle of at least 5 years is desirable.

3.5.11 Legal

- Design will be used in Africa. As far as we know, there are no specific laws regarding trapping of mole rats there. All local and federal laws should be obeyed when utilizing the trap.

4 EMBODIMENT AND FABRICATION PLAN

4.1 EMBODIMENT DRAWING

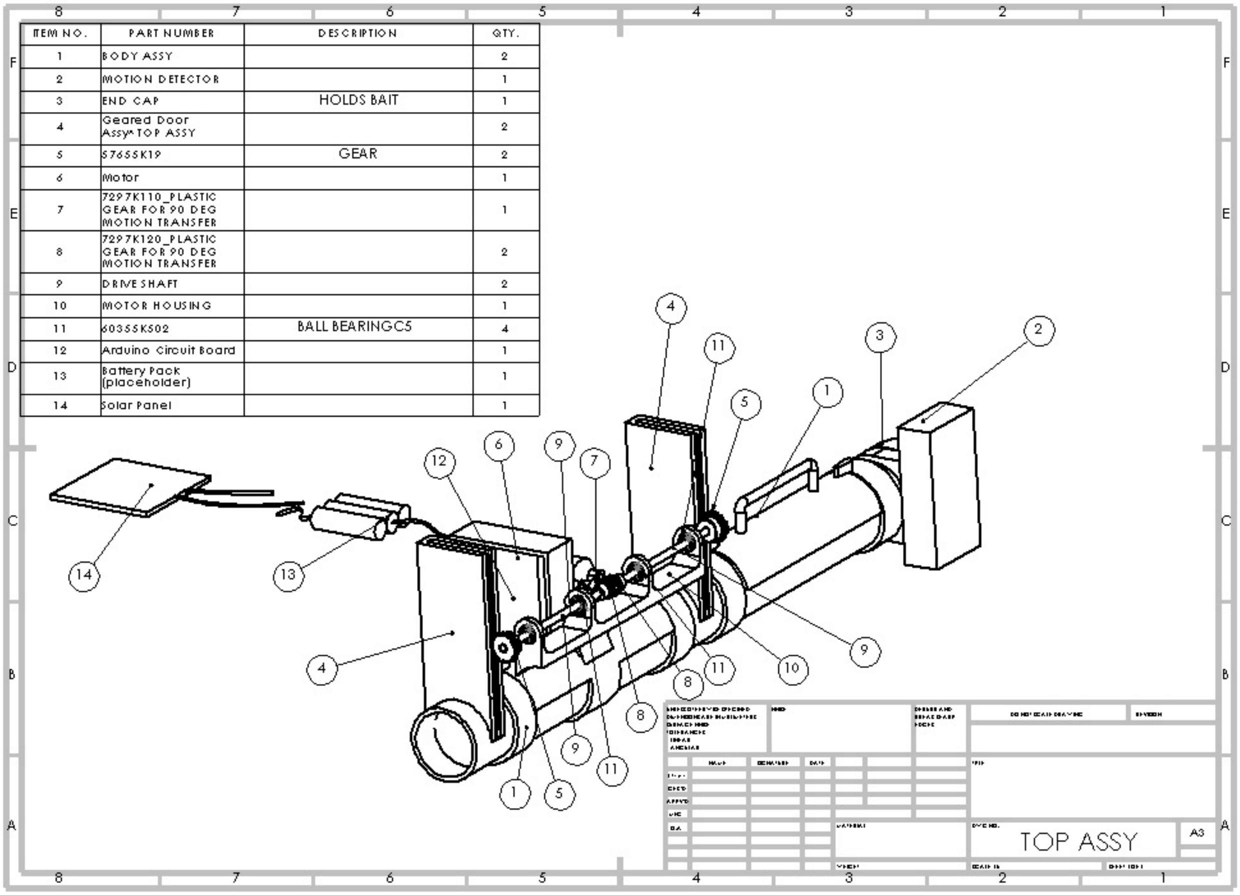


Figure 7: Top Assembly Drawing

4.2 PARTS LIST

See Appendix A

4.3 DRAFT DETAIL DRAWINGS FOR EACH MANUFACTURED PART

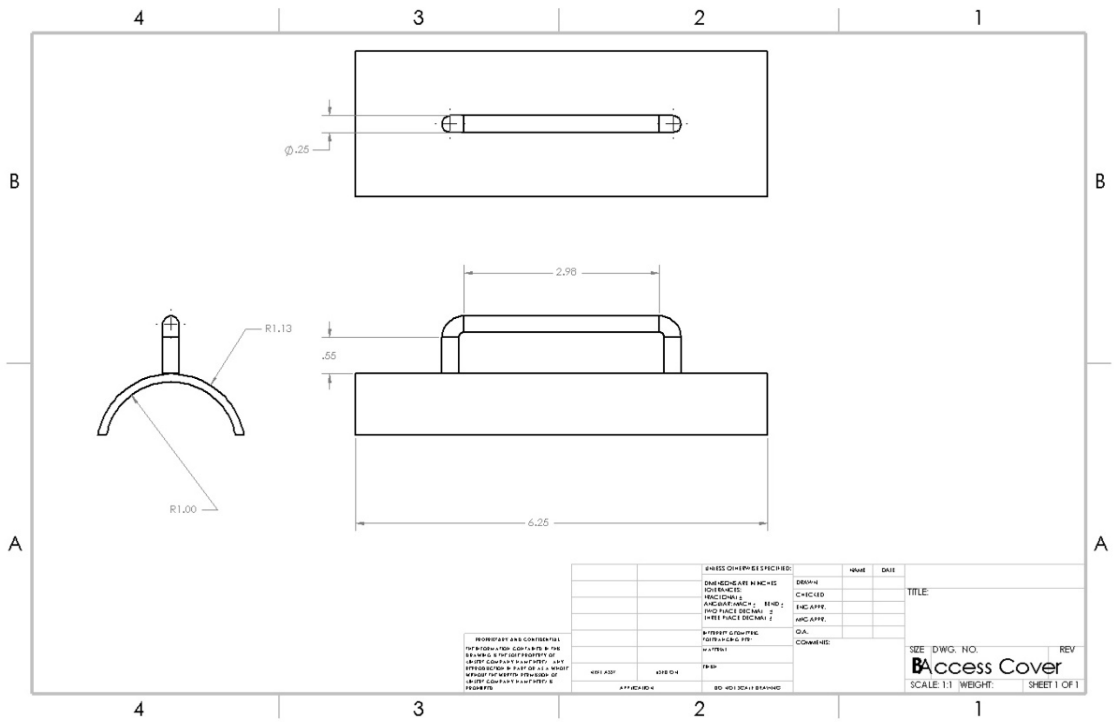


Figure 8: Access Cover Drawing

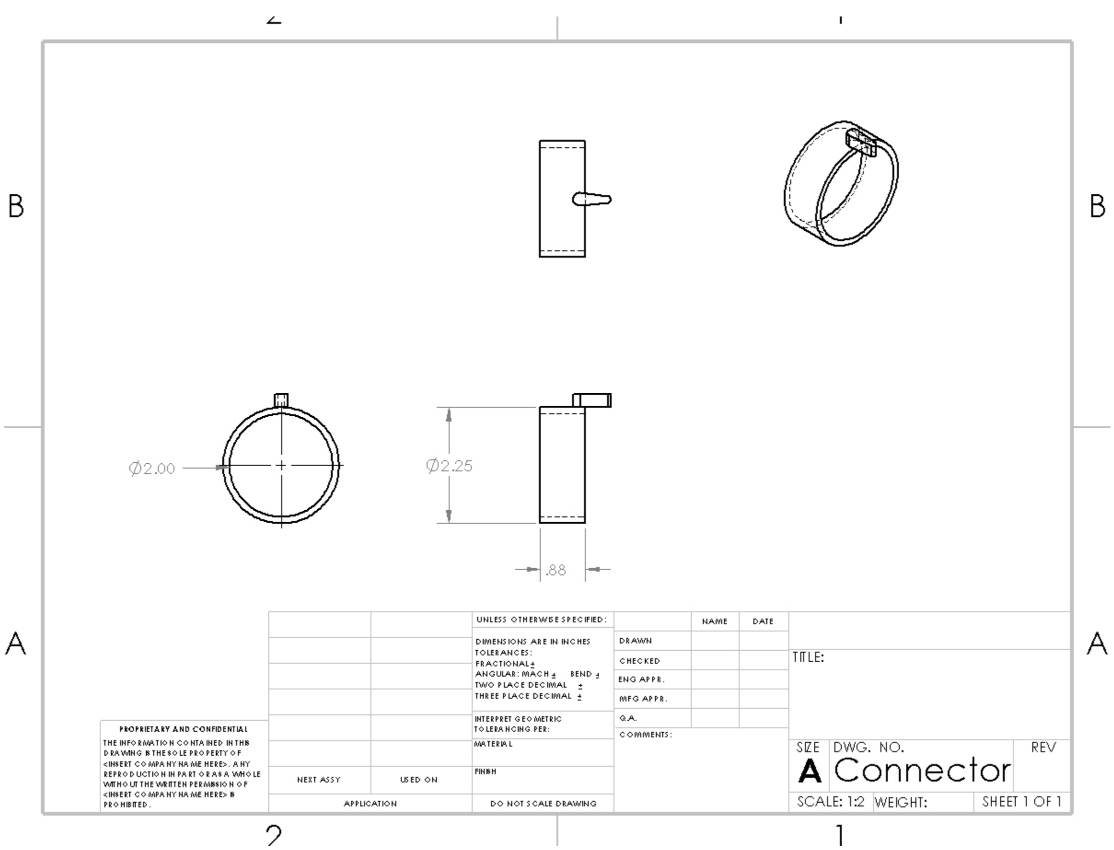


Figure 9: Connector Drawing

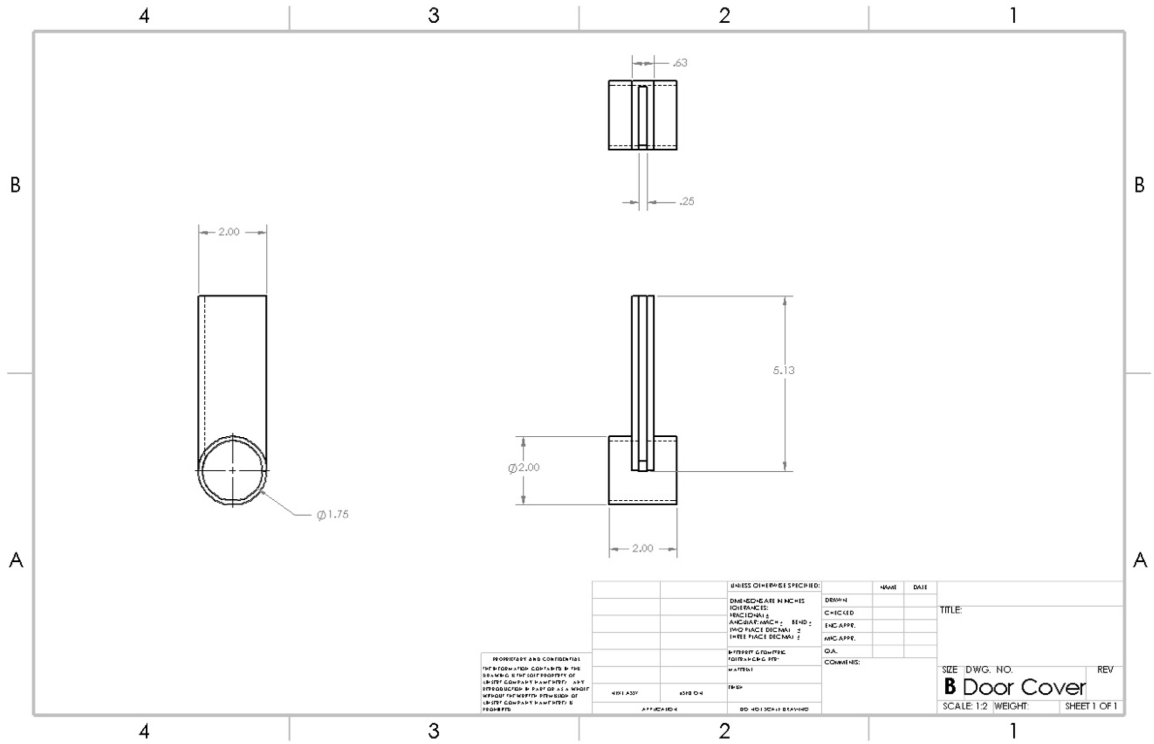


Figure 10: Door Cover Drawing

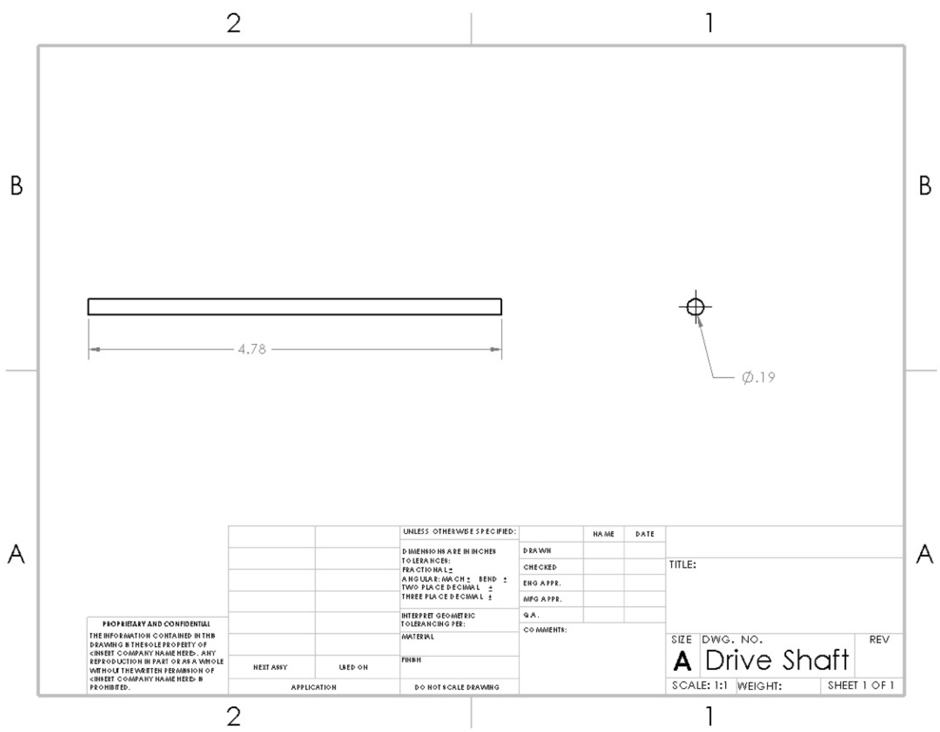


Figure 11: Drive Shaft Drawing

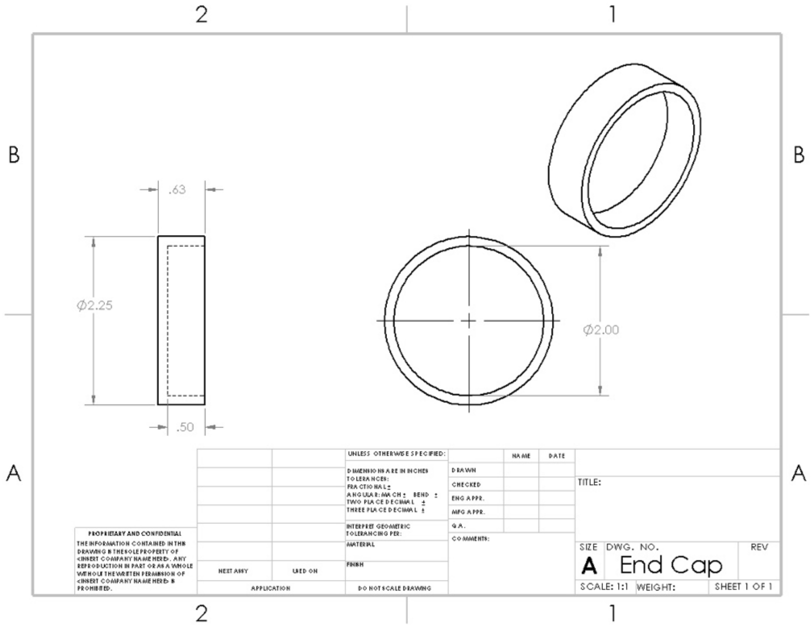


Figure 12: End Cap Drawing

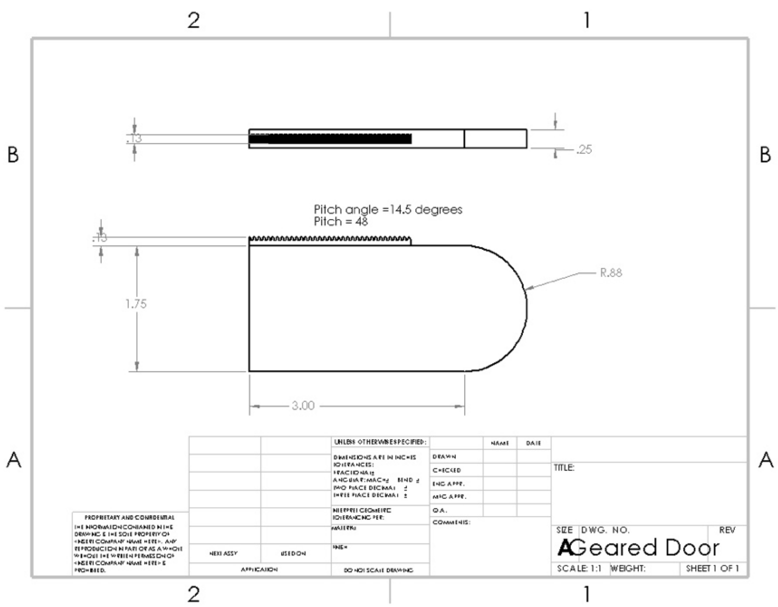


Figure 13: Geared Door Drawing

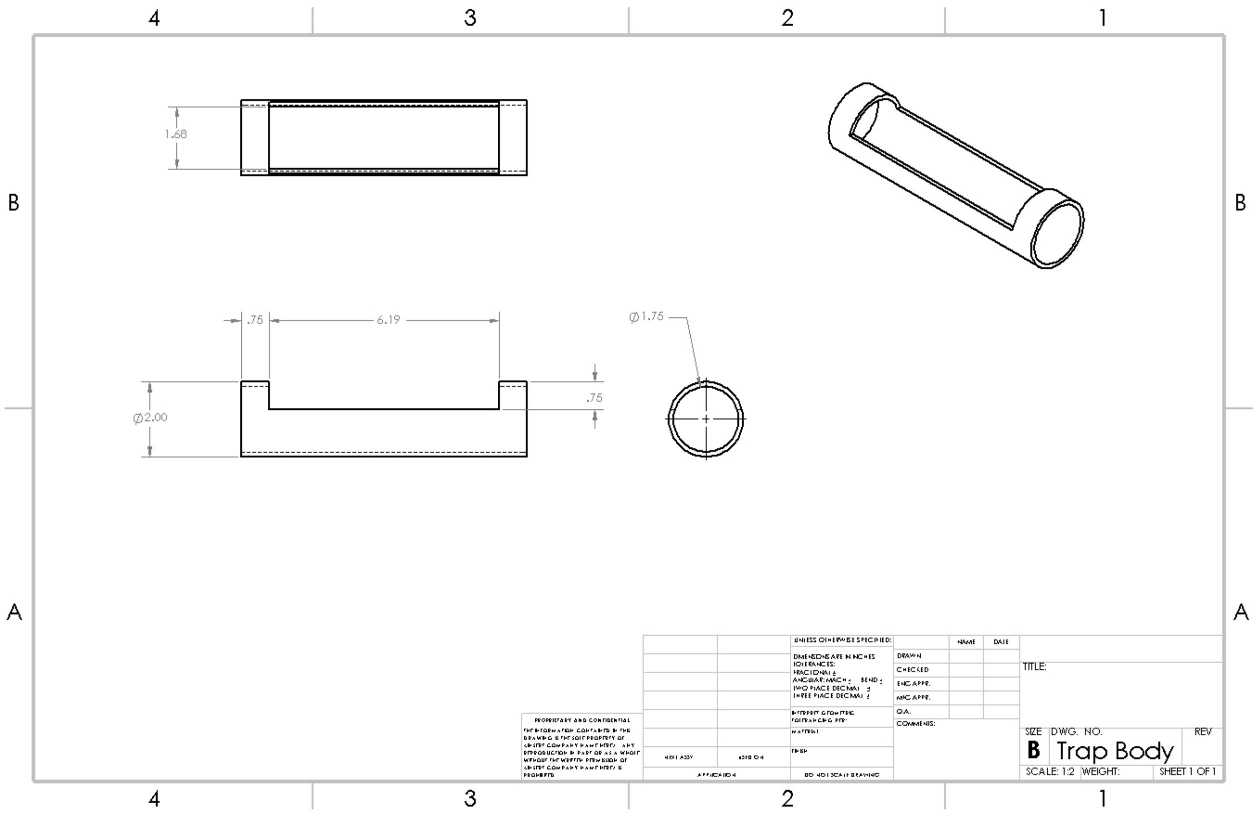


Figure 14: Trap Body Drawing

4.4 DESCRIPTION OF THE DESIGN RATIONALE FOR THE CHOICE/SIZE/SHAPE OF EACH PART

Correcting the motion of the doors: One door must go up as the other goes down. Therefore, the motor attaches to two 90 degree gears, so that the shafts connected to each door through a gear will turn in opposite directions as the motor spins.

Design Rational by Part Number:

#1 – Trap Body: Dimensions were chosen to match Dr. Braude's existing trap to retain modular status. Prototype part will be 3D printed to save time and money.

#2 - Motion Sensors: Infrared sensors will be able to detect rats in the dark. This is a fairly cheap option, with an adjustable delay to allow the rat to pass through the door before transmitting the signal to the logic board.

#3 – End Cap: Dimensions chosen to match existing trap.

#4 – Geared Door: Dimensions chosen to match existing door. Gears fit to part #5. Will be 3D printed.

#5 - Door gear assembly: Pitch matches the gears of the door, and plastic is lighter weight than metal. Housing keeps the door gears free of dirt while submerged.

#6 - Motor: RPM fit with the requirements for our system, and the small size allows for easy transportation and assembly.

#7 - Motor Gear: Shaft diameter is 1/8" to match motor stem diameter.

#8 - 90° angle shaft gear: These allows the doors to move in opposite directions as the motor turns. Pressure angle must be 20° in order to transmit motion at desired angle. Plastic gears are chosen to reduce weight. Shaft diameter is 3/16" to match shaft.

#9 - 3/8" Shaft: Shaft diameter fits our chosen gear. Will be 3D printed to save money.

#10 – Motor Housing: Keeps the motor from getting damaged by dirt, weather, or other animals. Prototype will be 3D printed.

#11 - Ball Bearings: Will allow the shaft to rotate without allowing translational motion.

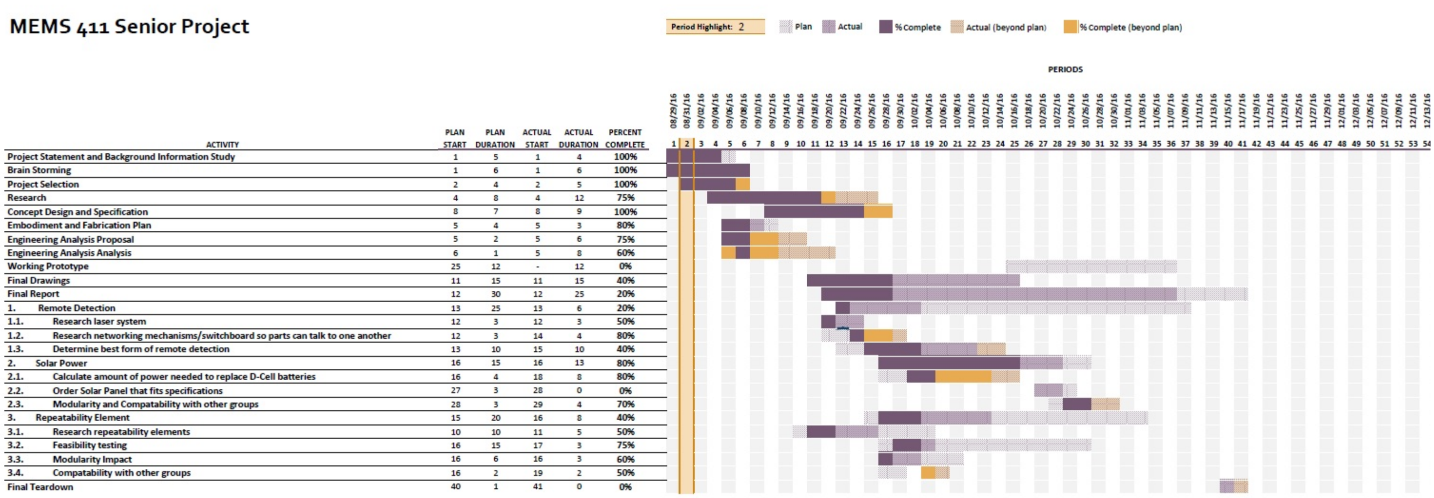
#12 - Logic Board: Picked Arduino pro due to its small size and low voltage requirement

#13 - Battery: Rechargeable means that the solar panel will charge it during the day and it can power the circuit at night. NiMH batteries can be taken in carry-on luggage, and the wattage is fairly high.

#14 - Solar Panel: Cheap option that should be easy to install. 2 panels will provide up to 24V, which should be enough to power the system.

 # 15 - Reverse blocking diode: This stops the solar panel from leaking current at night, when the voltage of the battery is higher than that of the panel. (Not shown in assembly)

4.5 GANTT CHART



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Project Statement and Background Information Study	1	5	1	4	100%
Brain Storming	1	6	1	6	100%
Project Selection	2	4	2	5	100%
Research	4	8	4	12	75%
Concept Design and Specification	8	7	8	9	100%
Embodiment and Fabrication Plan	5	4	5	3	80%
Engineering Analysis Proposal	5	2	5	6	75%
Engineering Analysis Analysis	6	1	5	8	60%
Working Prototype	25	12	-	12	0%
Final Drawings	11	15	11	15	40%
Final Report	12	30	12	25	20%
1. Remote Detection	13	25	13	6	20%
1.1. Research laser system	12	3	12	3	50%
1.2. Research networking mechanisms/switchboard so parts can talk to one another	12	3	14	4	80%
1.3. Determine best form of remote detection	13	10	15	10	40%
2. Solar Power	16	15	16	13	80%
2.1. Calculate amount of power needed to replace D-Cell batteries	16	4	18	8	80%
2.2. Order Solar Panel that fits specifications	27	3	28	0	0%
2.3. Modularity and Compatability with other groups	28	3	29	4	70%
3. Repeatability Element	15	20	16	8	40%
3.1. Research repeatability elements	10	10	11	5	50%
3.2. Feasibility testing	16	15	17	3	75%
3.3. Modularity Impact	16	6	16	3	60%
3.4. Compatability with other groups	16	2	19	2	50%
Final Teardown	40	1	41	0	0%

Figure 15: Gantt Chart

5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS PROPOSAL

5.1.1 A form, signed by your section instructor

N/A

5.2 ENGINEERING ANALYSIS RESULTS

5.2.1 Motivation

The most important engineering analysis done is the path of the guillotine door in the door assembly, and the placement of the motion detectors in the cover. The guillotine door must be free to slide up and down freely. Because gravity is the sole reason the door falls, it is a considerable risk that the door will jam. By animating the path of the door, potential sources of jamming can be visualized and eliminated.

The placement of the motion detectors is imperative in the accuracy and safety of the trap. Three motion detectors are used to trace the movement of the rat through the tubes. The motion detectors must have complete coverage of the tubes and the doors. By knowing the area in which the motion detectors can cover, the quantity and placement of motion detectors can be determined.

5.2.2 Summary statement of analysis done

For the guillotine door, a linear motion motor was used to simulate the up and down movement of the door. The time it takes for the door to rise, is reflective of the real world. The total travel time of the door was calculated by discovering the time it took for one revolution, and multiplying that by the fraction of drive shaft circumference and the total path travel.

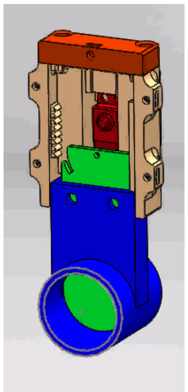


Figure 16: Door Assembly Model

When analyzing the motion detectors, a cone was calculated that reflected the region the motion detector could pick up. The formulas used a simple triangle to understand the spacing and the area of influence. The surveillance area can be calculated by multiplying the distance of the detector from the bottom of the tube by the tangent of the half angle. If this value is doubled, it yields the projected vertical horizontal distance the motion detector will cover. It is safe to assume that most mole rates will move near the bottom of the tube.

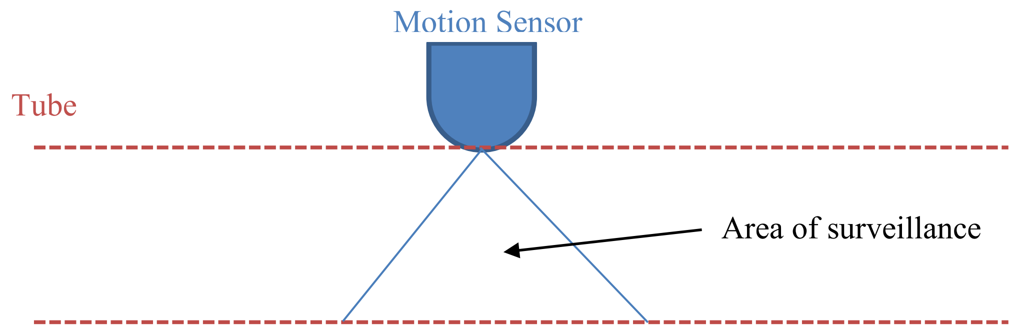


Figure 17: Motion Sensor Area of Surveillance

5.2.3 Methodology

We first knew that the door needed to travel somewhere between 1.7 and 1.8 inches; the diameter of the tube was 1.75 inches. When programming our motor, we also knew that the motor must be set to run for a set amount of time, thus it was most important that we knew how long it took for the door to rise and fall. By finding the rpm of the motor and the circumference of the drive shaft, we could predict how fast our small motor could lift the door. Once determined, the door was constrained so that its top plane remained parallel to the ground and it sides perpendicular to the ground. A linear motor was set in Solidworks Motion for the desired amount of time.

To analyze the motion detectors, the sensor's cone of detection was calculated and projected down to a flat surface. We then decided that the sensors should overlap a little incase the sensor's cone of detection is weaker at its edges. From there, the sensors were arranged evenly in the cover to provide complete coverage of the trap.

After the simulation, there was enough confidence that real world experimentation was not required to move forward with the project. The math was done correctly and precisely and the results reflected that. The real fear remained that the door would jam, however we knew that part modifications could be performed after assembly to ease the friction between the door and its groove.

A test rig was not required for any engineering analysis required here.

5.2.4 Results

Our results predicted that the trap door will take 1.3 seconds to travel its full path. The reasoning behind this is described in the Methodology section. When programmed into SolidWorks motion, the door rose constantly for 1.3 seconds to the top of the tube. The door moved freely and without obstacles. This was promising as the door was then poised to be able to fall quickly without jamming.

The motion detectors have a horizontal coverage of about 6 inches. This is surprisingly large coverage distance that was unpredicted. After a group conversation, we decided it was best to still move forward with three motion sensors as having duplicate coverage was not harmful. In the coding phase, we could write a formula to average out the inputs, helping to protect the design from a singular sensor failure.

5.2.5 Significance

The results help to influence the final prototype by giving reassurance that the door will go up and down without complications and jamming. The tolerancing around the door seems to be

sufficient and sharp edge contact seems to be avoided. Since the door will be 3D printed, the roughness of external surfaces is unknown now. We do have contingency plans to smooth the door and the groove that it slides in to lower friction and help with friction. In regards to the house of the motor and the door, the current design seems to allow plenty of space for the door to travel in. No further design changes are necessary to the door.
The motion sensors can now be place evenly throughout the cover. Since overlap is inevitable, the location and placement of the sensors is no longer as important as the coding. An advanced formula must now be used to average the input from the sensors. The repetitiveness will be beneficial in the long run, helping to support sensors if one were to fail.

5.2.6 Summary of code and standards and their influence

From our codes, it is most important that the naked moles rats unharmed. If all else fails, there must be precautions taken to protect the life of the naked mole rat. This engineering analysis demonstrates this. Our motion sensor will have the adequate and repetitive ability to know the position of the naked mole rat always. If the right code is used, this will inhibit a door from falling on the rap, causing injury or death.

5.3 RISK ASSESSMENT

5.3.1 Risk Identification

- Getting the Arduino Code to work correctly
- 3D printing lead time
- Hardware failure
- Circuit assembly
- Parts breaking during testing

5.3.2 Risk Impact or Consequence Assessment

- **Arduino code:** If the Arduino code does not function correctly then the doors will not be able to work and the trap will not work. The repeatability element with also be threatened. This is a very large concern for the group.
- **3D print lead time:** The risk associated with 3D printing lead time is strictly a schedule risk. We may not be able to meet deadlines if the lead time for 3D printing doesn't work out well.
- **Hardware Failure:** Depending on the hardware, we would have to order new parts which poses a schedule risk. If the Arduino or any other high priority hardware fails then the entire function of the trap may be in danger.
- **Circuit Assembly:** Successful circuit assembly means the Arduino and motors are operated correctly. Also necessary for solar power to charge the trap as well. Failure to design the circuit correctly would be quite detrimental to the completion of this project.
- **Parts Breaking During Testing:** Depending on the part, it would either need to be re printed or re-ordered, posing a significant schedule risk to the project.

5.3.3 Risk Prioritization

This risk assessment heat map indicates the priority breakdown of our risks. The more the risk is located towards the upper right quadrant, the greater threat that risk poses to the successful completion of the project.t

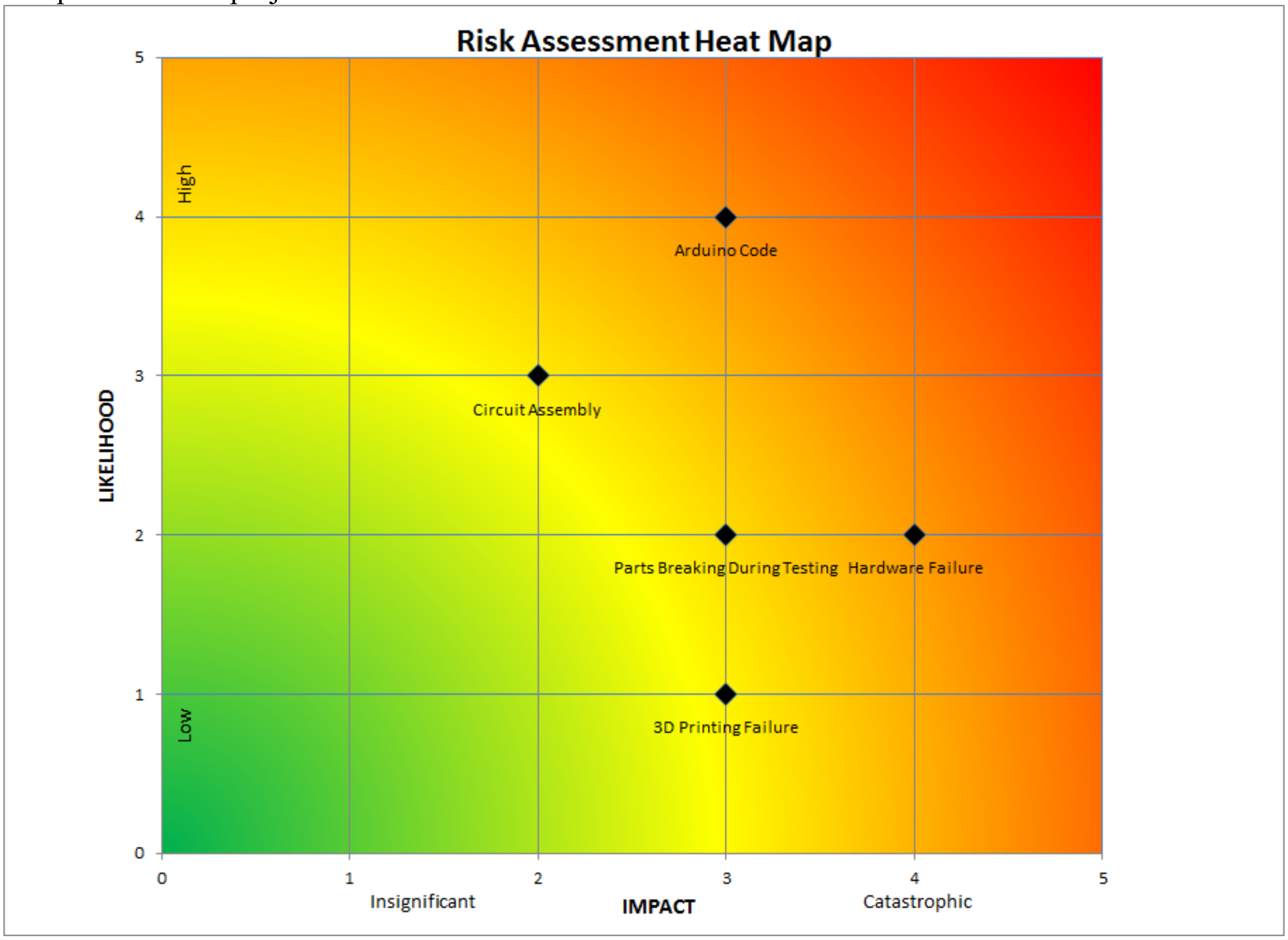


Figure 18: Risk Assessment Heat Map

6 WORKING PROTOTYPE

6.1 A FINAL DEMONSTRATION OF THE WORKING PROTOTYPE

Completed in class.

6.2 AT LEAST TWO DIGITAL PHOTOGRAPHS SHOWING THE PROTOTYPE

Figure 19: Full Assembly: Front View. Both Door Assemblies, with front door down and back door up

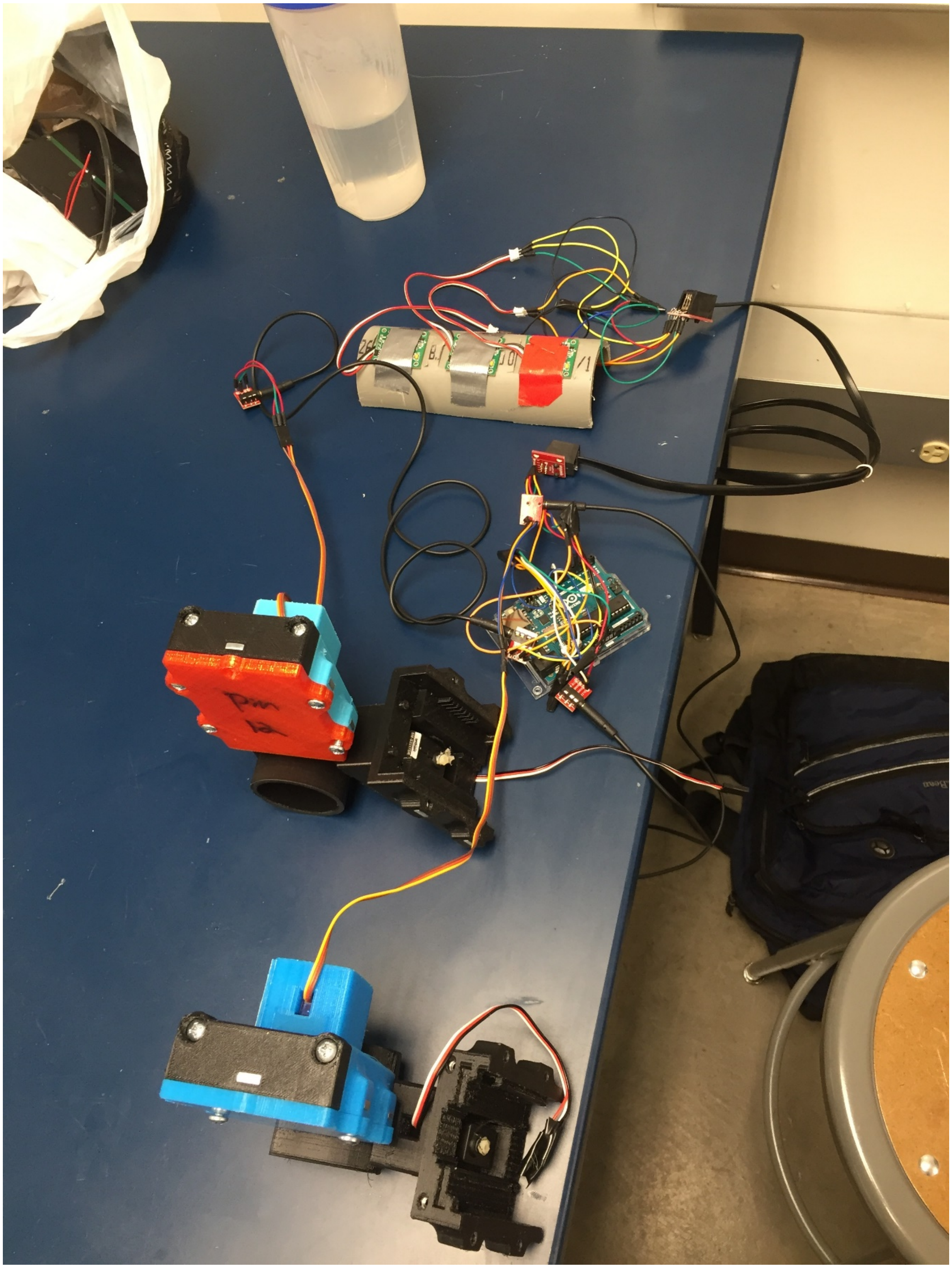


Figure 20: Full Assembly: Top View. Both door assemblies, connected to Arduino with auxiliary cables. Sensor Cover with motor sensors connected to Arduino using a phone cable.

6.3 A SHORT VIDEOCLIP THAT SHOWS THE FINAL PROTOTYPE PERFORMING

This video shows the front door descending as the back door ascends when the motion sensors are triggered in the correct order: the first sensor is triggered, then stops being triggered, and the second sensor is triggered.

https://www.youtube.com/watch?v=RrUiE0_73pw

6.4 AT LEAST 4 ADDITIONAL DIGITAL PHOTOGRAPHS AND THEIR EXPLANATIONS

Figure 21: The inside of the motor housing, showing the door and motor subassembly. The door is connected to the motor arm using thread that is looped over a shaft. The thread is tied to both the door and the motor arm.

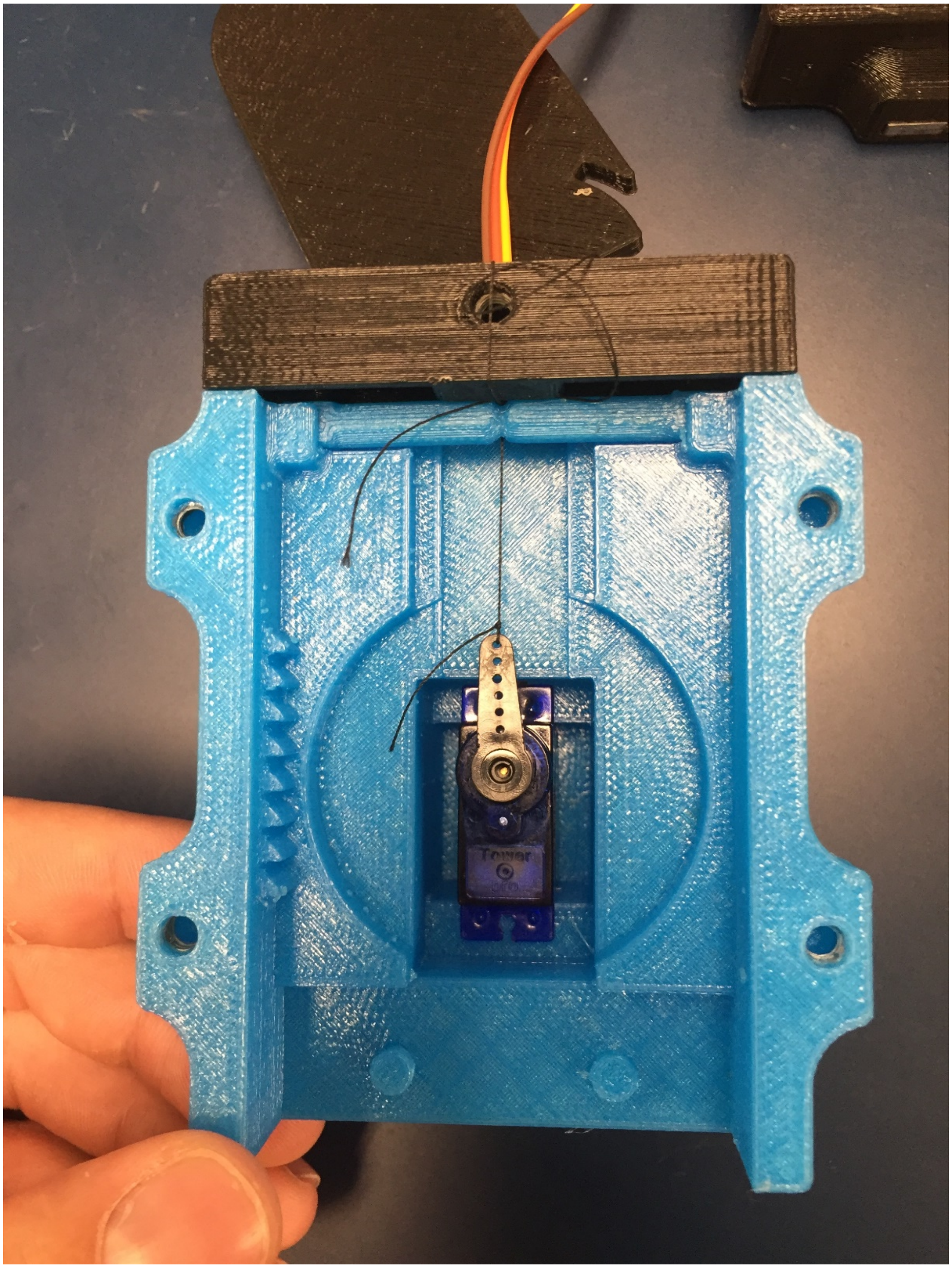


Figure 22: The inside of the motor housing, showing just the motor in its alcove. The motor is force fit into this position, so it does not slip.

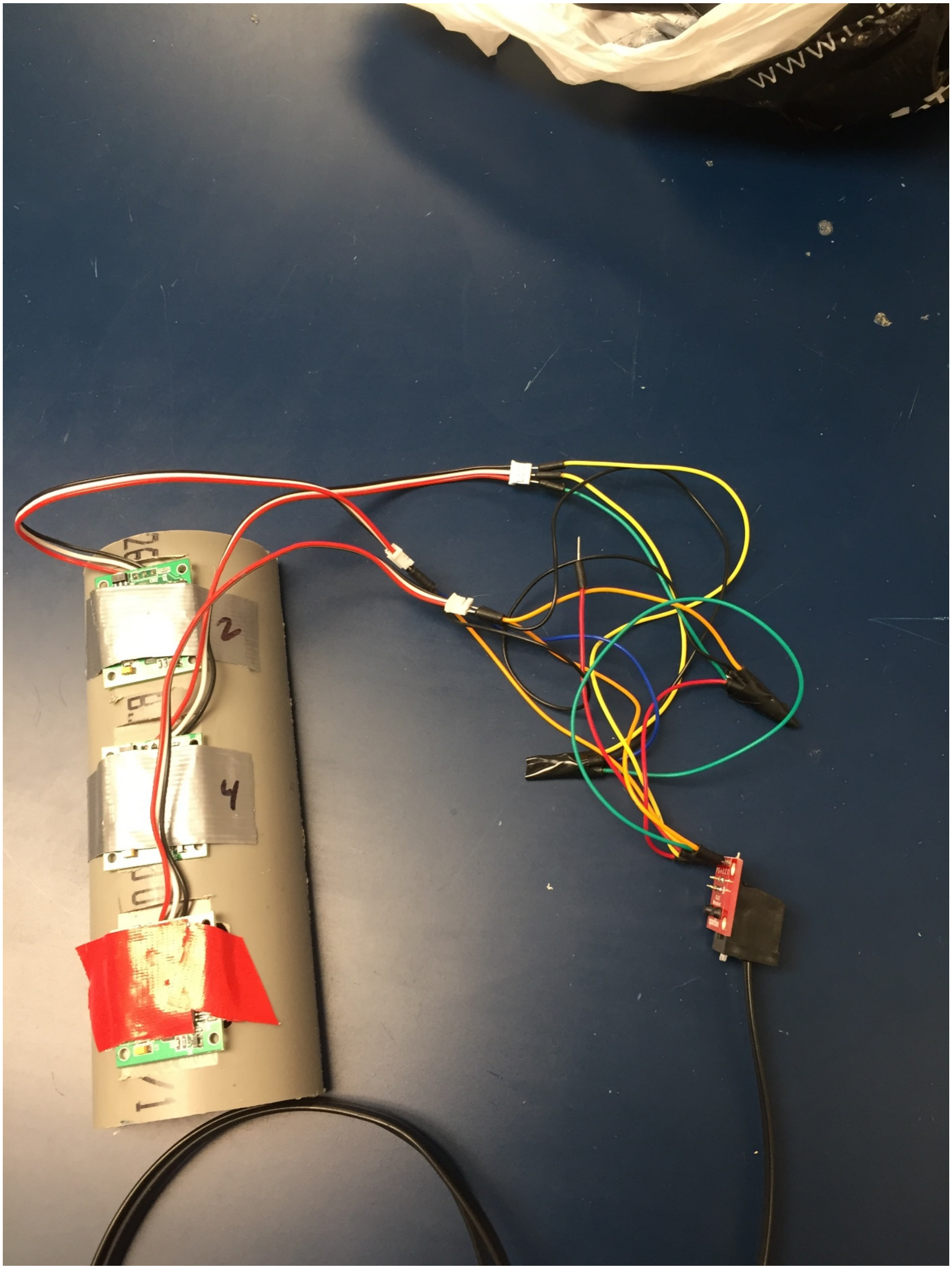


Figure 23: The sensor cover, with the sensors each connected correctly to the phone jack which then runs to the Arduino.

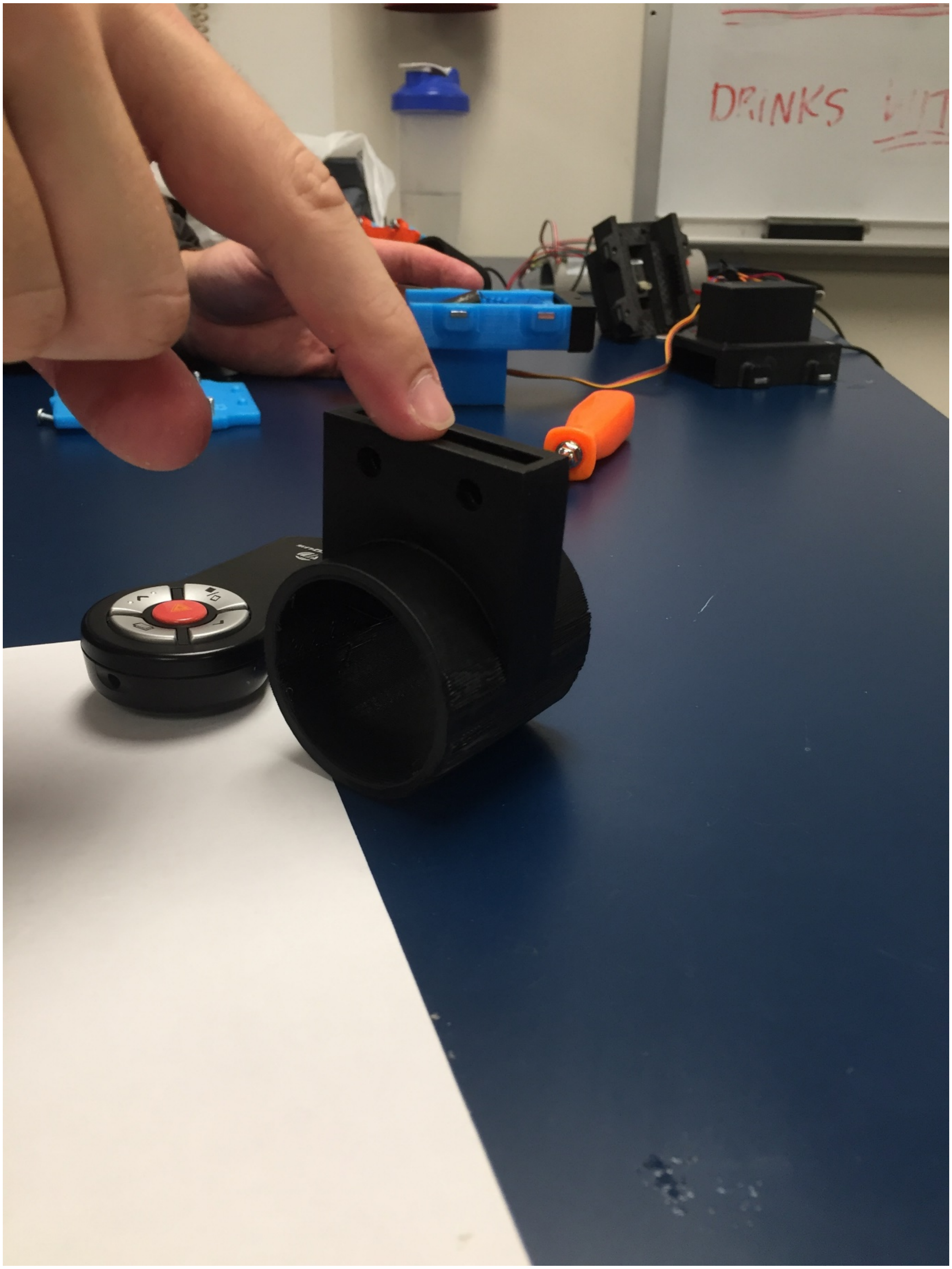


Figure 24: The door cover, which the motor housing sits on top of, and the door slides down through. This will also connect the tubes of the trap once it is integrated into the current tubular design.

7 DESIGN DOCUMENTATION

7.1 FINAL DRAWINGS AND DOCUMENTATION

7.1.1 Engineering drawing

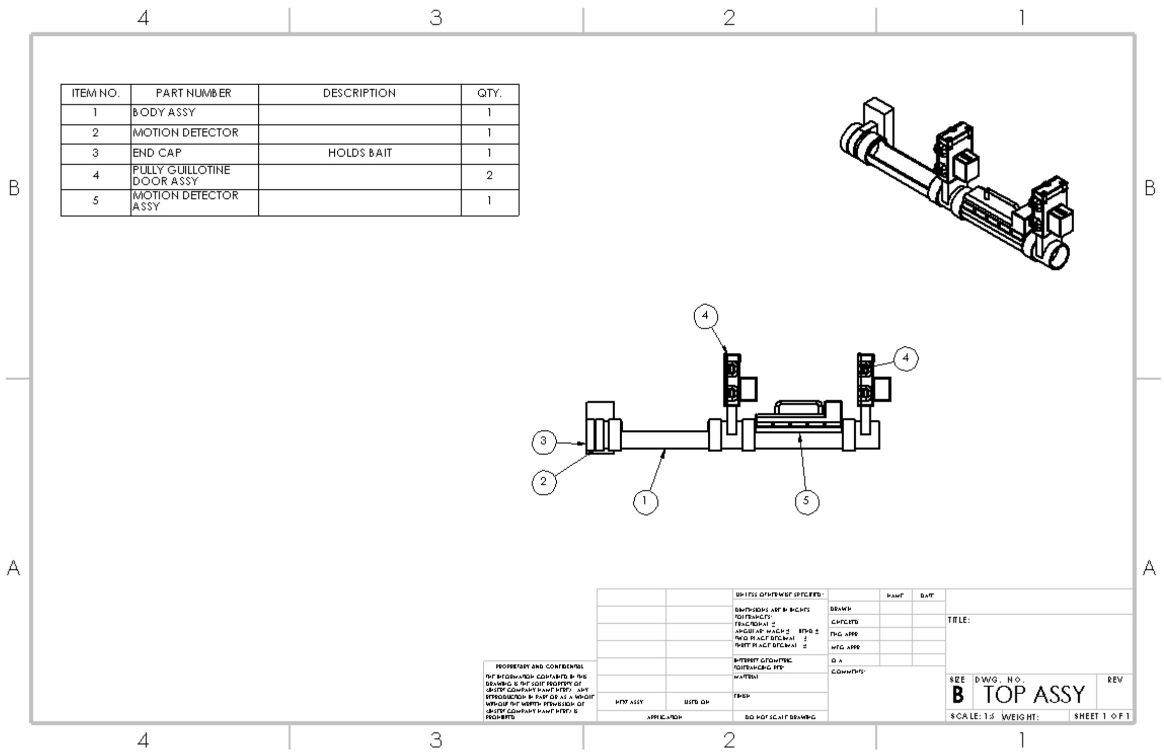


Figure 25: Final Top Assembly Drawing

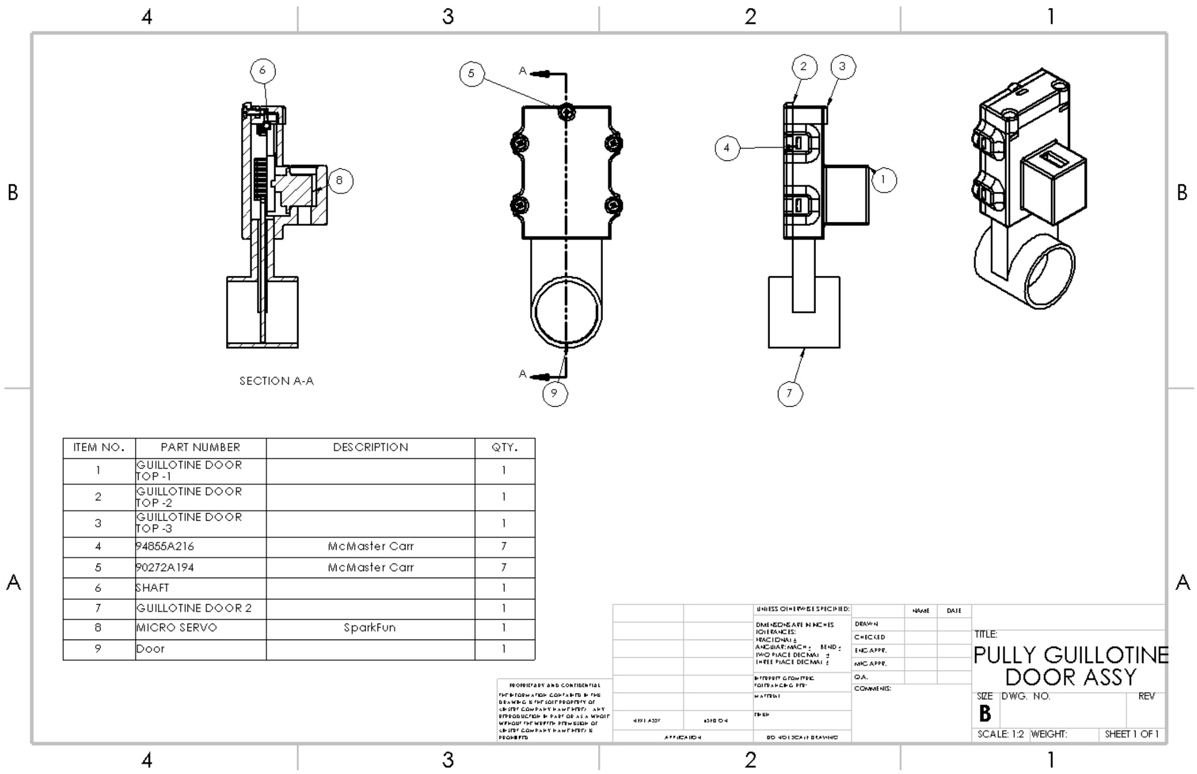


Figure 26: Final Pully Guillotine Door Assembly Drawing

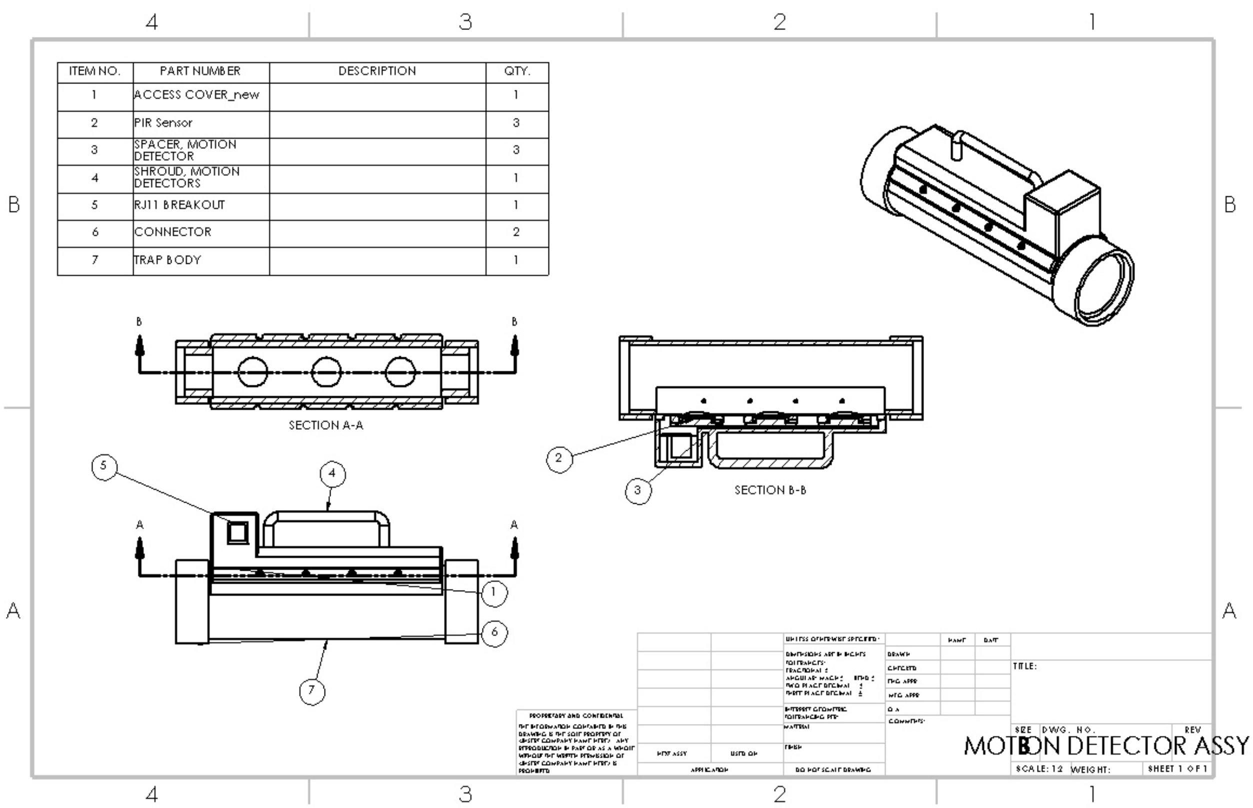


Figure 27: Final Motion Detector Assembly Drawing

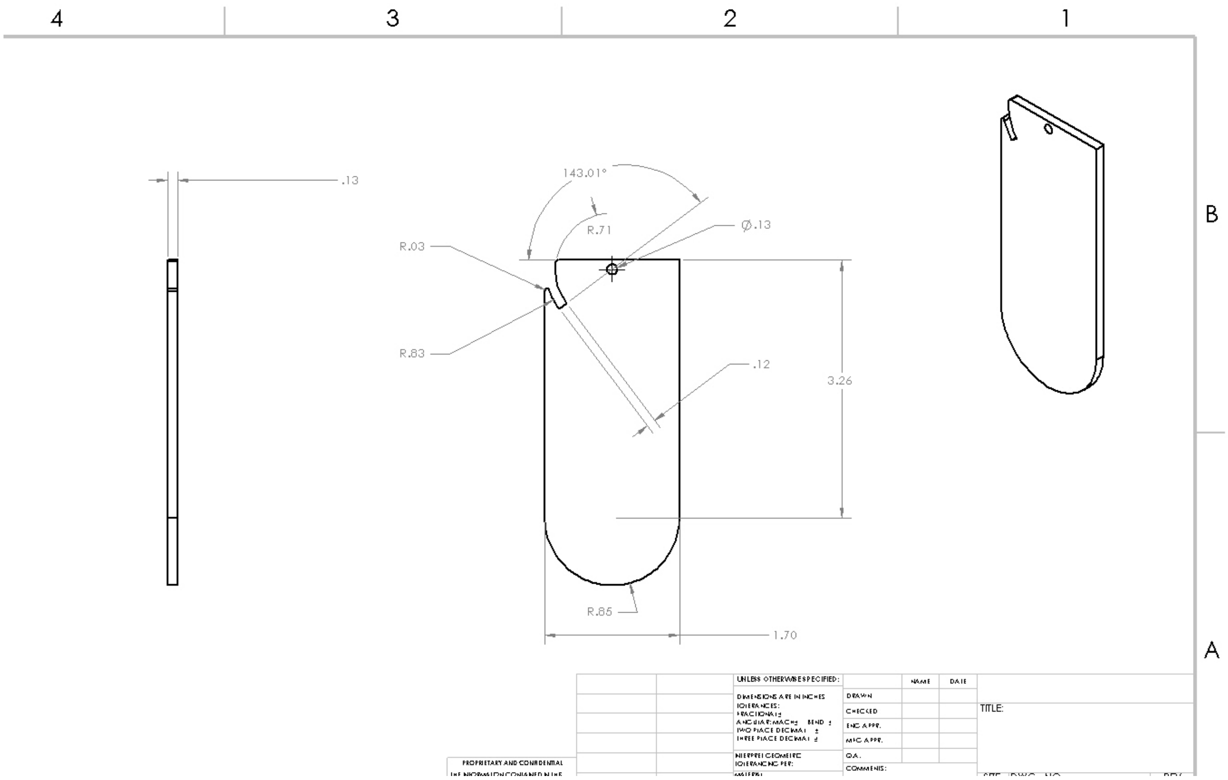


Figure 28: Final Door Drawing

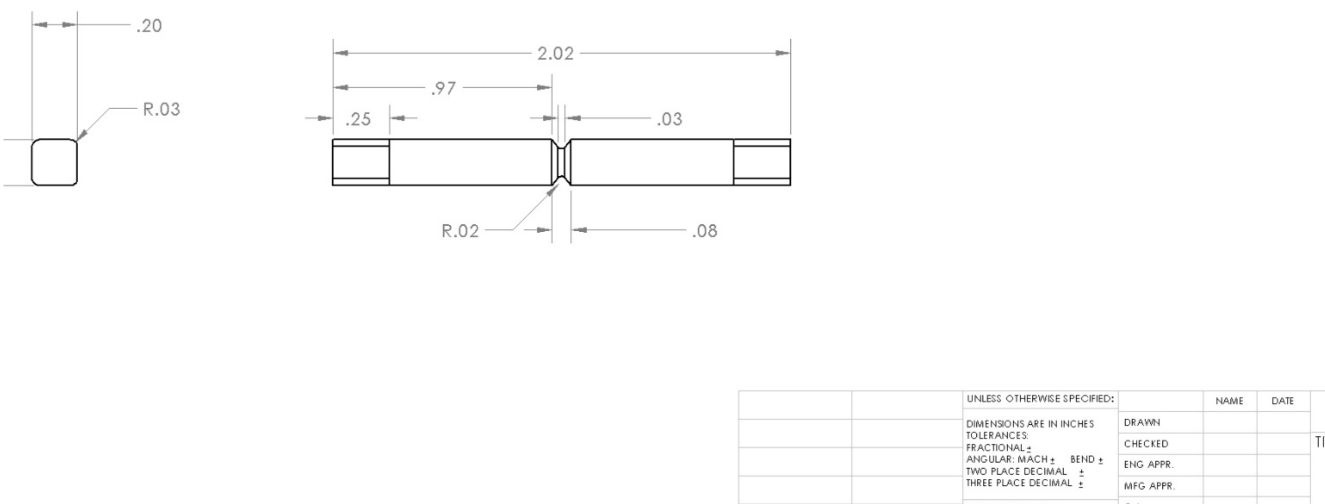


Figure 29: Final Shaft Drawing

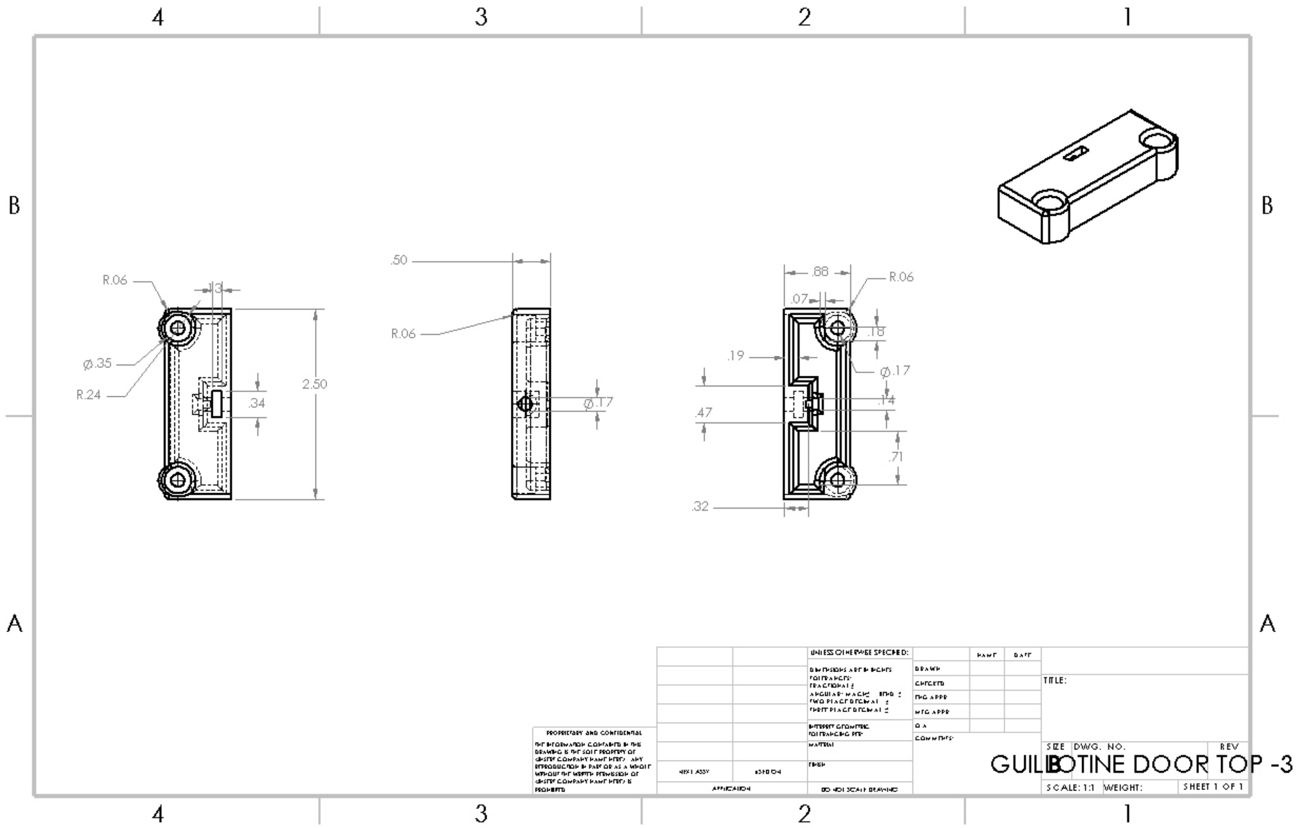


Figure 30: Final Guillotine Door Top - 3 Drawing

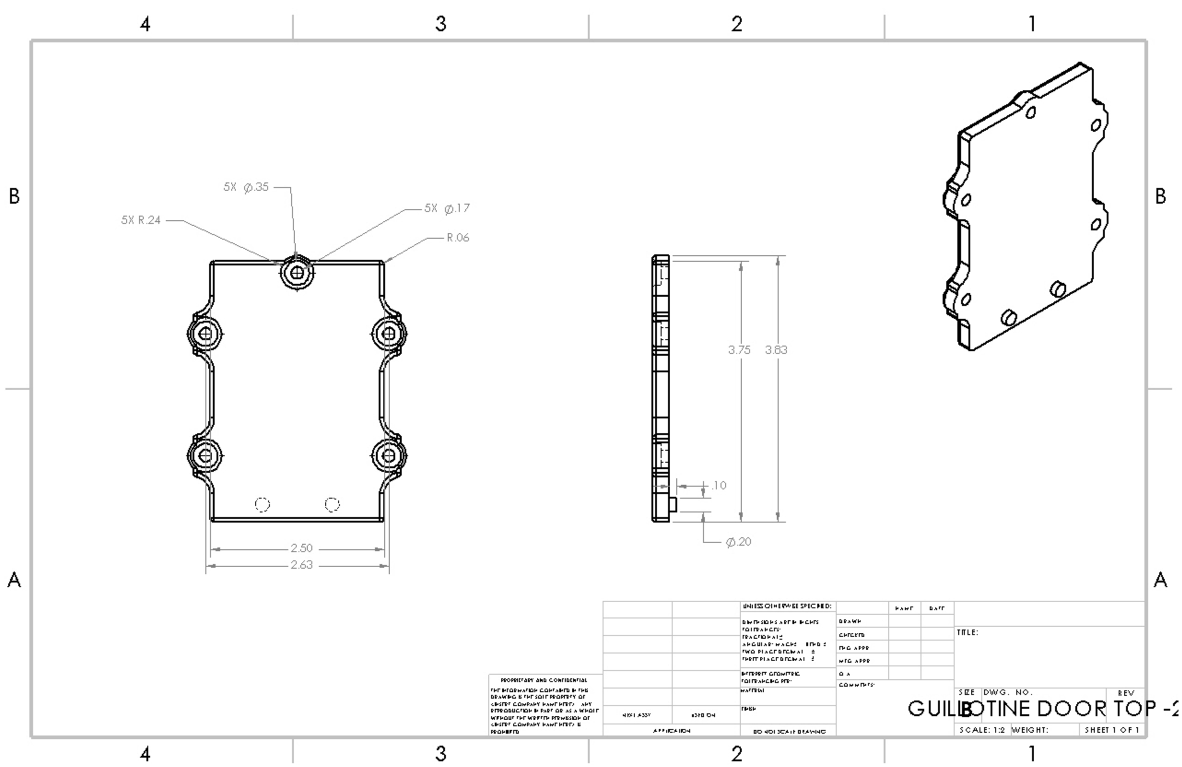


Figure 31: Final Guillotine Door Top - 2 Drawing

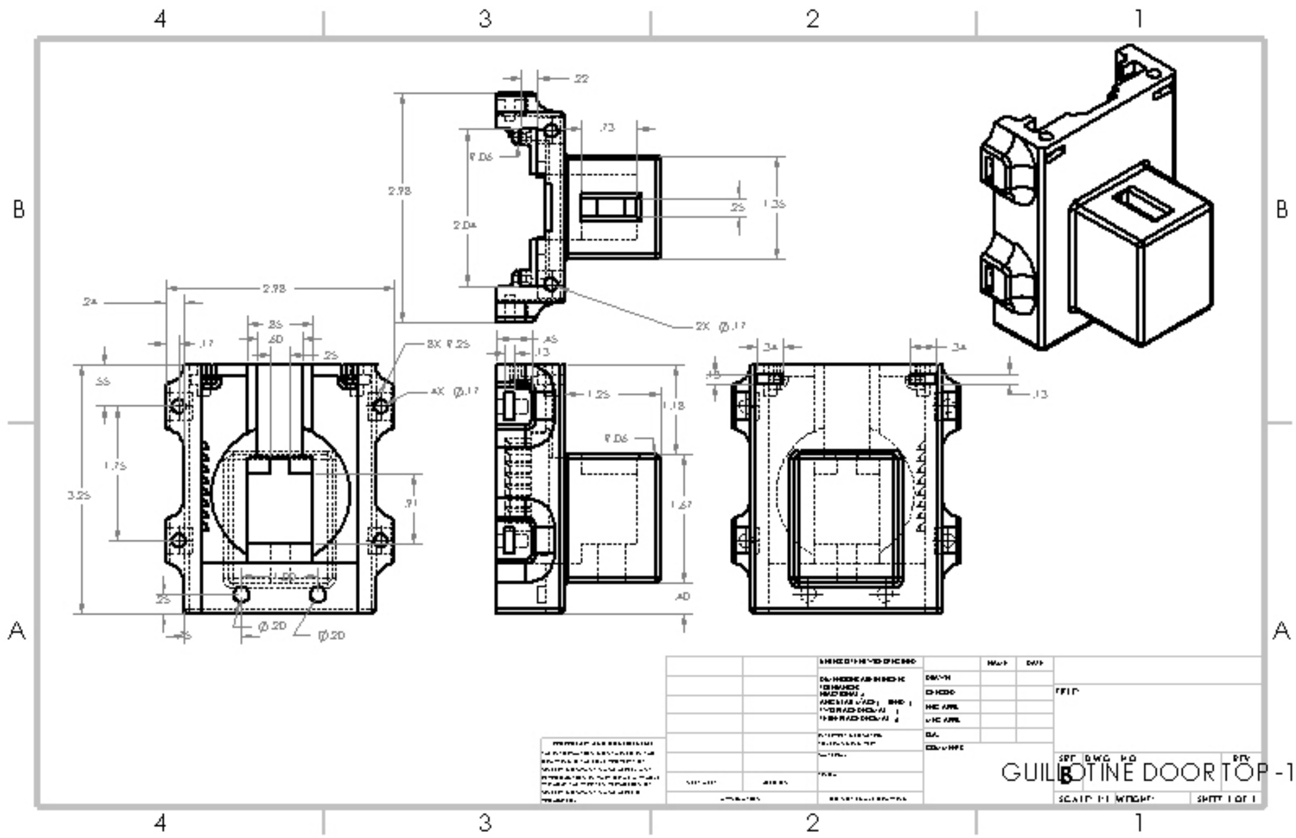


Figure 32: Final Guillotine Door Top – 1 Drawing

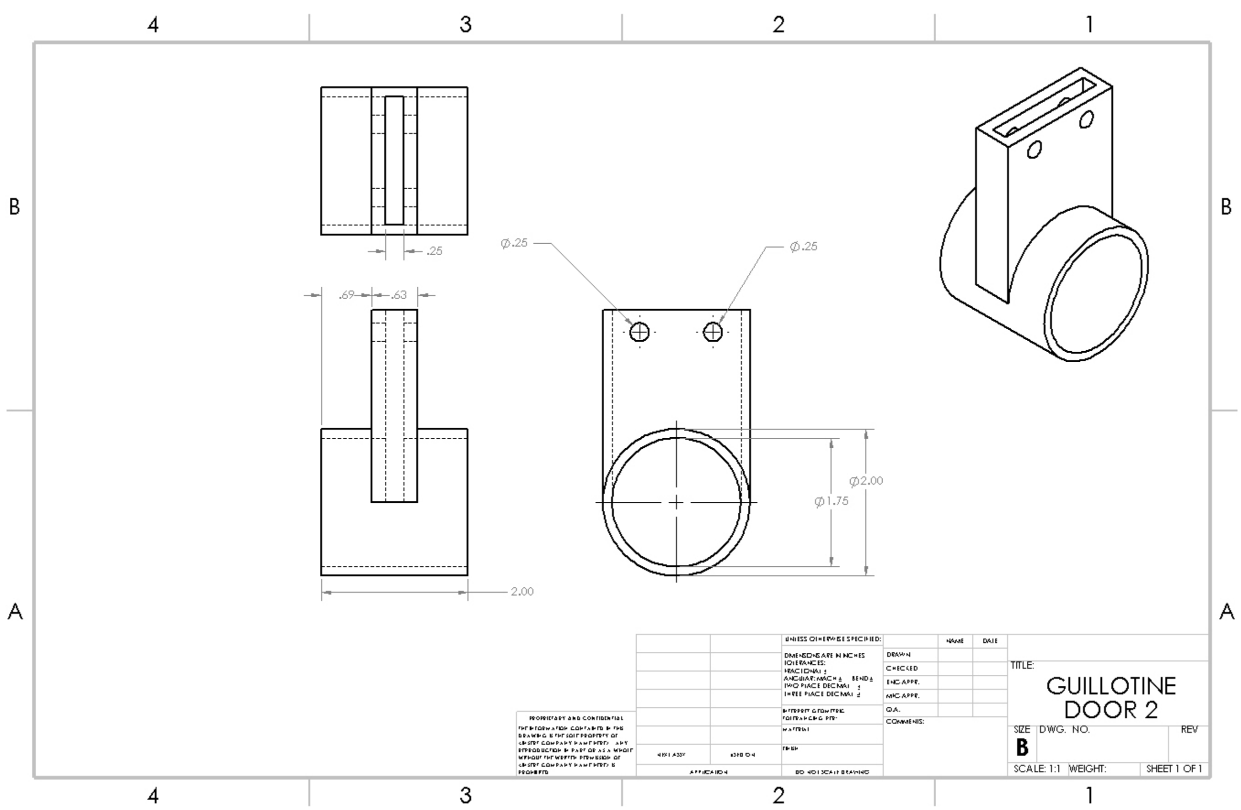


Figure 33: Final Guillotine Door 2 Drawing

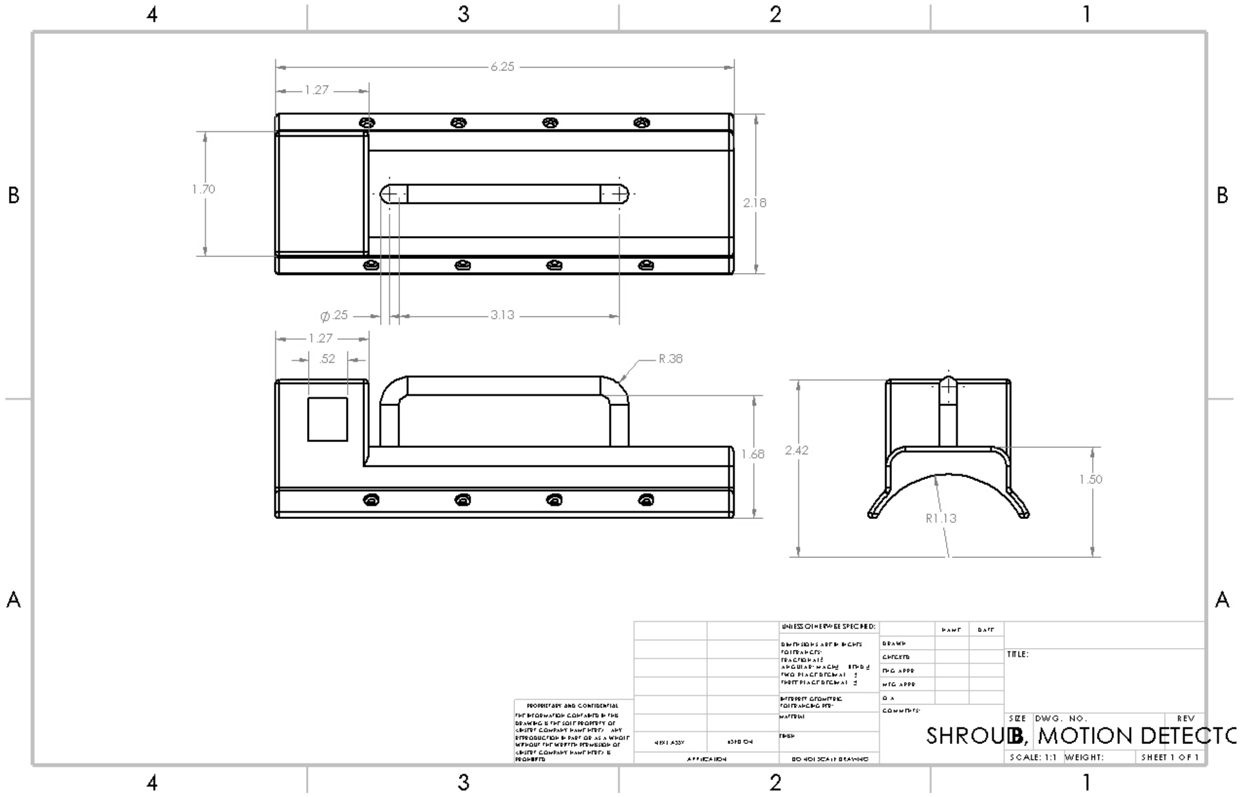


Figure 34: Final Motion Detector Shroud Drawing

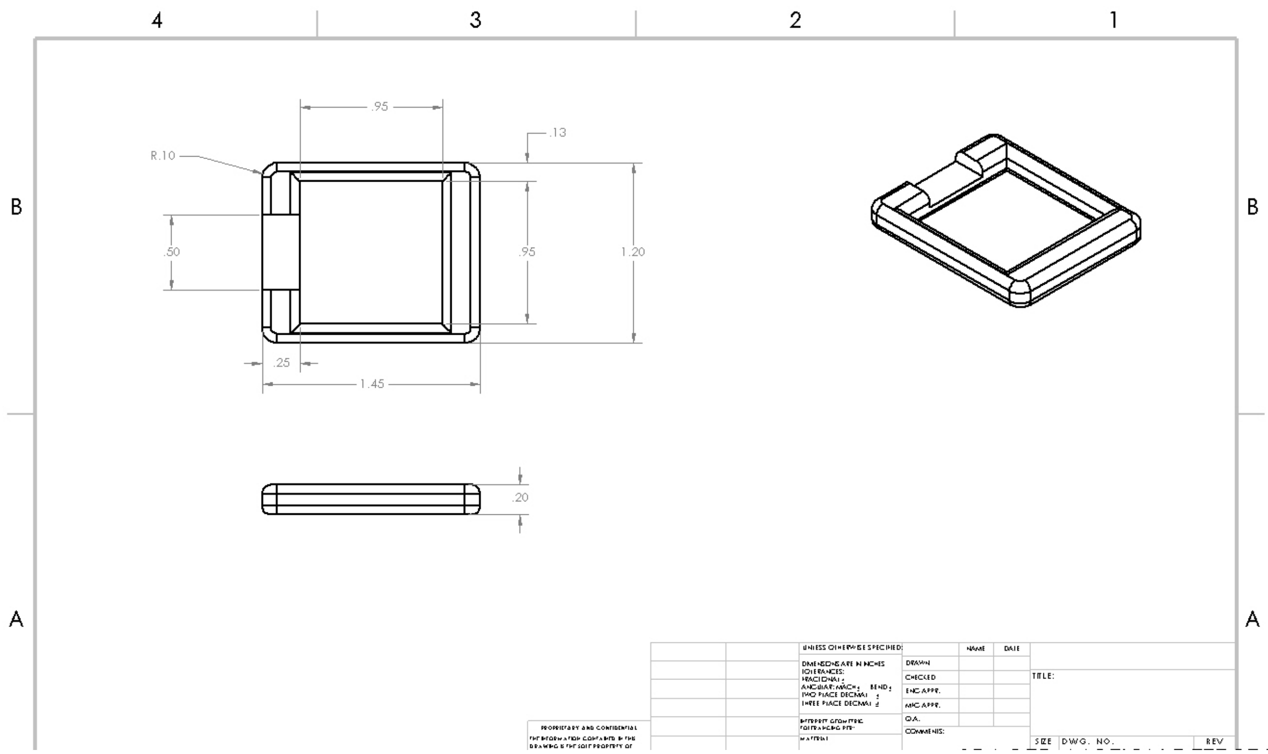


Figure 35: Final End Cap Drawing

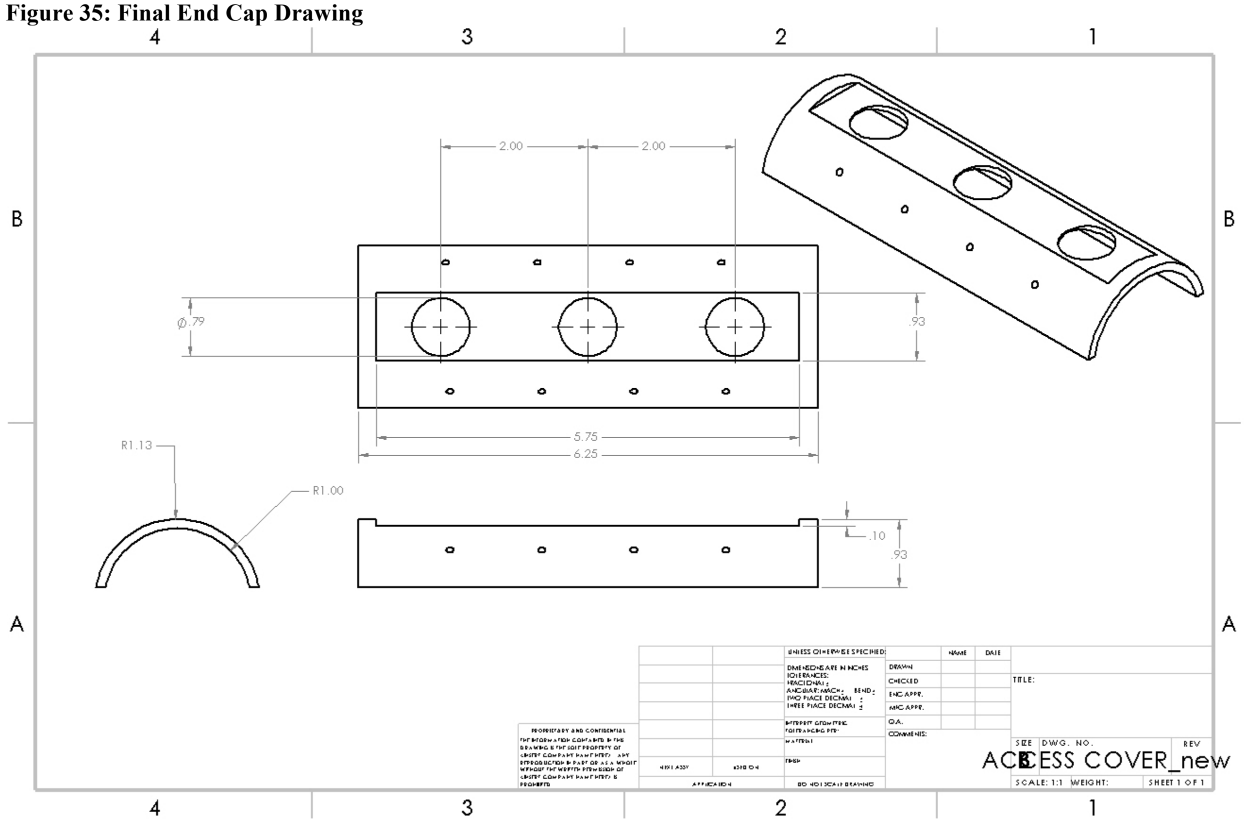


Figure 36: Final Access Cover Drawing

7.2 FINAL PRESENTATION

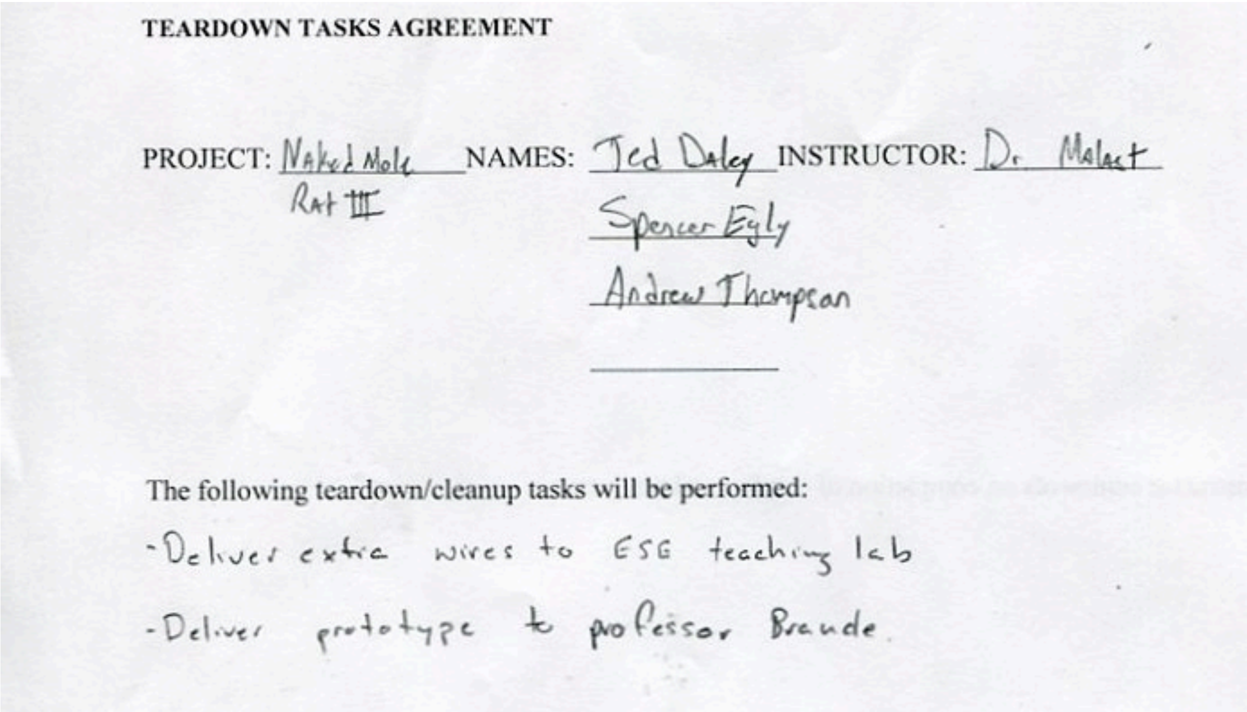
7.2.1 A live presentation in front of the entire class and the instructors

Completed

7.2.2 A link to a video clip

https://www.youtube.com/watch?v=RrUiE0_73pw

7.3 TEARDOWN



TEARDOWN TASKS AGREEMENT

PROJECT: Naked Mole Rat III NAMES: Ted Daley INSTRUCTOR: Dr. Malast

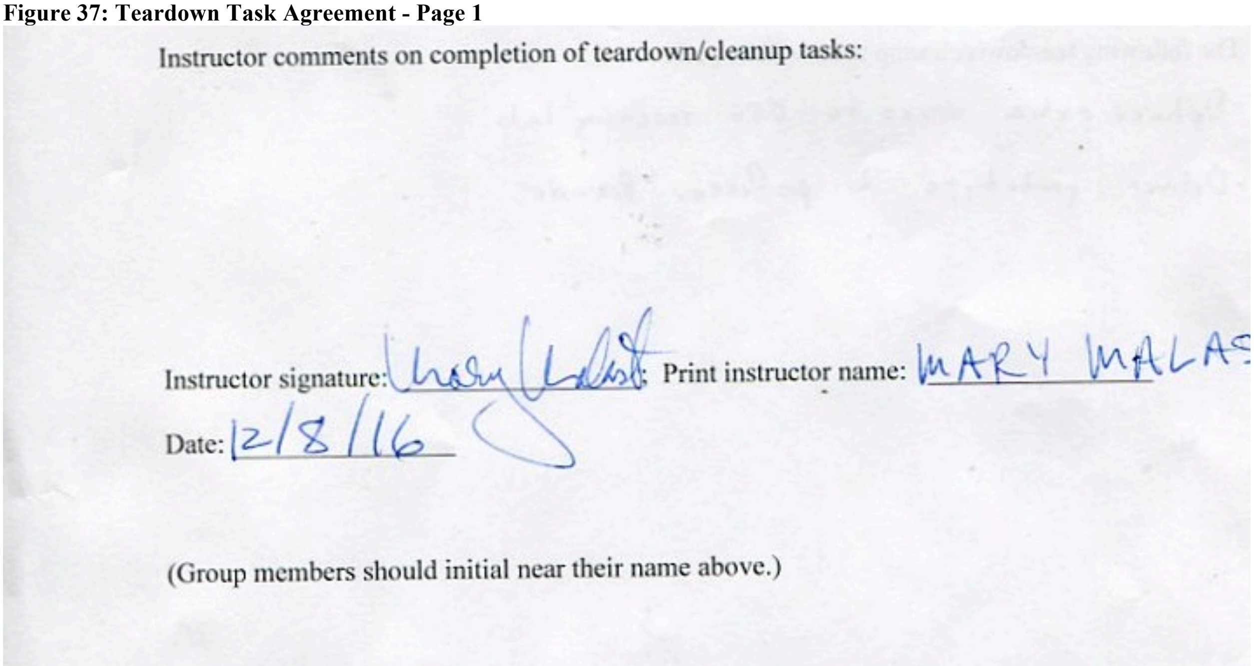
Spencer Egly

Andrew Thompson

The following teardown/cleanup tasks will be performed:

- Deliver extra wires to ESE teaching lab
- Deliver prototype to professor Brande.

Figure 37: Teardown Task Agreement - Page 1



Instructor comments on completion of teardown/cleanup tasks:

Instructor signature: Mary Malast Print instructor name: MARY MALAS

Date: 12/8/16

(Group members should initial near their name above.)

Figure 38: Teardown Task Agreement - Page 2

8 DISCUSSION

8.1 USING THE FINAL PROTOTYPE PRODUCED TO OBTAIN VALUES FOR METRICS, EVALUATE THE QUANTIFIED NEEDS EQUATIONS FOR THE DESIGN. HOW WELL WERE THE NEEDS MET? DISCUSS THE RESULT.

The needs and design requirements for the project were all met. We included a repeatability element in our design that allows the naked mole rat trap to catch multiple. The design alsos can be powered by solar power, relieving the need for battery power if desired. Additionally, the design maintains the important transportability aspect of Dr. Braude's previous rat trap. Most importantly, our design is modular so it can work with Dr. Braude's previous trap as well other group's design improvements.

8.2 DISCUSS ANY SIGNIFICANT PARTS SOURCING ISSUES? DID IT MAKE SENSE TO SCROUNGE PARTS? DID ANY VENDOR HAVE AN UNREASONABLY LONG PART DELIVERY TIME? WHAT WOULD BE YOUR RECOMMENDATIONS FOR FUTURE PROJECTS?

Most of our parts were either 3D printed or ordered from McMaster. Neither of these part sources posed large sourcing issues. The only issue we every ran into was a backlog of jobs needing 3D printing from other groups and other classes right before the prototype demonstration. We would recommend budgeting extra time for 3D printing to account for the possibility of this backlog.

8.3 DISCUSS THE OVERALL EXPERIENCE:

8.3.1 Was the project more of less difficult than you had expected?

Some aspects of the project were very difficult. For example, programming the Arduino code and getting the door logic down was very difficult and took up a lot of time for the project. On the other hand, 3D printing most of the parts for the project went rather smoothly and the part quality exceeded our expectations. That was a very pleasant surprise.

8.3.2 Does your final project result align with the project description?

Yes, Dr. Braude had a series of improvements that he wanted to see out of this project. We fulfilled many of them like solar power and repeatability, while still allowing room for modularity in our final model.

8.3.3 Did your team function well as a group?

Yes, our group has worked together for past projects in past classes and so we were able to function very well as a group.

8.3.4 Were your team member's skills complementary?

Yes, Andrew has a ton of experience with mechanical design and CAD work which was extremely helpful while Ted and Spencer both applied their skills and interests in other productive areas as well.

8.3.5 Did your team share the workload equally?

Yes, at times it was difficult to manage the workload with team members traveling for job interviews but overall the workload was split up relatively evenly.

8.3.6 Was any needed skill missing from the group?

It would have been very helpful to have someone with background in programming Arduino codes. This area was a bottleneck for our project and we had to seek outside resources in order to complete it.

8.3.7 Did you have to consult with your customer during the process, or did you work to the original design brief?

Yes, we initially met with Dr. Braude early in the semester to gather his customer needs that helped inform our design requirements.

8.3.8 Did the design brief (as provided by the customer) seem to change during the process?

It remained pretty constant throughout. Dr. Braude's needs were clearly defined during our initial meeting.

8.3.9 Has the project enhanced your design skills?

Yes, designing a prototype of a mechanical system from scratch is something that none of our group members had done in the past. Now we feel very comfortable with the design and prototyping process.

8.3.10 Would you now feel more comfortable accepting a design project assignment at a job?

Yes, absolutely. This project is great because it bridges the gaps of what we've learned in the classroom over the past couple years and has given us am opportunity to see the real world applications of everything that we have learned along the way.

8.3.11 Are there projects that you would attempt now that you would not attempt before?

This project definitely makes me more open to accepting projects that may be more challenging or pose greater risks along the way.

9 APPENDIX A – PARTS LIST

Table 1: Parts List

Part #	Part Name	Quantity
1	Trap Body	2
2	Motion Detector	3
3	End Cap	1
4	Geared Door and Housing	2
5	Door Gear	2
6	Motor	1
7	90° Motion Door gear	1
8	90° Motion Shaft Gear	2
9	Drive Shaft	2
10	Motor Housing	1
11	Ball Bearings	4
12	Arduino Circuit Board	1
13	Battery Pack	1
14	Solar Panel	1
15	Reverse Blocking Diode	1

10 APPENDIX B - BILL OF MATERIALS

Table 2: Bill of Materials

Part	Source Link	Supplier Part Number	Quantity
9V 150mA Solar Cel	Sundance Solar	700-10850-08-	1
RECTIFIER DIODE 1N5817	Sundance Solar	201-11111-12	1
Arduino Uno - R3	Sparkfun	DEV-11021	1
Rechargeable NiMH Battery Pack: 3.6 V, 2200 mAh, 3x1 AA Cells, JR Connector	Pololu	2220	1
SparkFun TRRS 3.5mm Jack Breakout	Sparkfun	BOB-11570	4
SparkFun RJ11 Breakout	Sparkfun	BOB-14021	1
SPDT Slide Switch	Sparkfun	COM-09609	1
Arduino Uno - R3	Sparkfun	DEV-11021	1
RJ11 6-Pin Connector	Sparkfun	PRT-00132	2
Servo - Generic Discrete Rotation (Micro Size)	Microcenter	847020	2
PIR Motion Sensor (JST)	Sparkfun	SEN-13285	3
ABS 3-D Printing Material	Washington University	N/A	N/A
Door	Washington University	3D Print	2
Shaft	Washington University	3D Print	2
Guillotine Door Top - 1	Washington University	3D Print	2
Guillotine Door Top - 2	Washington University	3D Print	2
Guillotine Door Top - 3	Washington University	3D Print	2
Guillotine Door 2	Washington University	3D Print	2
Motion Detector Shroad	Washington University	N/A	1
End Cap	Washington University	3D Print	1
Access Cover	Washington University	3D Print	1

11 APPENDIX C – DOWNDLOADABLE LINK TO CAD MODELS

https://gowustl-my.sharepoint.com/personal/andrew_thompson_wustl_edu/_layouts/15/guestaccess.aspx?guestaccesstoken=yxuqjwInxPdd8usR6evWpzhNa1soXcnE1RfZPLeo5iI%3d&docid=05fef1bd2b7754fe2a76c73d56bd2a823&rev=1