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Building a Better Naked-mole rat Trap MEMS 411- Senior Design Course

Alex Flammond

Washington University in St. Louis

Lance Middleton

Washington University in St. Louis

Andrew Chang

Washington University in St. Louis

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Washington University in St. Louis

SCHOOL OF ENGINEERING & APPLIED SCIENCE

The purpose of this project was to improve upon the existing design of a catch and release Naked-mole rat trap that is used by Dr. Braude who is professor of Biology here at Washington University in St. Louis. Dr. Braude has been studying these naked mole rats in Ethiopia and Kenya for over 25 years and has trapped over 10,000 naked mole rats throughout this period. Although Dr. Braudes traps have been successful overall, he insists there are improvements to be made.

Building a Better Naked-mole rat Trap MEMS 411- Senior Design Course

By: Lance Middleton, Alex
Flammond and Andrew Chang

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1 INTRODUCTION

1.1 PROJECT PROBLEM STATEMENT

Dr. Braude has had much experience with designing naked mole rat traps and his extensive experience in the field has allowed him to understand what makes a good catch-and-release trap for Naked-mole rats. Since the goal of this project was to design a better trap for Dr. Braude, all design requirements were provided by him and him alone. Amongst the list of problems that Dr. Braudes developed for his current trap design, the areas we decided to focus on were: tunnel clog detection, more reliable trap door, and an improved sensor detection system. An important aspect to keep in mind throughout this project was to maintain the modular design of Dr. Braudes existing trap design. Although the goal of this project is to improve the existing design, a modular assembly design would allow Dr. Braude to decide for himself which upgrades/modifications would give him the most success.

1.2 LIST OF TEAM MEMBERS



2 BACKGROUND INFORMATION STUDY – CONCEPT OF OPERATIONS

2.1 A SHORT DESIGN BRIEF DESCRIPTION THAT DESCRIBES THE PROBLEM

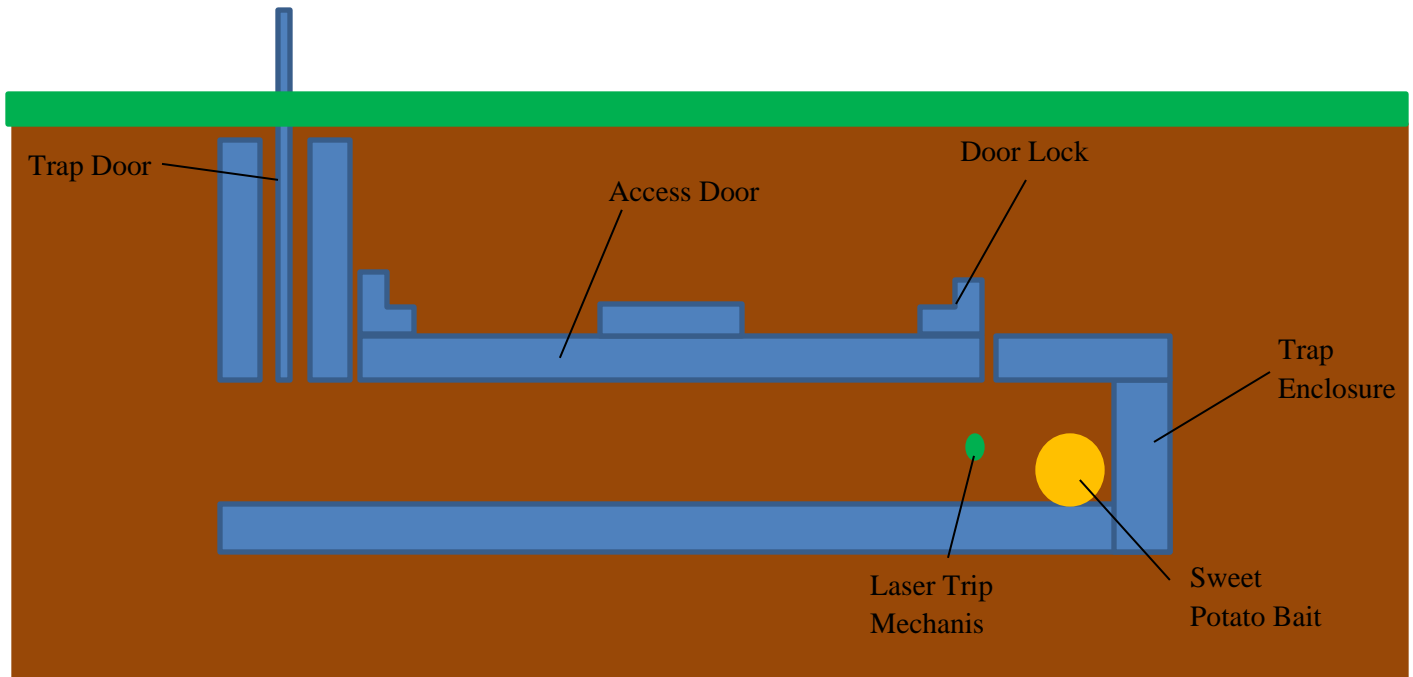
The purpose of the project is to design a Naked-mole trap so that Naked-mole rat colonies can be better studied by Professor of Biology, Dr. Braude. Despite that he has plenty of experience trapping these creatures, Dr. Braude believes there are ways to improve on his current trap design.

2.2 SUMMARY OF RELEVANT BACKGROUND INFORMATION

Current Designs:

Dr. Braude claims he has caught over 10,000 naked mole rats for his study and he has shared with us his current trap design. The trap consists of a tube like enclosure that has bait at the end to lure the rats in. Once the rat is far enough in, a light or infra-red beam is cut off which triggers a mechanism to release a trap door at the tubes entrance. Because the trap door is above ground in a set trap, a tripped trap is

indicated when the trap door falls beneath the ground. The naked mole rat is then taken out of the trap by an access door which is buried about two inches below the ground. A schematic of his current trap can be seen below.



There are alternate underground mammal traps that already exists as well. The department of Biology at Selcuk University in Konya, Turkey uses a similar tube like design but instead of a laser trip, this design uses a mechanical push design that causes a spring to release the trap door. The details can be seen in the following paper: http://www.ivb.cz/folia_zoologica/archive/62_130-132.pdf.

Risks:

Dr. Braude also discussed some of the risks and problems that are possible with his current design. His main concern was the issue of predators. The rats need to be tagged and released as soon as possible meaning that they should not be in the trap for too long. Another issue was the trap door becoming stuck or not tripping properly allowing the rat to escape before being tagged. Because these traps are in a desert climate, sand and dust becomes trapped in between the trap door and the enclosure casing; the doors also become stuck because of heat warping the pvc enclosure.

The article discussed earlier also mentioned some risks of these type of traps. It discusses how heat from the sun can radiate through the soil and cause the enclosure to become too hot(http://www.ivb.cz/folia_zoologica/archive/62_130-132.pdf).

Codes and Standards:

- ISO 10993-2:2006 Biological evaluation of medical devices -- Part 2: Animal welfare requirements.
http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=36405
These standards describe the importance of animal welfare in testing environments. Since this is technically for the use of testing, it is important we consider these requirements in our design.
- STP625 Test Methods for Vertebrate Pest Control and Management Materials.
http://www.astm.org/DIGITAL_LIBRARY/STP/SOURCE_PAGES/STP625.htm
These standards state the management of rodents in the wild and particularly focuses on disease control and crop protection. Since this design requires human interaction with the rodents, we must consider them in our design.

Design Brief:

After a thoroughly researching current trap designs and the required code and standards involving humane rat traps, there are details that should be addressed for the traps final design. In order to avoid the discussed problems of the current trap revision, I believe that the main focus of this design project is to improve upon Dr. Braudes current design. Dr. Braude has had great success with his current trap design but there definitely things that can be improved.

One possible option is the inclusion of some sort of remote detection system so that a trap does not need to be watched the whole time, but can send a remote signal to a handheld device. This will allow Dr. Braude to have knowledge of which traps were tripped whether or not he is on the mole location site or not. This system will also mean that rats will not be trapped for extended periods of time which would solve the predator and excessive heat problem. Another potential improvement could be to the enclosure material itself. Finding a cheap material that stands up to the desert climate would be beneficial. One other thing Dr. Braude suggested that would be useful is some sort of “sewer cam” so that he can see inside the enclosure so that the trapping method can be even further improved in the future.

There are many potential improvements to Dr. Braudes current trap design, and there are several ways to go about the improvements. Time and cost analysis will decide which improvements will be implemented in this design project.

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

<p>Prompt/Question 1 - Its unknown if trap is clogged or rat is caught</p> <ul style="list-style-type: none">•Implement mechanism to see inside trap•Intrepretated Operational Need: Install camera at end of trap•Operational Need Importance: 5
<p>Prompt/Question 2 - I dont know if rat is caught when off site</p> <ul style="list-style-type: none">•Implement mechanism to notify user when he is off site•Intrepretated Operational Need: Create mechanism that notify's user when trap door is tripped•Operational Need Importance: 4
<p>Prompt/Question 3 - Trap runs out of batteries frequently</p> <ul style="list-style-type: none">•Implement alternate power source•Intrepretated Operational Need: Install solar panels•Operational Need Importance: 3
<p>Prompt/Question 4 - Door becomes stuck</p> <ul style="list-style-type: none">•Impement door that doesnt trap sand•Intrepretated Operational Need: Create enclosed one way door mechanism.•Operational Need Importance: 5

Figure 1: Naked Mole Rat Trap Customer Goals/Needs Table.

3.1.2 Functional allocation and decomposition



Figure 2 Naked Mole Rate Operation Requirements

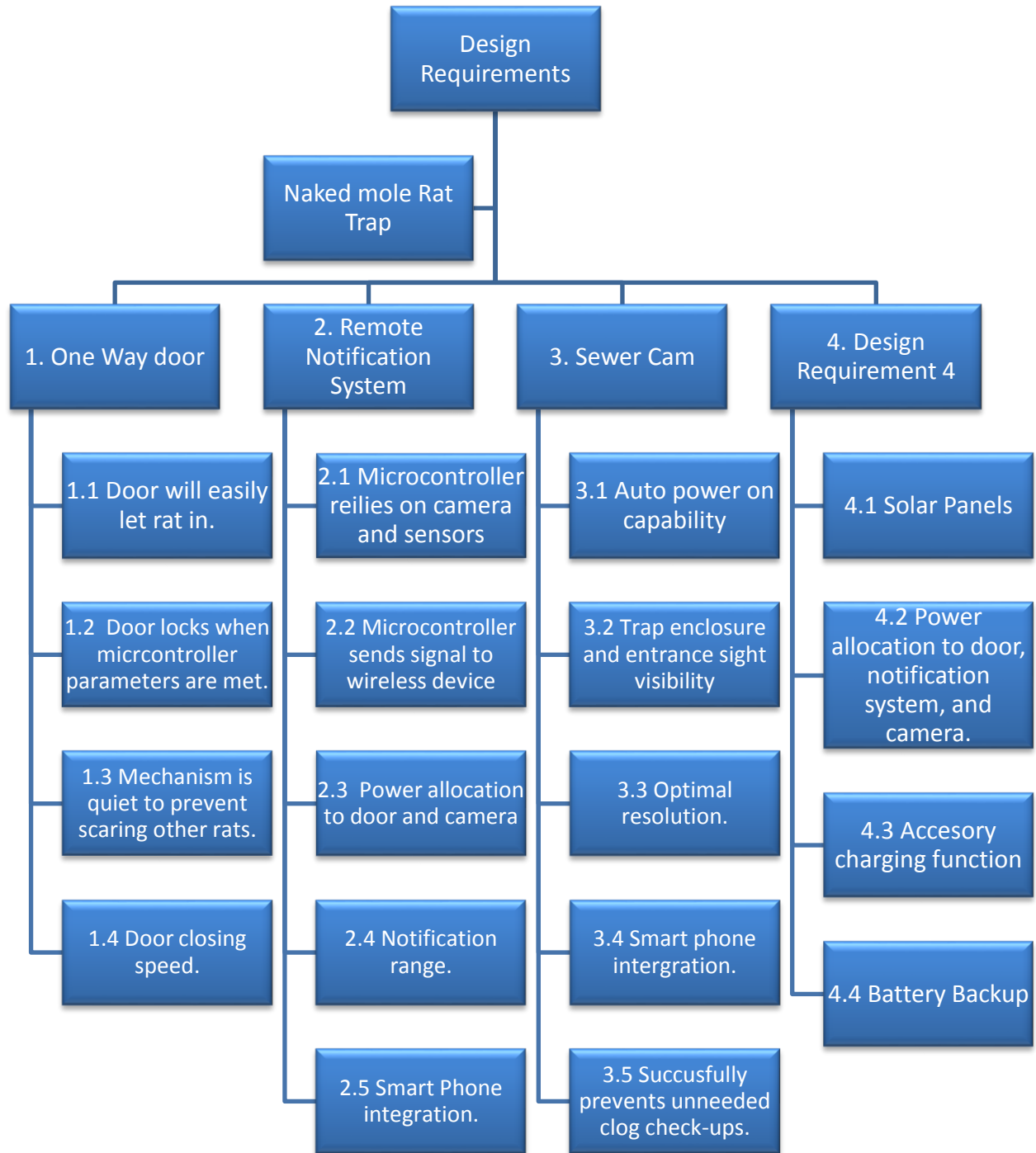
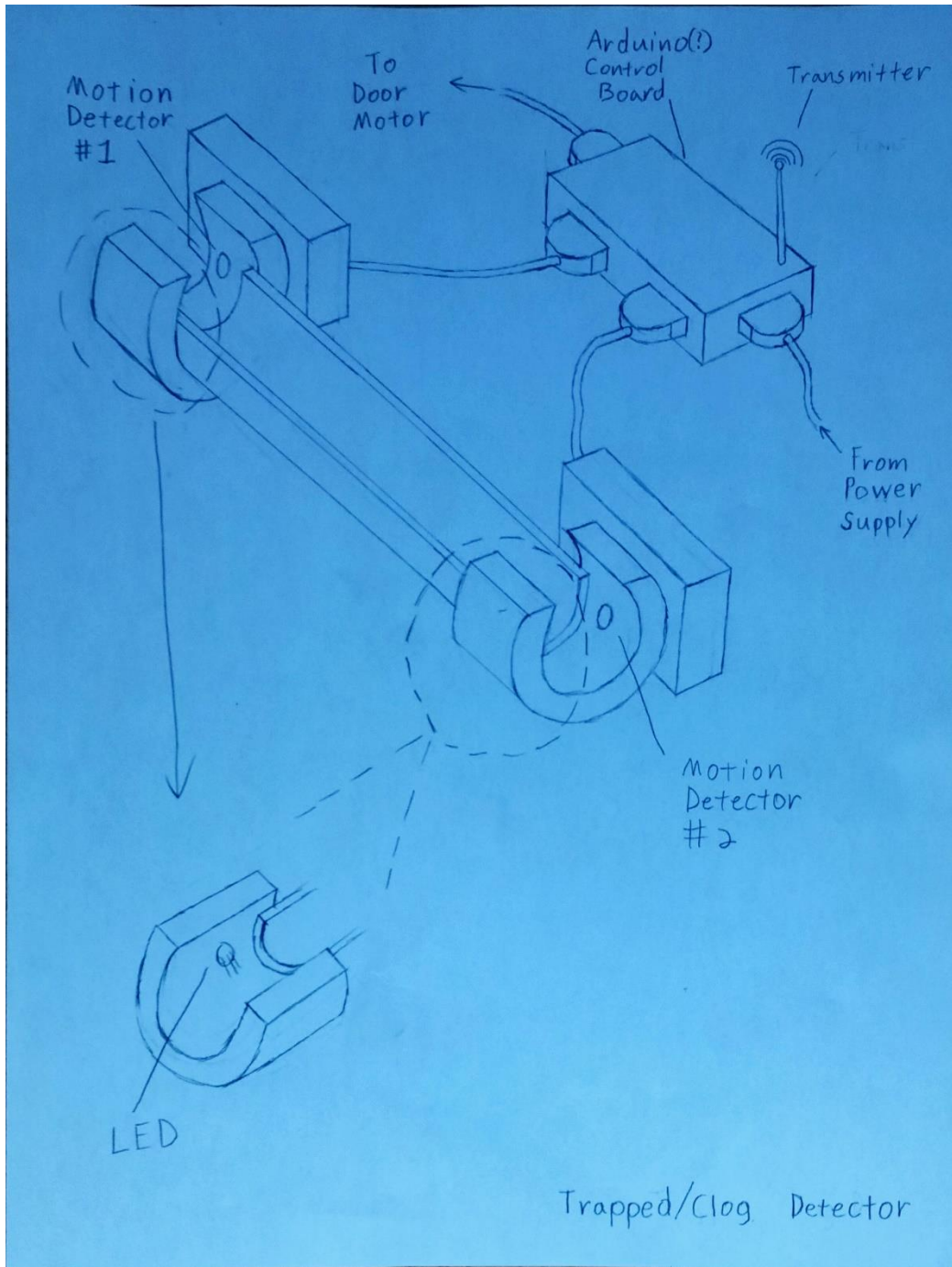


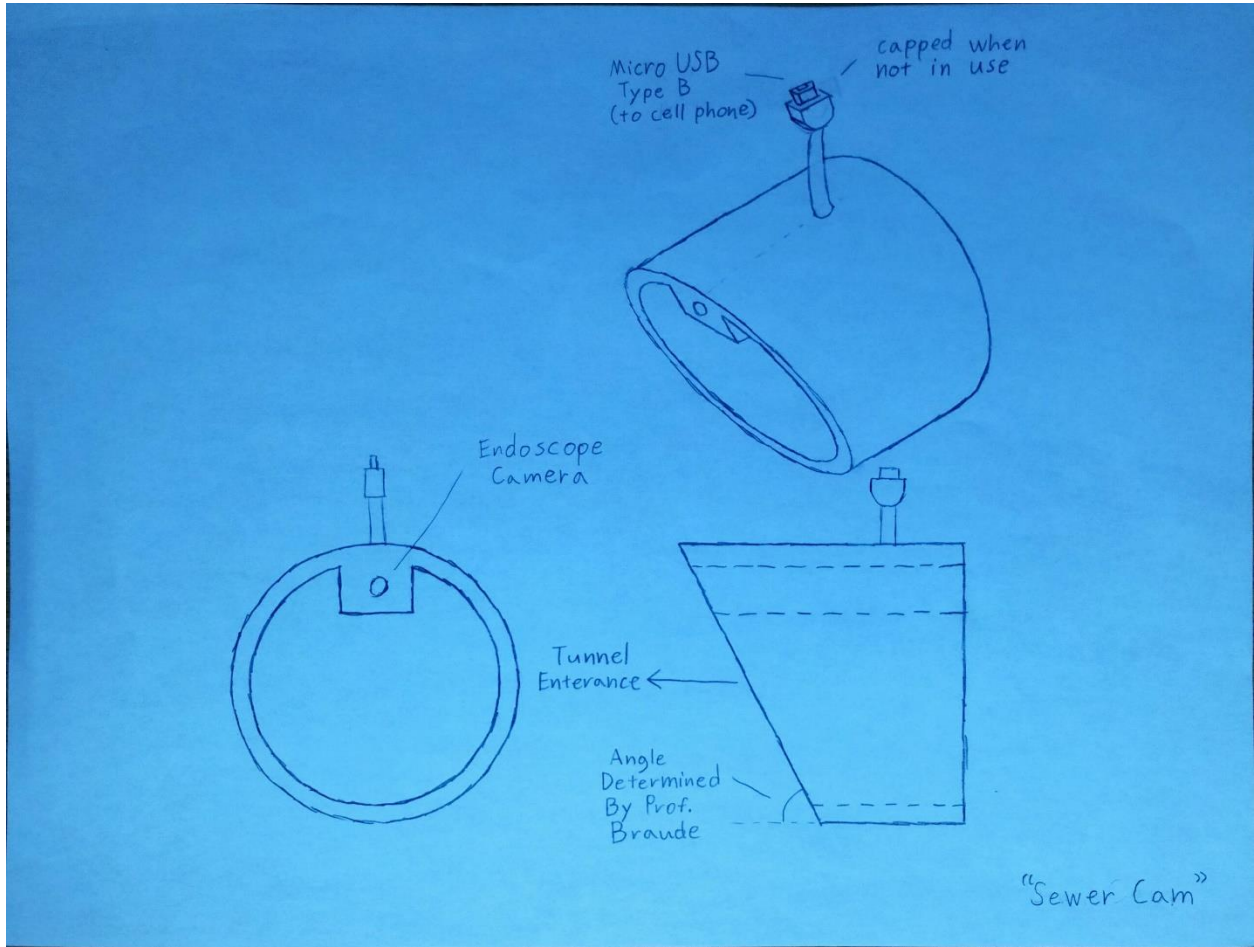
Figure 3 Naked Mole Rate Design Requirements

3.2 FOUR CONCEPT DRAWINGS

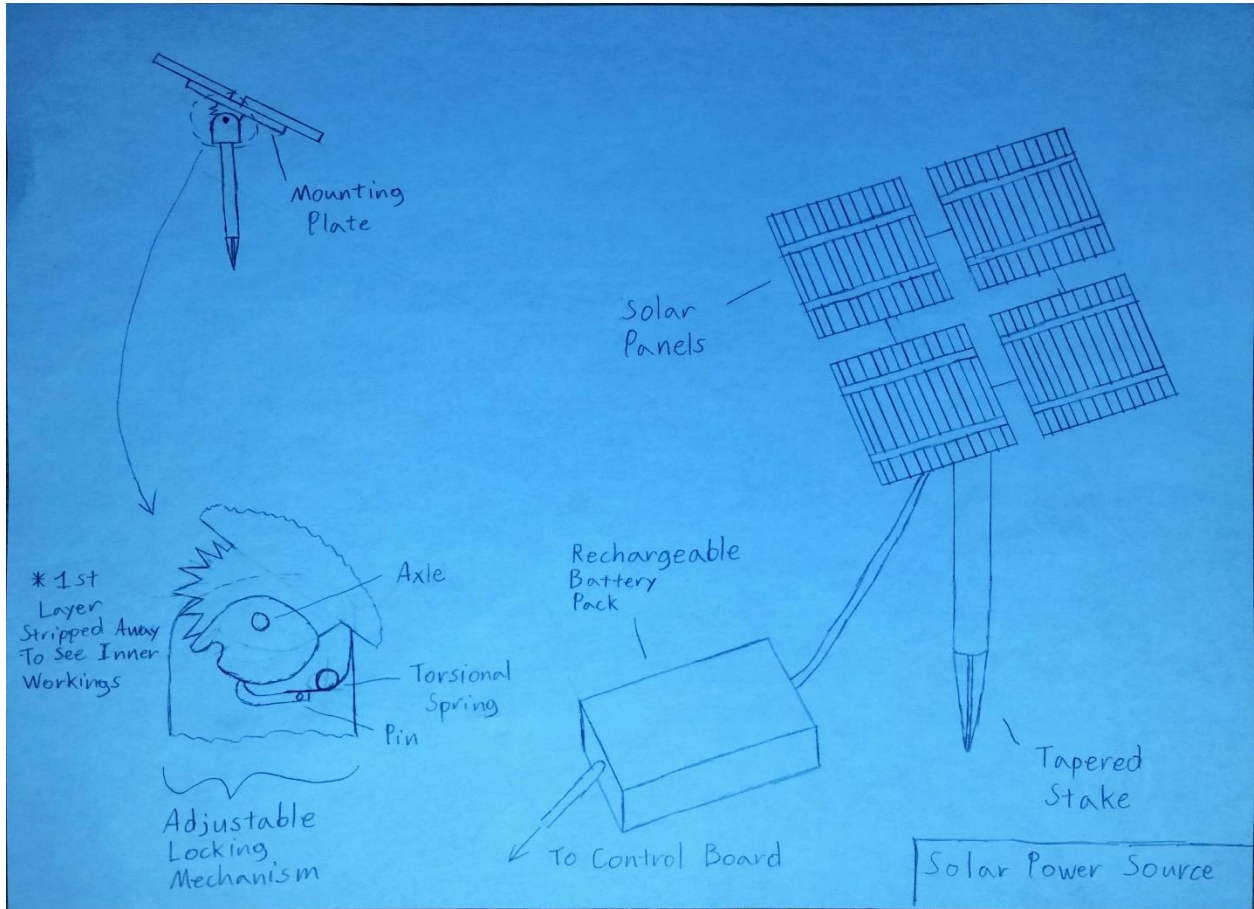
Concept 1: Remote Notification System



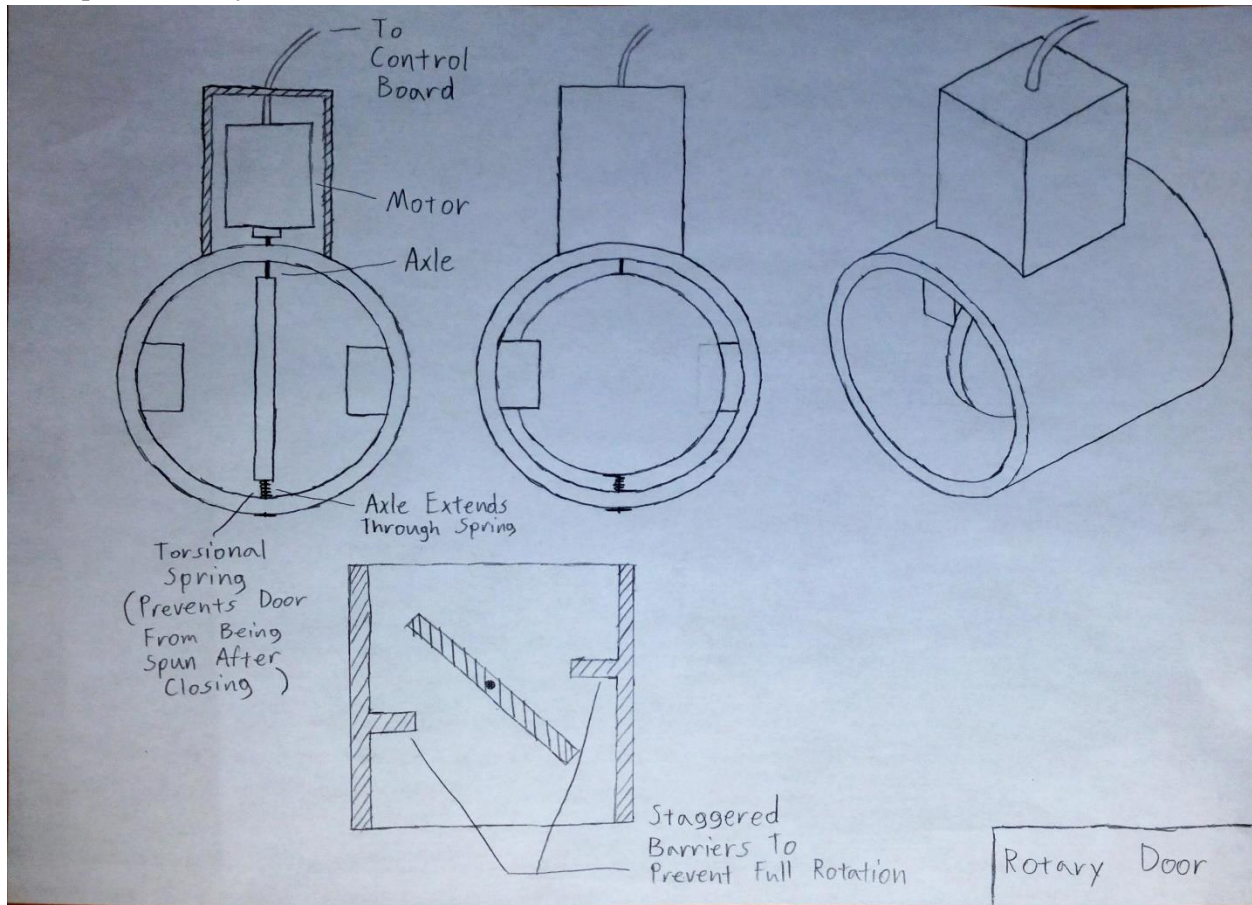
Concept 2: Sewer Cam



Concept 3: Solar Power Source



Concept 4: One-way Door



3.3 CONCEPT SELECTION PROCESS

3.3.1 Preliminary analysis of each concept's physical feasibility based on design requirements, function allocation, and functional decomposition

Concept 1: Remote Notification System

While our goal is to implement all four concepts, the final implementation of each concept will depend on successful design. Otherwise, the concept will need to be omitted, and the customer notified accordingly. With the remote notification system, we must meet the customer need of successful installation. Additionally, the system must trigger in at least 95% of instances where a mole rat enters the trap. In 95% of the instances where the system does trigger, it must successfully send a notification to the scientist's smartphone. Our design accomplishes these criteria, most importantly distinguishing between clogs and mole rats. The first sensor, located at the door, triggers when the mole rat passes through. The second sensor is towards the end of the trap, and engages when the mole rat goes for the bait. This two-sensor system is necessary to distinguish between a dirt clog and a rat. A dirt clog would only trigger the first sensor at the door, whereas the mole rat will trigger both. A notification would be sent in both situations,

alerting the scientist of the type of event. Each sensor successfully operates by detecting a blockage in light between the light source and receiver, similar to a burglar alarm. This is known to be successful, as Professor Braude has experimented with this method before. The signals are sent to an Arduino board, and then to a commercially-available RF transmitter. Using commercial parts will ensure the success of this component.

Concept 2: Sewer Camera

With the sewer camera concept, we need to meet the customer need of successful installation. We also must ensure the camera has a light or infrared source, and it must fit existing dimensions. Our commercial, USB-based sewer camera comes with a light or infrared source at purchase, meeting the requirement. Furthermore, our design conforms to the existing design. The endoscope tube channel can be added as an addition to the existing tube, by attaching to the inside wall. The channel is also small enough that the space available for mole rats to move is not significantly reduced. The only invasive alteration would be a hole drilled through the top of the tube, so the sewer camera can be inserted. Lastly, we consider whether the overall design will meet its intended purpose. The purpose of the sewer camera is to be able to check for blockages in the trap entrance and adjacent burrow without unburying the entire trap. Trap blockages cause a complete stop in trapping, so our design must work effectively. Our design should be able to effectively visualize the trap entrance using light or infrared sources.

Concept 3: Solar Power

With the solar power concept, we must meet the customer need of successful installation. Additionally, we must provide sufficient voltage so that the electronic components can operate reliably. These include the electric motor (on the electric motor variant), sensors, and sewer camera. To provide sufficient margin, we set the target for total voltage to 120% of required. The solar panel will be attached to an adjustable locking mechanism so the solar panel can be rotated and locked. The simplicity of the axle-spring-pin system will reduce the likelihood of jamming. The mechanism attaches to a stake that can be used to hold the solar panel in the ground. The solar panel will charge a rechargeable battery pack, so the trap will not be affected by periods with no sunlight.

Concept 4: One-way Door

The current mechanical door system is a gravity-assisted guillotine door. It is held in the up position by a pin attached to a fishing line, which is in turn attached to the metal bait prongs. When a mole rat taps the prongs, the fishing line is pulled and the pin comes out of the door. The door then falls, trapping the mouse. However, this system is prone to failure due to dust jamming the door slit. As such, the door does not fall, and the mole rat is free to escape. Our new design is an electromechanical one-way door. When the rat rotates the door and moves through, the motor ensures the door rotates all the way shut behind it. Offset barriers prevent the door from rotating continuously. The biggest risk with this method is that a rat gets stuck in the door, or that the motor fails to shut the door completely. Such a problem would drastically affect data by obstructing the capture of rats. However, this system is far less prone to failure due to dust jams.

3.3.2 Concept scoring

Since our project involves multiple components, we have done concept scoring based on the implementation of all four of the drawn subcomponents. Any reliability claims are based on conservative estimates from evaluating our designs.

Metric Number	Associated Needs	Metric	Units	Worst Value	Max Value	Actual Value	Normalized Value
1	1	RNS installation	Binary	0	1	1	1.000
2	2	RNS activation, 95%	Percentage	0	0.95	0.8	0.842
3	3	Smartphone alert, 95%	Percentage	0	0.95	0.95	1.000
4	4	Sewer cam installation	Binary	0	1	1	1.000
5	5	Dimension conformity	Binary	0	1	1	1.000
6	6	Light or infrared source	Binary	0	1	1	1.000
7	7	Solar panel installation	Binary	0	1	1	1.000
8	8	120% required voltage	Percentage	0	1.2	1.2	1.000
9	9	One-way door closes, 1 s.	Time	0	1	1	1.000
10	10	Acrylic tubing	Binary	0	1	1	1.000
						TOTAL	9.842

Operational Requirements: Identified Needs

Need Number	Need	Importance
1	Install remote notification system.	5
2	RNS must activate when mole rat enters, 95% success rate.	4
3	Alert is sent to smartphone when RNS is activated, 95% success rate.	4
4	Install sewer camera.	4
5	Does not alter existing dimensions for sewer camera.	4
6	Sewer camera has light or infrared source.	4
7	Install solar panels.	3
8	Solar panel must provide 120% of required total voltage.	4

9	Install one-way door must trap 100% of all mole rats	3
10	Tubing is acrylic.	5

3.3.3 Final summary

Because this project is only altering an existing modular design that has been established by Dr. Braude, it is a reasonably realistic goal to have all four of these concepts implemented into our final product. The main functions and dimensions have already been specified by Dr. Braude. With his extensive experience with these naked mole rat traps, details like trap size, materials, and baiting technique have already been chosen by Dr. Braude and lead to the most successful trapping of naked mole rats. These modular concepts should all be implemented within his existing trap design in order to give Dr. Braude even more success in trapping these rats in the field. This project will set each modification on different priority levels as we work to build prototypes and the final product. The highest priority modification is the one-way door mechanism. The one way door will replace the existing guillotine style trap door which introduces the problem of the door becoming stuck because dirt and dust from the outside elements would lodge in between the door and holding slots. The one way door will eliminate this exposure to such elements and should create a trap that requires less maintenance time overall.

The next modification will be the remote notification system. Currently, Dr. Braude must physically be on site in order to know whether or not the trap has caught a mole rat or not. He knows this by watching the trap door from falling. The newly implemented Remote notification system (RNS) will allow Dr. Braude to leave the trap site to accomplish other tasks. The notification system will ideally work up to a mile long range. It is important we make the system very reliable so that rats do not escape the trap if left alone for too long. Because there is already an existing electromechanical trip mechanism, we must alter the design so that the existing trip mechanism functions well with the new door motion sensor and has a similar detection success rate. This success rate was determined to be 95%, meaning that the motion detector will detect a rat 95% of the time and send a corresponding notification to a wireless device.

The sewer cam is a modification that will pair nicely with the RNS. As the design stands, there is no way to know whether or not a trap has caught a rat successfully or the trap simply malfunctioned. This sometimes leads to digging up traps that have caught nothing. A sewer cam placed at the end of the tube will allow Dr. Braude to see inside the trap before making the decision to dig it up. A sewer cam will also allow Dr. Braude to make sure the entrance of the trap is open and no clogging is present.

The last modification is a solar panel power source. The existing design uses alkaline batteries which need to be replaced often. Implementing a solar panel into the design will eliminate the need to bring batteries on site and should successfully power all implemented trap devices. It was determined that the solar panel should provide 120% of the total required voltage to ensure the trap will always function correctly. A rechargeable battery will be the main storage source so that power will be available even when

the sun is not out. USB compatibility is important with all of these design implementations in order to maintain the existing modular design of Dr. Braudes traps.

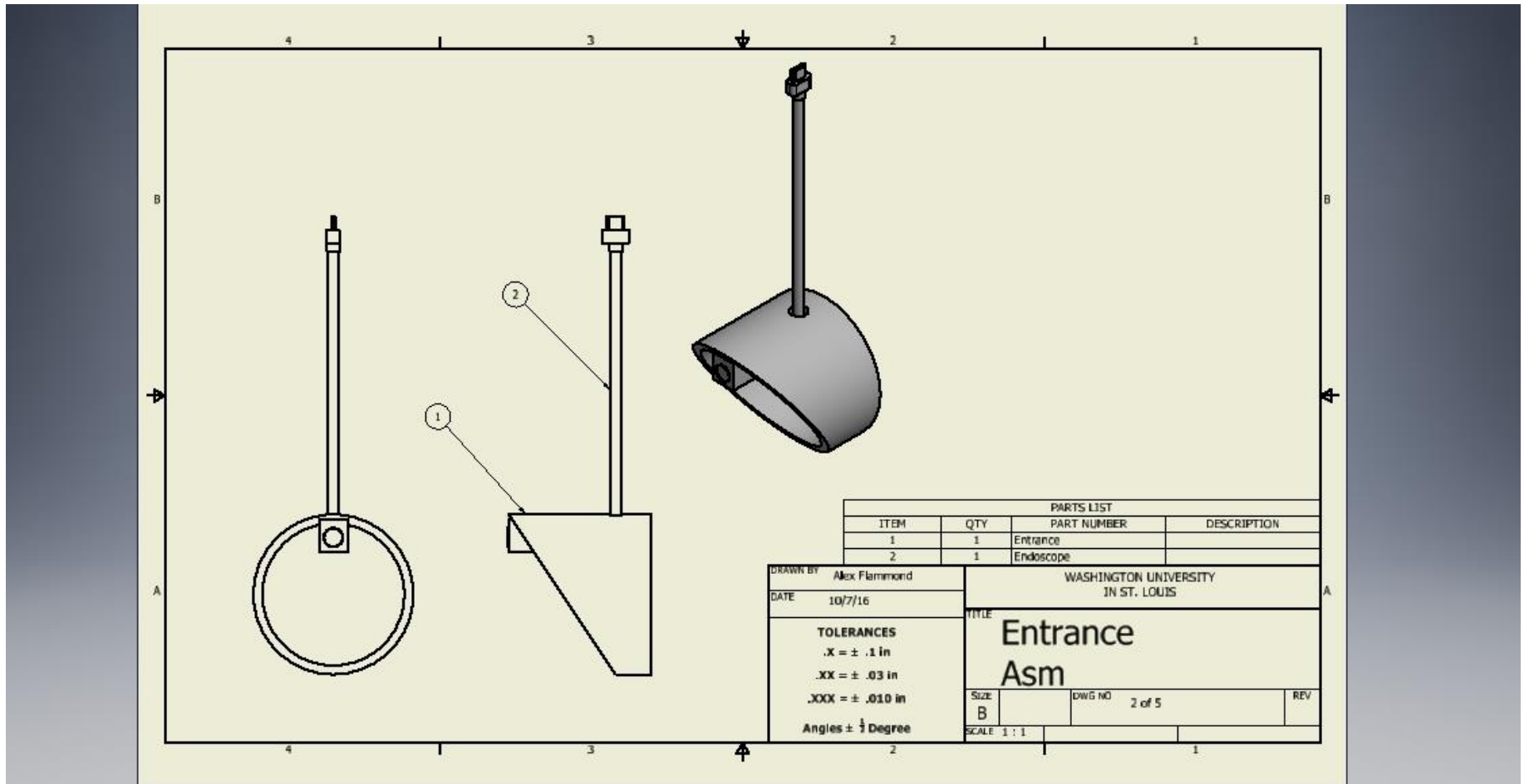
Summary of Performance Goals:

1. The one way door will eliminate exposure to outside elements and should create a trap that requires less maintenance time overall.
2. The newly implemented Remote notification system (RNS) will allow Dr. Braude to leave the trap site to accomplish other tasks.
3. The notification system will ideally work up to a mile long range.
4. The motion detector will detect a rat 95% of the time and send a corresponding notification to a wireless device.
5. Inside of trap viewable with camera for clog checkups.
6. Sewer cam will detect false alarms with malfunctioned or accidentally tripped traps.
7. Solar panel should provide 120% of the total required voltage.
8. All electronic components will be USB compatible.

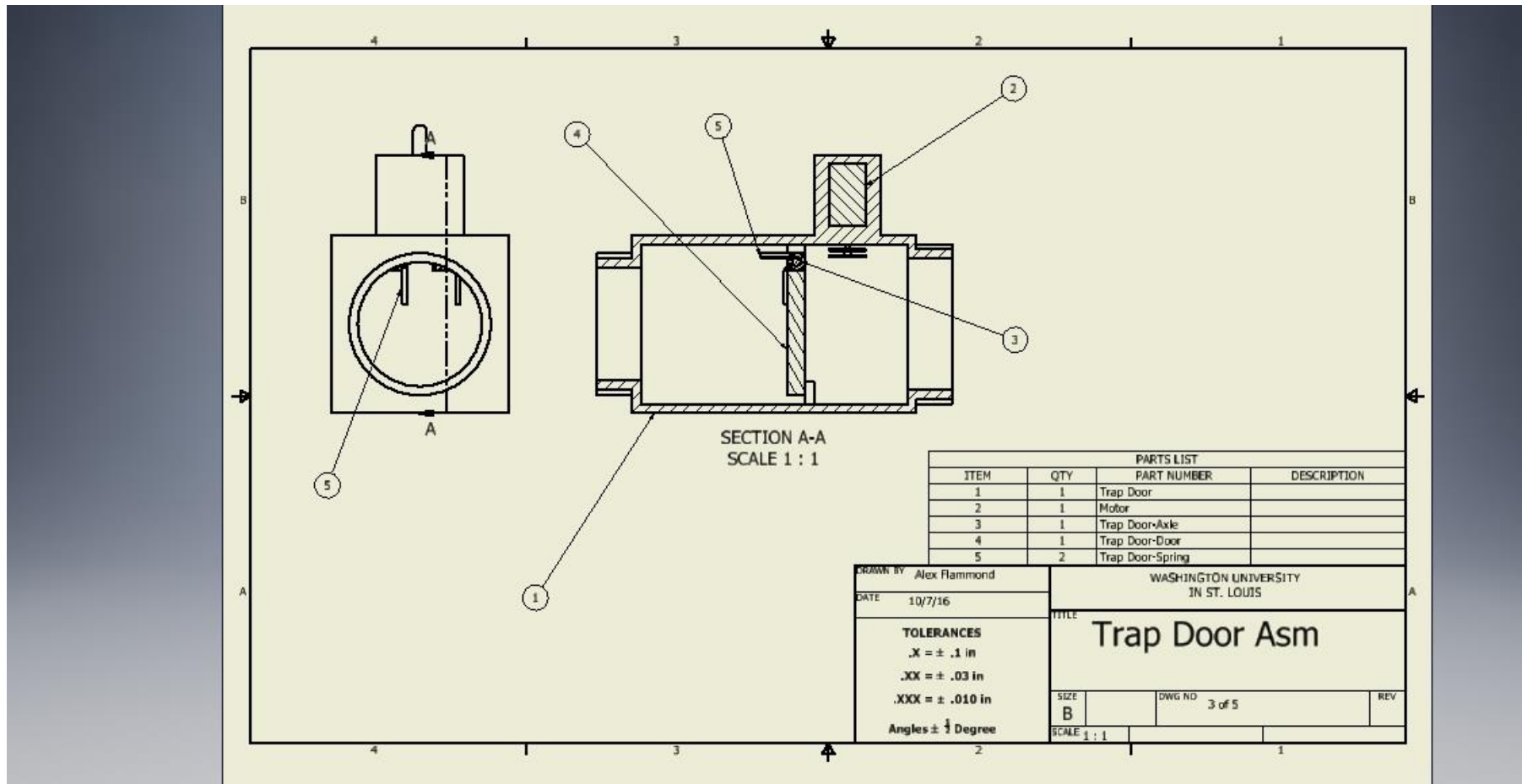
4 EMBODIMENT AND FABRICATION PLAN

4.1 EMBODIMENT DRAWING

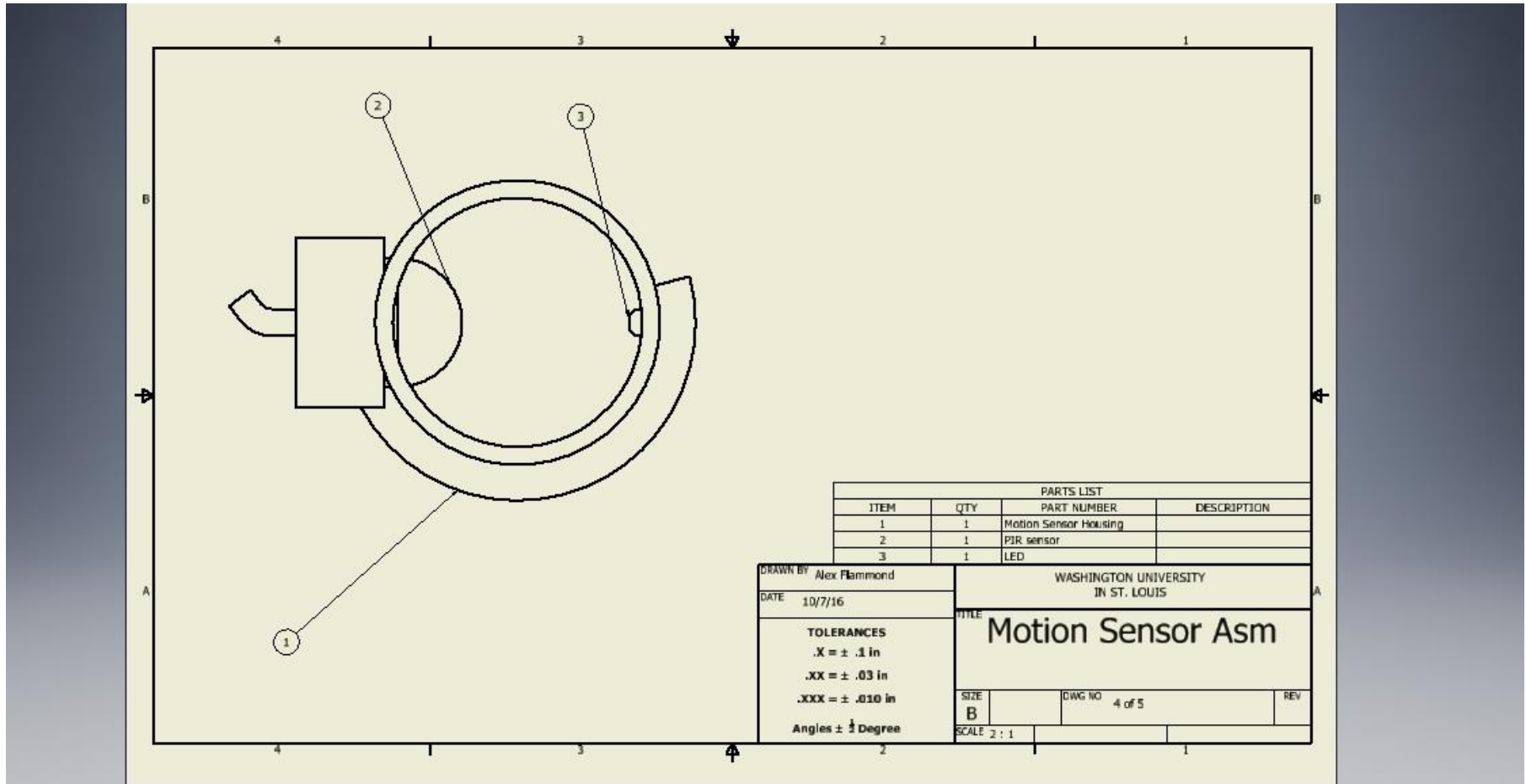
Entrance/ Endoscopic Camera Module:



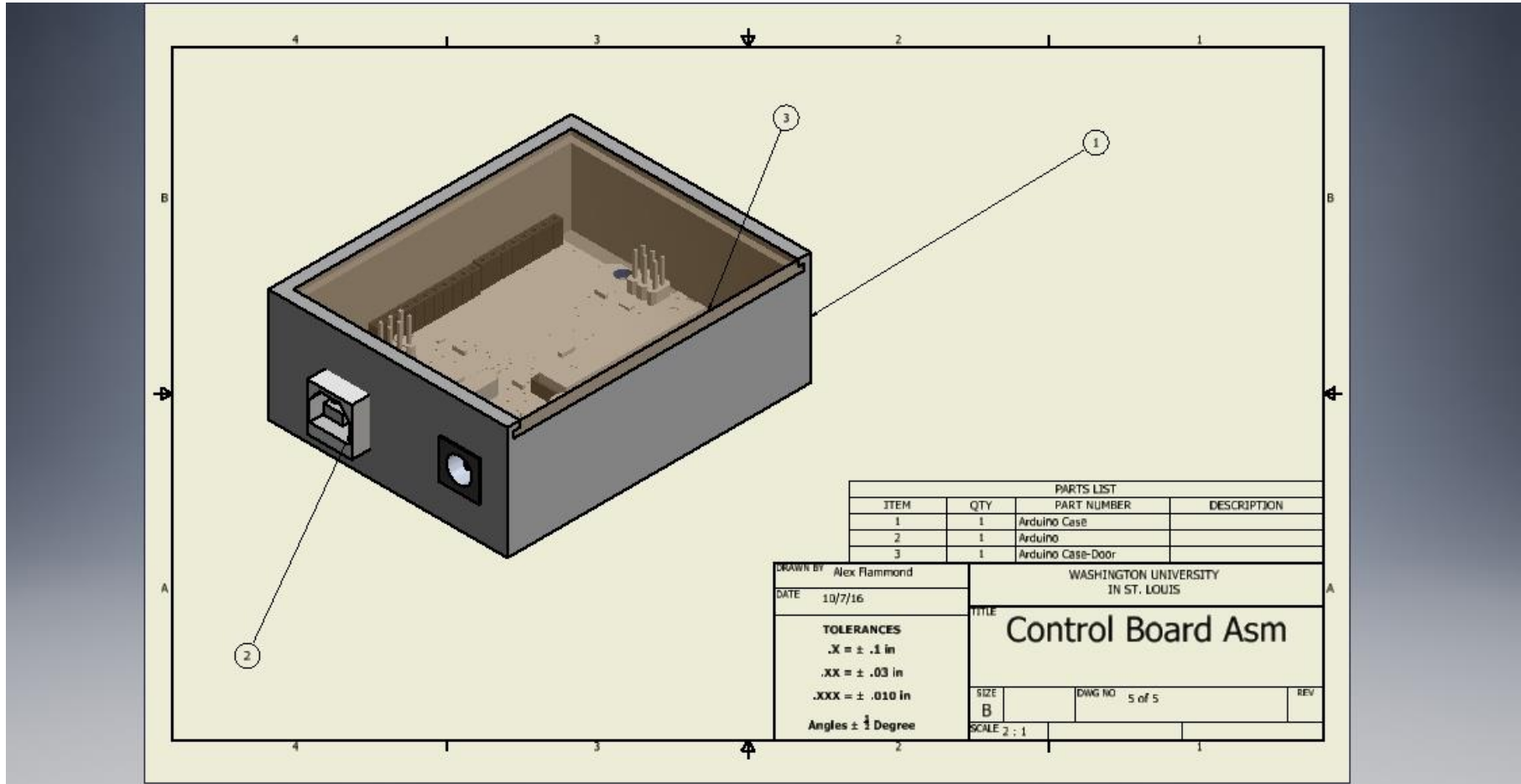
Trap Door Assembly:



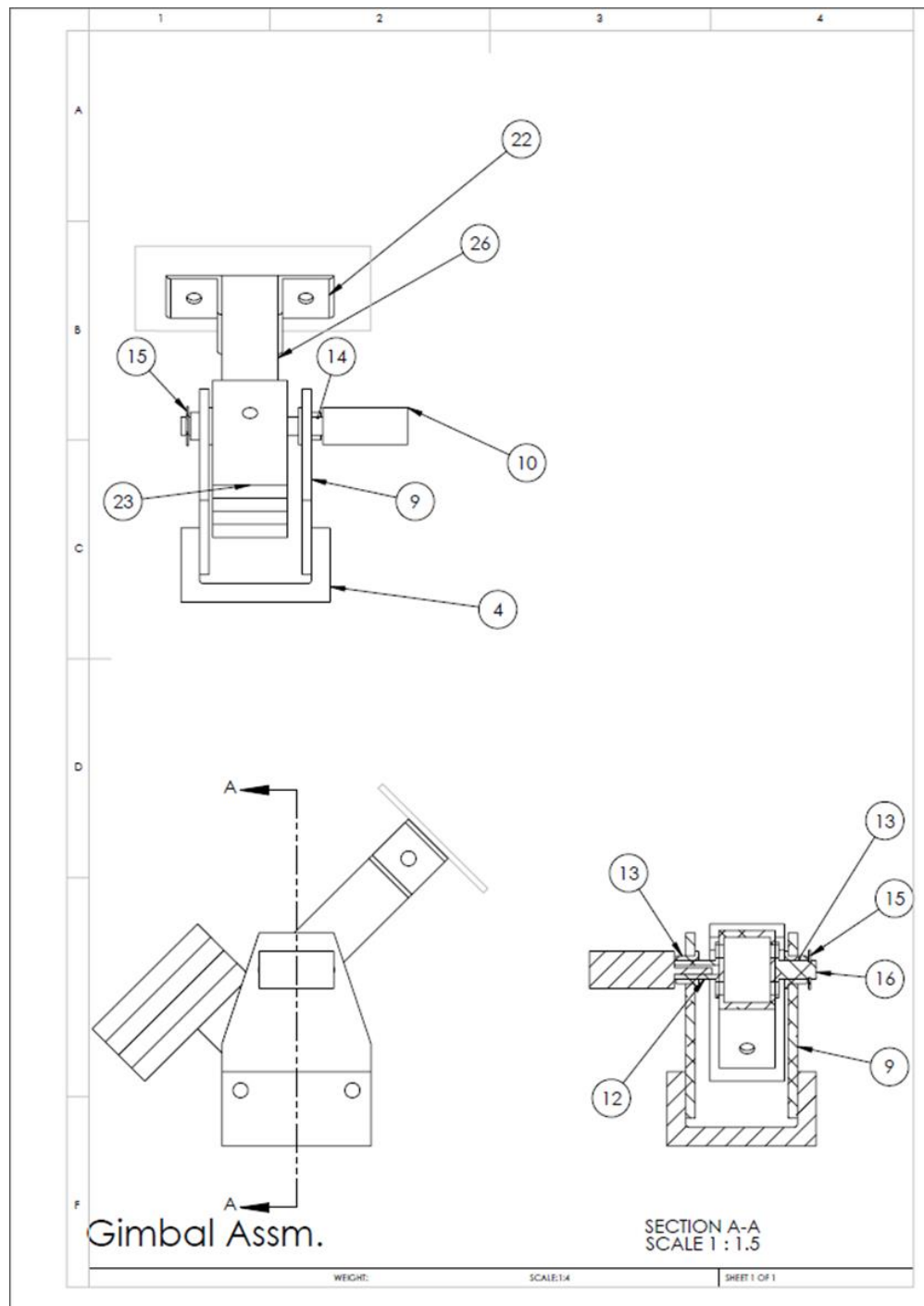
Motion Sensor Module:



Control/Arduino Board Assembly:



Solar Tracking Device:



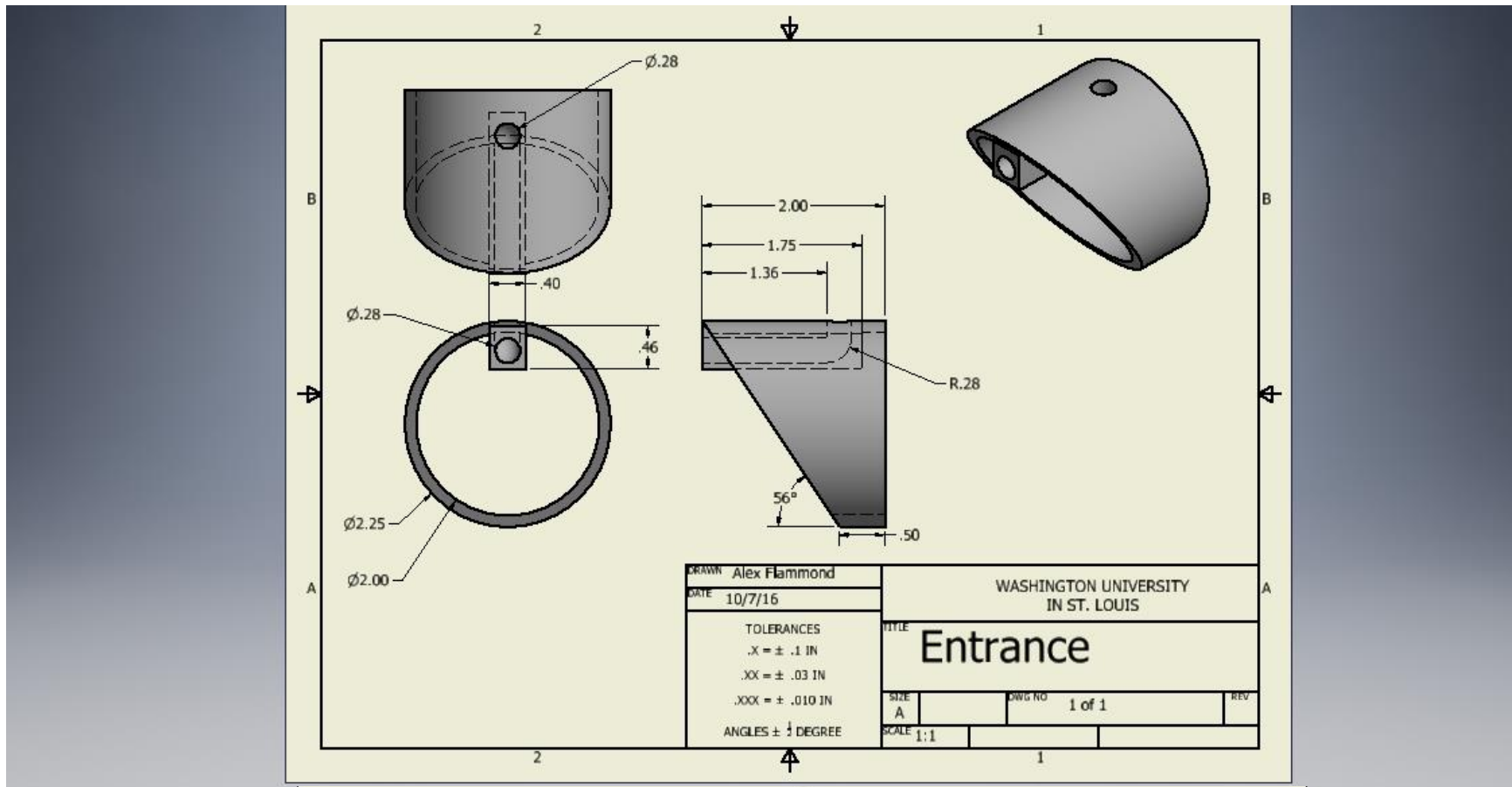
4.2 PARTS LIST

	<i>Part</i>	<i>Source Link</i>	<i>Supplier Part Number</i>	<i>Color, TPI, other part IDs</i>	<i>Unit price</i>	<i>Quantity</i>	<i>Total price</i>
1	Arduino Uno - R3	Sparkfun	DEV-11021		\$24.95	2	\$49.90
2	Standard Gearmotor	Sparkfun	ROB-12532	30 RPM (3-12V)	\$24.95	1	\$24.95
3	Torsion Spring	McMaster	9271K16	90 Degree Angle, .402 in - lbs. tourque , .56" OD	\$5.81	1	\$5.81
4	Infrared Emitters and Detectors	Sparkfun	SEN-00241	Contains emitter and detector	\$1.95	2	\$3.90
5	Endoscopic Camera	Amazon	5491673	Micro USB ready	\$13.99	1	\$13.99
6	XBee shield	Sparkfun	WRL-12847	Arduino compatible	14.95	2	\$29.90
7	XBee Module	Sparkfun	WRL-08742	1 Mile range	37.95	2	\$75.90
8	9V Li-ion Rechargeable Battery - 350mAh	Sparkfun	PRT-10053	350 mA capacity each	4.76	2	\$9.52

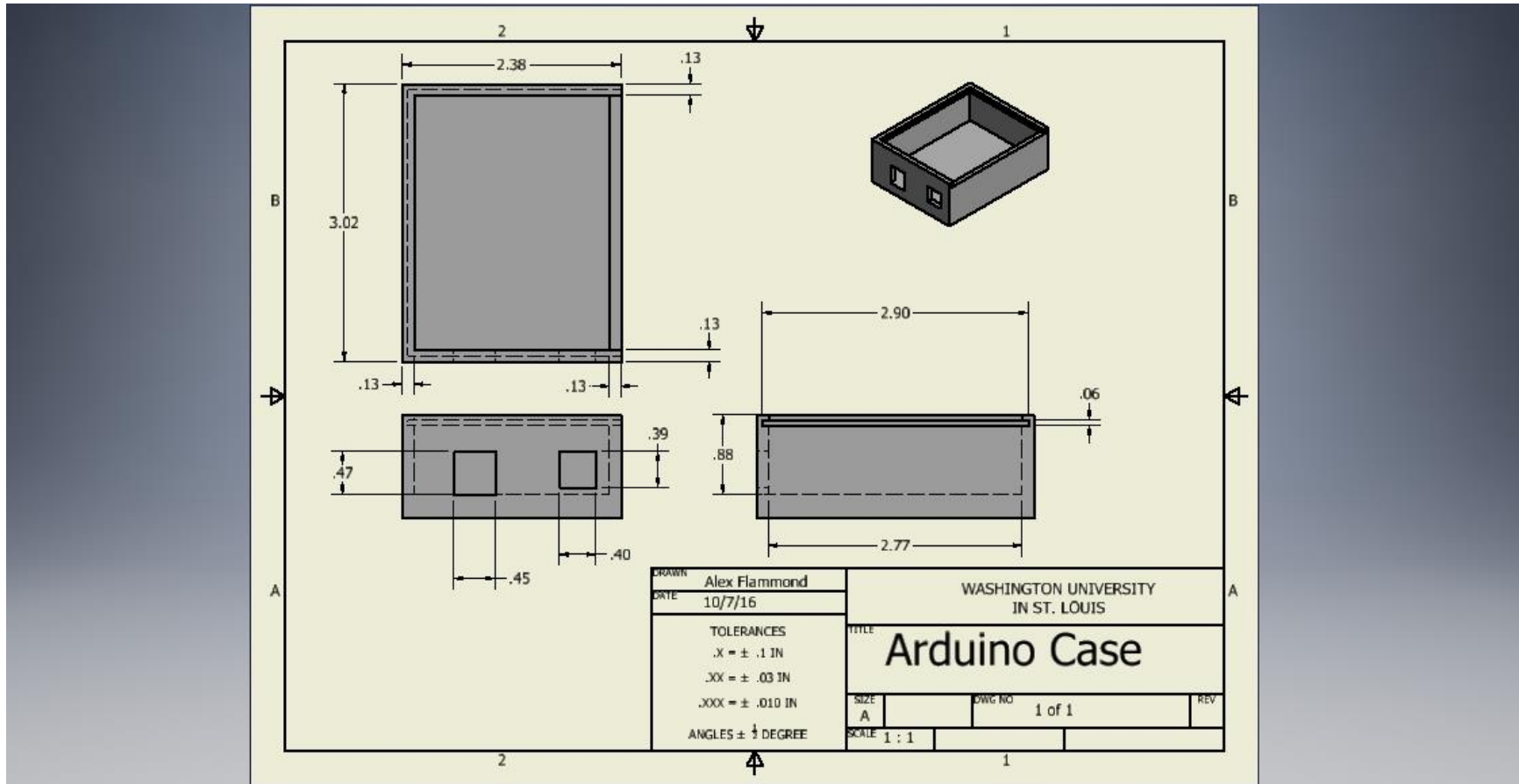
9	Molex Jumper 2 Wire Assembly	Sparkfun	PRT-09918	Easy connect/disconnect	0.95	2	\$1.90
10	18 AWG 2-Conduct Wire	Radioshack	2780567	25 ft.	8.72	1	\$8.72
11	Electrical Tape	Home Depot	813848010052	3/4"	1.97	1	\$1.97
12	12VDC Coil DPDT Miniature PC Relay	Radioshack	2750043	10 Amp max	10.49	1	\$10.49
13	Arduino Headers	Gateway Electronics	n/a	4 x 8 pin, 4 x 4 pin	4	1	\$4.00
14	.5 Oz. Rosin Core Solder	Home Depot	70042196306		3.47		\$3.47
15	9V Snap Connector	Sparkfun	PRT-00091	Easy connect/disconnect	1.25	2	\$2.50
Total:							\$246.92

4.3 DRAFT DETAIL DRAWINGS FOR EACH MANUFACTURED PART

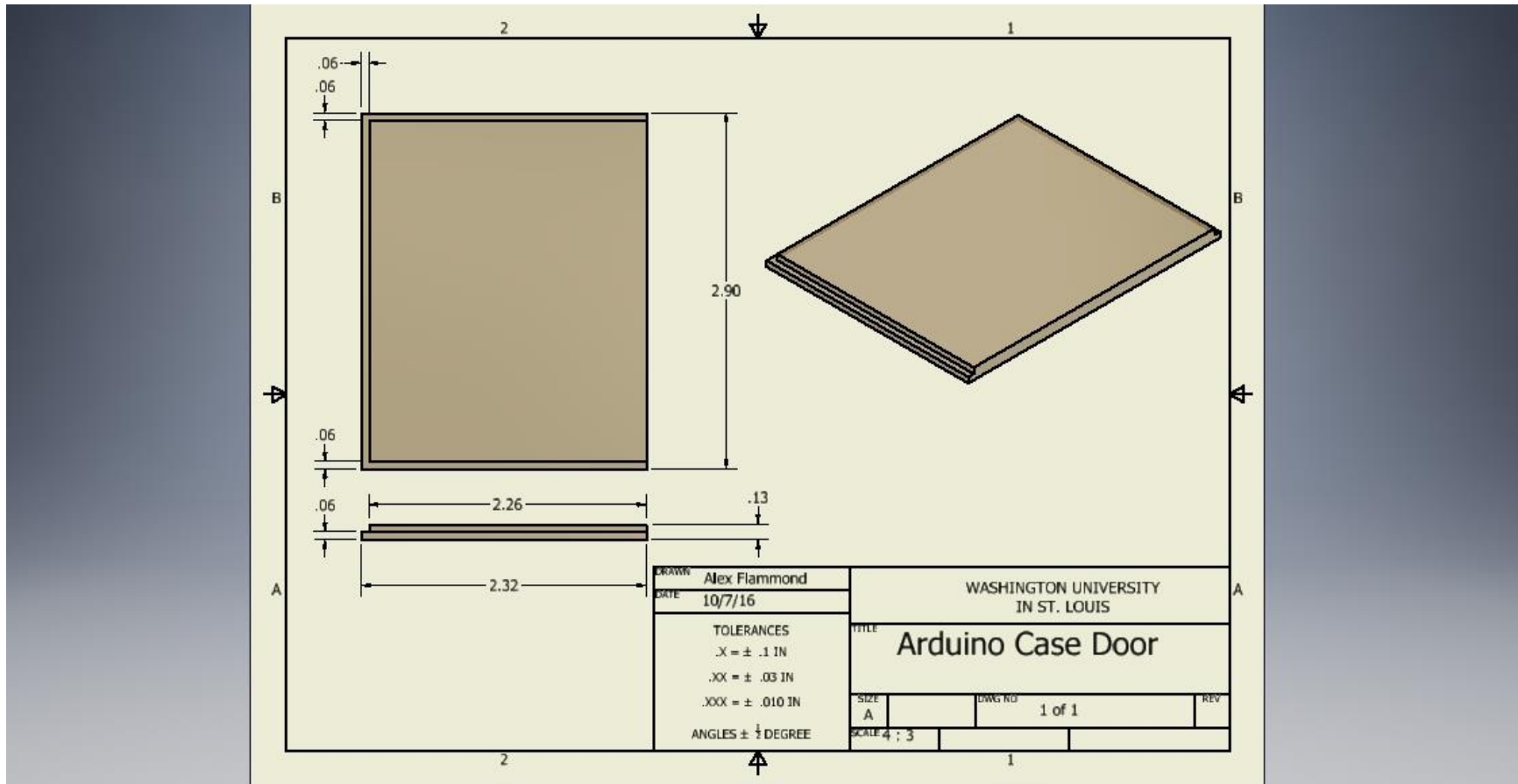
Entrance/Endoscopic Camera:



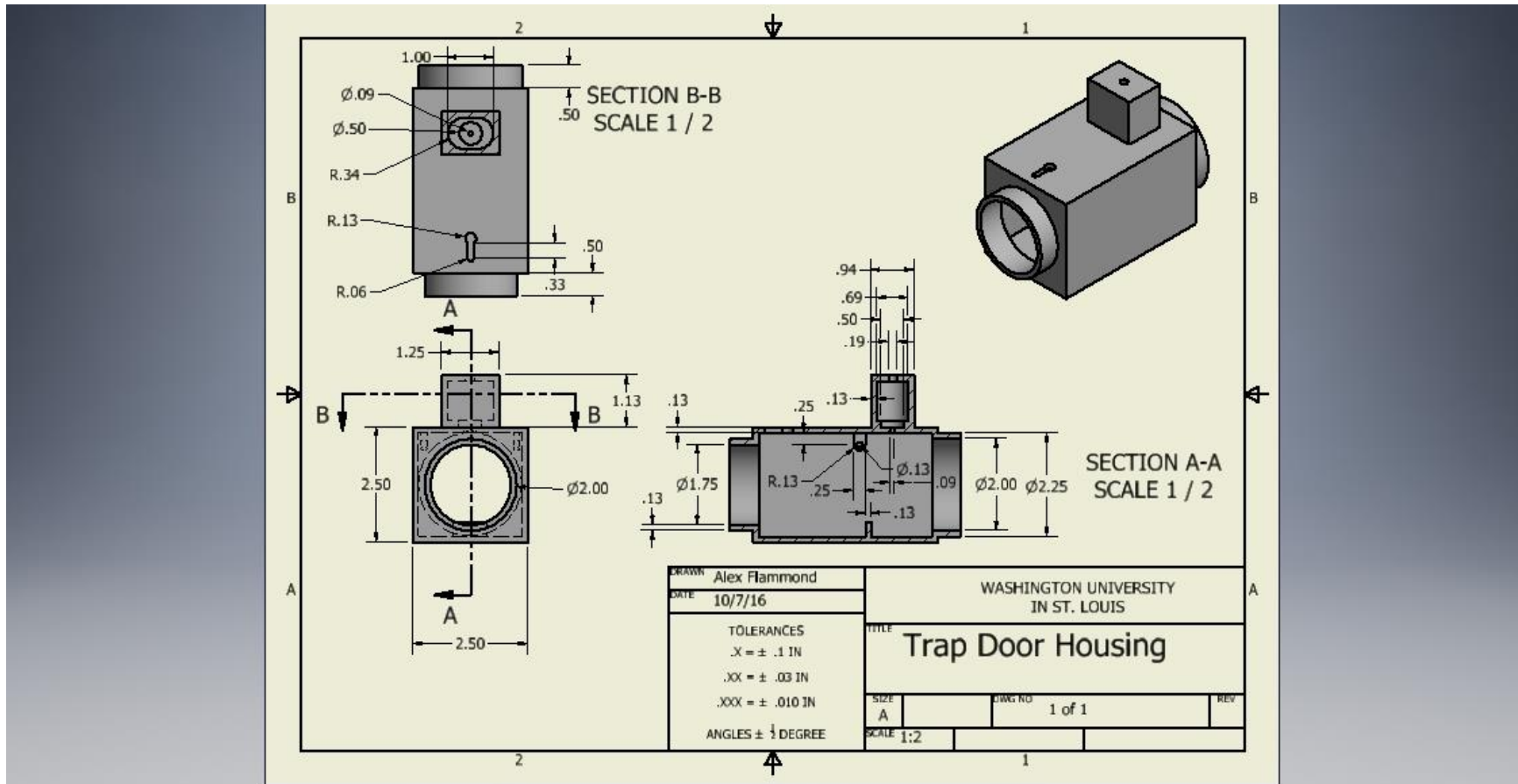
Control/Arduino Board Case:



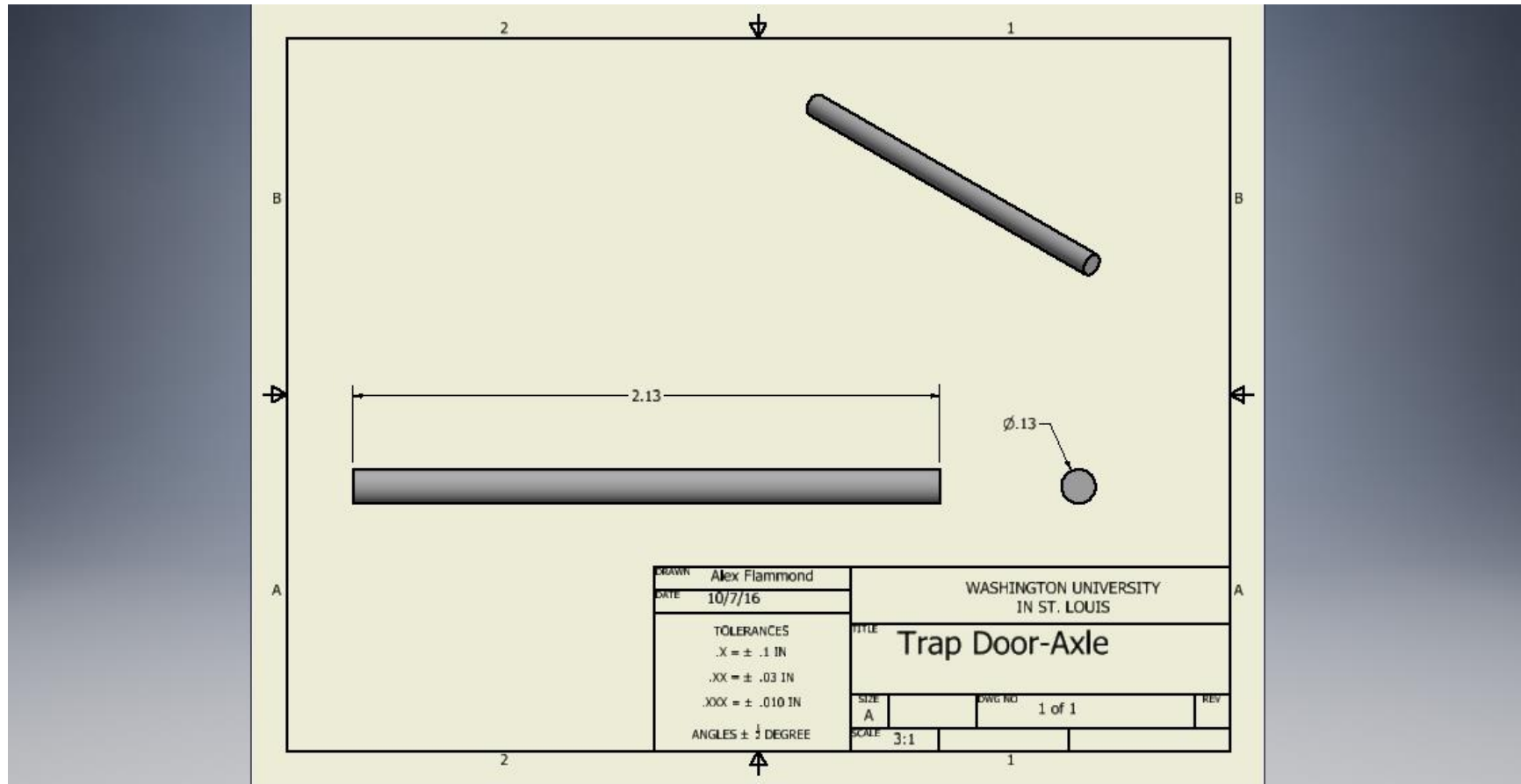
Control/Arduino Case Door:



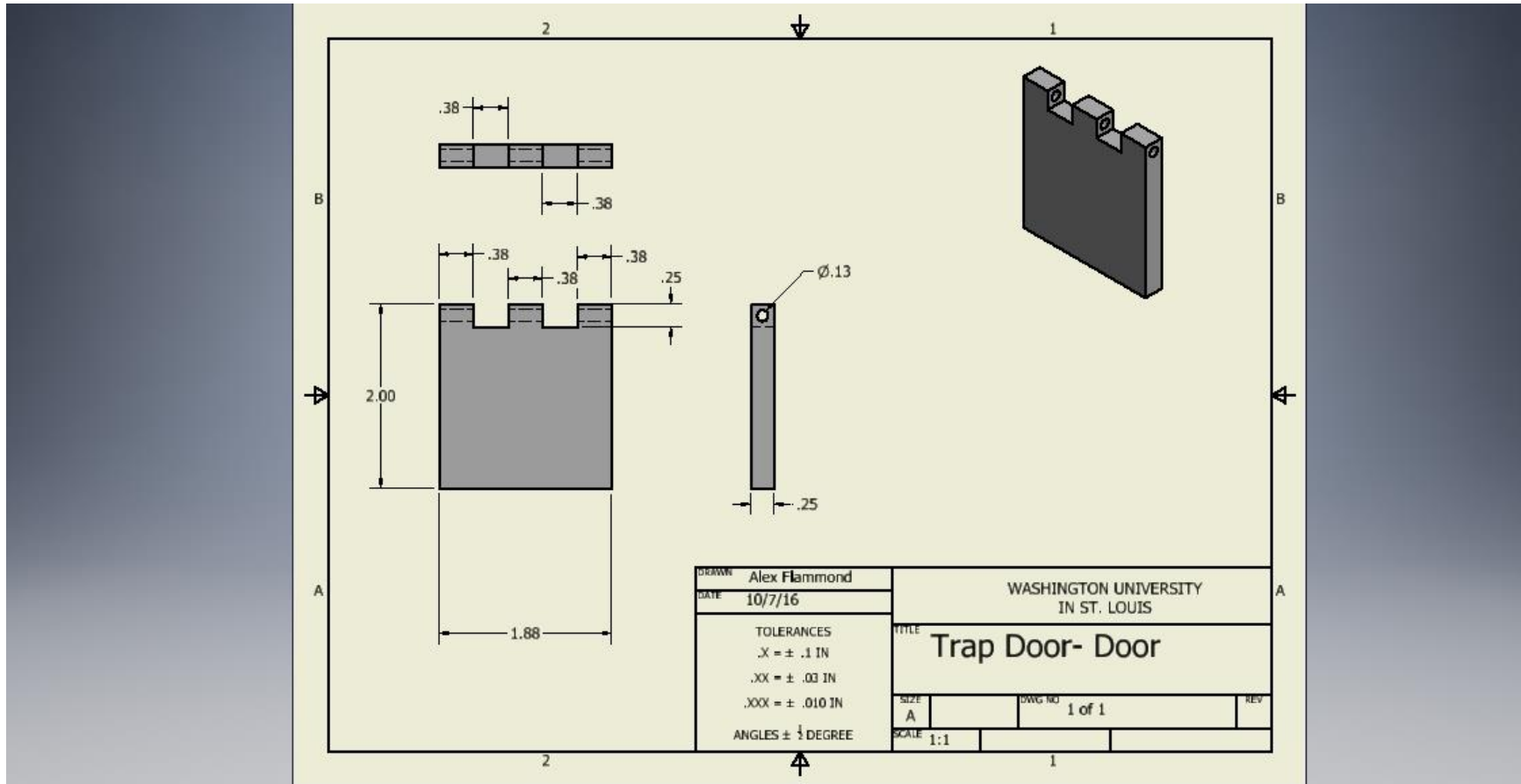
Trap Door Housing:



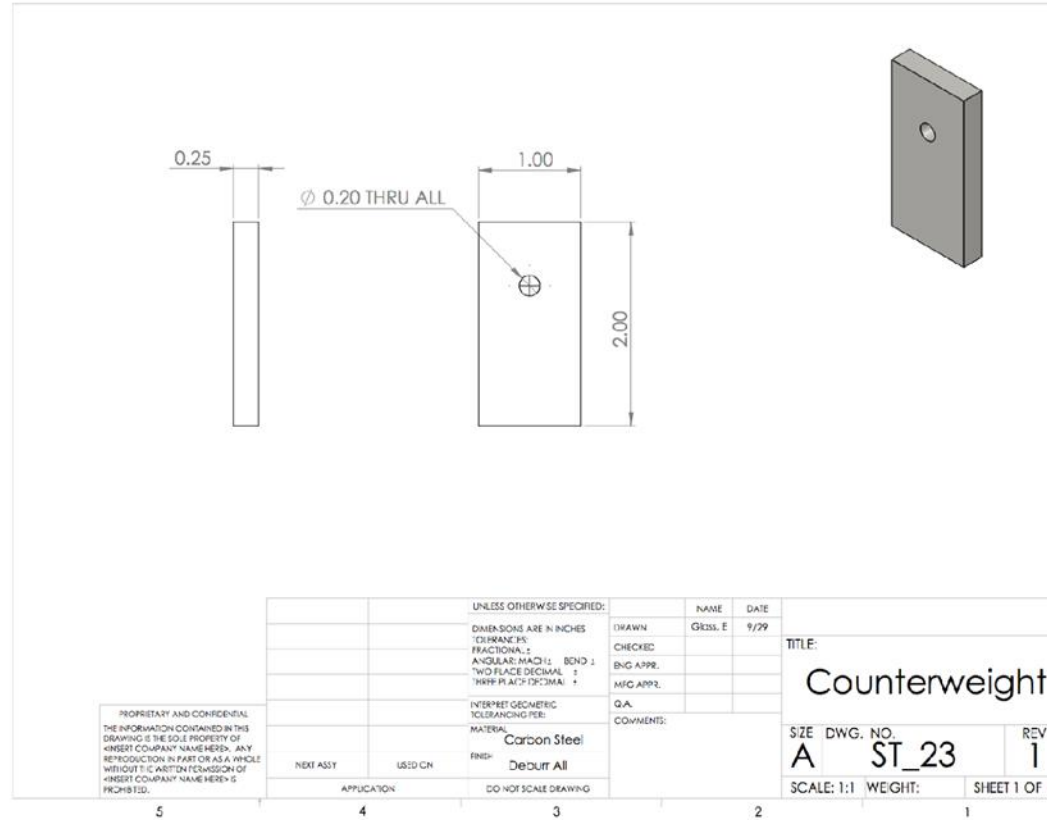
Trap Door Axle Rod:



Trap Door - Door:



Counterweight:



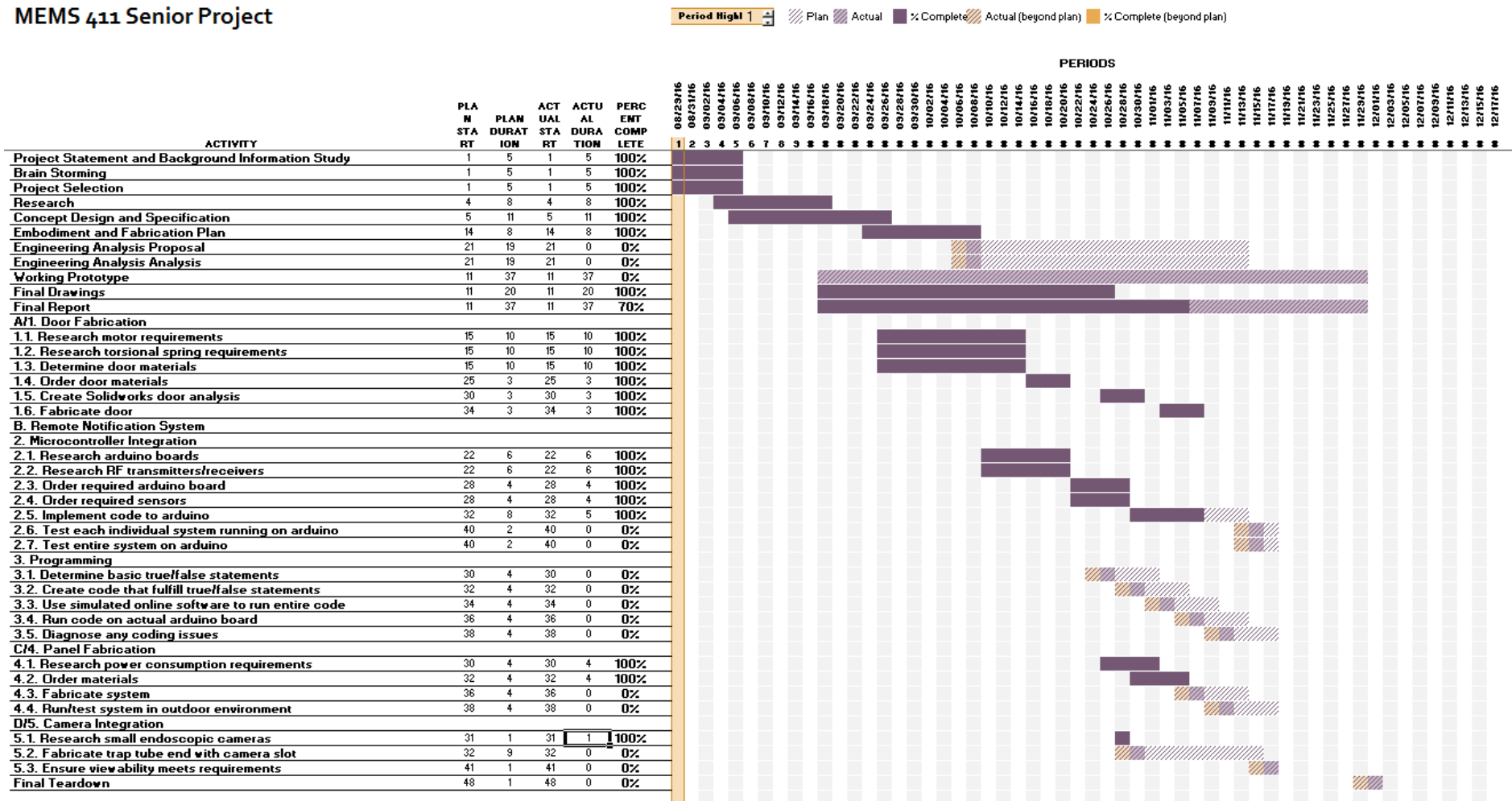
4.4 DESCRIPTION OF THE DESIGN RATIONALE FOR THE CHOICE/SIZE/SHAPE OF EACH PART

Part Rationale:

1. The Arduino Uno board will give us the capability to control the motor, camera switch and send RF signal to the wireless device based on input from two mini photocells. A second board will be needed for the RF receiver device.
2. This standard gear motor will provide enough voltage to pull the bead holding the torsion door via a keyhole. This motor only needs to function one way since door will be reset manually every time.
3. This UV resistant acrylic round tubing matches the dimensions of Dr. Braudes current trap design and will hold up to weathering and temperatures up to 180°F.
4. A 24"x24" (5/64" thick) UV resistant acrylic sheets will be fabricated to provide housing protection for the RF receiver device and gear motor.
5. A torsion spring with a rating of 5.518 in-lbs. of torque should provide enough force to keep door closed based on the assumption that a naked mole rat can push up to twice its body weight.
6. A simple mini photocell with a 10k Ohm dark resistance will be sensitive enough to detect obvious light changes based on whether or not a rat passes in front of an LED providing constant light output.
7. Assorted pack of LEDs will give sufficient light output for the photocells to detect. Voltage to LED will be determined do ensure LEDS from opposite ends of the tube do not interfere with opposing photocells.
8. This endoscopic camera is 7mm in diameter and will easily fit inside the traps end. The camera comes with 6 white LEDS and a resolution of 640x480 which will give a sufficient view of inside of trap. A waterproof design ensures weathering capabilities in the long run.
9. A RF Link transmitter will allow the Arduino to send a RF notification up to a 500 ft. range to a receiving device.
10. A RF Link receiver will receive the RF signal from the transmitter up to a 500 ft. range. The transmitter runs on the same frequency as the transmitter (434 MHz).
11. Flexible, "bend and stay" , 16 AWG wire will allow wiring of Arduino board to sensors, LEDs and RF transmitter/receiver.
12. A steel dowel pin will work in conjunction with the torsional spring to create force required to keep trap door shut. The pin will function as the hinge for the door.
13. An electronics enclosure will provide weather/dirt protection for the Arduino board, photocells, and LEDS
14. A 6Ah (6000mAh) rechargeable battery will provide enough storage space to power sensors, microcontroller, camera and motor for a sufficient amount of time without recharging.

4.5 GANTT CHART

MEMS 411 Senior Project



5 ENGINEERING ANALYSIS

5.1 ENGINEERING ANALYSIS RESULTS

5.1.1 Motivation

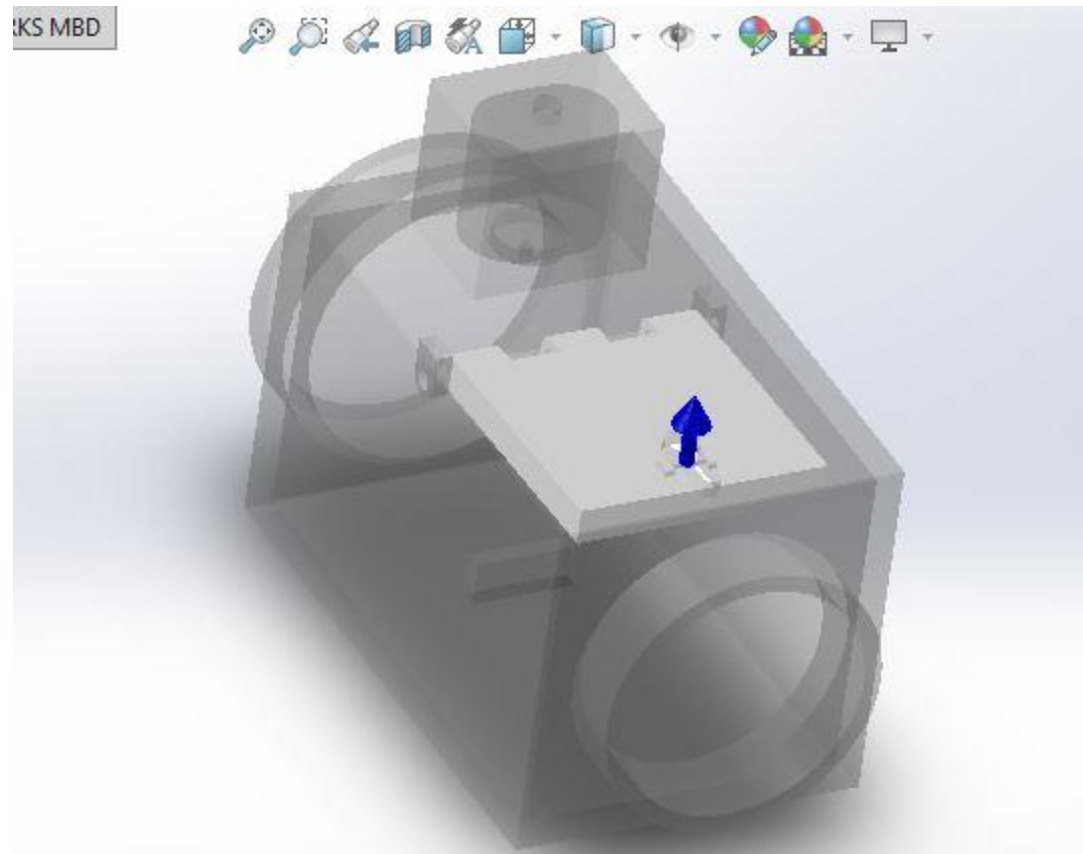
For our engineering analysis, we decided to focus on the only real moving part of our trap design; the spring door. We needed to ensure that there were no contact interferences between the trap door and trap door housing. It was also important that the door shut quickly enough to prevent the naked mole rat from escaping when the motor began turning to pull the lead ball through the key hole. We also needed to make sure that the door itself and the protruding stopper could handle the desired amount of torque/impact force that our spring provided.

5.1.2 Summary statement of analysis done

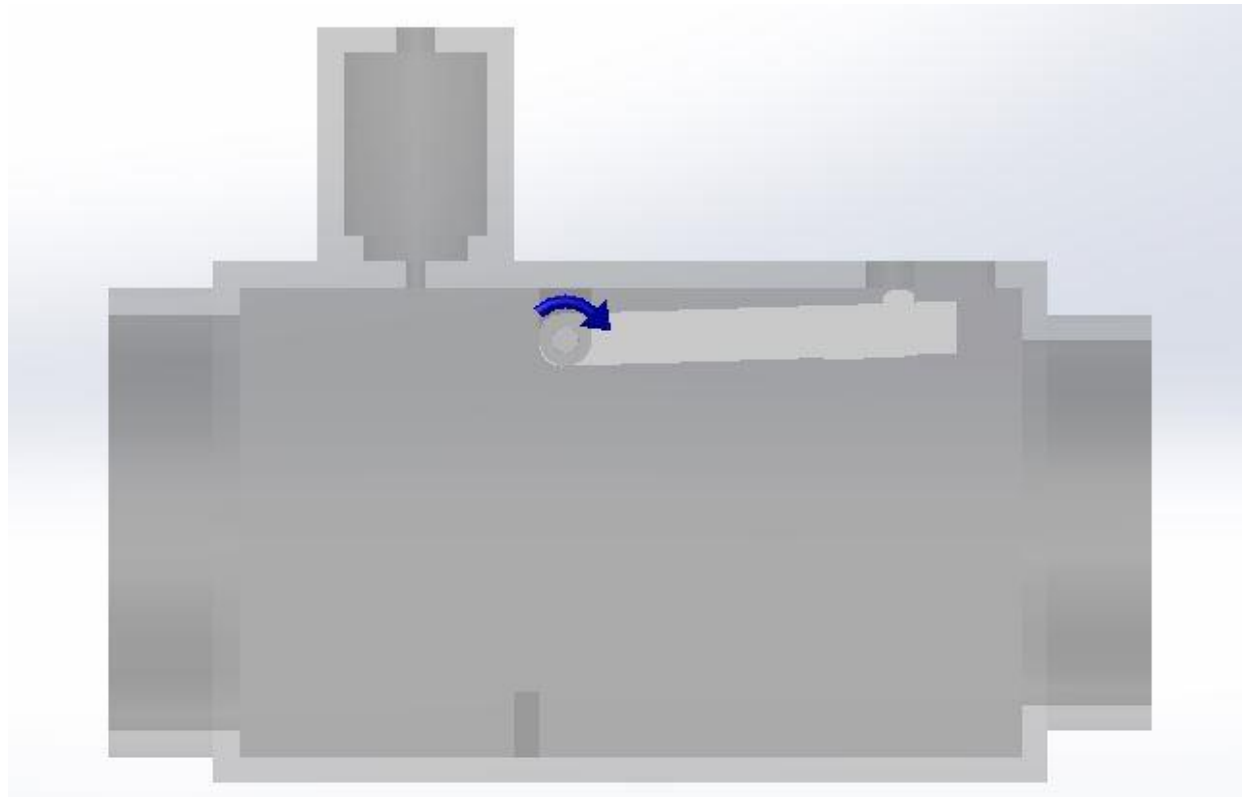
We carried out our analysis all through the Solidworks® software utilizing the motion analysis in Solidworks Motion® as well as Solidworks Simulation®. The results of the simulation showed that our design function properly as desired. After further investigation of the results, there were a couple aspects of the door design and door housing design that we changed because of alignment reasons. These changes will be discussed in the Significance section(5.2.5) of this report.

5.1.3 Methodology

For the motion analysis we created contact sets between the door housing, the door axle, and the door itself. We first modeled a .5 lb linear force pulling up on the door where the key line would be attached. This will be the default state of the trapped in its un-tripped setting. A picture of this can be seen below.

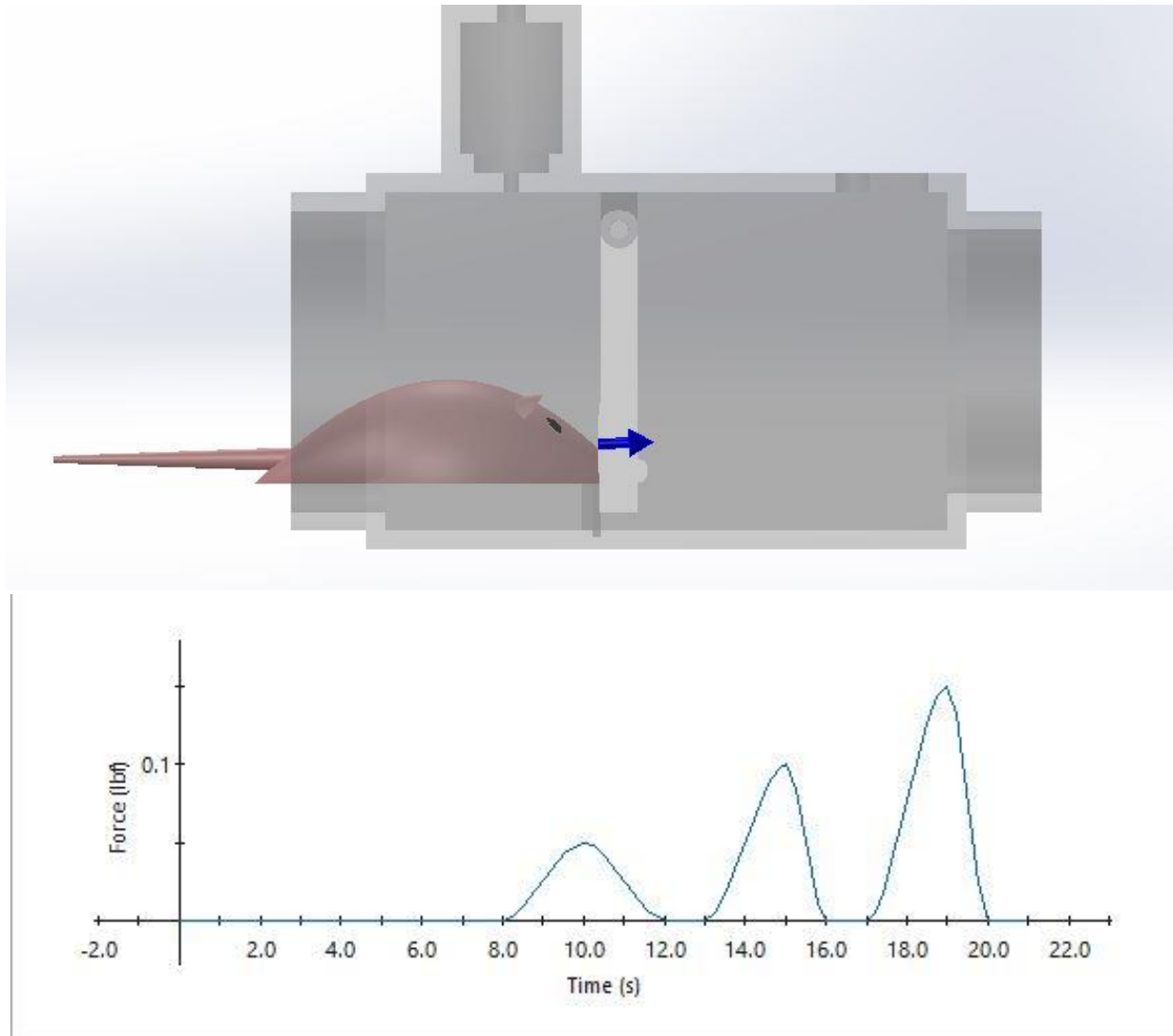


We then applied a .804 in-lb. torque on the doors hinge point to simulate the 90° torsion springs that we had decided to purchase. This torque rating was decided based on the fact that most animals can push/pull up to two times their body weight. Naked mole rats weigh an average of 1.0-1.2 oz. so we chose the .804 in-lb. with a factor of safety of 3. value based on this upper limit and the approximate area where the mole rat would likely push up against the door. A visual representation of this can be seen in the image below.

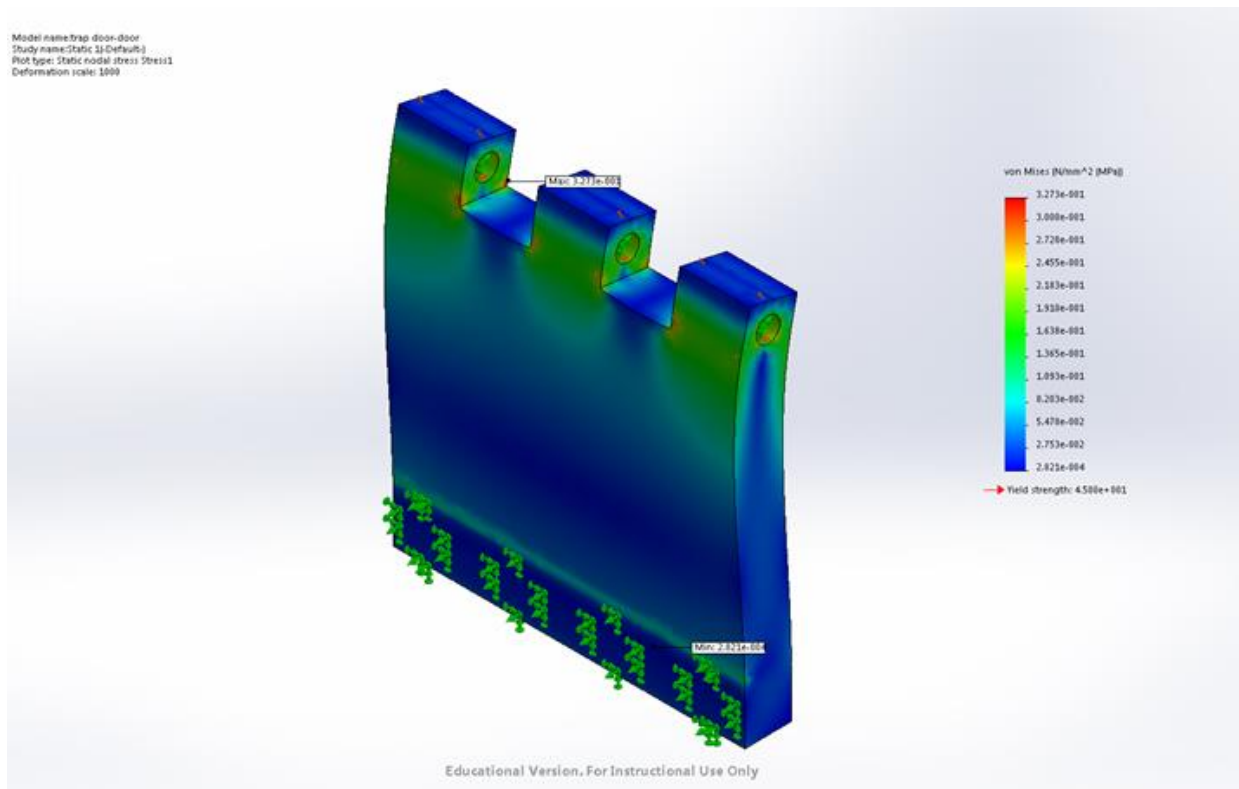


It should be noted that this torque will be constant and unchanging throughout this analysis to simulate real world conditions. After we had our initial trap settings in place, we inserted a pseudo-naked-mole-rat part into our analysis to give a better idea of the timing of our design. The rat was set to enter the trap and pass all the way through to the bait section at the end of the trap. (This would be the far left in the image above) When the rat reached the portion of the tube where the bait and the second infrared sensor, the .5 lb. linear force was removed to simulate the lead ball being pulled through the key hole and the door being released from its upward position. The analysis showed the expected results, being the door snapping shut in a short amount of time without any interferences between the door and the door housing. Now that we know that the tripping mechanism works as expected, we needed to model the pseudo-naked-mole-rat attempting to get out of the trap. To do this, we modeled a segmented forcing function based on the assumptions mention earlier, with the max force being twice the rat's body weight.

$$2 \times 1.2oz = 2.4oz \approx .15 lbs$$



For the stress analysis, we simply took the door during the time that rat was pushing a .15 lb. force on the bottom section and analyzed the stresses present. A peak stress of .23 MPa occurs near the hinges of the door, as would be expected. This is two orders of magnitudes below the yield stress of ABS plastic. A graphic of this analysis can be seen below.



Additionally, should the need arise, this mechanism can be simulated as a contact problem between the door and doorstop. This would be advantageous because it would show the mechanical behavior of the doorstop as well. However, this would require the use of Ansys® software, as Solidworks® does not provide high-fidelity contact simulation. Lastly, further simulation could be done to show the thermodynamic expansion and contraction within the assembly based on the traps in-the-field environment.

5.1.4 Results

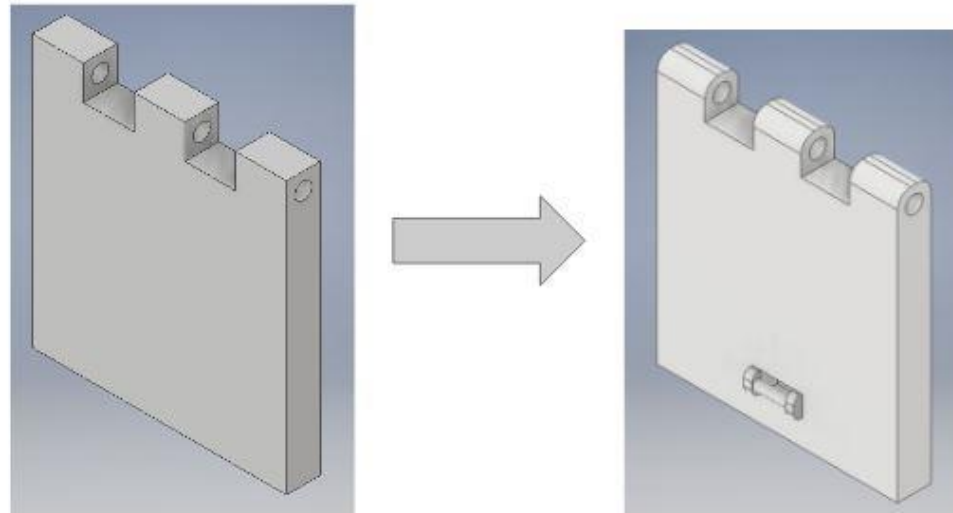
The results of our analysis is what was expected. Things we were anticipating were high Von Mises stresses on the door stopper and on the door hinge point. We did initially have trouble with our simulation when it showed the model intersecting with other parts of the model. For

example, when we first ran the simulation, the door would rotate all the way through the housing and pass right through the door stop. This was fixed after we realized our material was not set to ABS plastic. Other issues arose when we accidentally set the torsion force too high and the simulation again showed the door passing through the door stop showing that the impact force would have broken the door stop. This wrong value was realized when we realized that an average naked mole rat weighs 1.2 oz and NOT 1.2 lbs.

Other than the things mentioned above, our analysis showed the expected results. A video of our motion analysis can be seen here: <https://youtu.be/NmwfI7Wgvz4>

5.1.5 Significance

We did implement some design changes after carrying out our engineering analysis. Although, the stresses were not as high as we anticipated in the door, we decided to change the door design by adding rounded fillets to the hinge point to reduce the stresses where there were sharp angles. We also added a point for our fishing wire to connect to the door for our tripping mechanism. This change can be seen in the images below.



5.1.6 Summary of code and standards and their influence

After assessing the relevant codes and standards, the importance of making sure that the naked mole rat remained unharmed was very important. This acknowledgement did not influence the change in any of our mechanical design, but it did influence some of the coding for our sensors. The implantation of two sensors into our trap (one at the front and another where the bait is placed) was originally to detect trap blockage. But in order to ensure the rat's safety, it was decided that the door will only shut if the back sensor is tripped. The tripping of the trap will happen immediately after the back sensor was tripped to ensure that the rat was far enough away from the door so that it would not be exposed to unsafe conditions.

5.2 RISK ASSESSMENT

5.2.1 Risk Identification

When identifying the potential risks in our project, it was easy to see that the electromechanical aspect of the project would be most difficult in developing. None of the members of our group had any previous experience with circuit design or Arduino coding.

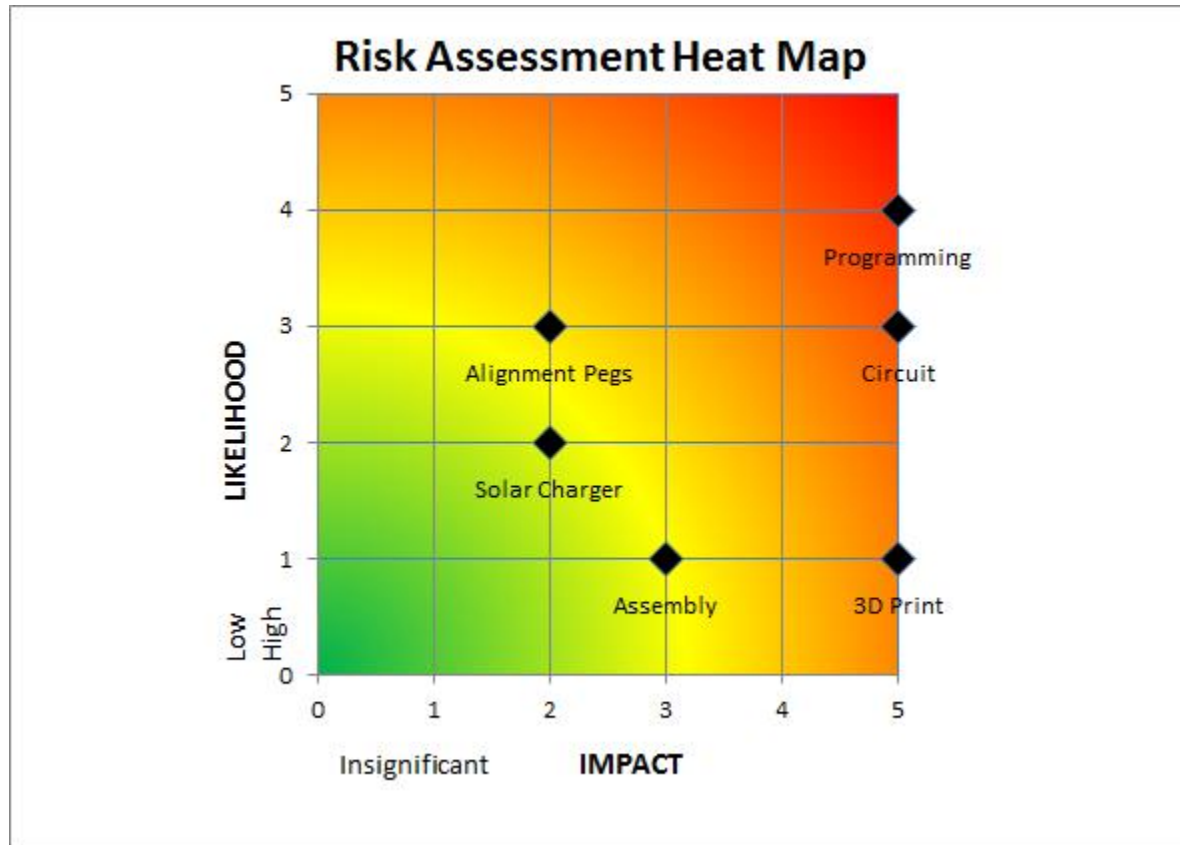
Another risk that was determined early on was the ability to produce accurate parts through 3D printing. It was decided early on that 3D printed parts would be the most logical method for fabricating our trap. Not only was it anticipated that 3D printed parts could come out less desirable than designed, but we needed to consider the fact that many other design groups would be using the 3D printers as well as engineering students in general. Because we needed to print our parts in ABS, this limited us to using the Makerbot® since it had a heated bed to prevent warping. Thus, availability of 3D print time was further diminished.

5.2.2 Risk Impact or Consequence Assessment

As a consequence of the identified risks, we made it a priority that we taught ourselves the necessary skills to build our circuit before the prototyping phase began and that we began printing prototype parts early on.

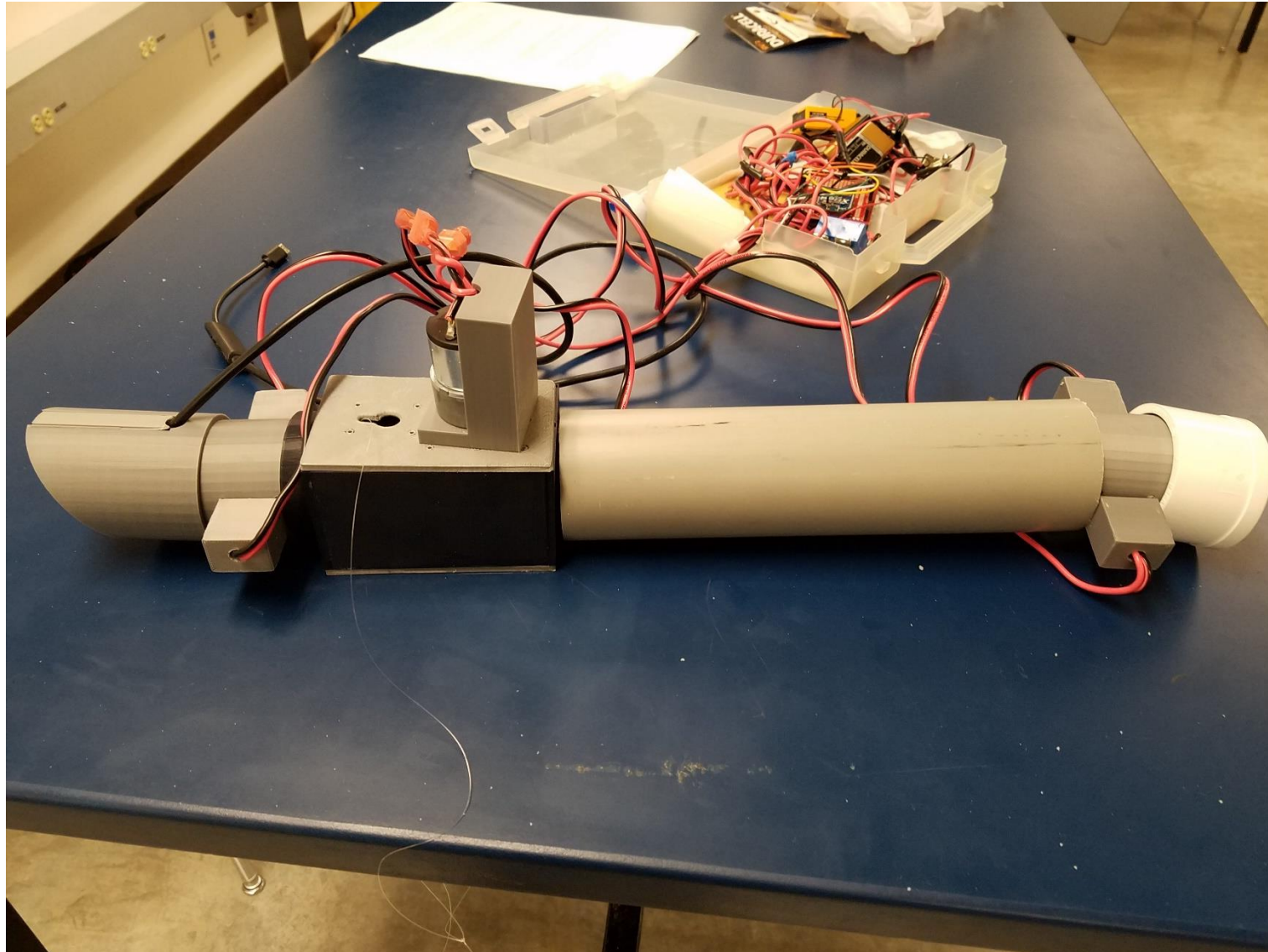
5.2.3 Risk Prioritization

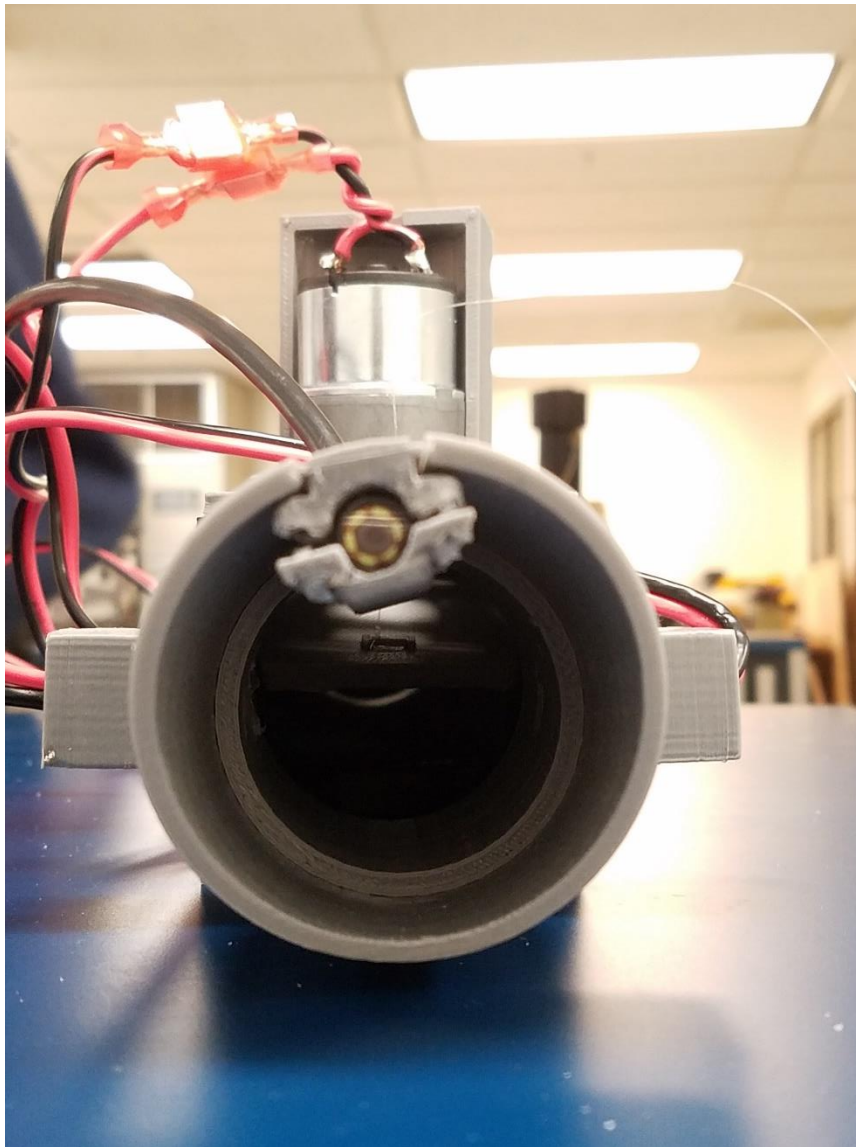
To better decide on how to approach the prototyping phase of this project, we developed a heat map by assigning a likelihood and impact rating for each identified risk. The result can be seen in the figure below.



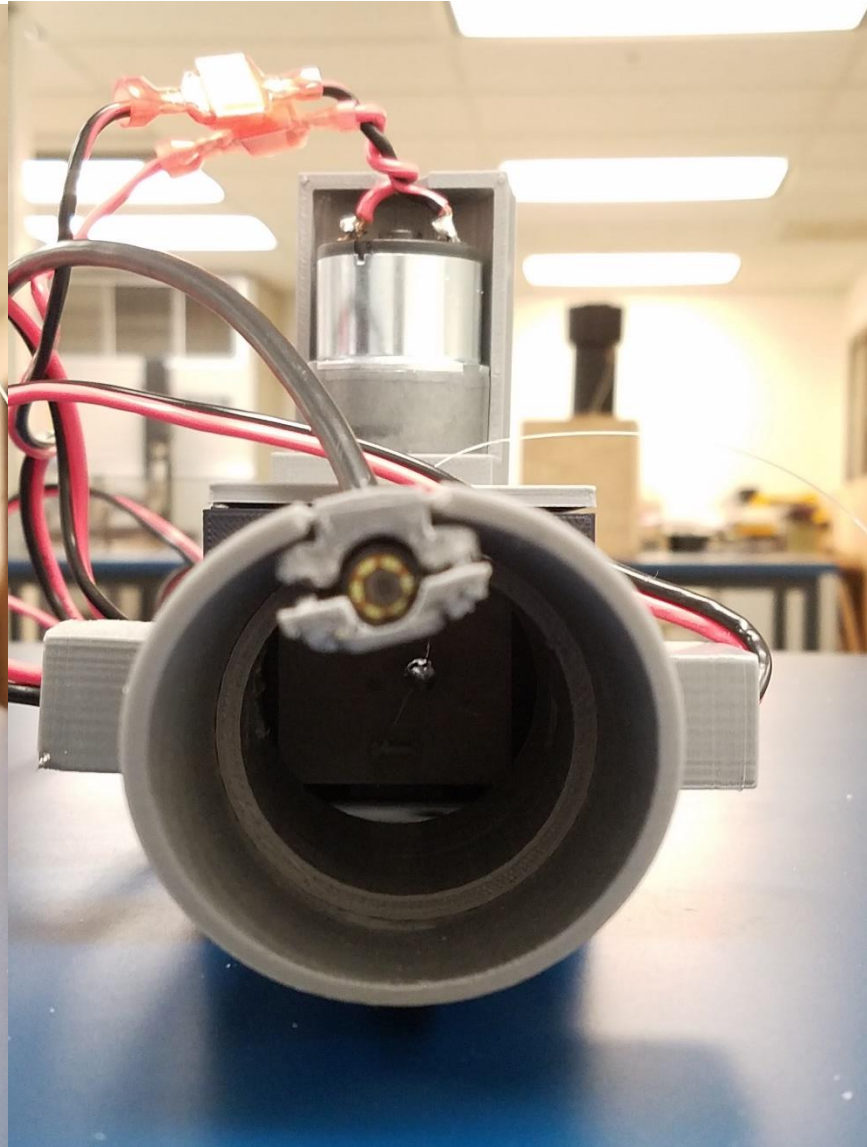
6 WORKING PROTOTYPE

6.1 AT LEAST TWO DIGITAL PHOTOGRAPHS SHOWING THE PROTOTYPE





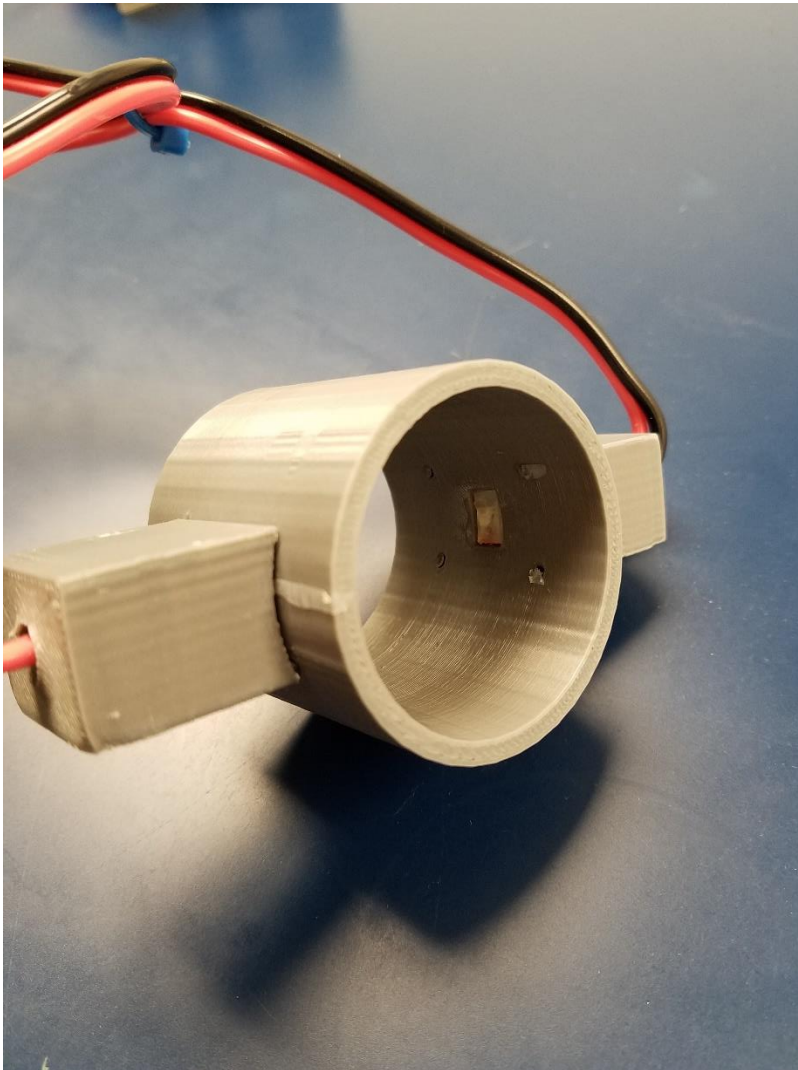
Un-tripped Trap



Tripped Trap

6.2 A SHORT VIDEOCLIP THAT SHOWS THE FINAL PROTOTYPE PERFORMING

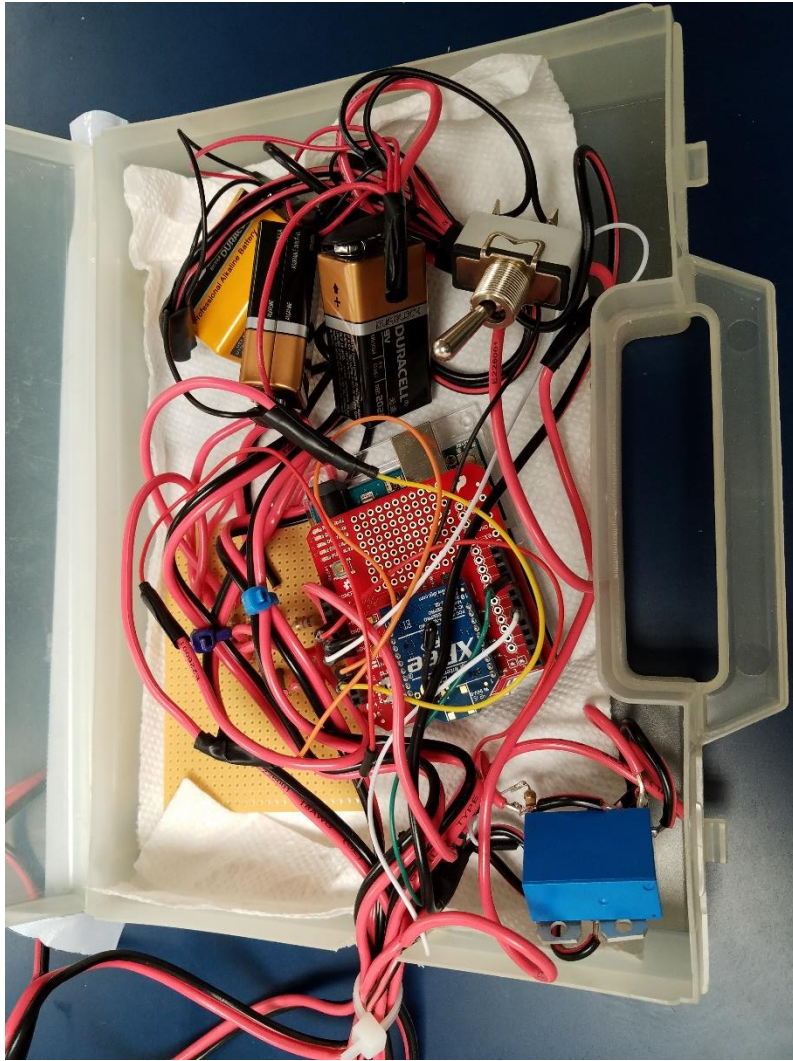
6.3 AT LEAST 4 ADDITIONAL DIGITAL PHOTOGRAPHS AND THEIR EXPLANATIONS



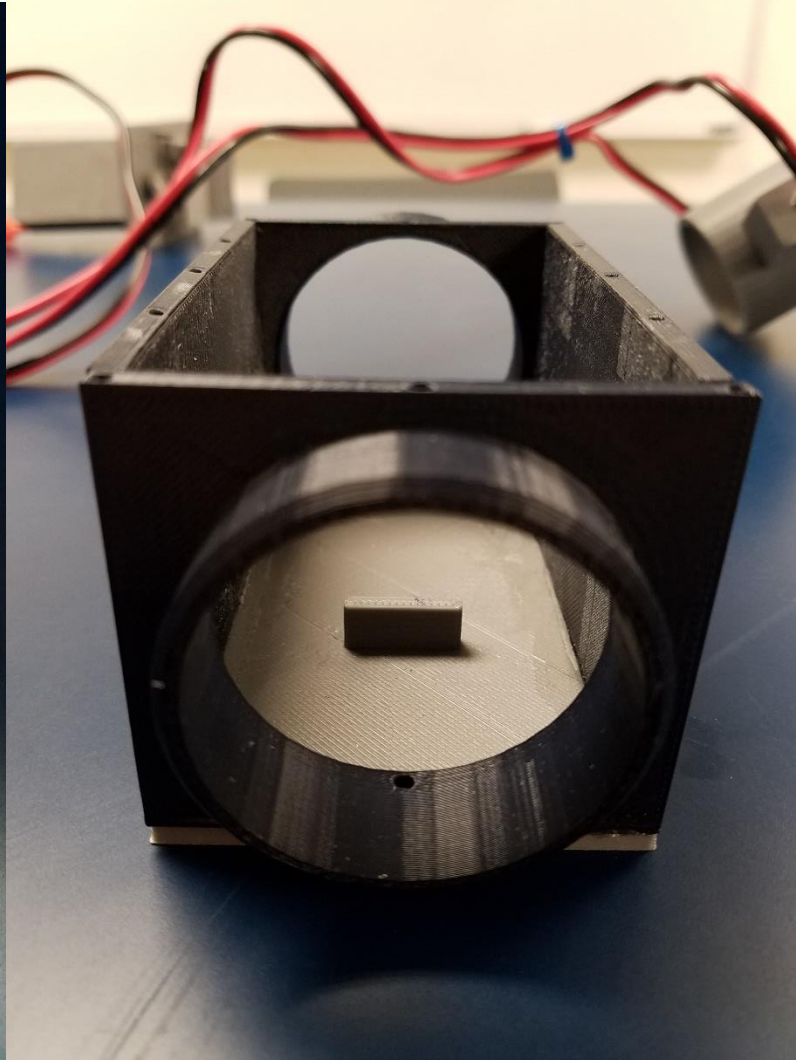
One of two Sensor modules



Close up view of ball-and-keyhole style trap door



Electronics/Controller Case



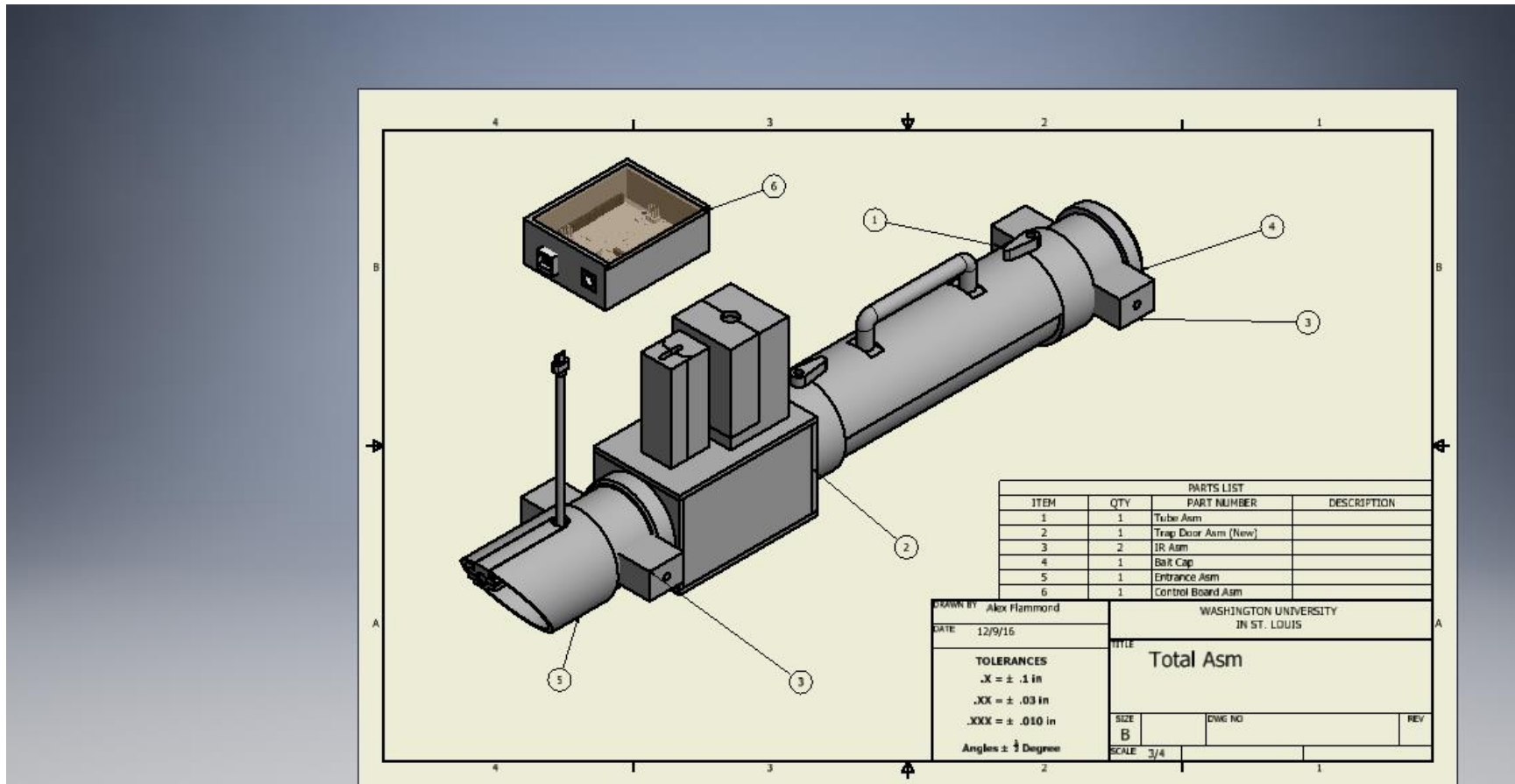
Door Housing

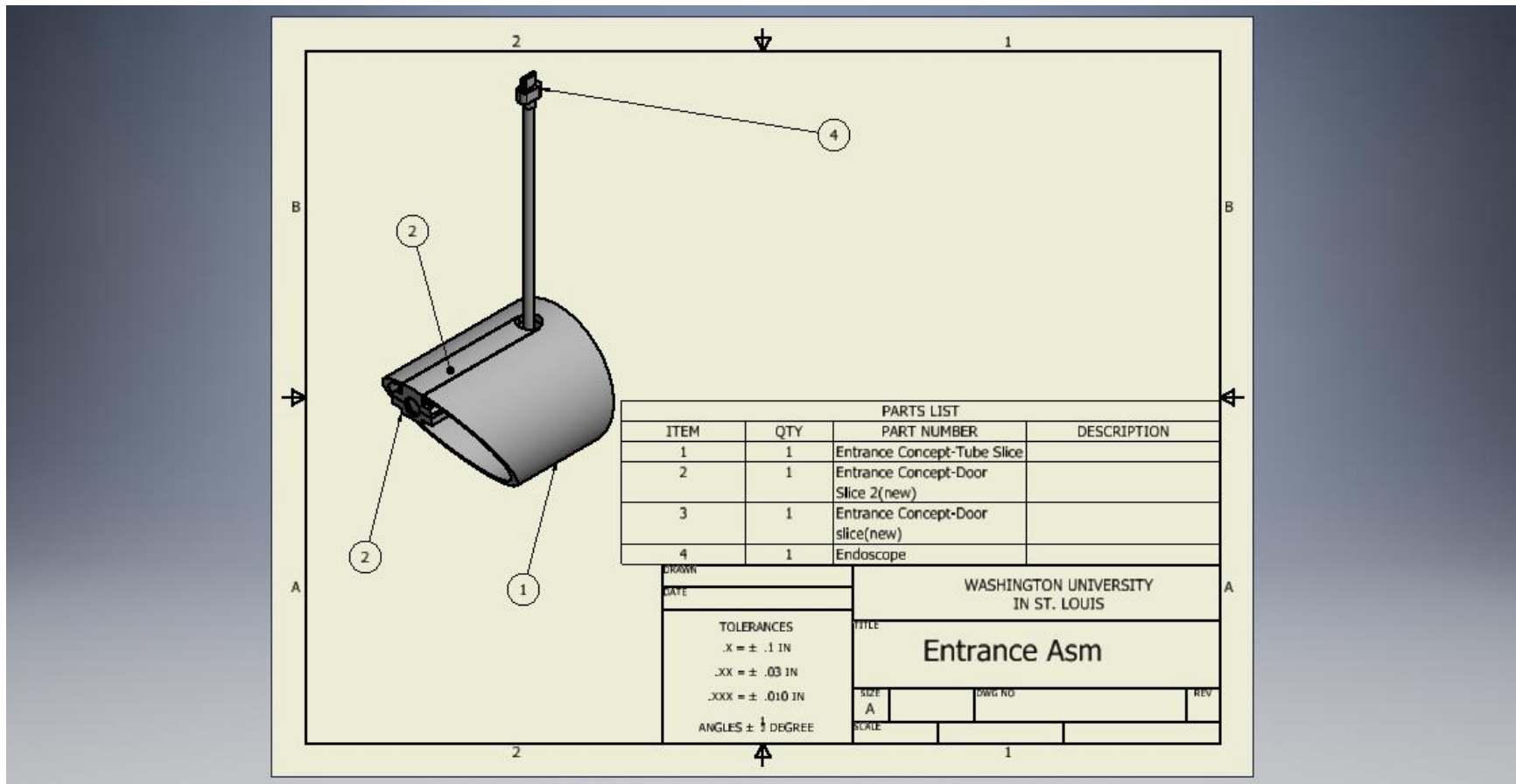
7 DESIGN DOCUMENTATION

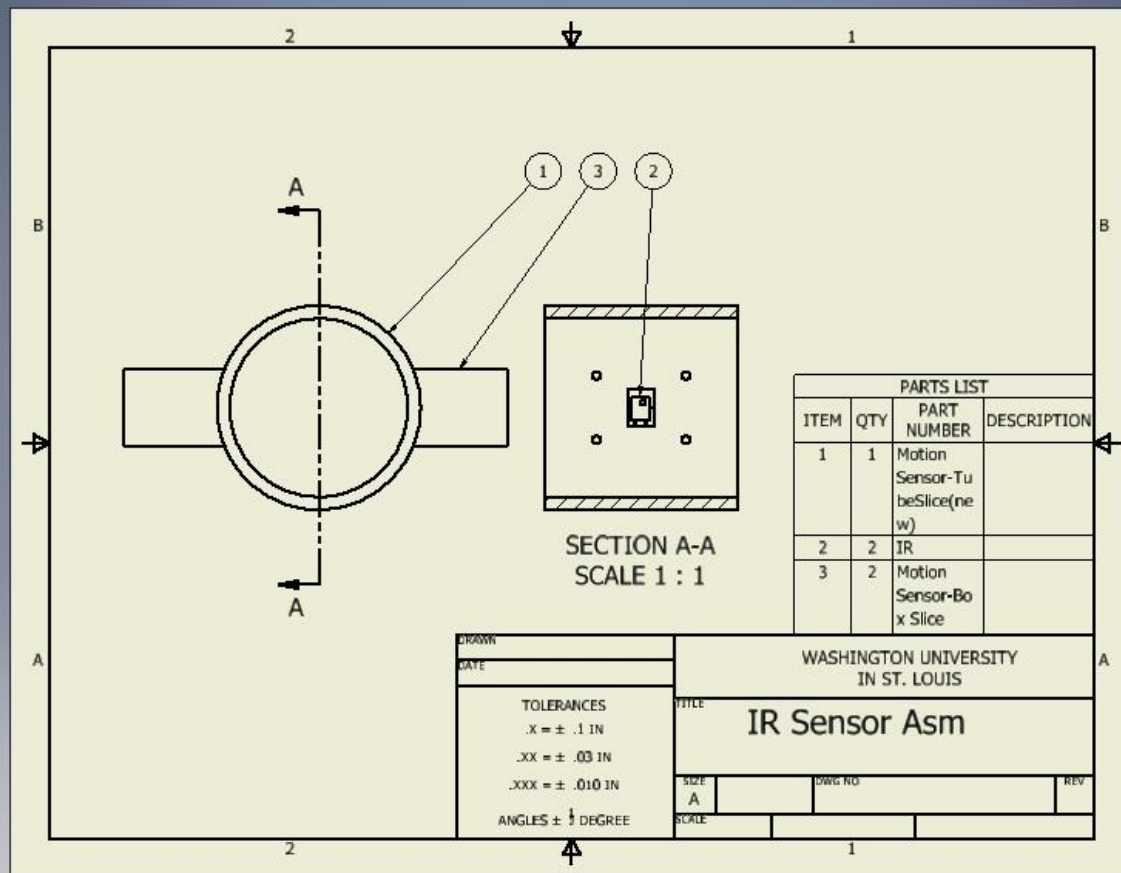
7.1 FINAL DRAWINGS AND DOCUMENTATION

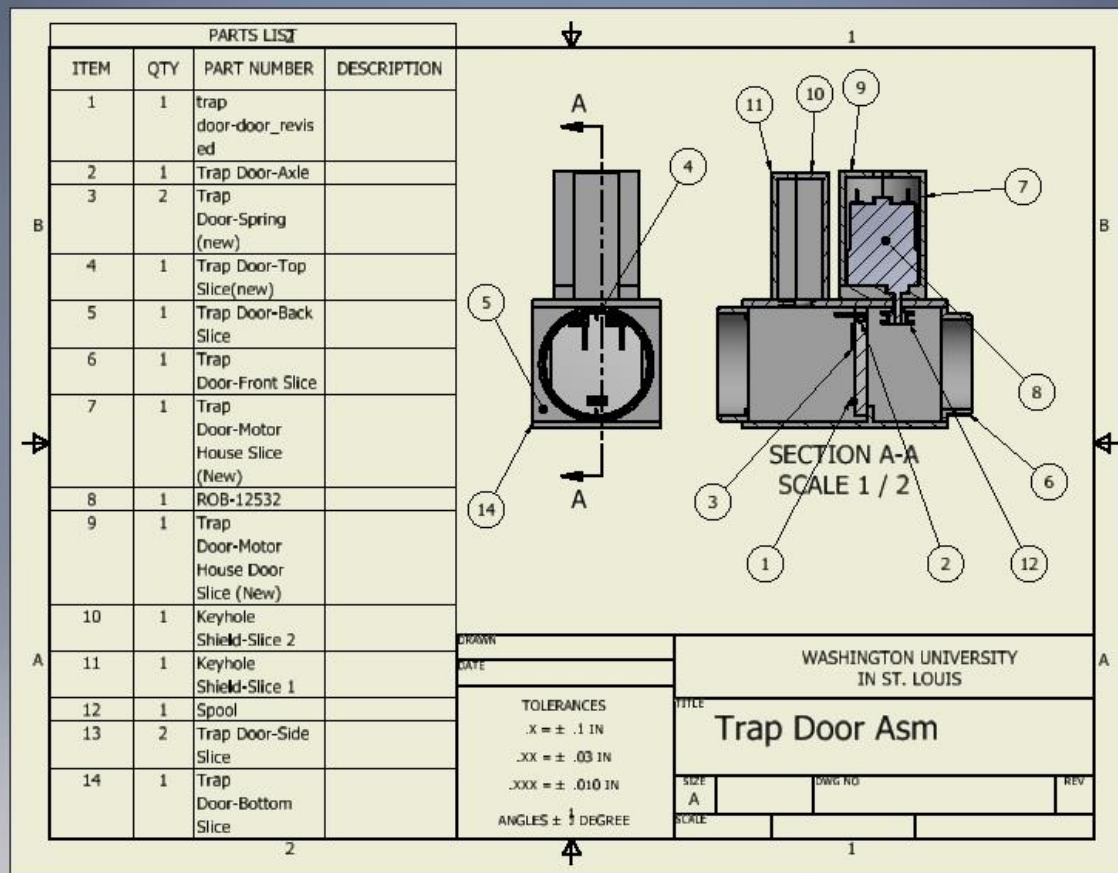
7.1.1 Engineering drawings

That includes all CAD model files and all drawings derived from CAD models. *Include units on all CAD drawings.* See Appendix C for the CAD models.









7.1.2 Sourcing instructions

7.2 FINAL PRESENTATION

7.2.1 A link to a video clip

Simple Demonstration: <https://youtu.be/V0AdPdRz98Y>

Full Project Walkthrough: <https://www.youtube.com/watch?v=Ets1OdAqP6M&index=12&list=PLpaIgTgYdmcJ-6mZULCZI73bxzSJODK80>

7.3 TEARDOWN

N/A - Project will be continued through Spring 2017 semester.

8 APPENDIX A - PARTS LIST

	<i>Part</i>
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1	Arduino Uno - R3
2	Standard Gearmotor
3	Torsion Spring
4	Infrared Emitters and Detectors
5	Endoscopic Camera
6	XBee shield
7	XBee Module
8	9V Li-ion Rechargeable Battery - 350mAh
9	Molex Jumper 2 Wire Assembly
10	18 AWG 2-Conduct Wire

11	Electrical Tape
12	12VDC Coil DPDT Miniature PC Relay
13	Arduino Headers
14	.5 Oz. Rosin Core Solder
15	9V Snap Connector

9 APPENDIX B - BILL OF MATERIALS

10 APPENDIX C - CAD MODELS

12 ARDUINO CODE

// Trap detection/trip using infrared sensors

```
// Author: Lance Middleton
```

```
// Date: 10/10/2016
```

```
int IRpinPurp = A0;      // IR photodiode on analog pin A0
int IRpinBlue = A1;     // IR photodiode on analog pin A1
int ambientIRPurp;     // variable to store the IR coming from the ambient
int ambientIRBlue;     // variable to store the IR coming from the ambient
int motorPin = 5;      // motor control on digital pin 9
int motorPinRev = 8;   //reverse direction

int distancePurp;
int distanceBlue;
```

```
void setup(){
  Serial.begin(9600);    // initializing Serial monitor
  pinMode(motorPin,OUTPUT); // Motor in digital pin 9
  pinMode(motorPinRev, OUTPUT); //Motor reverse in digital pin 10
}
```

```
void loop(){
```

```
distancePurp = readIRPurp(1);    // calling the function that will read the distance and passing the "accuracy" to it
distanceBlue = readIRBlue(1);    // calling the function that will read the distance and passing the "accuracy" to it
Serial.println(distancePurp); // writing the read value on Serial monitor
Serial.println(distanceBlue); // writing the read value on Serial monitor
motor();
//test();
}
```

```
int readIRPurp(int times){    //reads first entry sensor
for(int x=0;x<times;x++){
    ambientIRPurp = analogRead(IRpinPurp); // storing IR coming from the obstacle
delay(500);    //delay .5 sec
}
return(ambientIRPurp);
}
```

```
int readIRBlue(int times){    //reads second bait sensor
for(int x=0;x<times;x++){
    ambientIRBlue = analogRead(IRpinBlue); // storing IR coming from the obstacle
delay(500);    //delay .5 sec
```

```
    }  
    return(ambientIRBlue);  
}  
  
/*void test(){  
    Serial.println("forward");  
    digitalWrite(5,HIGH);  
    digitalWrite(8,HIGH);  
    delay(3000);  
    digitalWrite(5,LOW);  
    delay(3000);  
    digitalWrite(5,HIGH);  
    digitalWrite(8,LOW);  
    delay(2000);  
  
}*/  
  
void motor(){  
    digitalWrite(5,LOW);  
    if(ambientIRPurp>1000){ //indicates if second sensor detects proximity within certain sensitivity  
        delay(5000); } //wait 5 seconds to see if rat passes second IRsensor
```

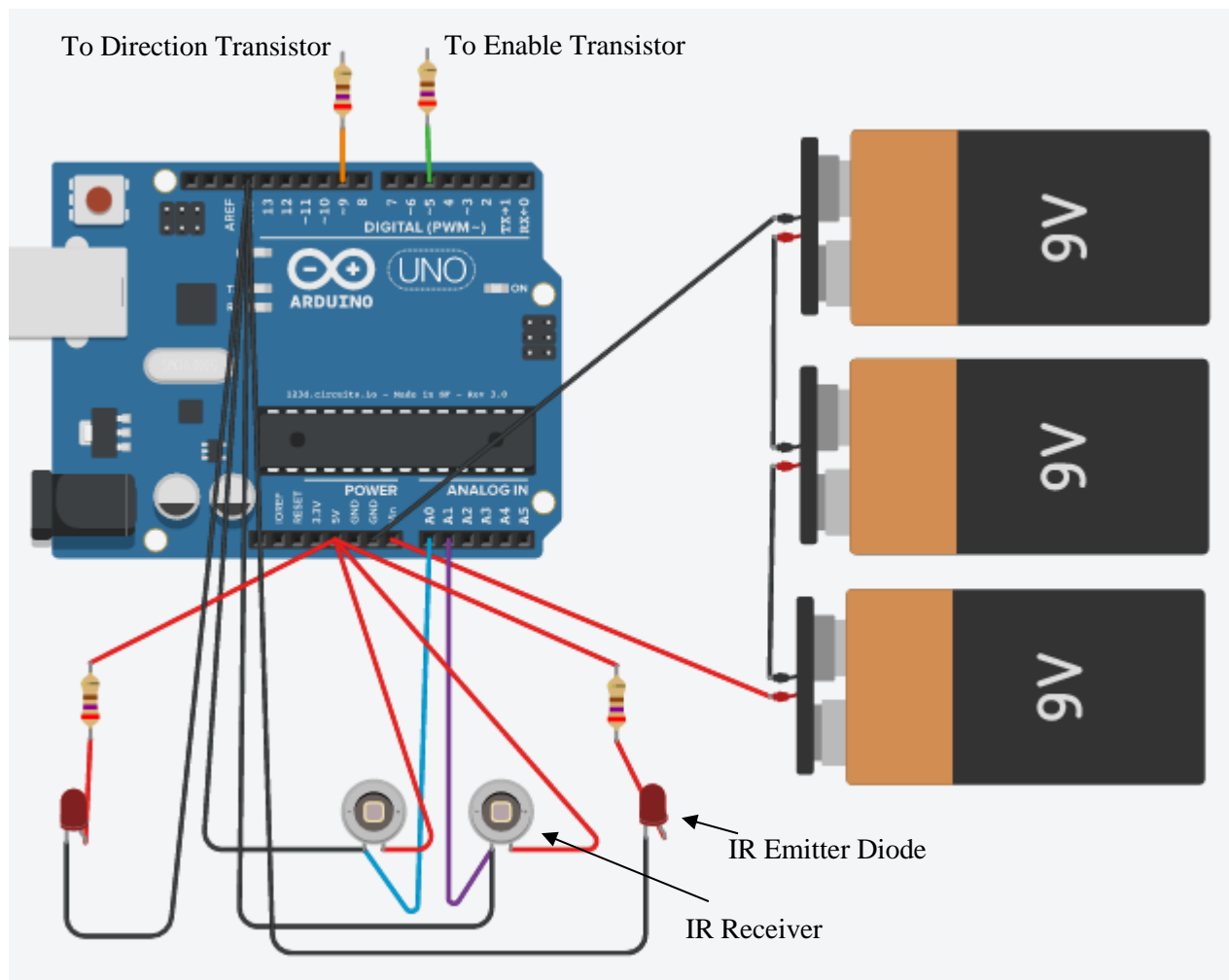


```
if(ambientIRBlue>900){ //indicates if second sensor detects proximity within certain sensitivity
  Serial.println("TRIPPED");
  digitalWrite(5,HIGH); //turns motor on
  digitalWrite(8,LOW);
  delay(2000); //leave motor on for 1 sec
  Serial.println("Reset");
  digitalWrite(8,HIGH);
  delay(2000);
  digitalWrite(5,LOW);

}
}
```

13 CIRCUIT DIAGRAM

Arduino Diagram:



*Note: All resistors are 220 Ohm

Motor Circuit Detail:

