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# Power Wheelchair Canopy

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# Power Wheelchair Canopy

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# Table of Contents

# Chapter 1: Introduction

## 1.1 Background

Some power wheelchair users can not drive and independently hold an umbrella at the time because they do not have much upper body strength. Therefore, users are unprotected from the rain and are getting soaking wet. One of the members of this group is in a wheelchair and faces this problem. He has previously searched for something to protect him from rain, but could not found something he could independently use.  What users need is a powered umbrella that attaches to their power wheelchair. There is no such umbrella available in the market. In this project, the solution to this problem will be designed and built in the form of an umbrella for his wheelchair.

Exploration of various methods of rain protect will be explored. Calculations will be performed to verify that everything will work when assembled. The prototype will then be built. Assuming there will be some issues, as there always seem to be, several iterations of the prototype will be built. This is assuming that there will still be money left in the budget to complete these other iterations. It is also desired to make it inexpensive. This will allow power wheelchair users all over the world to purchase it for themselves. In order to achieve this, the project will lean heavily on the 3-D printing capabilities that the University of Akron has to offer.

## 1.2 Product Definition

Due to Mohamed's disability he is incapable of carrying a normal umbrella because he does not have much upper body strength. Knowing and understanding this problem, yields possibility for a solution. As a group project, a power wheelchair mounted umbrella system, will be designed and constructed. There are no umbrellas in the market that mount directly to power wheelchairs, therefore our design has to. It also has to be detachable so when it is not raining it can be removed and for easy transportation. A requirement that Mohamed put into place was that it needs to be button actuated, with the button requiring little to no force to press. It is also required that this umbrella system fit through doorways. It will be lightweight and compact for easy transport, but strong enough to withstand wind and heavy rain. It will also need to be easily manufacturable, which will be taken into consideration during the design stages.

Our design is a rectangular box, mounted to a steel post and connected to a power wheelchair, housing a roller of waterproof material, 2 spools, 2 batteries, 2 rotating motors, and part of the outer most tube of a set of 3 telescoping tubes on each end.

The way it works is rotating spools powered by motors wind wires, run through a set of 3 telescoping tubes on each end of the box, in one direction to telescope the tubes out of each other and unroll the material through a slit in the box. The other direction telescopes the tubes into each other and rolls the material through the slit in the box. This is happening while the end of the roller of material is attached to end of the inner most telescoping tube on each end of the box.

# Chapter 2: Conceptual Design

To begin the conceptual design process, each group member began researching the current market to find existing designs of power wheelchair umbrellas and to find ideas and opportunities for improvement. Internet searches were conducted to find products that could accomplish our task and to find out how certain features could help our own design as well as quickly show us which features would not help our design. Much information was gathered by each group member before the group met for a brainstorming session. During brainstorming, each member presented as many new or modified concepts as possible and these ideas were filtered and improved throughout the discussion. The ideas developed from brainstorming were then narrowed down to four different concepts. Concept sketches were created for each of the ideas

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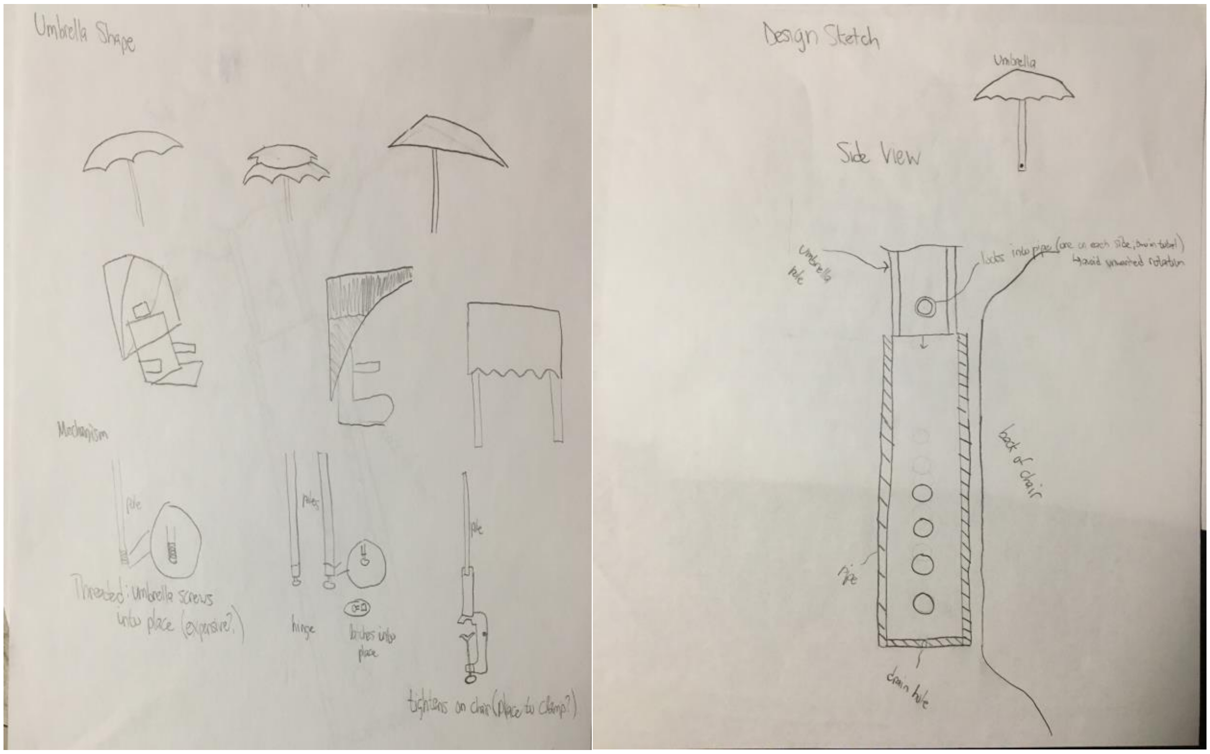


**Figure 1 Hand Drawn Sketches**

The group then began identifying and defining design criteria by which the concepts will be evaluated to break down the ideal design into several categories that could be looked at individually so that the ideas could be compared easily. These design criteria were then assigned weighting factors to indicate the importance to the design as evaluated by the group. The value of each category was easily determined since one of the group members is the target consumer for this product. An objective tree was created to display the importance of each criteria.

**Table 1 Design Criteria Definitions**

| Design Criteria | Definition |
|---|---|
| Material Cost | How much do all the needed components cost. |
| Durability | Ability to withstand heavy rain and strong winds. |
| Transportability | How easy it is to transport when detached from the power wheelchair. |
| Operation | How easy it is to use. |
| Reliability | Ability to consistently perform its function. |
| Safety | Do any of the components cause harm. |

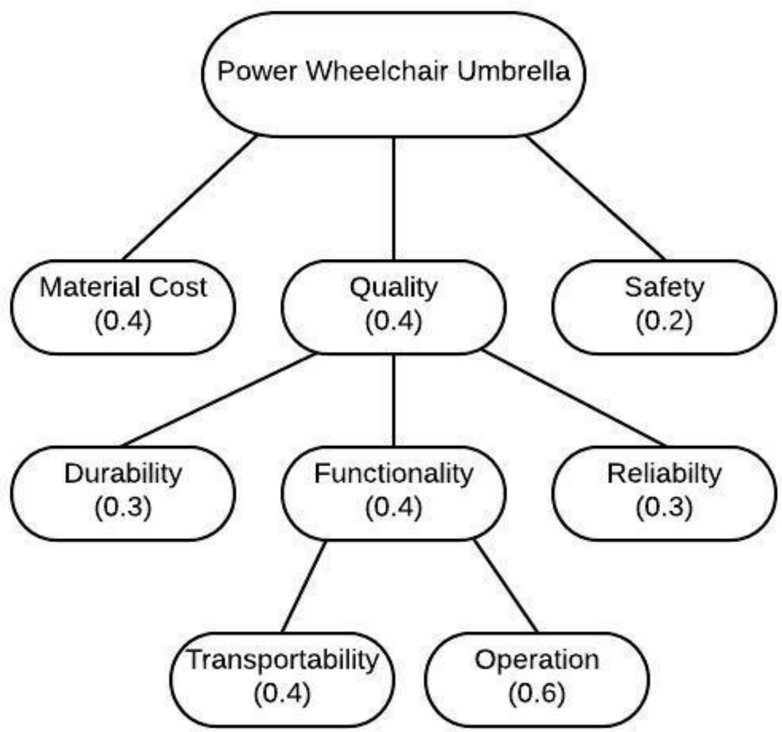


**Figure 2 Design Criteria Objective Tree**

The objective tree was used to create a weighted decision matrix to evaluate competing concepts by rating the design criteria with weighting factors and scoring the degree to which each design concept meets the criteria. A scale from 1-5 with five being excellent and 1 being poor was used. This made comparing the different concepts into a more quantitative process instead of a qualitative one. The weighted decision matrix weighted the scores so that the most important criteria had a stronger effect on the overall score. Based on the total scores of each concept in the weighted decision matrix, the group determined that the awning concept was the best design to continue to work on and improve.

**Table 2 Weighted Decision Matrix**

| | Awning | | Flip Canopy | | Umbrella | Baby Carriage | | |
|---|---|---|---|---|---|---|---|---|
| Weighting Factor | Score | Rating | Score | Rating | Score | Rating | Score | Rating |
| 0.4 | 2 | 0.8 | 3 | 1.2 | 5 | 2 | 2 | 0.8 |
| 0.12 | 3 | 0.36 | 2 | 0.24 | 1 | 0.12 | 5 | 0.6 |
| 0.064 | 2 | 0.128 | 3 | 0.192 | 4 | 0.256 | 0 | 0 |
| 0.096 | 5 | 0.48 | 2 | 0.192 | 1 | 0.096 | 3 | 0.288 |
| 0.12 | 5 | 0.6 | 4 | 0.48 | 1 | 0.12 | 2 | 0.24 |
| 0.2 | 3 | 0.6 | 3 | 0.6 | 1 | 0.2 | 4 | 0.8 |
| 1 | | 2.968 | | 2.904 | | 2.792 | | 2.728 |

**Table 3 Reasoning Behind Weighted Decision Matrix**

| | |
|---|---|
| Material Cost | The Umbrella concept was determined to have the cheapest material costs because we'd be able to adapt a premade umbrella to the design. The other concepts were about the same. |
| Durability | The baby carriage concept was given the best durability rating but the awning concept also scored fairly well because of the fixed supports. |
| Transportabilty | The umbrella concept was given the highest score because it would be the easiest to attach and detach. |
| Operation | The awning concept got the best score for operation because it could be a one button opertion. |
| Reliability | The awning and flip canopy recieved the best reliability scores because we believe they would be the most successful. |
| Safety | The umbrella concept is the least safe due to the size necessary to achieve the task. It would require a diameter of at least 6 feet so this would be way to large for practical use. |

# Chapter 3: Embodiment Design

The next step in the design process was to select a single design concept and begin to develop and improve it. Based on the results of our conceptual design stage, the awning concept was selected to be further developed. The group began working to create the product architecture that would successfully and efficiently carry out the functions required by the design. We started by identifying the different functions that would need to be accomplished during the operation of the product. Through the continuous improvement of the idea, we found a technique that would allow us to use simple tube and string to telescope the arms of the awning covering from a short collapsed length to the final extended length. Using this technique, we were able to develop a design that would involve the awning covering to collapse to a smaller size when it was not in use and still extend to the full covering length required to fully protect the consumer from the rain. The physical components of the design began being identified and a sketch was created to show how they would be configured with respect to each other in the design.

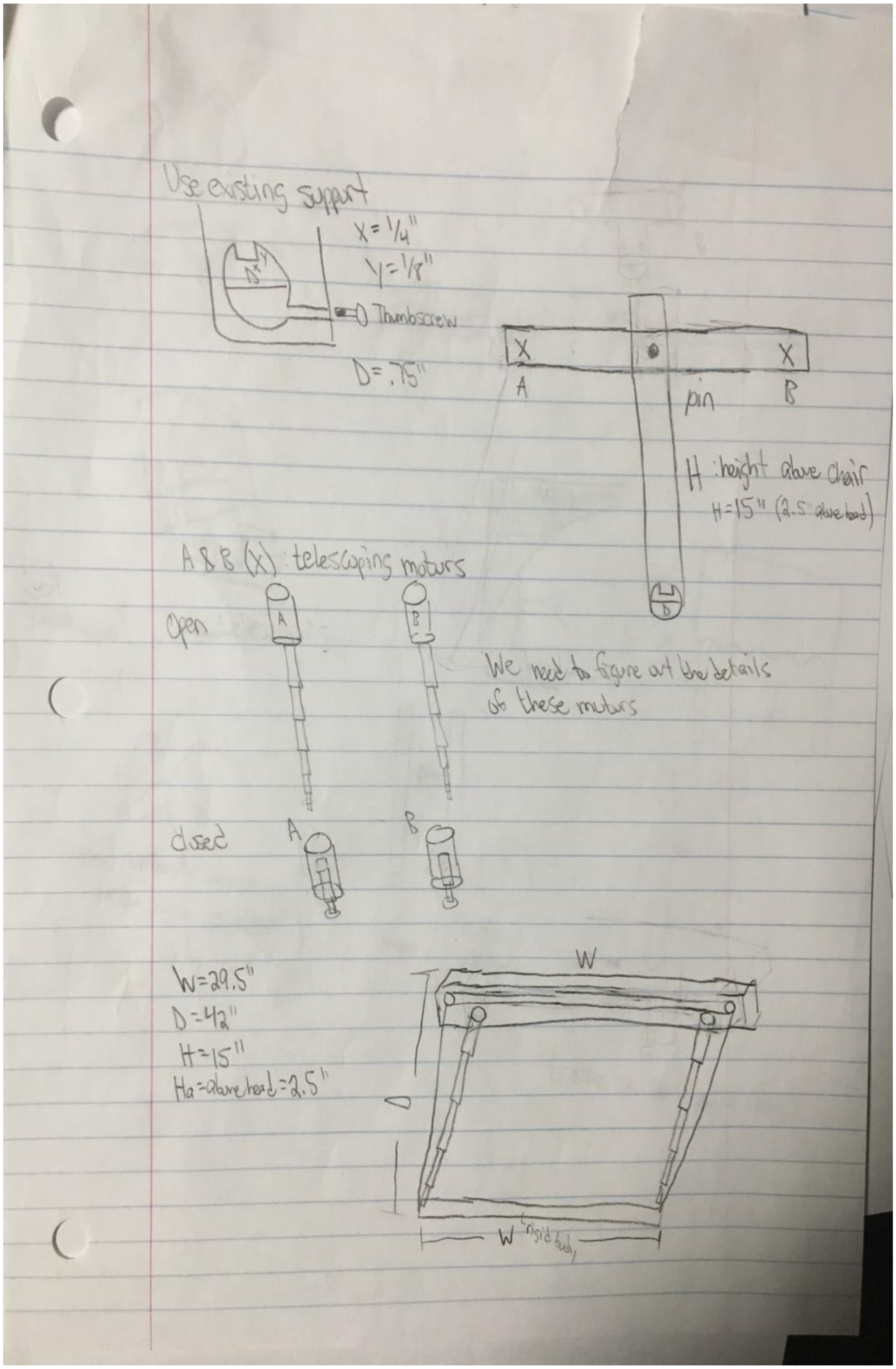


**Figure 3 Collapsible Awning Concept Sketch**

It was determined that the covering would be attached to telescoping tubes, so it extends and collapses the covering. These telescoping tubes would be powered using a rotating motor and an attached spool to adjust the speed of the extension. The motor would be driven by a simple switch that will be able to rotate the motor clockwise, counter clockwise, and stop rotation. Since the covering itself will not be a rigid body, a pull down blind will be used as the covering material in order to utilize the spring loaded system involved in drawing the blind. This spring system would make the covering roll up for easy storage during collapsing as well as keep the covering taught at all times during operation. All of these components wil=[ be stored in a simple enclosed box that would be suspended above the user's head by a support beam. A function structure diagram was created to show the function each component has on the design. A schematic diagram was created to explain the operation of the design. There are several Solidworks drawings that show the configuration of the components in relation to each other. There are also pictures that show the roller mechanism and the switch wiring.

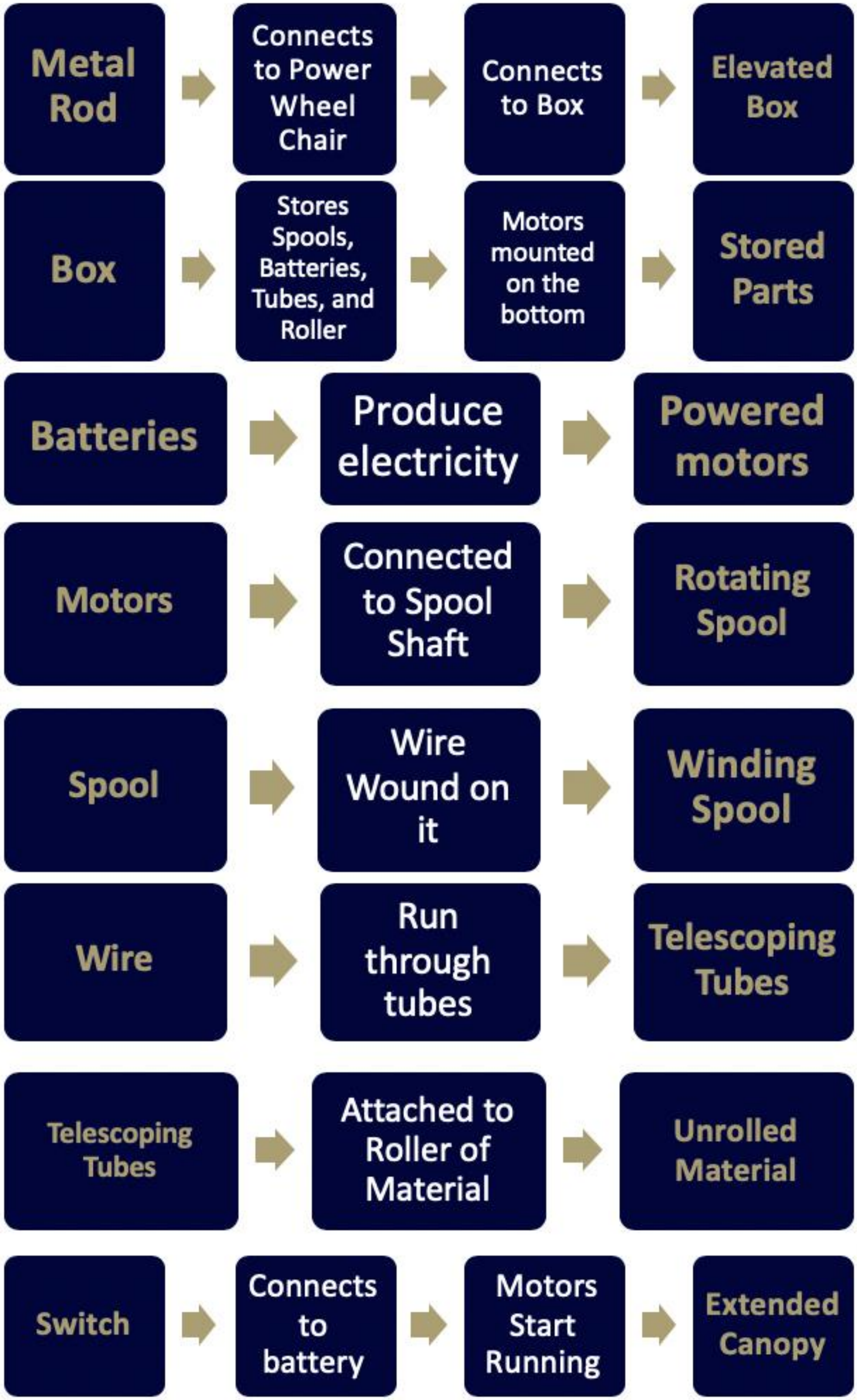


**Figure 4 Function Structure Diagram**

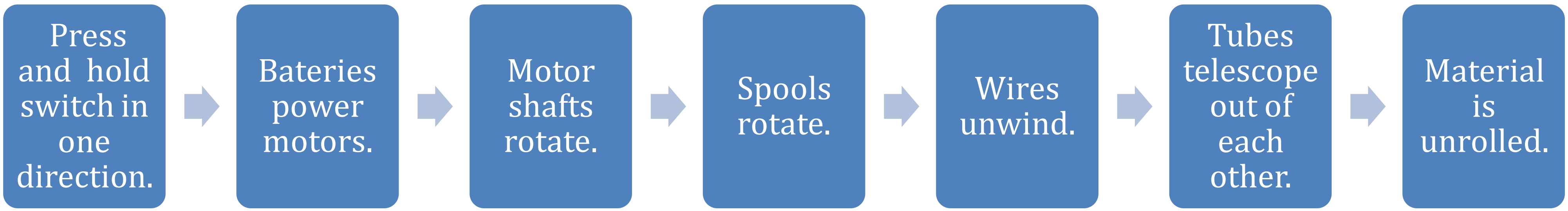


**Figure 5 Extended Canopy Schematic Diagram**

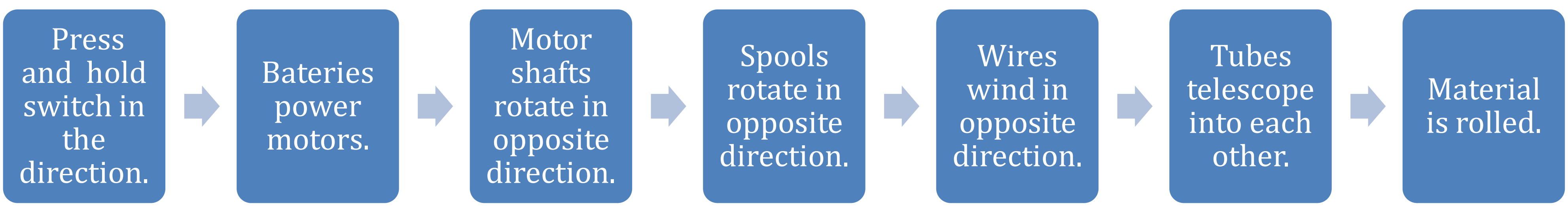


**Figure 6 Collapsed Canopy Schematic Diagram**

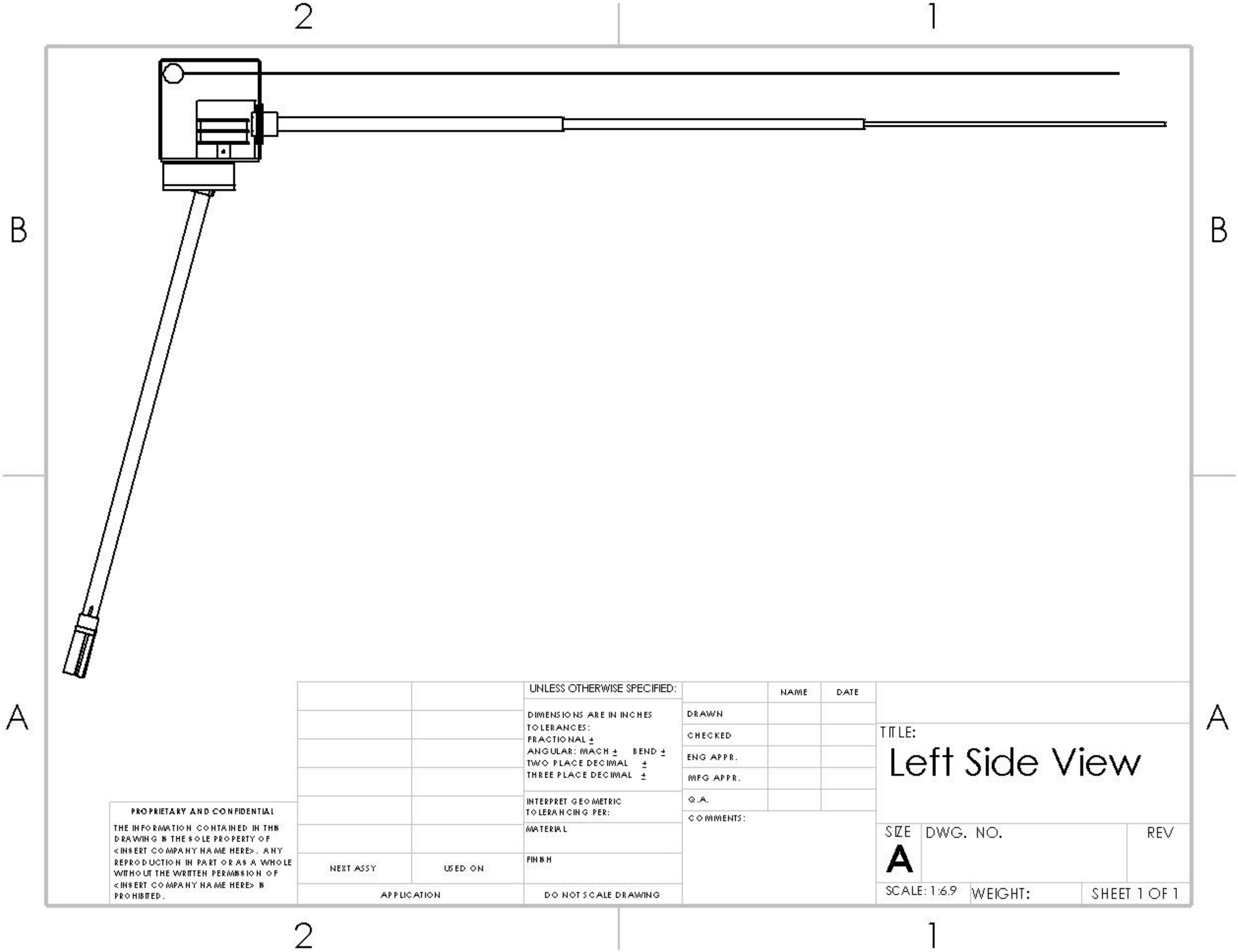


**Figure 7 Left Side View Drawing**

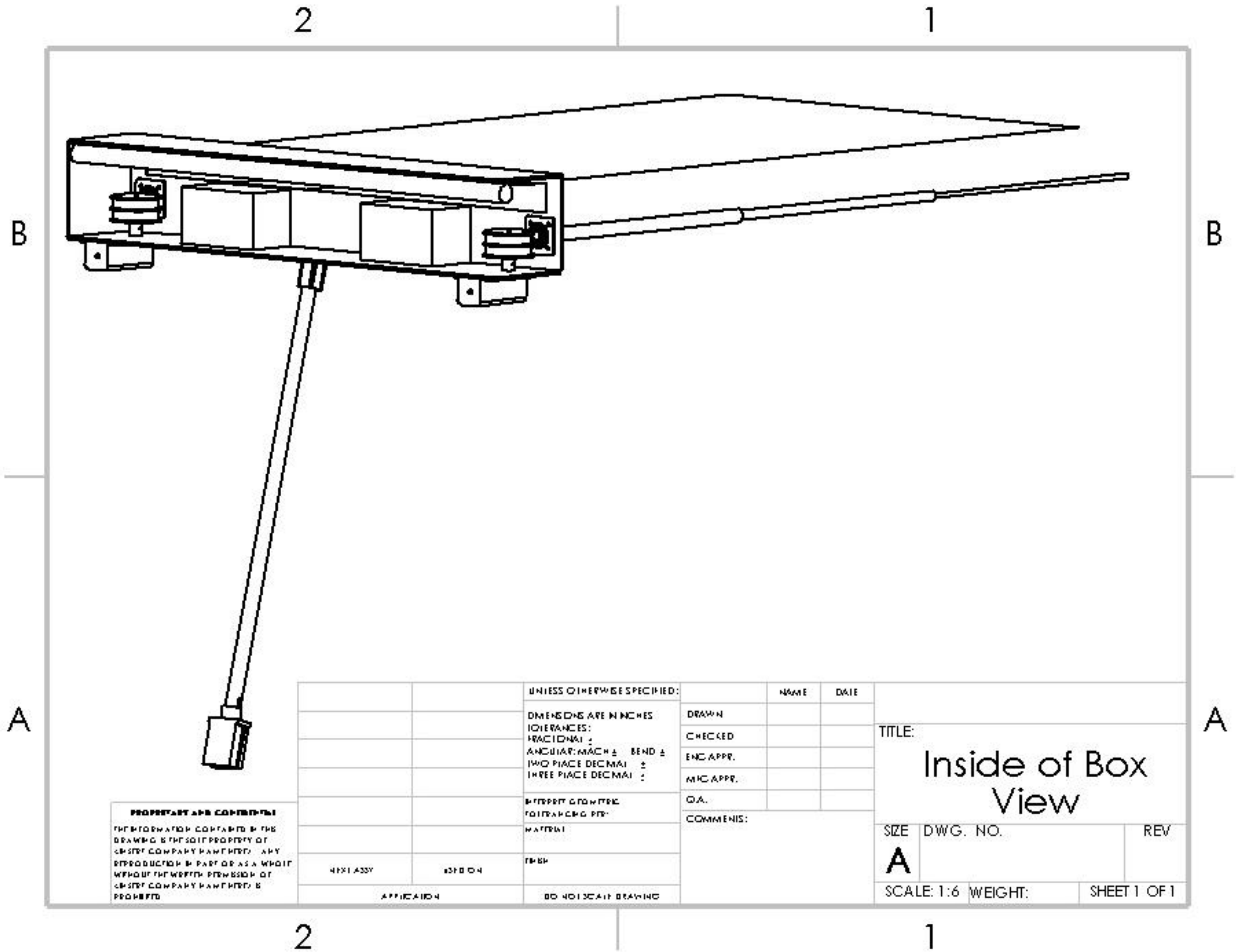


**Figure 8 Inside of Box View Drawing**

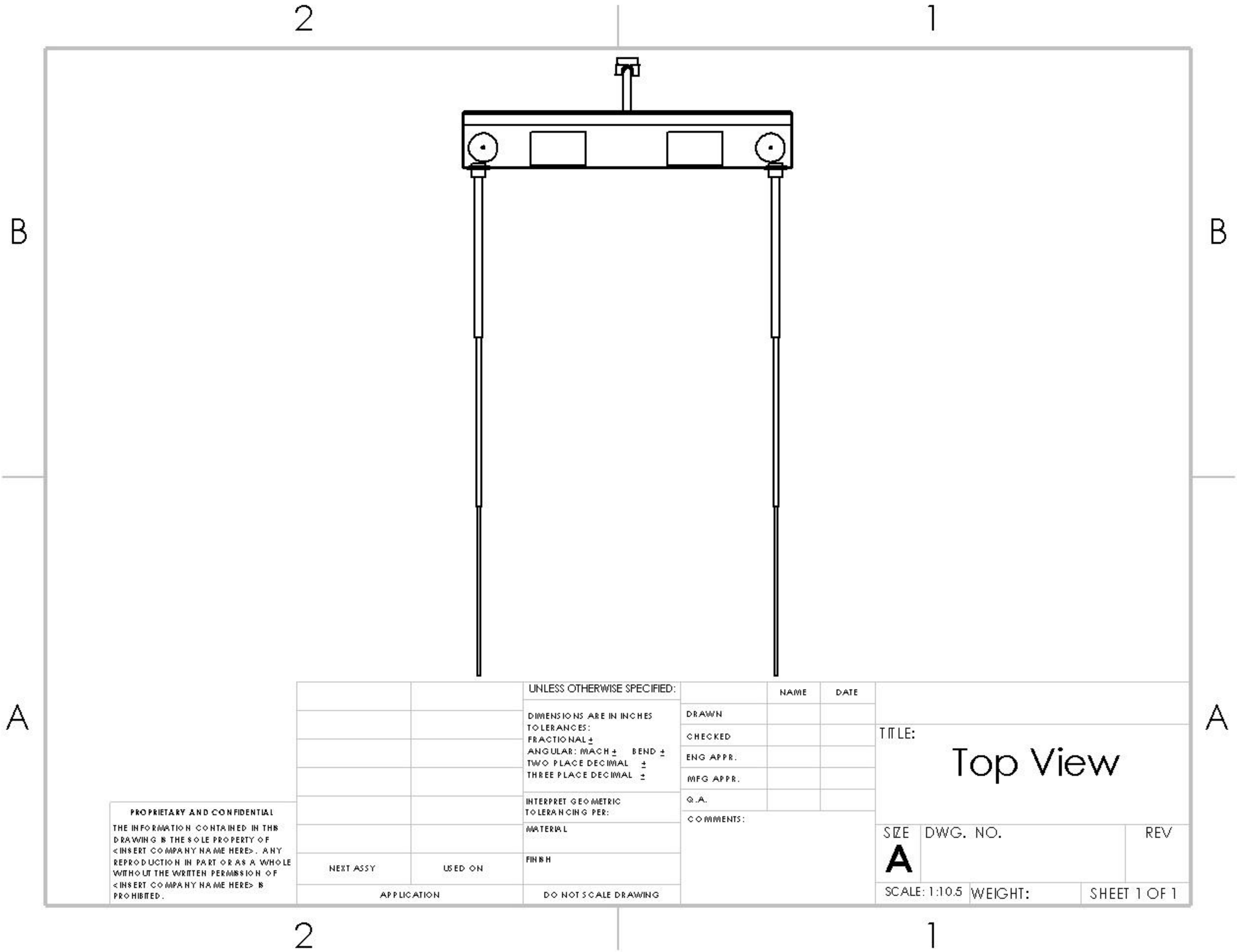


**Figure 9 Top View Drawing**

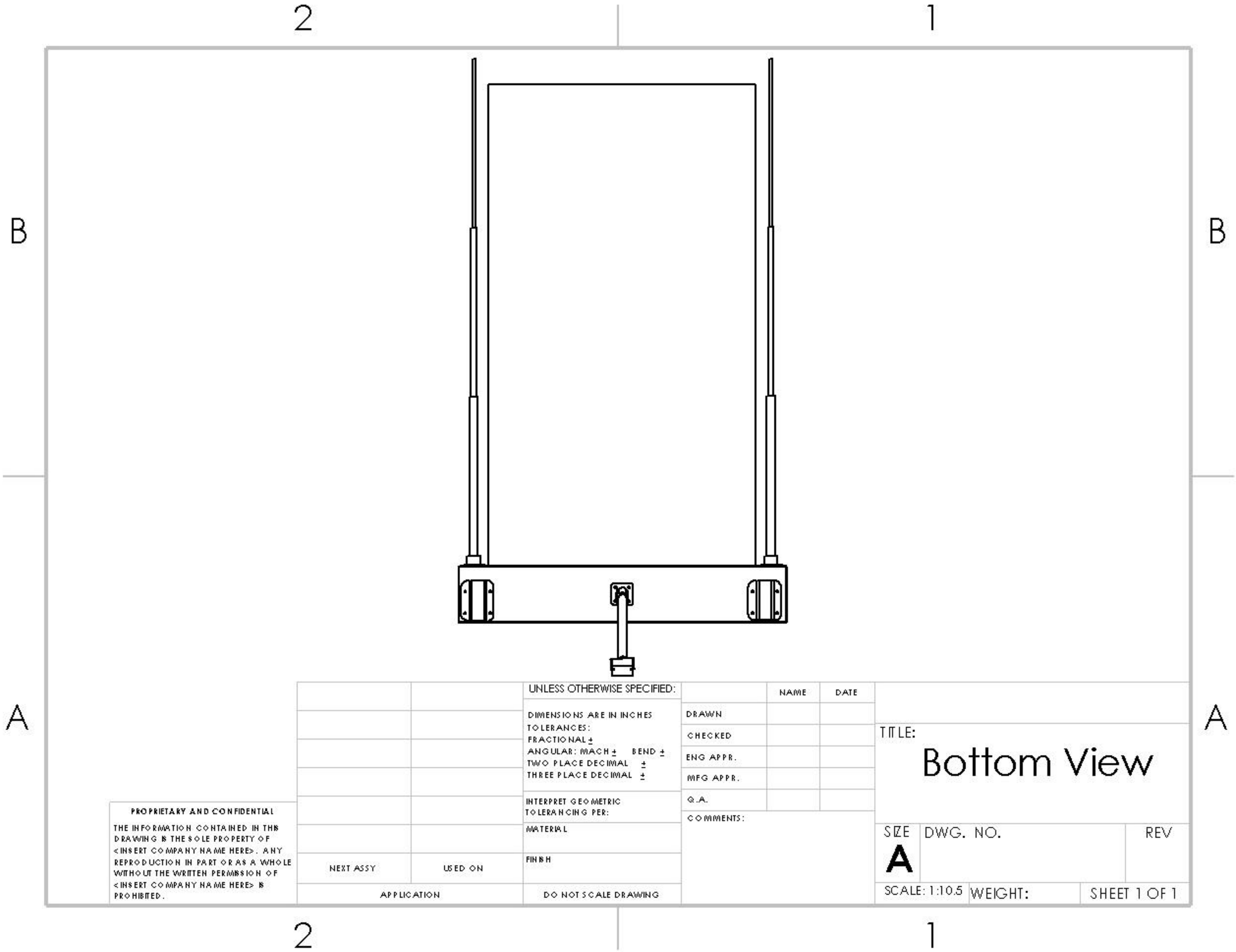


**Figure 10 Bottom View Drawing**

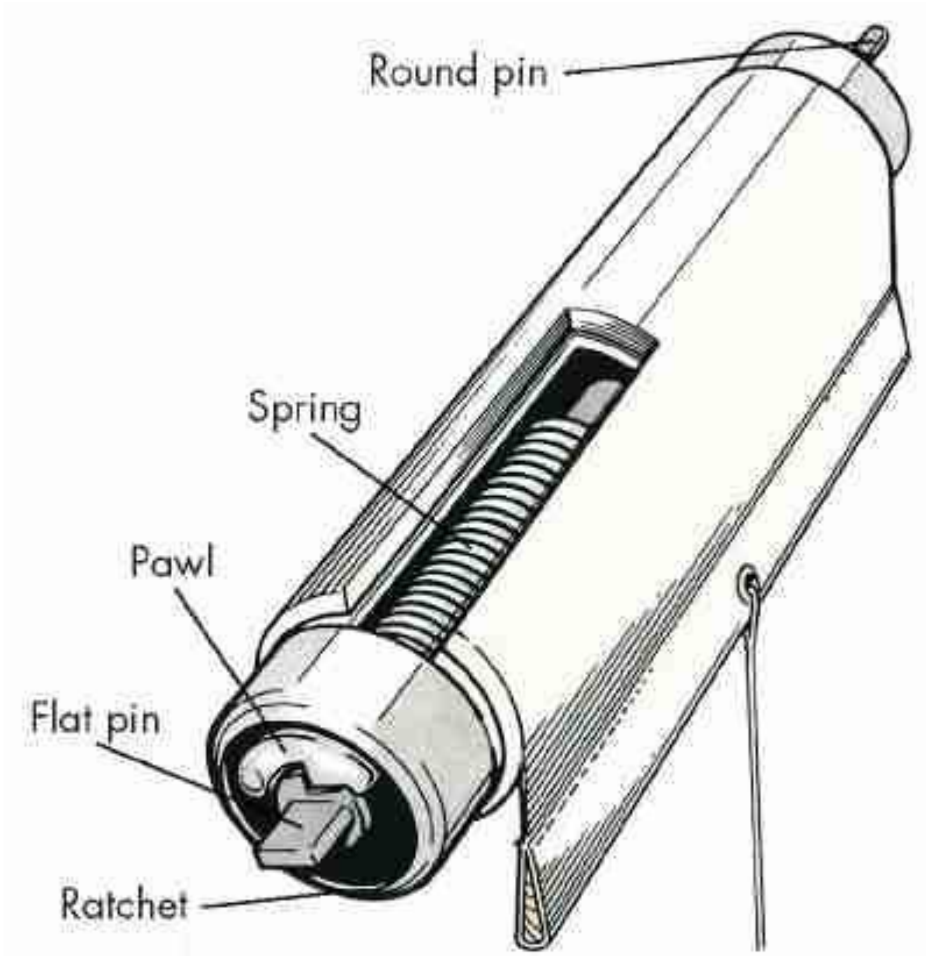


**Figure 11 Roller**

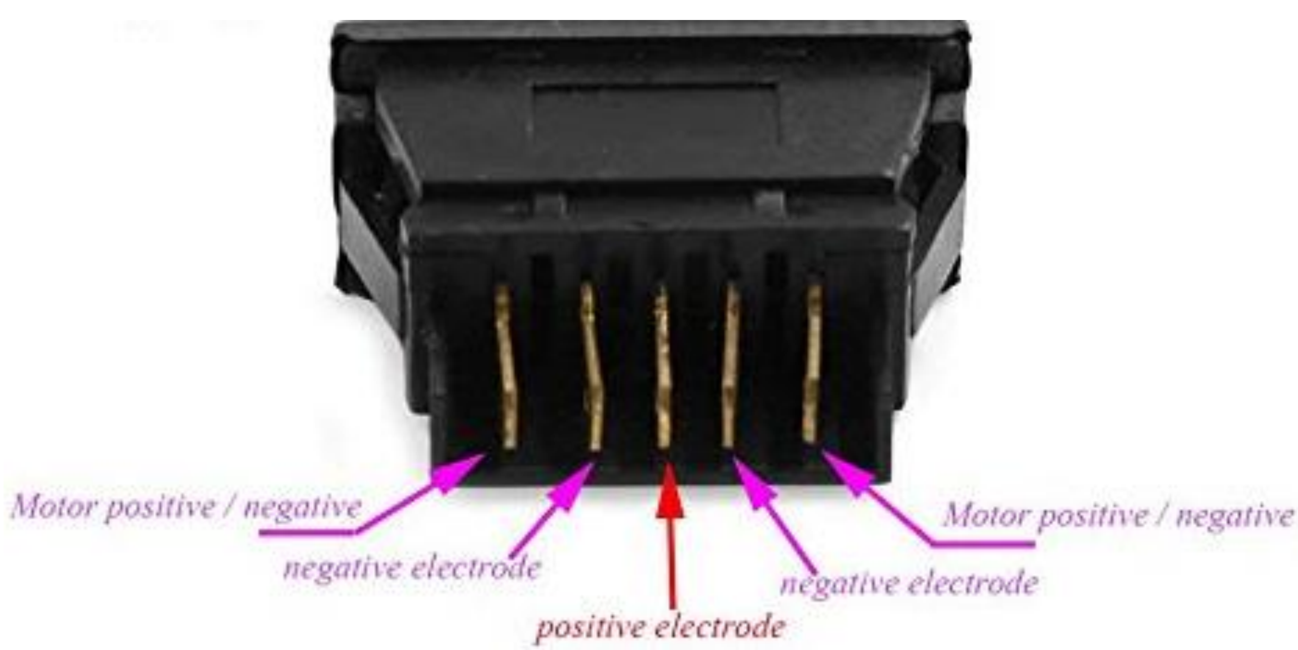


**Figure 12 Switch**

# Chapter 4: Detail Design

After embodiment and conceptual designs were completed, the detailed design stage began. Parts began to be chosen and outsourced to places that could produce them. Parts that needed custom manufacturing such as the mounts, brackets, fasteners, and other similar parts, were 3-D modeled and then 3-D printed. Due to the nature of 3-D printing, detailed 2-D part drawings are not required, thanks to the capabilities of the machine. The use of 3-D printing was crucial in prototyping, due to its cost efficiency.

Early on the big question was posed, “how will this assembly mount to the wheelchair”. The main mounting joint had to fit inside of a bracket, that was on the existing wheelchair. It was then tightened down using a screw mechanism that was pre-existent on the chair. This was where it was chosen to be attached, as it was an easy, and stable, mounting position. The mount will be a ¾ inch thin walled metal rod and a custom 3-D printed joint, to reduce weight. This will allow the rod to fit tightly, in order to reduce the assembly from moving or swaying when the chair is in motion.

The next part that had issues were the telescoping tubes. The strings inside that drive them, had much more friction than what was intended. This would require a high torque motor to run. It was also desired to run it at a reasonable speed, to allow the canopy to be extended quickly. In order to complete both of these tasks in conjunction, a high torque motor was selected and a spool to wind the string was 3-D printed. This spool was given a much larger diameter than originally intended, to allow an increase in speed. The diameter that was determined to be sufficient was 3 inches. With a 20 RPM high torque motor and the 3 inch diameter spool, the calculated time for full extension would be close to 9 seconds. This was determined by Mohamed to be an acceptable speed. The spool was 3-D printed using ABS. Unfortunately, during the building process some issue arose. The box became too congested with the addition of the larger spool. The team made a quick decision to 3-D print a smaller spool and order a motor with a higher RPM. With a 100 RPM high torque motor and the 2.75 inch diameter spool, the calculated time for full extension was close to 3.5 seconds.

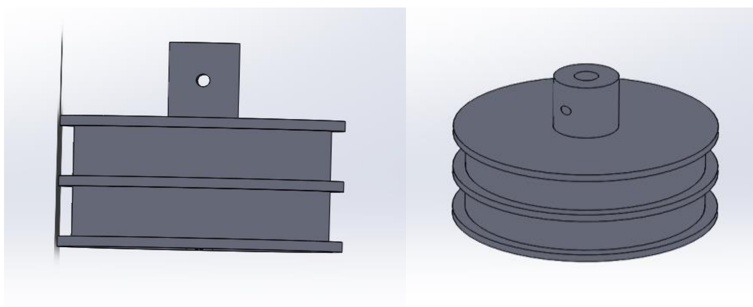

**Figure 13 Spool**

A 5” x 5” x 36” box was built and assembled to hold all the components. The box was made out of very durable, yet lightweight wood. Flex Seal was purchased in order to waterproof this wood. Sizing was measured and all components fit nicely in the box, after the addition of the downsized spool and relocating the motors to be mount on the bottom of the box, through use of separate motor compartments. These separate motor compartments were specifically designed to free up space inside of the box, while giving a more secure mounting point for the motors. Another effect that was gained was wiring protection. The soldered wires were now secure from outside elements.

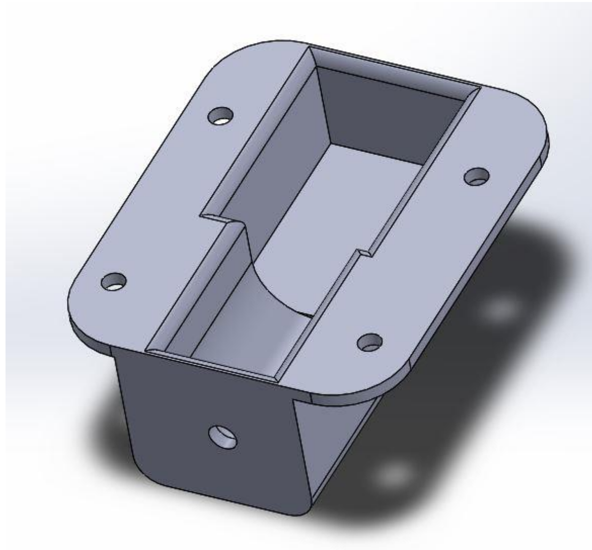

**Figure 14 Motor to Outside of Box Mount**

Over the course of the build, many types and sizes of mounting brackets were required. These brackets included; inside PVC mounts, outside PVC mounts, inside bottom mount, outside bottom mounts, motor mounts, and the main mounting joint. All mounts were 3-D printed with ABS, to allow for quick turnaround time as well as being an inexpensive material, given the lack of funding.

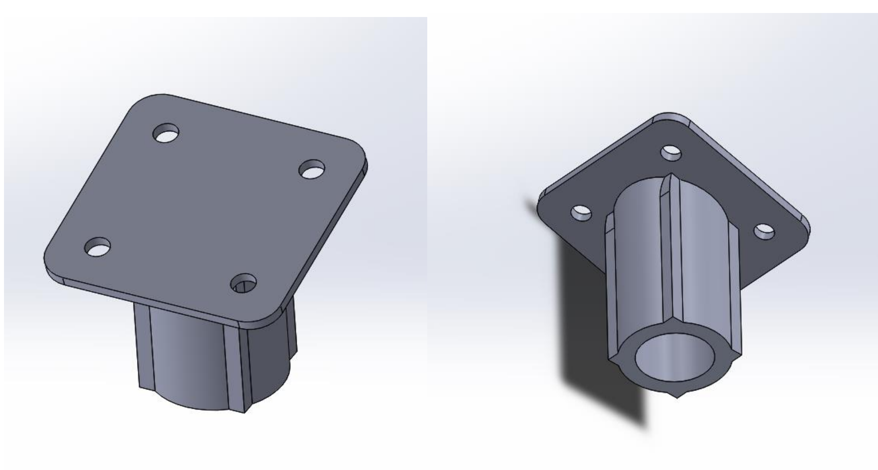

**Figure 15 Rod to Outside of Box Mount**

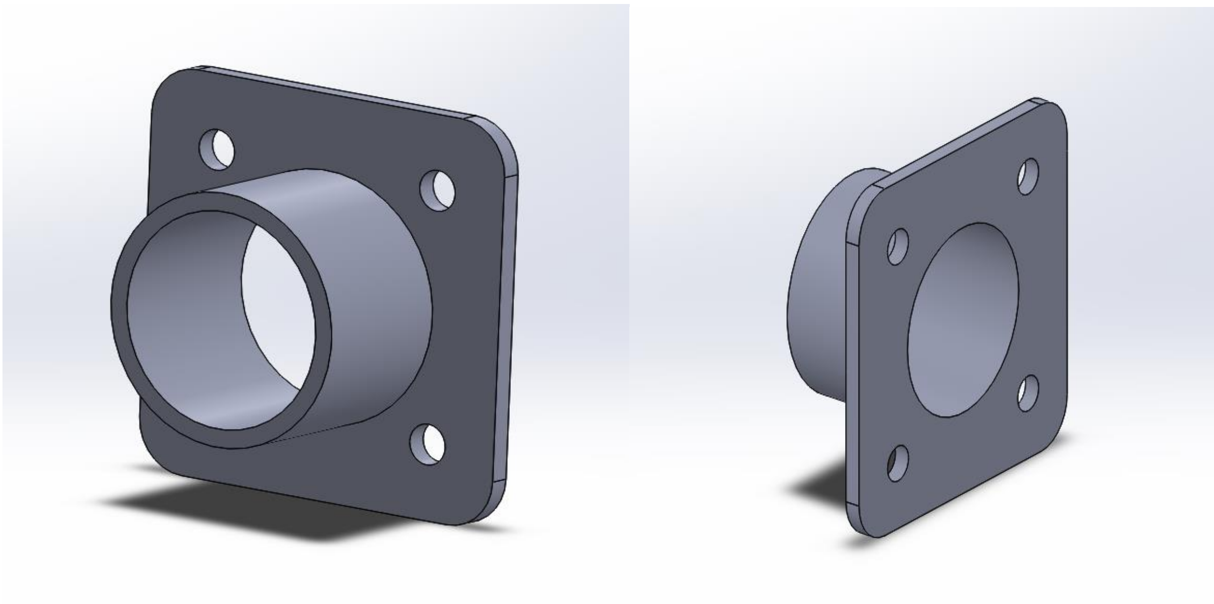

**Figure 16 Tube to Outside of Box Mount**

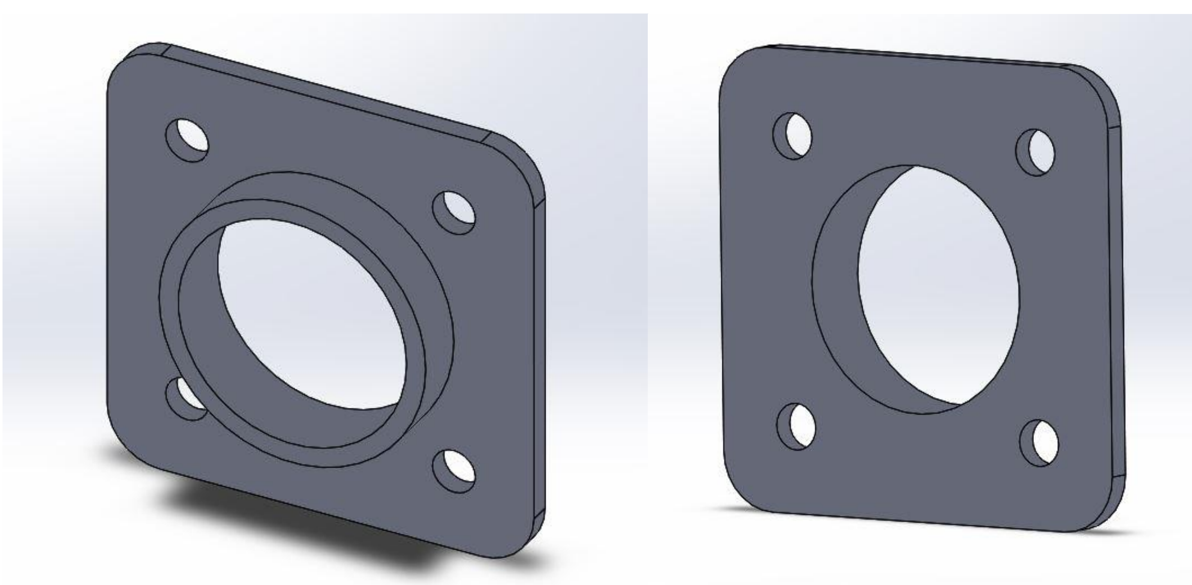

**Figure 17 Tube to Inside of Box Mount**

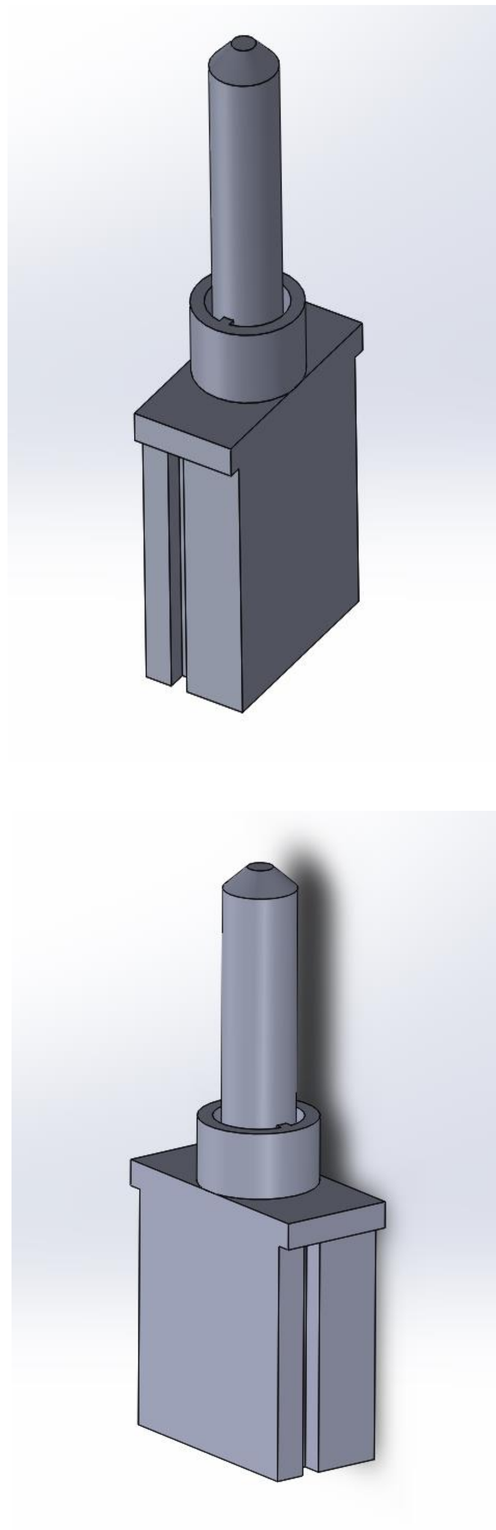

**Figure 18 Wheelchair to Rod Mount**

In total the assembly required 10 components to be 3-D printed including: (2) PVC tube to inside of box mounts, (2) PVC tube to outside of box mounts, (1) rod to outside of box mount, (1) wheelchair to rod mount, (2) spools, and (2) motor to box mounts. It also required (1) thin walled metal rod, (3) sizes of PVC (¾", ½", and ¼"), (1) spool of monofilament fishing line, (2) 6V batteries, (1) switch, (1) enclosure box, (2) motors, and some wiring.

As far as dimensions for components goes, all dimensions were measured, rather than being calculated. All components have to fit into a confined area of an already existing body, therefore measurements are a better way to figure out dimensions, than calculations would be. Two 3-D models show the assembly and exploded assembly on the next page followed by a bill of materials and total cost of the materials. The following pages show Solidworks drawings with dimensions for all the components. Due to advisor instruction, the whole project was designed and built prior to 3-D modelling. All models were created as the project proceeded, and therefore, any issues that arose were solved in the same manor.

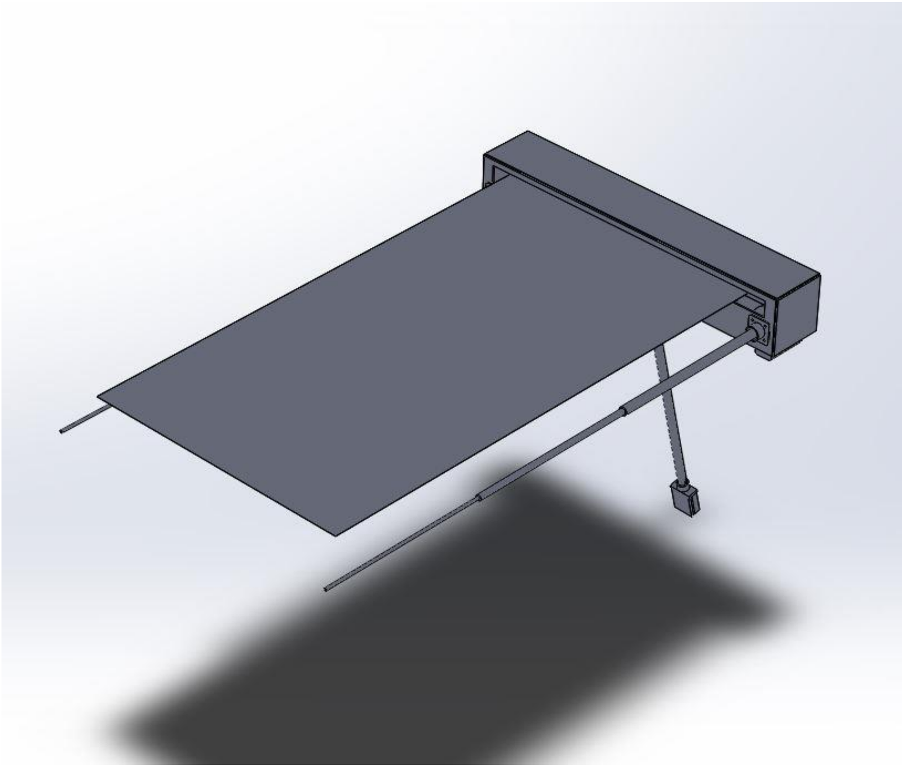

**Figure 19 Assembly**

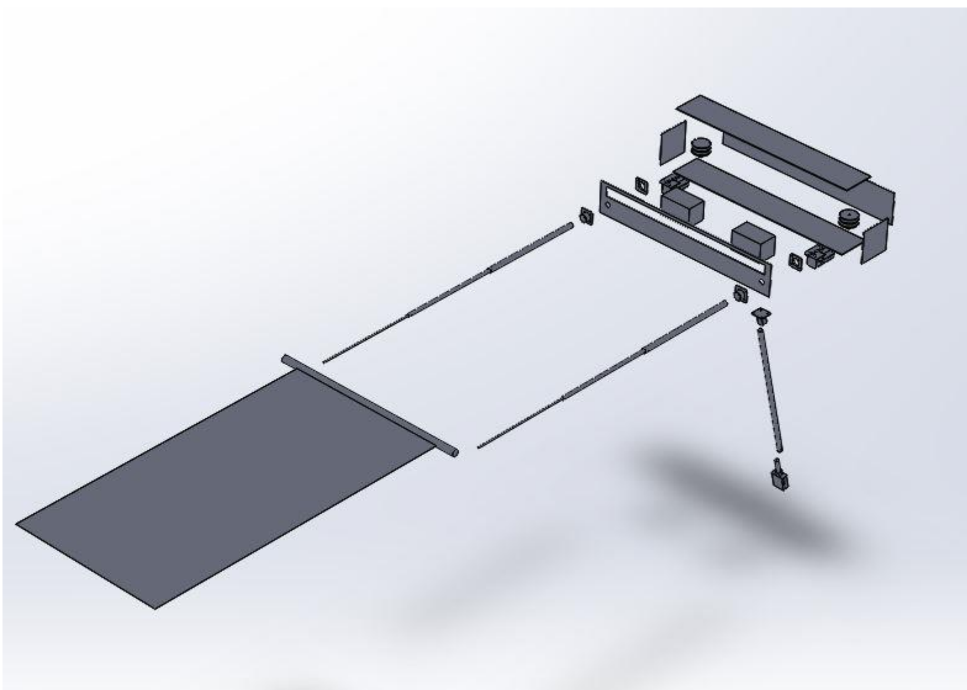

**Figure 20 Exploded Assembly**

**Table 4 Bill of Materials**

| Bill of Materials | | | |
|---|---|---|---|
| Parts | Number Needed | Cost Per Part ($) | Source |
| 0.25" X 3' pvc tube | 1 | $ 1.00 | Home Depot |
| 0.5" X 3' pvc tube | 1 | $ 2.00 | Home Depot |
| 0.75" X 3' pvc tube | 1 | $ 2.50 | Home Depot |
| Steel Bar (0.75" OD x 24") | 1 | $ 8.00 | Home Depot |
| Wood Box (30"X 5"X 5") | 1 | $ 7.00 | Home Depot |
| Roller (1" ODx30") | 1 | $ 5.00 | Walmart |
| Switch | 1 | $ 10.00 | Amazon |
| Wiring | N/A | N/A | N/A |
| Motor (RC motor) | 2 | $ 12.00 | Amazon |
| String for the motor | N/A | N/A | N/A |
| Batteries | 2 | $ 6.00 | Amazon |
| Screws, Nuts, Washers, Lock Washers | N/A | $ 15.00 | Home Depot |
| Flex Seal | 1 | $ 12.00 | Home Depot |
| | Total cost | $ 80.50 | |

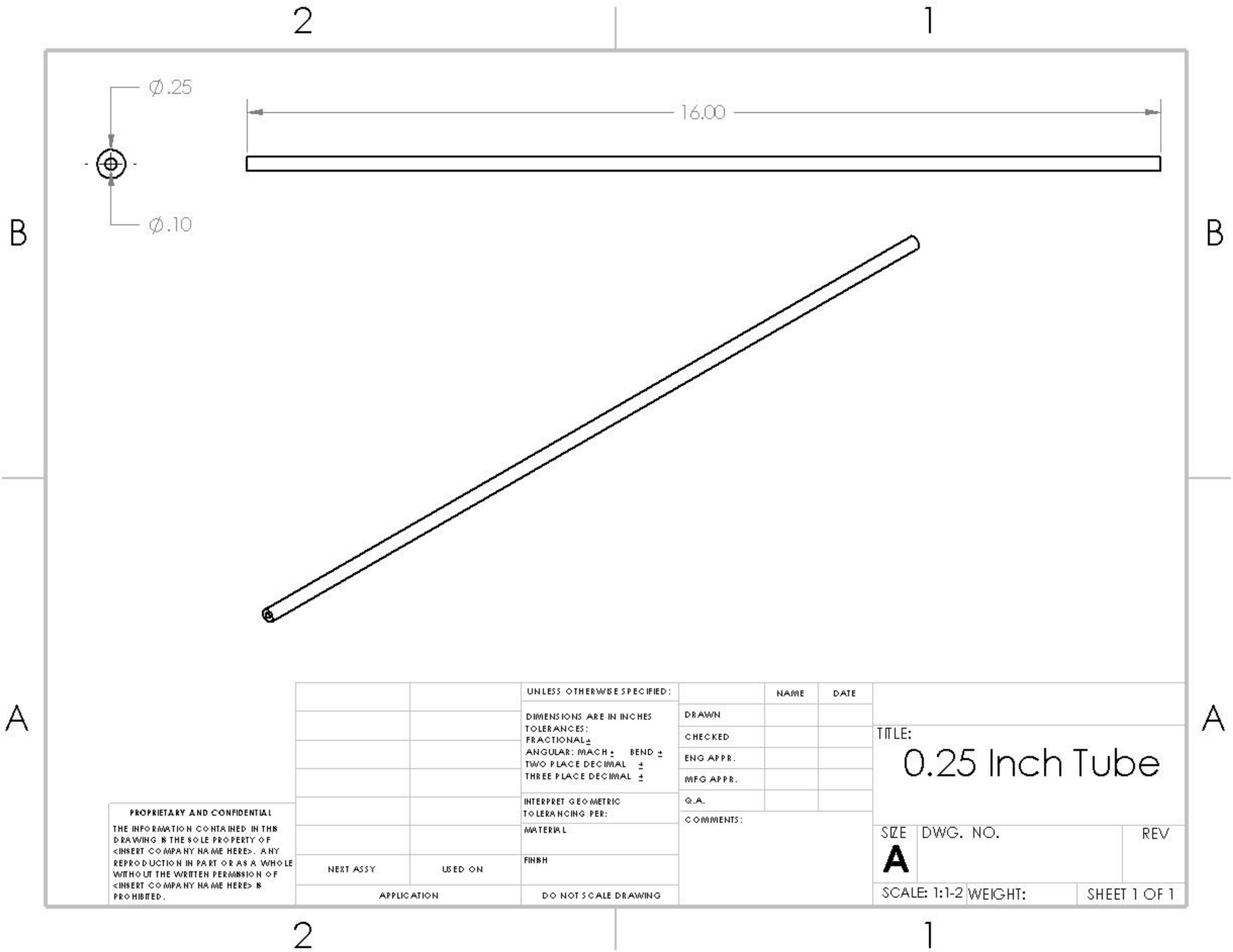


**Figure 21 0.25 Inch PVC Tube Drawing**

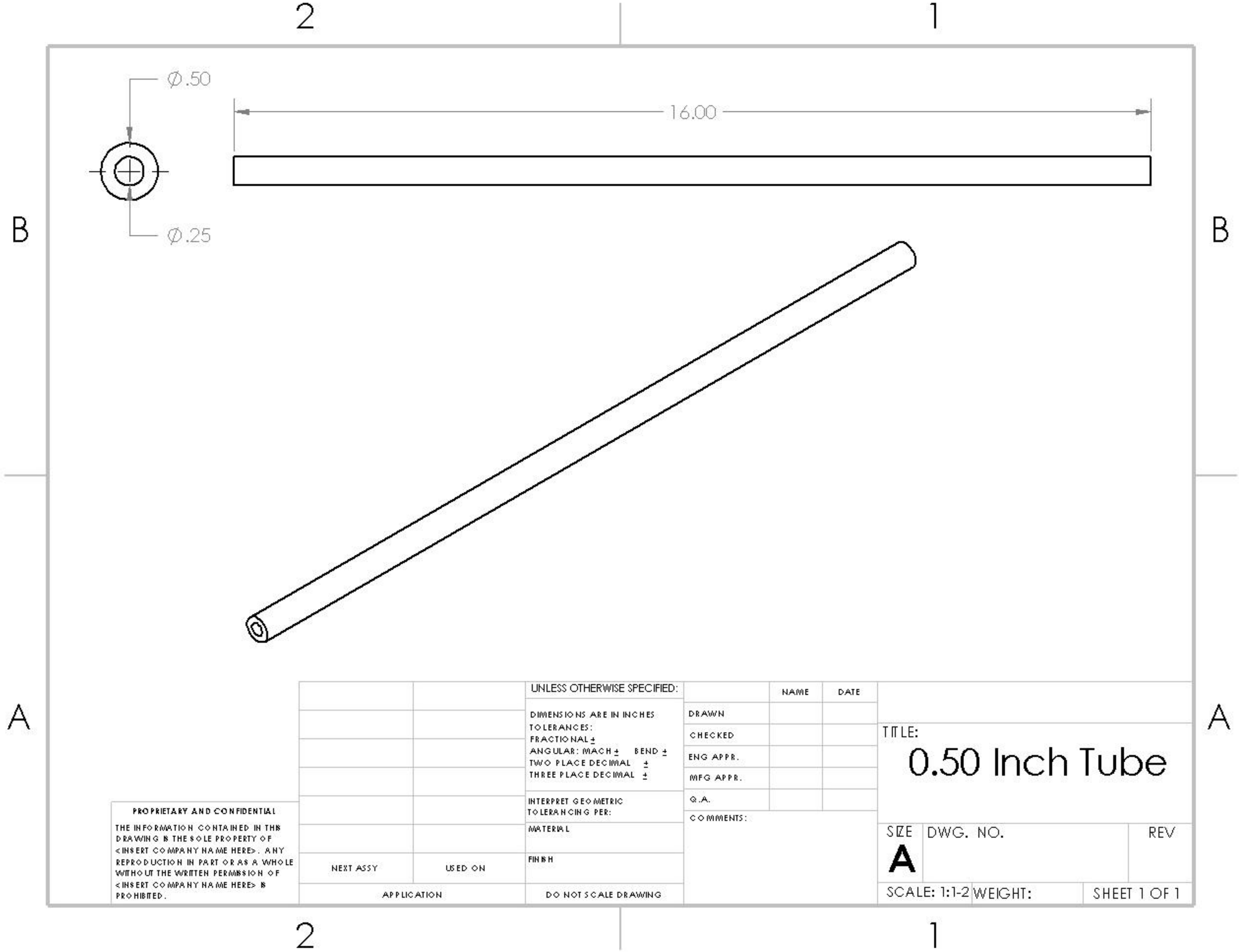


**Figure 22 0.50 Inch PVC Tube Drawing**

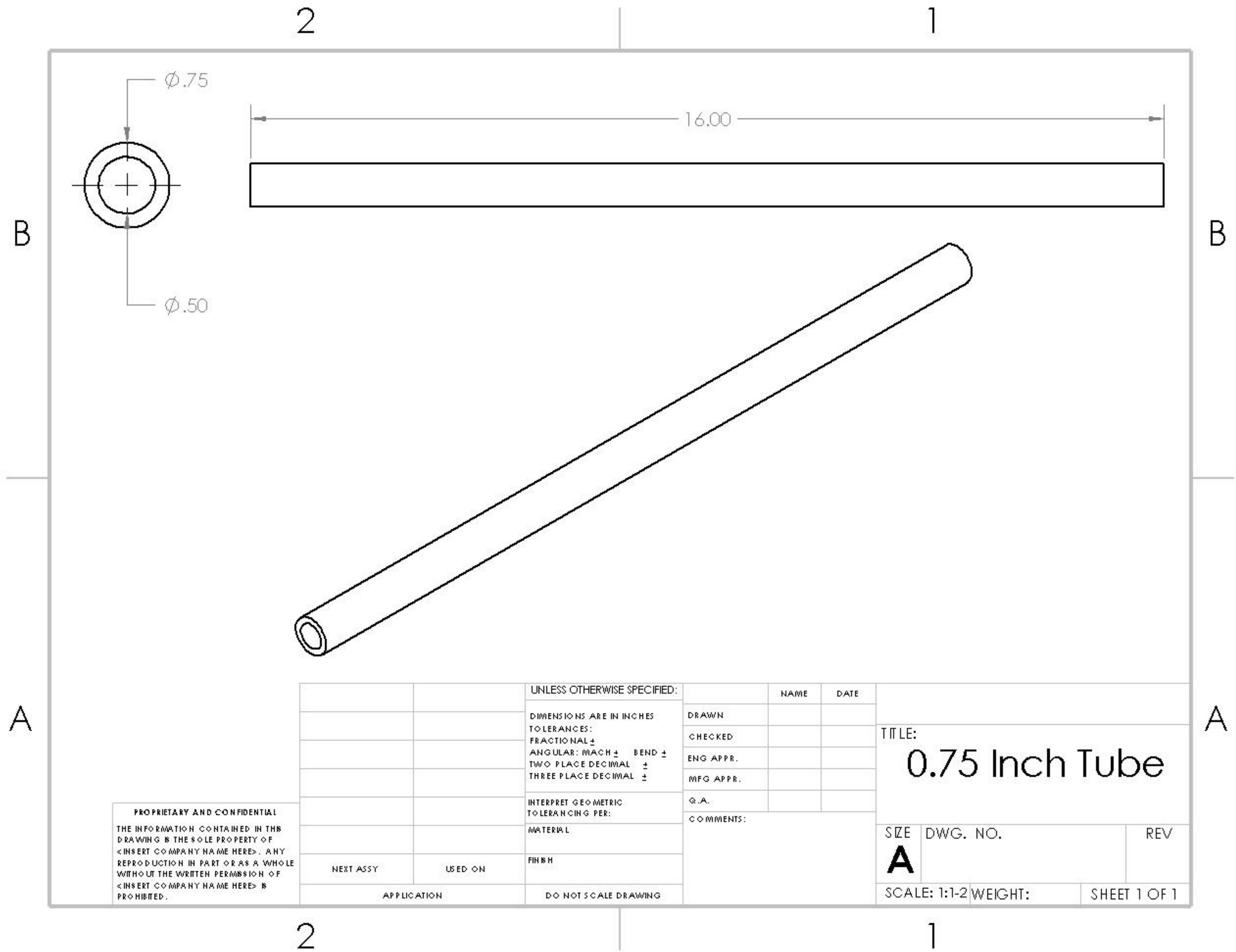


**Figure 23 0.75 Inch PVC Tube Drawing**

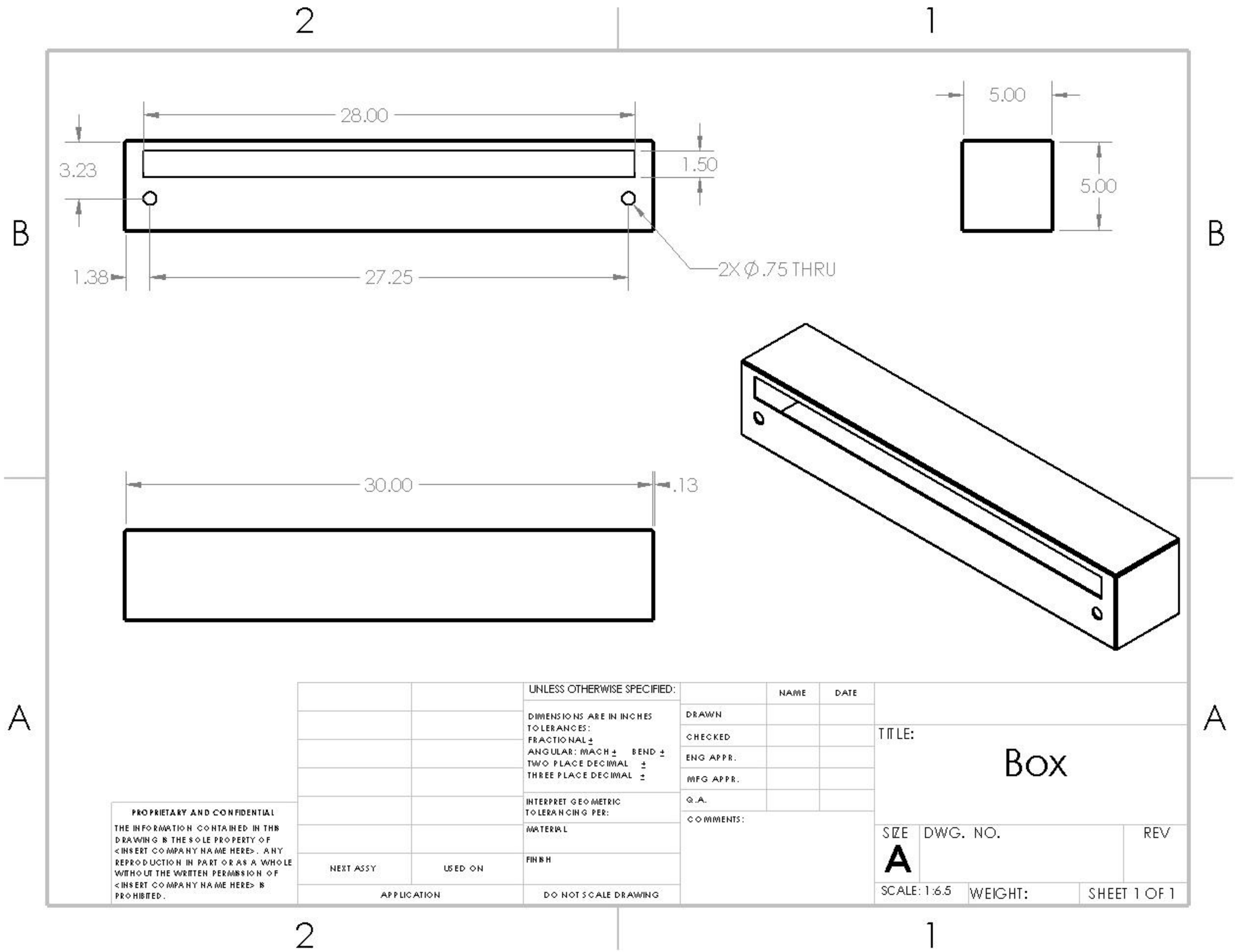


**Figure 24 Box Drawing**

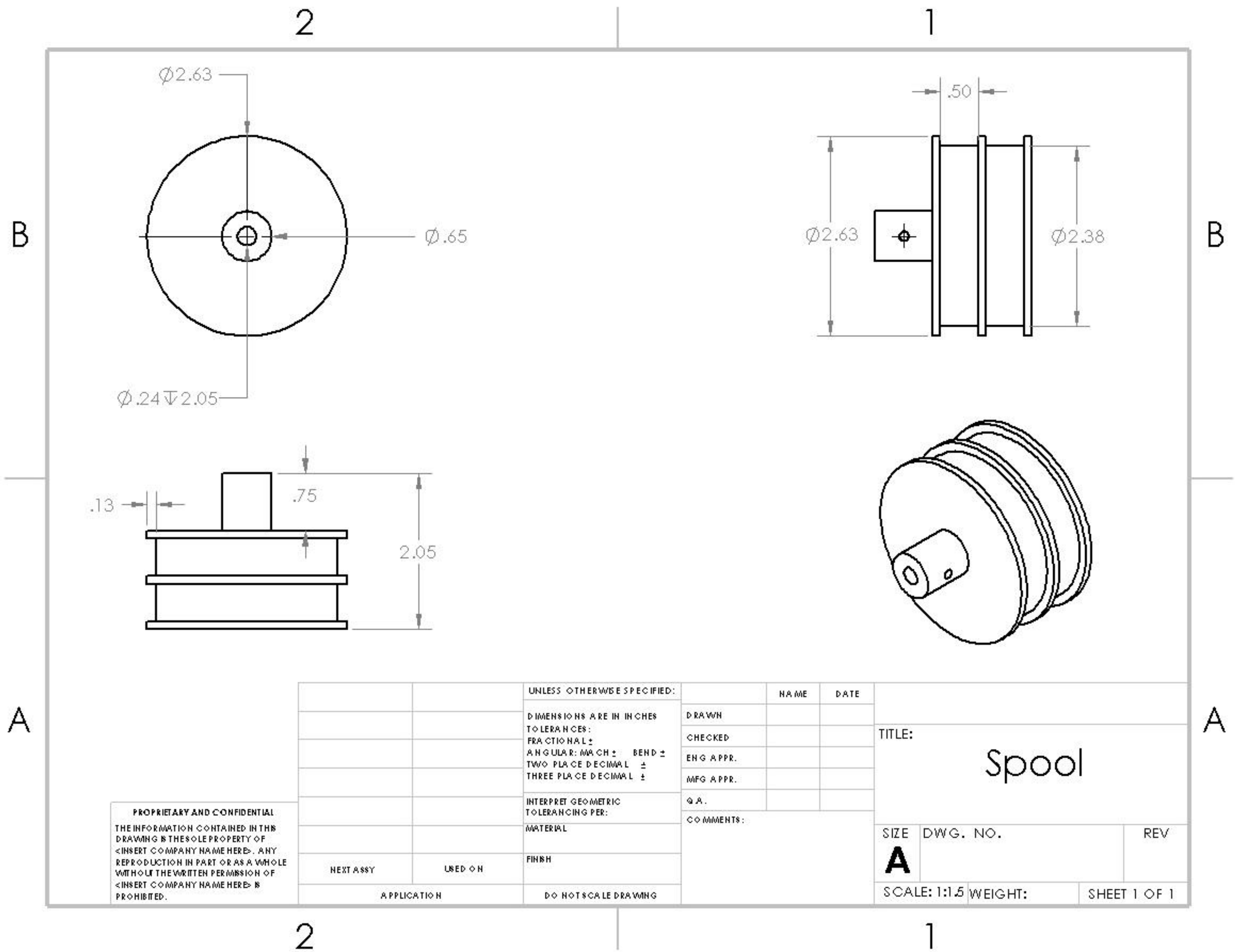


**Figure 25 Spool Drawing**

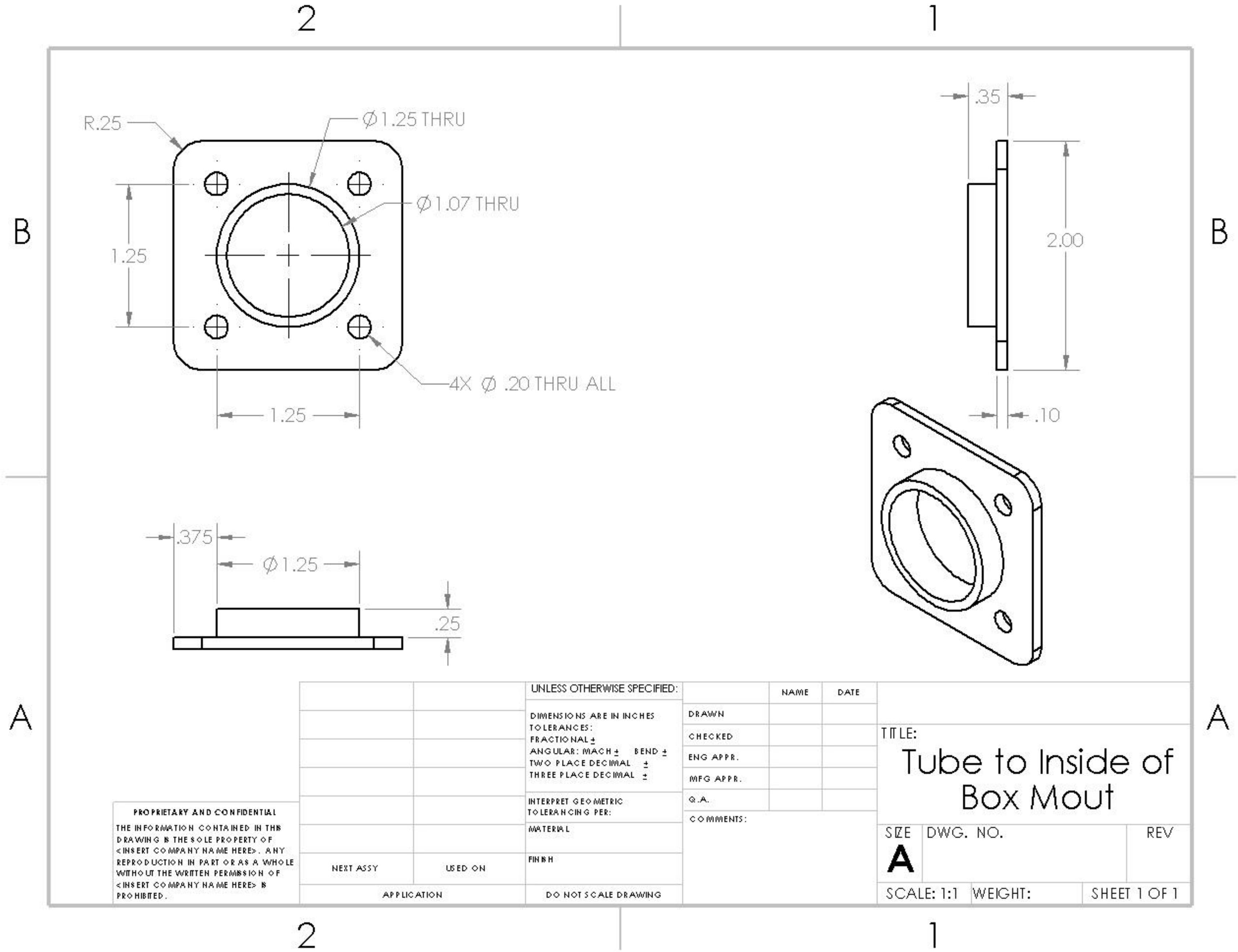


**Figure 26 Tube to Inside of Box Mount Drawing**

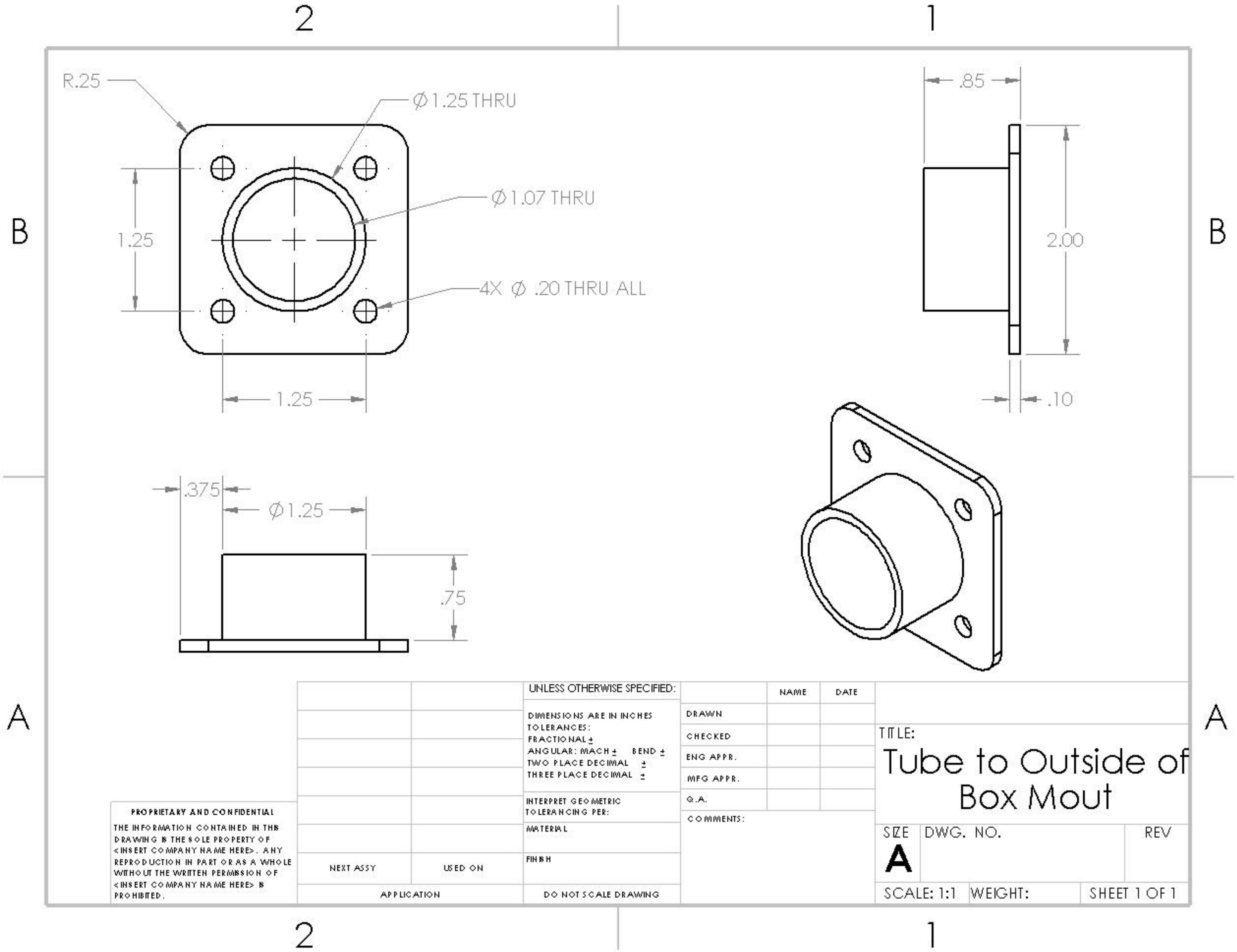


**Figure 27 Tube to Outside of Box Mount Drawing**

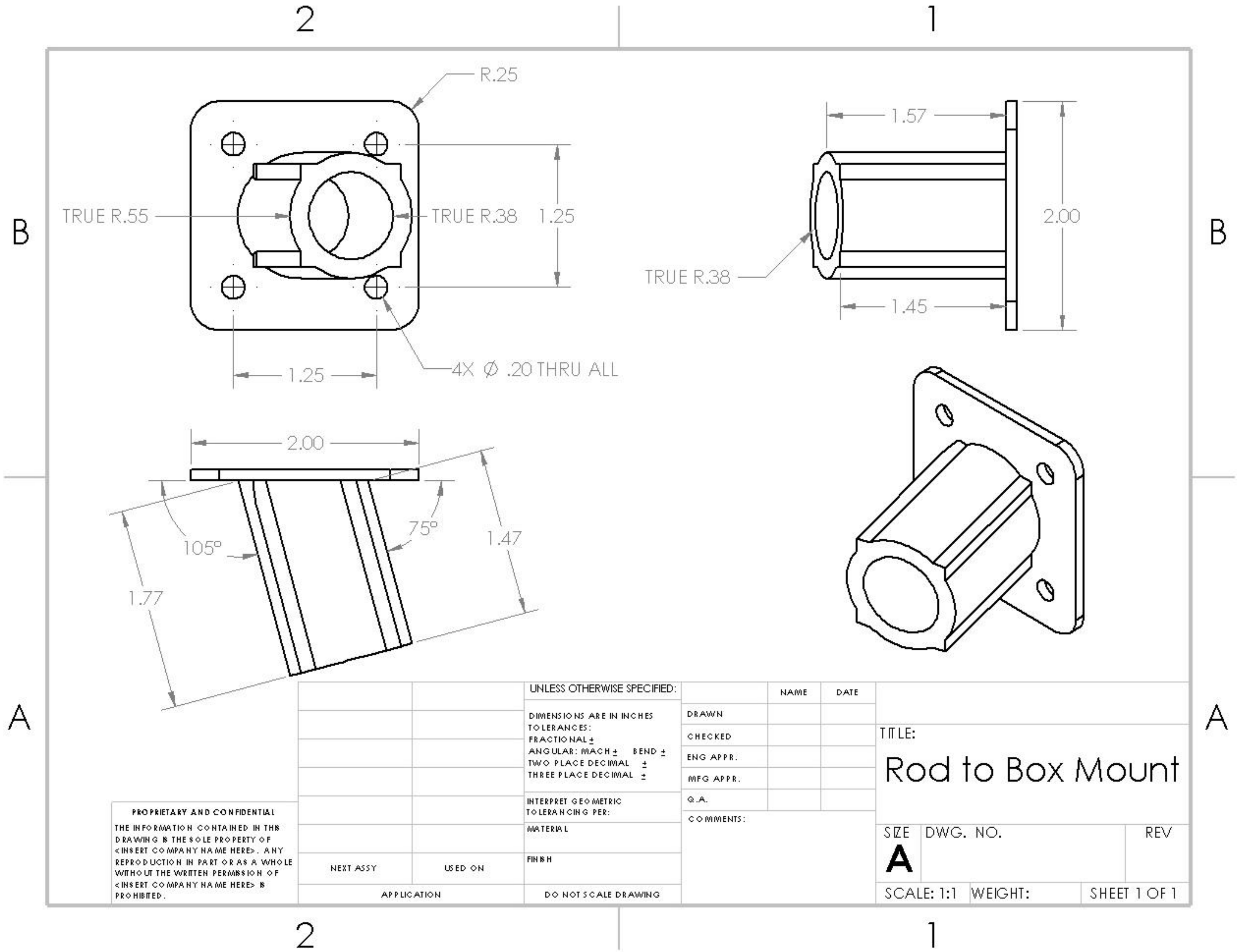


**Figure 28 Rod to Box Mount Drawing**

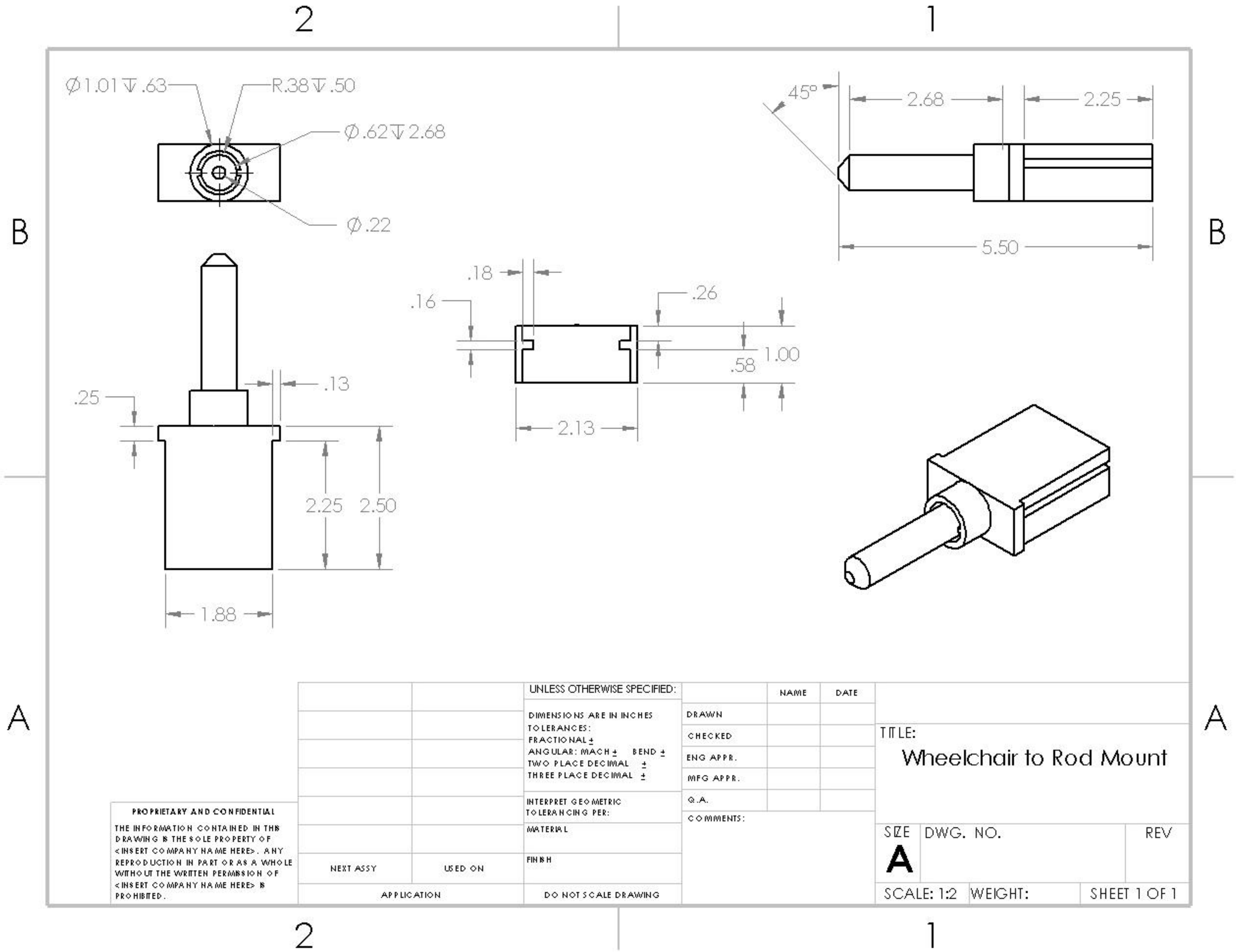


**Figure 29 Wheelchair to Rod Mount Drawing**

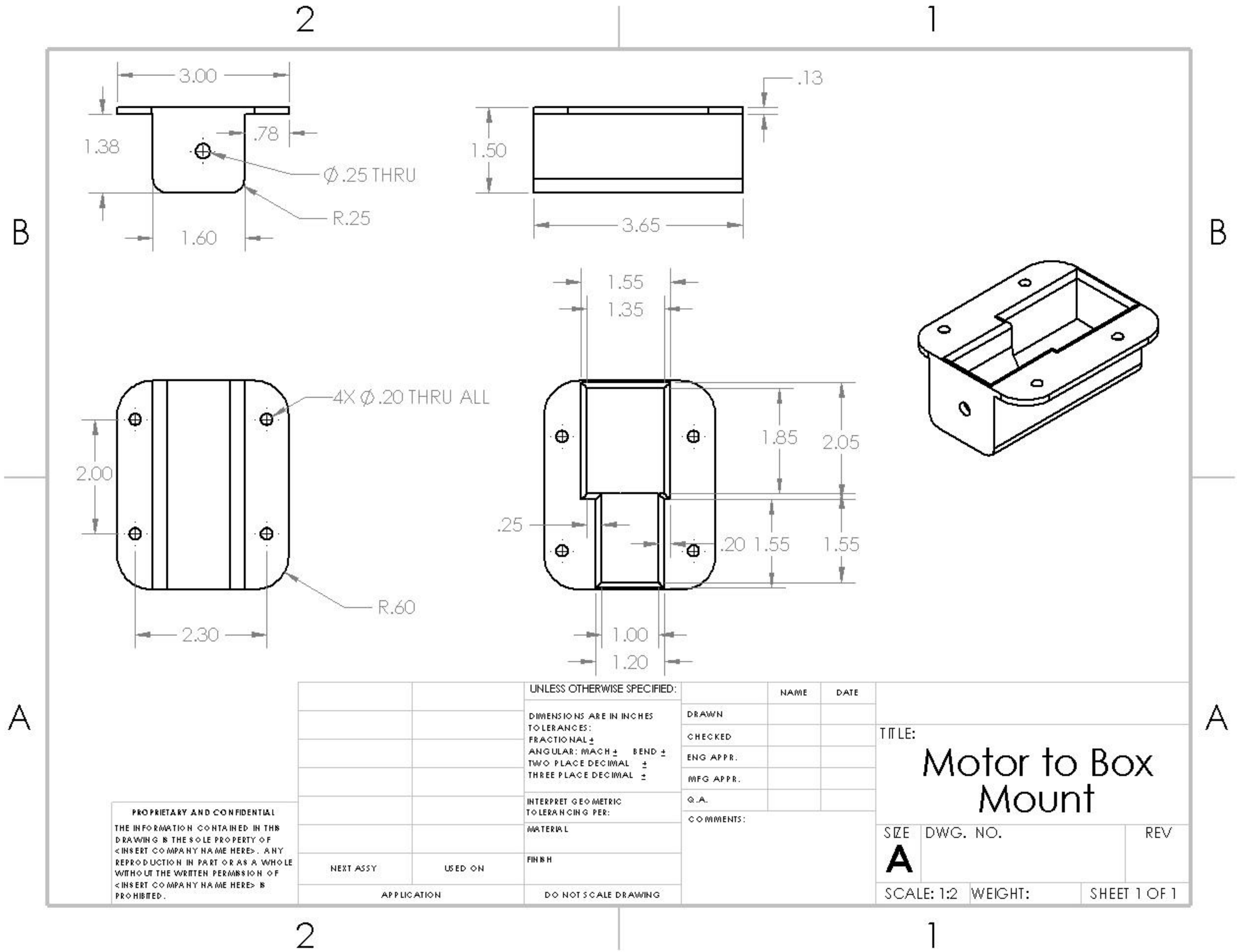


**Figure 30 Motor to Box Mount Drawing**

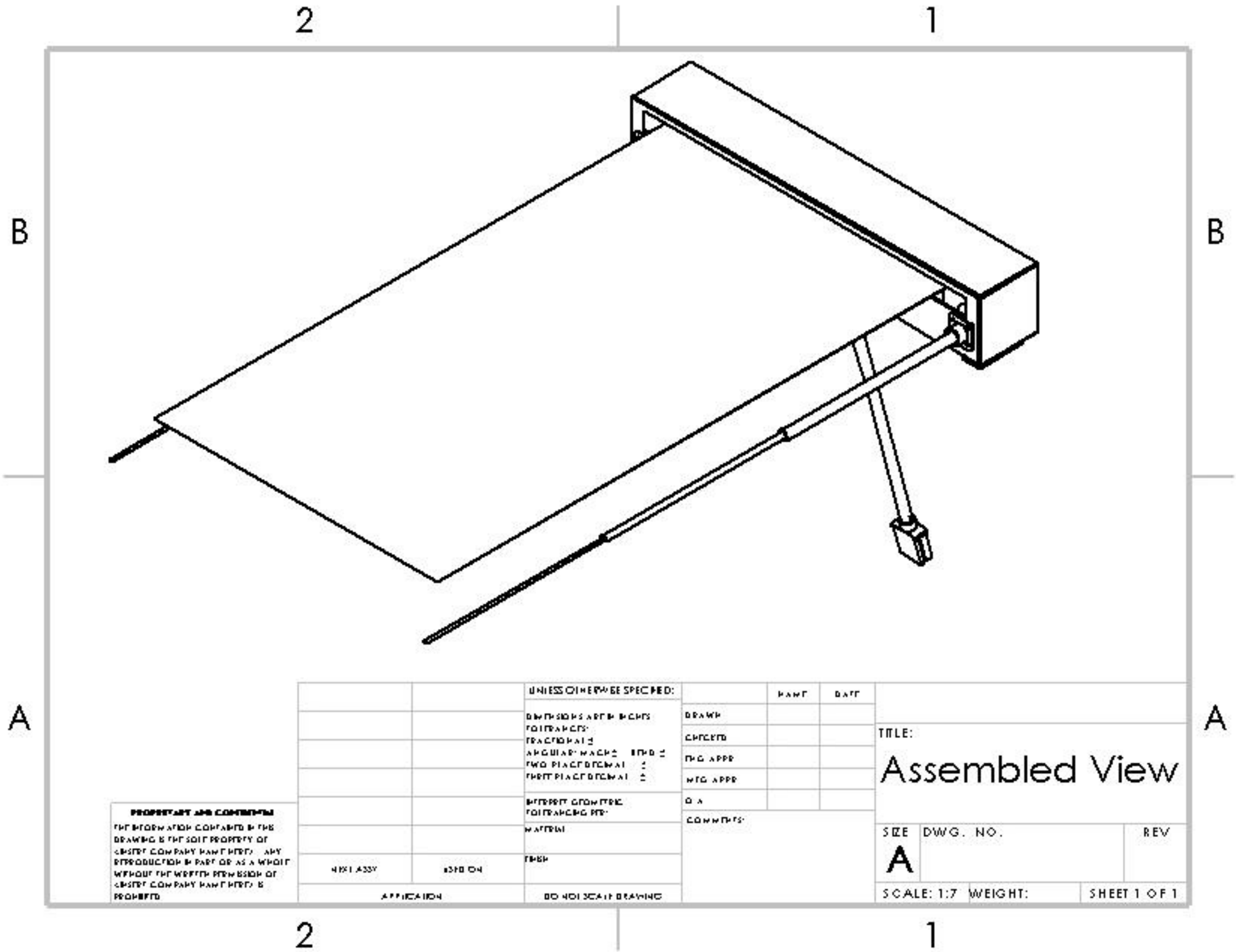


**Figure 31 Assembled View Drawing**

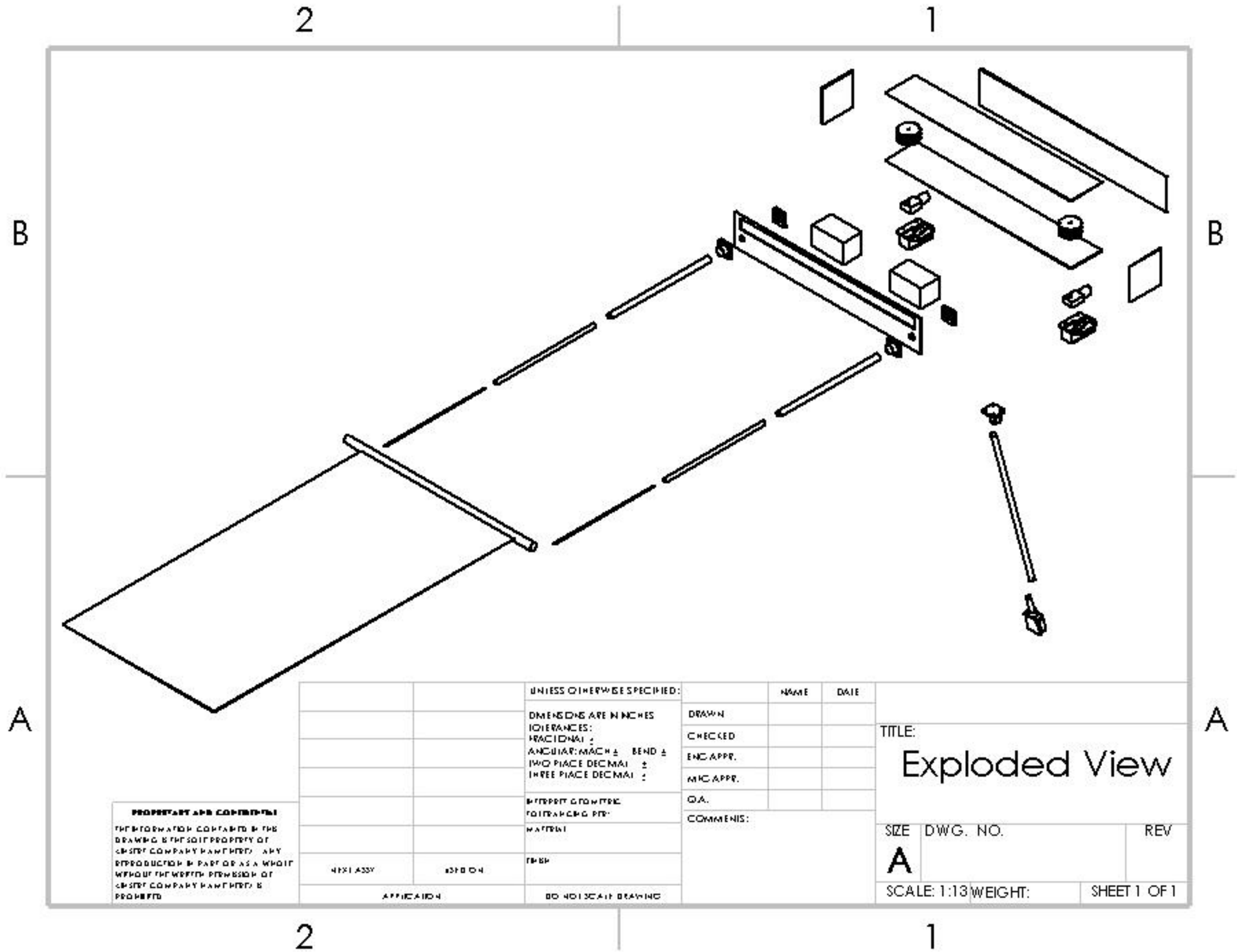


**Figure 32 Exploded View Drawing**

# Chapter 5: Discussion

Over the course of the first semester, the group was able to thoroughly brainstorm ideas and identify a clear design for the project. The design continued to improve with each meeting and was steadily developing. All of the components required to construct a rough prototype were identified and acquired. During this semester, a 3D model of the design was developed to use as a blueprint for actual construction. This will help in the precise placement and sizing of components to avoid interferences and other small problems that may occur during the first prototype production. After all the placement of the components are determined, the group built the first prototype. The group hoped to make several irritations of the prototype, but due to a lack of funding we were unable. Also Mohamed was injured and out for two weeks and got a new power wheelchair. This delayed the ability to redesign the wheelchair to rod mount to work with new power wheelchair. Since we had time for only one prototype we did everything we could to identify the problems in our telescoping mechanism in the prototype and fix it.

# Chapter 6: Conclusions

The absence of easily accessible weather protection is a struggle that many power wheelchair users face on a daily basis. This device could ideally allow power wheelchair users the capability of operating this canopy independently. It will allow for individuals incapable of opening and supporting an umbrella a safe and easy to use alternative.

Unfortunately, our first prototype was unsuccessful. The main issue was that the motors were not strong enough to telescope the tubes out. The springs in the blind want to roll up in the opposite direction. This resistance plus friction from the fishing line was too much for the motors handle. Another issue was the fishing line was falling of the spool and had to be rewind.

This project involved knowledge gained through our combined 19 years of mechanical engineering schooling at the University of Akron. For example, Solidworks was used to model several different pieces and parts that were then sent to be 3-D printed. Several of the parts had to be redesigned and reprinted after troubleshooting resulted in some unforeseen issues we had not considered.

If given adequate time and funds our group strongly believes that this product could be taken to market. If so, it could potentially be sold as a wheelchair accessory that could help many people. With a few mounting modifications this product could be used with a variety of different power wheelchairs.

After completing the first prototype, our group has several ideas for possible improvements. For example; it would be beneficial to decrease the overall weight of the product as it will allow for better operation and safer conditions. A few ways to accomplish this could be a different selection of materials as well as mounting the 6V batteries to the wheelchair itself rather than inside the box. Another potential improvement to the design would be the conversion of telescoping through the use of wires, spools, and motors to telescoping through hydraulics. Hydraulics would eliminate many of the problems we have encountered with this type of design and greatly increase manufacturing capabilities. Therefore, if we were to attempt to take this to market, it would be in our best interested to redesign the system to use hydraulics.

# References


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

https://www.youtube.com/watch?v=oS4VuXM0SGc&authuser=0

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