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Solar Tracker

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By

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Mechanical Engineering Technology

Contents

Abstract:

The purpose of this project is to find how to maximize the amount of time that the solar panels receive direct sunlight or the nearest possible sunlight angles. The solar tracker is a device that can change the position of solar panels in both vertical and horizontal direction to increase solar energy absorption. The device uses a gear motor to drive the shaft that is fixed to the solar panel, so the solar panel can rotate in vertical direction. Based on the vertical sun position in Ellensburg, 85^{o} E in the morning, 180^{o} S in the noon, and 276^{o} W in the evening. The motor, which is controlled by Arduino control chip will change the position of solar panel with a fixed angle to increase to amount of time solar panel faces direct sunlight. At the end of the day, Arduino control chip will control the motor to drive the solar panel back to the original position that will face the incoming morning sunlight for next day. Moreover, the horizontal direction of the solar panel faces have to change by hand since it only change a small angle each month. The testing result showed the panel to be perpendicular (90^{o}) to incoming sunlight, with 2^{o} deviation. This device increased the energy absorption by 20%.

INTRODUCTION

Description:

Nowadays, most of solar water heaters and solar street light used both solar energy and electricity. Electricity is the majority energy resource and solar energy only occupies a small part because the lower receive rate.

Motivation:

This project was motivated by a need for a device that automatically tracks the sun throughout the daylight hours to increases the amount of solar energy.

Function statement:

A device can change the position of solar panels in both vertical and horizontal direction, so they always face forward to incoming sunlight with only 2^o tolerance from 90^o. Generate more electricity than their stationary counterparts due to increased direct exposure to solar rays.

Requirements:

- Panels needs to perpendicular to incoming sunlight 90^o, with 2^o deviation.
- The budge limit of the project is 500 dollars.
- A steel frame to install 22.25” * 12.57” panels.
- Use 1 sensor and 1 controller chip, also program skills.
- Increased around 20% energy flue in the surface from incoming sunlight by change position of solar panel.
- Both axes must be animated.

Engineering Merit:

This project applies several of engineering concepts learned from the Central Washington University Mechanical Engineering Technology program. This project required to calculate the torque of the main shaft, intensity of solar, and angle between incoming sunlight and solar panel.

Scope:

The Solar Tracker will focus only the motors, sensors and flame part which can change the position of solar panel, so it will not include any design of new panel. However, the design of frame and choice of motors and sensors will be depended be the data that come from calculations.

Success Criteria:

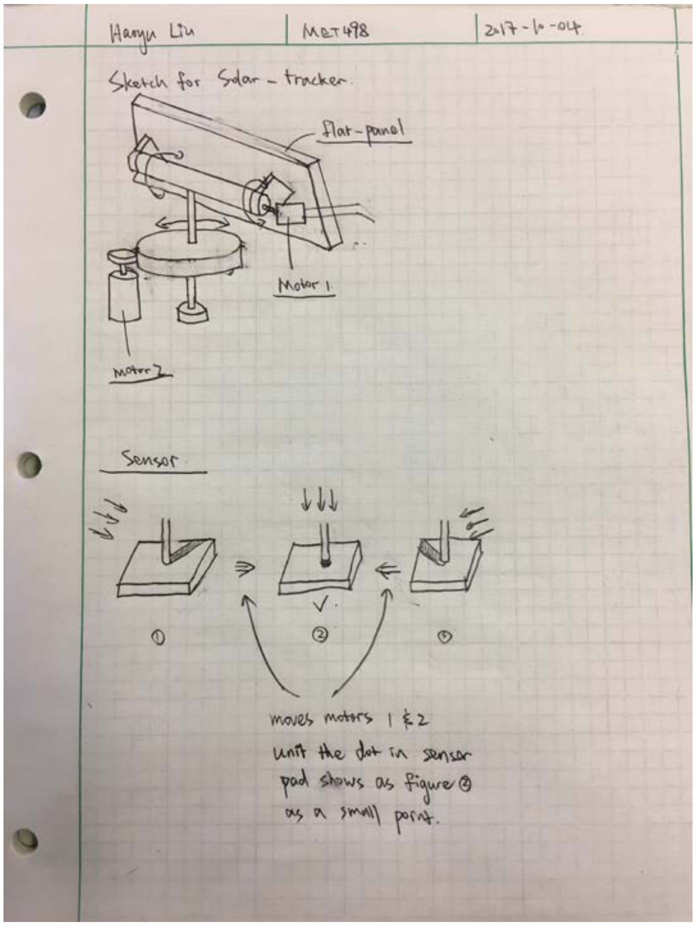
The success of project will be based on the performance of project, which the position of panels on the solar tracker always face to incoming sunlight. Increase 20% more solar energy collect than traditional solar panels that the position is fixed. Also, it will limit the tolerance angle within 2 degrees.

DESIGN & ANALYSIS

Proposed Solution:

Working Device on the desk:

Sketch:



The drawing above is the rough draft sketch for solar tracker. As the sketch shown, there are two motors and one sensor are going to use.

Benchmark:

A similar solar tracker was to use one motor to drive the solar panels, and the position of panels changed according to the time.

Performance Predictions:

The solar tracker will automotive face to incoming sunlight. Increase 20% more solar energy collect than traditional solar panels that the position is fixed. Also, it will limit the tolerance angle within 2 degrees.

Description of Analyses:

Analyses:

Green Sheet:

The main problem that needs to analyze are the size of solar panel and tolerance angel between solar panel and incoming sunlight.

As the green sheets shown in appendix A, the isolation intensity and energy flux into surface reached highest value when the angle is 90 degrees, and larger surface area caused rays to be spread out and reduced intensity of the radiation. Based on $I_{surface}=I_{direc}t*cosA$. The intensity will be 98% in 80 degrees, 87% in 60 degrees, and 64% in 40 degrees.

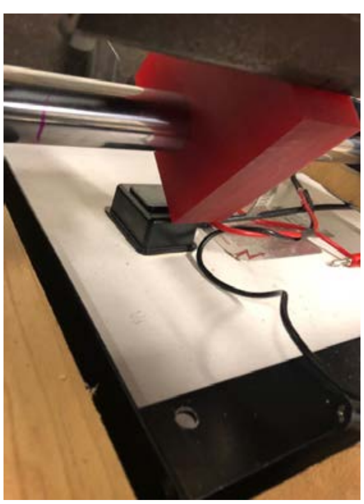
The second problem that needs to analyze are the factors that affected tolerance angle between incoming sunlight and solar panel. Based on the green sheets in appendix A, the angle will depend on the length of shadow, and the length of shadow depends on the length of shaft, diameter of shaft, and distance from bottom of shaft to panel. Assume the diameter of shaft use for sensor if 1 in and 5 in long. The shadow should be limited within 1.1746 inches.

As the green sheets page 4 and 5 shown in appendix A, the 2L004 model of parallel-shaft gear motor offered 46 lb-in which can be fitted and used to drive the frame with 21.81 lb-in torque force and change the position of the solar panel with 32.22 lb-in torque force.

As the green sheets page 6 shown in appendix A. The moment for shaft will be 84.28 lb-in if installs shaft in one end side. And the moment for shaft will be 0 lb-in, if installs shaft in middle and two equal forces action on both sides.

Winter quarter additional analysis:

As the green sheets page 7 shown in appendix A, the gear that used for 2L004 motor and 1.25'' shaft has to change to 1:3, compare to original design and calculated that 1:1 was enough to drive the shaft to rotate in green sheets page 4 and 5 shown in appendix A. The change was due to the wrong weight that used to calculate the torque in fall quarter, the original calculate only contains the weight of solar panel, but the total weight has to be the weight of the whole top parts which including solar panel, 1.25'' shaft, two side supports, two plastic supports, and two wood beams. Therefore, the total weight was 36 lb. instead of 6.61 lb. for solar panel only. Since the gear ratio changed, it required a large size of gears that was not fit inside the back space of solar panel, so the gear had to locate outside the frame. This change caused a new problem that one of plastic supports could not rotate 90 degree because the power source block the way after changed the location. Therefore, two new holes had to drill in shaft in order to re-locate a new position for plastic support to rotate 90 degrees at least.



Drawing:

Based on page 6 of green sheet in appendix A, the original design option 1 will create more moment at support point than option 2. It means option 2 is more reasonable design. The build of project will be similar like the last drawing called combined in appendix B. The final drawing tree is shown in Appendix B which including 9 parts as total.

Decision Matrix

	Cost	Time	Design Difficulty	Math Difficulty	Result	Total
Weight (1-5)	2	3	4	4	5	
1 motor with fixed angle	1	2	5	1	2	42
2 motors with fixed angle	1	2	2	3	2	38
2 motors and 1 sensor	4	4	1	5	5	69

The table above shown three options.

The first option is using 1 motor which will move fixed angel along time, and this option will be cheap, save time, easy to calculate, and easy to design.

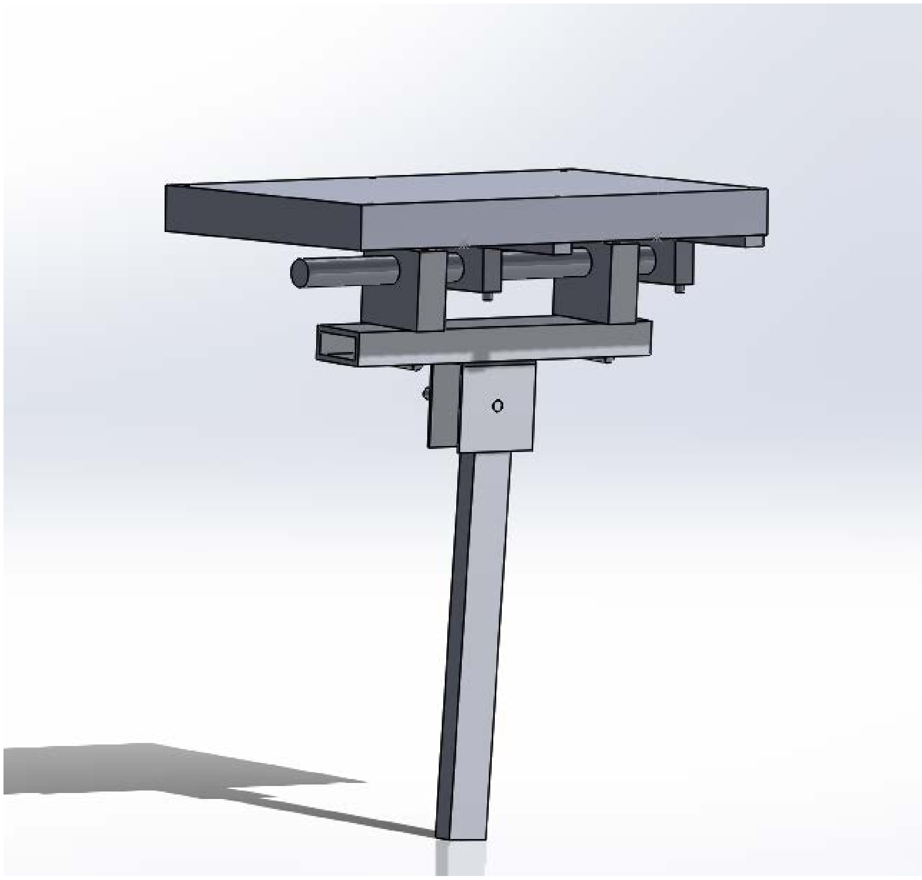
The second option is using 2 motor which will move fixed angel along time with horizontal and vertical directions. This option is not expensive, not difficult to design, but it will require some calculate skills.

The third option is using 2 motors and 1 sensors, this option will reduce the angle between sunlight and solar panel compare last two options, which means the solar panel can collect more energy. However, it will cost more money, more time, more calculation and more difficult to design. The third option will be choice because it will have better performance and it will include some skills from others major.

METHODS & CONSTRUCTION

This project was conceived analyzed and designed at CWU. The parts will be supported by resources and documents from library and parts will be made in the lab at Central Washington University. This project is made of 12 parts. Four of them will be obtained from suppliers, and the rest of them will be designed and manufactured at Central Washington University. The four parts that will be obtained from suppliers are solar panel, sensor, and two motors. The designed and manufactured parts are base for central support, central support, two side supports, and shaft. And the drawing of designed and manufactured parts will be uploaded weekly in Appendix B. After input the program and connect to battery or power, and motors will accept order from sensor and automatic change to position of solar panel to face to incoming sunlight all the time.

The final construction was almost the same as the assembly and drawings shown in drawing in winter quarter in the Appendix B. There were 9 parts that made in machine shop and one of those parts was made in both wood and machine shop. As drawing in Appendix B and pictures shown below. The solar panel connects with two wood beams as drawing no.6; Each wood beam connects one metal side support as no.4; there were three holes at the top of metal side support, the U-bolt went through the two holes on the side to lock wood beam and metal side, and a screw went through both middle hole and the hole on the shaft. As result, the solar panel, wood beams, metal side supports, and 1.25'' shaft were fixed together, and it will rotate together as a whole part. Then there were two plastic supports as no.3 that installed on the shaft but were not fix with the shaft, which means the shaft can rotate along with those two plastic supports. A tube beam as no.2 was used under the plastic supports and installed three sheet metals. One sheet metal as no.7 was used to install motor, and used chain to drive the 1.25'' shaft on the top part. Other two sheet metals as no.8 were used to hold the support tube as no.5, and connected with a base as no.9 at the bottom of the device.



There were five manufacturing issues. The first issue was that the 1.25 inches' shaft could not go through the hole at the center of metal side supports that mill in lathe machine, even though the hole was mill 0.05 inches over size. This issue was caused by the bugs inside the hole and the different sizes in each side of the hole, so the solution was putted the metal side supports in holding device and used one size larger extension drill to turn in. Therefore, the hole was expanded and the shaft could go through the holes. The second issue was that the holes at the center of plastic supports did not go through perfectly when mill in lathe machine because it was too hot, and it tended to burn the plastic instead of mill it. Therefore, the cold water needed to put on for each 0.05-inch mill in to reduce the temperatures. The third issue was that the holes used to put in U-bolt to connect tube beam and plastic supports were not match up because the holes were the same size as the U-bolt's cylinder parts and the holes were not perfectly drill through the plastic supports vertically. When the cylinder parts went through the plastic supports, one support looked vertical and another one looked opened. Therefore, the holes had to expand on tube beam in order to use U-bolt to connect plastics supports and tube beam.

TESTING METHOD

The purpose of testing was to compare the project with original design.

Dimensional testing: before installed solar-tracker, checked and ensured the size and weight of parts were met the design requirements. A device should be installed together perfectly if all the parts have correct dimension

Power testing: connect power supply for motor, timing sensor, and Arduino control chip. The shaft should be able to rotate slowly drove by the motor.

Install testing: at the beginning of the testing part, the solar-tracker should be built completely. The solar panel can be installed to the frame, and motors can driver the solar panel in both horizontal and vertical direction. After finished the build of solar tracker, the two methods will be used for testing it in two different places.

Angle and tolerance testing: the first place is inside the room, and the first method is Visual Observation method, which observe if the solar panel changes the position by eyes when use an electric torch to shoot the sensor panel from different angle. The second method is Math Calculate method, determine the length of shadow in the sensor panel and the size of shaft to calculate the tolerance angle that the solar tracker created, and the calculate way is the same as the analysis shown in analysis section.

Function testing: After those testing, the function testing will be taken in an open area in sunny day to test the same experiment again to make sure it works in real environment. And testing time will be 6 in the morning, 12 at noon, and 5 in the afternoon.

BUDGET

At the end of winter quarter, the total cost of project was $343.25 for the 13 parts that were planned to use. The parts required and cost is shown in Appendix C, and total cost of parts, labor, and time is shown in Appendix D. The total cost of materials is $343.25 which including 2 2L004 model of motors with $91.5 each, 2 round shaft bar for pivot shaft and main support with $39.99, two steel flat bar for two side supports and main support with $48.96, 1 round shaft bar for main support shaft with $10.79, two flat bars for two beams connect between side supports and solar panel with $21.84, one timing sensors with $20.00, 4 U-bolts with $13.25, and 16 screws with $5.32. All of those raw materials were ordered from EBay and Amazon that shipped to Hogue directly and small piece of materials like screws and U-bolts were purchased in locate hardware store. All of those information, like the descriptions, supporting metadata, and sources of parts, are list in Appendix C.

Moreover, the budget is under control because some materials were got from machine shop and wood machine that either people left before or abandoned, like the wood pieces as no.9, steel tube as no.10, and plastics bar as no.13 in parts list. Also, one part was got from friend which was the Arduino control chip as no.8 in parts list. However, some parts were wasted due to change of design and change of materials. The project will only use one 2L004 motor to move the panel in vertical direction instead of two motors that move the project in both horizontal and vertical, and the wood beams were used to replace steel beams since they were strong enough and lighter than steel beams. The total cost was under the estimate cost which was $500, but the it may increase in spring quarter as test and it may need to change some parts until it works.

SCHEDULE/PROJECT MANAGEMENT

The project will be managed as Appendix C, D, and E shown. In fall quarter, the proposal and project was followed the schedule table and graph in Appendix E, and finished all the drawing on time. As the Gantt chart in Appendix E shown, the materials were ordered at the beginning of winter quarter, but most of materials arrived late than original plan and arrived at the middle of February and the design of project was kept changing based on Professor Rogue's advice along with new materials added. Therefore, the working time was started late and spent extra time in the machine shop to manufacture the parts and used SolidWorks assembly to show to motion and relation between different parts to make sure the parts can be installed together and the project was finished it on time. The 90% of project was finished and installed at the end of winter quarter except a base that will be finished at the first three days of spring quarter.

The number of part and drawing number in Gantt chart was re-ordered at the end of winter quarter. The documentation estimate time was 17 hours, but the actual time spent was 29 hours due to the additional calculation, change the size of the parts, re-design the parts, and find other better materials. Most of time was used to change the SolidWorks assembly and drawing because one part changed was caused the change of other parts. The part construction estimate time was 29 hours, but the actual time spent was 44 hours due to part tolerance like the holes in plastics supports and tube beam did not match up. Therefore, the time was spent to fix those problem. The total actual time spent on the project was 137 hours from fall quarter to the end of the winter quarter. As a result, the additional schedule will need for spring quarter and leave additional free and flexible time to fix the un-known problem.

DISCUSSION

Manufacturing issue

There are more issues may come out during the time of manufacturing the project. So it may need help from Matt and Ted. Also it may still exist some calculation problems like the use of gears. This section will keep record the issues happen during this period.

Design Evolution:

The choosing of material will be different than original design and final result based on the real situation and stress analyze. And some parts may need to re-manufacture to make sure it match the final dimension and work properly.

Risk Analysis:

The main risk of this project is to use sensors to control motors because using of sensors are not a main study area for Mechanical Engineering student. Therefore, choosing the using sensors are main challenge for this project. And if the sensor does not work. The second plan will be adopted that use control chip to control the motors move the limited angle along with time. it can still increase energy flue in the surface from incoming sunlight by change position of solar panel but less than original plan with 20%.

Successful:

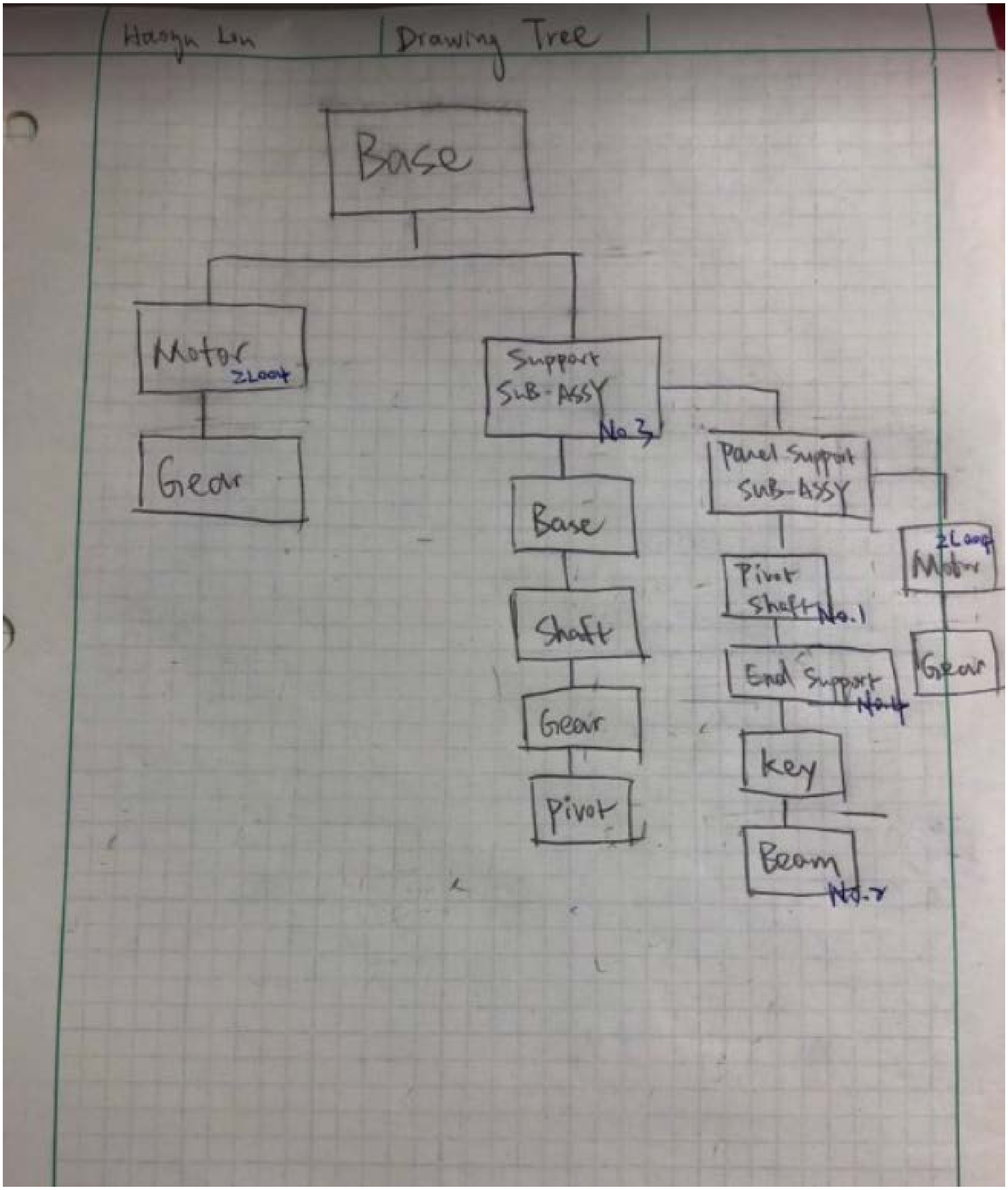
The overall skills required for this project are stress analyzing, SolidWorks designing, and CNC machining. And it is extremely important that a material that will meet all the design requirements was selected. In addition to the stated requirements this material had to be able to be machined, cut, formed, and hardened to its final state.

Development:

There are some disadvantages of solar tracker system, and it is slightly more expensive than their stationary counterparts and ongoing maintenance is generally required because the more complex technology and moving parts necessary for their operations. Also, the solar tracker may have more development in the future, for example, does not plug in any AC or DC source, and use the energy that transfer from solar energy from solar panel.

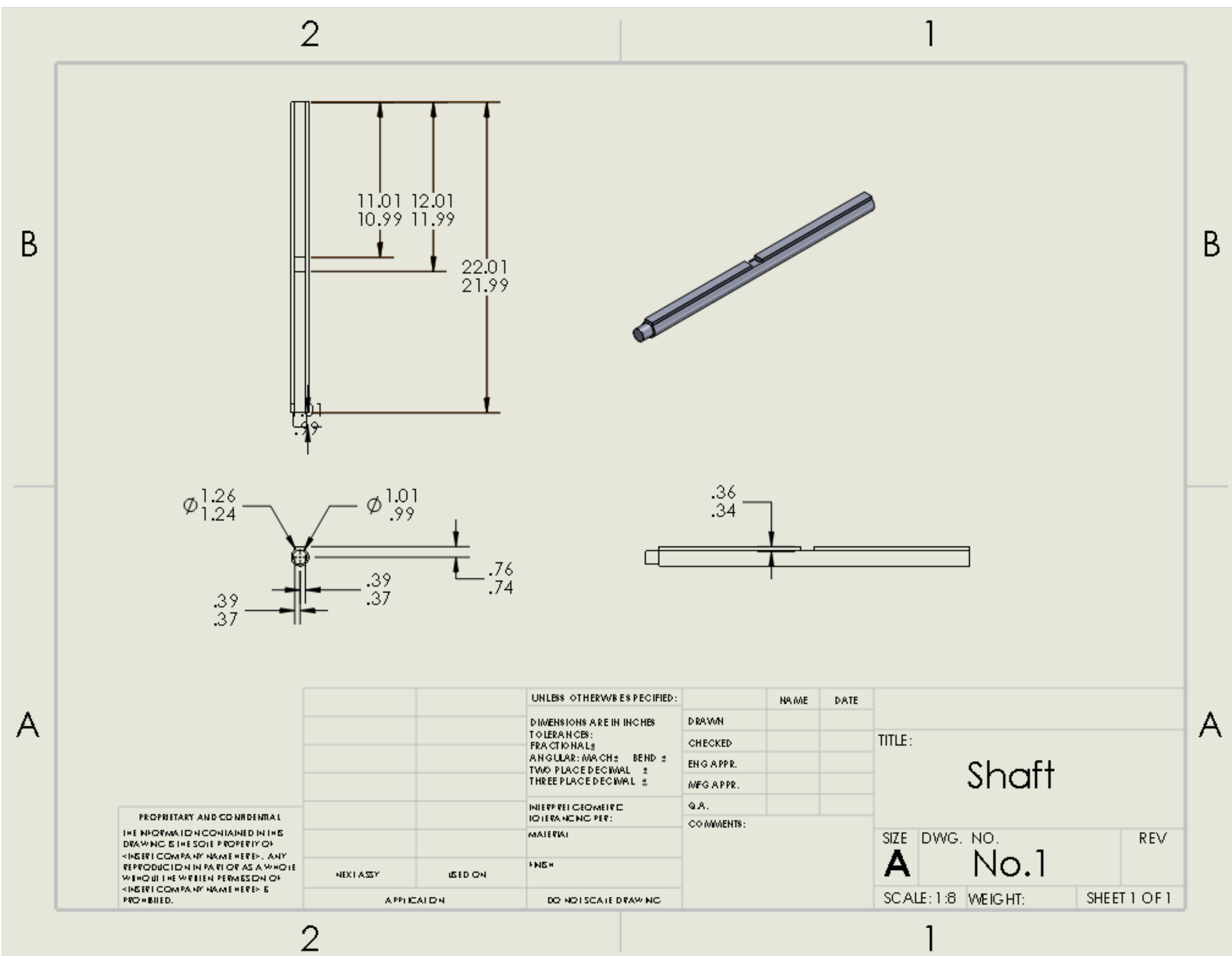
Documentation

There are two parts will order directly instead of manufacture and design. The two 2L004 models that support 46 lb-in torque, and all the details and information post in Grainger website, and based on the information provided by offered. The motors can be used in this project, and it will work properly. The control chip will be the Android control chip that allow to program and control the motions of the motors.

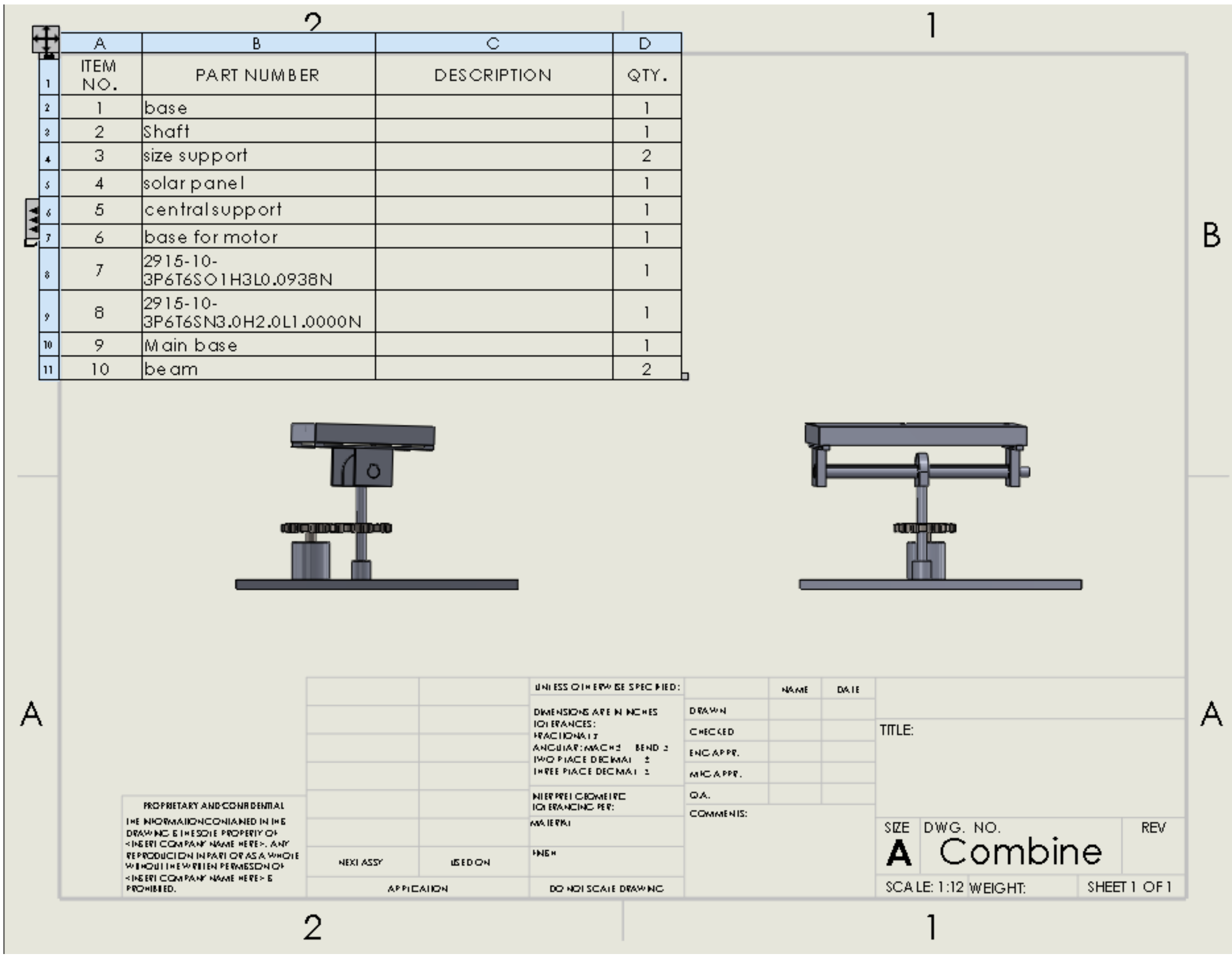


There are four main parts required to manufacture in lab with CNC machine, and the drawing shown in Appendix B with drawing number 1 to 4. And the drawing tree shown after all the drawing. Based on the drawing tree, it requires one base on the bottom of the build that connect the support and motor, and make sure the distance between motor and the shaft of main support to ensure the gears can match each other. The main support are combined by three parts, which are shaft, gear, and pivot hole. The pivot hole is used to connect main shaft. The panel support parts are combined by six parts, which including solar panel, two beams that install two side under the solar panel and connect between solar panel and side supports. And the main support, side support, and motors will be connected by main shaft.

Once the install finished, the solar panel is be able to move both horizontal and vertical directions.



The most important part for this project shown as the drawing above. It has a key way, a small round, and a center gap. Those shape will require different operation to finish such as milling and turning.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	base		1
2	Shaft		1
3	size support		2
4	solar panel		1
5	central support		1
6	base for motor		1
7	2915-10-3P6T6SO1H3L0.0938N		1
8	2915-10-3P6T6SN3.0H2.0L1.0000N		1
9	Main base		1
10	beam		2

The final build of the project should look like the drawing above that contains all the parts list in the table on the left top of the drawing. However, it is only the design drawing, and final result will look more complex.

CONCLUSION

To conclude, the solar tracker is designed to move the solar panel perpendicular and minimum the tolerance angle of less than 2 degrees to incoming sunlight. The entire design was divided into three main parts. The frame with 1 shaft with 1.2-inch diameter, 2 side supports, and 1 one support, a solar panel with 12 Voltage and 25 watts, and two motors with HP.

This project is a big challenge to the skills of designer for stress analyzing, SolidWorks designing, and CNC machining. All the design was carefully though through and documented to ensure all the parts can be combined together, and the motors and sensor can support the solar panel. At the end of winter quarter, the project met the salient results expected in 3 major points. The first point was the project was finished build that the solar panel was be able to rotate along with shaft and drive by motor that fix in the tube beam and base. The second point was the motor was enough to drive the solar panel used 1:3 gears even though the weight was 5 times larger than expected. The third point was the solar panel was installed in the steel frame perfectly and the budget was under control and still have extra budget that prepare to use in spring quarter if the project need to fix and change any parts.

ACKNOWLEDGEMENTS

Acknowledgements to Central Washington University for providing the machine shop, tools software, library resources, and references. And thank Dr. Craig Johnson and Professor Charles Pringle for helping and checking the process of proposal and entire project, Professor Roger Beardsley for helping change the design the calculation, Professor Matt for offering and helping to choose materials, and Professor Ted Bramble for machining help. Thanks all of them who supported and helped at different stages of this project.

APPENDIX A – Analyses

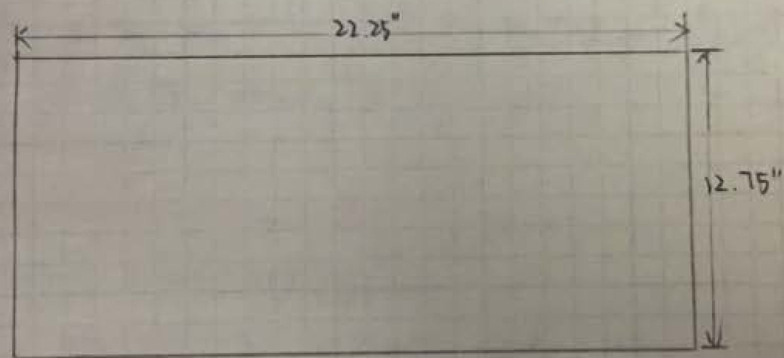
Haoyu Liu | 10/10/17. | 1/2

Given: 1. A solar panel 2. A Sensor.

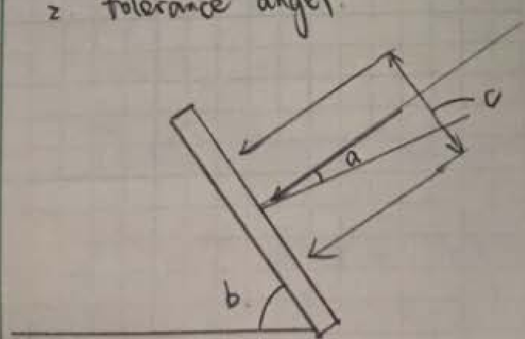
Find: 1. Size of solar panel
2. tolerance angel

Sol'n: Size of solar panel
Use measuring tape and rules to measure
Find out details number of solar panel.

1 "ARCO Solar" – 12 V_{DC} 25W.



2 tolerance angel

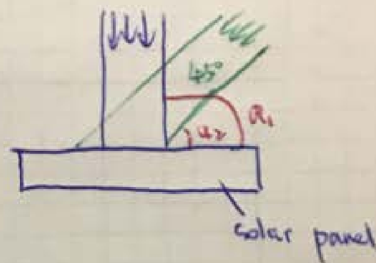


Assume I is intensity of solar radiation (W/m^2). A is collector surface area.

$Q = IA$

The equation of insolation intensity:

Intensity $I = \sin(A)$



$\sin 80° = 0.98 = 98\%$

$\sin 60° = 0.87 = 87\%$

$\sin 40° = 0.64 = 64\%$

$\sin 20° = 0.34 = 34\%$

$\sin 0° = 0 = 0\%$

The intensity of solar radiation depends on the angle of incidence instead of cover surface area.

Because the rays to be spread out over larger surface area. reducing the intensity of the radiation

$I_{surface} = I_{direct} \cdot \cos(A)$

Assume I_{direct} = ~~too~~ $350 W/m^2$.

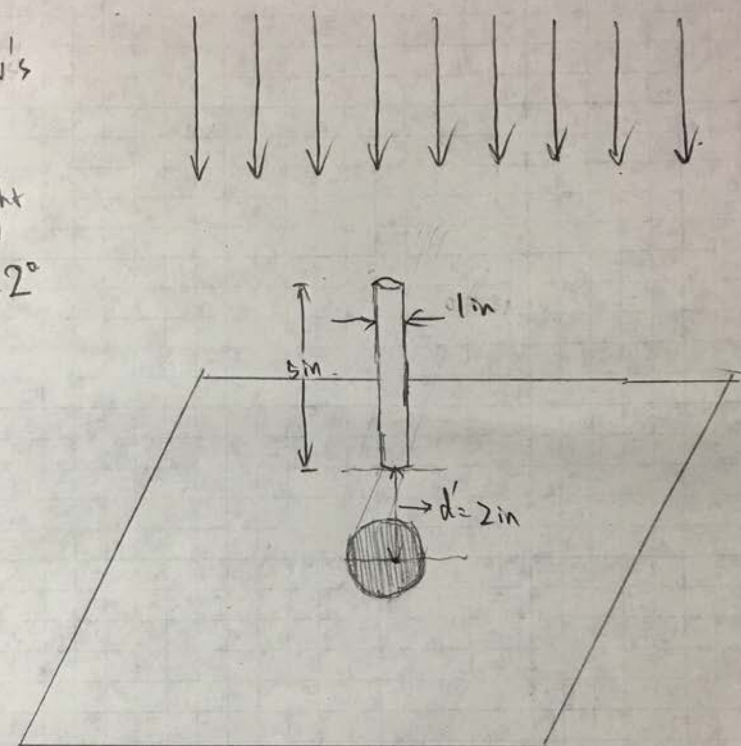
when angel = 70° $I = 350\cos(90°) = 35[illegible] W/m^2$

when angel = 15.5° $I = 350\cos(15.5) = 337 W/m^2$

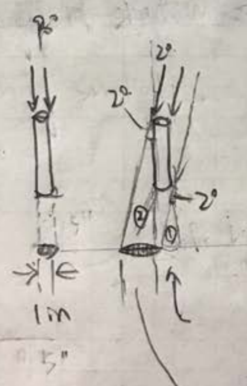
Thus: Energy flux into the surface and insolation intensity reached highest value when the angle is 90°!

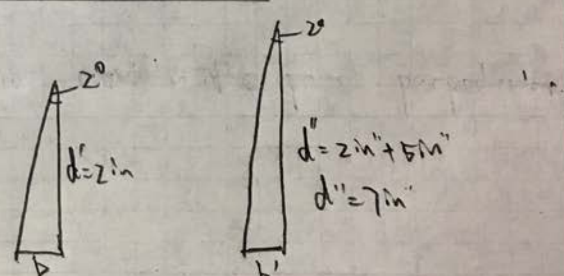
Given: Incoming sunlight perpendicular to solar panel.
The distance from shaft to solar panel $d' = 2in$, $L = 5in$
Diameter of shaft = 1 in

Find: Shadow's lenght when incoming sunlight between 90° ± 2°



Sol'n:





① $\tan 2^\circ = \frac{b}{2in} \Rightarrow b = 0.06984$ in.

② $\tan 2^\circ = \frac{b'}{7in} \Rightarrow b = 0.24444$ in

$= 1 - ① + ②$

∴ The largest lenght of shadow can be allowed is 1.1746"
when the shaft has 5" long and 1" diameter. 2" from panel.

Given: Sketch of Shaft $W_{?} = 3kg$

Find: Moment – Motor choice

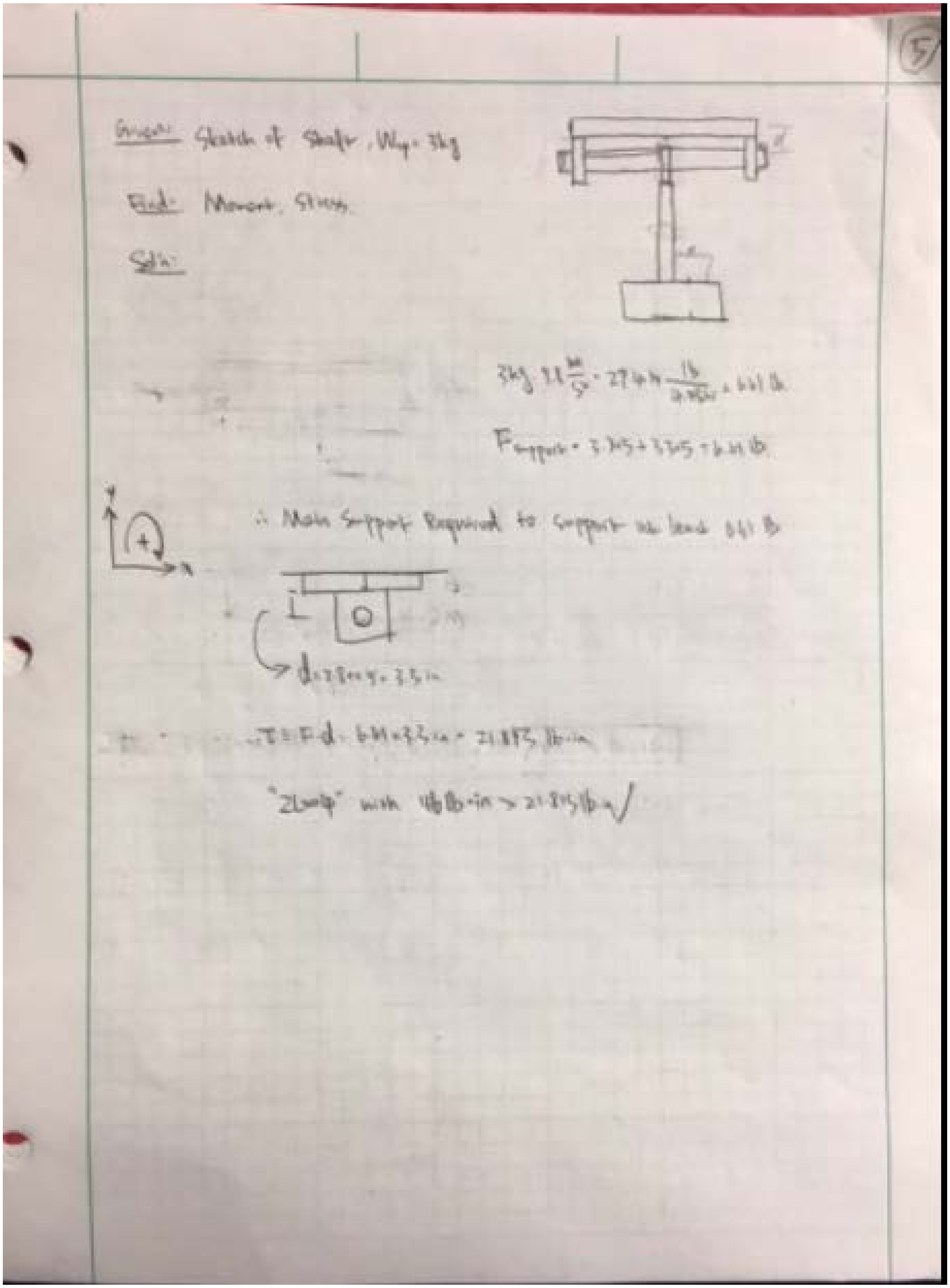
Sol'n:

$F = mg = 3kg \cdot 9.8\frac{m}{s^2} = 29.4N \cdot \frac{1lb}{4.45N} = 6.61 lb$

d = 0.5 + 8.75 + 0.5 = 9.75 in

$T = F \cdot d = 3.305 \cdot 9.75 = 32.2238 \, lb \cdot in$

$32.2238 \, lb \cdot in < 46 \, lb \cdot in$ "[illegible] Motor" works ✓


Given: Sketch of Shaft, W = 3kg
Find: Moment, Stress
Sol'n:
F support = 3.305 + 3.305 = 6.61 lb
∴ Main Support Required to support the load 6.61 lb
T = F·d
"Zlamp" with

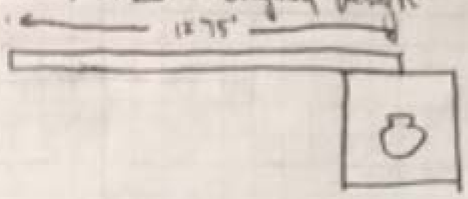
Haoyu Lin ⑥

Given: Solar panel, Size Support, $W_{sp} = 3kg$

Find: Best position of Size Support

Sol'n:

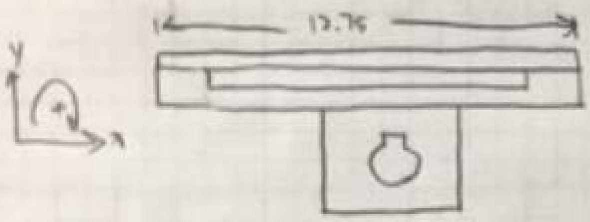
Option ① Size – Original design



$3kg \cdot 9.8\frac{m}{s^2} = 29.4N$

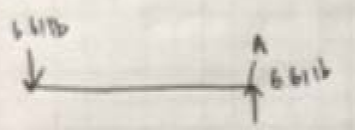
$29.4N \cdot \frac{1lb}{4.448N} = 6.61lb$

Option ② Mid



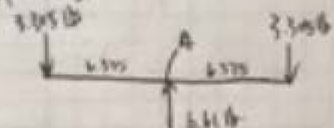
A: Support point

Option ①



$\circlearrowleft \Sigma M_A = -6.61lb \cdot 12.75in = -84.28lb \cdot in$

Option ②



$\circlearrowleft \Sigma M_A = -3.305 \cdot 6.375 + 3.305 \cdot 6.375 = 0$

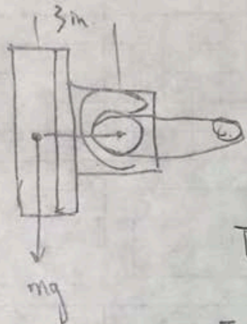
Option ② better than option ①

Haoyu Liu | MET 487 | 3/2/18 | (1)

Given: T_{max} of torque, Weight

Find: Gear Ratio

Sol'n.



$\Rightarrow$ $m = 36$ lb

$r = 3$ in.

$$T = ~~Fr~~ + I\alpha = Fr + \frac{Ia}{r} \Rightarrow \left(\alpha = \frac{a}{r}\right)$$

$$I = mr^2 = 36\text{ lb}\,(3\text{ in})^2 = 324\text{ lb}\cdot\text{in}^2$$

$$Fr = 36\text{ lb}\cdot 3\text{ in} = 108\text{ lb}\cdot\text{in}$$

2L004 | $T_{max} = 46$ lb·in.

1.5 RPM

$$\Rightarrow a = \frac{T}{mr^2}$$

$$\frac{108}{46} = 2.25 \Rightarrow$$ **1:3 Gear at least**

Decision Matrix

	Cost	Time	Design Difficulty	Math Difficulty	Result	Total
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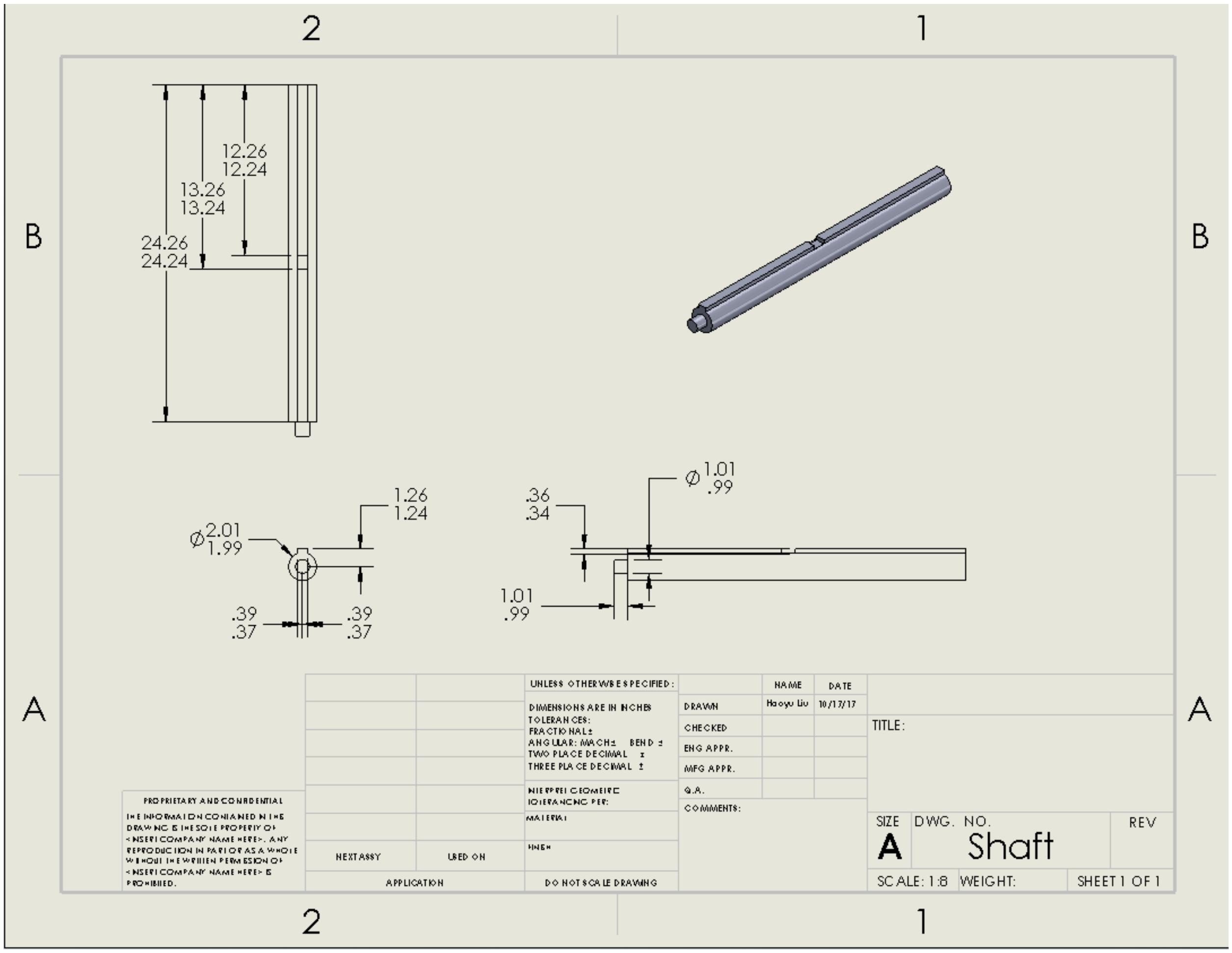
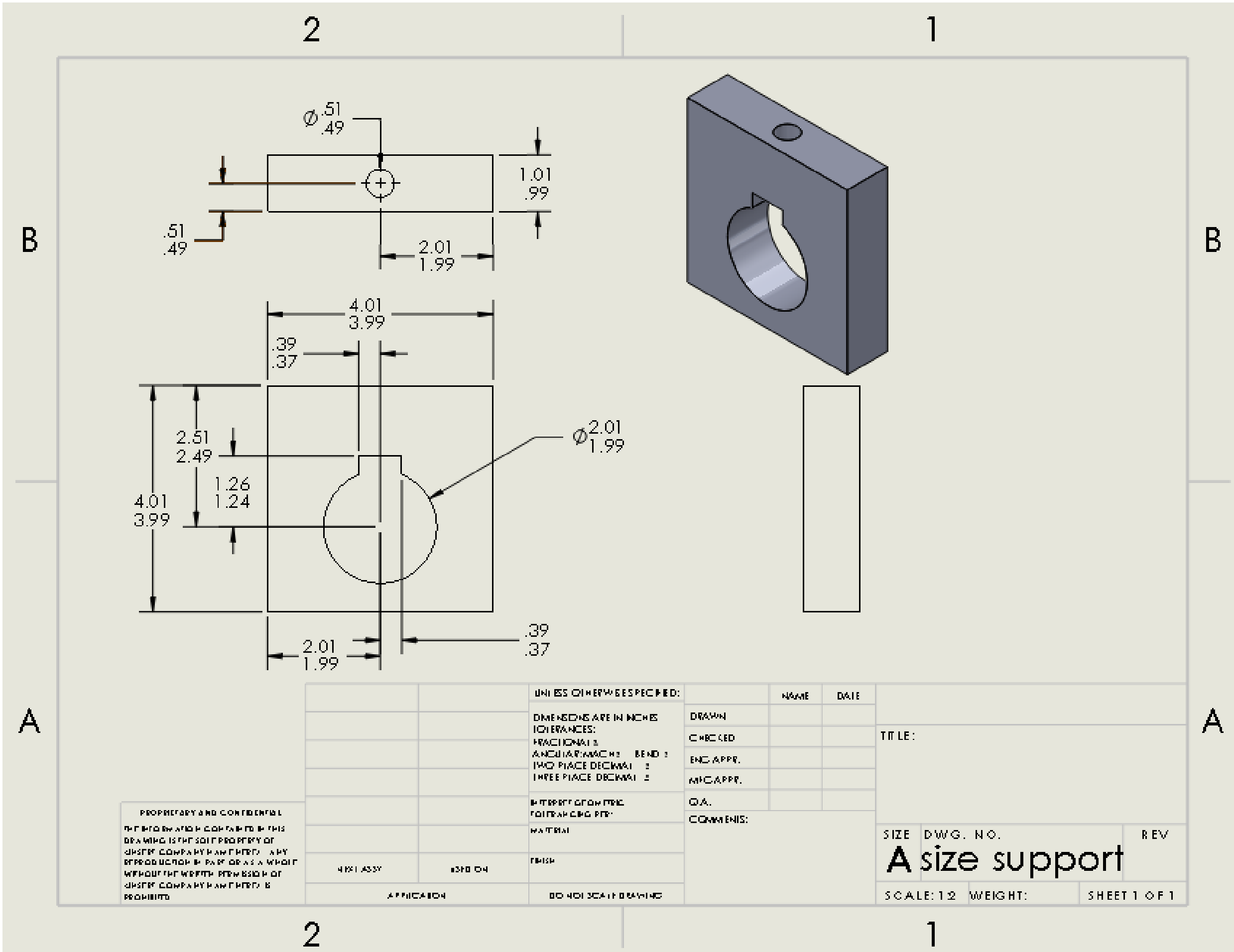
2 motors and 1 sensor	4	4	1	5	5	69

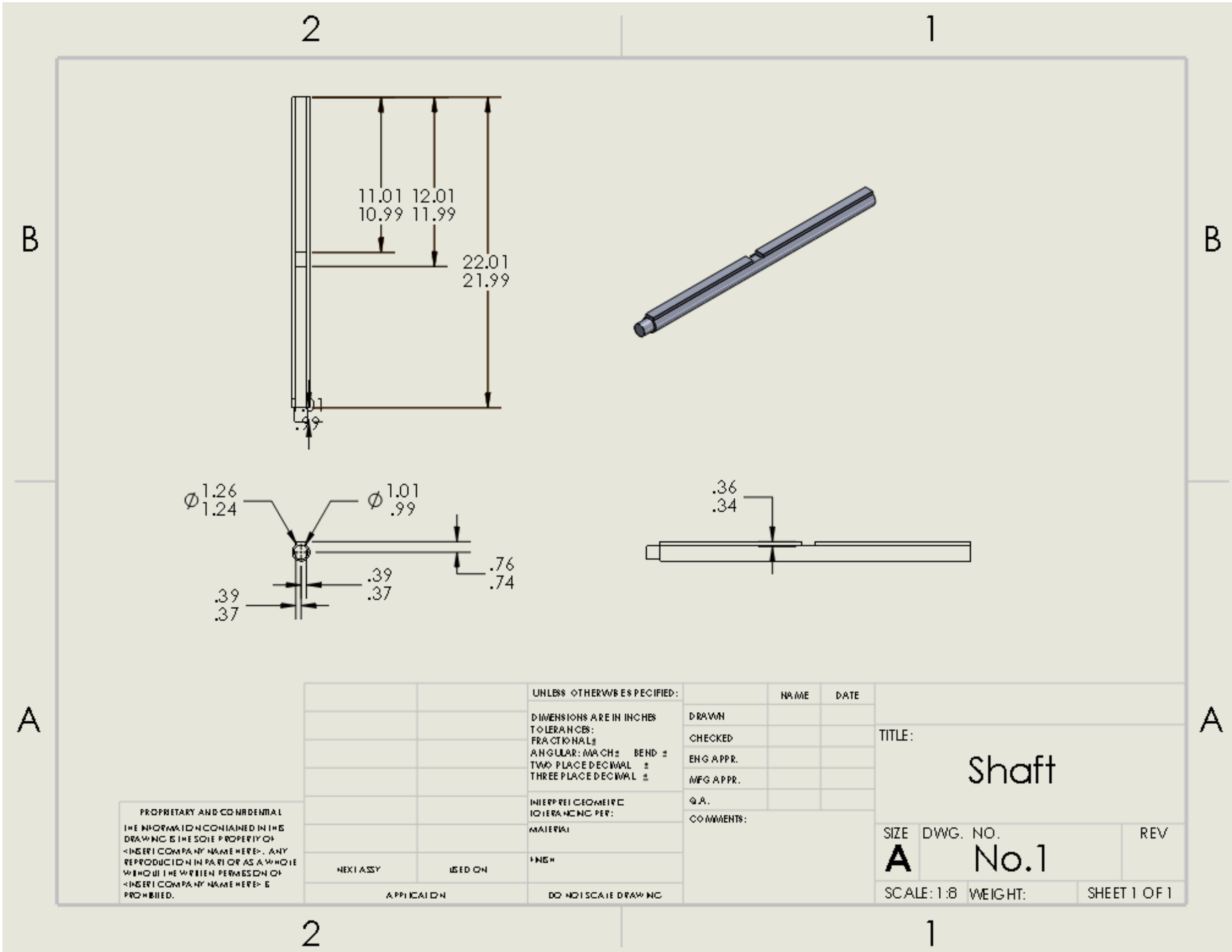
APPENDIX B –drawings, pictures, and videos



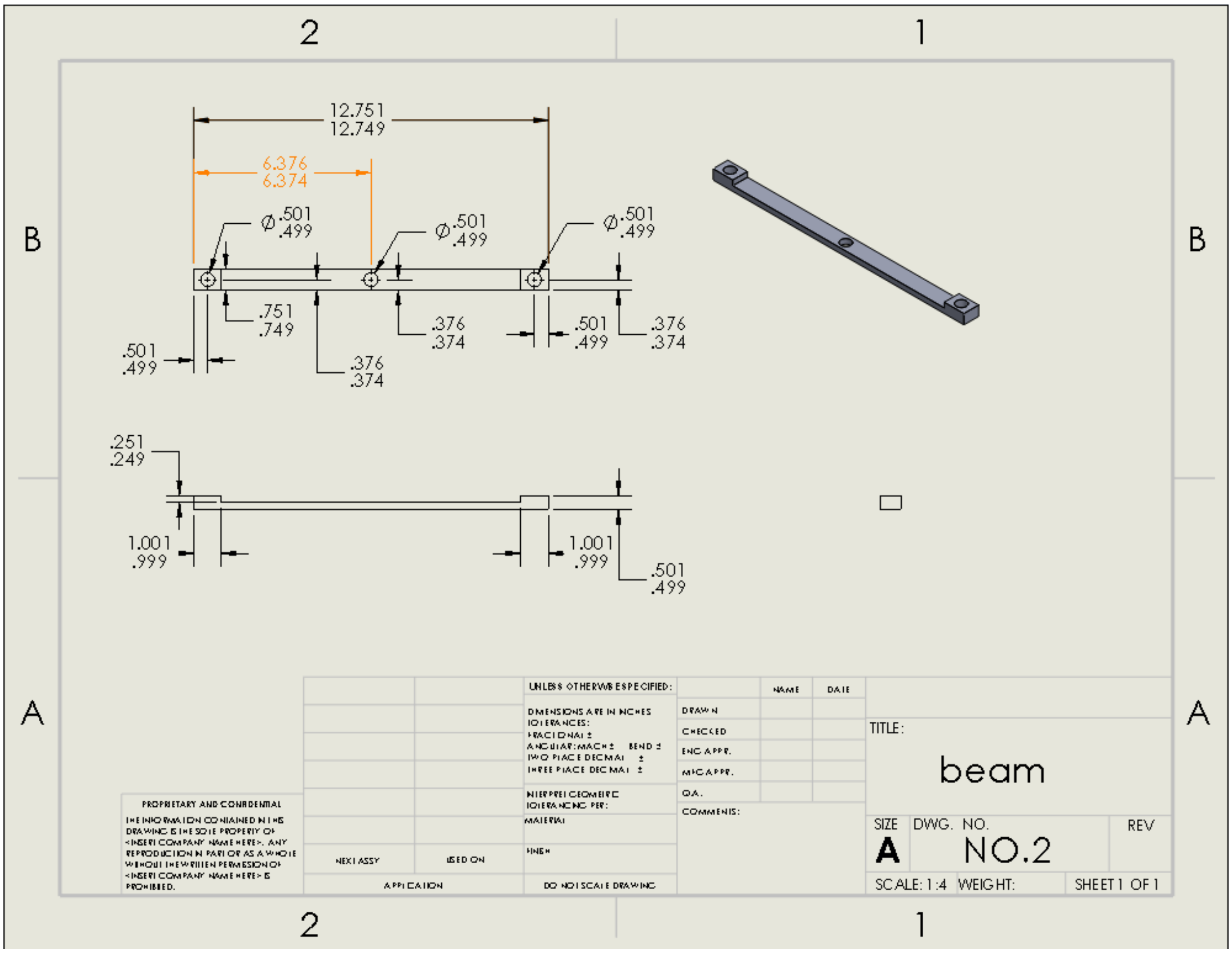
Orignal design-old one

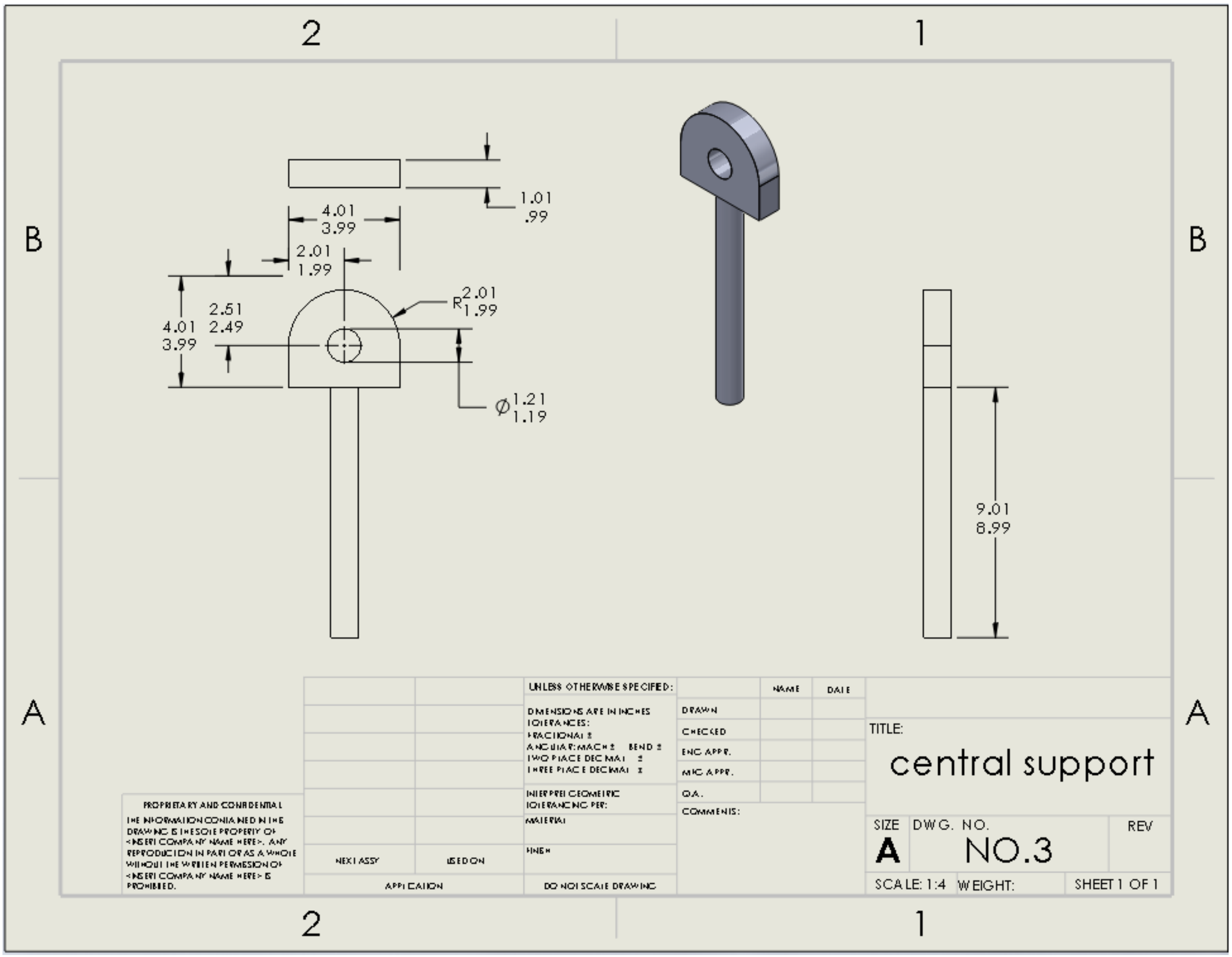


Orignal design-old one

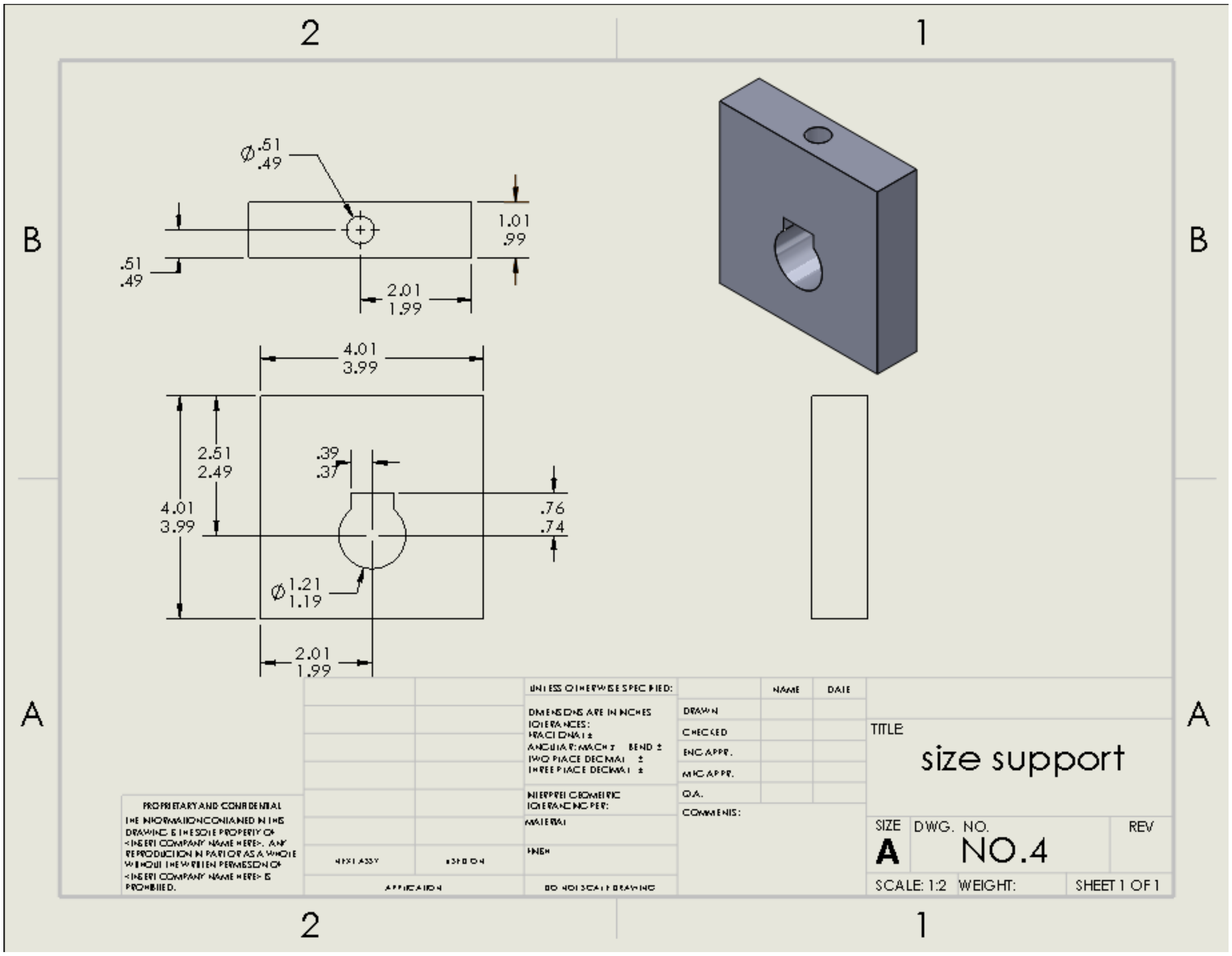


2
1
B
A
11.01 10.99
12.01 11.99
22.01 21.99
Ø1.26 1.24
Ø1.01 .99
.39 .37
.39 .37
.76 .74
.36 .34
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Shaft
SIZE
A
DWG. NO.
No.1
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL

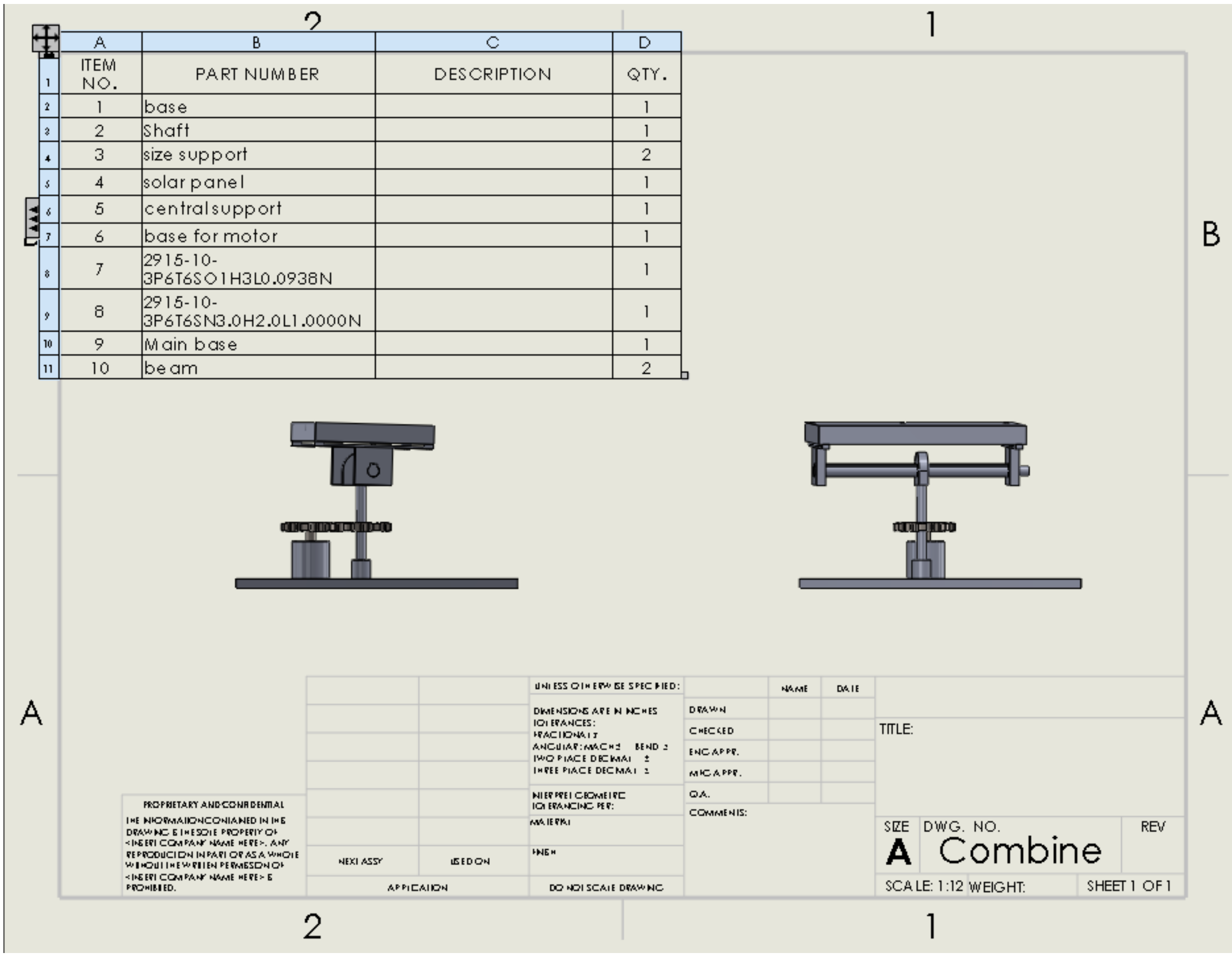

2
1
B
A
12.751
12.749
6.376
6.374
Ø .501
.499
.751
.749
.376
.374
.501
.499
.251
.249
1.001
.999
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
TITLE:
beam
SIZE
A
DWG. NO.
NO.2
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1



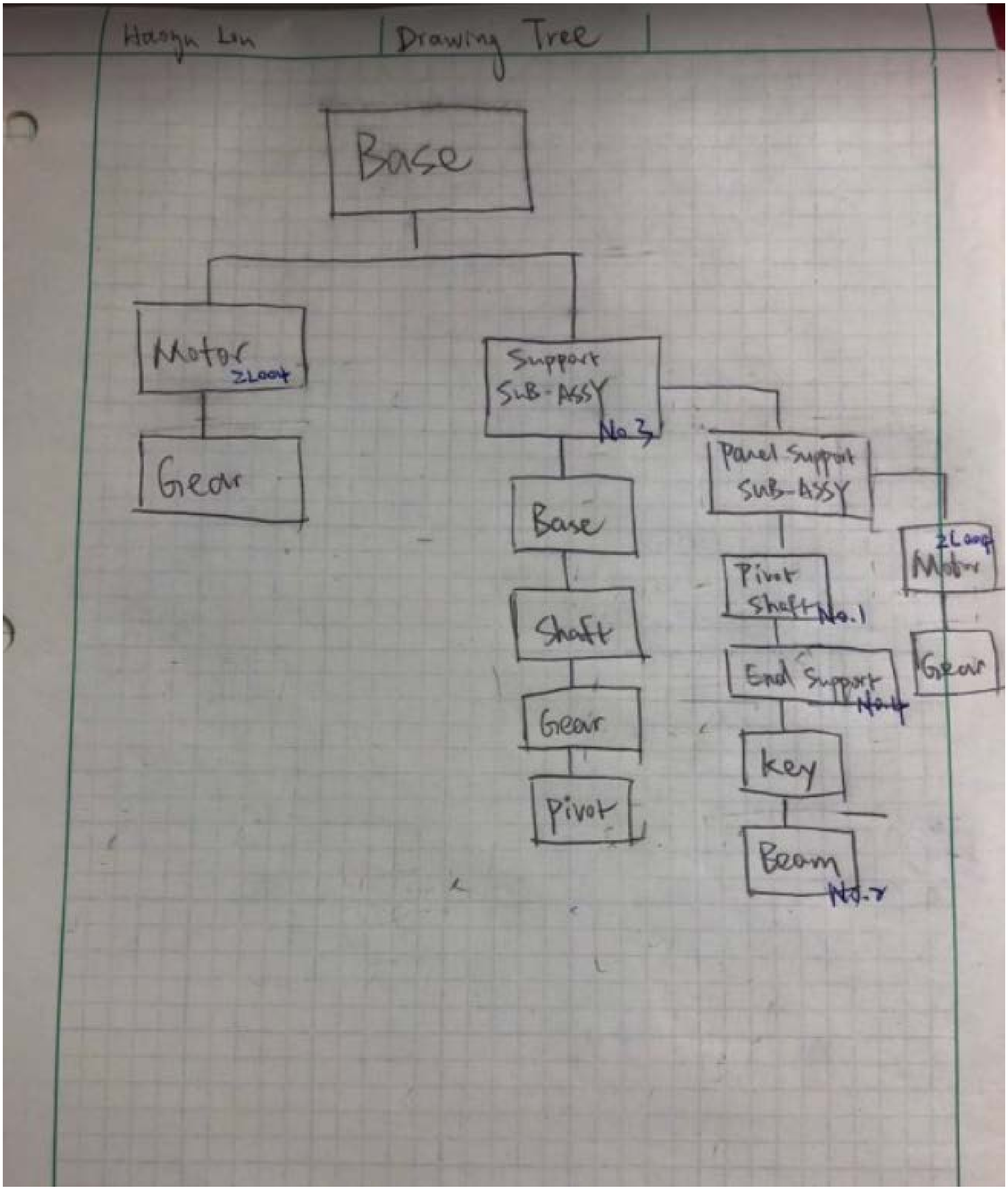
1.01
.99
4.01
3.99
2.01
1.99
R2.01
1.99
4.01
3.99
2.51
2.49
Ø1.21
1.19
9.01
8.99
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
TITLE:
central support
SIZE
A
DWG. NO.
NO.3
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1



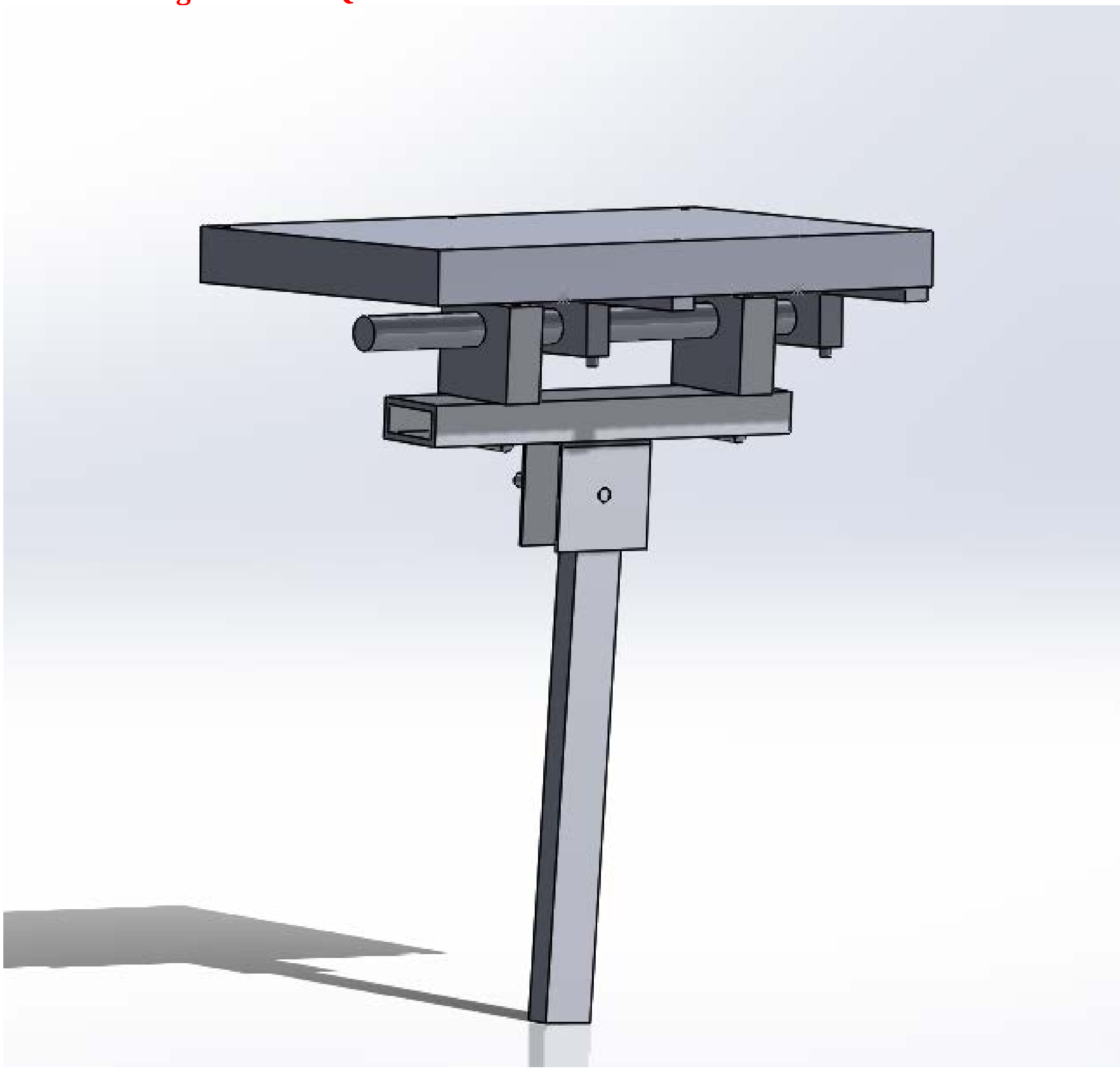
size support
NO.4
TITLE:
SIZE
A
DWG. NO.
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL



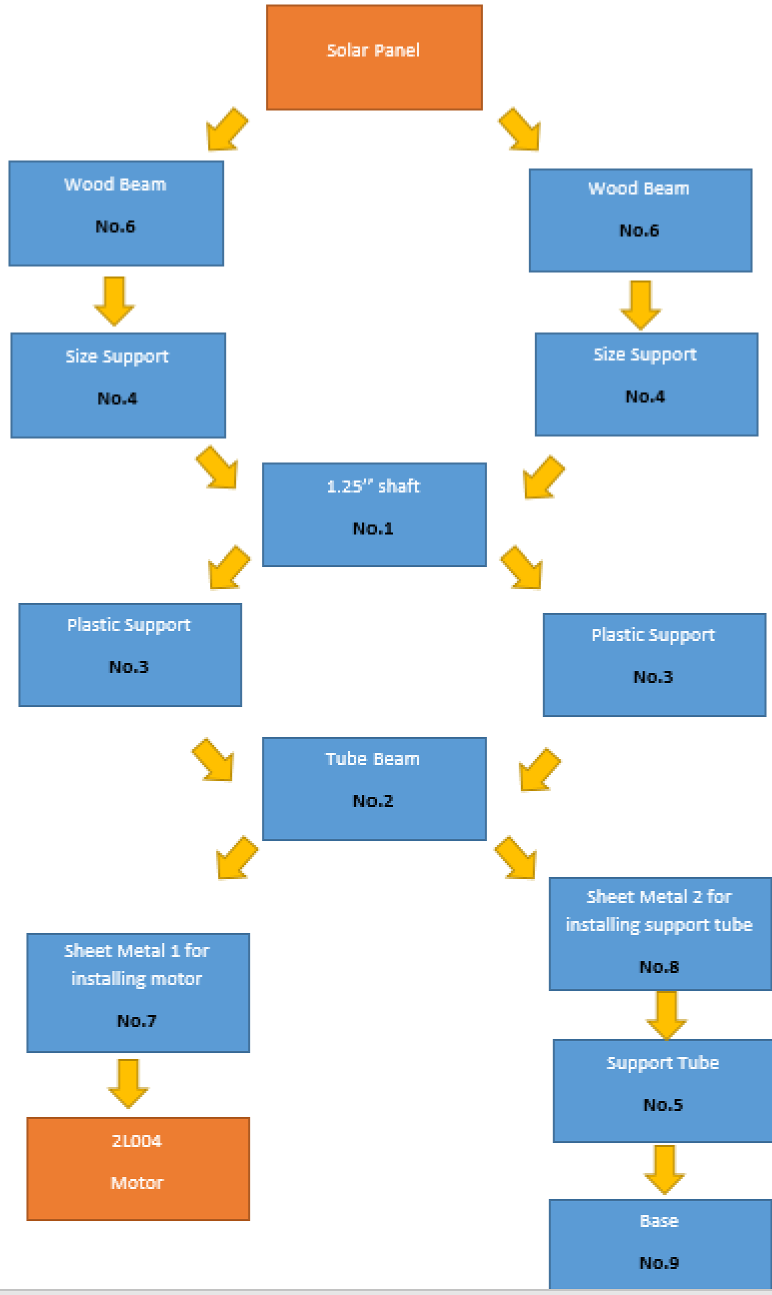
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	base		1
2	Shaft		1
3	size support		2
4	solar panel		1
5	central support		1
6	base for motor		1
7	2915-10-3P6T6SO1H3L0.0938N		1
8	2915-10-3P6T6SN3.0H2.0L1.0000N		1
9	Main base		1
10	beam		2

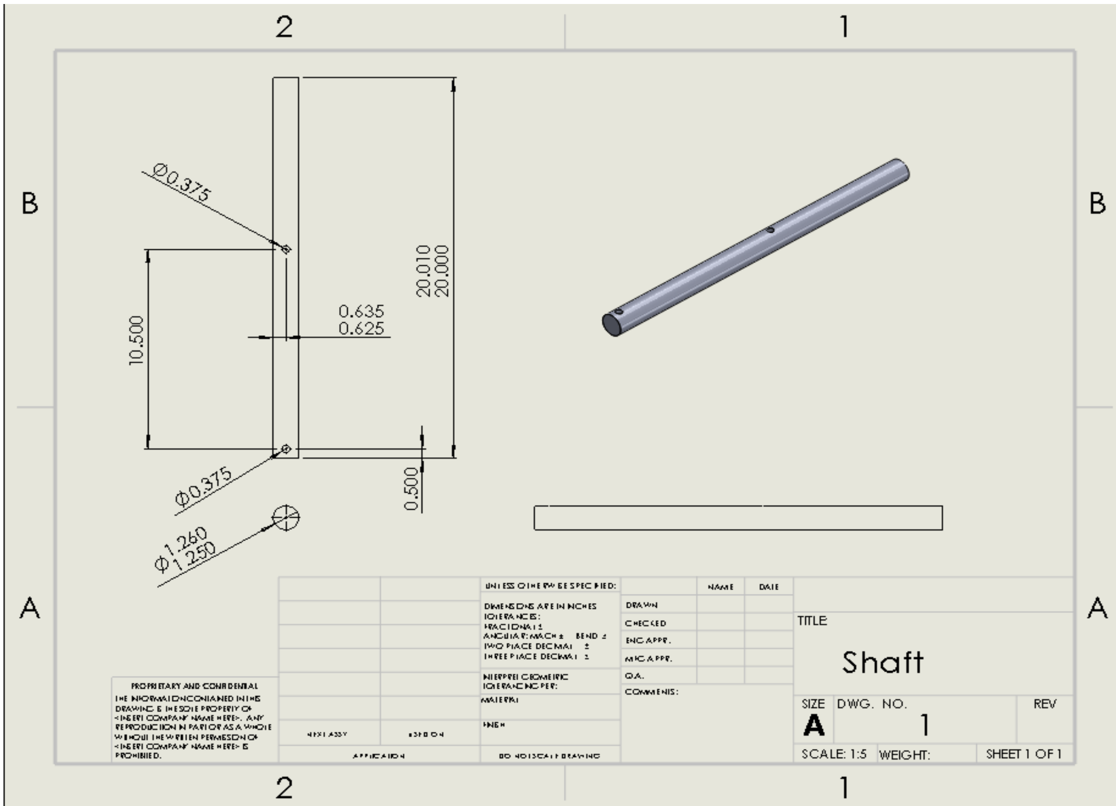

Drawing Tree
Base
Motor
2L004
Gear
Support SUB-ASSY
No.3
Panel Support SUB-ASSY
Base
Shaft
Gear
Pivot
Pivot Shaft
No.1
End Support
Key
Beam
Motor
Gear

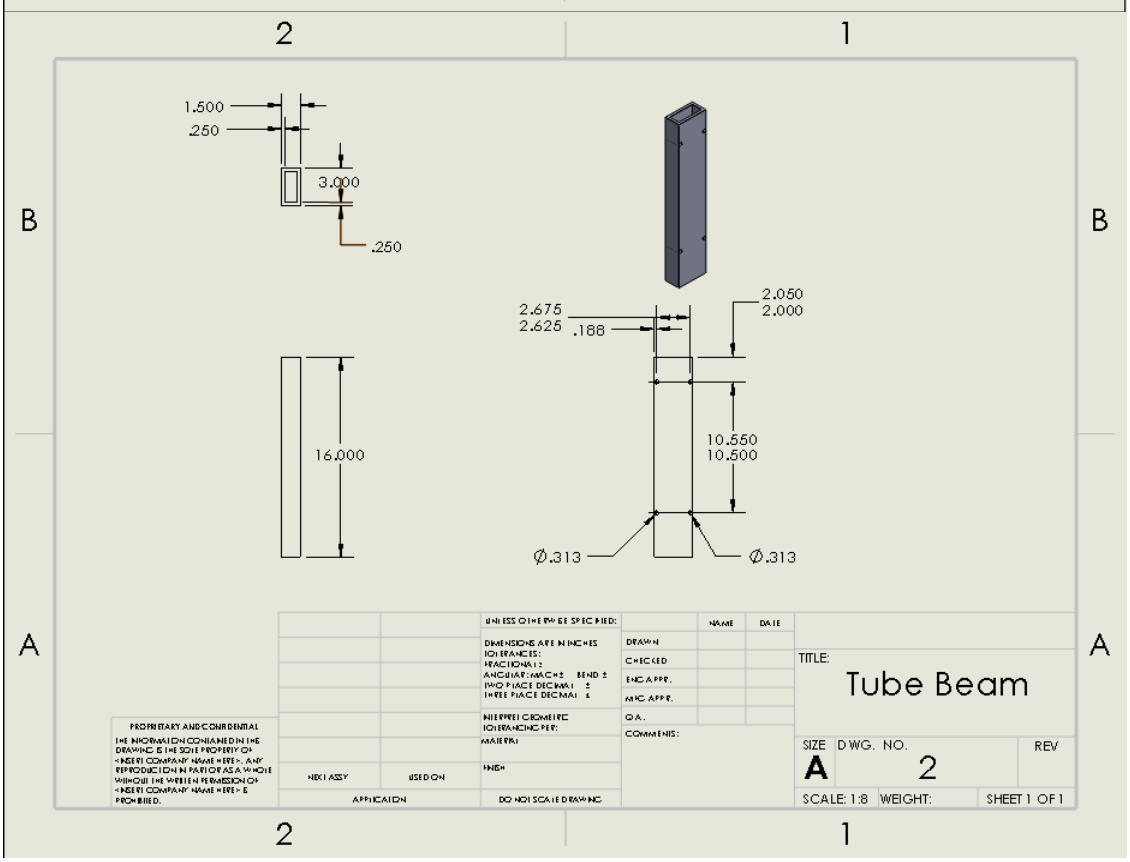
Final Drawing in Winter Quarter:

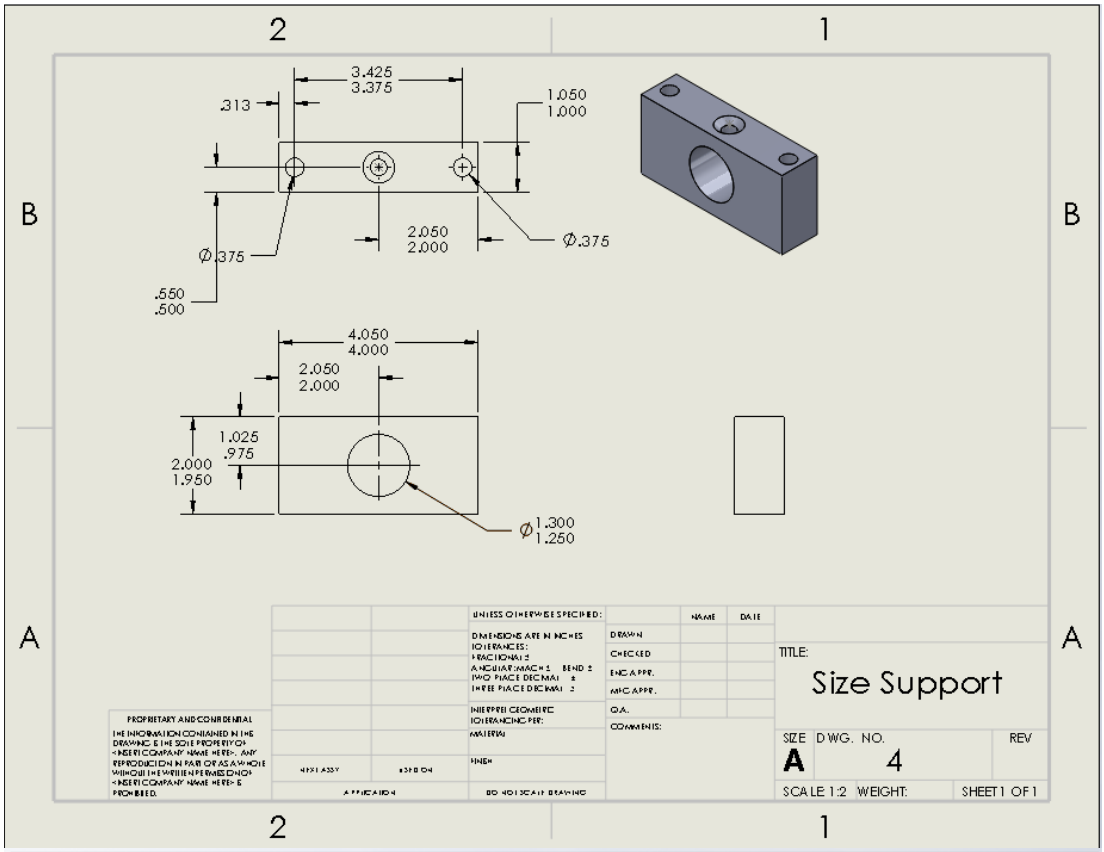


Drawing Tree




Ø0.375
10.500
0.635
0.625
20.010
20.000
Ø0.375
0.500
Ø1.260
Ø1.250
PROPRIETARY AND CONFIDENTIAL
TITLE:
Shaft
SIZE DWG. NO. REV
A 1
SCALE: 1:5 WEIGHT: SHEET 1 OF 1


1.500
.250
3.000
.250
2.675
2.625
.188
2.050
2.000
16.000
10.550
10.500
Ø.313
Ø.313
PROPRIETARY AND CONFIDENTIAL
TITLE:
Tube Beam
SIZE DWG. NO. REV
A 2
SCALE: 1:8 WEIGHT: SHEET 1 OF 1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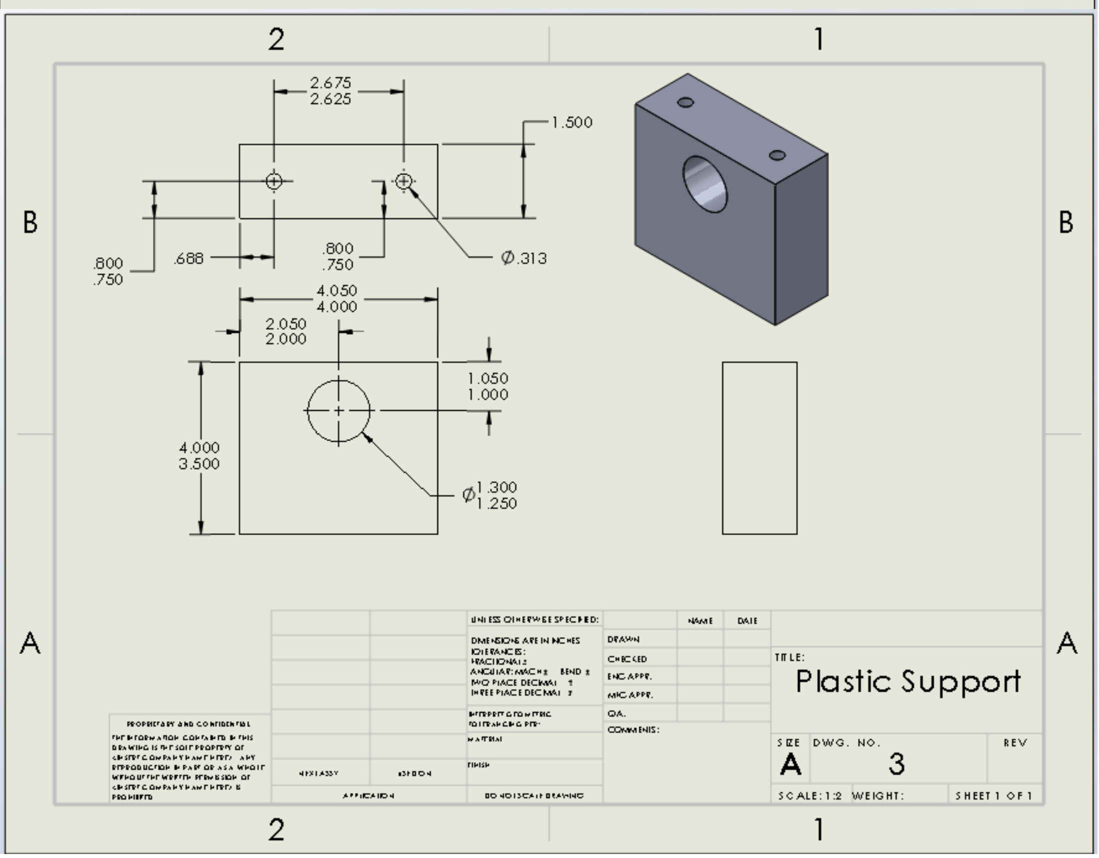
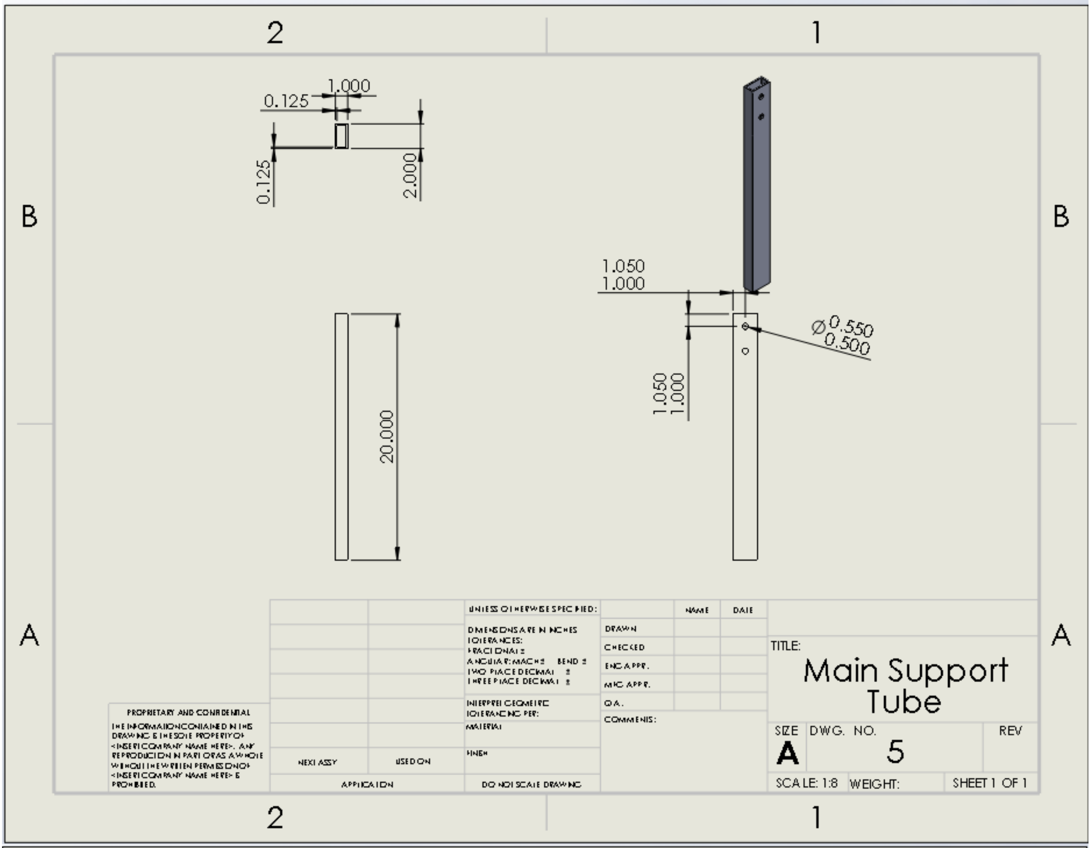
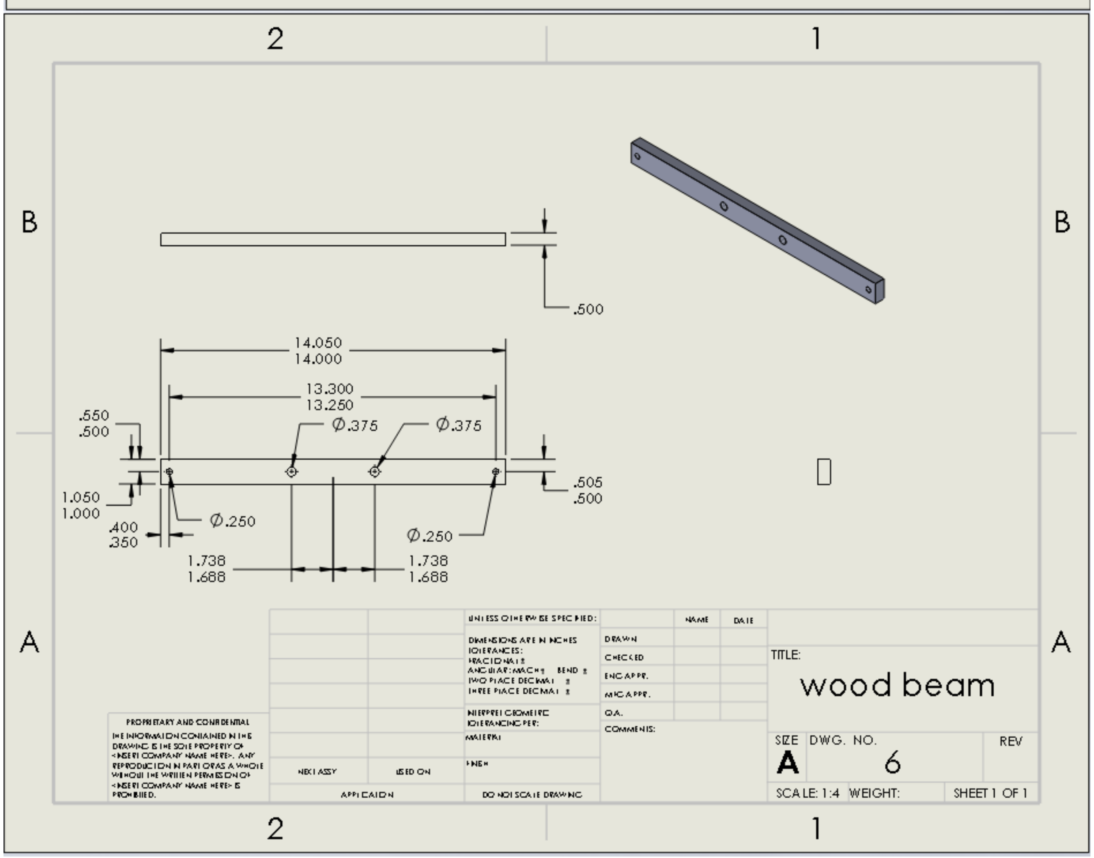
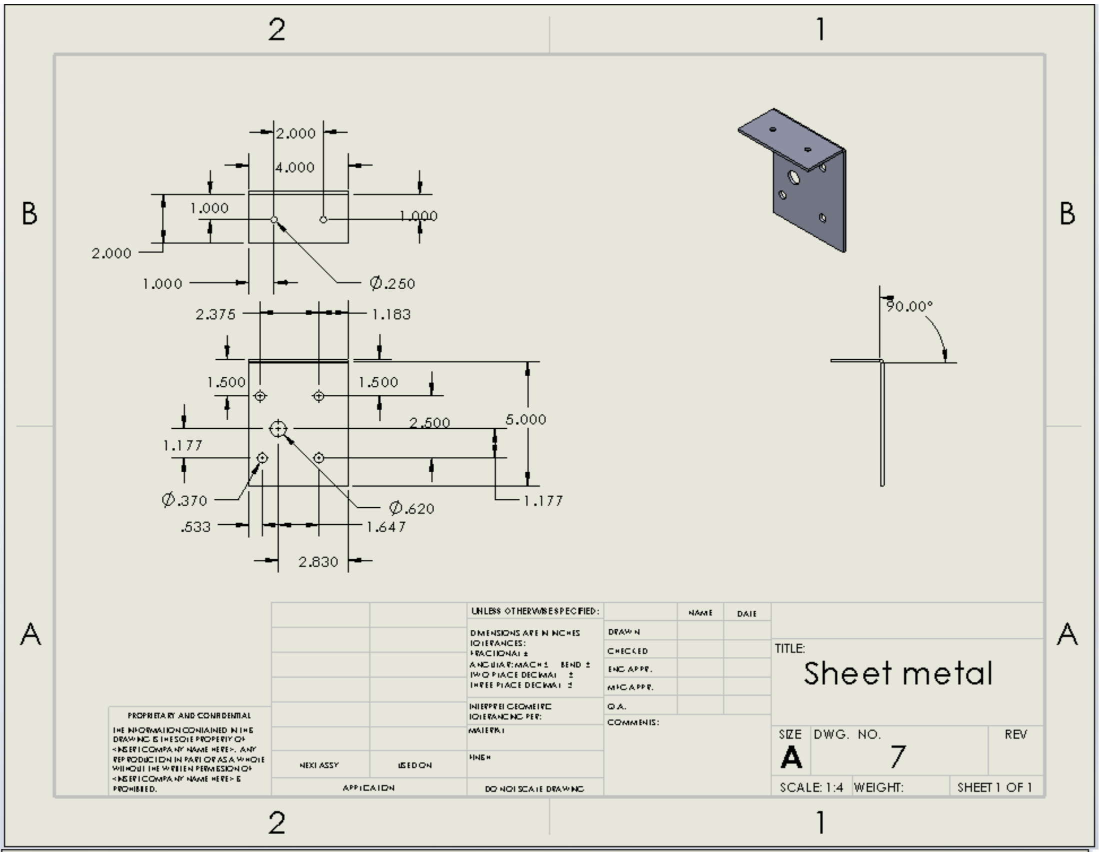
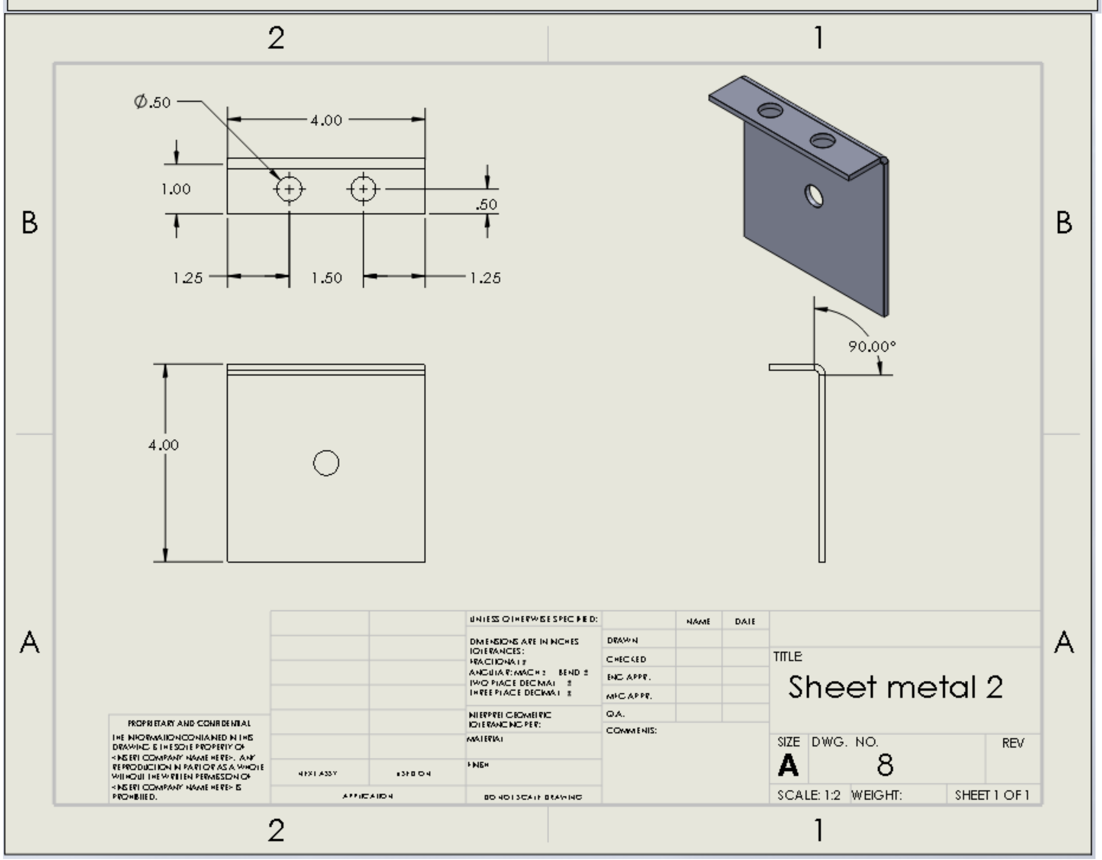
3.375
.313
1.050
1.000
Ø.375
Ø.375
2.050
2.000
.550
.500
4.050
4.000
2.050
2.000
1.025
.975
2.000
1.950
Ø1.300
1.250
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Size Support
SIZE
DWG. NO.
REV
A
4
SCALE 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL


2.675
2.625
1.500
.800
.750
.688
.800
.750
Ø.313
4.050
4.000
2.050
2.000
1.050
1.000
4.000
3.500
Ø1.300
1.250
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Plastic Support
SIZE
DWG. NO.
REV
A
3
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL


0.125
1.000
0.125
2.000
20.000
1.050
1.000
Ø 0.550
0.500
1.050
1.000
TITLE:
Main Support Tube
SIZE A
DWG. NO. 5
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DO NOT SCALE DRAWING


.500
14.050
14.000
13.300
13.250
.550
.500
Ø.375
Ø.375
1.050
1.000
Ø.250
.505
.500
.400
.350
Ø.250
1.738
1.688
1.738
1.688
TITLE:
wood beam
SIZE A
DWG. NO. 6
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DO NOT SCALE DRAWING


2.000
4.000
1.000
2.000
1.000
Ø.250
2.375
1.183
1.500
1.500
2.500
5.000
1.177
Ø.370
Ø.620
1.177
.533
1.647
2.830
90.00°
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Sheet metal
SIZE
DWG. NO.
REV
A
7
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING


Ø.50
4.00
1.00
.50
1.25
1.50
1.25
90.00°
4.00
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Sheet metal 2
SIZE
DWG. NO.
REV
A
8
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
APPLICATION

APPENDIX C – Parts List and Costs

Number	Parts	Part Desciption	Source	Cost	Disposition
1	Motor 1	Drives panel in vertical direction	Amazon	$91.5	Arrived
	Motor 2	Drives panel in horizontal direction	Amazon	$91.5	Arrived
2	Solar Panel*1	panel used to collect energy from incoming sunlight	student left from 2016 academic year	$0	in CWU lab
3	Steels Circle*1	use to manufacture shaft	EBay	$39.99	Arrived
4	Steels Bar*2	use to manufacture sizes supports & main support	EBay	$48.96	Arrived
5	Steels Circle*1	use to manufacture main support shaft	EBay	$10.79	Arrived
6	Steels Bar*1	use to manufacture two beams	Amazon	$21.84	Arrived
7	Timing Sensors*1	Use to determine the time that motor moves	Amazon	$20.00	Arrived
8	Arduino control chip*1	collect information from sensor to control motors	Friend	$0	Ready in friend's house
9	Wood Pieces*2	Use as beams connect with solar panel	Wood shop	$0	Ready
10	Steel Tube*2	Use as beam connect with motor and base	Machine shop	$0	Ready
11	U-bolt*4	4 U-bolts along with 2 metal and 2 plastics supports	Hardware store	$13.25	Purchased
12	Screw*16	Connect motor, beam, and etc.	Hardware store	$5.32	Purchased
13	Plastics Bar*2	Use as supports	Machine shop	$0	Ready

APPENDIX D – Budget

Number	Parts	Part Desciption	Source	Est Cost	Act Cost
1	Parts	All the parts required	Purchase/existed	$500	$343.15
2	Labor	Labor cost to finish this project	Myself	$0	
3	Time	Time spend on the project		10 hours/week	

APPENDIX E – Schedule

Note: March x Finals
Note: June x Presentation
Note: June y-z Spr Finals

PROJECT TITLE: Solar-tracker
Principal Investigator.: Haoyu Liu

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	November	Dec	January	February	March	April	May	June
1	Proposal*										
1a	Outline	1	2								
1b	Intro	2	4								
1c	Methods	2	3								
1d	Analysis	20	18								
1e	Discussion	4									
1f	Parts and Budget	4	4								
1g	Drawings	12	15								
1h	Schedule	2	2								
1i	Summary & Appx	6									
	subtotal:	53	48								
2	Analyses										
2a	Intensity diff angle	2	2								
2b	Length of shadow	2	2								
2c	Choosing Motors	3	4								
2d	Torque and stress Calcu	2	3								
2e		2	3								
	subtotal:	11	14								
3	Documentation										
3a	Part 1:shaft 1.25	1	2								
3b	Part 2:Tube Beam	2	4								
3c	Subassembly torso	2	2								
3d	Part 3:Plastic support	2	4								
3e	Part 4:side support	2	4								
3f	Subassembly	1	1								
3g	Part 5:Support Tube	1	2								
3h	Part 6:Wood beam	1	2								
3i	Part 7:sheet metal 1	2	4								
3j	Part 8:sheet metal 2	1	2								
3k	Part 9:base	2	2								
3l	Update Webiste		0								
3m	Make Object Files		0		-------------------------->						
	subtotal:	17	29								
4	Proposal Mods										
4a	Project Schedule	2	2								
4b	Project Part Inv.	1	0								
4c	Crit Des Review*	1	0								
	subtotal:	4	2								
7	Part Construction										
7a	Make Part 1 Shaft	2	4								
7b	Make Part 2 Tube Beam	2	3								
7c	Make Part 3 Plastic Support	2	5								
7d	Make Part 4 Side Support	2	6								
7e	Make Part 5 Support Beam	2	3								
7f	Make Part 6 Wood Beam	1	2								
7g	Make Part 7 Sheet Metal 1	2	4								
7h	Make Part 8 Sheet Metal 2	1	2								
7i	Manufacture Plan*	15	15				--->				
	subtotal:	29	44								
9	Device Construct										
9a	Assemble beam and panel	2	2								
9b	Assemble support and shaft	2	2								
9c	Assemble shaft and motors	2	2								
9d	Check Entire Project	2	4								
9e	Take Dev Pictures	1	1								
9f	Update Website	5	4								
	subtotal:	14	15								
10	Device Evaluation										

10	Device Evaluation			
10a	List Parameters	2	2	
10b	Design Test&Scope	2	2	
10c	Obtain resources	2	2	
10d	Make test sheets	2	3	
10e	Plan analyses	2	2	
10f	Testing motor	4	6	
10g	Testing whole device	10	14	
10h	Perform Evaluation	4	8	
10i	Take Testing Pics	2	2	
10h	Update Website	10	2	
	subtotal:	40	43	
11	495 Deliverables			
11a		0	0	
11b		0	0	
11c		0	0	
11d		0	0	
11e	Create Presentation	5	8	
11f		0	0	
11e		0	0	
11f	Update Website	5	8	
11g		0	0	
	subtotal:	10	16	
	Total Est. Hours=	178	211	=Total Actual Hrs
Labor$	100	17800		
Note:	Deliverables*			
	Draft Proposal			
	Analyses Mod			
	Document Mods			
	Final Proposal			
	Part Construction			

APPENDIX F – Expertise and Resources

https://searchlib.cwu.edu/primo-explore/fulldisplay?vid=CWU&search_scope=cwu_alma_summit&tab=default_tab&docid=TN_sciversesciencedirect_elsevierS0960-1481(14)00388-7&lang=en_US&context=PC&adaptor=primo_central_multiple_fe&query=any,contains,solar%20tracker&sortby=rank&offset=0

APPENDIX G – Evaluation sheet (Testing)

Object	Worked	Worked but had issue	Not worked
Motor	Yes		
Base	Yes		
Solar Panel	Yes		
Left Sensor	Yes		
Right Sensor	Yes		
Voltage meter	Yes		
Resistor	Yes		
Time Program		Yes/No	
Sensor Program	Yes		
Time-voltage data		Yes/No	
Sensor-voltage data	Yes		

APPENDIX H – Testing Report

Introduction:

Requirement:

The testing was focusing on three statements, panels needs to perpendicular to incoming sunlight 90^o, with 2^o deviation, increased around 20% energy flue in the surface from incoming sunlight by change position of solar panel, and the panel is able to rotate in both vertical and horizontal directions.

Parameters of interest:

The parameters of interest were the voltages in three situations which were the device rotated and followed the incoming sunlight, the device fixed and was not able to move, the device faced different angle from sunlight. Then, based on the voltages to calculate the power in those two situations.

Predicated performance:

The original predicted was that device will rotate both vertical and horizontal directions automatically and increase around 20% energy flue in the surface from incoming sunlight by change position of solar panel.

Data acquisition:

The tools used to collect data were voltage meter, resistor, and laptop.

Schedule:

As the Gantt chart shown, the test sheets and plan analyses were created and wrote at the second week of April, and then all of those tests were starting after the sheets and analyses made. The motor testing was finished at the end of first week, and whole device testing was started at the first week and finished at the second week of April. Based on the performance, the evaluation and improvement were made from second week of April to the end of first week of May.

Method/Approach:

Resources:

A 13.5 V battery to drive 2L004 motor, a 3V battery to supply Arduino control chip, and a laptop to program. Thank Ben T. Lanza who is a computer science student to offer programming assistant. Moreover, there was no extra cost during the testing process.

Data capture/doc/processing:

The software used was Excel that record voltage and calculate power, and PowerPoint to show data in the presentation.

Test Procedure overview:

Testing the power of motor and testing the program performance.

Operational limitations:

Used resistor to reduce the voltage down to 5V to avoid the voltage transfer from solar panel burn the control chip.

Precision and accuracy discussion:

All of angles during the testing had 5^0 tolerances, and 0.5 V tolerance for all data. The testing was repeat three times to take average to increase accuracy.

Data Storage/manipulation/analysis:

Data record in both notebook and Excel that storage in both hard drive and computer lab.

Data presentation:

Data was present in PowerPoint, website, and poster.

Test Procedure: (formal procedure)

- **Summary/overview**
  Test if the program is able to control the motor, and if the motor is able to drive the shaft rotates in vertical direction.
- **Specify time, duration,**
  Apr 12, 19, and 26, Morning 7am to 12 noon.
- **Place**
  Outside the Hogue building
- **resources needed**
  The motor's voltage and current information from website
  The guide book for program in Arduino control chip
- **Specific actions to complete the test,**
  - **Step 1:** Connect Mini-Kit with motor and Arduino control chip
  - **Step 2:** Post the program to Arduino control chip
  - **Step 3:** Connect with power supplier and record the rotation speed.
- **Risk, safety, evaluation readiness, other?**
  Control rotation speed as low as possible in first test.
- **Discussion**
  Once the program is able to control the motor and motor is able to offer enough torque force to rotate the solar panel.

APPENDIX I – Testing Data

Deliverables:

Parameter values:

Angle	Tolerance	Voltage
10^0	+/- 5^0	9.88 V
60^0	+/- 5^0	13.01 V
90^0 (face sunlight)	+/- 5^0	13.51 V
120^0	+/- 5^0	4.01 V
160^0	+/- 5^0	1.45 V

Angle	Tolerance	Voltage	Times
90^0	+/- 5^0	13.16 V	7
90^0	+/- 5^0	13.21 V	8
90^0	+/- 5^0	13.41 V	9
90^0	+/- 5^0	13.62 V	10
90^0	+/- 5^0	13.14 V	11
90^0	+/- 5^0	13.52 V	12

Calculated values:

Resistor	**Voltage**	**Voltage**	**Times**	**Power-Tracker**	**Power**	
10 ohms	13.16 V	9.88 V	7	17.31 W	9.76 W	
10 ohms	13.21 V	13.01 V	8	17.45 W	16.92 W	
10 ohms	13.41 V	13.51 V	9	17.89 W	18.52 W	
10 ohms	13.62 V	12.01 V	10	18.55 W	14.42 W	
10 ohms	13.14 V	11.45 V	11	17.27 W	13.11 W	
10 ohms	13.52 V	9.76 V	12	18.80 W	9.53 W	
Compare				1930860 W	1480680W	76.68%

APPENDIX J – Resume

Target position

Mechanical Engineer assistant

Education

Gong Yuan Road Primary School

Liuzhou No.12 Junior High School

Liuzhou High Level Scholl

Central Washington University Undergraduate

Awards

- 2005 World Robot Cup, teenager group, football 2vs2 event, champion
- 2009 Guangxi province Science Creation Competition first prize
- 2010 Guangxi province Science Creation Competition first prize
- Patent: helping the disable machinery

Work experience

Science and technology association, robot club ***2006 – 2011***

Liuzhou government | Liuzhou high-technology area

Club president

Skills

- Basic computer program
- AutoCAD Solid and works skills