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SonoProbe

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"SonoProbe" Ultrasound Probe

By

Christian Barrett

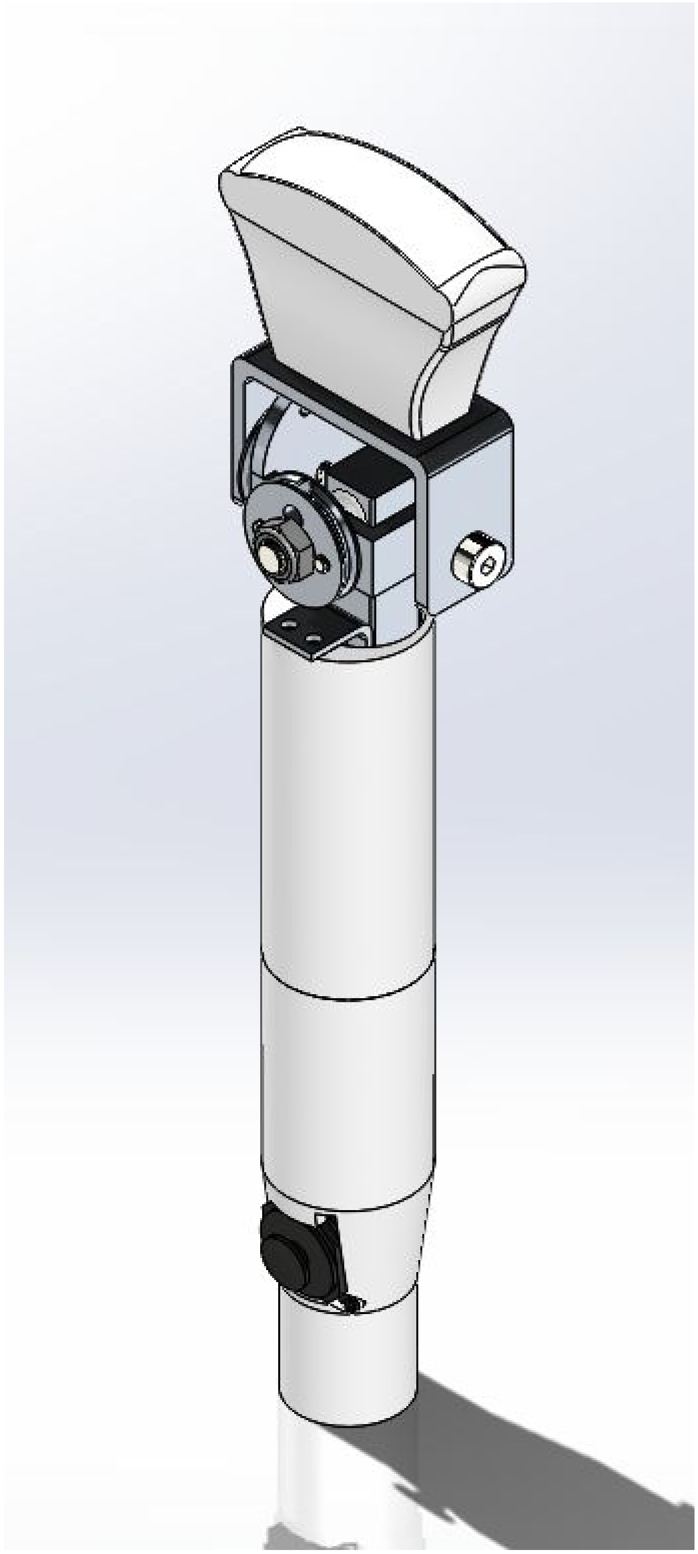
Central Washington University

Mechanical Engineering Technology

Abstract

The current ultrasound probes being used in hospitals today have been the same design since the mid 90s. Ultrasound probes generally consist of a transducer at the end of a handle. To perform an exam, an ultrasound technician must manipulate the probe at the wrist. Different angles with a certain amount of pressure against a patient is required to produce clear images. Due to the extensive rotational movement and pressure the wrist takes when scanning a patient with an ultrasound probe, there is a high rate of carpal tunnel and other wrist injuries in sonographers. This ultrasound probe will take the rotational movement out of the technicians wrist and isolate the rotational movement to the probe. Initial conception and design of the device was sketched on my own time and further developed at Central Washington University. Mariah Barrett was consulted when conceptualizing design requirements. The majority of the construction will be conducted using the machine shop as well as the Senior Project Lab in Hogue Hall at Central Washington University. The probe must stand up to 40 pounds of vertical force from the grip to the head of the probe. Other testing methods will be created to properly test the strength and efficiency of the first prototype of the SonoSafe ultrasound probe.

Table of Contents



Introduction

Description:

The current ultrasound probes being used in hospitals today have been the same design since the mid 90s. Ultrasound probes generally consist of a transducer at the end of a handle. To perform an exam, an ultrasound technician must manipulate the probe at the wrist. Different angles with a certain amount of pressure against a patient is required to produce clear images.

Motivation:

Due to the extensive rotational movement and pressure the wrist takes when scanning a patient with an ultrasound probe, there is a high rate of carpal tunnel and other wrist injuries in sonographers.

Function Statement:

This ultrasound probe will take the rotational movement out of the technicians wrist and isolate the rotational movement to the probe.

Requirement:

The device will meet the following requirements.

- 90 degrees of rotation about the x and y axis
- Must stand up to 40 pounds of vertical force from the grip to the head of the probe

Factors:

- The force required to move the head shall be less than the force required to rotate the wrist
- The technician must be able to rest the weight of their arm on the probe to be able to relax their shoulder muscles

Success Criteria:

The success of this project will be based on the ability of the probe to withstand the pressure whilst at the same time isolating the rotation movement to the probe head to successfully perform an ultrasound exam.

Scope of Effort:

The focus of this design is to transfer the rotational movement of the wrist to the ultrasound probe. With minimal effort by the sonographer, the rotation of the probe head must be isolated to the probe itself.

Design and Analysis

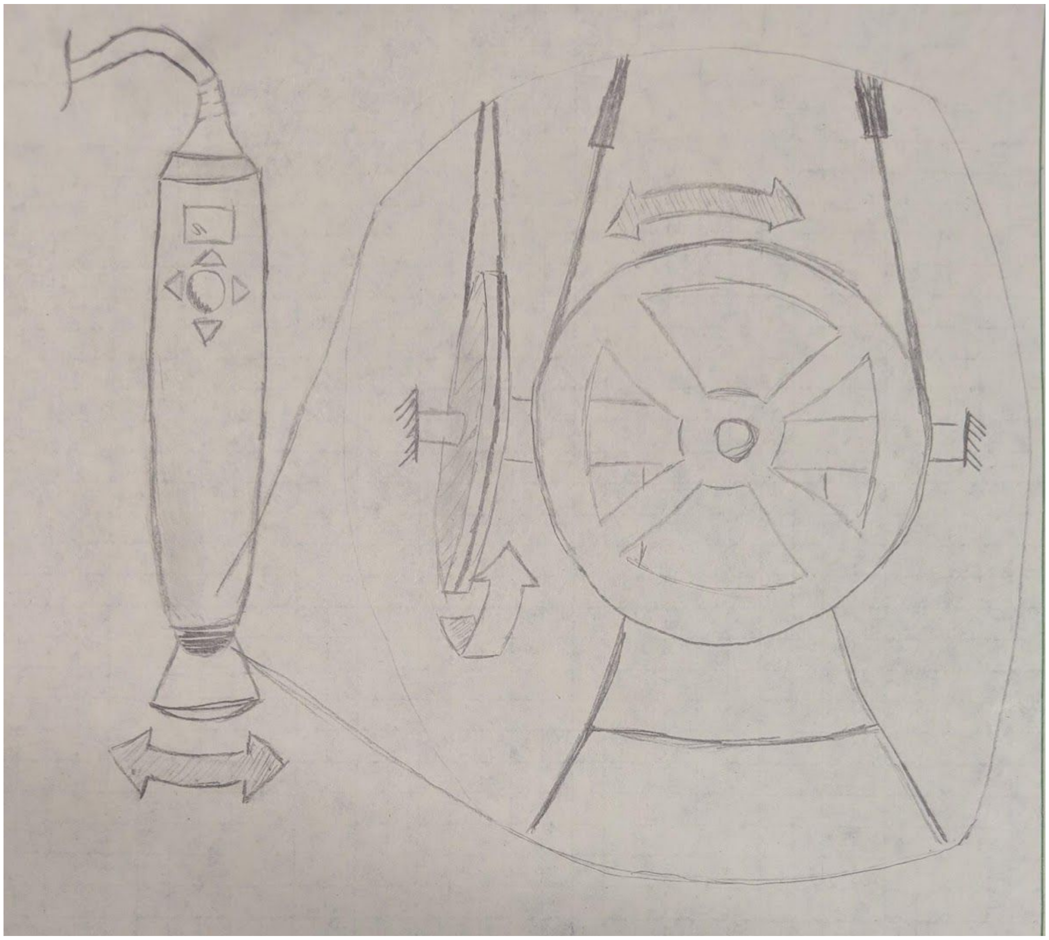


Figure 2 - Concept drawings of the cord and wheel method

Approach: Proposed Solution

The initial design inspiration came from an unusual source, Star Wars. More specifically the mechanism used to power the BB-8 droid for a red carpet event. The design portion that is applicable to this project is the mechanism that rotates BB-8's head. Cables are used to transfer energy from motors located at the bottom of the droid to a joint that rotates BB-8's head in a swivel motion. The joint acts much like a universal joint where one end of the joint can remain stationary while the other end of the joint has a large range of movement to swivel.

Design Description:

Much like the mechanism in the BB-8 droid, the Ultrasound probe head must have a swivel action. To perform the swivel motion, the head will be powered by an external motor unit. Bowden cables will transfer energy to the head of the transducer. Bowden cables are a type of cable that utilize an outer sleeve and an inner, load transferring cable to redirect force from one area to another. The most common applications for bowden cables are for bike brake lines and car clutch cables. The cables in this device will be attached to a joint that will create motion in the yaw and pitch directions. The external motor unit will be controlled by joystick that is attached to the probe handle. The joystick is wired up to a motor controller which will power the motors in precise movements.

Description of Analysis:

One analysis that is crucial to the success of the device is shown in Appendix A-2 and A-3. This analysis focuses on the amount of force that the motors must overcome to move the probe head from a total horizontal position to a vertical position. The amount of stress is greatest when the probe head is horizontal. In analysis A-2, arbitrary numbers were used to get a close answer. In analysis A-3, the design and measurements on the probe was locked down and a final force that the cable must be able to overcome was around 242.8 pounds. The 242.8 pounds was then used to find the torque needed from the motors.

Analysis A-6 explands on the force needed to move the cables when the probe is under load. The radius of the motor shaft was used to find the torque requirements of the motor. The torque requirement calculated was 38.22 lb-in. A motor was found that is rated at 43.4 lb-in, which according to the analysis, the motor will work in the system.

Methods and Construction

Initial conception and design of the device was sketched on my own time and further developed at Central Washington University. Mariah Barrett was consulted when conceptualizing design requirements. The majority of the construction will be conducted using the machine shop as well as the Senior Project Lab in Hogue Hall at Central Washington University.

Construction:

Most of the device was constructed out of aluminum. Aluminum is ideal for this device because of aluminums property of being easy to machine and also its property of being lightweight. Other parts, such as the pins will be constructed out of steel round pin stock. Construction of the ultrasound probe consisted of the following parts.

Cable Wheel

Figure 3 - Cable Wheel

The function of the cable wheel is to transfer load from the bowden cables to the rotating probe head. The cable wheel was constructed from 1060 aluminum. A high carbon cutting bit was specifically ground down the angle that is necessary to capture the cables. Aluminum round stock was turned turned down on a lathe to the outer diameter. The custom cutting bit was then plunged into the wheel and created the grove that the cables will nest into. A center hole was drilled out on the lathe using a ¼ inch drill bit. A cutoff bit was used to cut the wheel to a larger overall length. The wheels were then loaded into a soft jaw on the lathe and was faced with another cutting bit to obtain the overall length. Both sides of the cable wheels were faced. The Wheels were then put into the Bridgeport milling machine. The vice that the wheels were clamped into were parallel to the path of the cutter. The center hole was found with a dual-axis dial indicator was used to find the center of the wheel. The digital readout was set to zero and the center of the wheel was used as a datum to measure off of to drill the pin and cable holes. Order of operations page for the wheel can be found in the Appendix B.

Handle Cable Bracket

The handle cable bracket is designed to stop the outer sleeve of the bowden cables while still giving movement to the inner bowden cable. 1/16 inch aluminum plate was cut to 1/2 inch width and 1.625 inch length. Four holes were be laid out and drilled, two ¼ inch and two ⅛ inch. The plate was then be bent at an inch to create the final bracket shape. Due to the thin metal, multiple attempts were made to bend the bracket. First a piece of aluminum was drilled and broke while being bent. A test was made and heat treated to take the temper out of the aluminum. The test piece was bent and broke again. 5053 aluminum was then chosen and a test piece was made, heat treated and bent. The new aluminum bent with no problem so a last piece bracket was drilled, heat treated and bent.

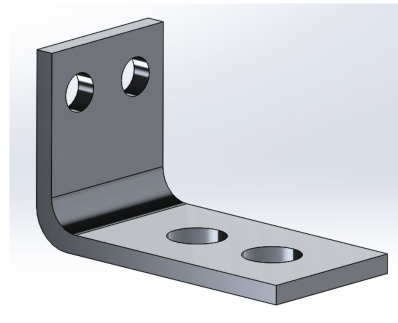


Figure 4 - Handle cable bracket

Handle Sleeve

A 1060 extruded aluminum tube with an outer diameter of 1.325 inches will be cut to an overall length of 5 inches. Holes were drilled perpendicular to each other at the top and bottom of the tube. These holes are used to mount the handle sleeve to the mounting stock. A hole will be cut in the sleeve to accommodate the joystick electronics. The Handle sleeve will be used to create a more comfortable grip for the probe and house the bowden cables. The handle sleeve design has been altered since the original draft and a 3D printed part took the place of the aluminum tube. The 3D printed part is superior over the aluminum tube because of its ability to house the joystick in a specific position. The handle was also able to be cut in half horizontally. The new two piece handle design is much more convenient with running line and working on the electronics.

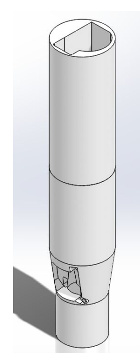


Figure 5 - Outer Handle

Mid Bracket

The mid bracket is one of the most vital parts in the device. The mid bracket is attached to the mounting stock and to the top bracket. The mid bracket was constructed from 1.25 inch 1060 aluminum square stock. The square stock was cut overlength on the vertical bandsaw. The bottom face of the bracket was cut down with and end mill to double check to make sure that the end was a flat surface to measure off of. After a flat surface was made, it was used to measure off of to drill holes on all of the fours sides that needed holes to be drilled. Appropriate drill sizes were used to get a press fit for the pins and a running fit on the shaft holes. The mid bracket was then cut on the vertical bandsaw to create a tab that captures the bowden cable sleeves when a load is put on the inner string. Once much of the material was taken off from the bandsaw the bracket was put back into the milling machine and the correct overall length, excluding the cable tab, was milled with an end mill bit. The tab was then scribed and rounded over on the belt sander to create the circular shape. A photo of the complete mid bracket can be found in figure ____.

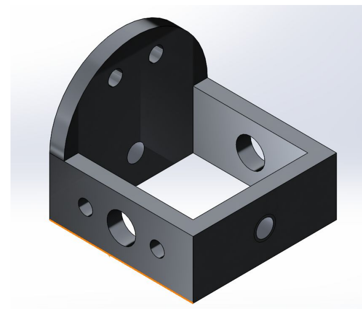


Figure 6 - Mid Bracket

Mock Transducer Head

Due to the fact that ultrasound transducers are hundreds of dollars, a transducer head has been modeled to be 3D printed. The 3D transducer head will be used to replicate a regular ultrasound probe head while testing. The mock transducer head was printed by James McPherson on his 3D printer and the print material was provided by Ryan Skerbeck.

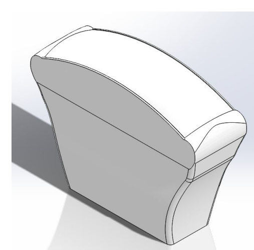


Figure 7 - Mock Probe Head

Mounting Stock

The mounting stock is the part that most of the device will be attached to. A piece of ½ inch extruded aluminum was cut down to be cut down to 6 ¼ inches in length on the metal chop saw. The burs from the cut were filed off and the square rod was placed in the milling machine. One end of the rod was faced and then was referenced as a new datum. A #7 drill bit was used to drill the screw holes in the

Figure 8 - Mounting Stock

correct locations. The other end of the rod was finished after all holes were drilled. A ¼-20 tap was then used to thread the holes to receive the socket head screws.

Nylon Bushings and Washers

Both nylon bushings and washers is being used to cut down on metal on metal rubbing in the device. The Nylon bushings and washers were ordered off of McMaster Carr. The nylon bushings were used as spacers to correctly position the mid and top bracket. A washer was sized to fit in between the top bracket cable wheel and the mid bracket to minimize energy loss due to friction. Both bushings and washers had a little excess material so they were sanded down to insure proper fitment and positioning in the device.

Threaded Through Rods

¼ inch steel round stock was cut down to length and tapped ¼-20 threads.

Figure 9 - Threaded Through Rod

Top Bracket

The top bracket is the portion of the ultrasound probe that attaches the mechanical joint to the head of the transducer.The original plan for the top bracket was to build it out of a 2 inch C-channel but 2 inch C-channel without webbing is very hard to come by. Instead of a C-channel, Matt Burvee provided a 2 inch by 4 inch square tubing. A section of the tubing was cut out of the square tubing to act as the top bracket. The needed holes were drilled while the tubing was still intact to insure correct hole placement. After the holes were drilled, The top bracket was cut out of the tubing. There was a slight bow in the bracket once cut. To combat the bow the bracket was put in the vice to be massaged with a hammer.

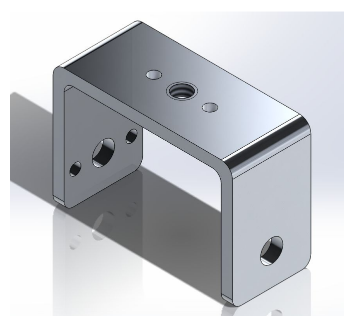


Figure 10 - Top Bracket

Device Operation:

The device operates off of the concept that bowden cables transfer a load from an external power source and distributes the load to move the probe head in a multitude of directions. To use the ultrasound probe a joystick will be located on the probe handle to drive the probe head in different directions.

Benchmark:

The device should perform within a 15% margin of error compared to the calculations made surrounding the amount of force can be transmitted through the probe, the amount of time for the probe head to travel, and the degree of motion of the probe head. The device must also meet the requirements discussed in the requirement section of this report.

Performance Predictions:

The rotational ultrasound probe will isolate the rotational movement sonographers must make to navigate an ultrasound exam. The probe will take longer than the calculated time to move the whole range of motion as well as transfer about the same amount of force that is calculated.

Testing Methods

Testing:

Testing of the ultrasound probe will begin with testing the range of movement. With the mock probe detached, the testing be documented against a background that will measure the angle of the top threaded probe head. Once the total angle of movement is determined then the next step of testing is to time how long the probe will take to perform the whole range of movement. The speed at which the probe head moves is important to not only the safety of the patient but also the effectiveness of the device towards the problem the device was built to solve. These tests will help hone in the coding that will be done to power the probes movement. First the total angle of movement will be used to determine the total range of movement of the servos. The range of movement will be specified in the arduino code. After the total range of movement is specified in the code, the speed at which the the joystick will move the probe head will be tested and implemented to the Arduino code.

The last major testing on the probe is to test the maximum amount of pushing force the probe have when moving into different positions. The reason for this test is to quantitate how much pressure an ultrasound technician can exert on the probe without failure in the device. This test will also show the effect of friction throughout the system due to pins and bowden cable sleeves.

Test Plan

Overview

An ultrasound technologist puts a certain amount of weight on a probe while they scan. The weight applied depends on the technologist but the average amount of pressure that is applied by most sonographers is 20 pounds of force. In this test the probe must withstand and push up to 30 pounds. The importance of doing these tests is to quantify how much pressure a technician can exert on the prode without breaking the probe. This test will also show the effect of friction throughout the system due to pins and bowden cable sleeves.

Setting

This test will be performed in the materials lab at Central Washington University on April 9th, 2019. The duration of the test will take 3 hours including setup time.

Resources

A few resources will be needed in this test. Line will be needed to hang weight off the end of the probe head. The probe will also have to be mounted to a table so a special bracket must be made to hold the unique shape of the probe. Weights will also be needed to to test the strength of the probe.

Test Actions

Step 1: mount the probe handle to the tabletop

Step 2: Plug the motor system into a power source

Step 3: hang line from the hook in the probe head

Step 4: hang a weight from the probe head

Step 5: operate the full range of movement. time how long the probe takes to perform this task

Step 6: repeat steps 4 and 5 for an array of different weights

Step 7: Record data into a document

Step 8: Calculate the optimal weight and speeds

Risks

The risks of this test include;

1. Breakage of probe
2. Breakage of probe head
3. Breakage of line and cable
4. Breakage of 3D printed handle sleeves

5. Breakage of motors

Testing Results:

For test one a basic system functionality performance test was performed. The intention was to get the system up and running as well as testing the reliability of the code added to the arduino. The arduino ecosystem was used to code two servos to perform the movements needed to drive the probe head. The test was isolated to one axis of the joystick and one servo. How the system works is the user uses a joystick that sends two different signals dependant on the position of the joystick in the x and y position. The values from the joystick is send to an arduino which then interprets the values that determines the position of the servos. The arduino code that was used to interpret the inputs from the joystick can be found below. For this test the ‘joyVal” value was the changed variable. The “joyVal” variable dictates the speed at which the servo turns. The higher “joyVal” is, the faster the servo turns. In this initial test it was found that the servo would top out when “joyVal” was around 4. The servos couldn’t move much faster than that value. The optimal speed of the servo when no load was applied was when “joyVal” = 2.

Budget, Schedule, and Project Management

Cost and Budget:

The device was designed with ease of building in mind. Many of the parts on the probe are cutoffs of stock aluminum. Designing the parts around stock aluminum greatly decreased the cost that would have been needed to build custom parts. Due to the simplistic nature of the materials, about a third of the materials being used to manufacture the ultrasound probe will be provided by the CWU machine shop. It is a money and time saver that a good portion of this senor project can be provided by the machine shop. The more unique materials as well as electronics were purchased from Amazon. The grand total of parts and material from Amazon is $131.38, including shipping and tax. Some more specific bolts, washers, bushing, ect. Were purchased from McMaster Carr. the grand total from this order is $36.42. Compared to original cost projections, the ultrasound probe is on track to cost under $300. Another cost to keep in mind is the cost of 3D printing. The mock probe head, probe handle, motor wheels and motor mount all are to be created via rapid prototyping. The cost of 3D printing is dependant on certain variables including in-fill and quality of plasting going into these parts. Cost chart is found in Appendix D-1.

Schedule:

The schedule of the production of this device is in Appendix E. When looking at the Gantt chart, each quarter is planned out for each phase of the senior project. Each task has an estimated duration on the chart. The completed task durations were imputed to the table to be compared to the projected duration.

Discussion

The “SonoProbe” ultrasound probe had a few different iterations before the version that we have today. First linear actuators were considered to give the ultrasound probe head movement. After struggling for a few weeks to come up with a feasible way of mounting the linear push rods a new design idea came up. Referring to a .GIF file of the mechanism that powers the head of a droid in Star Wars, the current concept of using cables to power the rotational movement of the probe head was implemented.

When first conceptualizing the idea of the “SonoProbe” Ultrasound probe, There were grandiose plans for testing. The first idea for testing was to construct a platform for the probe to push against to measure the amount of weight that the probe movement can handle. This test would be one of the most accurate way of replicating a real life situation and make it easy to quantify the exact weight the probe could handle. The problem with that test is that it demands a lot of design and construction of the testing platform. Another problem is that both axises would have to be working flawlessly before this test can be performed. The initial tests were changed to testing the range of movements and times dependant of the code. This was a smarter choice so that the probe code will be refined before any load is applied.

Conclusion

The purpose the rotational ultrasound probe is to give relief to the sonographers that use the probes day in and day out. The idea is to use bowden cables to transfer the transitional movement of an external motor pack to power the movement of the ultrasound probe head. With careful calculations, the objective of designing a device that will perform these functions has been created. Further calculations are welcome. The “SonoProbe” has passed through the pre-production phase and is in a good spot to begin the manufacturing phase of the project.

Acknowledgements

People

Mariah Barrett - Ultrasound Technician, Kittitas Valley Hospital

Huge source of information in regards to transducer orientation and movement

Ryan Skerbeck - Fellow Classmate

For saying it couldn't be done and motivating me to prove him wrong

Matt Burvee

Helping with designs, material choices, machining processes

Dr. Criag Johnson - CWU Professor, Senior Project Educator

Helping with design concepts and analysis

Professor Charles Pringle - CWU Professor, Senior Project Educator

Helping with analysis and calculations

Professor John Choi - CWU Professor, Senior Project Educator

Helping with analysis and calculations

Central Washington University

CWU Engineering Department

Appendix A - Analyses

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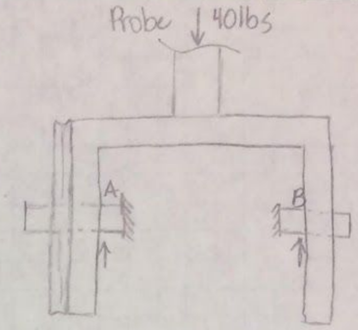
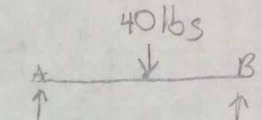
Given:
$F = 40 lbs$
A36

τ - shear
$S_y(\tau) = 0.5(S_y)$



Find: pin size w/saftey factor of 2

Methods:
1) FBD
2) sum forces
3) Shear Equation



Solution:

$$\Sigma F_y = 0 = -40lbs + A_y + B_y \qquad A_y = B_y$$
$$2A_y = 40 lbs$$
$$A_y = 20lbs$$

$$\tau = \frac{V}{A} \quad S_y(\tau) = 0.5\frac{(S_y)}{S_f}$$

$$A = \frac{V}{S_y(\tau)} = \frac{V}{0.5(\frac{S_y}{2})} = \frac{V}{9ksi} = \frac{20lbs}{9ksi} = .002 in^2$$

$$A = \pi\frac{d^2}{2}$$

$$d = 2\sqrt{\frac{A}{\pi}} = 2\sqrt{\frac{.002in^2}{\pi}} = .0266 in \rightarrow \boxed{0.125 in}$$ (1/8in pin size)

$$\tau = \frac{20lbs}{\pi(\frac{.125in}{2})^2} = 1629.7 psi < 18 ksi$$

✓

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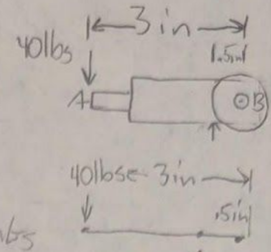
COMET
3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

Given: $L = 3in$
$r = .5in$
$F = 40lbs$
$F_c = ?$



Methods: 1) sum of moments

Solution:

$$\circlearrowleft + \Sigma M_B = 0 = -40lbs(3in) + F_c(.5in)$$

$$\boxed{F_c = 240lbs}$$

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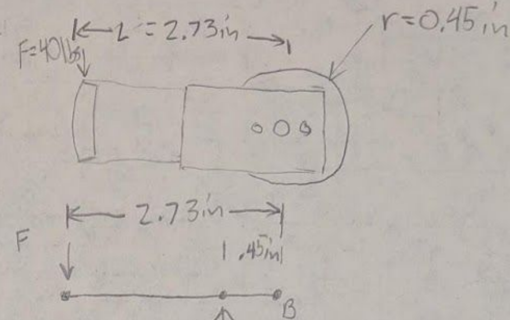
COMET
3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

Given: $L = 2.73in$
$r = 0.45in$
$F = 40lbs$
$F_c = ?$



Methods: 1) ΣM

solution: $\circlearrowleft + \Sigma M_B = 0 = -40lbs(2.73in) + F_c(.45in)$

$$F_c = \frac{40lbs(2.73in)}{.45in}$$

$$\boxed{F_c = 242.67\ lbs}$$

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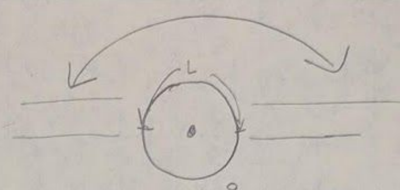
Given: $r = 0.5$ in

$L = \frac{1}{2}$ circumference

Bowden Cable



180° movement

Methods: Circumference Eq

Solution: $C = 2\pi r \Rightarrow L = \pi r$

$L = \pi\, 0.5\text{in}$

$\boxed{L = 1.57\text{ in}}$ linear movement in Cable

COMET
3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

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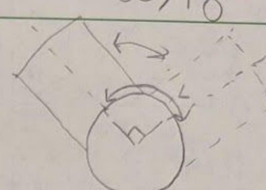
Given: $r = 0.45$ in

90° of movement

$L = \frac{1}{4}$ Circumference

Bowden Cable



Methods: Circumference Equation

Find: linear movement of Cable

Solution: $C = 2\pi r \Rightarrow L = \frac{1}{2}\pi r$

$L = \frac{1}{2}\pi(0.45\text{in})$

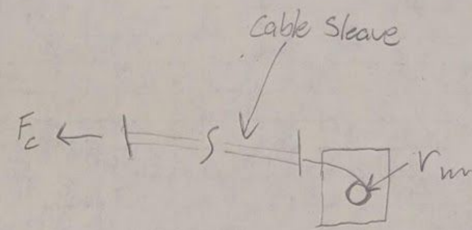
$L = \boxed{0.707\text{in}}$ of linear movement

COMET
3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

Given:

$r_m = 0.15748 \text{ in}$

$F_c = 242.67 \text{ lbs}$



Find: Torque on motor

Methods: $T = F \times r$

Solution: $T_m = F_c r_m$

$T_m = (242.67 \text{ lbs})(0.15748 \text{ in})$

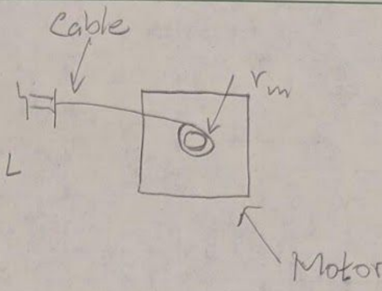
$T_m = \boxed{38.22 \text{ lbs in}}$ ←

38.22 lbs-in < rated 43.4 lbs-in

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

Given: $r_m = 0.15748\,in$
$\Delta L = 0.707\,in$

Find: n of rotations for ΔL



Methods: 1) Circumference
2) C_m vs ΔL

Solution:

1) $C_m = 2\pi r_m$
$C_m = 2\pi(0.15748\,in)$
$C_m = 0.989\,in$

2) $n_{rev} = \frac{\Delta L}{C_m}$
$n_{rev} = \frac{0.707\,in}{0.989\,in}$
$n_{rev} = \boxed{0.714\ rev}$

Given: 7rpm (selected motor)

$n_{rev} = 0.714$

Find: How long the motor takes to perform full movement

Solution: $7rpm = \frac{7rev}{1min} \frac{1min}{60sec} = 0.117 \frac{rev}{sec}$

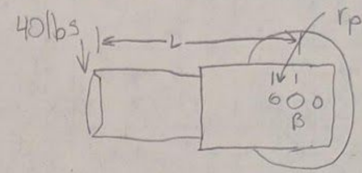
$\Delta t = \frac{n_{rev}}{0.117 \frac{rev}{sec}}$

$\Delta t = \frac{0.714\ rev}{0.117 \frac{rev}{sec}}$

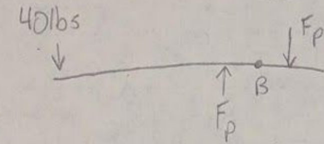
$\Delta t =$ **6.12 seconds** for full range of movement

COMET 3-0235 — 50 SHEETS — 5 SQUARES 3-0236 — 100 SHEETS — 5 SQUARES 3-0237 — 200 SHEETS — 5 SQUARE 3-0137 — 200 SHEETS — FILLER

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET



Given: $L = 2.73 in$
$\varnothing = 0.125 in$
$F = 40 lbs$
$r_p = 0.25 in$



Find: pin shear stress

Methods: 1) Σ Moment
2) shear stress Equation

Solution: 1) $\curvearrowleft + \Sigma M_B = 0 = -40lbs(2.73in) + F_p(r_p) + F_p(r_p)$

$$\Sigma M_B = 0 = -40lbs(2.73in) + 2F_p(0.25in)$$

$$F_p = \frac{109.2\ lb\text{-}in}{0.5in}$$

$$F_p = 218.4\ lbs$$

2) $$\tau = \frac{F_p}{A} \Rightarrow \frac{F_p}{\left(\pi\left(\frac{\varnothing}{2}\right)^2\right)}$$

$$\tau = \frac{218.4\ lbs}{\pi\left(\frac{0.125in}{2}\right)^2}$$

$$\tau = \boxed{17.8\ ksi}$$

Given: Nylon Spacers

OD = 0.375in

ID = 0.25in

μ (Nylon on Aluminum) = 0.7

N = .5lbs

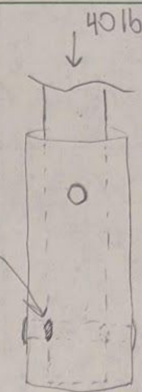
Find: friction force of Nylon Spacers

Methods: $F_f = \mu N$

Solution: $F_f = 0.7(.5\text{lbs})$

$$\boxed{F_f = 0.35\text{ lbs}}$$

COMET 3-0235 — 50 SHEETS — 5 SQUARES 3-0236 — 100 SHEETS — 5 SQUARES 3-0237 — 200 SHEETS — 5 SQUARES 3-0137 — 200 SHEETS — FILLER



Given: $F = 40lbs$
$\varnothing = 0.1875 \text{ in}$

Find: shear forces on one through pin

Methods: 1) calculate force on one pin hole
2) $\tau = \frac{F_1}{A}$

Solution: $F_1 = \frac{40lbs}{4 \text{ pin holes}}$

$F_1 = 10lbs$ per pin hole

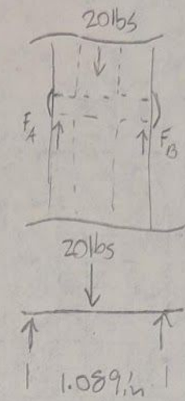
2) $\tau = \frac{10lbs}{A} = \frac{10lbs}{\pi\left(\frac{0.1875in}{2}\right)^2}$

$\tau = \boxed{362.17 \text{ psi}}$ ←

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

Given: $F = 20lbs$
$L = 1.089in$
$\varnothing = 0.1875in$
$E = 10{,}000ksi$



Find: Max yeild

Methods: 1) Find I
2) Max Beam Deflection formula

Solution:

1) $I = \frac{\pi \varnothing^4}{64}$

$I = \frac{\pi (0.25in)^4}{64}$

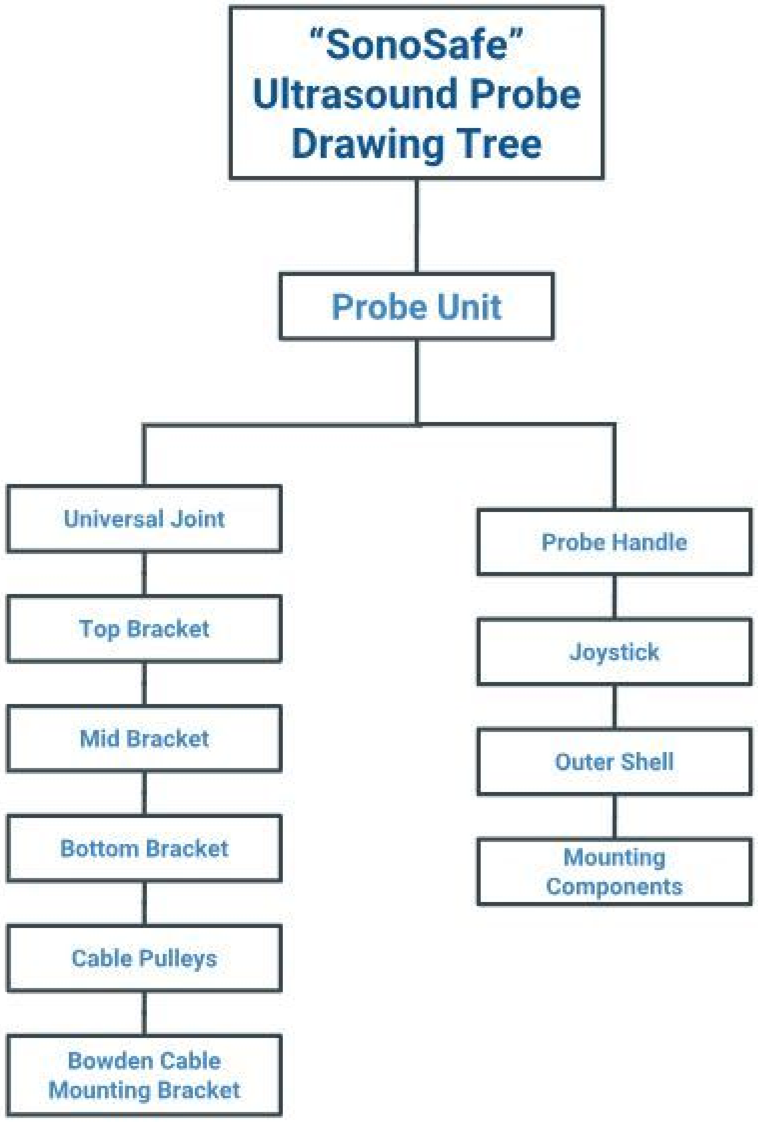
$I = 0.0001917$

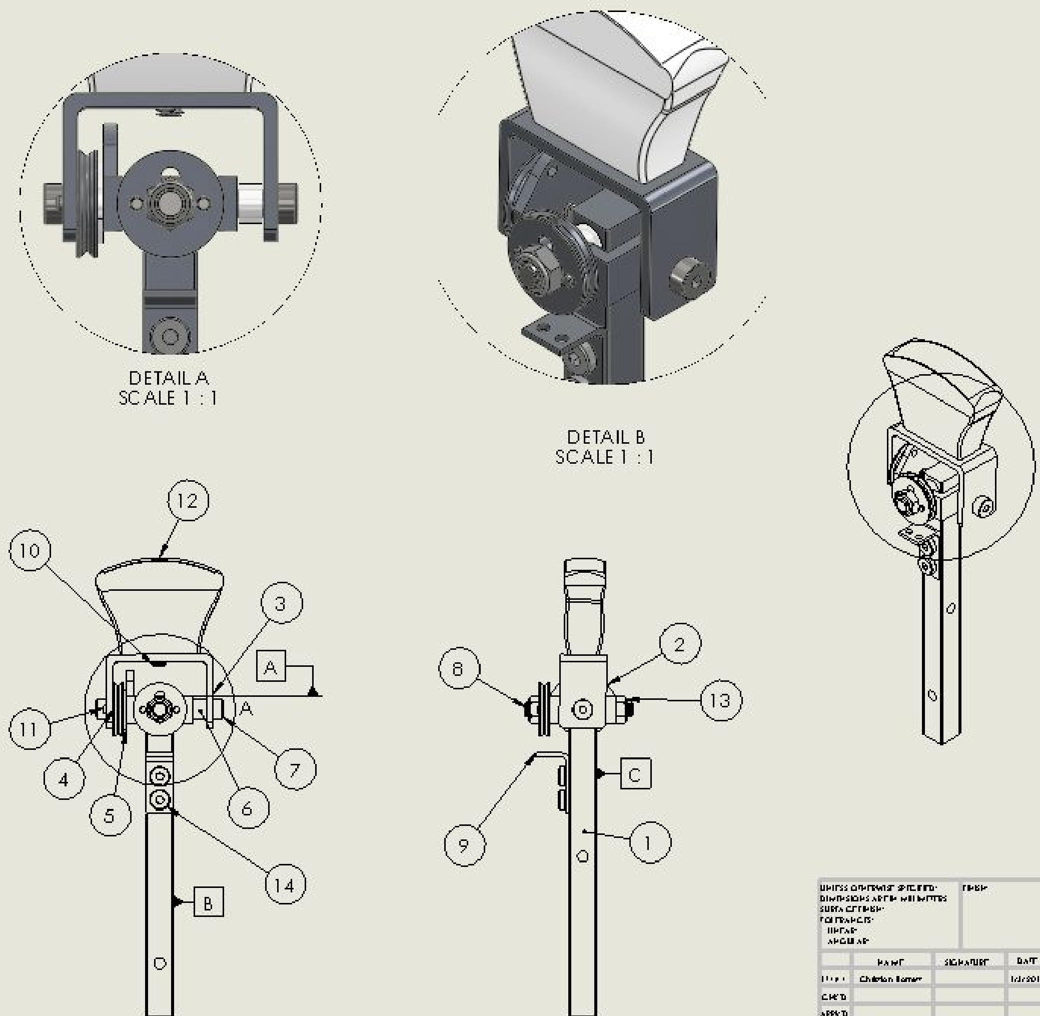
2) $Y_{max} = \frac{-FL^3}{48EI}$

$Y_{max} = \frac{-20lbs(1.089in)^3}{48(10{,}000ksi)(0.0001917)}$

$Y_{max} = \boxed{0.0028in}$ ←

Appendix B - Drawing



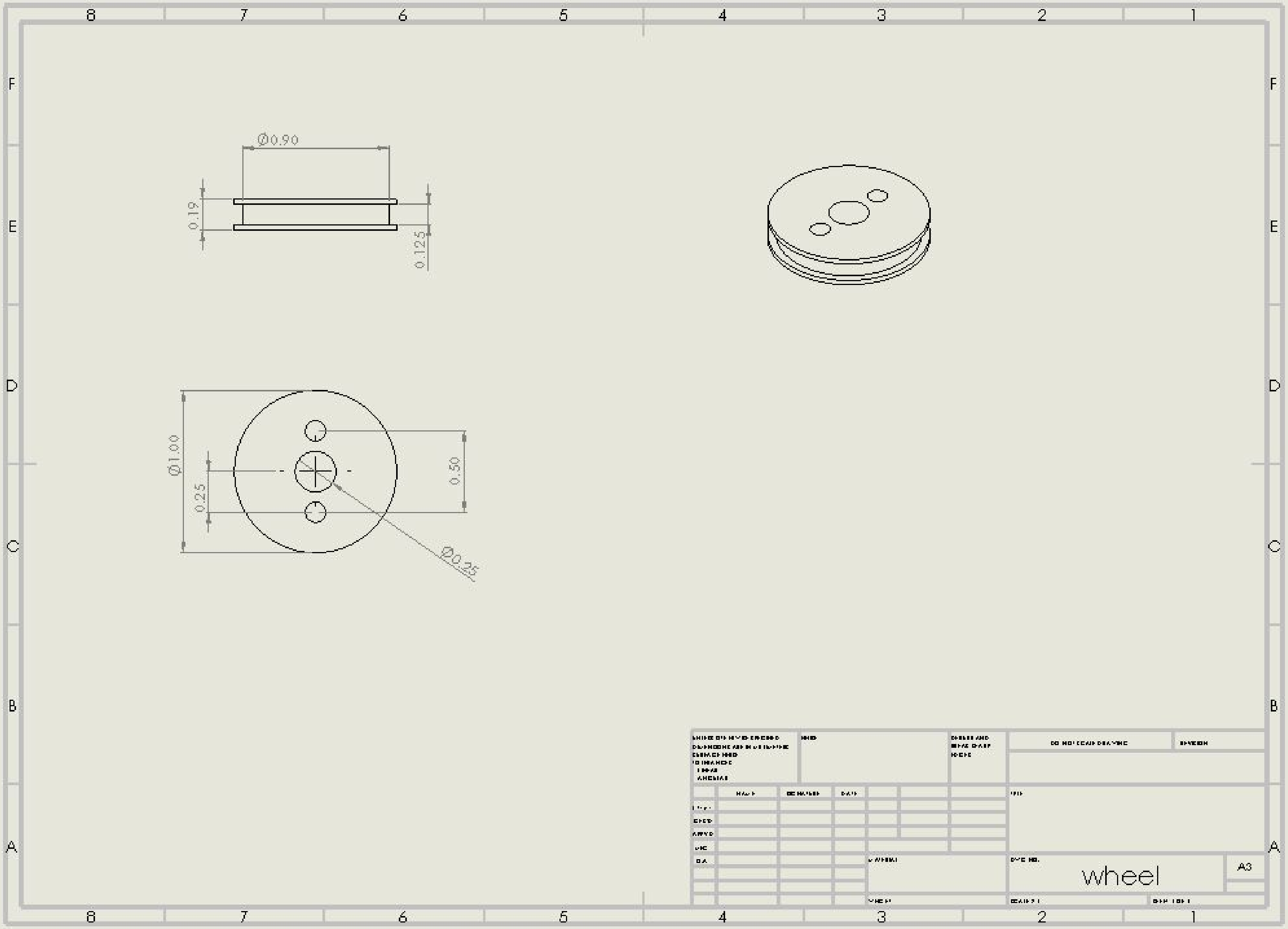


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	421-1	mounting stock v2	1
2	421-2	Mid Bracket v2	1
3	421-3	Top Bracket v2	1
4	421-4	wheel v2	2
5	421-5	Washer	1
6	421-6	Bushing	3
7	421-7	Shoulder Bolt	2
8	421-8	Through Rod v2	1
9	421-9	handle cable bracket v2	1
10	421-10	Top Threaded Rod v2	1
11	421-11	Wheel Pin	4
12	421-12	Mock Transducer	1
13	97367A113	Lock Nut	2
14	93615A410	Bracket Handle Bolt	2

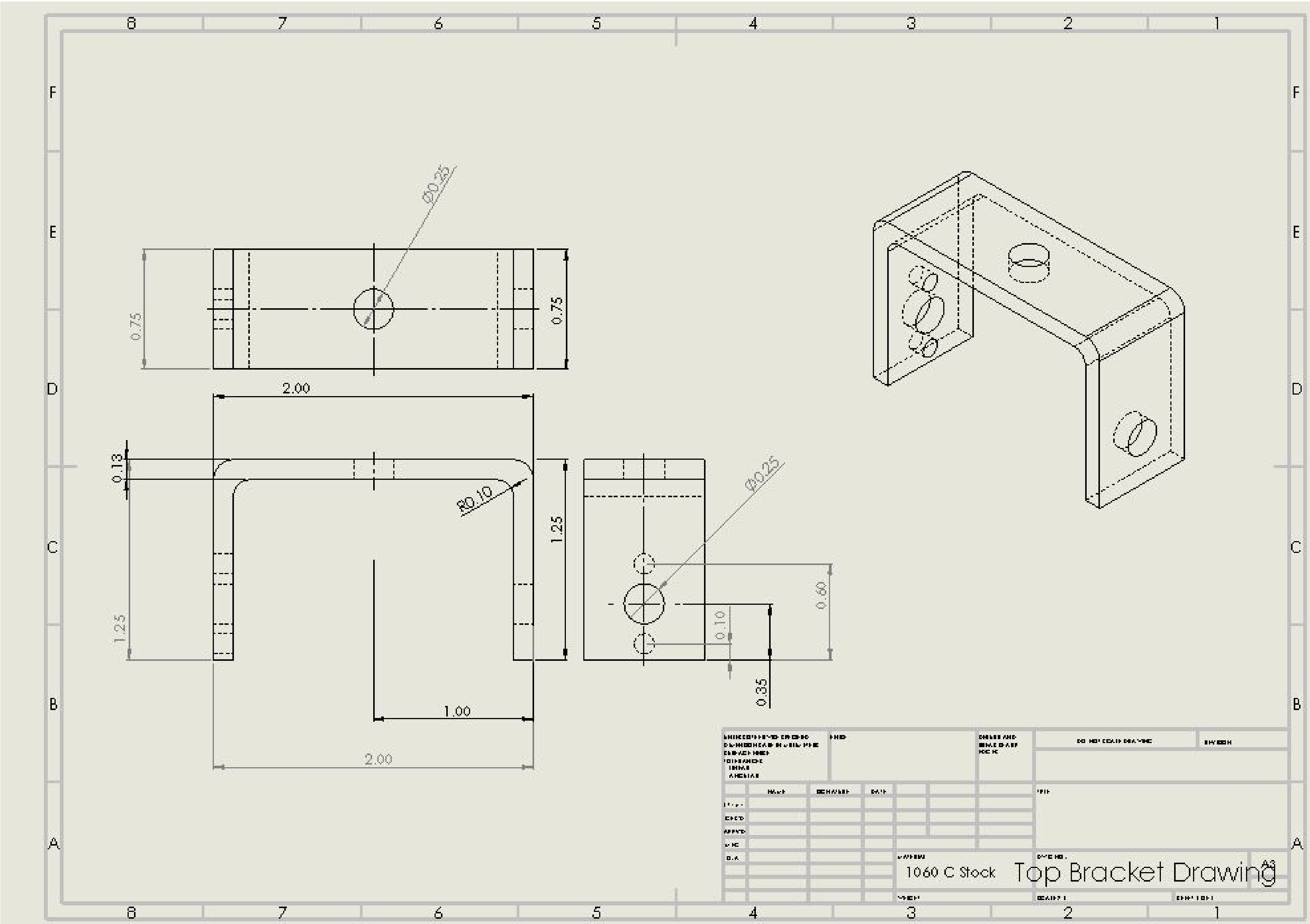
ASSEMBLY-BOM

C1

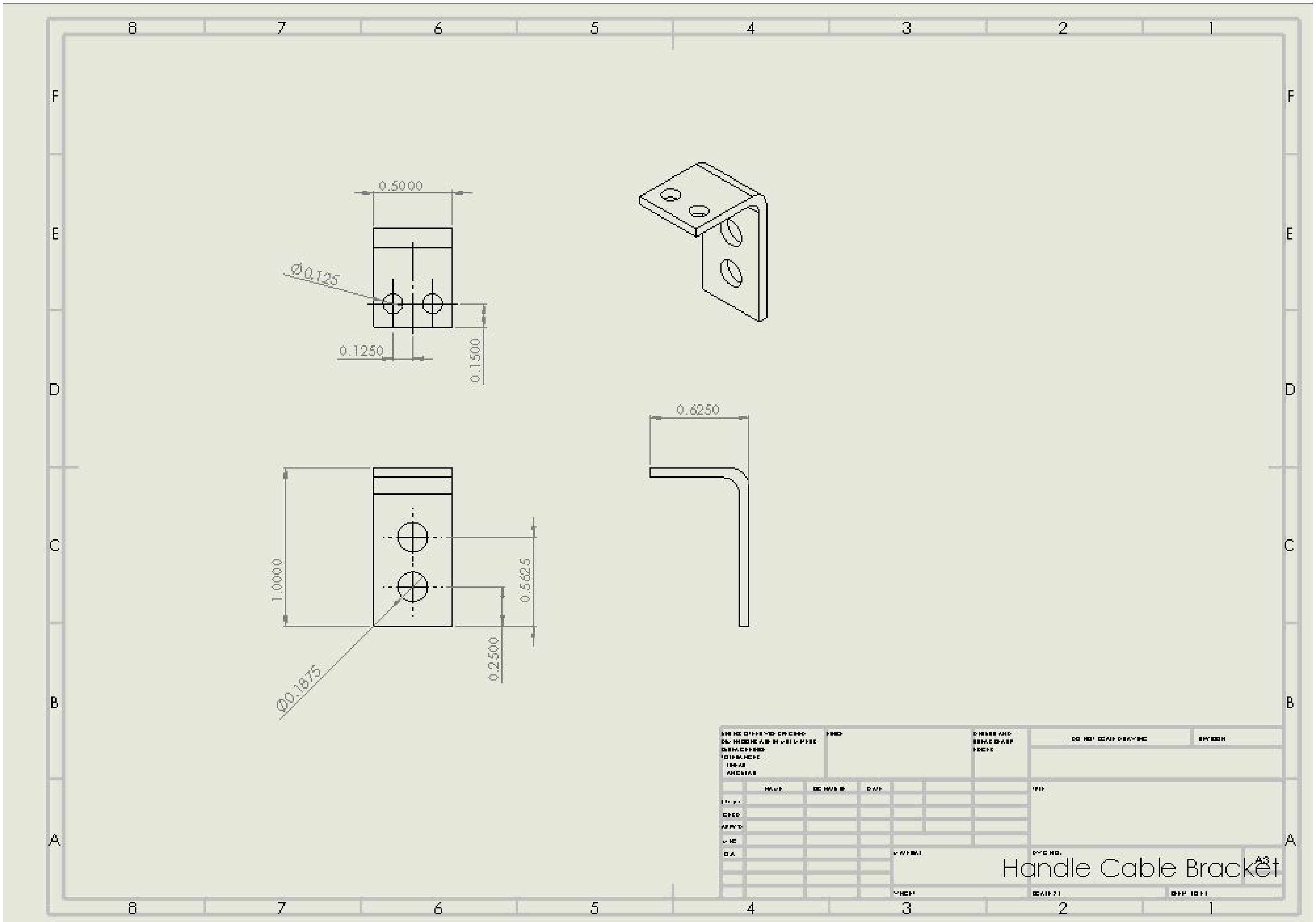
A3

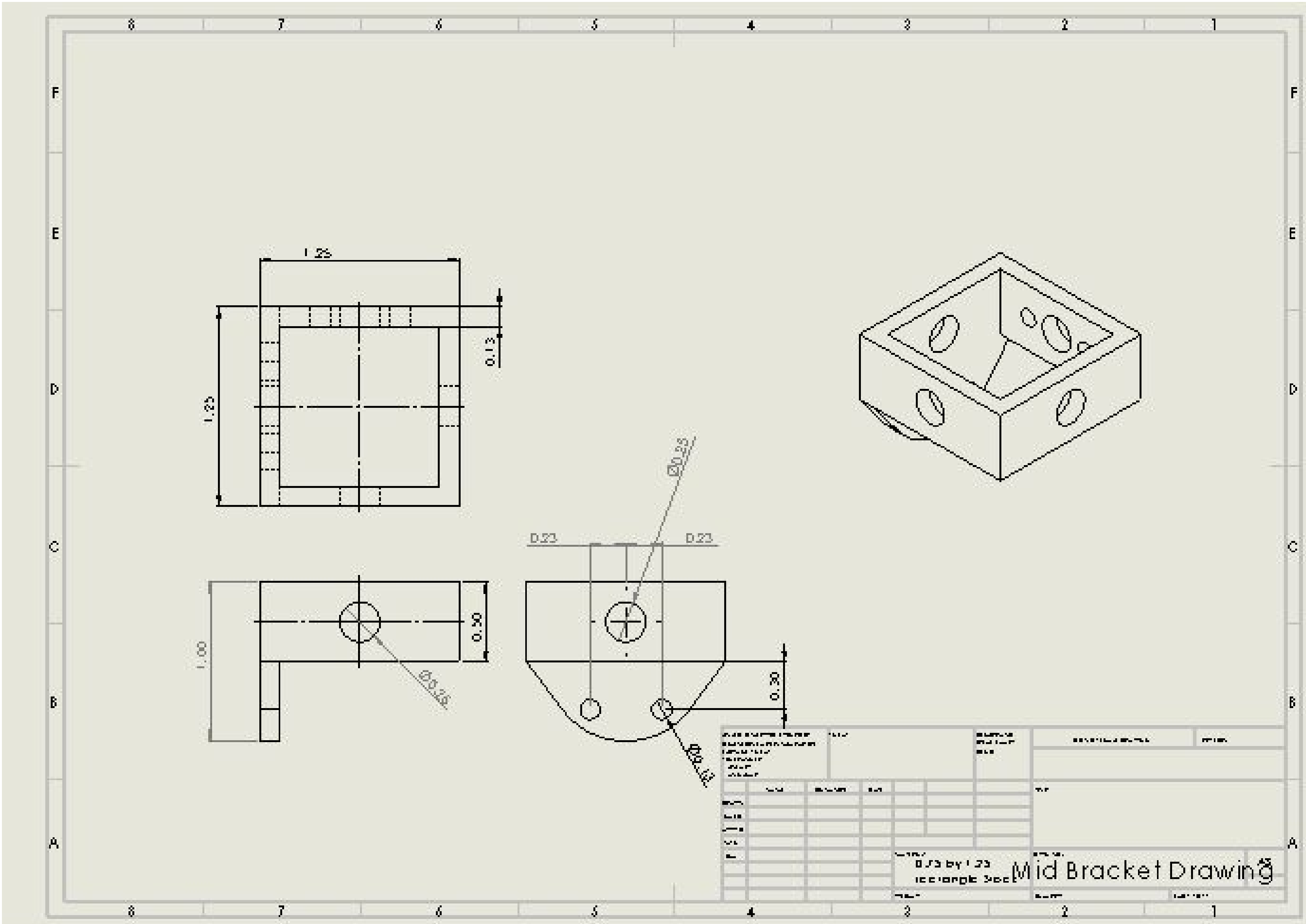


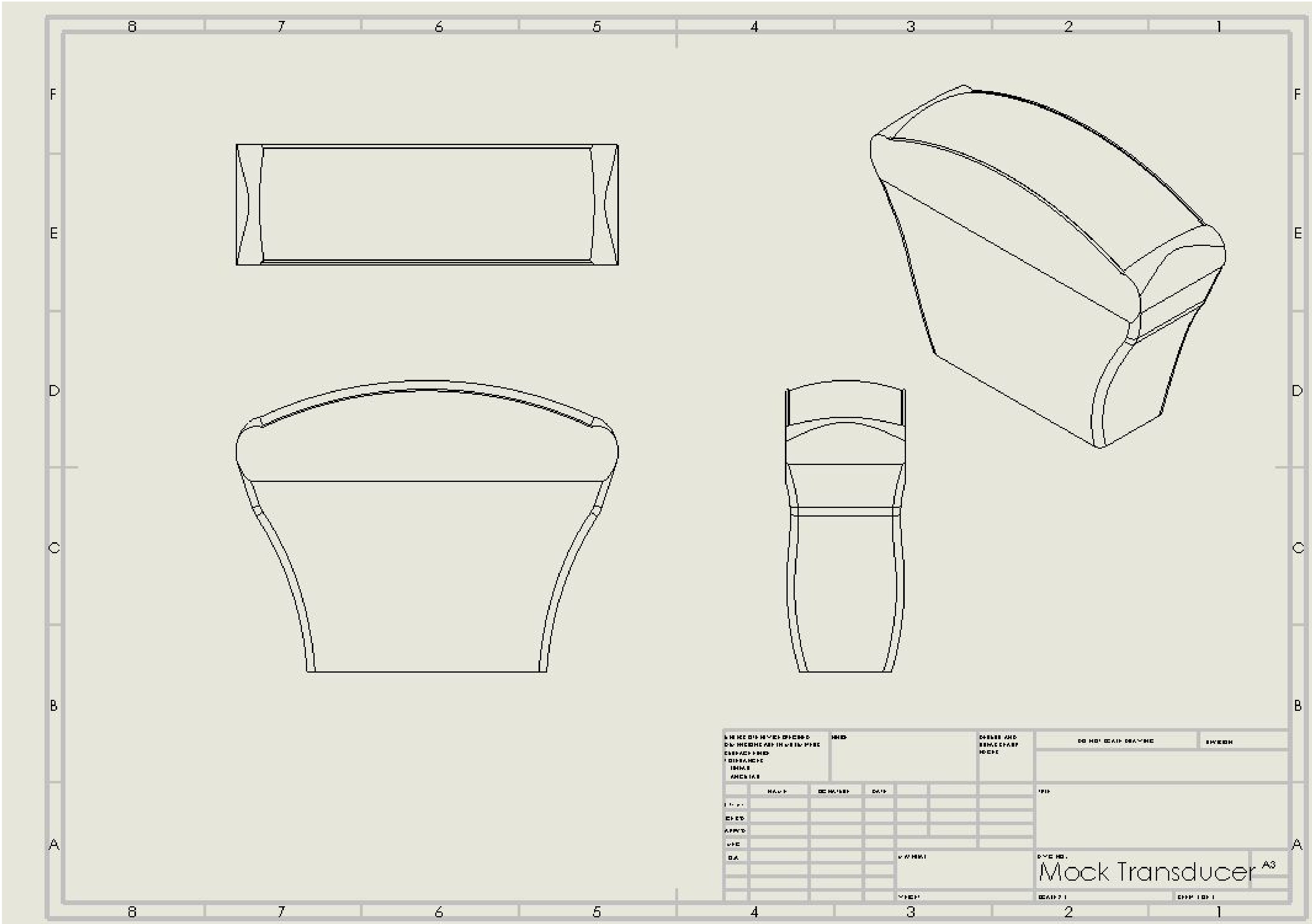
Ø0.90
0.19
0.125
Ø1.00
0.25
0.50
Ø0.25
DO NOT SCALE DRAWING
REVISION
DWG NO.
wheel
A3



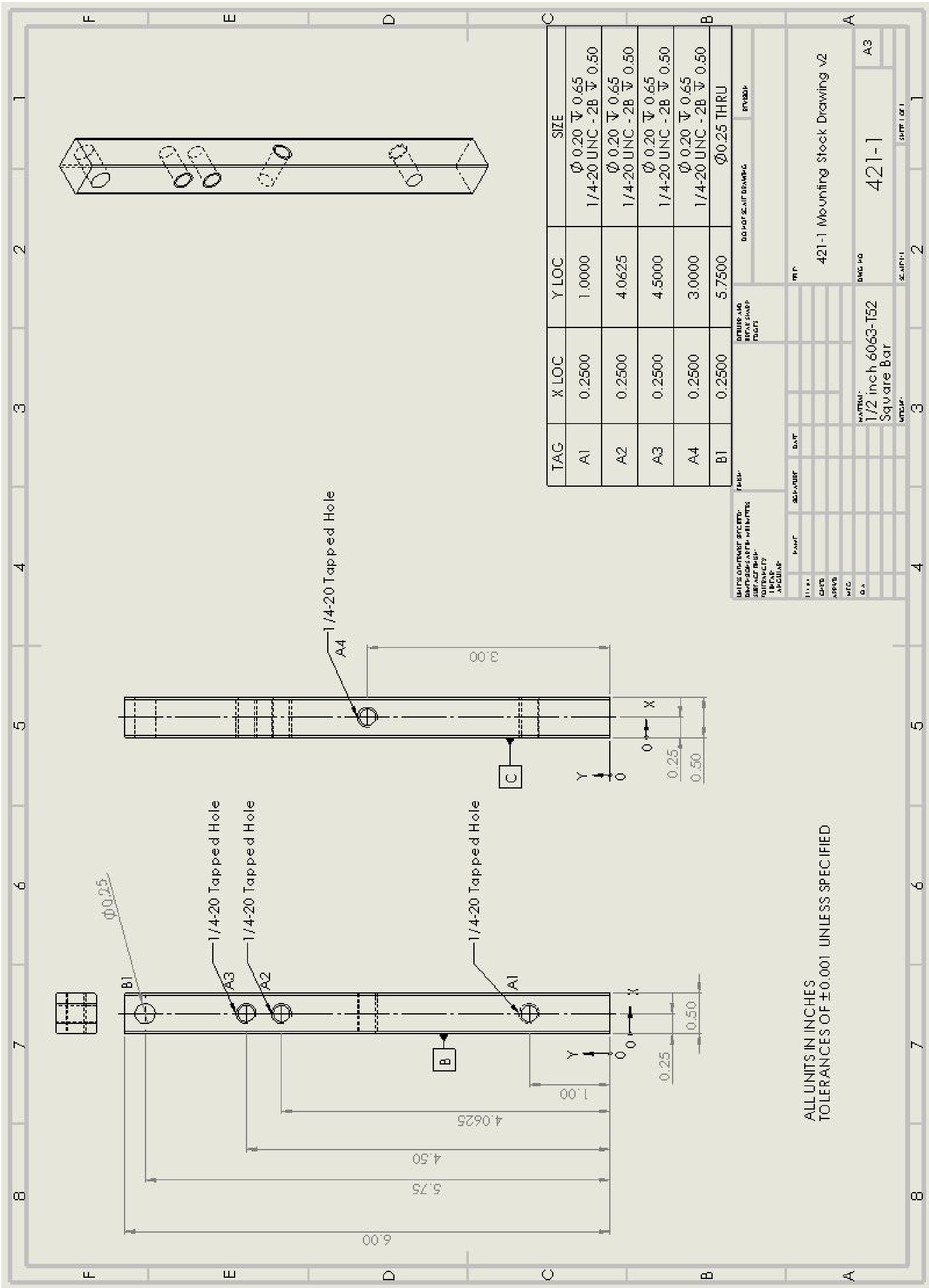
Ø0.25
0.75
0.75
2.00
0.13
R0.10
1.25
Ø0.25
0.60
0.10
0.35
1.25
1.00
2.00
1060 C Stock
Top Bracket Drawing
A3

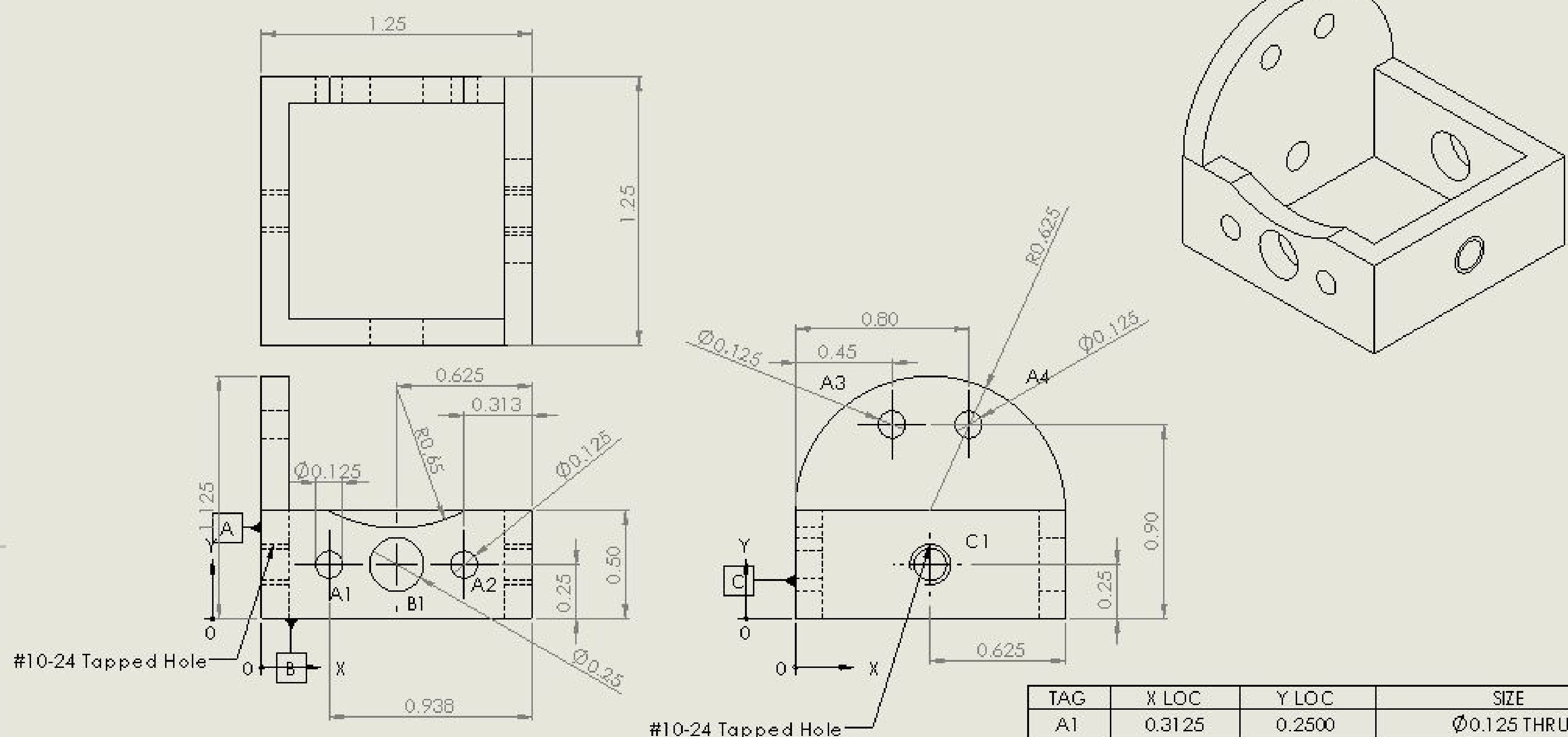

0.5000
Ø0.125
0.1250
0.1500
0.6250
1.0000
0.5625
0.2500
Ø0.1875
Handle Cable Bracket
A3


1.25
1.25
0.13
1.00
0.50
Ø0.38
0.23
0.23
Ø0.25
0.30
Ø0.13
Mid Bracket Drawing


Mock Transducer
A3

Revision Drawings





ALL UNITS IN INCHES
TOLERANCES OF ±0.001 UNLESS SPECIFIED

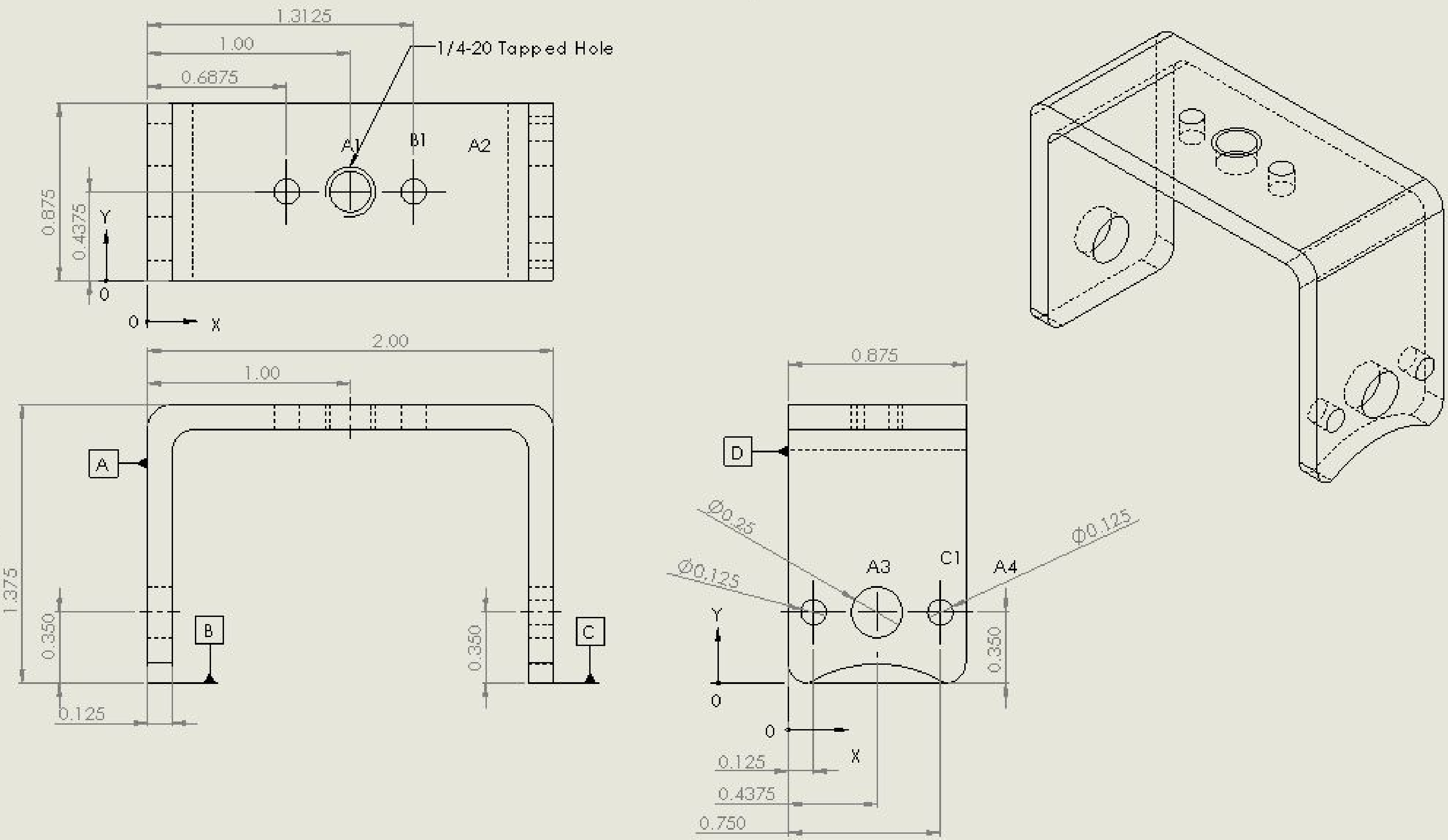
TAG	X LOC	Y LOC	SIZE
A1	0.3125	0.2500	Ø0.125 THRU
A2	0.9375	0.2500	Ø0.125 THRU
A3	0.4478	0.9000	Ø0.125 THRU
A4	0.8022	0.9000	Ø0.125 THRU
B1	0.6250	0.2500	Ø0.250 THRU
C1	0.6250	0.2500	Ø 0.150 THRU ALL 10-24 UNC - 2B THRU ALL

MATERIAL:
1 1/4 inch 6063
Aluminum Square Tube

TITLE: Mid Bracket v2

DWG NO. 421-2

A3



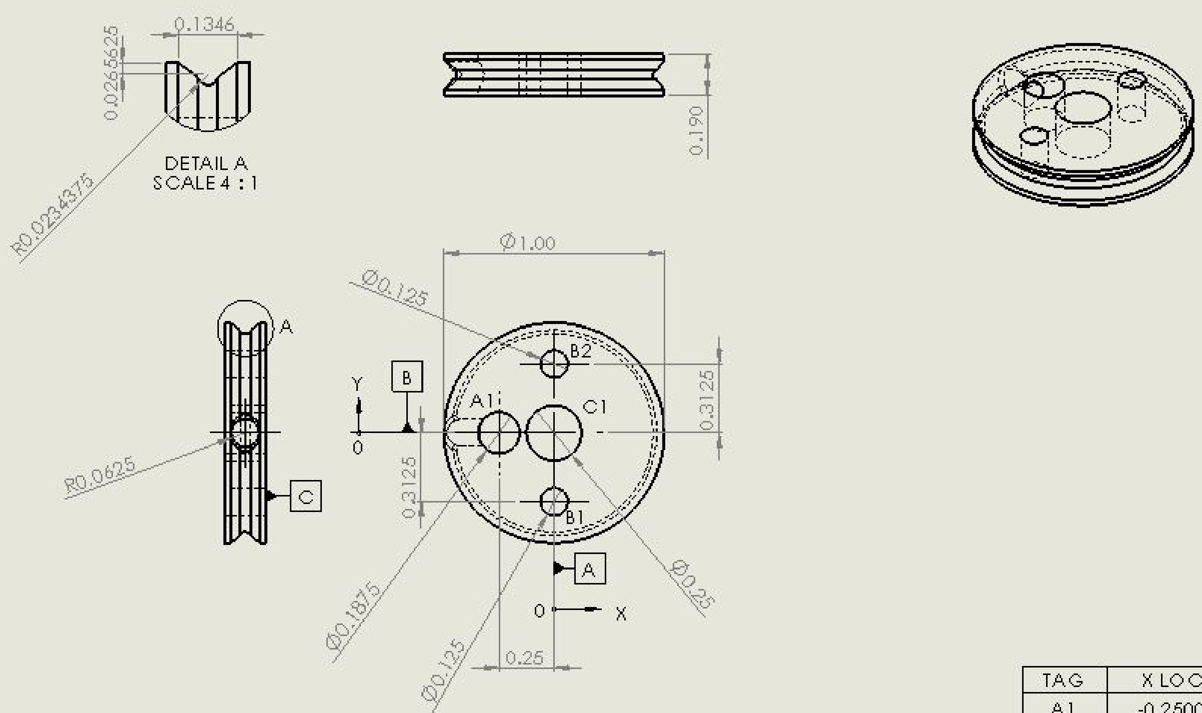
TAG	X LOC	Y LOC	SIZE
A1	0.6875	0.4375	Ø0.13 THRU
A2	1.3125	0.4375	Ø0.13 THRU
A3	0.1250	0.3500	Ø0.13 THRU
A4	0.7500	0.3500	Ø0.13 THRU
B1	1.0000	0.4375	Ø 0.20 ↧ 0.65 1/4-20 UNC - 2B ↧ 0.50
C1	0.4375	0.3500	Ø0.25 THRU

MATERIAL: 2 INCH 1060 C-CHANNEL

TITLE: 421-3 Top Bracket Drawing v2

DWG NO. 421-3

A3



ALL UNITS IN INCHES
TOLERANCES OF ±0.001 UNLESS SPECIFIED

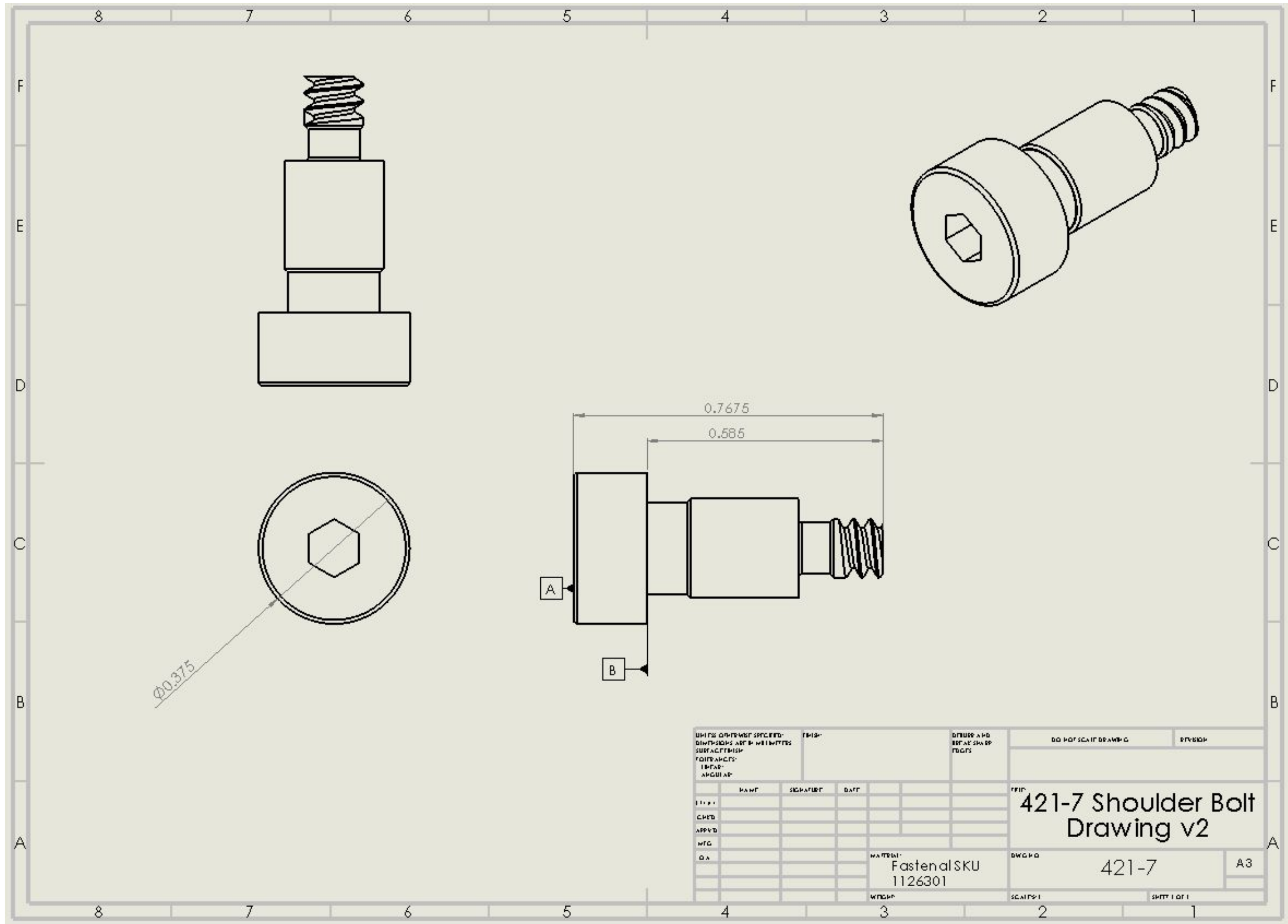
TAG	X LOC	Y LOC	SIZE
A1	-0.2500	0.0000	Ø0.1875 THRU
B1	0.0000	-0.3125	Ø0.1250 THRU
B2	0.0000	0.3125	Ø0.1250 THRU
C1	0.0000	0.0000	Ø0.2500 THRU

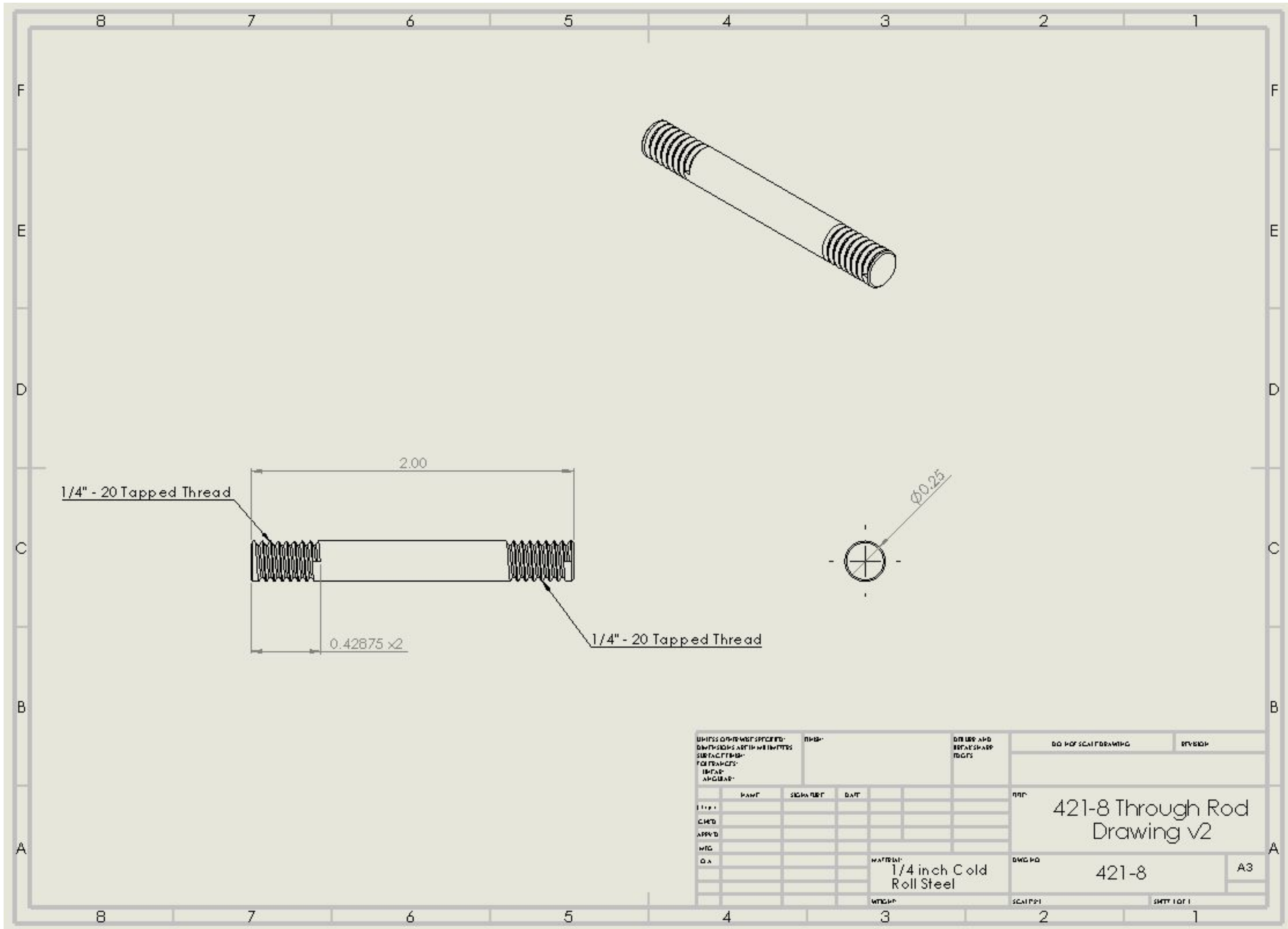
MATERIAL: 1 1/8 Aluminum Round Stock

421-4 Wheel Drawing v2

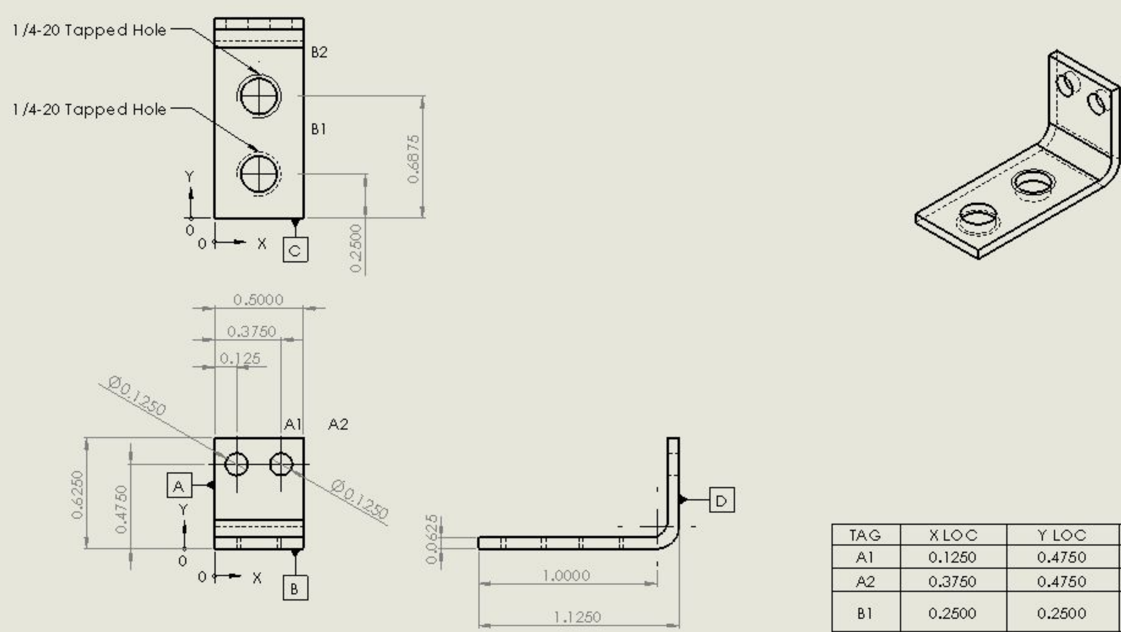
DWG NO. 421-4

A3


0.7675
0.585
A
B
Ø0.375
421-7 Shoulder Bolt Drawing v2
Fastenal SKU 1126301
421-7
A3



1/4" - 20 Tapped Thread
2.00
0.42875 x2
1/4" - 20 Tapped Thread
Ø0.25
DO NOT SCALE DRAWING
REVISION
421-8 Through Rod Drawing v2
MATERIAL
1/4 inch Cold Roll Steel
DWG NO.
421-8
A3



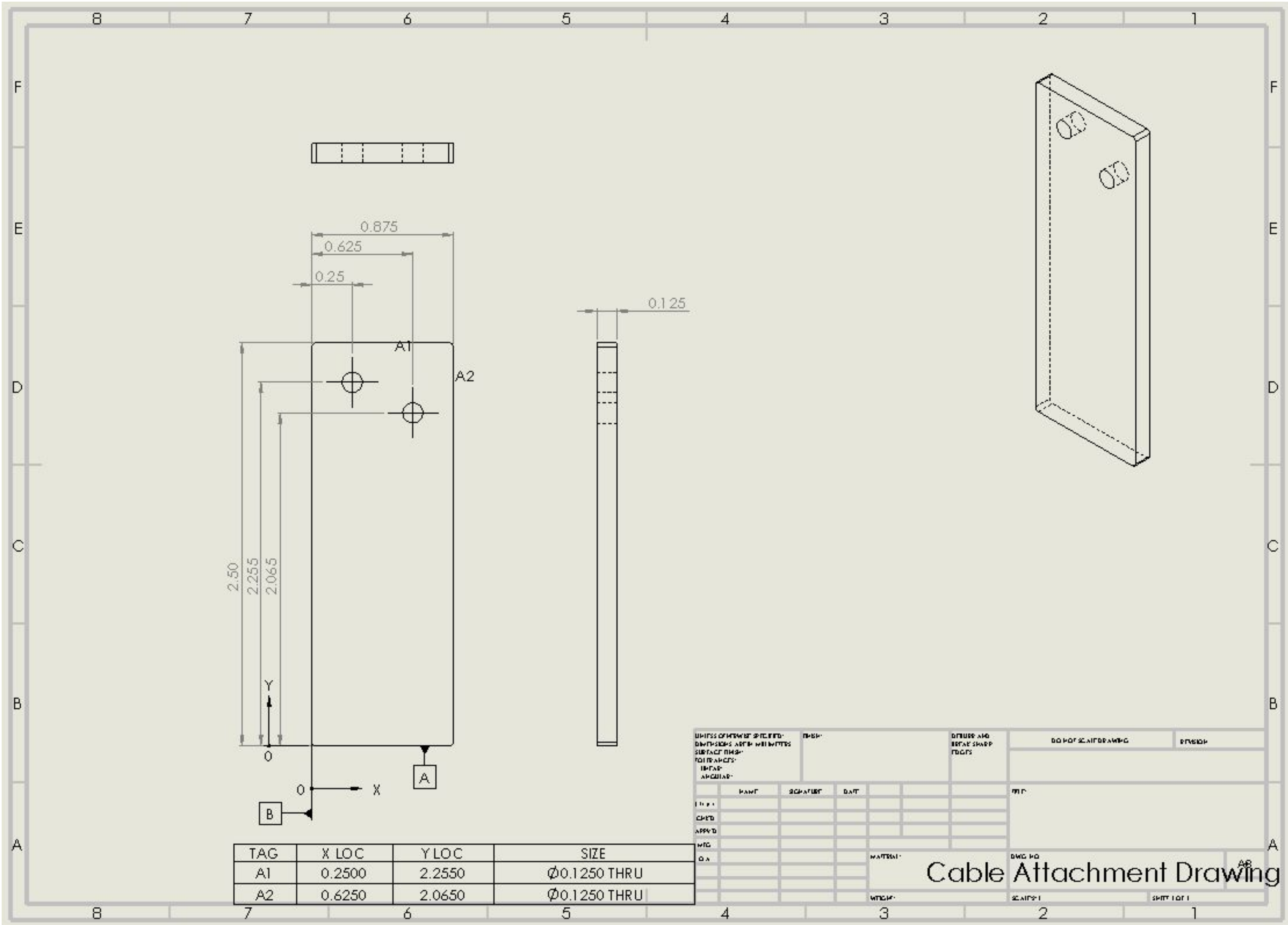
TAG	X LOC	Y LOC	SIZE
A1	0.1250	0.4750	Ø0.1250 THRU
A2	0.3750	0.4750	Ø0.1250 THRU
B1	0.2500	0.2500	Ø 0.2010 ↧ 0.6500 1/4-20 UNC - 2B ↧ 0.5000
B2	0.2500	0.6875	Ø 0.2010 ↧ 0.6500 1/4-20 UNC - 2B ↧ 0.5000

TITLE: Cable Bracket - Handle v2

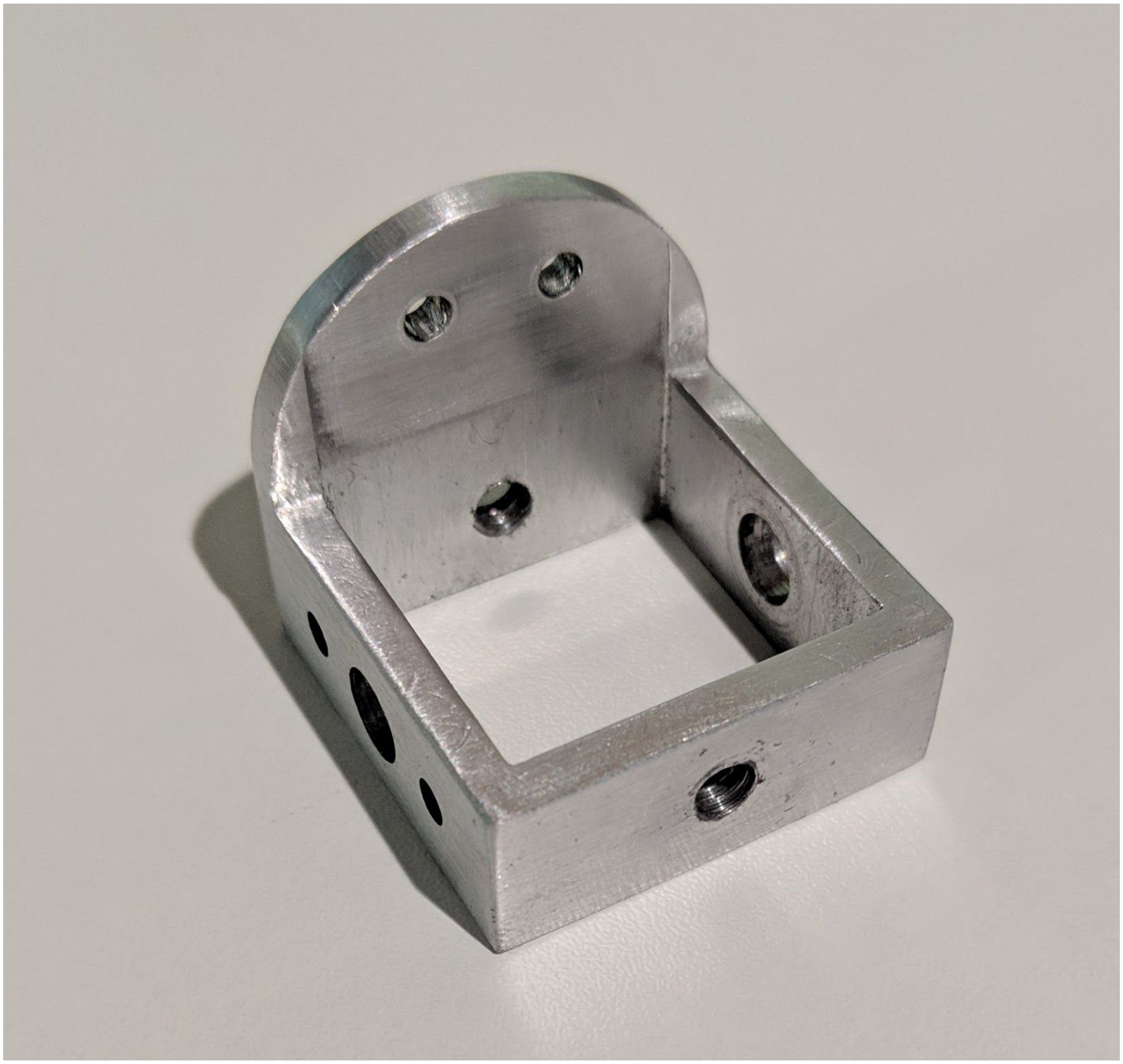
MATERIAL: 1/16inch 7075 Treated Flat Stock

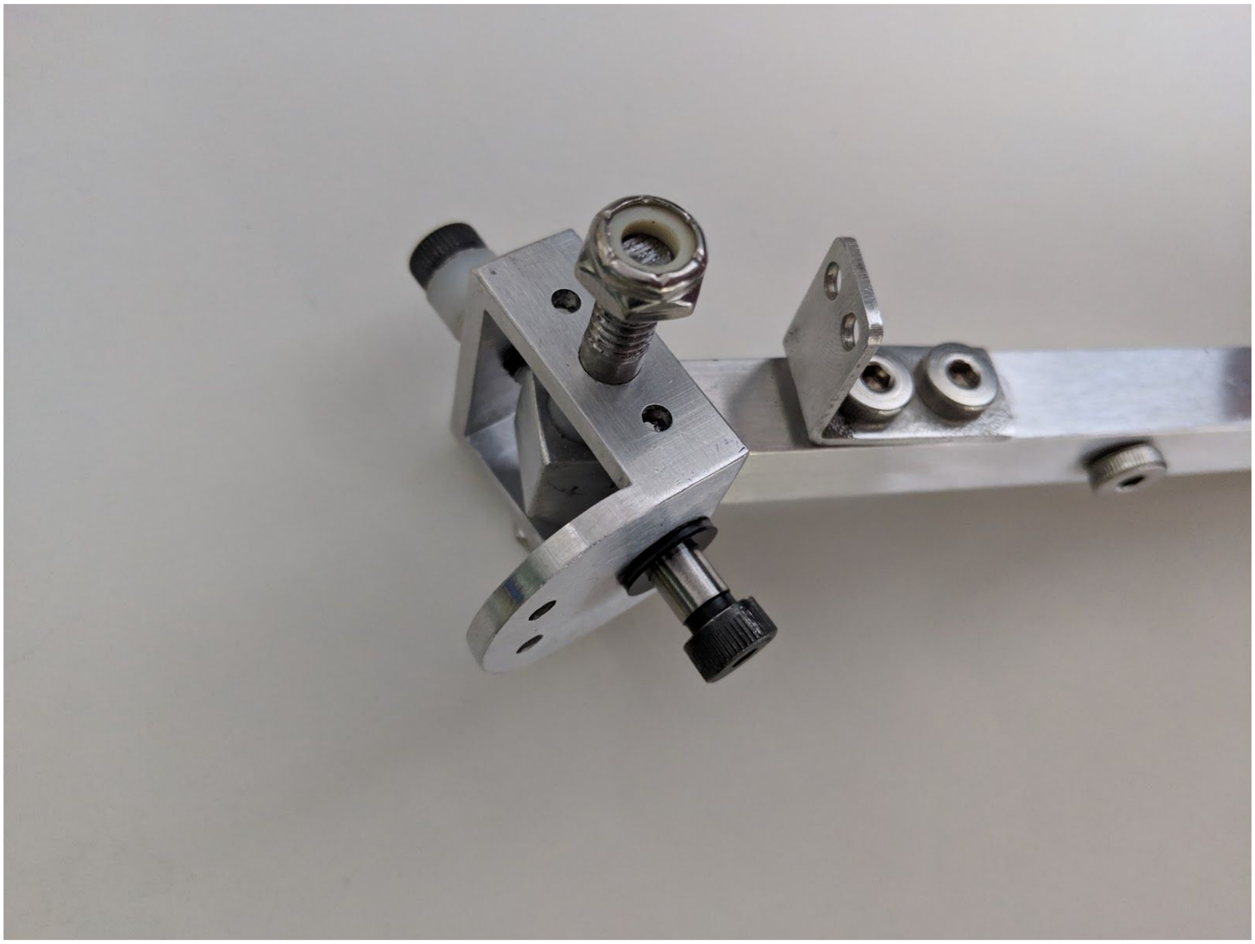
DWG NO. 421-9

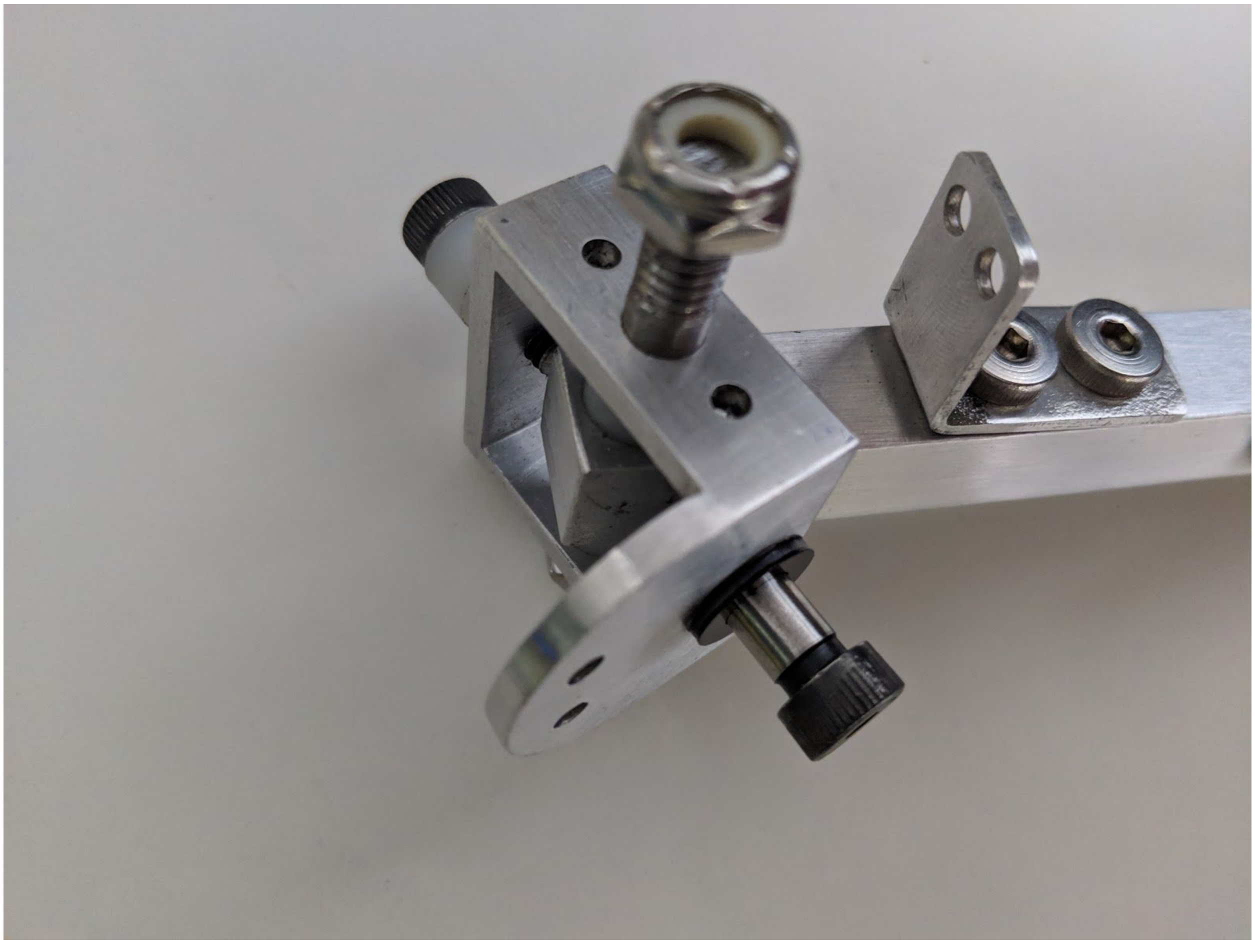
A3

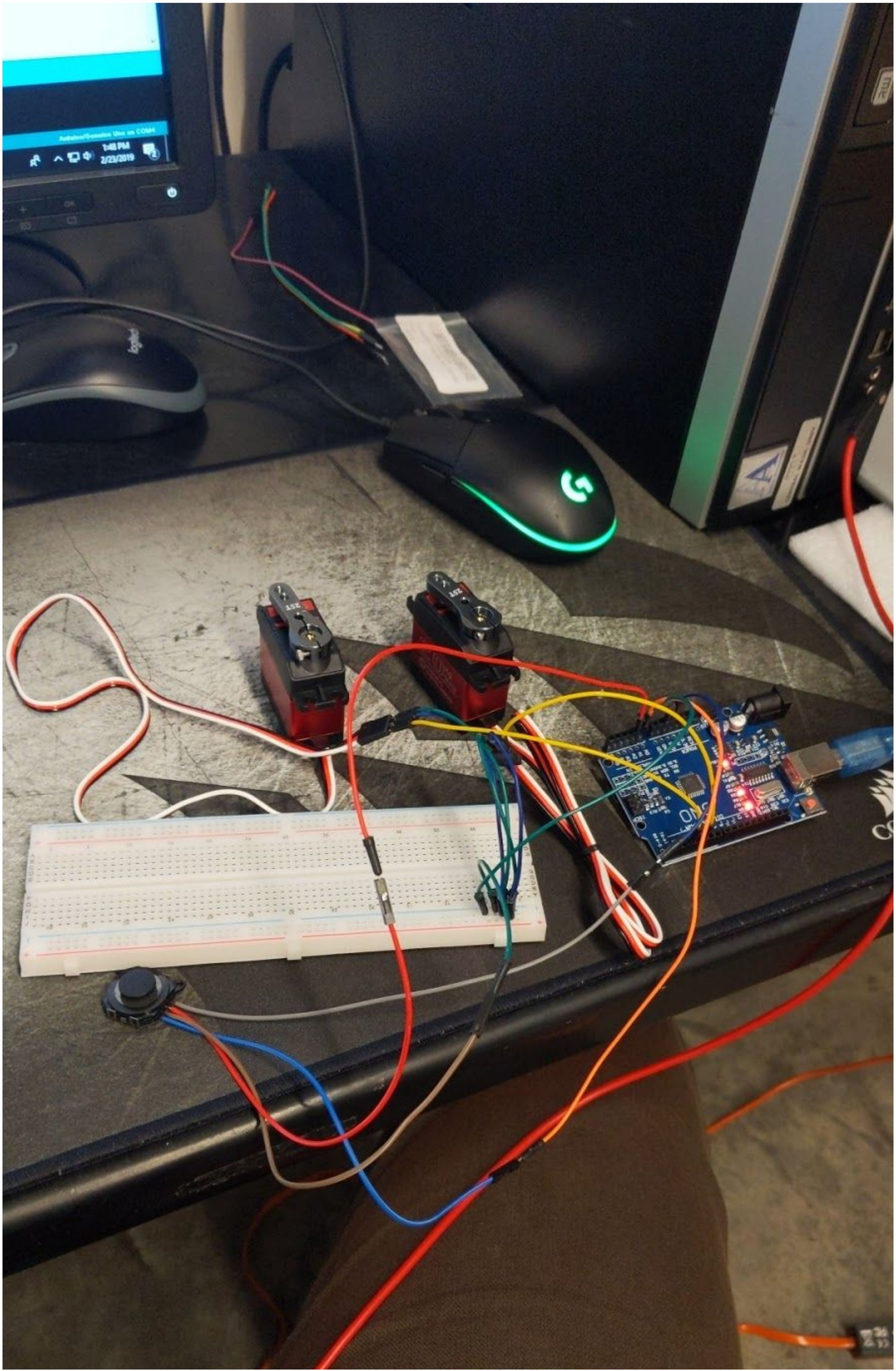


TAG	X LOC	Y LOC	SIZE
A1	0.2500	2.2550	Ø0.1250 THRU
A2	0.6250	2.0650	Ø0.1250 THRU

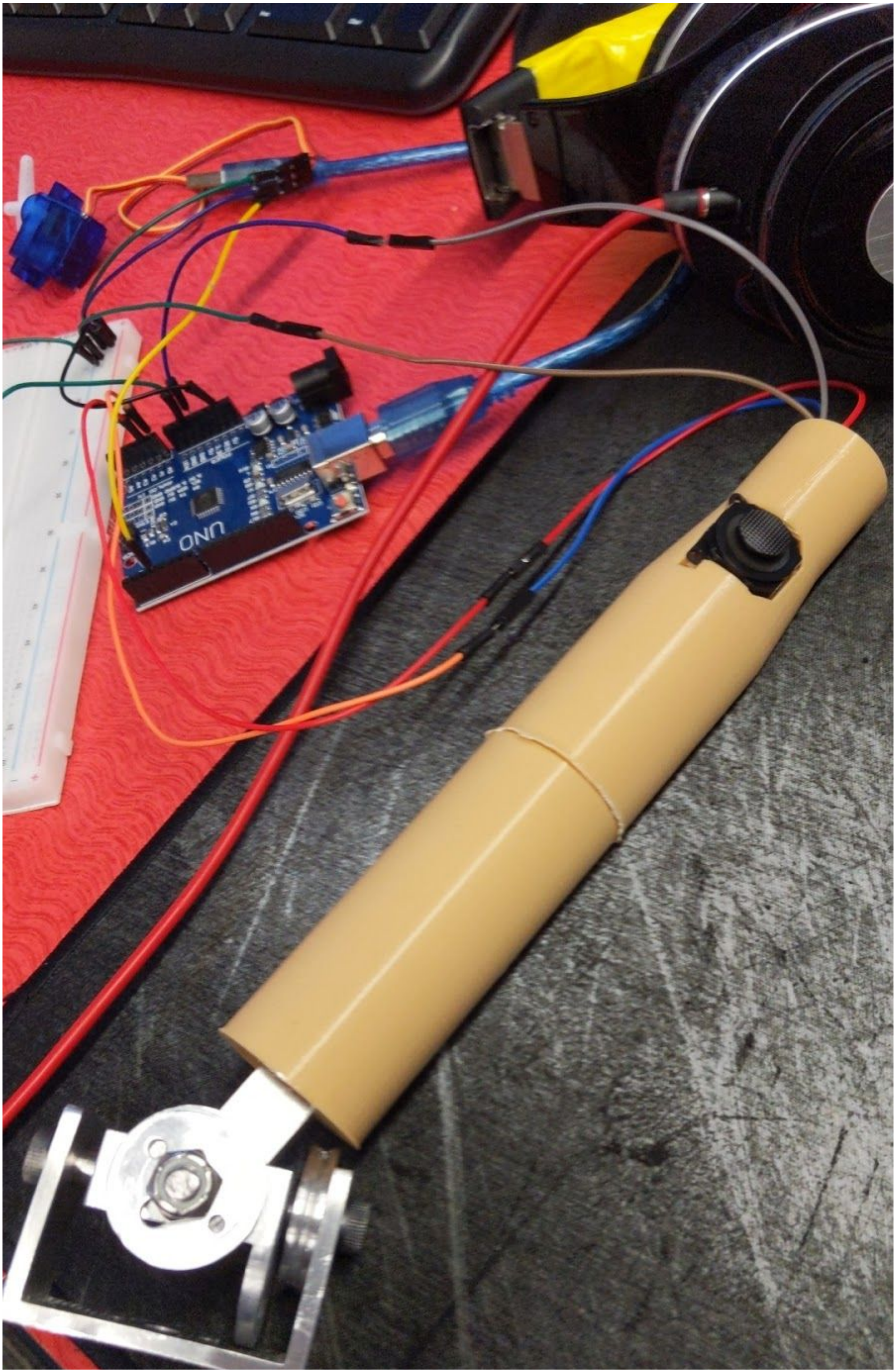


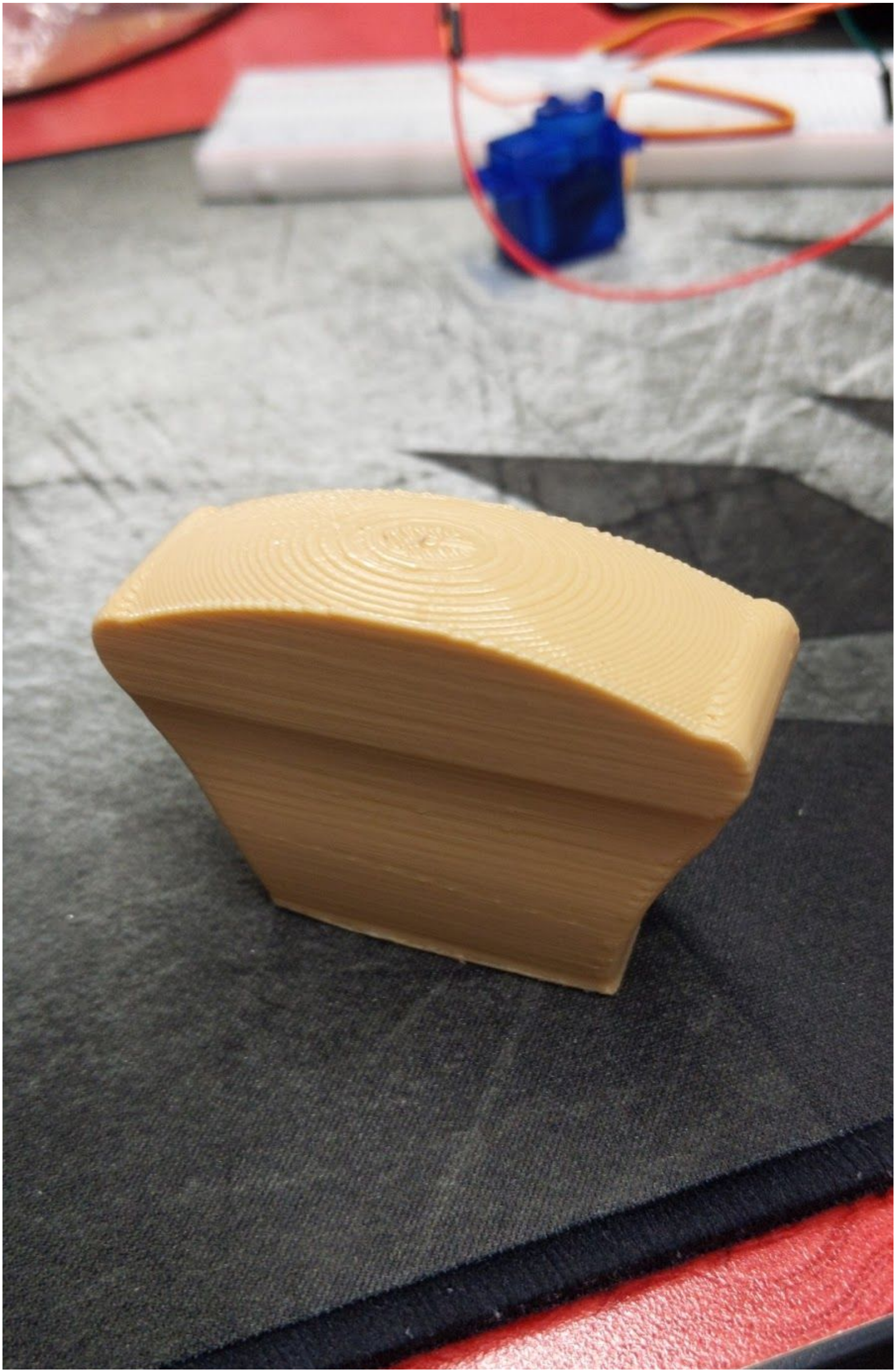


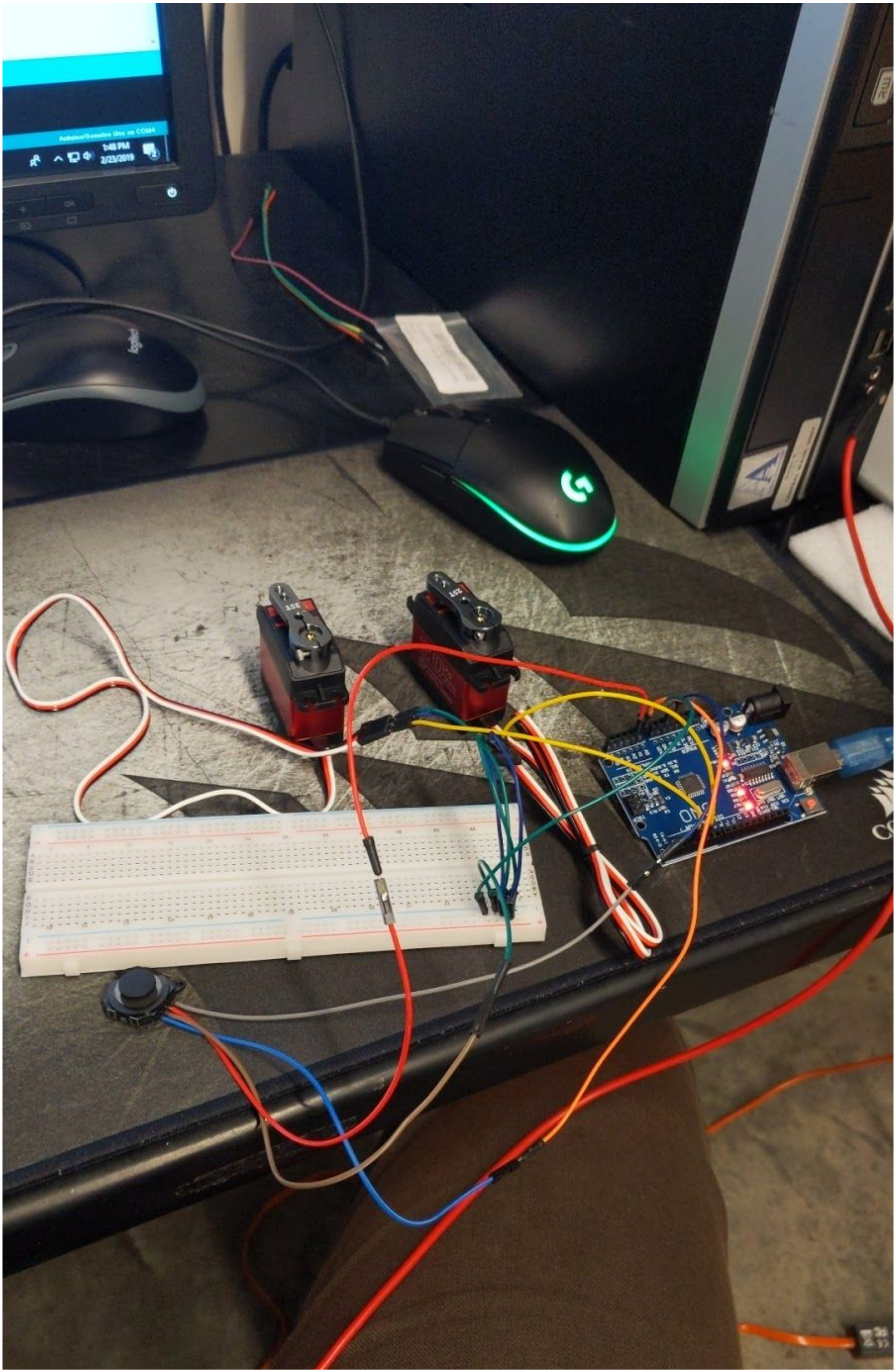


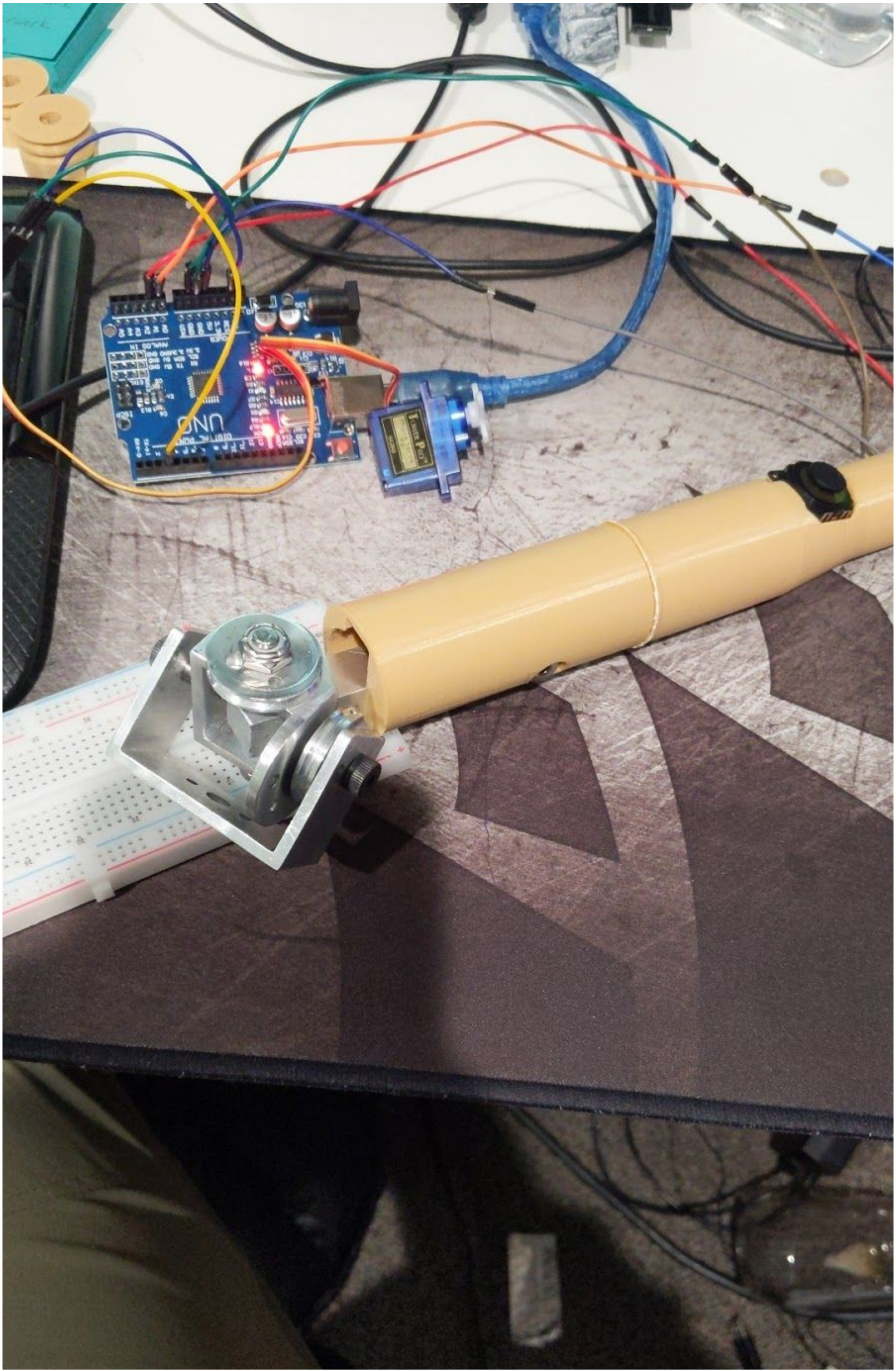


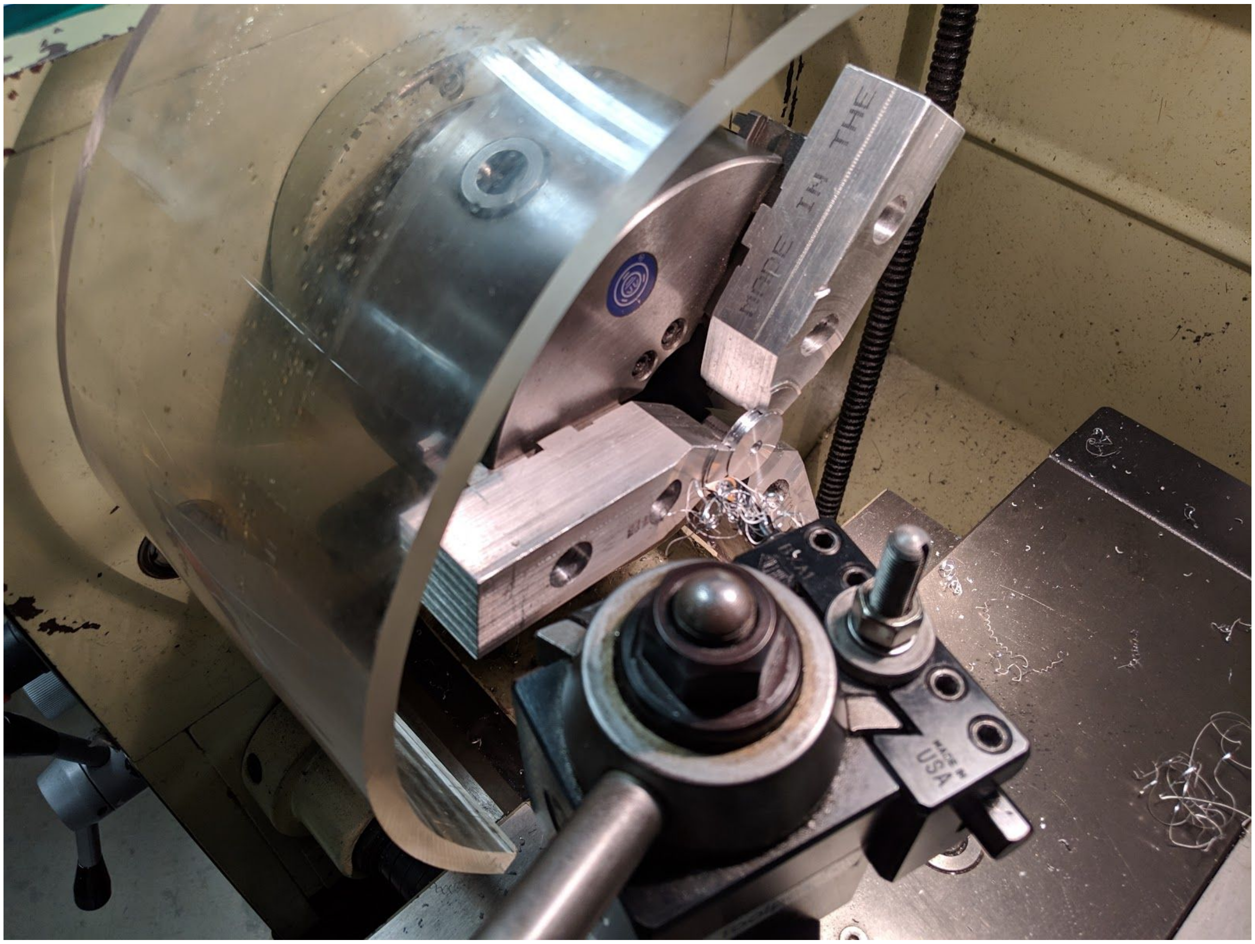
2/23/2019

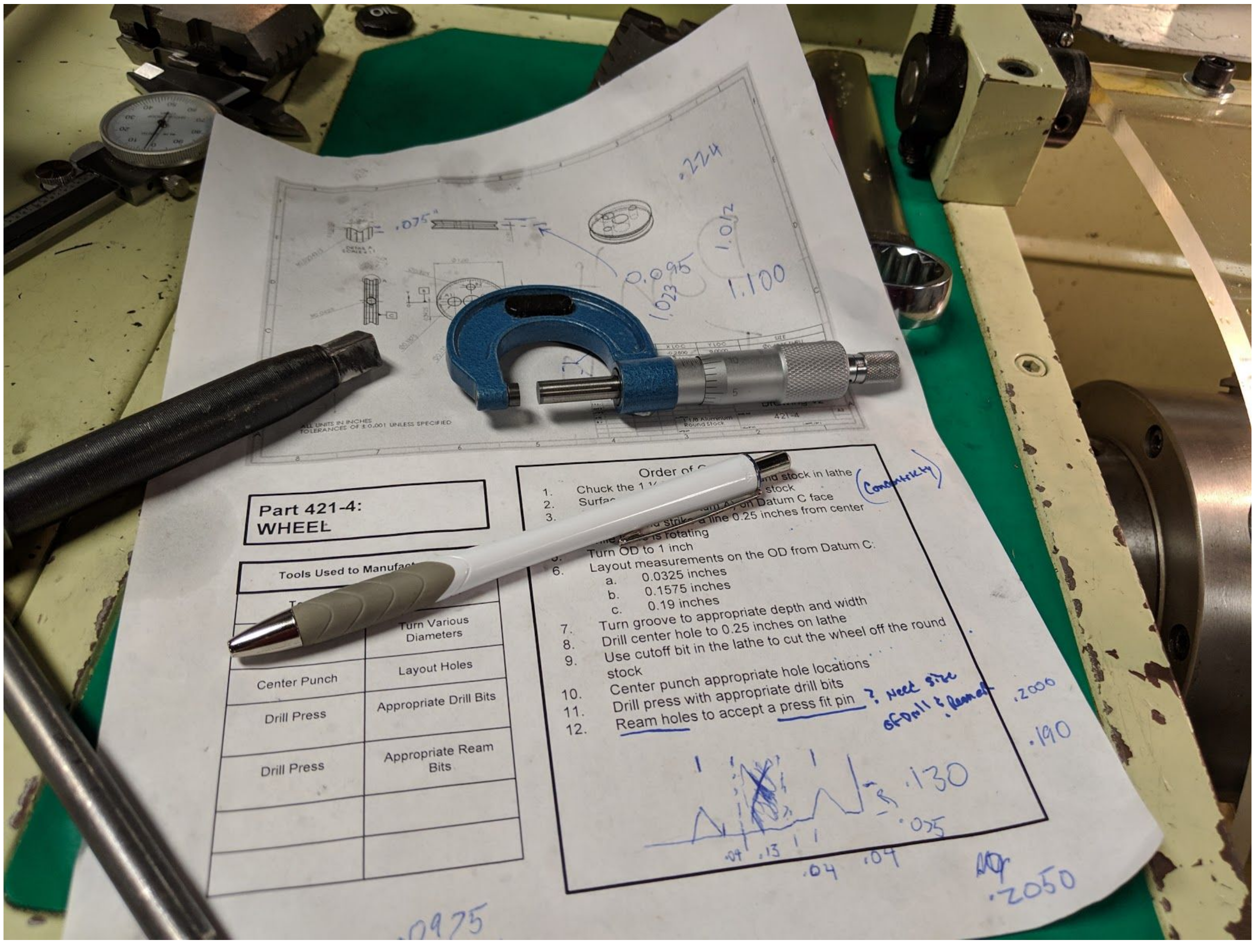

UNO

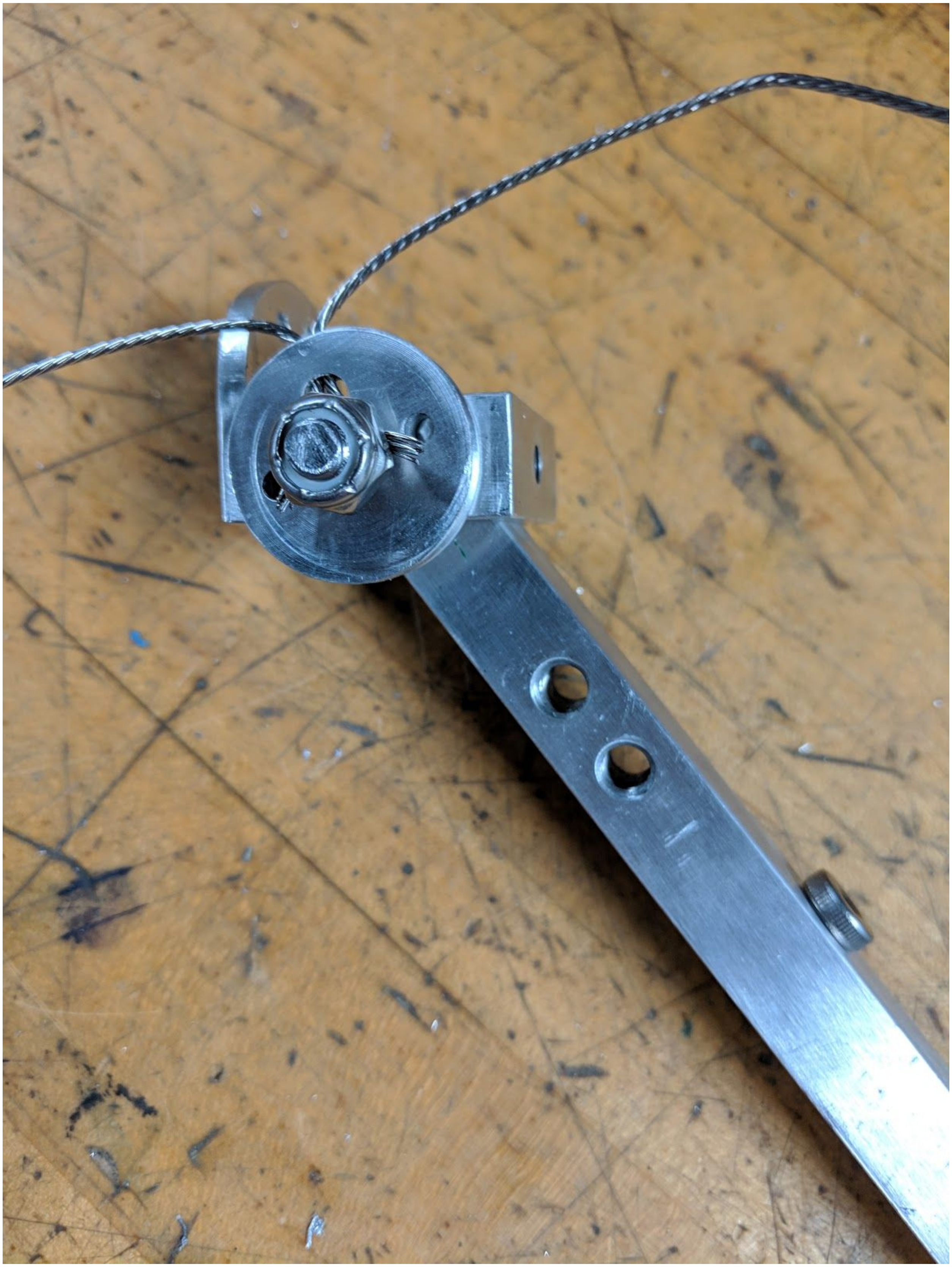


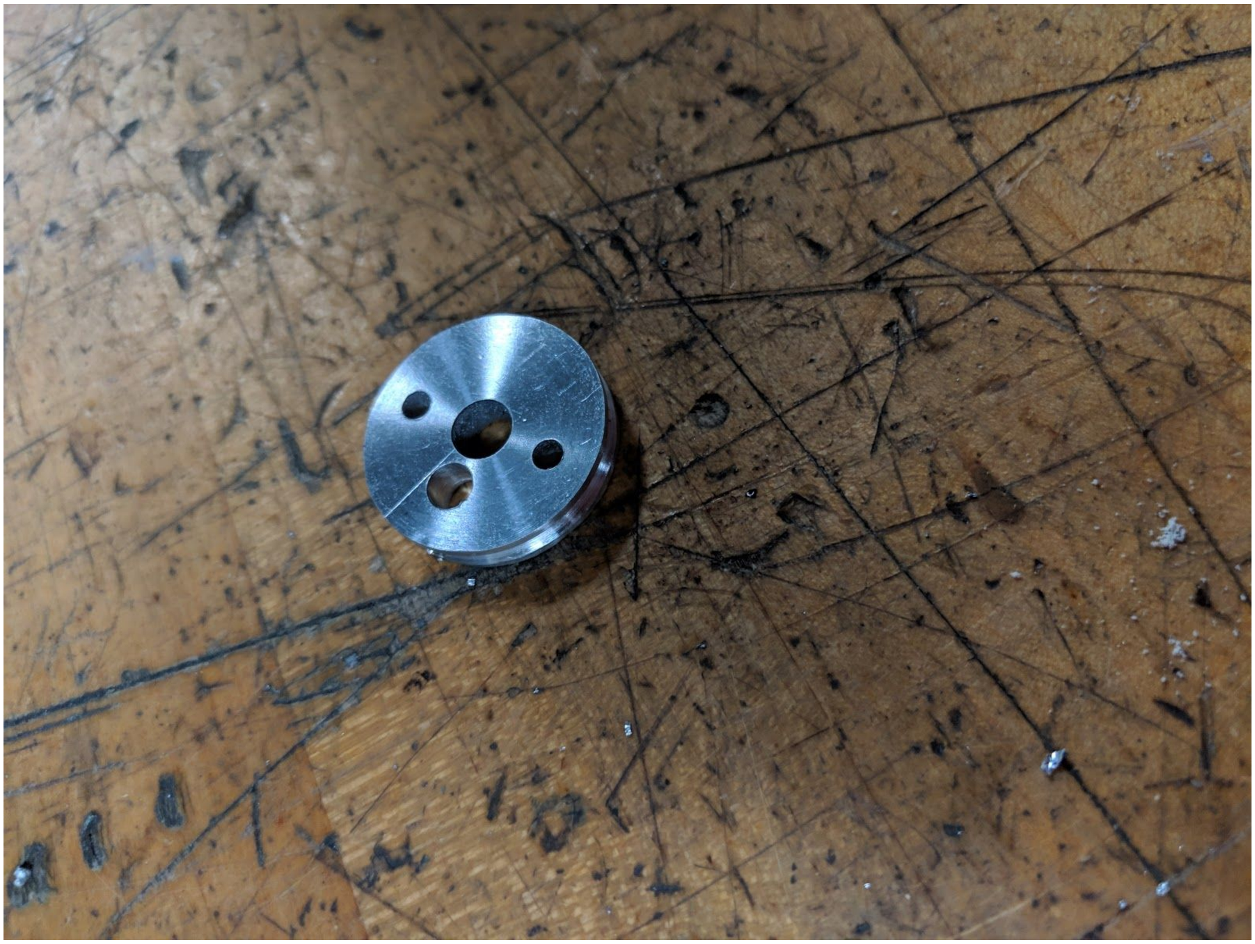


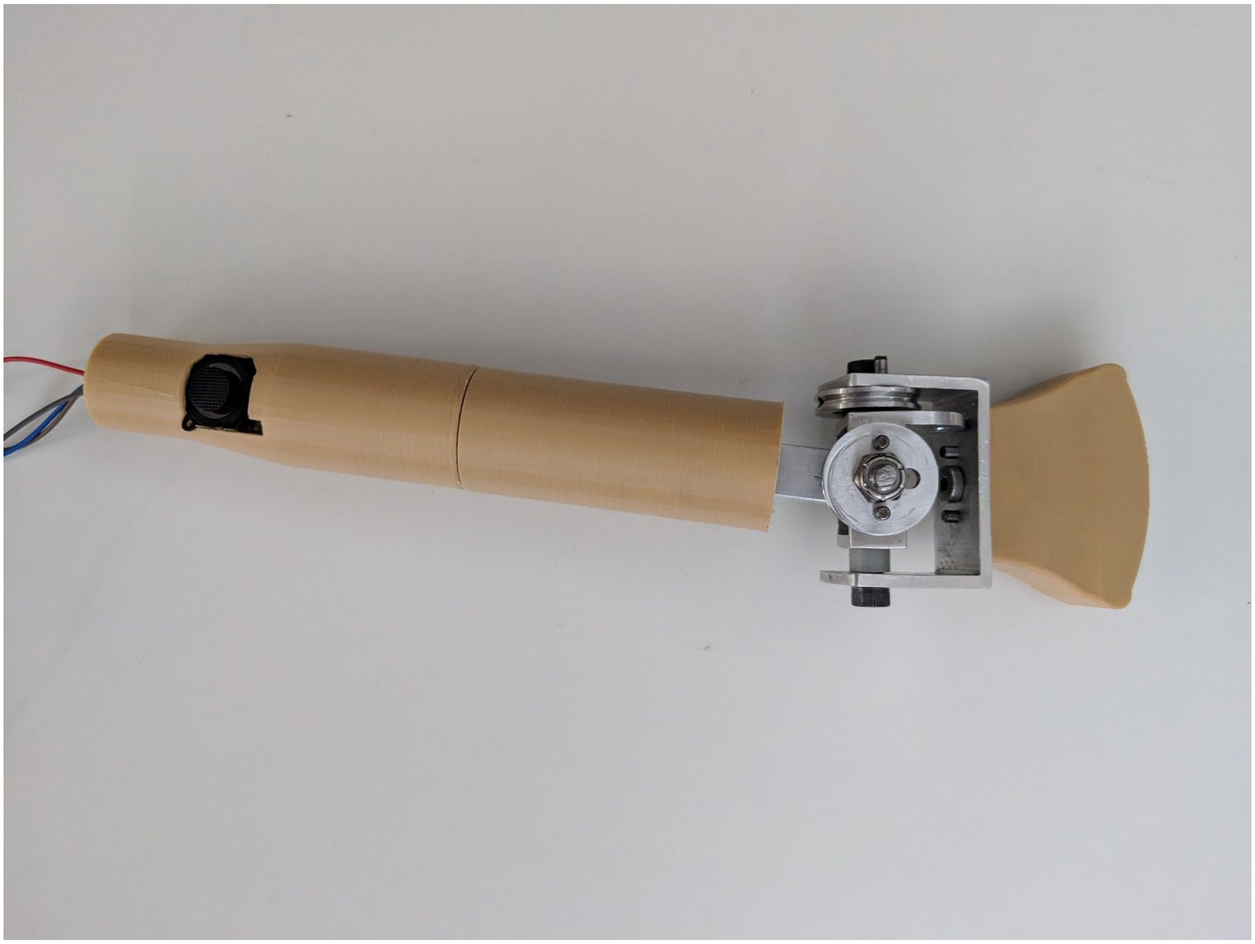


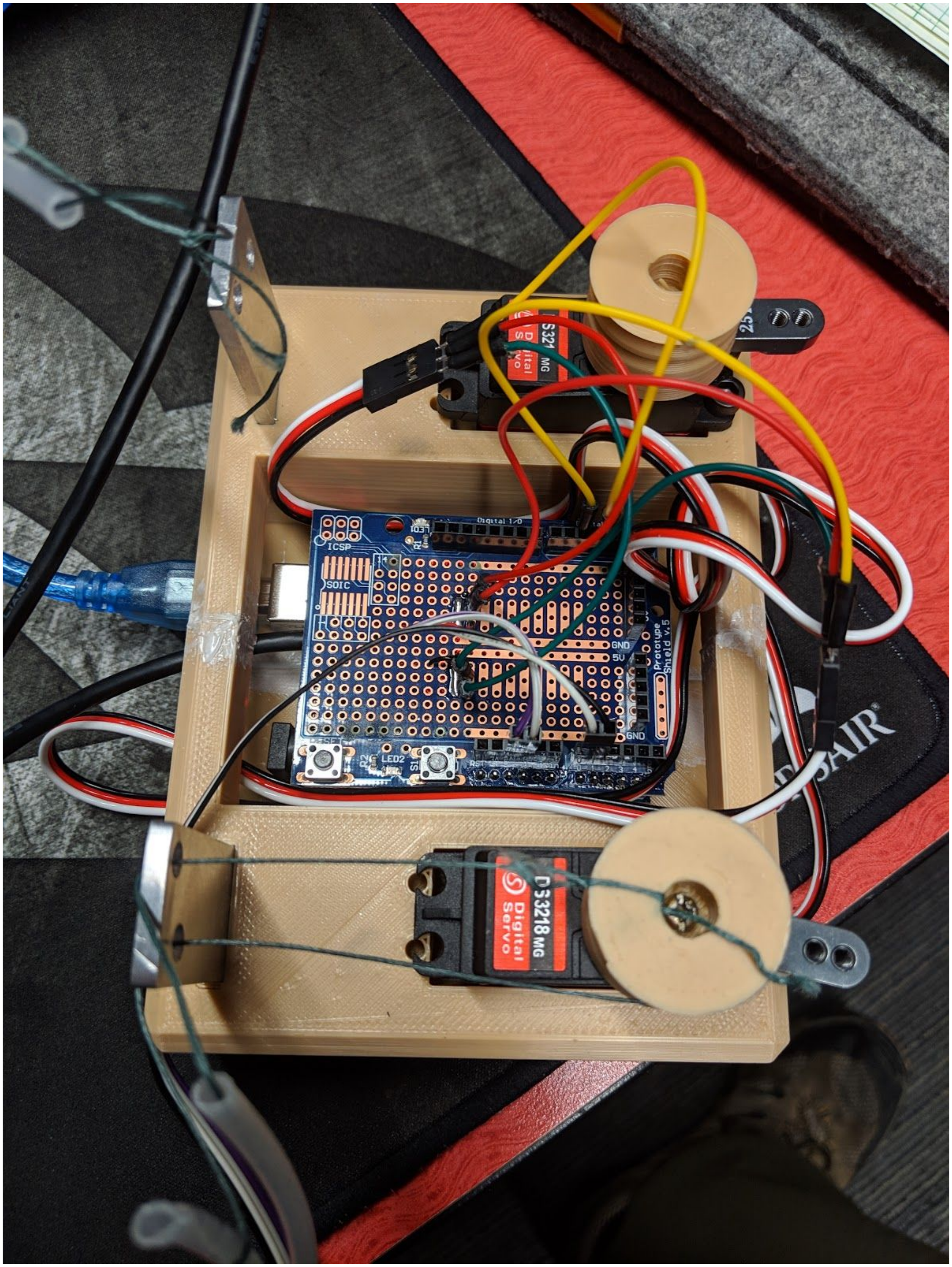

USA


Part 421-4:
WHEEL
Tools Used to Manufacture
Turn Various Diameters
Center Punch
Layout Holes
Drill Press
Appropriate Drill Bits
Drill Press
Appropriate Ream Bits
Turn OD to 1 inch
6. Layout measurements on the OD from Datum C:
a. 0.0325 inches
b. 0.1575 inches
c. 0.19 inches
7. Turn groove to appropriate depth and width
8. Drill center hole to 0.25 inches on lathe
9. Use cutoff bit in the lathe to cut the wheel off the round stock
10. Center punch appropriate hole locations
11. Drill press with appropriate drill bits
12. Ream holes to accept a press fit pin
ALL UNITS IN INCHES
.075"
.224
0.095
1.100
.2000
.190
.130
.2050








DS3218 MG
Digital Servo
ICSP
SOIC
GND
5V
GND
Prototype Shield v.5

Appendix C - Parts List

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	421-1	mounting stock v2	1
2	421-2	Mid Bracket v2	1
3	421-3	Top Bracket v2	1
4	421-4	wheel v2	2
5	421-5	Washer	1
6	421-6	Bushing	3
7	421-7	Shoulder Bolt	2
8	421-8	Through Rod v2	1
9	421-9	handle cable bracket v2	1
10	421-10	Top Threaded Rod v2	1
11	421-11	Wheel Pin	4
12	421-12	Mock Transducer	1
13	97367A113	Lock Nut	2
14	93615A410	Bracket Handle Bolt	2

Appendix D - Budget

PARTS AND BUDGET								
SonoSafe Ultrasound Probe								
ITEM ID	ITEM Description	Item Source	Brand Info	Model/SN	Price/Cost (US Dollars) ($ / Hour)	Quantity (or Hours)	Cost: Subtotals	Actuals $
1	Nylon Tube	McMaster-Carr		8628K51	$5.31			$5.31
2	Nylon Washer	Amazon		14973171223	$9.49			$9.49
3	Self Locking Wormgear	Amazon	Uxcell		$34.99	2		$69.98
4	Aluminum 2 in. C-Channel	Grainger	Granger Approved	6ALY4	$18.30			$18.30
5	Aluminum 1 1/4 in. Square Tube	Grainger	Granger Approved	6ALP9	$5.35			$5.35
6	Aluminum Bar Stock	Grainger	Granger Approved	6ALL9	$11.35			$11.35
							Total:	$119.78

Appendix E- Schedule

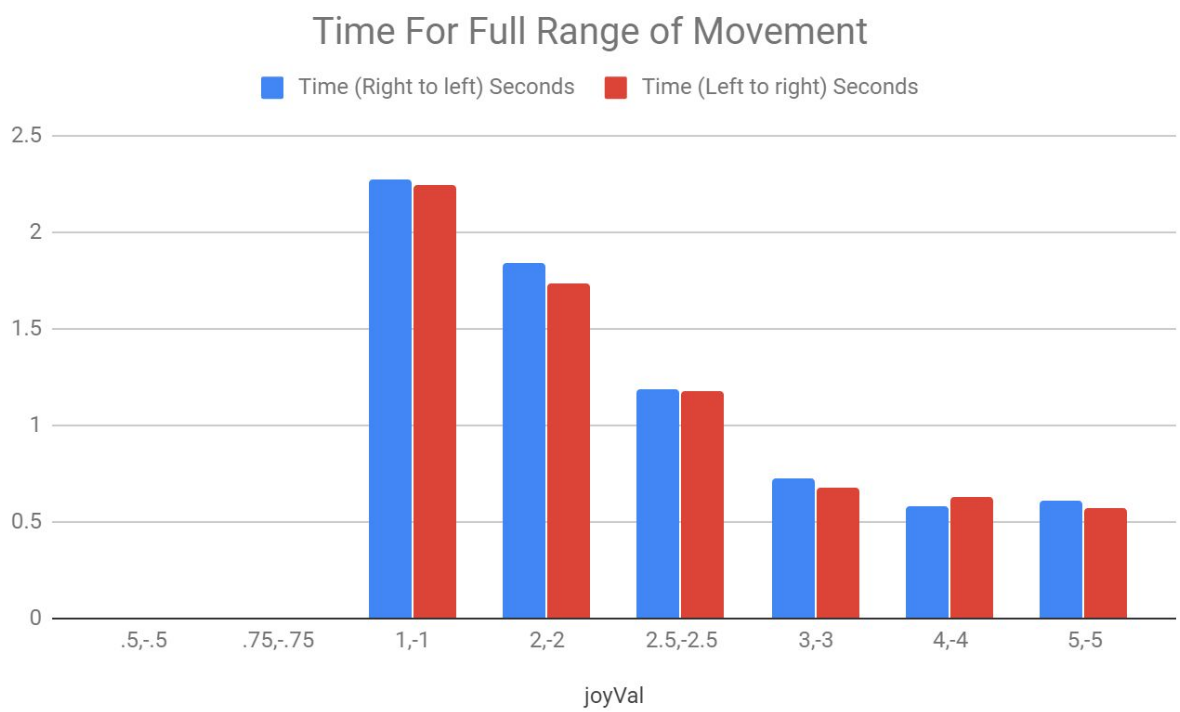
Estemated Duration (Hours)	Actual Duration (Hours)	Task	Task Number
		Fall Quarter	
		Proposal	
3	5	Introduction	F1
2	2	Outreach Summary	F2
60		Design & Analisys	F3
40		Methods & Construction	F4
40		Testing	F5
20	15	Budget/ Schedule/ Project Manegment	F6
20		Discussion	F7
5		Conclusion	F8
3	1	Acknowledgements	F9
45	14.5	Appendix A (Green Sheets)	F10
15	11	Appendix B (Drawings)	F11
3	4	Appendix C (Parts List)	F12
3	3	Appendix D (Budget)	F13
3	3	Appendix E (Schedule)	F14
2	3	Appendix J (Safety)	F15
		Analisys	
2	1	A1	F16
2	2	A2	F17
3	2	A3	F18
3	1	A4	F19
2	0.5	A5	F20
3	2	A6	F21
2	1	A7	F22
3	1	A8	F23
3	1	A9	F24
3	1	A10	F25
3	1	A11	F26
3	1	A12	F27
		Design	
1	1.5	Top Bracket	F28
1	1	Mid Bracket	F29
1	1	Transducer Mount	F30
0.5	0.5	Pins	F31
2	1	Wheels - Bracket	F32
2	2	Line Mounts	F33
2	1	Joint to Body Mount	F34
1	1	Body	F35
		Winter Quarter	
		Construction	
		Probe Joint	
5		Finalize SolidWork Files	W1
3	8	Redesign	W2
3		Purchase Stock	W3
10		**Machine**	
1	4	Machine 421-1 (Mounting Stock)	W4
1	4.5	Machine 421-2 (Mid Bracket)	W5
1	0.5	Machine 421-7 (Soulder Bolts)	W6
1	1	Machine 421-8 (Through Rod)	W7
1	4	Machine 421-9 (Handle Cable Bracket)	W8
1	0.3	Machine 421-10 (Top Threaded Rod)	W9
4		Machine 421-3 (Top Bracket)	W10
6		Machine 421-4 (Wheel)	W11
1		Install Wheels - Motor	W12
1		Install Wheels - Bracket	W13
1		Install Pins	W14
1		Print Probe Handle	W15
		Print Probe Head	W16
		Controll System	
2		Purchase Servos	W17
2		Purchase Line	W18
1		Purchast Arduino	W19
1		Print Motor Mount	W20
2		Manufacture case	W21
1		Solder Joystick	W22
1		Install Servo Wheel	W23
10		Program and Troubleshoot Arduino	W24
		Spring Quarter	
		Testing	
5		Function Test	
5		Weight Test	
5		Modifications	

Appendix - G Testing Data

Time Trial Coding Test 1					
joyVal	Time (Right to left) Seconds	Time (Left to right) Seconds	Observations		joyVal = the value the code adds during each loop to determine the position of the servo
.5,-.5	~	~	Only moved right for home		
.75,-.75	~	~	Only moved right for home		
1,-1	3.1	3.1	Seems to chug along too slow		
2,-2	1.84	1.73	closest to time requirement, good servo sound pitch		
2.5,-2.5	1.47	1.23	One way faster than the other		
3,-3	1.33	1.42	a little too fast for operation		
4,-4	1.09	1.1	Similar to 4 in speed, higher pitch servo		
5,-5	1.15	1.06	too abrupt/ choppy movement		

Time Trial Coding Test 2			
joyVal	Time (Right to left) Seconds	Time (Left to right) Seconds	Observations
.5,-.5	~	~	Only moved right for home
.75,-.75	~	~	Only moved right for home
1,-1	2.27	2.24	Seems to chug along too slow
2,-2	1.84	1.73	closest to time requirement, good servo sound pitch
2.5,-2.5	1.19	1.18	with load better JoyVal
3,-3	0.72	0.68	a little too fast for operation
4,-4	0.58	0.63	Similar to 4 in speed, higher pitch servo
5,-5	0.61	0.57	too abrupt/ choppy movement

Appendix - H Data Evaluation



```
//code Library
  #include <Servo.h>

  //define servos
  Servo servo1;
  Servo servo2;

  //define joystick pins (analog)

  int joyX = 0;
  int joyY = 1;
  int joySumX = 90;
  int joySumY = 90;

  //Variables to read the values from the analog pins

  int joyVal;



void setup() {
// put your setup code here, to run once:

// attach servo pins PWM 3-5
servo1.attach(3);
servo2.attach(5);

}

void loop() {
```

```
  // put your main code here, to run repeatedly:
joyVal = analogRead(joyX); // read values of the joystick (between 0-1023)



if (joyVal < 341) {
  joyVal = -2;
}
else if (joyVal < 641) {
  joyVal = 0;
}
else {
  joyVal = 2;
}



joySumX += joyVal;  // adding joyVal to joySumX and updating to new total

if (joySumX > 180) {        //upper limit of servo value
  joySumX = 180;
}
else if (joySumX < 0) {     //lower limit of servo value
  joySumX = 0;
}
else {
}
servo1.write(joySumX); // set servo position according to updated joystick value
```

```
joyVal = analogRead(joyY);

if (joyVal < 341) {
  joyVal = -2;
}
else if (joyVal < 641) {
  joyVal = 0;
}
else {
  joyVal = 2;
}

joySumY += joyVal;  // adding joyVal to joySumY and updating to new total

if (joySumY > 180) {        //upper limit of servo value
 joySumX = 180;
}
else if (joySumY < 0) {     //lower limit of servo value
joySumY = 0;
}

servo1.write(joySumY); // set servo position according to updated joystick value

delay(15);

}
```

Appendix- I Testing Report

Test Report

Introduction

The current ultrasound probes used in hospitals today use the same design produced in the mid 90s. Ultrasound probes consist of a transducer at the end of a handle. To perform an exam, an ultrasound technician (sonographers) must manipulate the probe at the wrist. To produce a clear image, the technician must apply pressure against the patient at different angles. Due to the extensive rotational movement and pressure the wrist takes when scanning a patient with an ultrasound probe, there is a high rate of carpal tunnel and other wrist injuries in sonographers. This new ultrasound probe will take the rotational movement out of the technicians wrist and isolate the rotational movement to the probe. This rotational movement is achieved by a swiveling transducer head. The majority of the construction was conducted using the machine shop as well as the Senior Project Lab in Hogue Hall at Central Washington University. The probe must withstand up to 40 pounds of vertical force from the grip to the head of the probe. The head must also perform the full range of movement in less than 2 seconds. Different sized pulley wheels and programed speeds are tested to achieve these operation standards.

Overview

For testing a basic system functionality performance test was performed. The intention was to get the system up and running as well as testing the reliability of the code added to the arduino. The arduino ecosystem was used to code two servos to perform the movements needed to drive the probe head. The test was isolated to one axis of the joystick and one servo. How the system works is the user uses a joystick that sends two different signals dependant on the position of the joystick in the x and y position. The values from the joystick is send to an arduino which then interprets the values that determines the position of the servos. The arduino code that was used to interpret the inputs from the joystick can be found below. For this test the ‘joyVal” value was the changed variable. The “joyVal” variable dictates the speed at which the servo turns. The higher “joyVal” is, the faster the servo turns. In this initial test it was found that the servo would top out when “joyVal” was around 4. The servos couldn’t move much faster than that value. The optimal speed of the servo when no load was applied was when “joyVal” = 2.

Setting

This test will be performed in the materials lab at Central Washington University on April 9th, 2019. The duration of the test will take 3 hours including setup time.

Resources

A few resources will be needed in this test. Line will be needed to hang weight off the end of the probe head. The probe will also have to be mounted to a table so a special bracket must be made to hold the unique shape of the probe. Weights will also be needed to to test the strength of the probe.

Appendix J - Safety Job Hazard Analysis

JOB HAZARD ANALYSIS
Forming Middle Bracket to Specifications

Prepared by: Christian Barrett	Reviewed by: Approved by:

Location of Task:	Hogue Machine Shop
Required Equipment / Training for Task:	Machine Shop PPE Training: Drill Press, Band Saw, Belt Sander, Grinder
Reference Materials as appropriate:	Appendix B-2

Personal Protective Equipment (PPE) Required
(Check the box for required PPE and list any additional/specific PPE to be used in “Controls” section)

Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
☐	☐	☒	☐	☒	☒	☐

Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.

PICTURES (if applicable)	TASK DESCRIPTION	HAZARDS	CONTROLS
	Cut Square Stock to appropriate length on band saw	**Cutting Hazard**	**double check measurements, order of operations, Clamps**
	specific holes on the drill press	**Moving drill chuck**	**Use of vise grips, layout, center punch**
	Grind and smooth part edges	**nitial sharp edges from cutoff, rotating grinder, abrasion from belt sander**	**Correct training on both abrasive tools**