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Stair Climbing Hand Truck

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By

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Abstract

Getting a heavy object up a flight of stairs usually requires a team of two or more people. Even with a team of people, the task is often still difficult, dangerous, and possibly insurmountable by one person. This problem is especially prevalent in for those who are moving into apartment complexes. Most apartment complexes have many buildings with two or more floors of living quarters, and elevators are often missing. This project sought to offer a solution to this problem. The solution in question; a motorized hand-truck with 2, trigonal planar pinwheels in place of the stock wheels. The stock wheels were removed. Pillow block bearings were put in their place. These pillow block bearings are the mount for an axle shared by the two trigonal planar pinwheels. Power from a modified winch is supplied to the shared axle by way of chain drive. The two trigonal planar pinwheels also have two “foot wheels” on either side of the end of each respective arm. The “foot wheels” are such that the hand-truck can be rolled around as a normal hand-truck while on flat ground. This project was predicted to be capable of carrying heavy loads of 60-150 lbs. In testing, the final product was shown to be capable of carrying 160 lbs.

Introduction

It can be very difficult to get heavy boxes/furniture/appliances up one or more flights of stairs. This problem could be helped by a powered hand truck that could climb stairs while carrying the heavy payload.

Motivation:

Carrying heavy objects up stairs is difficult, time consuming, and potentially dangerous. Many employers enforce policy that limits the amount of weight that their workers are allowed to lift on their own. This project will allow individuals, for purposes either business or personal, to move payloads up stairs on their own with ease.

Function Statement:

A device is needed to assists a single person in moving heavy payloads, of between 60 to 150 lbs, up stairs.

Requirements:

The powered hand truck

- Must be able to lift 70kg (about 150 pounds) up a flight of stairs
- Lifting must take no longer than 5 seconds per step to climb.
- The apparatus itself must weigh no more than 100 lbs.
- Any load bearing structures must have a safety factor of 1.5 or greater.

Scope:

Will include:

-Structural design of "pinwheels"
-Design of Pinwheels to mount wheels
-Foot wheel selection
-Design of foot wheel axles
-Selection of appropriate drive motor
-Design of motor mounting apparatus
-Design of drive axle
-Design of drive train
-Manufacturing of parts
-Modification of parts

Benchmark:

Wesco makes a powered stair climbing hand truck that works with hydraulic pistons. It has to push up with pistons one step at a time, and then retract for the next step. The wesco hand truck climbs at about 4.5 seconds per step. Beating the speed of this product would be a great bonus, but the goal is to get in the same ballpark at 5 seconds or less per step.

Success Criteria:

This project will be considered a success when:

-The powered hand truck climbs up the stairs with a load of 60 -150 lbs

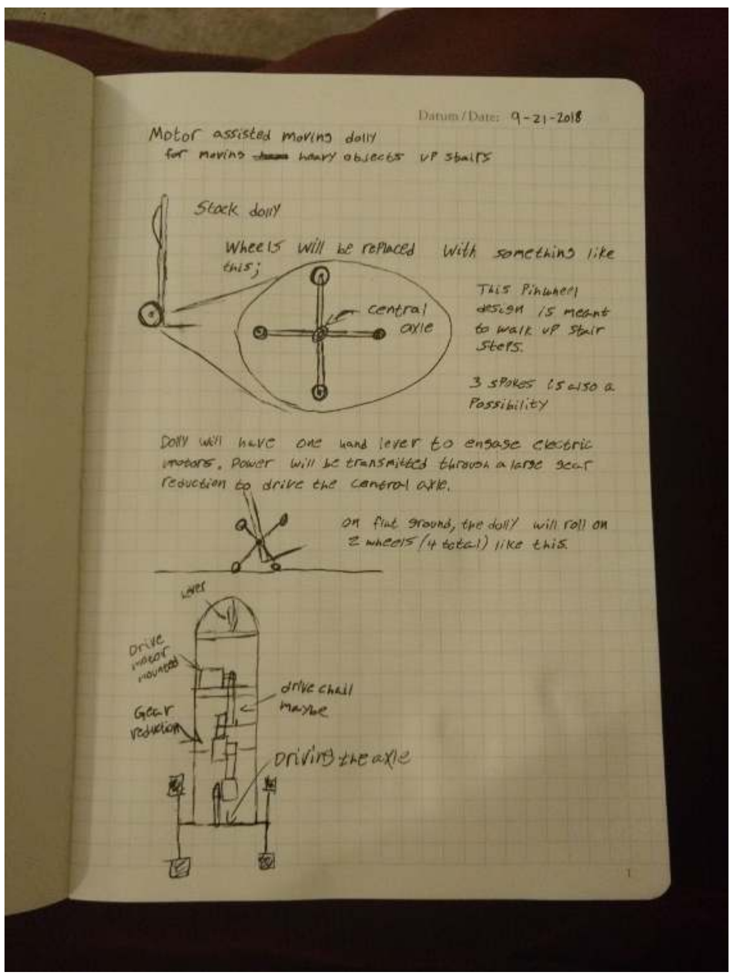
-The powered hand truck climbs with the appropriate load at a speed no slower than 5 seconds per step

-The powered hand truck performs its function without showing visible or audible signs of strain

DESIGN & ANALYSIS

This project was conceived over dinner. While looking for an appropriate project the thought process went something like this.

-Mechanical devices provide mechanical advantage.
-Mechanical advantage would be very helpful when trying to move heavy objects.
-It is very difficult to move heavy objects up stairs.
-Hand trucks are usually used to provide mechanical advantage.
-This project should be the engineering and creation of a hand truck capable of assisting the user in moving heavy objects up stairs.



This is a photo of the original conception.

Engineering Merit

-Design with CAD software

-This report includes a full drawing package in APPENDIX B. This drawing package includes multiple exploded view assembly drawings, and complete tolerancing. All drawing were made from 3D models designed, and validated with virtual assembly, in SolidWorks. These drawings were effectively used as reference in the machine shop during the manufacturing of this project.

-Manufacturing methods

-This project has required the use of several different manufacturing and fabrication methods.

-The Pinwheels were design in CAD, then exported to and cut on a CNC plasma routing table.

-The control housing was designed in CAD, and 3D printed with a personal fused deposition modeling printer.

-Conventional machining tools were used to fabricate many other parts including the shaft, winch bracket, winch spacer, and pillow block mounting brackets.

All these different methods require their own unique design consideration.

-Finite Element Analysis

-The design of the pinwheels was validated using finite element analysis

-Power Transmission

-This whole project hinged on getting power and torque to the main shaft. This required many hours of research and shopping to find a capable and affordable motor.

-Chain drives come with their own challenges. The chain must have sufficient tension. The spockets must match the chain.

-Reverse engineering

-This project consists of many of the shelf parts that were modified and put together. To make this happen, parts were taken apart, measured, modeled, and then cut. The control housing in particular, was designed for additive manufacturing after careful measurement of the original handheld control housing.

-Creative Part Selection

-This whole project depended on finding an affordable motor that is capable of producing enough torque to enable proper function of the system. Many options were considered for this project. All of the standard options proved far too expensive for this project. In the end, an affordable 2,000 lb winch was selected, purchased and modified. This solution made the whole project possible.

-Strain Gauge Testing

-The Strain values in the pinwheels, predicted with finite Element analysis, was tested after construction with strain gauge methods. This includes, surface finishing, chemical cleaning, glueing, wiring, careful soldering, and the operation of a strain gauge monitor.

All formal calculations and analyses are listed in Appendix A.
These calculations/analyses include a look at many parts of the design including Stress,energy,power,voltage etc.
All analyses include a brief narration of the significance of what is shown.
Assembly Drawing and all other drawings are included in Appendix B.

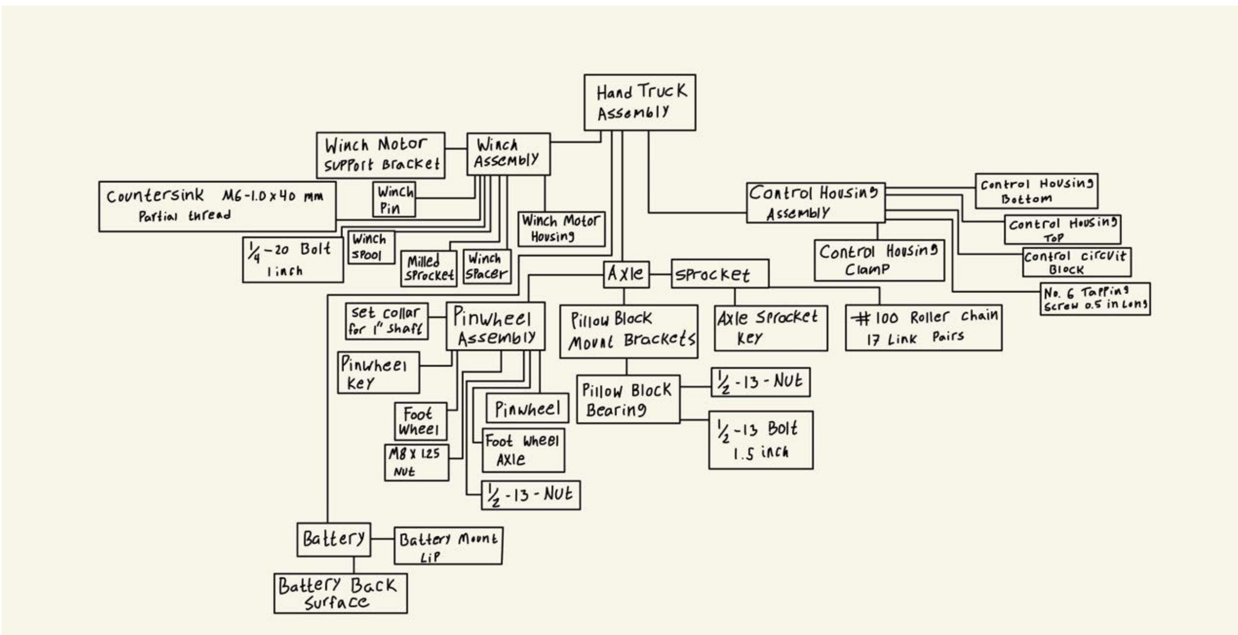
Solutions to Issues Found in Testing

Before any formal tests were done, a general function test was performed. The goal of this test was to make sure that, 1) The winch motor turns the shaft, 2) The machine can carry its own weight up the steps. The winch motor transferred power to the main shaft with no problem. However, when the machine's ability to carry its own weight was tested, it worked fine, but the frame quickly developed a significant bend in the piece of flat bar on which the driving winch motor was mounted. (Shown in picture below) To fix the bending issue, a piece of ¼" thick angle iron was cut, and clamped to the bent material to straighten it out. That same piece of angle iron was then welded to the previously bent material to strengthen the mounting point and prevent future bending. (Shown in picture below)

METHODS & CONSTRUCTION

This project was conceived, and completed at Central Washington University. The CWU facilities, equipment and resources will be used. A “donor” hand truck was purchased, and that hand truck was modified. The stock wheels were removed and replaced with two of the pinwheels depicted in Appendix B. The pinwheels are connected to, and turned by a shared axle, that is connected to a winch by chain drive. This shared axle is attached by mounted bearings, which are bolted to 2 mounting brackets, which are welded to the frame of the hand truck. An on-board motorcycle battery powers the winch.

Parts/Drawing Tree



All parts that have been manufactured or modified for this project each have their own drawing. Unaltered store bought parts do not.

Assembly drawing and all other drawings are included in Appendix B.

-HandTruck

The hand truck comes stock with an axle and mounting bracket. The mounting bracket was removed with a hacksaw. This was to make way for the pillow block mounting brackets.

-Control Housing

The control housing was made by reverse engineering the stock control housing. A new one was made with the extracted dimensions because the original one was hand held. The new housing is made to fit onto the frame of the hand truck so both hands can be free to control the machine. This new housing was 3D modeled with SolidWorks and then 3D printed with the personal 3D printing machine of project leader James McPherson.

-Pinwheels

The pinwheels were made in two stages. The basic shape was cut out of ½ inch plate steel by way of CNC plasma routing table. The various holes in the pinwheel, that require more precision than can be provided by CNC plasma cutter, were located manually, and then the 3 smaller holes were drilled using a drill press. The larger Center hole was drilled with a milling machine.

-Main Axle

The main axle was made out of 1” diameter 1018 cold roll round bar stock. The axle features multiple key way slots to secure the pinwheels and the sprocket. The bar stock was cut to rough length with a cold saw, and then faced at each end to exact length with a machine lathe.

-Foot wheel axles

The 6 foot wheel axles were made out of ½” diameter 4130 normalized round bar stock. The foot wheel axles feature 1 section with a ½” diameter with 2 sections with an 8mm diameter on either side. The 8mm diameter was turned have a snug slip fit inside the bearings of the foot wheels. The ½” diameter sections features 2 lengths of ½-13 thread that have been cut with a ½-13 die. The 8mm sections each feature 1 length of M8 x 1.25 threads that have been cut with an M8 x 1.25 die.

-Winch mounting bracket

The sprockets for 100 roller chain are too large to fit on the winch spool, and also inside the stock winch mounting bracket at the same time. So a taller bracket that makes room for the sprocket had to be made. This bracket was made out of ¼" x 4" A36 steel flat bar. This was chosen because it was readily available from the MET department, and it was quite appropriate for creating the needed bracket. A length of about 1' was cut. The length of flat bar was bent at a 90° at ~ half the 12" length of the bracket. Then 2 mounting holes were drilled. 1 hole for the spool was drilled. The stock mounting bracket comes with a press fit bushing for the spool to rotate against. This bushing was reused and press fit into the new spool hole.
The pinwheel is depicted in appendix B8 and the axle is depicted in Appendix Bl0.

-Operation

When on flat ground the hand truck can be rolled around in an ordinary way. The pinwheels are such that 2 of the 3 arms are touching to the ground with their foot wheels, and one of the arms sticks straight up. When the user desires to move his payload up a flight of stairs, he will align the back side of the hand truck with the bottom of a flight of stairs. When the hand truck is aligned he will press the left button on the control housing, that will supply power to the winch. The pinwheels will start to turn, driven by the winch, and carry the hand truck up the stairs. The button may be released at any time if the user feels is it necessary.

-Benchmarking

There are similar examples of what this is, on the internet, but those examples don't look to be intended for heavier payloads. There are also examples that are intended for heavier payloads, but those examples use hydraulic pistons to lift the hand truck instead of pinwheels.
This project is intended to carry payloads of 60-150 pounds up a flight of stairs with the ease of use offered by pinwheels.

-Prediction

This project is predicted to be capable of climbing 20 steps in one minute.

TESTING

General Function Test;

A plain dry run was performed to test the general function of the device. The hand truck was lined up with the steps with no weight attached to the platform. The “go” button was pressed on and off to turn the pinwheels while the operator walked backwards up the steps. This test was successful. The hand truck quickly walked up each step with ease. This is where that piece of flat bar was bent. This is addressed above.

Test 1: Up The Stairs Test:

Plan:

The first test was going to be very straightforward. The tester was to load the hand truck with 150 lb of cargo in a box, and use the device to carry the cargo up the stairs. The ascent was to be timed. Several trials were to be run and an average was to be taken. The average was to be decided by the number of steps climbed in each trial. The target was 5 seconds or less per step. Any number less than or equal to 5 seconds would signify a success.

Stairs in the Fluke Lab of Hogue Tech Building CWU was used for testing.

Original Test Sheet:

Trial	Climbing Time	No. of Stairs
1		
2		
3		(Average)/(No. of Stairs)
4		
5		
Average		

Safety Note: All tests were performed with the payloads securely tied down to the hand truck.

Test 1 Results:

This test was did not go according to plan. The machine was loaded up with 160 lbs, and one trial was done. The weight was 160 lbs because the weights used were 20 lbs each. When the test was performed, two significant problems became quite apparent. The machine is very difficult to use, and if sufficient effort it's not applied, the hand truck is at risk of falling down the stairs. It's a heavy machine, with a heavy load, the danger of such a device taking a fall is self evident.

The main shaft is transmitting a very high torque, which is necessary to drive the machine up and over the steps. This also imposes an equal and opposite torque back on the frame. So, while climbing, the user has to apply his own counteracting force to the frame in order to keep the machine from throwing itself forward down the stairwell.

For this reason only one trial of the test was done. The first trial went off without accident, but with much effort. More trials would have been more and more dangerous to perform just from wearing out the user. Further trials also would have required more weight to be added, making the problem even worse.

However, the one trial that was performed, was technically success. 17 steps were climbed in 78 seconds. That is 4.59 seconds per step, which is lower than the goal of 5 seconds. (Diagram and Analysis of Results in APPENDIX A)

Following the formal test, a demonstration was done with an 80 lb load. This demonstration went off with zero problems. The climb was effortless and quick with the help of the machine. 80 lbs is still a meaningful load, even if greater loads are more difficult to get up the stairs.

Test 2: Down The Stairs Test:

This device has been made to assist the user in moving heavy loads down stairs as well as up. To test this secondary function. The hand truck will be lined at the top of the stairs by the user. A heavy payload will be secured to the platform.
The user will then engage the winch motor in opposite direction by pressing the correct button. Left is up/backwards. Right is down/forwards.

-Pass
The hand truck will slowly walk down the stairs in a controlled manner. The user won't be rushing down the steps to keep up, and the payload will remain secure.

-Fail
The hand truck will be hardly slowed by the mechanism. The movement will be close to falling. The user will have to exert inordinate force to retain control over the hand truck. The payload will be disturbed by the disorderly and uncontrolled motion.

Test 2 Results:

This test was not expected to be successful. In previous operations of the machine, it was far easier to get the machine up a flight of stairs than it is to get the machine down a flight of stairs, even with no load attached. Because of these expectations, this test was performed with no load. After all, if this test is failed with no load, how could the machine be expected to pass with a load?

The results of this kind of test are qualitative in nature, so it can be difficult to discern a pass from a fail. In order to quantify the results from this test, a series of possible positive and negative descriptors were laid out. If a positive descriptor was fulfilled by the results of the test, that was a +1. If a Positive descriptor was not fulfilled by the test, that was a -1. If a negative descriptor was fulfilled by the test that was a -1. If negative descriptor was not fulfilled by the test that was a +1. All the resulting values were to be added up to a total end value. If the end value was a net positive that would be considered a pass. If the end value was a net negative that would be considered a fail.

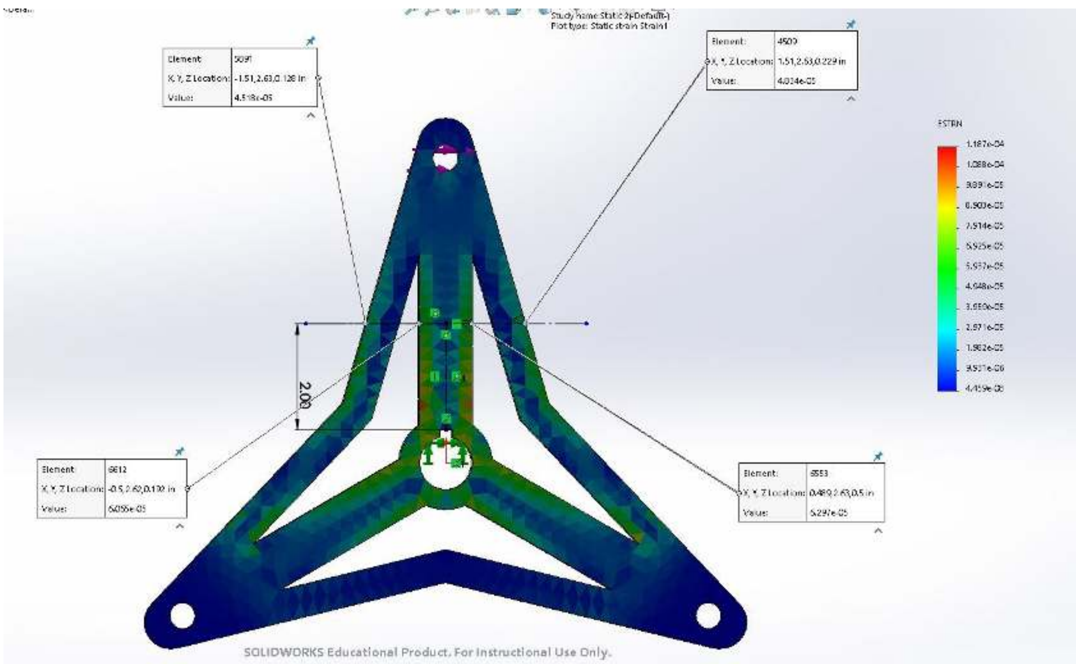
The outcome of this test was as expected. The test was failed, but just barely. The total end value was -1. The end value would certainly become even more negative as more weight were added. (Data Sheet in APPENDIX D)

Test 3: Strain Test

This test is not at all critical to this project. It was mostly performed out of curiosity.
It is non critical because FEA, early on in this project, showed that these pinwheels have a safety factor in excess of 10 with expected loadings.

A strain gauge will be applied to the support struts of the pinwheels
The strain gauge will reveal the strain/stress experienced by these components.

- -Pass-------Below Yield Strength of the material
- -Fail--------Close to, At, or Above Yield Strength of the material.



The two outer points on the photo were the ones tested. It is difficult to apply strain gauges to the small in-between space.

Point 2 (on the left)- Simulated Value of 4.518 E-5 in/in

Point 1 (on the right)- Simulated Value of 4.834E-5 in/in

Just a note these values are way below the yield strength of this material. So it would be very strange if this test were to be failed.

Test 3 Results:

This test cannot be considered a pass or a fail bases of the the results. It is very clear that the yield strength of the machine is not at all exceeded. This can be known because no elastic deformation can be visibly observed while the machine is in operation. If there is no elastic deformation, there certainly is no plastic deformation.

The highest strain reading at point 1 is 104 E-6 in/in
The highest strain reading at point 2 is 129 E-6 in/in

These values are almost certainly unreliable. The readings has to be taken while the machine was in motion. It is now apparent that this is not a very good application of strain gauge methods. These methods would be much better applied in a static situation. Such a situation could have been arranged. However, specific hardware would have had to be manufactured, like a jig of some sort. This test is non critical, so, in the interest of time this more elaborate setup was not pursued.

BUDGET/SCHEDULE/PROJECT MANAGEMENT

Cost and Budget:

The cost of this project was supported by the project leader, James McPherson.

Labor was performed for free by project leader, James McPherson, with assistance from shop faculty/staff, who are paid by the department.

Labor has included tasks such as machining, welding, assembly, disassembly, modification, purchasing, transportation, 3D Printing, Documenting, Designing, etc.

The total cost of this project was estimated to be about $700.00.
Actual Cost is $763.36.

35		Proposed						
36	Part Number	Part Name	Product #	quantity	Price	Source	Price*Quantity	
37	1	Safeco Hand Truck	4069	1	$55.38	Amazon	$55.38	
38	2	Set of 4FREEDARE Longboard Wheels	B07CNW6J9K	3	$21.99	Amazon	$65.97	
39	3	Trakker 1 HP/winch	KT2000	1	$64.35	Lowes	$64.35	
40	4	25 ft 6 gauge wire	CBL-CSRD-06-25	1	$26.12	Amazon	$26.12	
41	5	100B8 Sprocket	100B8-SPROCKET	2	$19.99	USARollerChain	$39.98	
42	6	10 ft 100 Roller Chain	100-1X10FT	1	$62.99	Amazon	$62.99	
43	7	12 volt Motorcycle Battery	2113-0012	1	$118.95	J&P Cycles	$118.95	
44	8	3ft one inch steel bar	4797	1	$23.94	Online Metals	$23.94	
45	9	Welding Rod	770462	1	$14.99	Amazon	$14.99	
46	10	Plate steel for Pinwheels	205058577	3	$16.99	Home Depot	$50.97	
47	11	Fasteners	N/A	1	$50	Fastenal	$50	
48	12	UN-Forseeable Costs	N/A	1	$100	N/A	$100	
49	13	3ft half inch steel bar	7363	1	$9.11	Online Metals	$9.11	
50	14	Keyway	57503	1	$9.06	Amazon	$9.06	
51				Total	$682.75			
52								
53		Actual						
54	Number	Part Name	Product #	Quantity	Total Cost Per Unit	Source	Price*Quantity	Shipping Cost Included in Total Cost Per Unit
55	1	Harper Hand Truck	BKB85	1	$63.89	Amazon	$63.89	
56	2	10 ft 100 Roller Chain	100-1X10FT	1	$68.22	Amazon	$68.22	
57	3	25 ft 6 gauge wire	CBL-CSRD-06-25	1	$28.29	Amazon	$28.29	
58	4	Set of 4FREEDARE Longboard Wheels	B07CNW6J9K	3	$23.82	Amazon	$71.46	
59	5	Pillow Block Mounted Bearings	P205-1	2	$10.78	Amazon	$21.56	
60	6	Trakker 1 HP/winch	KT2000	1	$69.69	Lowes	$69.69	
61	7	TRITAN Sprocket 100BS10HX1 1-1/4"	B757014	2	$59.78	Global Industrial	$119.56	
62	8	12 volt Motorcycle Battery	2113-0012	1	$128.82	J&P Cycles	$128.82	
63	9	3 ft length of 0.5" & 1.0" Steel Rod	4797 & 7363	1	$61.72	Online Metals	$61.72	
64	10	0.5" x 1.0' x 3.0' Plate Steel	N/A	1	$102.94	Western Metal	$102.94	
65	11	Fasteners	N/A	1	$27.21	Fastenal	$27.21	
66						Total	$763.36	

This is a spreadsheet showing the details of spending, proposed vs actual.

The set budget of $700 has been surpassed. The budgeted $100 for unforeseen costs has proved to be a wise decision, even if not a large enough estimation of over spending. In planning, shipping costs were totally disregarded. Costly mistakes were also made when purchasing parts. (Detailed in discussion below)

The most expensive components were the battery, the plate steel for the pinwheels, and the winch. The plate steel was almost wasted. The CNC plasma routing table malfunction while cutting out the pinwheel pattern and nearly ruined the usefulness of the whole plate. That would have been a very expensive loss. Thankfully, the pinwheels were successfully salvaged.

This is a photo of the failed pinwheel cut. The Plasma cutter was not starting or stopping consistently, and the plasma stream did not penetrate all the way through in many places. In other places, the plasma cutter effectively welded the cut back together immediately after blasting through.

To save money, the resources of the department were used whenever possible. Several key components were designed with a particular piece of material stock in mind. The angle iron retrofit is one good example of this. The bent material was discovered, and the shop was searched for suitable material to solve the issue before any CAD or design work was done. This is also true for the winch support bracket. Several important dimensions depended on the thickened of the selected material. This is all done as part of a strategy to save money. If design work was done before knowing what material is available there is a good chance that expensive materials would have to be ordered from far away.

Schedule:

The schedule for this project was constrained by the MET 495 course and is shown in Appendix D. This project was completed by the last week spring quarter 2019.

Scheduling had to be altered on a week by week basis to account for unexpected challenges.

Most of these challenges, in winter quarter, had to do with part/material acquisition. At the start of winter quarter most of the parts needed for this project were ordered within the first week of class. Among those parts is the roller chain sprockets. The wrong sprockets were ordered initially, so the correct ones were then ordered. After the correct sprockets were ordered, the order was cancelled by the vendor. So then a different set of suitable sprockets were ordered. That order made it through.

Something similar happened with the plate steel for the pinwheels. The wrong material was ordered. When it arrived it was driven to the nearest store for a refund. An attempt was made to buy the correct material at a discounted price through the MET department. After the order fell through, the material was bought from Western Metal Co. near CWU.

After the correct material for the pinwheels was acquired, an attempt was made to get the pinwheels cut out with the CNC plasma routing table owned by the MET department.
It didn't work out the first time. The plasma table proved to be malfunctioning. A good portion of the plate steel was damaged in the process. These setbacks also cost a good amount of time.

Scheduling during spring quarter was largely dictated by assignment deadlines. A test demonstration was due on a certain day, so the work needed to prepare that demonstration was done during the week or so leading up to the deadlines. Similarly, the SOURCE event happened on May 15th of 2019, so the main body of project work had to be completed, and the SOURCE poster had to be finished before the deadline. The time slots for performing work that were predicted in fall quarter, at the beginning of this project, were a very rough guess. Those time slots were adjusted as needed, according to deadlines that were revealed as the project progressed.

Tasks are delineated in the Gantt chart included in Appendix D.

-Milestones:

-Acquiring of main store bought components
-Removal of wheels from the hand truck
-Stripping and modification of winch
-Mounting of Sprocket on modified winch
-Machining of drive axle
-Plasma cutting of pinwheels
-Mounting of longboard wheels on pinwheels
-Total assembly of drive train
-Wiring and mounting of battery
-Testing

Total Estimated time: 115 Hours
Actual Time So Far (end of winter quarter): 145.5 Hours
Project Management:

Project management was a fluid process. The initial plan proved indispensable when it unclear what to do next. Challenges were solved as they arose. If problems required help from someone outside this project, that help was sought. If more money was needed, it was spent. The 0.5” plate steel for the pinwheels is a prime example of this. The plate steel ended up being about twice as expensive as predicted.

The worst thing that could have happened in this project would be if the winch was irreparably damaged. That would have been the worst part to have break, but many of the parts were in that same boat. Breaking parts is bad, and particularly so for this project. So extra special care was taken whenever the parts in this project were going to be altered. Principal engineer, James McPherson was responsible for seeking advice, acting carefully, and getting it right in the course of this project.

That said, this project is a success. All the necessary resources and expertise needed for success have been found within the CWU Mechanical Engineering Technology department.

Principal Engineer, James McPherson has applied nearly all his skills (resume in Appendix F) to complete this project. Advice and expertise from MET faculty has been indispensable as principal engineer, McPherson’s expertise was not sufficient to complete many of the necessary tasks.

DISCUSSION

The original conception of this project involved a relatively high rpm motor, a gearbox, a hand truck, and two four-pronged pinwheels. Those were all the details of the project. None of the particulars had been considered. At the completion of this proposal, very few of those original details remain, and many more details have been worked out (see Appendix A).

The four pronged pinwheel design was abandoned early on for a three arm design. After the geometry of the situation was considered, it was concluded that a four arm pinwheel would require the individual prongs to be much longer than in a three arm design in order to achieve the same clearance over the steps. Longer arms, would make for a greater moment on the drive shaft to be overcome by the drive motor. Less force is easier and cheaper to generate than more force.

When the search for an appropriate motor/gearbox began it became clear that the search wasn't going to be easy. Professor Pringle was consulted, and he recommended the use of a gear motor. A gear motor allows the designer to skip the search for a gearbox entirely. When the search for an appropriate gear motor began, the extremely prohibitive cost was realized. Gear motors capable of supplying the torque required for this project had a price tag around $1,000. That's when a winch was considered as an option. The winch selected for this project is estimated to produce around 250 ft-lb, which is plenty, and the cost is only around $70.

After grasping the actual scale of sprockets for #100 roller chain when it arrived, it became clear that the winch would require a new support bracket for the spool. The winch comes stock with a supporting bracket that does not have enough room for the necessary sprockets. This problem was solved by designing a new bracket with a spacer. (depicted in drawing, appendix B)

The foot wheels on the larger pinwheels are repurposed longboard wheels. Longboard wheels come stock with bearings that include an 8mm bore. 8mm isn't a very large diameter, so a design choice was made to have foot wheels on either side of both pinwheels. This was accomplished by designing the foot wheel axles to be located in the pinwheels on the nominally 0.5" diameter portion by 0.5" nuts. Then on either side of the 0.5" portion are 2, 8mm diameter portions for the footwheels to slide on to, and then be secured with 8mm nuts.

One of the more significant point in this project was getting the sprocket fixed to the winch spool. A the beginning of the school year, the plan was to do so the same way that the other sprocket was fixed to the main axle, with a key and keyway. The sprockets come with a precut ¼" keyway. This plan looked all well and good until the winch spool had been properly examined. The spool is hollow in the middle. This is to allow for a disengaging mechanism in the winch. A steel rod runs through the centerline of the spool that releases a transfer spline from the planetary gearing in the motor housing when pulled. This means that only so much material can be removed from the outer walls of the spool while still maintaining structural integrity. After the outer wall was turned down to fit the inner diameter of the sprocket bore, not enough material was left to cut a keyway. So it was decided that the sprocket would be fixed to the spool with a ⅜" dowel pin instead. The strength of the ⅜" diameter dowel pin is more than sufficient to transfer the necessary torque for this project. So the outer walls of one of the 2 sprockets were milled down so drilling would be more straightforward, and a ⅜” hole was drilled through the sprocket hub and the spool. This removed a very minimal amount of material from the wall of the spool.

CONCLUSION

This proposed project was conceived, analyzed, designed, budgeted, scheduled, manufactured, and managed, all according to the requirements for a successful senior project. The budget and schedule have both been within the collective means of principal engineer McPherson and the MET department. The technical requirements of the project are all within the means of the MET department’s tools and equipment.

The working device has performed to the standards described in this report, with some limitations. Principal engineer McPherson is very satisfied with how the hand truck has turned out. There are some points of concern to watch during testing however. The piece of flat bar that supports the winch did have to be modified. There was some concern about how well the winch spool would hold up during testing. Aluminum is not the best load bearing material, but it has held up just fine in in this application.

This project meets all the requirements for a successful senior project, including:

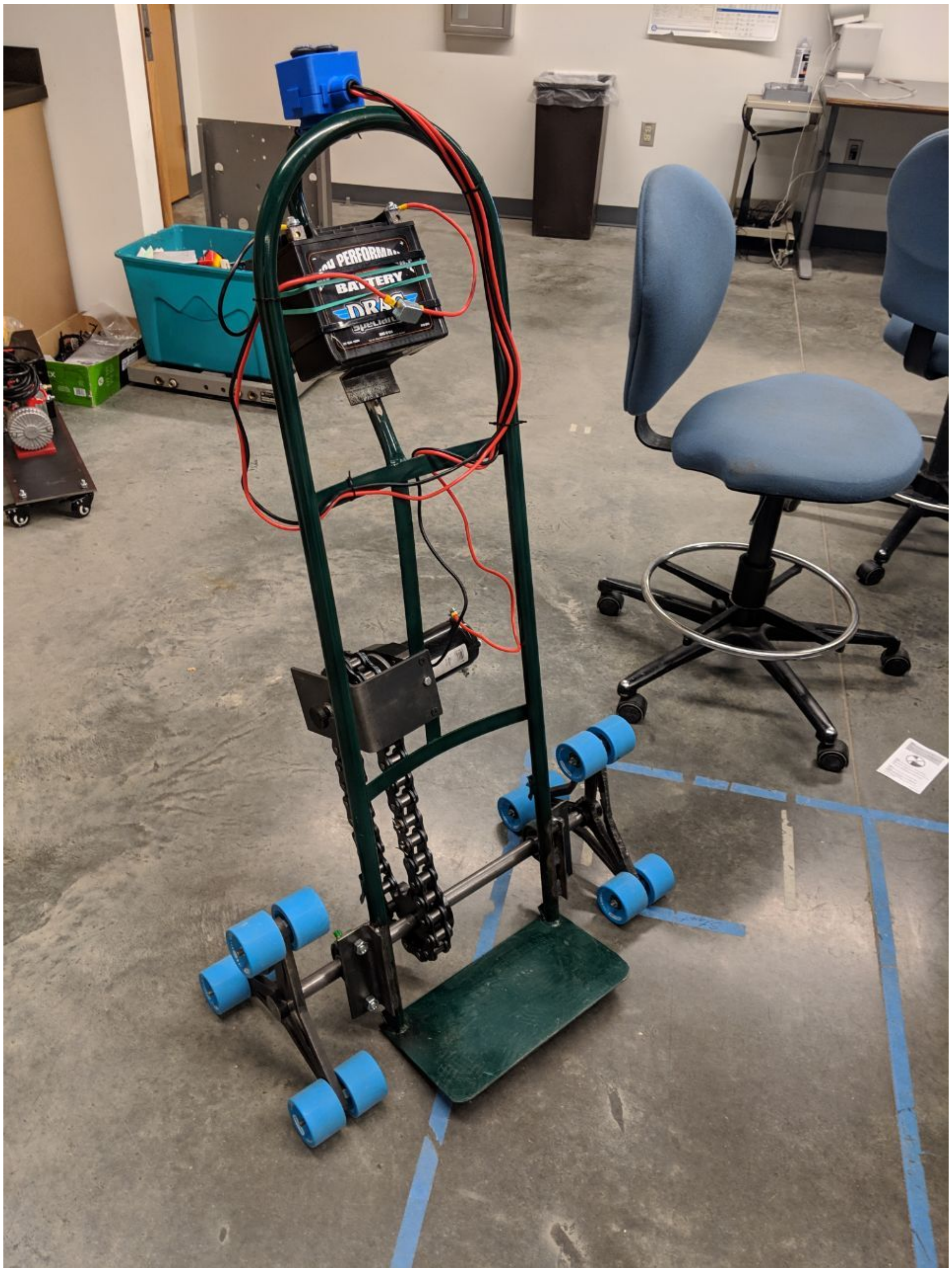
1. Having substantive engineering merit in the areas of structural design, reverse engineering, power transmission (other areas mentioned above in the design section).
2. Size and cost within the parameters of our resources.
3. Being of great interest to principal engineer, McPherson.
4. Solving a real world problem in useful way
5. Successful Manufacture of a functioning device
6. Meaningful application of a broad range of skills and principles
7. Sensible use of additive manufacturing
8. Successful project management and documentation
9. Passing tests that are relevant to the original design requirements

With this report, and the information herein, a functioning device, and test results this project can now be concluded.

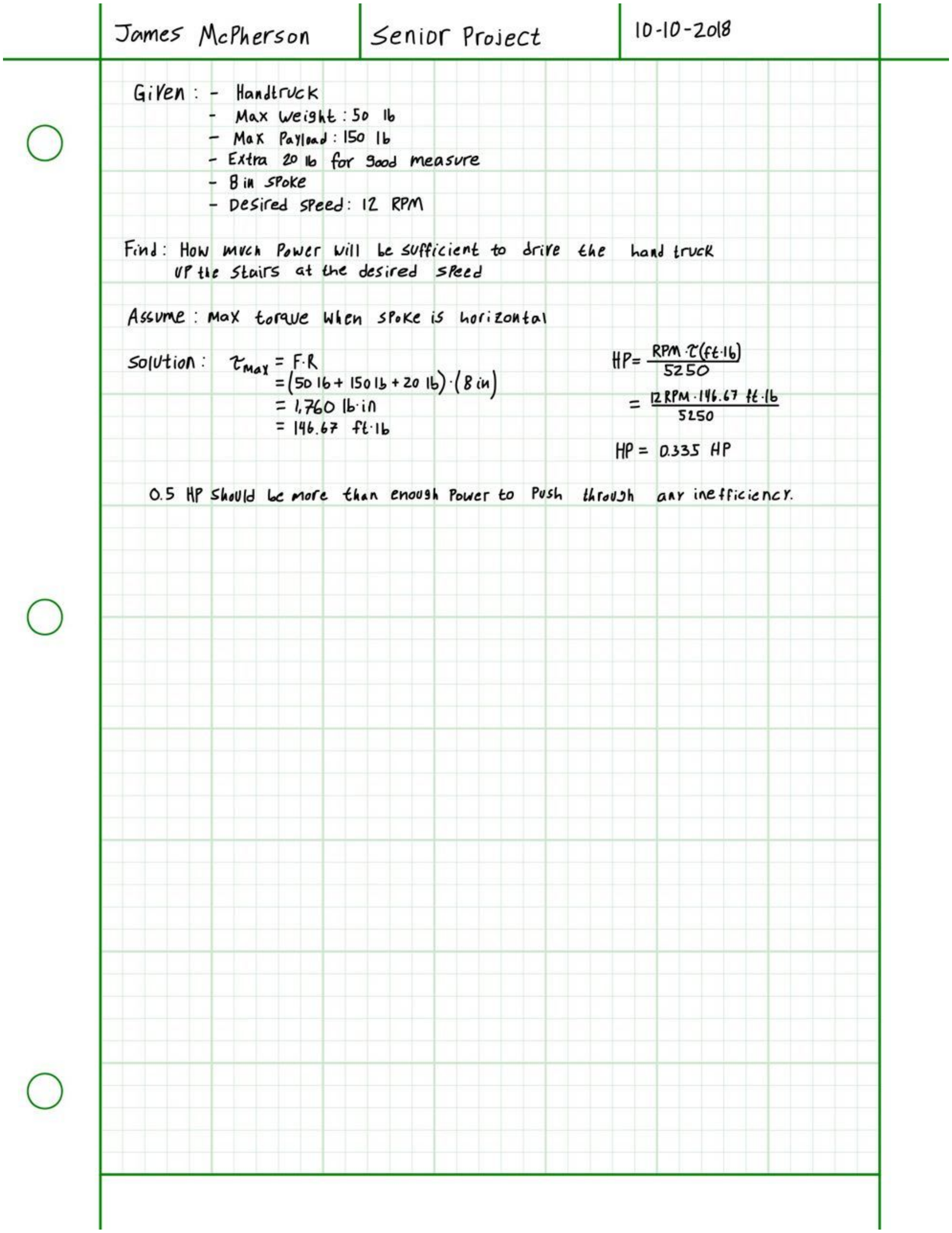
ACKNOWLEDGEMENTS

Dr. Craig Johnson, Professor Charles Pringle, Professor Roger Beardsley, and Dr. John Choi advised, mentored, and educated Principal Engineer McPherson Principal engineer McPherson’s friends help to conceive of this project over dinner. Matt Burvee, and the rest of the shop authorities have been responsible for the manufacturing of this project.

Photo of Working Device at The End of Winter Quarter



APPENDIX A – Analyses


James McPherson | Senior Project | 10-10-2018

Given: - Handtruck
- Max Weight: 50 lb
- Max Payload: 150 lb
- Extra 20 lb for good measure
- 8 in spoke
- Desired speed: 12 RPM

Find: How much power will be sufficient to drive the hand truck up the stairs at the desired speed

Assume: max torque when spoke is horizontal

Solution:

$$\tau_{max} = F \cdot R = (50\ lb + 150\ lb + 20\ lb) \cdot (8\ in) = 1{,}760\ lb \cdot in = 146.67\ ft \cdot lb$$

$$HP = \frac{RPM \cdot \tau (ft \cdot lb)}{5250} = \frac{12\ RPM \cdot 146.67\ ft \cdot lb}{5250}$$

$$HP = 0.335\ HP$$

0.5 HP should be more than enough power to push through any inefficiency.

A1: calculation of power requirement

This is the calculation of required power, using regular energy methods, to rotate the pinwheel at 12 rpm, while under maximum load. The calculated figure is 0.335 HP. The project is intended to be a robust piece of equipment, and a 0.5 HP motor is expected to be much more available than a 0.335 HP motor.

James McPherson | Senior Project | 10-12-2018

Given: - Max Torque: 1,760 lb·in
- Max Vertical Load: 220 lb
- Material: A36 steel

Find: - Min ø for Torsional shear
- Min ø for Direct shear

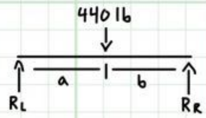
Assume: - SF = 2.0

Solution: (max Torque)(SF) = (1,760 lb·in)(2.0) = 3,520 lb·in

S_y = 36,000 psi

0.57 S_y = 20,520 psi
Shear Yield

(max Vertical Load)(SF) = (220 lb)(2.0) = 440 lb



a = b

$R_L = R_R$ = 220 lb

$S_{y_\tau} = \frac{F}{\pi r^2}$

20,520 psi = $\frac{220 \text{ lb}}{\pi r^2}$

r = 0.058 in
D = 0.116 in

0.116 in ø rod needed to withstand direct shear

$\tau_{max} = \frac{Tc}{J}$ $J = \frac{\pi D^4}{32}$

τ_{max} = 3,520 lb·in

Shear Stress 20,520 psi = $\frac{3520 \cdot 32}{\pi D^4}$

D = 1.15 in

1 in ø Rod will work. Higher grade steel will also be used.

Bending shouldn't be an issue in this Configuration

A2 : Calculation of shared axle diameter

This is the calculation of the diameter required for the axle to sustain the maximum load with a safety factor of 2. The calculated diameter needed, for an A36 steel rod to sustain to required loads, with a safety factor of 2, is about 1 inch.

Criteria	Weight (1-5)	1018	1018 weighted	A36	A36 weighted	303	303 Weighted	ideal		
Elastic Modulus	5	3	15	2	10	1	5	15		
Density	2	2	4	3	6	1	2	6		
Cost	3	2	6	3	9	1	3	9		
Hardness	1	2	2	1	1	3	3	3		
Finish	4	2	8	1	4	3	12	12		
	•									
Total		1018 Total	35	A36 Total	30	303 Total	25		Ideal Total	45
	Material	Normalized Total		Bias Value	11.11111111				Normalization factor	2.222222222
	1018	77.77777778								
	A36	66.66666667								
	303	55.55555556								

A3: Axle Material Decision Matrix

The last analysis determined the necessary diameter, with the assumed material of A36, for the shared drive axle. This is a decision matrix set up to evaluate some other material options. 1080 steel is the preferred option.

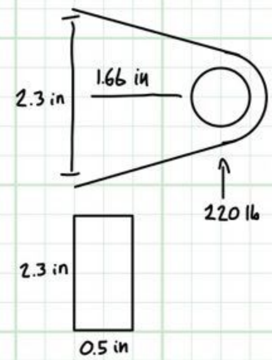
James McPherson | Senior Project | 10-19-2018

Given : Drawing of Pinwheel

Find : Shear stress 1.66 in from foot wheel

Solution : $\tau = \frac{V}{A} = \frac{220 \text{ lb}}{2.3 \text{ in} \times 0.5 \text{ in}}$

$\tau = 191.364 \text{ Psi}$



A4: Calculation of shear stress in pinwheel 1.66 in from foot wheel

This is just a check calculation. The value is less than 1 KSI so there's nothing to worry about.

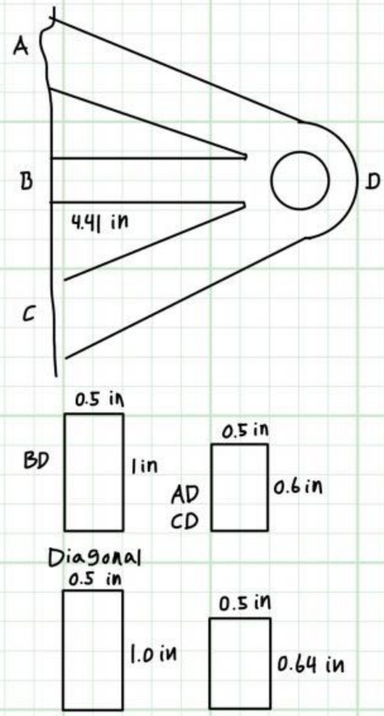
James McPherson | Senior Project | 10-19-2018

Given: Drawing of Pinwheel

Find: Shear stress 4 in from foot wheel

Solution: $\tau = \frac{V}{A} = \frac{220\ lb}{2(0.64\ in \cdot 0.5\ in) + (0.5\ in \cdot 1\ in)}$

$\tau = 687.5\ psi$



A5: Calculation of shear stress in pinwheel 4.4 in from foot wheel
This is just a check calculation. The value is less than 1 KSI so there's nothing to worry about.

James McPherson | Senior Project | 11-2-2018

Given:
- Load 220 lb
- Saftey factor: 2.0
- Quad Shear
- Ø 0.315 in

Find: suitable material to carry load

Method: Aea, Shear stress, Material from tables

Solution: $\text{Area} = \frac{\pi D^2}{4} = \frac{\pi(0.315 \text{ in})^2}{4}$

$\text{Area} = 0.0779 \text{ in}^2$

$\text{Saftey Load} = 220 \text{ lb} \cdot 2.0 = 440 \text{ lb}$

$\text{Shear stress} = \frac{440 \text{ lb}}{4(0.0779 \text{ in}^2)} = 1{,}412 \text{ Psi}$

Material must have shear strength of 1412 Psi or more

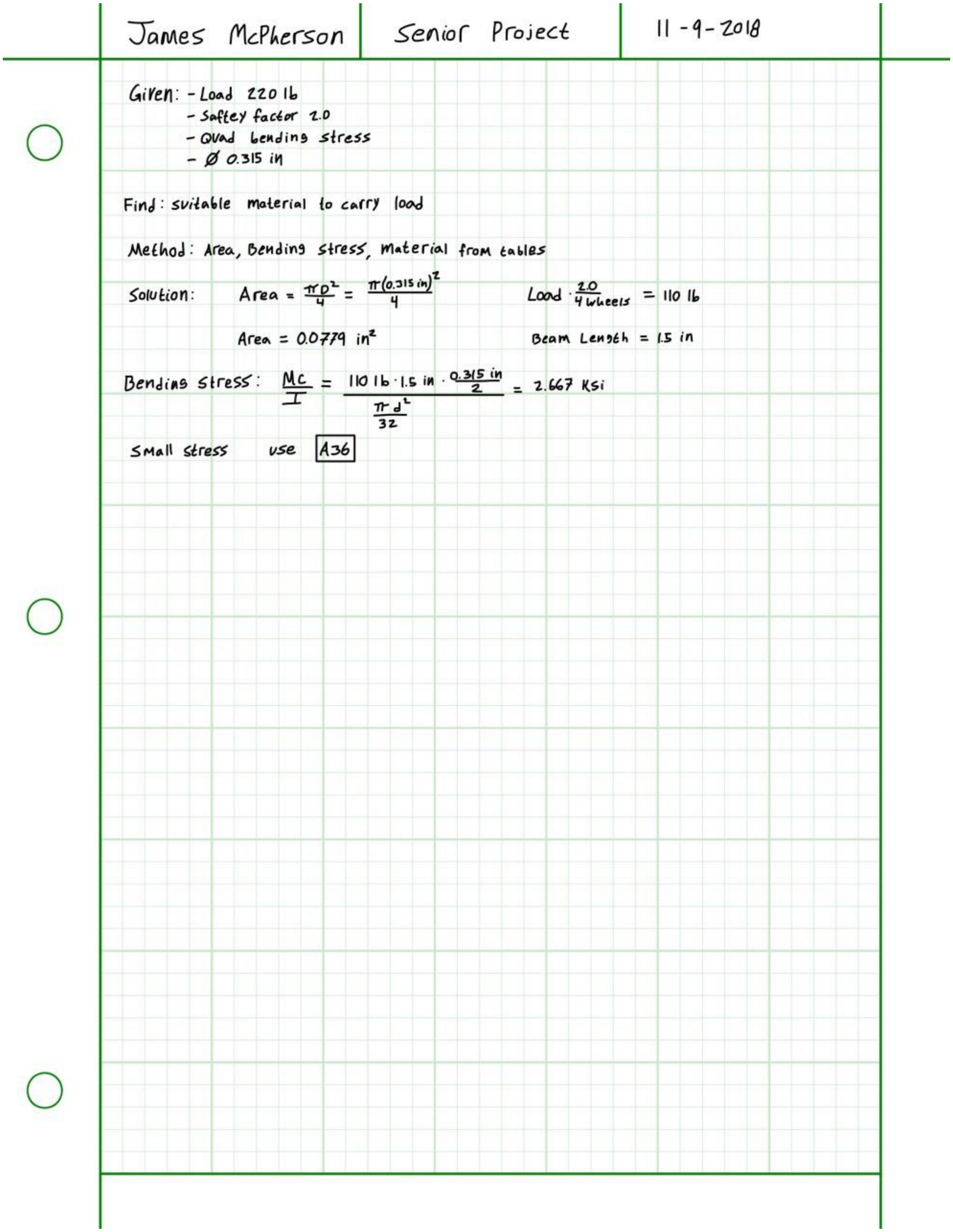
Just about any steel should work

1412 Psi is small

I'll use **A36**

A6: Design check of foot wheel axle diameter by shear

This project will be using longboard wheels as the “foot wheels” longboard wheels spin on bearings will an inner race diameter of of 0.315 in. This calculation is a design check on the diameter, with a material choice of A36 steel. The shear stress is so relatively low that any steel would work. A36 is a good assumption.



James McPherson | Senior Project | 11-9-2018

Given: - Load 220 lb
- Saftey factor 2.0
- Quad bending stress
- Ø 0.315 in

Find: suitable material to carry load

Method: Area, Bending stress, material from tables

Solution: $\text{Area} = \frac{\pi D^2}{4} = \frac{\pi (0.315\text{ in})^2}{4}$ $\quad$ $\text{Load} \cdot \frac{2.0}{4\text{ wheels}} = 110\text{ lb}$

$\text{Area} = 0.0779\text{ in}^2$ $\quad$ Beam Length = 1.5 in

Bending stress: $\frac{Mc}{I} = \frac{110\text{ lb} \cdot 1.5\text{ in} \cdot \frac{0.315\text{ in}}{2}}{\frac{\pi d^2}{32}} = 2.667\text{ Ksi}$

Small stress use **A36**

A7: Design check of foot wheel axle diameter by normal stress.
This analysis is very similar to the previous one. The main difference being the type of stress being checked. This checks the normal stress due to bending.

James McPherson | Senior Project | 11-9-2018

Given: - $\frac{1}{2}$ HP Motor

Find: - Battery specs

Method: Watts

Solution: $\frac{1}{2}$ HP -> 372.85 Watts

$P = IV$ Most batteries are 12 Volts

$\frac{372.85\ W}{12\ V}$ Call it 400 $\frac{400\ W}{12\ V} = 33.3$ AMPS

Battery must have 12 Volts and min 33.3 AMPS

Motorcycle Battery

A8: Calculation of battery specs

In research, this project has seen that nearly all motor solutions are intended to run on a 12v power supply. Motorcycle batteries are nearly all 12 volt batteries, and have a wide variety of available amperages.

James McPherson	Senior Project	11-9-2018

Given: 40 Amps
12 Volts
2 feet long

Find: wire gauge

Solution: From tables

Either 8 or 6 gauge

A9: Calculation of wire gauge
After determining the type of battery to be used, easily available wire gauge charts were found on the internet and used to determine the appropriate gauge for this project.

James McPherson | Senior Project | 11-24-2018

Given: - Winch
- Max load 2,000 lb
- Estimated radius 1.5 in

Find: - Max torque

Solution: $T = rF$

$= 1.5 \text{ in} \cdot 2000 \text{ lb} = 3000 \text{ in-lb}$

$\frac{3000 \text{ in} \cdot \text{lb}}{12 \text{ in}} = 250 \text{ ft} \cdot \text{lb}$

250 ft-lb is more than enough.

Performance

KT2000

Line speed and Motor current (first layer)

Line Pull	Lbs	0	500	1000	1500	2000
	Kgs	0	227	454	680	907
Line speed	FPM	13	10	7	5.5	4.5
	MPM	3.96	3.05	2.13	1.68	1.37
Motor Current	Amps	8	40	70	90	110

Line pull & cable capacity

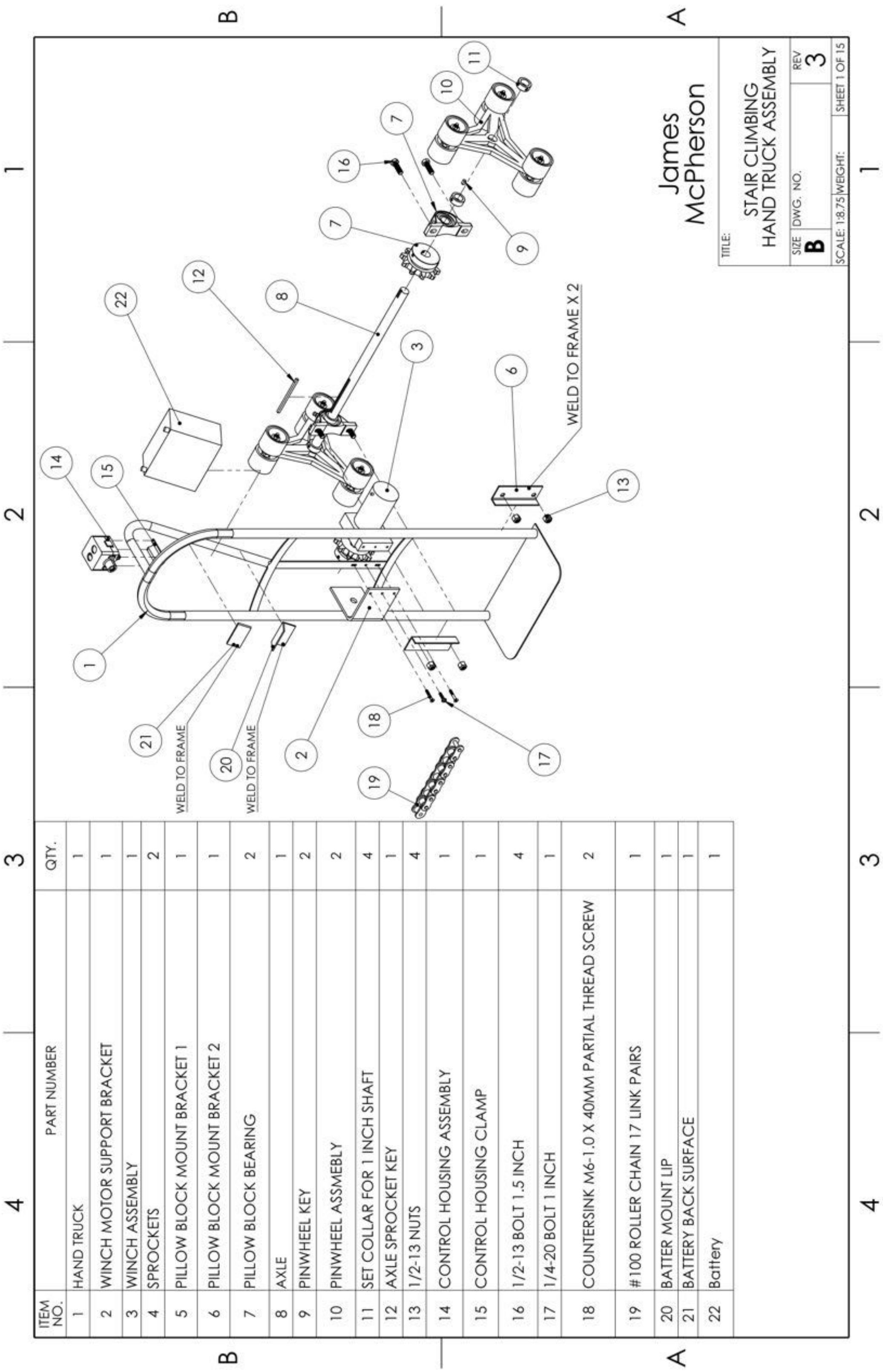
Layer of cable		1	2	3	4	5
Rated line pull per layer	Lbs	2000	1745	1550	1394	1266
	Kgs	907	792	703	632	574
Cable capacity per layer	Ft.	6.69	8.17	9.66	11.15	12.63
	M	2.0	2.49	2.94	3.4	3.85

Rolling Load Capacities (first layer)

Slope*	10% (4.5°)	20%(9°)	40%(18°)	100%(45°)
Lbs	10500	6803	4308	2175
Kgs	4763	3086	1954	987

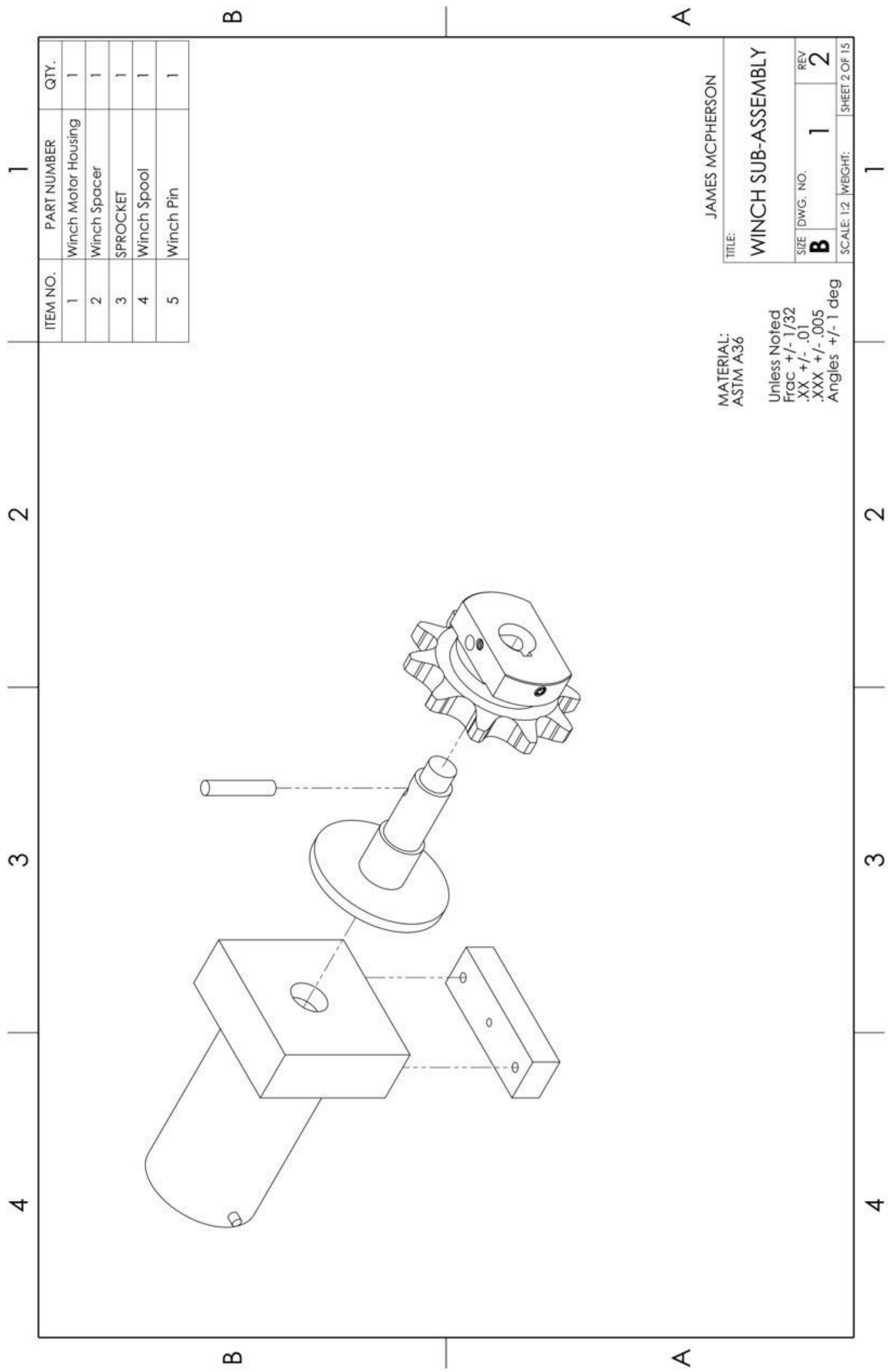
A10: Design Check on Winch Torque.

Due to the very prohibitive cost of high torque gear motors, this project will use a consumer grade winch. This project, at absolute worst case scenario, requires less than 150 ft-lb of torque. So a winch capable of 250 ft-lb at max should work well.

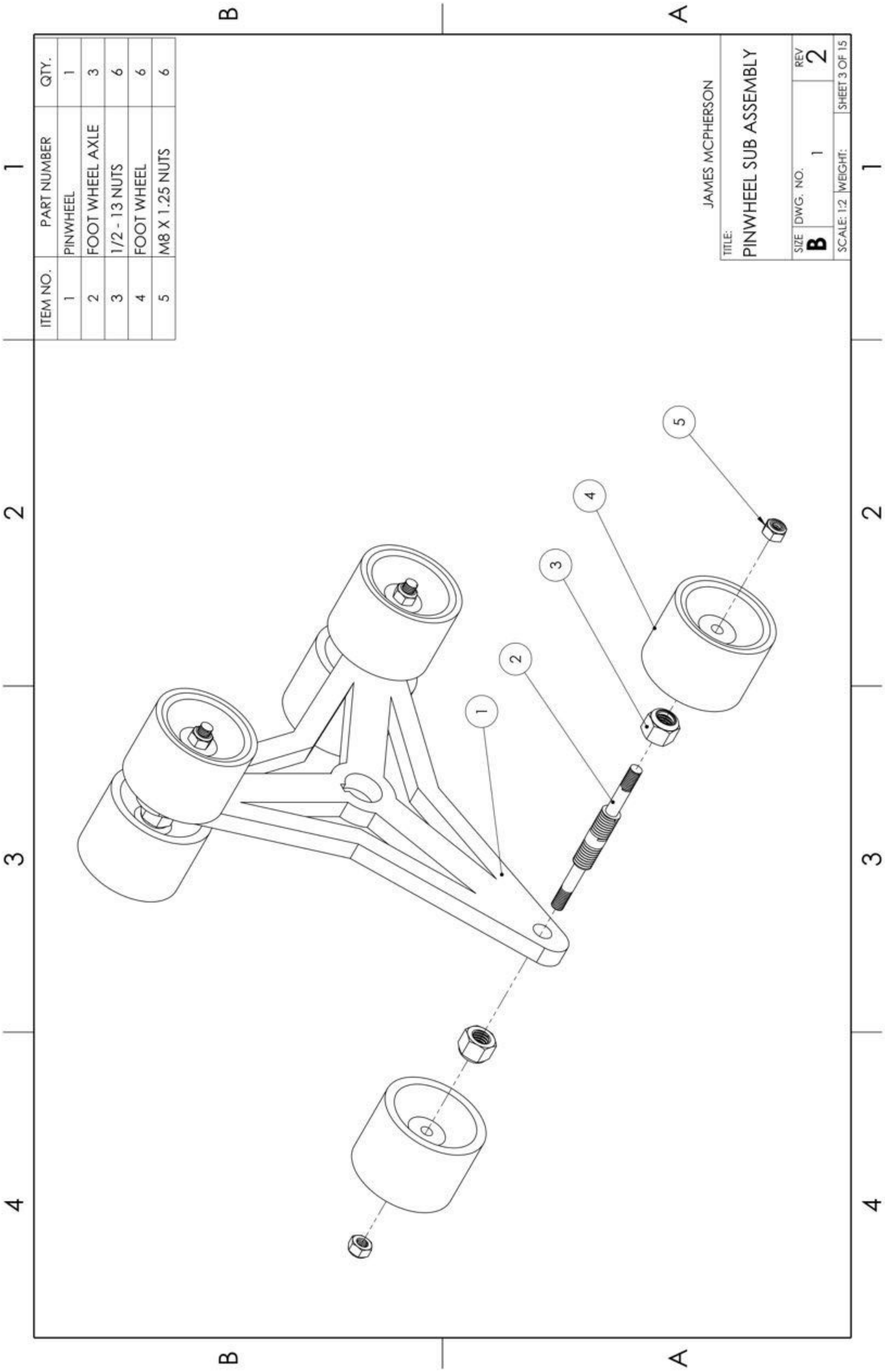


ITEM NO.	PART NUMBER	QTY.
1	HAND TRUCK	1
2	WINCH MOTOR SUPPORT BRACKET	1
3	WINCH ASSEMBLY	1
4	SPROCKETS	2
5	PILLOW BLOCK MOUNT BRACKET 1	1
6	PILLOW BLOCK MOUNT BRACKET 2	1
7	PILLOW BLOCK BEARING	2
8	AXLE	1
9	PINWHEEL KEY	2
10	PINWHEEL ASSEMBLY	2
11	SET COLLAR FOR 1 INCH SHAFT	4
12	AXLE SPROCKET KEY	1
13	1/2-13 NUTS	4
14	CONTROL HOUSING ASSEMBLY	1
15	CONTROL HOUSING CLAMP	1
16	1/2-13 BOLT 1.5 INCH	4
17	1/4-20 BOLT 1 INCH	1
18	COUNTERSINK M6-1.0 X 40MM PARTIAL THREAD SCREW	2
19	#100 ROLLER CHAIN 17 LINK PAIRS	1
20	BATTER MOUNT LIP	1
21	BATTERY BACK SURFACE	1
22	Battery	1

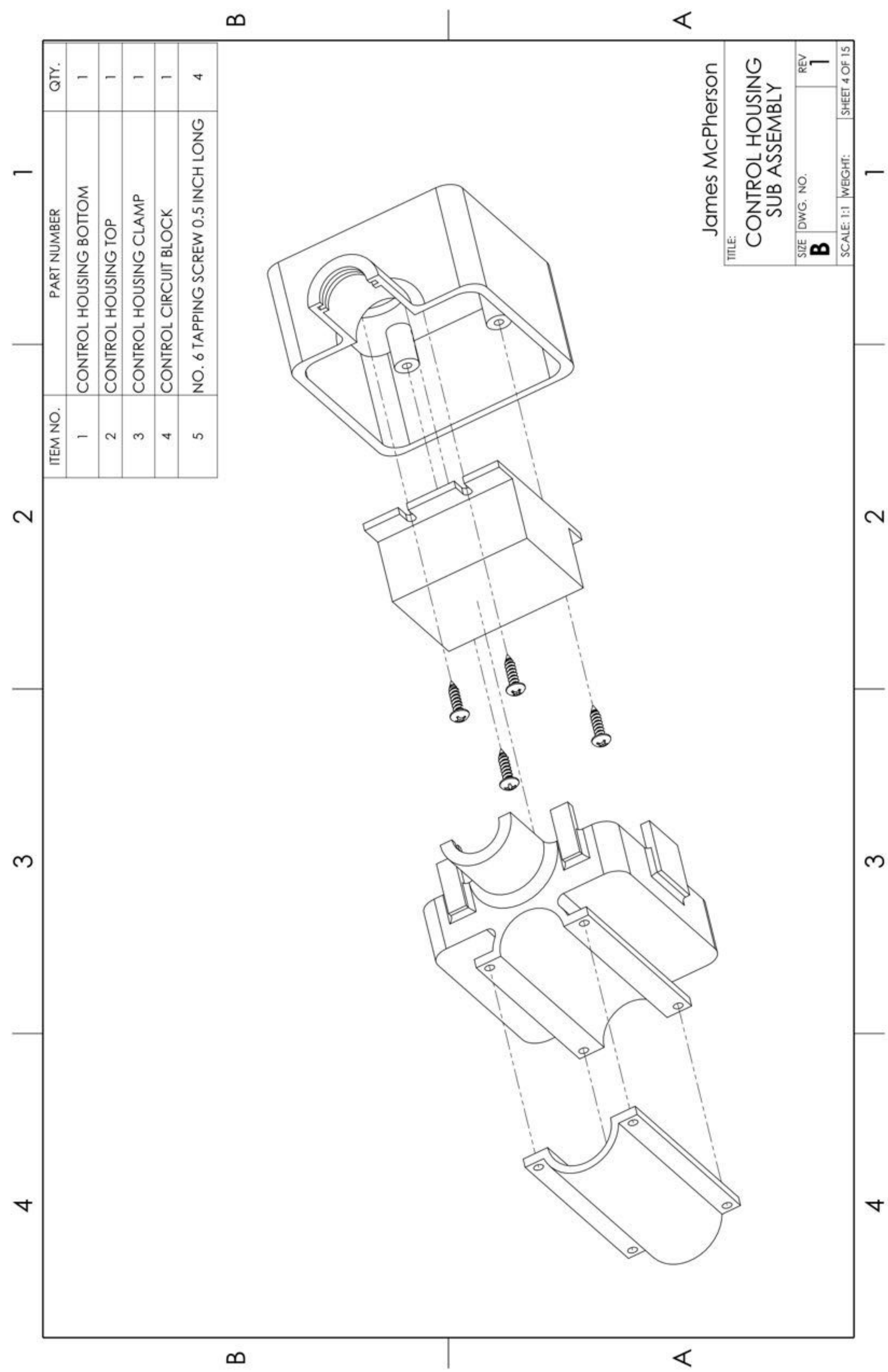
B1: Drawing of Full Assembly



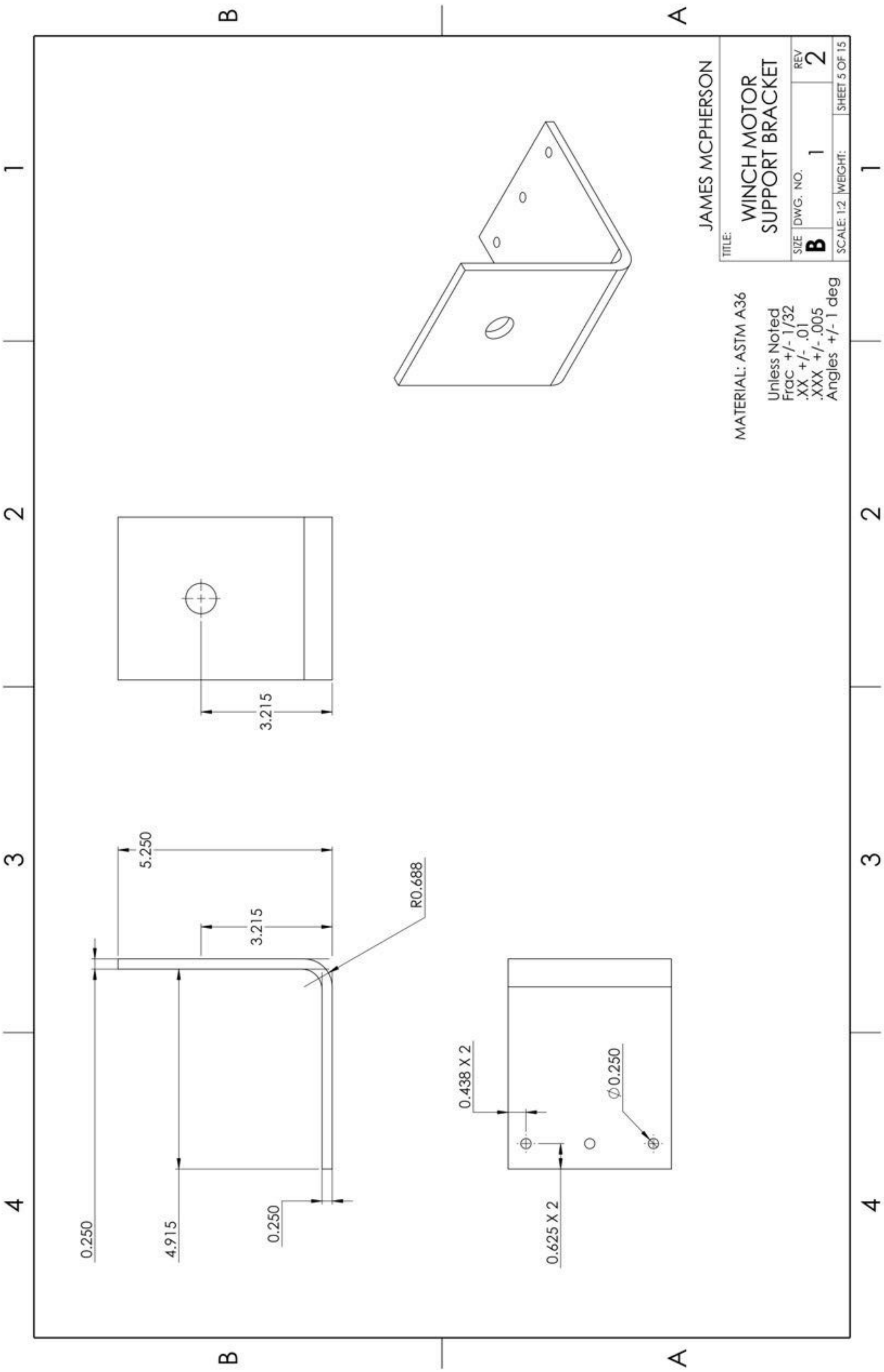
B2: Drawing of Winch Sub Assembly



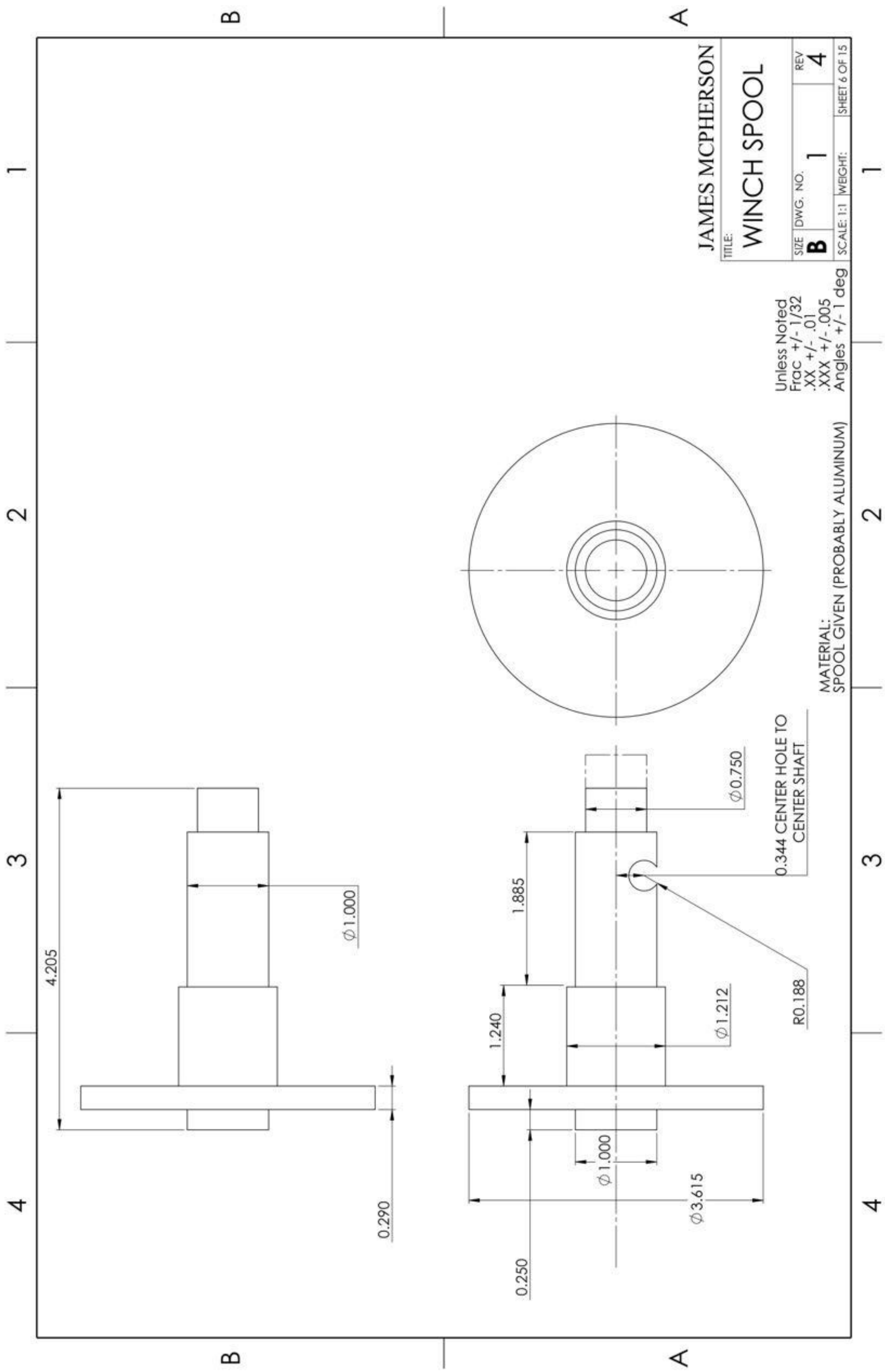
B3: Drawing of Pinwheel Sub Assembly



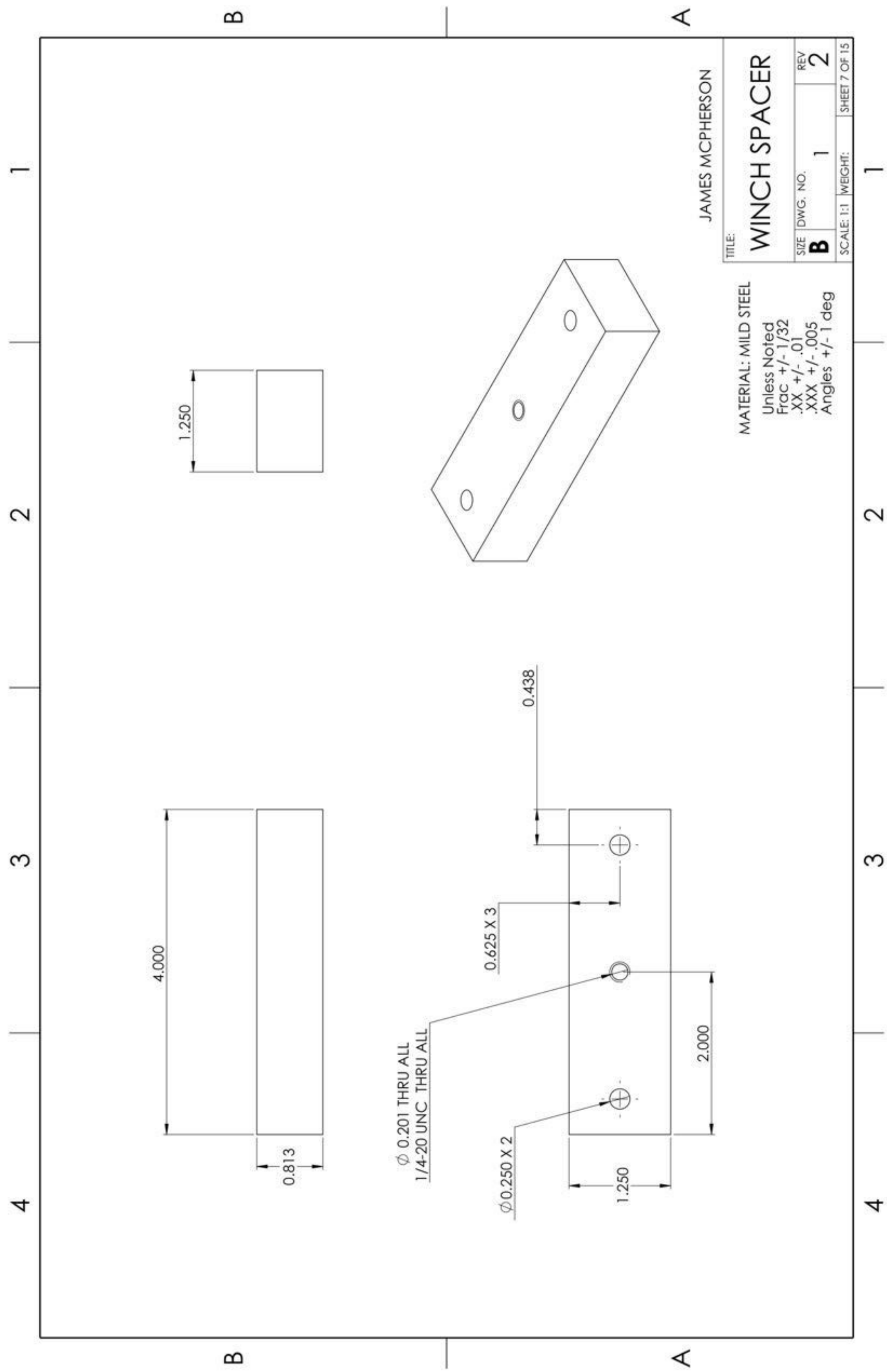
B4: Drawing of Control Housing Sub Assembly



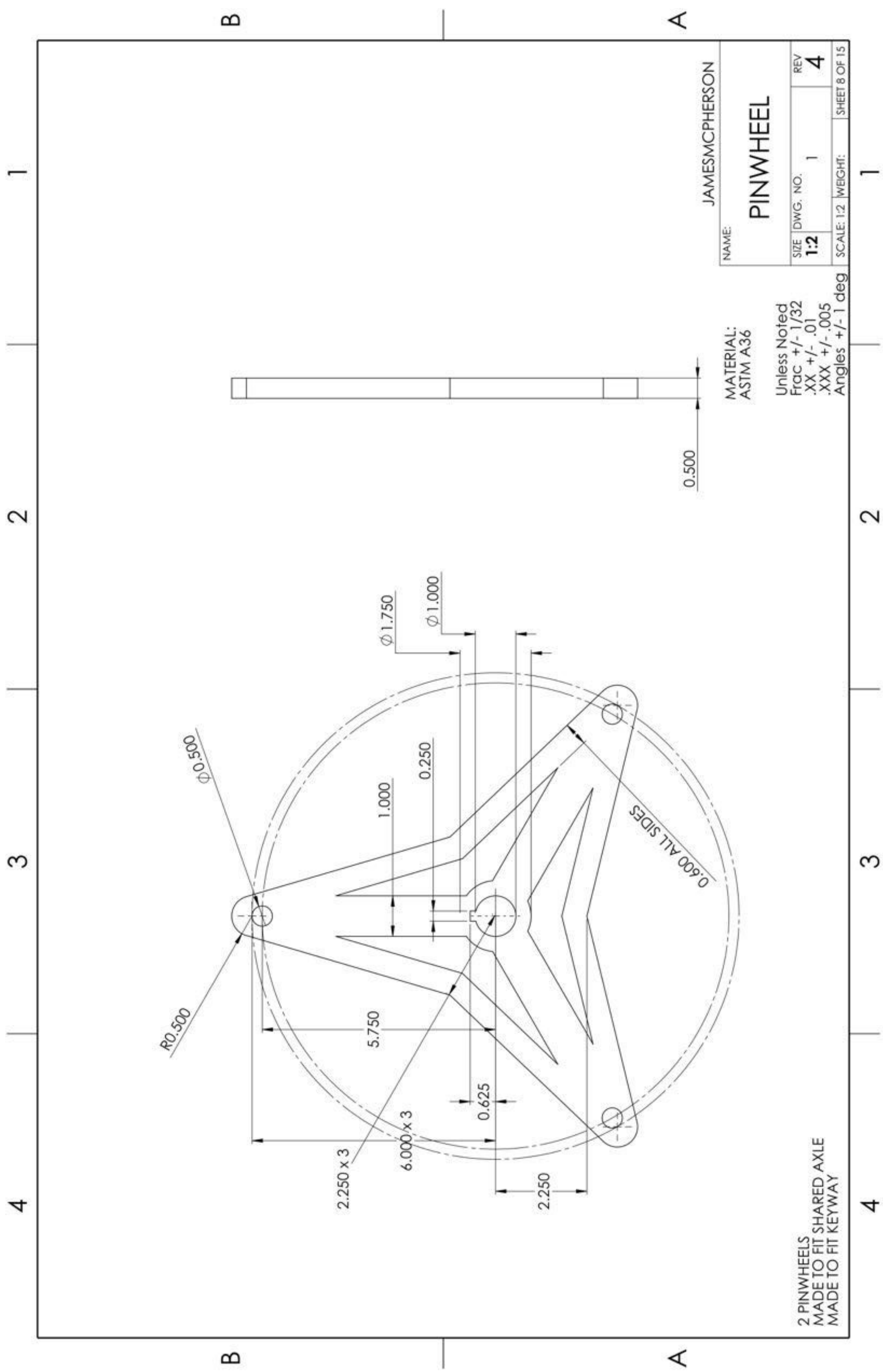
B5: Drawing of Winch Motor Support Bracket



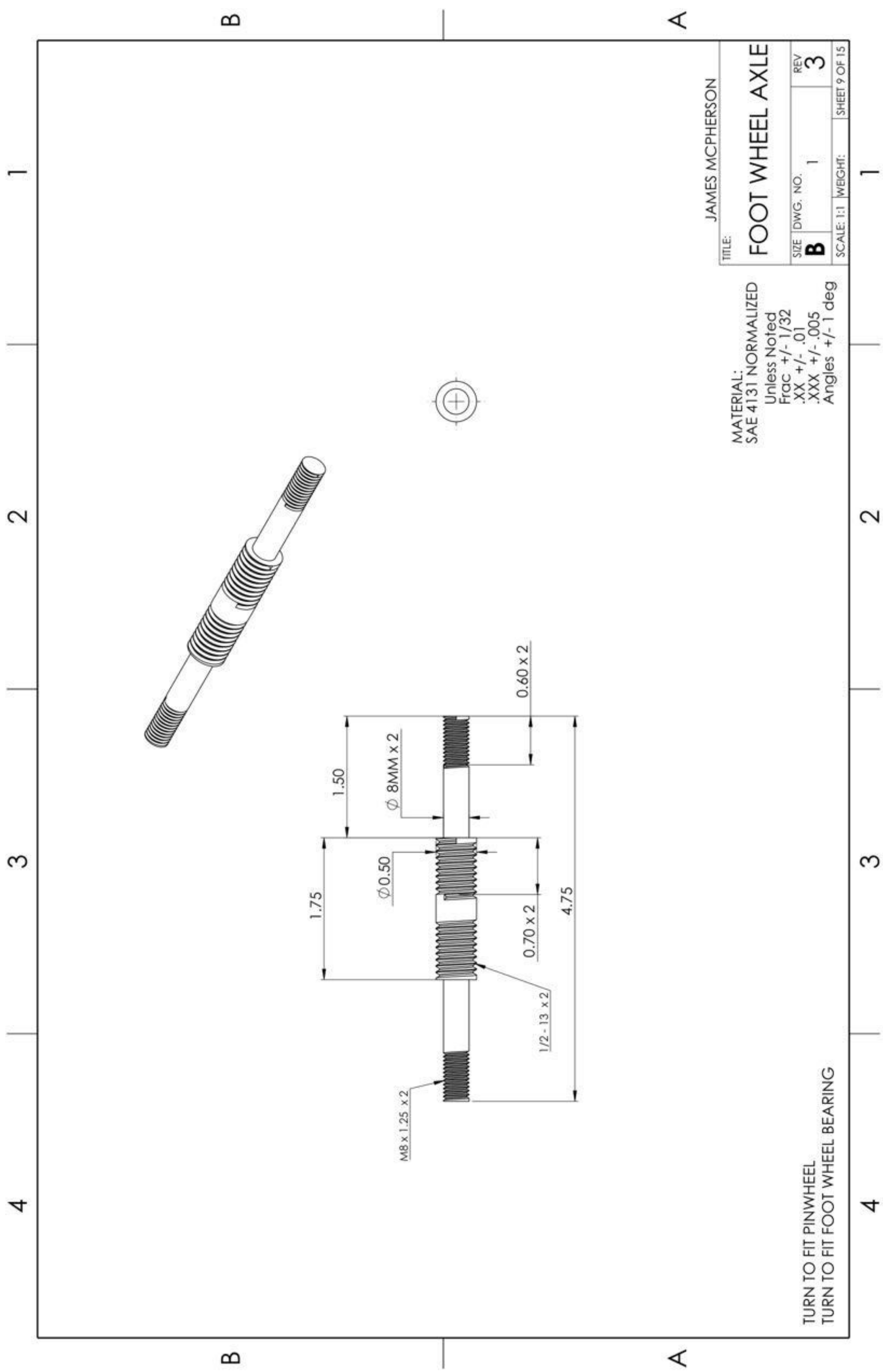
B6: Drawing of Modified Winch Spool



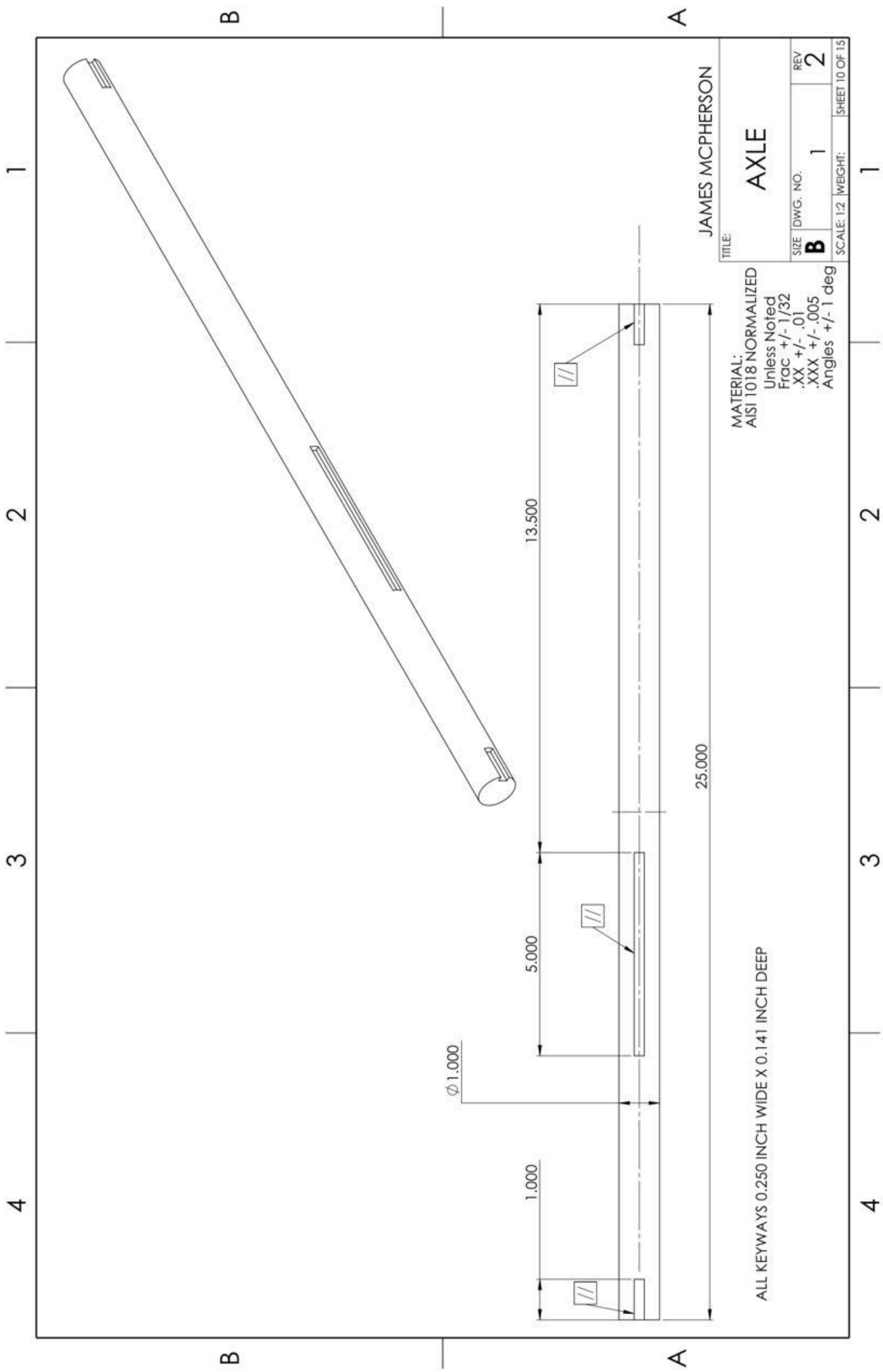
B7: Drawing of Winch Spacer



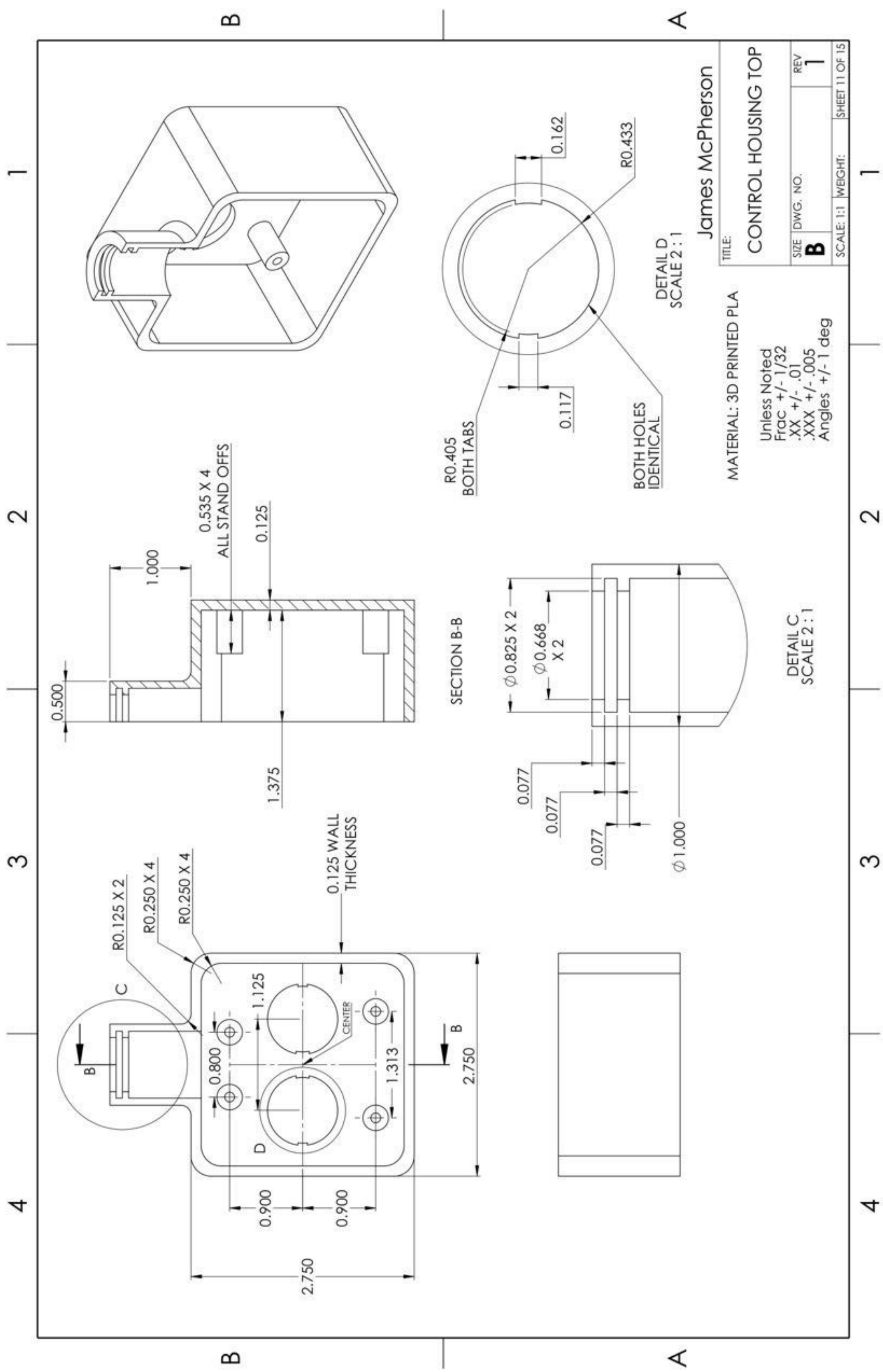
B8: Drawing of Pinwheel



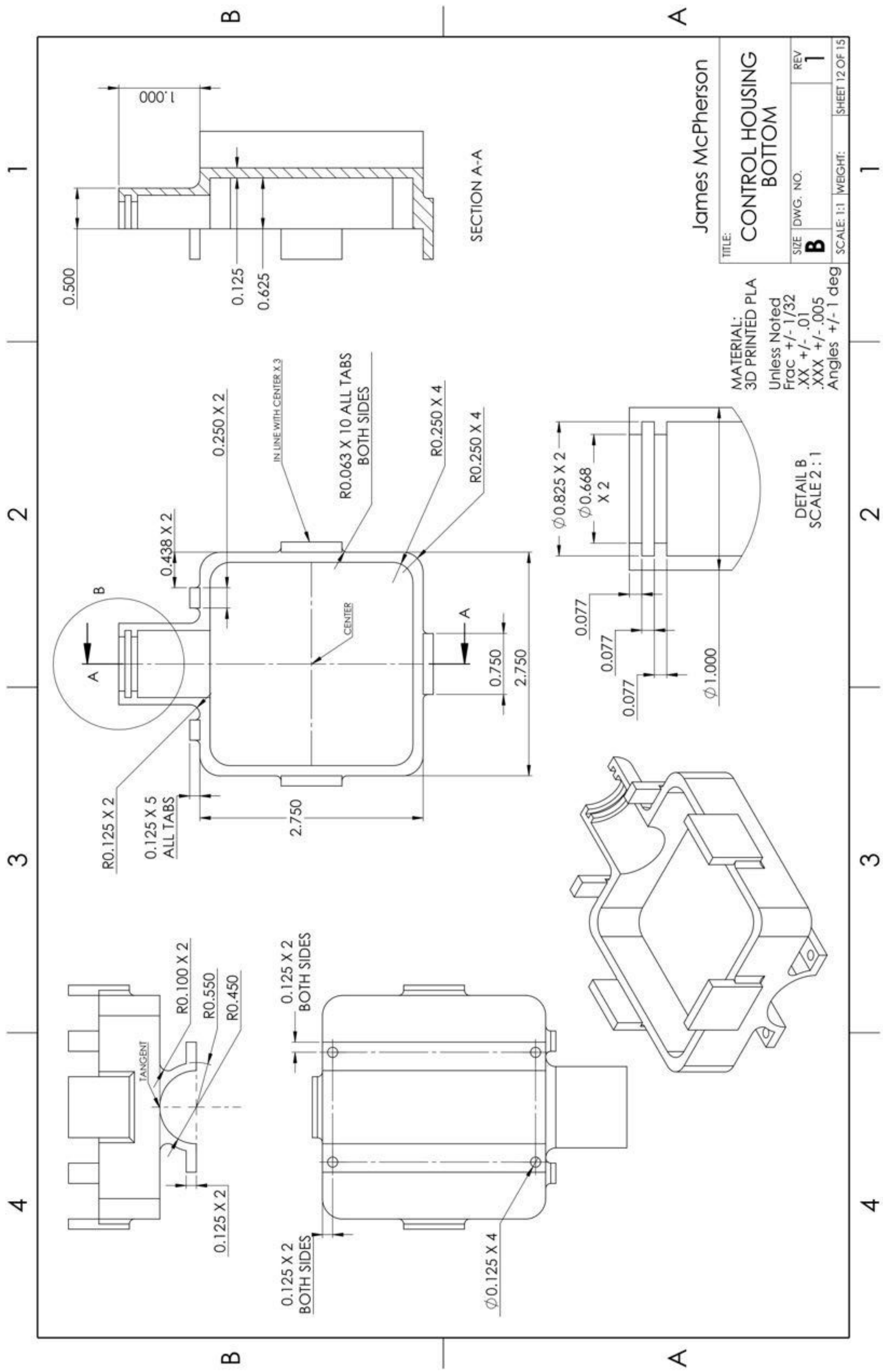
B9: Drawing of Foot Wheel Axle



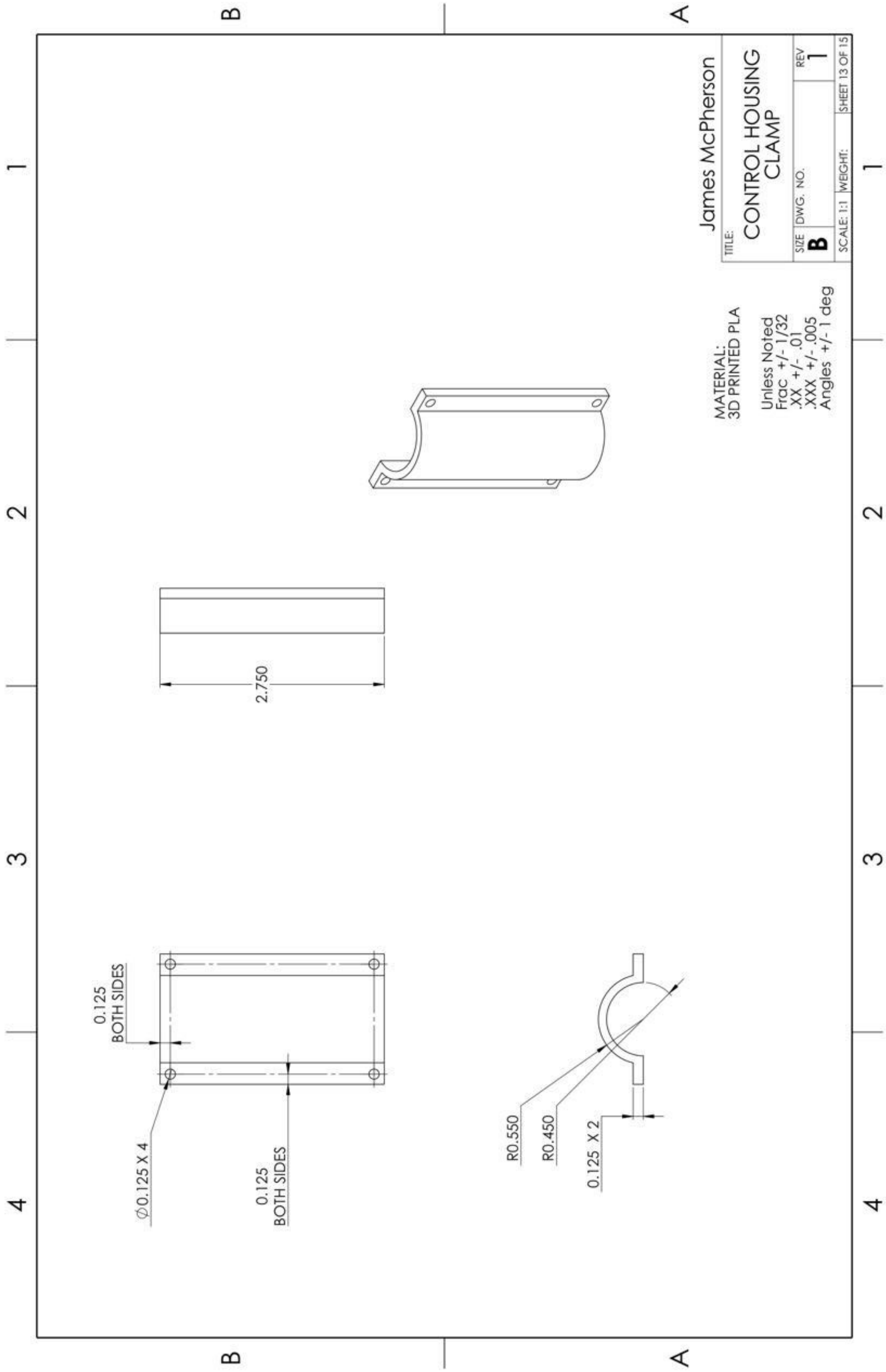
B10: Drawing of Axle



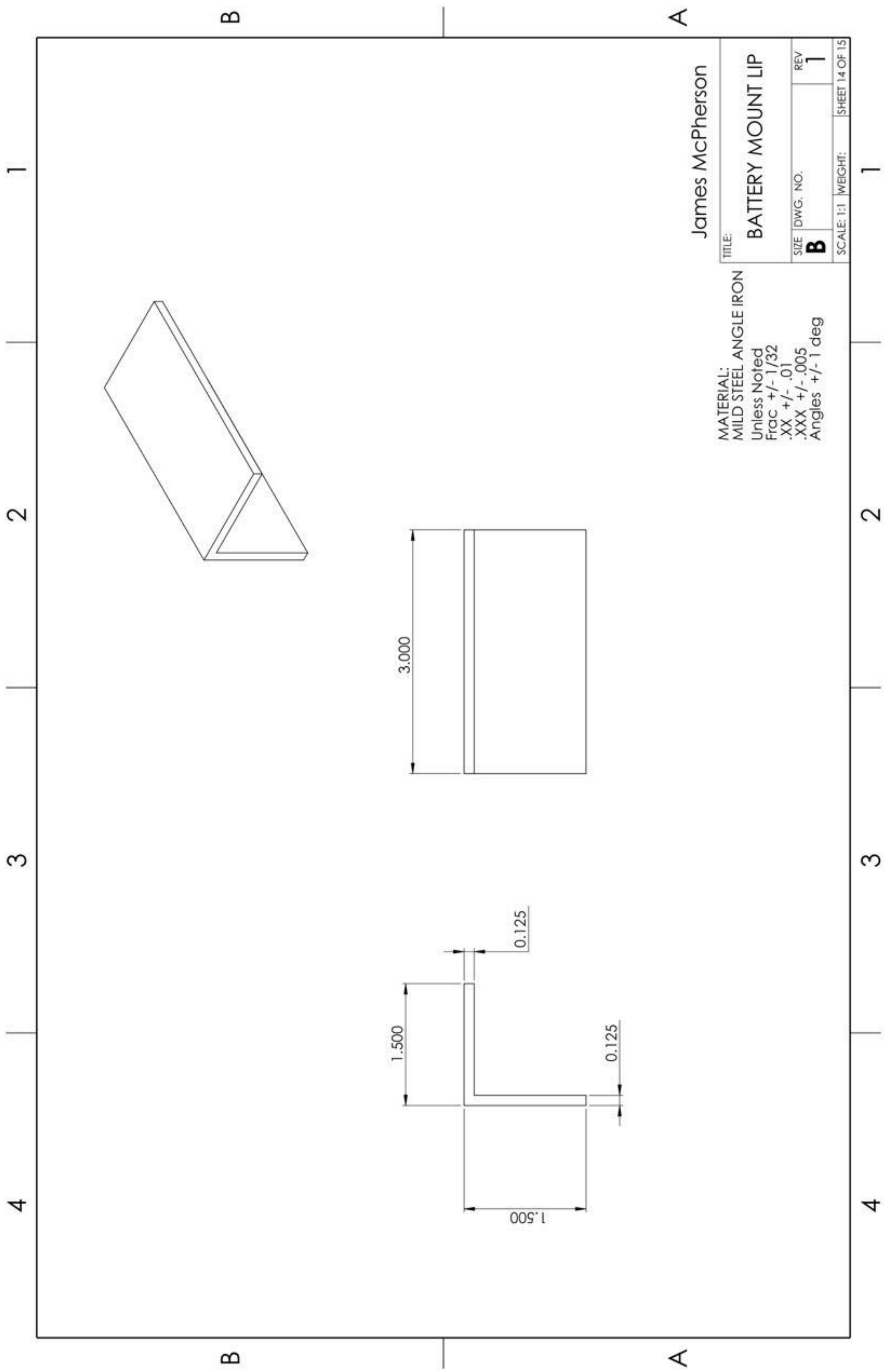
B11: Drawing of Control Housing Top



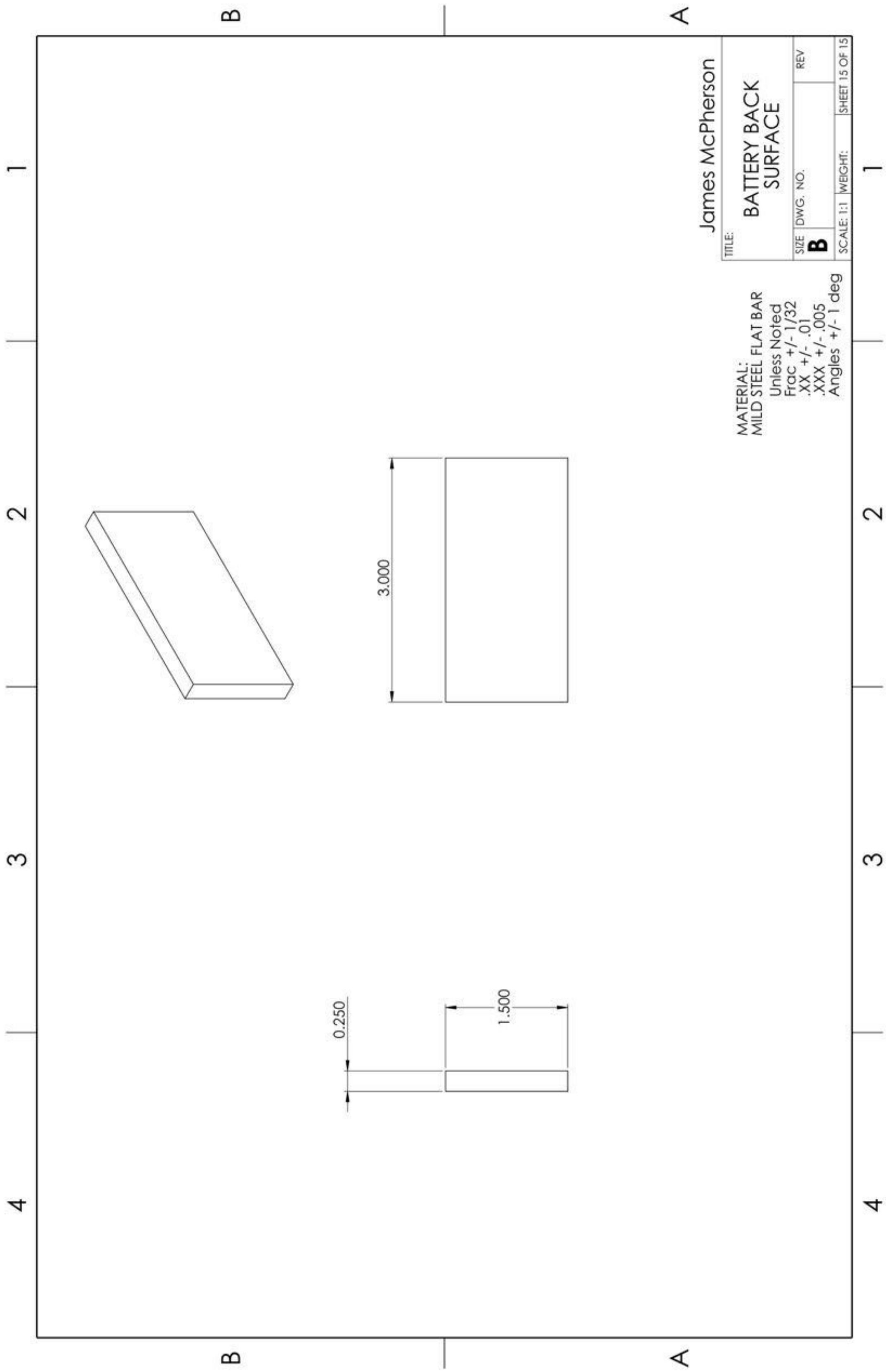
B12: Drawing of Control Housing Bottom



B13: Drawing of Control Housing Clamp



B14: Drawing of Battery Mount Lip



B15: Drawing of Battery Back Surface

APPENDIX C - Parts List

No.	Part Name	Quantity
1	Hand Truck	1
2	Winch Motor Support Bracket	1
3	Winch Motor Housing	1
4	Winch Spacer	1
5	1/4 - 20 Bolt 1.5" Long	1
6	Countersink M6 - 1.0 x 40mm Partial Thread Screw	2
7	Sprocket for #100 Roller Chain - Milled	1
8	Winch Spool	1
9	3/8" Dowel Pin - 2" Long	1
10	Pillow Block Mount Bracket 1	1
11	Pillow Block Mount Bracket 2	1
12	Pillow Block Bearing	2
13	1/2 - 13 Nut	16
14	1/2 - 13 Bolt 1.5" Long	4
15	Axle	1
16	Axle Sprocket 1/4" square Key 5'" Long	1
17	Sprocket for #100 Roller Chain	1
18	Pinwheel 1/4" square Key 0.5" Long	2
19	Set Collar for 1" Shaft	4
20	Pinwheel	2
21	Foot Wheel Axle	6
22	Foot Wheel	12
23	M8 x 1.25 Nut	12
24	#100 Roller Chain 17 with Link pairs	1
25	Control Housing Top	1
26	Control Housing Bottom	1
27	Control Housing Clamp	1
28	Control Circuit Block	1
29	No. 6 Tapping Screw 0.5" Long	4
30	Battery Mount Lip	1
31	Battery Back Surface	1
32	12 V Motorcycle Battery	1
	Total	87

C1: Parts List

APPENDIX D - TESTING

Test 1 Report

Introduction

Requirements-

This project, the stair climbing hand truck, was built to perform one primary function. That is to carry heavy loads up stairs. So the goal of this test is to evaluate the ability of this project to do just that. The stated function of the device is to carry loads of between 60 to 150 lbs, up stairs. Success is claimed of the 150 lb load is carried in 5 seconds per step, or less.

Parameters of Interest-

This test will be a timing test. The device will be used to carry loads, and the time used to carry said objects will be recorded.

Predicted Performance-

This device is predicted to carry a load of 150 lbs up 20 steps in one minute. That is equal to 3 seconds per step.

Data Acquisition-

A stopwatch / phone timer was used by the operator’s assistant to record. the time.

Schedule-

This test was performed on Thursday June 4, 2019. See Gantt chart in APPENDIX E in main report for other schedule details.

Method

Resources-

All the resources for this test are provided by the CWU MET department by Matthew Burvee. Items provided include, box, weights, cones, slack strap, ect. See below for more details. Access to the testing location is also provided by the department.

Data Capture-

Data Capture is very straight forward. Time will be measured with a stopwatch, and recorded on paper.

Test Procedure overview-

Weights are put into a box. That box is strapped to the stair climbing hand truck. That hand truck is used by the operator to carry the load up 17 steps to the first landing of a flight of stairs. The time will is recorded by an assistant. See below for greater detail on procedure.

Operational Limitations-

The main operation of this machine in the upward climbing of a set of stairs. All other possible operations were are performed in this test. The downward function of the device is addressed in test 2.

Precision and accuracy-

The precision and accuracy of this test are limited by the reaction time of the operator's assistant, and the precision provided by the assistant's stopwatch.

Data Storage/manipulation/analysis-

The climbing time for each load is stored on paper or in a spreadsheet. A line graph of climbing time vs load is made with the data.

Data presentation-

Data is presented in line graph.

Test Procedure

Summary/Overview-

This Project is designed to carry heavy loads up stairs. So this test will apprehend the ability of this project to do just that. The hand-truck will be loaded with heavy weights and scrap, and the user will operate the hand-truck while keeping time.

Time, Duration-

This test will be performed on Thursday, June 4th, 2019, at 11:30 AM. While the test should not be rushed, the expected end will be at 2:00 PM on the same day.

Place-

This test will be performed in the Fluke Corporation Interdisciplinary Lab, which is located in the Hogue Technology Building on the Central Washington University Campus. There are two stairwells on the north and south walls of the interdisciplinary lab. The stari well on the southern wall will be used for this test.

Resources Needed-

- Stair Climbing Hand Truck
- 1.5’ x 1.5’ x 1.5’ Cardboard Box (or comparable size)
- 200 lbs of Weights and Scrap
- SLACK Strap
- Orange Hazard Cones
- Foot Protection
- Eye Protection
- Stopwatch/Smartphone
- Notebook for Recording Climbing Times
- 1 Assistant
- Philips Head Screwdriver

Specific Actions to Complete Test-

1. Clear the area surrounding the entrance to the top and bottom of the stairwell. The test has the potential to be hazardous.
2. Set up orange hazard cones at the top and bottom of the stairwell.
3. Place hand-truck in position at the bottom of the stairs.
4. Secure Cardboard box to hand-truck frame with bungee cord.
5. Load Cardboard box with 150 Lbs of weights and scrap.
6. Line up hand-truck with stairwell.
7. Connect positive red wire to battery.
8. Assistant starts timer.
9. Press the left button on the blue control housing to engage the chain drive up the stair. Press and release the button as needed to guide the machine up the steps.
10. Stop at the first landing. Assistant stop timer. Record time and number of steps.
11. Carefully guide the hand-truck back down to ground level using the right button to go down and the left button to come back up as necessary.
12. Load another 25 Lbs of weights and scrap.
13. Realign and repeat steps 8-11.
14. Load another 25 Lbs of weights and scraps.
15. Realigns and repeat steps 8-11 one more time.
16. Remove box and weights.
17. Disconnect battery from positive red wire.
18. Remove orange hazard cones.

Risk/Safety Evaluation-

This test has a fair bit of potential to be hazardous. This is why the orange hazard cones are called for. Unaware bystanders should not be near to, or interfering with, this test. If the operator loses grip of the hand-truck, and the whole apparatus falls, that is a very dangerous thing to be near. The assistant, who is running the timer, should also be watching out for other bystanders, and keeping clear of the bottom of the stairwell.

Discussion-

This test, and the information hearing should be sufficient to accomplish what is needed. However, if any obvious changes become apparently necessary on the day of, the operator and assistant should not hesitate to make them.

Deliverables

Only one trial ended up being performed for this test. During this one trial the machine proved very dangerous and difficult to use with the 160 lb load. The driving torque had to be counteracted by the operator with great effort. Because of this, no more trials were performed in order to avoid damaging the device, or injuring either the operator or the assistant.

Parameter Values-

When this test was performed, the weights used were all 20 lbs. So the possible carry loads were all multiples of 20 lbs. So the first load was 160 lbs. The first run of 17 steps was done in 78 seconds.

Calculated Values-

17 steps in 78 seconds calculates to 4.59 seconds per step.

Success Criteria Values-

Success for this test is claimed if the stairs are climbed in less than 5 seconds per step. By this criteria, 4.59 seconds is a success.

Conclusion-

This test demonstrates the upper limit of operations for the device. A demonstration was given shortly after the test. This demonstration was performed with an 80 lb load, which is a meaningful load. This demonstration was swift and effortless. Up to ~ 120 lbs this device is quite effective and easy to use.

Test Report Appendix

Data Forms-

No forms were necessary for this test. The only data is one recorded time.

James McPherson	Senior Project	4-25-2019

Down The Stairs Test

Line up at the top of a shallow stair well.
Right button to go down, Left button to go up.
Use both as necessary.

+ 9 best
− 9 worst

+ Pass
− Fail

Positive

- [x] Slow — +1 each, −1 for nun
- [ ] Controlled
- [ ] Secure — -2
- [ ] Ease

Negative

- [x] Not Slowed — -1 each, +1 for AVll
- [ ] Falling
- [ ] Inordinate Force Required
- [x] Dissorderly — +1
- [ ] Disturbed Payload

1-2 = -1 Total — Fail

D1: Test 2 Data Sheet

APPENDIX E - Schedule

TASK: ID	Description	Est. (hrs)	Actual (hrs)	%Comp.	S / October / November / Dec / January / February / March / April / May / June
1	Proposal*				
1a	Outline	1	1	100	
1b	Intro	1	1	100	
1c	Methods	1	1	100	
1d	Analysis	11	11	100	
1e	Discussion	1	1	100	
1f	Parts and Budget	3	3	100	
1g	Drawings	5	5	100	
1h	Schedule	5	5	100	
1i	Summary & Appx	1	1	100	
	subtotal:	29	29		
2	Analyses				
2a	Power Needed	1	1	100	
2b	Needed Axle Diameter	1	1	100	
2c	Material decision matrix for axle	1	1		
2d	Shear stress in pinwheel 1.66 in from footwheel	0.50	0.50	100	
2e	Shear stress in pinwheel 4 in from footwheel	0.50	0.50	100	
2f	Material needed for footwheel axles from shear	1	1	100	
2g	Material needed for footwheel axles from bending normal	0.50	0.50	100	
2h	Battery specs	0.50	0.50	100	
2i	Wire guage needed	0.50	0.50	100	
2j	Winch Check	0.50	0.50	100	
	subtotal:	7	7		
3	Drawings				
3a	PinWheel Drawing	1.5	1.5		
3b	Axle Drawing	0.5	2		
3c	Foot Wheel Axle Drawing	0.5	0.5		
3d	PinWheel Assembly Drawing	1	1		
3e	Full Assembly Drawing	2	1.5		
3f	Winch Sub Assembly Drawing	2	2.5		
3g	Winch Spool Drawing	2	2		
3h	Winch Support Bracket Drawing	1.5	3		
3i	Winch Spacer Drawing	0.5	0.5		
	subtotal:	11.5	14.5		
4	Proposal Mods				
4a	Project Robot Schedule	0	0		
4b	Project Robot Part Inv.	0	0		To Be Recorded as Project Progresses
4c	Crit Des Review*	0	0		
	subtotal:	0	0		
7	Part Construction				
7a	Winch Modification	3	15		
7b	Hand Truck Modification	3	4		
7c	Axle Construction	2	4		
7d	Foot Axle Construction	2	10		
7e	PinWheel Fabricaton	2	6		
7f	3D Printing prep and finishing	3	4		
7g	Take Part Pictures	1	1		
7h	Pillow Block Mounting Bracket	4	4		
7i	Winch Spacer	4	5		
7j	Winch Mounting Brackets	4	5		
7k	Update Website	2	8		
	subtotal:	30	66		
9	Device Construction				
9a	Winch Mounting	3	6		
9b	Sprocket assembly	2	8		
9c	Pinwheel Asembly with foot wheels	3	3		
9d	Battery Mounting	2	2		
9e	Pillow Block Mounting	2	2		
9f	Wiring	1	1		
9g	Axle Assembly	3	3		
9h	Drive Train Finally Assembly	3	3		
9i	Update Website	3	3		
	subtotal:	22	31		
	Device Evaluation				
10	List Parameters	1	NYD		
10a	Design Test&Scope	2	NYD		
10b	Obtain resources	2	NYD		
10c	Make test sheets	3	NYD		
10d	Plan analyses	2	NYD		
10e	Test Plan*	1	NYD		
10g	Perform Evaluation	2	NYD		
10h	Take Testing Pics	1	NYD		
10i	Update Website	2	NYD		
10h	subtotal:	16	0		
	495 Deliverables				
11	Get Report Guide	1	NYD		
11a	Make Rep Outline	2	NYD		
11b	Write Report	3	NYD		
11c	Make Slide Outline	1	NYD		
11d	Create Presentation	2	NYD		
11e	Make CD Deliv. List	2	NYD		
11f	Write 495 CD parts	2	NYD		
11e	Update Website	2	NYD		
11f	Project CD*	2	NYD		
11g	subtotal:	17	0		
	Total Est. Hours=	132.5	147.5		=Total Actual Hrs
	100	13250			
Labor$					
	Deliverables*				
Note:	Draft Proposal				
	Analyses Mod				
	Document Mods				
	Final Proposal				
	Part Construction				
	Device Construct				
	Device Evaluation				
	495 Deliverables				

APPENDIX F - Resume

JAMES **MCPHERSON**

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James.mcpherson027@gmail.com

EDUCATION

2017 – CURRENTLY ENROLLED
BACHELOR OF SCIENCE: MECHANICAL ENGINEERING TECHNOLOGY, CENTRAL WASHINGTON UNIVERSITY
On Track to Graduate: Fall Quarter 2019
Relevant Course Work: SolidWorks, Mechanical Design, Strengths of Materials, Technical Dynamics, Statics, Business Stats

2014 – 2017
ASSOCIATE OF ARTS, OLYMPIC COLLEGE

EXPERIENCE

JUNE-AUGUST 2018
FABRICATION INTERN, PROVEL INC., CLE ELUM, WA
Fabrication of Parts for Industrial Machines Including: Machining, Tooling, Assembling

JULY- SEPTEMBER 2017
CREW MEMBER, FARREL TREE AND LAWN, ELLENSBURG WA
Lawn Maintenance Including: Mowing, Trimming, Hauling, Splitting Wood

MAY-JULY 2017
TRASH VALET, VALET LIVING, TAMPA FL
Trash Collection Including: Travel Between Apartment Complexes, Door to Door Collection, Hauling Away, Late Hours

FEBRUARY- JUNE 2017
MATH TUTOR, OLYMPIC COLLEGE, BREMERTON WA
Assisting Students with Course Work Including: Math from Algebra to Upper Division Calculus, and some physics

SKILLS

- Certified SolidWorks Associate - CSWA
- Proficient in AutoCAD, & Other CAD Packages
- Experienced Owner of Multiple 3D Printers
- Proficient in Microsoft Office, Including Word & Excel
- Displays a Positive Demeanor
- Learns Tasks Quickly
- Keeps Cool Under Pressure
- Proficient in Basic Fabrication & Machining Tasks

APPENDIX G - Other Photos

Photo of fitting the sprocket to the freshly turned outside diameter of the winch spool

Photo of partially finished pinwheel. This is the Pinwheel that turned out nicer. The other pinwheel got chewed up pretty badly by the plasma cutter

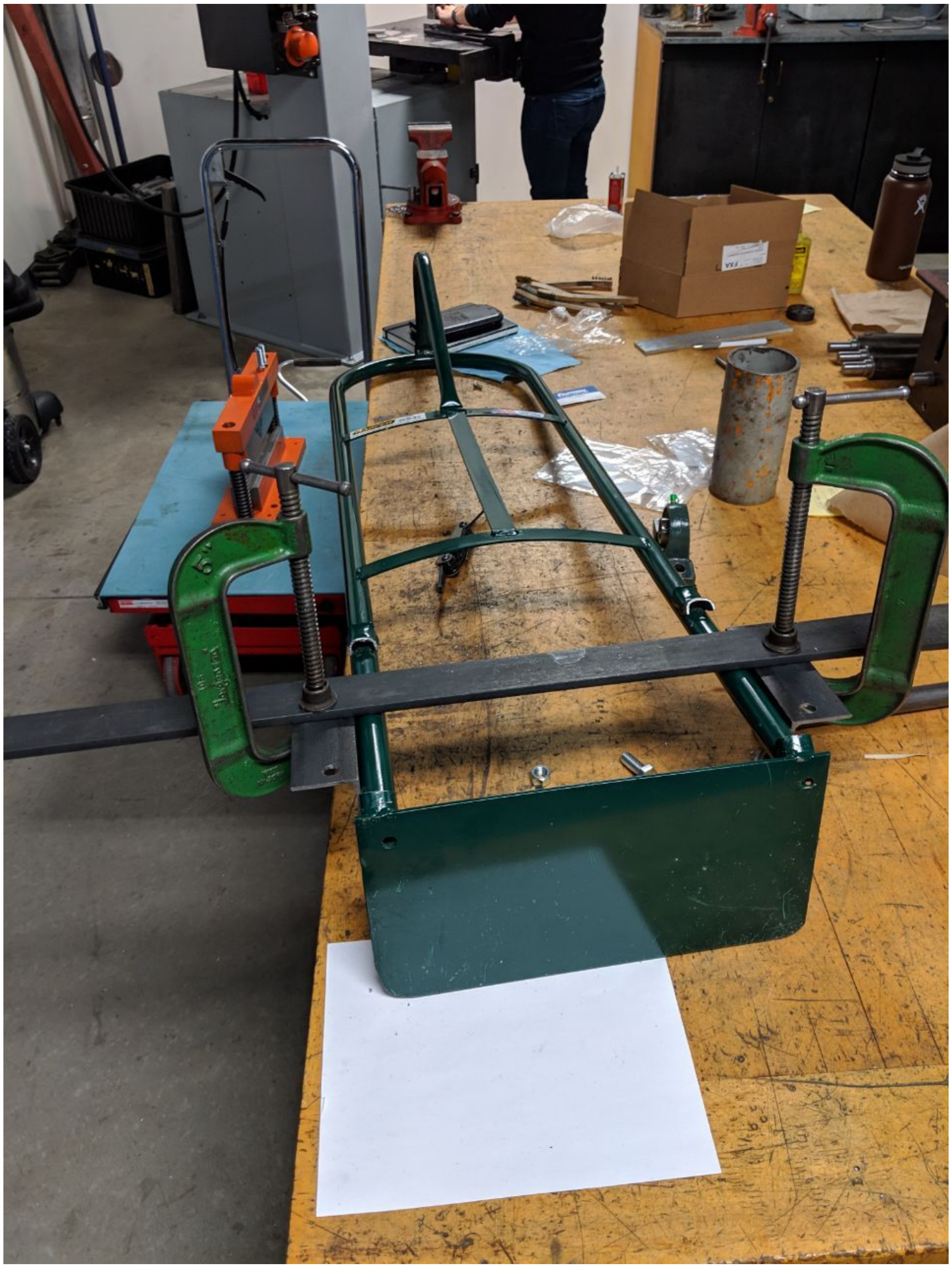

Photo of the makeshift fixture used to place the pillow block mounting brackets. The brackets were later welded in place

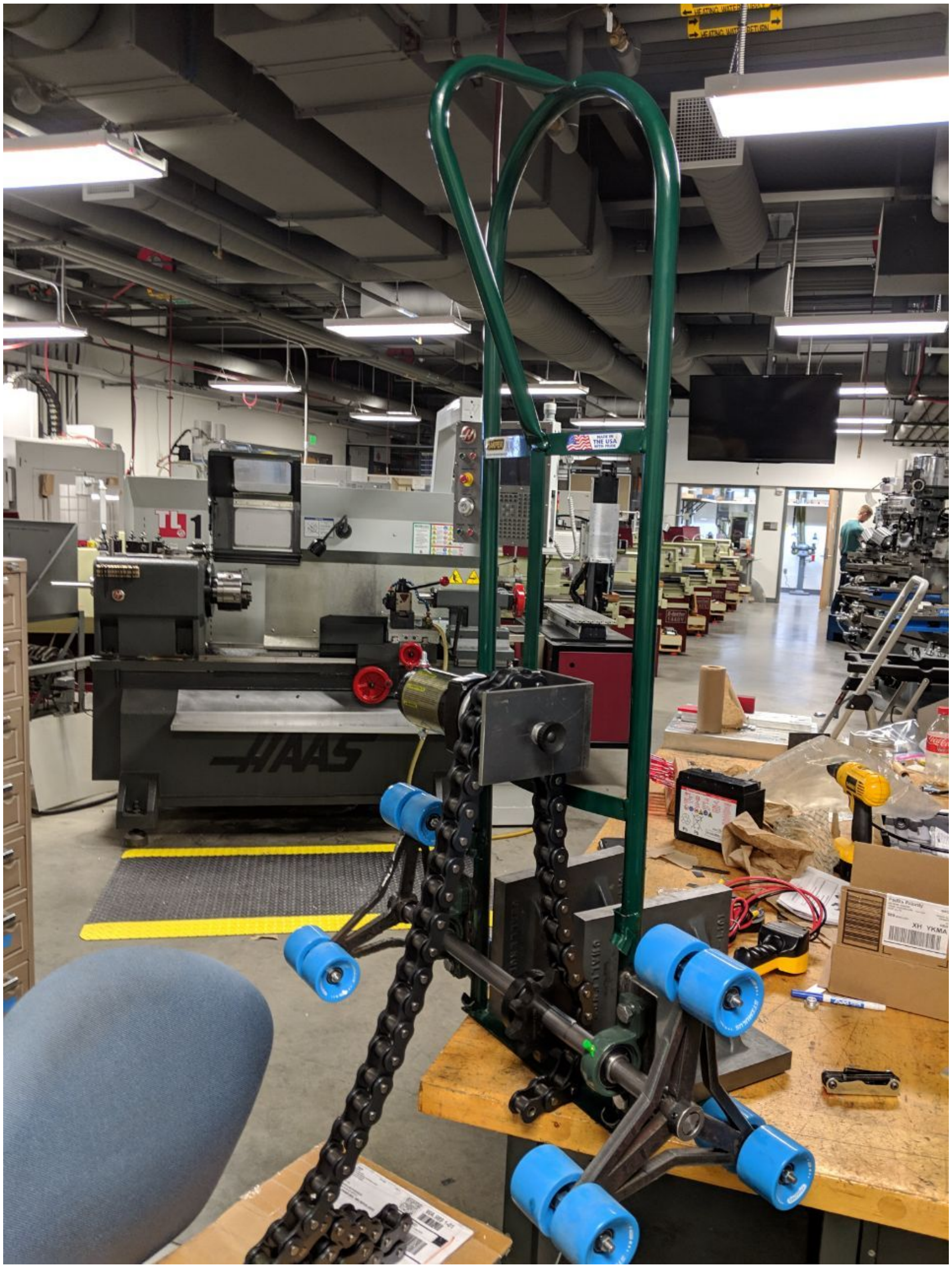

Photo of the setup used to fit the #100 roller chain to the drivetrain assembly

Photo of the finished and mounted 3D printed control housing