Robotic Patient Transfer Device

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Senior Design II

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Executive Summary

In the medical industry, the majority of the workforce are nurses and caretakers. Without these key personnel, patients would go without care and possibly die. Due to the long hours, stress, and difficult lifting situations, nurses and caretakers become injured and have to take time off from work due to these injuries. The majority of these injuries come from lifting patients in and out of a bed and wheelchair. The most common injury due to this is Musculoskeletal Disorder (MSD) which affects the lower back region of the caretaker .To mitigate these injuries, companies in the past have developed different lifting systems. These lifting systems however, have their disadvantages such as being bulky, difficult to maneuver, and they do not eliminate the risk of a lower back injury in nurses and caretakers.

The purpose of this report is to provide documentation showing that a device can be designed and built to satisfy the following requirements. The device must safely transfer the patient from a bed and then to a chair or wheelchair and vice versa. The operation of the device must also be safe for the nurse and caretaker and help mitigate lower back injuries. These are the main areas that the chosen concept was designed on.

During the design phase of developing concepts, three designs were generated. On the chosen design, a finite element analysis along with other analysis applications were ran using Autodesk Inventor software. With the results, the concept was confirmed to be feasible.
sides that extend from the frame as the primary mode of patient transfer. The frame is mounted to a scissor lift device that allows for vertical adjustments. Also incorporated into this design, is a sling device to help lift and transfer patients securely. The RPTD can also rotate 180 degrees to help in the transferring process in confined areas. Another way this device can be used is as a gurney. With regards to all of these attributes, the RPTD is a patient centric transfer device that focuses on safety and comfortability of both the patient and operator.

Concept Statement

Develop a Robotic Patient Transfer Device (RPTD) to be an effective and safe device for nurses in lifting and transferring patients from a bed to a wheelchair, back to a bed.

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Introduction

The medical industry is one of the most important industries in the world. An industry that garners devices for the capability of saving lives is one of the most critical industries that affects everyone on a day to day basis. In the medical industry, there is a group of people that is on the front lines to helping and saving people's lives. This group of people is called nurses. On the other side of the spectrum, there is another group of people that help take care of people that are ill and unable to care for themselves. This group of people is called caretakers.

Both of these groups of people are depended on by the disabled, sick, injured, and dying patients. Unfortunately, many nurses and caretakers become injured due to transferring patients. According to the Bureau of Labor, "In 2008, there were 36,130 occupational musculoskeletal disorder (MSD) cases in private industry where the source of injury or illness was a health care patient or resident of a healthcare facility." [1]. Astoundingly, "Almost all (98 percent) of the cases involving patient handling occurred within the health care and social assistance industry, composing 55 percent of the 64,300 total MSD cases in that industry." [1]. Every time a nurse or caretaker becomes injured, another person has to take their place. This can cause stress in the workplace by not having enough qualified personnel to do daily tasks or respond to emergencies. To mitigate the number of nurses being injured due to MSD would be a substantial gain in the medical industry.

What is musculoskeletal disorder? According to the Center of Disease Control, "Musculoskeletal disorders (MSD) are injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs." [2].The main problem area for nurses and caretakers dealing with musculoskeletal disorder is in the lower back region. This is due to continuous lifting of patients and overexerting themselves due to not having enough help to take some of the load off of their own body in the lifting process to transfer the patients. Many factors contribute to how much of a load a nurse or caretaker can handle such as age, size, and physical well-being. To eliminate or partially eliminate the process of manually lifting patients would mitigate the chance of nurses and caretakers becoming injured due to MSD.

To help attenuate injuries due to lifting and transferring patients, companies in the past designed and built transferring devices. However, nurses and caretakers are still being injured with MSD due to the extent of the manual labor they perform while using these devices. One of the most popular devices out on the market today is a hoist mechanism. This requires a nurse to secure a patient in a harness, attach the harnessed patient to the hoist device, and then lifting and moving the patient slowly to the desired destination. Although, this system safely transfers the patient and mitigates the risk of the nurse or caregiver being injured, there is still room for improvement in transferring a patient safely while ensuring that the nurse or caretaker will be injury free.

Through investigative research and analytical and numerical analysis, Triple C JT Robotics designed a Robotic Patient Transferring Device (RPTD) to safely transport a patient from a bed to chair and from a chair back to a bed while ensuring that the nurse or caretaker will remain injury free from this procedure.

Background

Triple C JT Robotics (TYL 5) was given the proposal to design and build a Robotic Transfer Patient Device (RTPD) for the Department of Nursing and the Department of Health and Kinesiology. The advisor for the Triple C JT Robotics team is Dr. Goh. The team for this project is comprised of four mechanical and one electrical engineering students. The key areas in engineering that are of interest in this project are robotic controls, DC power output, statics, dynamics, and material science.

The purpose of this project is to design and build a Robotic Transfer Patient Device to safely transfer a patient from bed to wheelchair and from the wheelchair back to bed while making the transfer ergonomically friendly for the nurse or caretaker. One of the main obstacles encountered with this design is transferring the patient from the wheelchair due to the design of the wheelchair with the back wheels getting in the way of the transfer. The other obstacle encountered is countering the moment of the system with weight distributed at the maximum range to keep the RPTD from tipping over.

The main parameters for this project consist of the following. The Robotic Patient Transferring Device must incorporate a 1.5 Safety Factor to the 350 pounds required weight that the device must lift. With this 1.5 Safety Factor incorporated, a distributed load of 525 pounds will be used in calculating the moment and stress on the components of the RTPD. The device must also incorporate robotic arms to transfer the patient and the device must do this safely for both the patient and nurse or caregiver.

Specifications, and Constraints

The following five main requirements had to be met to start constructing the Robotic Patient Transfer Device:

1. The RPTD must safely transfer the patient from a bed to the device.
2. The RPTD must safely transfer the patient from the device to a chair.
3. The RPTD must safely transfer the patient from a chair to the device.
4. The RPTD must safely transfer the patient from the device to the bed.
5. The transferring process in the past four requirements has to be ergonomically safe for the nurse or caretaker.

The following specifications for the project were created by both the sponsors and the Triple C JT Robotics team:

Table 1: Specification Chart

Function Needs	Performance Value	Testing Method	Units	Possible Implementation	
lift most patients	>350 lbs.	FEA	lbs.	scissor lift	
safe to use	1.2-1.4 Safety Factor	NA	unitless		
compatible with wheelchairs	functional	functional test	TBA		
transfer from/to bed	functional	functional test			
transfer from /to chair	functional	functional test		robotic arms	
up to 6 hrs. of continuous use	watts/hr.	NA	watts/hr.	large capacity battery	
store in closet	dimensions TBA	spec limit	inches		
wheels	4 wheels	NA	unitless		
indoor positioning system	functional	functional test	TBA		

Knowing the requirements and constructing the specifications for the Robotic Patient Transfer Device, Triple C JT Robotics proceeded to the next stage of the design process concerning the constraints for the project.

Constraints

The design of the Robotic Patient Transfer Device has constraints that have to be met. These constraints are budget, scope, quality, customer satisfaction, resources, and time. Being mindful of these constraints as seen in Table 2 ensures a successful design and construction of the RPTD.

Table 2: Constraint Chart

Constraint	Description
Budget	The budget of the RPTD project is a crucial constraint. The budget for this project is $5,000.00. Ensuring that the costs of this project is below the budgeted amount is critical in the design of the RPTD because the parts that are required to build the RPTD are paramount in the success of the project.
Scope	Another crucial constraint for the RPTD is the project's scope. The scope for this project is to develop a Robotic Patient Transfer Device to reduce lower back pain in healthcare professionals. This is a critical constraint that has to be met in order to create a device that fulfills the needs of the customer.
Quality	The quality of the RPTD is another important constraint of the project. The RPTD must reliably and safely transfer patients. The quality must be that of other medical devices since the main use of this device will be in a medical setting.
Customer Satisfaction	Customer satisfaction is another paramount constraint imposed on the RPTD. If the customers do not like the design or function of the RPTD, then the project will be a failure. Designing a RPTD that satisfies the customer is important in successfully completing this project.
Resources	Resources are critical in the construction of the RPTD. These resources involve tools and equipment along with the materials and parts that are to be used to construct the RPTD. Ensuring that these required resources are available are important to the success of the construction of the RPTD.
Time	The time constraint for the RPTD is another critical constraint that cannot be compromised. The due date to have a fully functional RPTD is April 01, 2020.

Standards Implemented into Design

1. ASTM A513 / A513M - 19 Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing

2. ASTM B209 - 14 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

Final Design Details and Considerations

Selected Design

The selected design that we presented in our final design review had many changes from our initial selection of Design Concept 3. Through many iterations of finite element analysis and stress calculations, the team tweaked that design to finally be the one shown below in Figure 1. This design incorporates sliding mechanisms under arms in the neck and knee area along with two under a plate that sit under the hips. The two arms are attached to a linear actuator so that the healthcare professional can operate them remotely, while the hip slider is manually moved.

The advantages of this device were of the following:

1. The Sliding Arm Method can easily transport the patient from a bed to a chair or a chair to a bed and is more feasible than Concept 3.
2. The Sliding Arm Method will use linear actuators to further reduce the load on the nurse during transfer.

These disadvantages of this device were of the following:

1. The arm method would be a complex system to design and build.
2. Tilting of the entire device under load is a concern, therefore, a leg system must be incorporated.

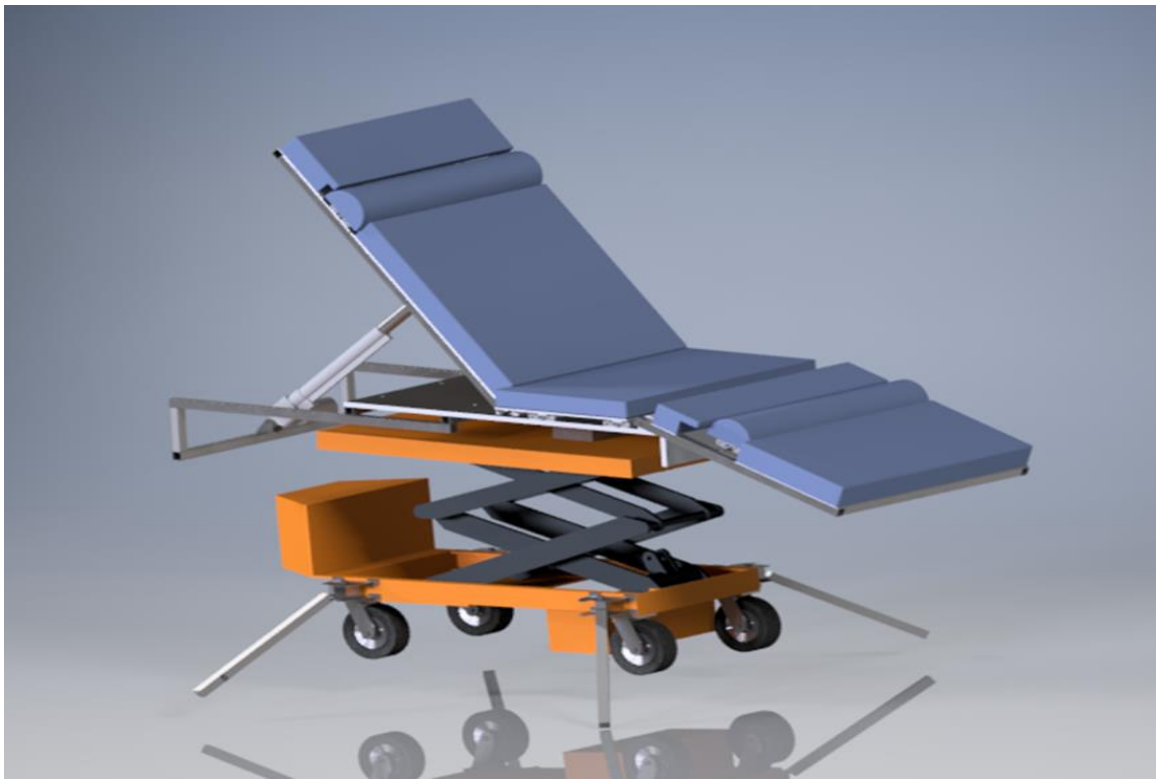


Figure 1: Selected Improved Design

Mechanical Aspects of the Chosen Design

There are many mechanical aspects of the chosen design as seen in Figure 6. There are two sliding arms and a hip plate, the upper and lower parts of the frame pivot like a hospital bed, and the whole assembly sits on a turntable-type mechanism to allow for 180 degrees of movement. All of this is attached to a scissor lift to allow it to move to any height for transferring of a patient.

The two arms are attached to sliding mechanisms like what would be found attached to a drawer. These mechanisms are joined to the frame giving the arms strength and stability. Each arm has a linear actuator attached to it to allow for remote extension and retraction to make it more convenient for the nurse.

The hip plate, like the arms, is connected via two sliders. The hip plate, however, will not be motorized. The decision was made by the team to keep the hip slider manual to allow for greater control and saving space which will allow for easier transfers.

The upper and lower frames will be attached to the device by two pillow block bearing assemblies each. These pillow block bearing assemblies allows the sub frames to move independently to match the position of the patient whether they are in a chair or a bed. This will also be achieved using actuators to raise and lower the sub frames.

All the above-mentioned mechanical features will be attached to the top of a scissor lift via a turntable mechanism. This mechanism will support the full weight of the device plus the weight of the patient minus the weight of the scissor lift. This design will allow for 360 degrees of movement; however, we will restrict it to only 180 degrees to meet the requirements for transfer as directed by the customer.

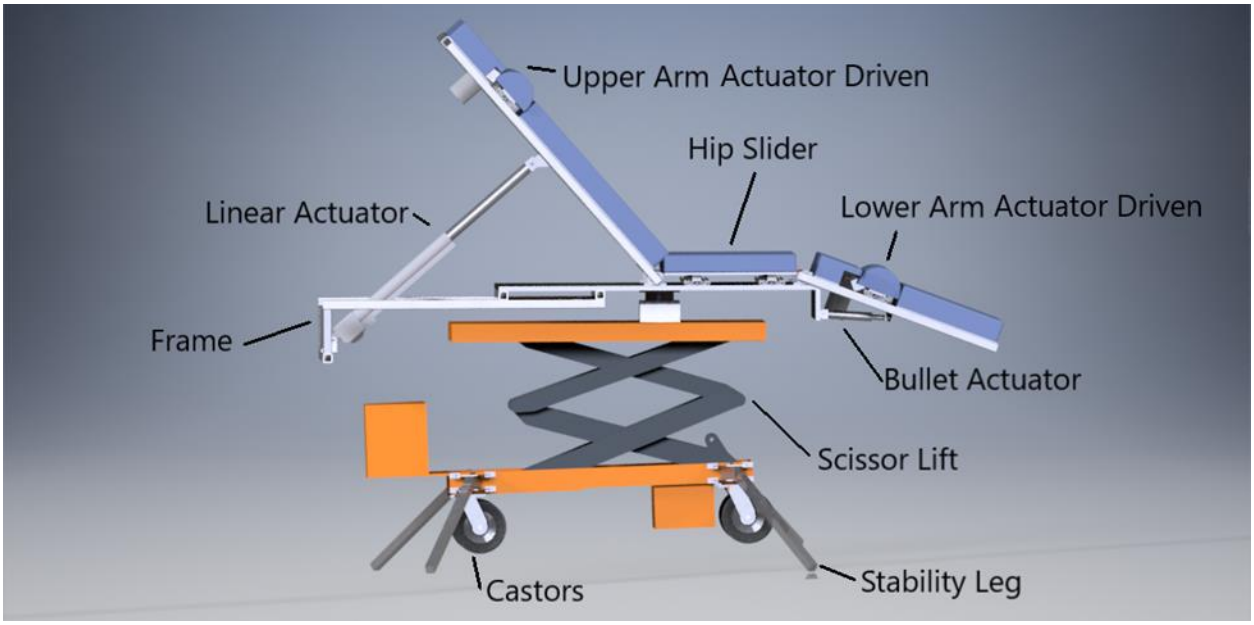


Figure 2: Mechanical Aspects of Chosen Design

Final System and Subsystems'

To help define the RPTD system, all inputs and outputs were considered in the process of the device being in use. The inputs, which are the items that are put into the system to be used are placed on the left side of the black box. The outputs, which are the results of what was put into the black box are on the left. The following Black Box Diagram in figure 3 shows the inputs and outputs. The Functional Diagram in figure 2 shows how the inputs and outputs are integrated.

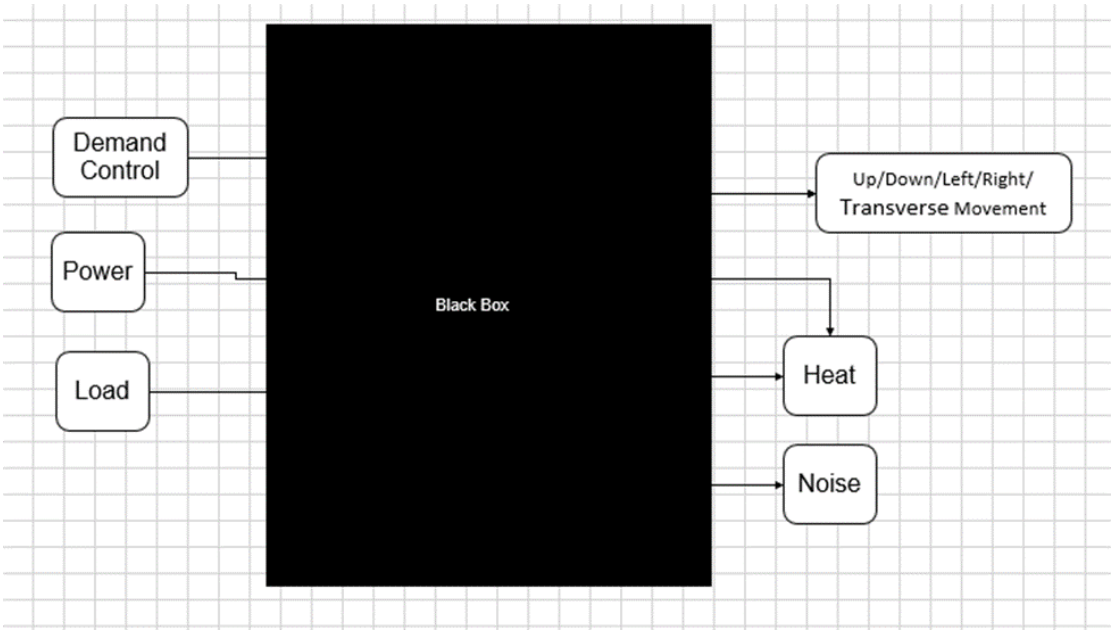


Figure 3: Black Box Diagram

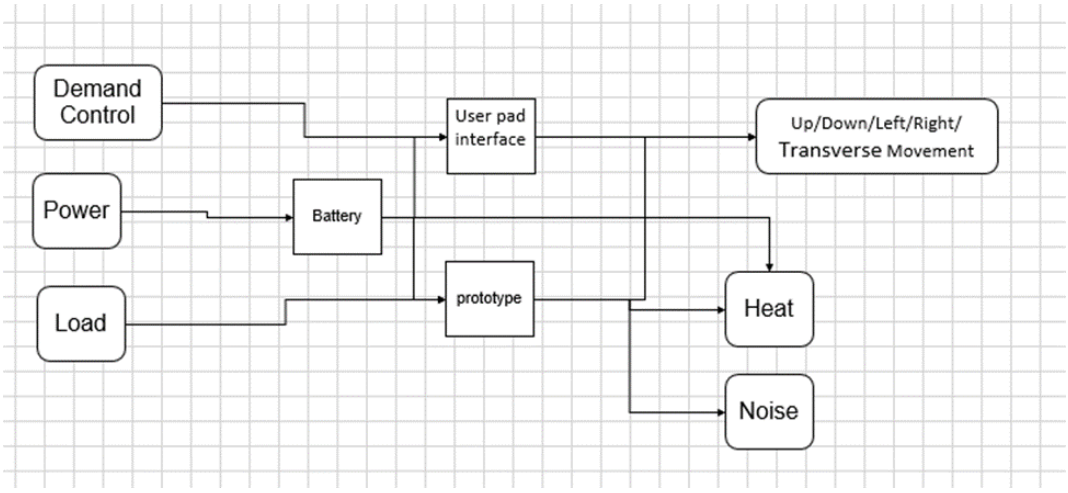


Figure 4: Functional Diagram

Final Calculations and Results

Center of Gravity

The center of gravity was calculated through the Computer Aided Drawing Software named Inventor. As shown in Figure 5 and Figure 6, the center of gravity was found to be near the center of the device. The center of gravity is an important factor in finding the moment about the device so that the final design can be designed to be stable while in use.

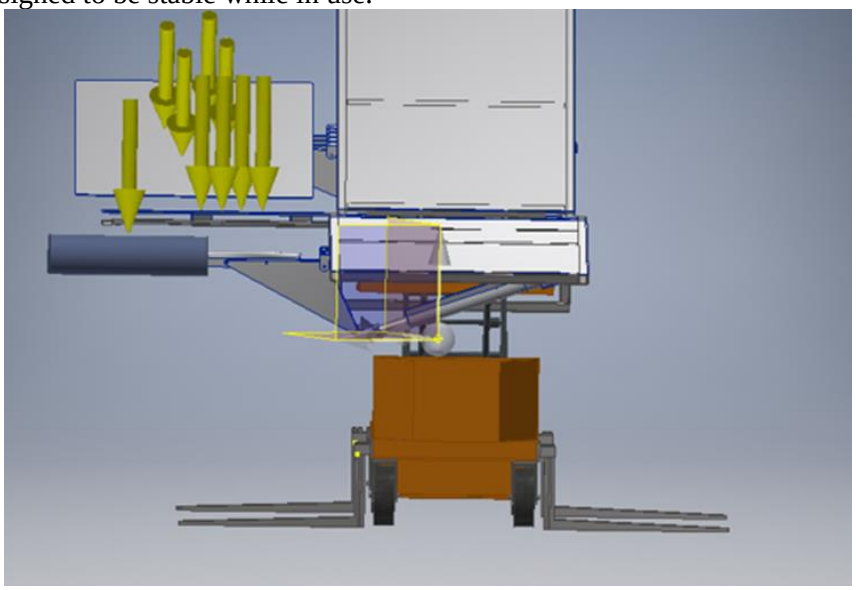


Figure 5: Center of Gravity Position

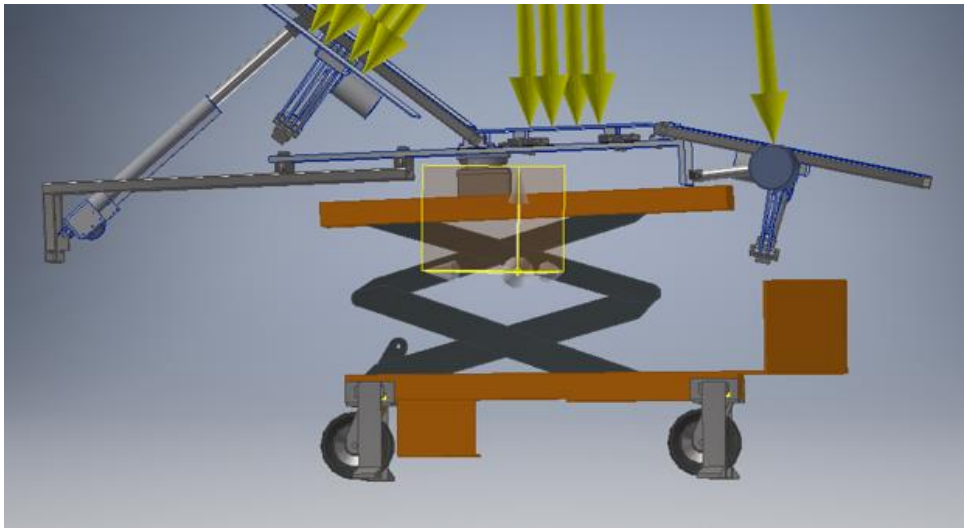


Figure 6: Center of Gravity Position

Angle of Force for Actuators

Lower Plate:

To find the actuator's placement, the minimum angle of the actuator needs to be calculated so that the force produced by the actuator can overcome the force of the patient and lower the device assembly's weight. Figure 7 depicts the lower plate with the maximum forces acting on the system.

1. The driving force of the chosen linear actuator is 400 lbs.
2. The weight of 15% of the patient's body and device's lower assembly is 98.75 lbs.

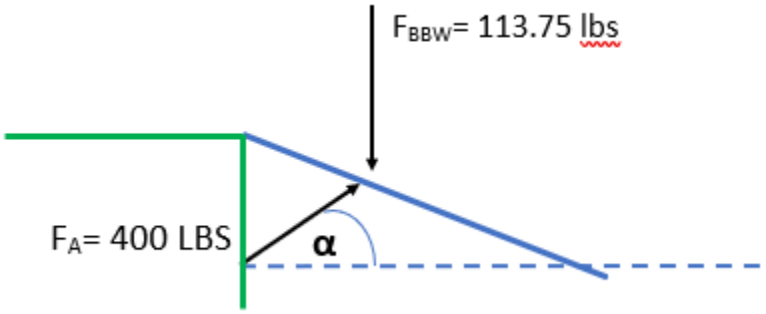


Figure 7: Lower Plate Free Body Diagram

F_A= Force of Actuator = 1000lbs
F_{BBW}= Weight of Body and Upper Assembly = (.15 x 525 lbs.) + 20 lbs. =98.75 lbs.

$$F_A - F_{BBW} = 0$$

$$F_A Sin(\alpha) - F_{BBW} = 0$$

$$Sin(\alpha) = \frac{F_{BBW}}{F_A}$$

$$\alpha = Sin^{-1}(\frac{F_{BBW}}{F_A})$$

$$\alpha = Sin^{-1}\left(\frac{98.75}{400}\right)$$

$$\alpha = 14.29°$$

The minimum angle that the actuator can be placed to overcome the force of the patient and lower assembly is at 14.5°.

Upper Plate:

To find the actuator's placement for the upper plate, the minimum angle of the actuator needs to be calculated so that the force produced by the actuator can overcome the force of the patient and upper device assembly's weight. Figure 8, depicts the upper assembly plate with maximum forces acting on the system.

1. The driving force of the chosen linear actuator is 1000 lbs.
2. The weight of 30% of the patient's body and device's upper assembly is 207.5 lbs.

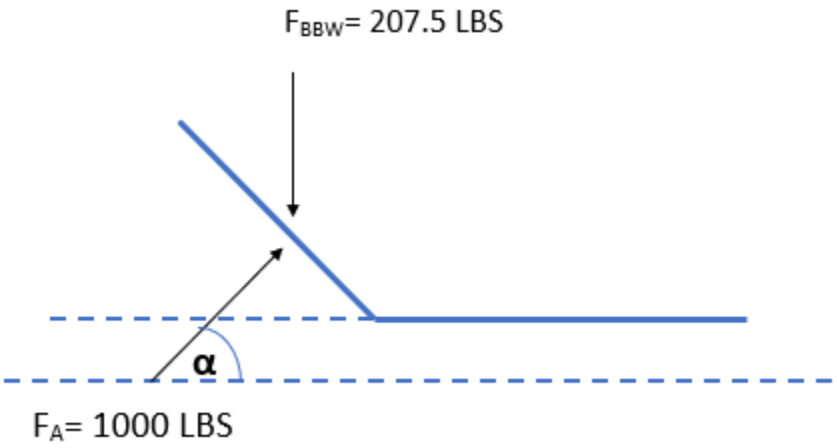


Figure 8: Upper Plate Free Body Diagram

F_A= Force of Actuator = 1000lbs
F_{BBW}= Weight of Body and Upper Assembly = (.30 x 525 lbs.) + 50 lbs =207.5 lbs.

$$F_A - F_{BBW} = 0$$
$$F_A Sin(\alpha) - F_{BBW} = 0$$
$$Sin(\alpha) = \frac{F_{BBW}}{F_A}$$
$$\alpha = Sin^{-1}(\frac{F_{BBW}}{F_A})$$
$$\alpha = Sin^{-1}\left(\frac{207.5}{1000}\right)$$

$$\alpha = 11.97°$$

The minimum angle that the actuator can be placed to overcome the force of the patient and upper assembly is at 12°.

Angle of Force Created by Sling

The angle of force created by the sling was calculated with the following equations, variables, and free body diagram in Figure 9.

- T_1= Tension 1
- T_2= Tension 2
- Length is from robotic arm to center of harness system upon load

$$T_1 Cos(50°) - T_2 Cos(5°) = 0$$
$$T_1 Sin(50°) + T_2 Sin\,(5°) = 350$$
$$\frac{T_2 Cos(5°)}{Cos(50°)} + T_2 Sin(5°) = 350$$

The two equations acquired for T_1 and T_2 are the following:

$$T_1 = \frac{T_2 Cos(5°)}{Cos\ (50°)}$$

$$T_2 = \frac{350}{\frac{Cos(5°)}{Cos(50°)} + Sin(5°)}$$

T_1=135 LBS T_2=213 LBS

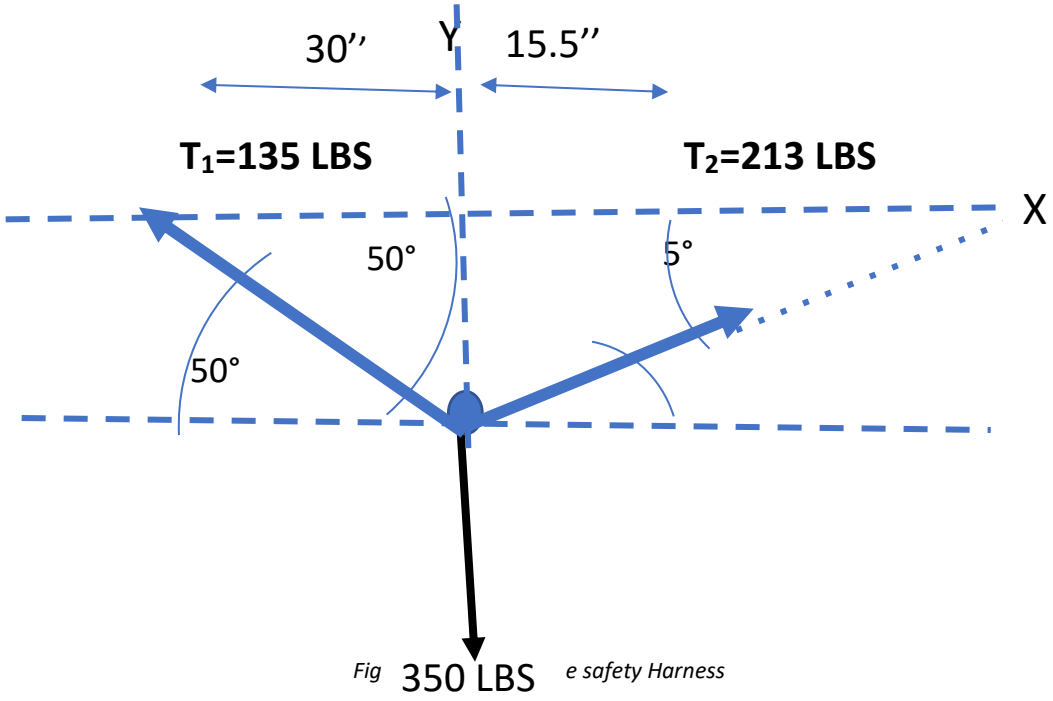


Fig *e safety Harness*

The moment acting on each arm with these equations:

$$Moment\ at\ Upper\ Arm = T1(radius\ of\ armpad)$$
$$135lb(2.5in) = 337.5\ lbs * in$$
$$Moment\ at\ Lower\ Arm = T2(radius\ of\ armpad)$$
$$215lbs(2.5in) = 537.5lbs * in$$

Power Calculations

All battery life calculations were calculated with maximum loads in mind. Although battery cell dissipation is not linear, to simplify the calculations it is assumed to be. The Maximum current draw was calculated for each individual component and then separated into the power supply they would be drawing from. The energy for the respective batteries was determined from their specification sheets. This energy in A/hr is divided by the maximum current draw to determine the battery life at maximum load.

12V Source:

Table 3:Current Load for 12V Supply

Component	Minimum Current (A)	Maximum Current (A)
H-bridge Load	0	5(limited by actuators)

The 12V battery is only supplying for the linear actuators, and the motor controller. The losses for the controller are in the milliamp range and thus are negligible. The current listed in table 3 approximates the total current drawn by any one linear actuator. This current is entitled H-Bridge Load as it is the load attached across the H-bridge motor control board.. Typical 12V batteries intended for ATV vehicles like the one incorporated in this design supply 12-18 A*Hrs. Given a total current draw of approximately 5A at max load. The hours of operation are calculated below.

Hours of operation=12AHr/5.02A= 2.4Hr

When driving two actuators at once, such as when both arms are being retracted simultaneously, the current is simply doubled.

Hours of operation=12AHr/10.04A= 1.2Hr

While this doesn't seem like an exceptional amount of time, keep in mind that the device won't be using power aside from the transfer of the patient from one device to another.

5V Source:

Table 4: Current Load for 5V Supply

Component	Minimum Current (mA)	Maximum Current (mA)
Display Base Operation	0.25	.25
Display Backlight	3	3
Button input	3.3	3.3
Logic output	.02	.2
Misc. Resistors	1.6	1.6
Arduino Base	26	26

The rest of the board is powered by 5 1.5V AA batteries. These batteries are connected in series so their voltage adds, but their energy does not. Typical AA batteries supply 2400mAH. To validate the decision not to include backlighting the max draw was calculated with and without it. The increased battery life is shown below.

$$maximum\ total\ current\ with\ backlight = 1 + 3 + (3.3)(6) + (.2)(8) + 1.6 + 2 = 53mA$$
$$maximum\ total\ current\ without\ backlight = 1 + (3.3)(6) + (.2)(8) + 1.6 + 2 = 50mA$$
$$Hours\ of\ operation\ with\ backlight = \frac{2400mAHr}{53mA} = 45Hr$$
$$Hours\ of\ operation\ without\ backlight = \frac{2400mAHr}{50mA} = 48Hr$$
$$\%decrease\ with\ backlight = \frac{48Hr - 45Hr}{48Hr} = 6.25\%$$

While this current increase is much lower with the implemented display than it was with the display incorporated in the design, the backlight was not included due to the lack of necessity. The use of this device in poorly lit areas is not recommended.

Component Selection Reasoning

Mechanical:

Aluminum 6061:



Density: 2.7 g/cm³

Tensile strength (σ_t): 124–290 MPa (18.0–42.1 ksi)

Young's modulus (E): 68.9 GPa (9,990 ksi)

Aluminum 6061 was used for the arm assemblies and base plates for the frame. It was used due to its lighter density when compared to steel. The assembly drawings can be found in Appendices F and K.

Firgelli Automations Linear Actuators:

Model - FA-400-L-12-XX

Dynamic Force- 400 lbs

Screw Type- Worm Gear

Input- 12 v DC

Stoke- 24in



Firgelli Linear Actuators were used to power all motion in the frame and arm assemblies. They were chosen to power the motion of the back and leg parts of the frame and the arms to extend out. The arms were designed with actuators in mind to simplify the system. The specific model was selected due to its low current draw at max load. The lower current draw leads to a greatly improved battery life. Part drawings for the actuator can be found in appendix F.

Accuride Full Extension Drawer Slides:

Flat mount- 180 lbs

Fully extends- 24 in



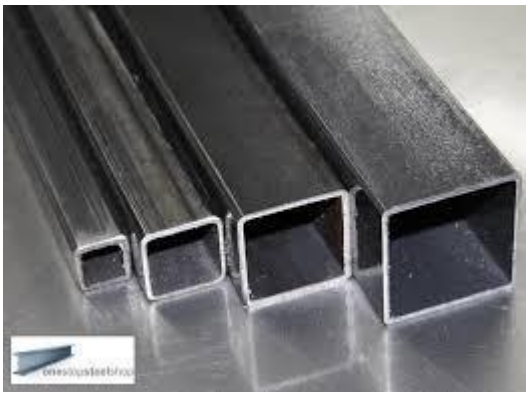
the Accuride Drawer slides were used in the arm assembly and hip plate assembly. They have a rating of 180lbs each, which is enough support with the weight distributed across all 4 included in the design. this part drawing can be found in appendix F

Steel Frame:

Tensile strength: 420 MPa (60.9 ksi)

Young's modulus: 200 GPa (29000 ksi)

Shear Modulus: 80 GPa(11600ksi)



Steel was chosen for the frame to add stronger support. A previous design used aluminum 6061 for the frame and it warped and broke under weight. Since the frame is sitting over the device's natural center of mass the greater density of the material became advantageous in preventing tilt. Drawings for the frame and how it is put together can be found in appendices F and K.

Safety Harness:

Safety Harness is used to hold the patient while in transfer over the side of the device. Our initial market research provided us with the knowledge that many patients feel unsafe in the current existing patient transfer devices. To help us overcome this hurdle we included the safety harness and straps to create a device more focused on the comfort of the patients.



Safety Straps:



Safety Straps were a request from the sponsors of the project. This is additional support to ensure a patient would not fall out of the device, during the transfer process, of their own actions.

Scissor Lift Device:



Raise loads up to **5x faster** with the push of a button.

Hefty 1HP DC motor easily lifts heavy items.

100 lifts per charge: 24-volt, 30 Ah maintenance-free battery with built-in charger.

Height Range: 14 3/4in – 51 ¼ in

Is a device that was inherited from the previous iterations of this project. It is used for the vertical adjustability of the system, raising and lowering the device to meet the level of transfer for chairs or beds.

Pillow Block Bearings:

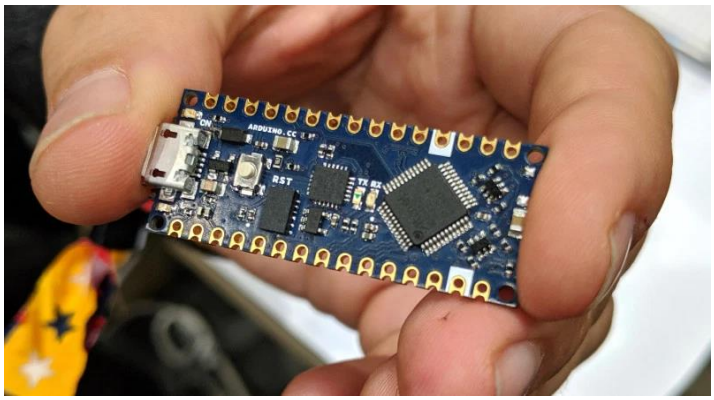
Static Load Capacity: 25,000 lbs

Vibration damping

There are support rods that act as a joint for parts of the frame to anchor them to an Aluminum base. The pillow bearings carry the rods and allow them to have a degree of freedom.



Electrical:



Arduino Nano 33 BLE:

Processor - Cortex M4F

Clock - 64MHz

Flash - 1MB

Ram - 256kB

Supported I/O Voltage - 3.3VDC

The Arduino although unnecessary in the current design, was implemented so that a wireless controller could be incorporated in further iterations of the product. This specific board was selected due to its low economic impact, energy efficiency, and possession of a Bluetooth card. The Bluetooth card is intended to be the means of communication between the remote and the control board. Included in its 30 pins are enough GPIO pins for all 16 of our inputs/outputs(Appendix G Figure 2).

MDD10A:



Manufacturer- Cytron Technologies

Maximum Continuous Current Operation - 10 A

Maximum Current Peak - 30 A

Pulse-width Modulation Max Frequency - 20 kHz

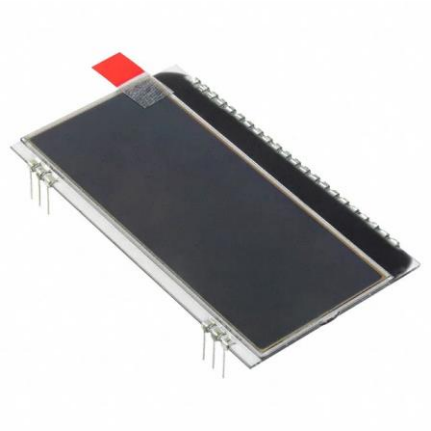
Continuous Voltage Operation - 5-30V

Logic Input High - 3-5.5 V

Logic Input Low- 0-0.5 V

Although a control board and PCB were designed implementing the NXP MC33932EKR2(Appendix G Figures 4&5), there were complications with errors in the PCB and an inability to solder the small pitch of the control chip without shorting connections. Due to these complications the design pivoted to include the aforementioned board. The cost of this pivot was a delay for the testing phase and the necessity for a second board(each board will only drive 2 motors. The Cytron MDD10A was selected as its current threshold lies within the desired values. Most competitors have current thresholds much lower or charge a much higher price as they are designed for hobby electronics and industrial purposes respectively. The board is equivalent to the one that was designed as it includes an H-Bridge design, Flyback diodes, overvoltage/overcurrent protection and error LEDs. These fly back diodes are required to handle transient voltage released from the energy storing elements in the DC motor. When the transistor switches off instantly the DC motor wants to discharge. If the transient voltage build up exceeds the saturation voltage of the transistors it will reach breakdown and force its way through the transistor. This can cause damage

to components. To avoid these diodes are placed to funnel these transients back through the motor or back out to the supply line. The current regulator provides built in short circuit protection as well as a operating current cutoff of 10A. This cutoff current isn't important as the linear actuators contain overcurrent protection. What is important is that it will allow the amount of current required for the linear actuators to operate at full load.



EA DOGM204S-A:

Manufacturer -Electronic Assembly Display Visions

Viewing Area - 59.00mm W x 26.00mm H

Interface - SPI

Supply Voltage - 3V

Operating Temperature - -20-70˚C

The EA display is powered by a 3V source so it can be reliably driven by the 3.3V supply of the Arduino Nano 33 BLE. It also uses I2C. This is a protocol for serial data transmission. Although I2C has few parity bits which can lead to noise, it won't cause an issue over the relatively short distance we will be transmitting. This display was chosen in part due to the familiarity with the manufacturer. EA uses the same control chip on all their displays. The familiarity with commands and protocol greatly reduced time investment required to develop the necessary software. The display has an optional backlight feature, which is not enabled for this design. The device is intended for use in the hospital setting, which is typically well lit. Additionally, the back light reduces the life cycle of the battery. Due to the two prior statements the overall design is optimized by the omission of the backlight. The initial Design used a New Haven Display, but due to a miscalculation regarding The dimensions of the display, a replacement was required. The display is part of the circuit depicted in Appendix G Figure 1, with its PCB in Appendix G Figure 3.

List of Risks Involved and Failure Mode Analysis

Failure Mode Analysis

The team performed a Failure Mode and Effect Analysis (FMEA) as shown Table 5 in order to recognize possible flaws and risks for the chosen design. The table includes the description of potential failure situations, which includes its location and how it could happen. The analysis grades the severity, occurrence and detection from 1-10 (one being the lowest and 10 being the highest on each category). The next step is to determine a Risk Priority Number (RPN), which is determined by a multiplication of the grades assigned to severity, occurrence and detection.

Next, actions recommend for each situation re-describe, as long with a responsibility matrix for each. The actions taken are described, and the severity, occurrence and detection along with the RPN is ranked. The initial and final (post recommended action) RPNs are then compared in order to determine if an improvement was achieved.

The analysis showed that the highest risks were associated with the support leg for the device and the electrical components. If the support legs are not addressed correctly, the device can tilt with a patient on top of it; and if the electrical control system is not correct, the device is in operant.

Table 5: Failure Mode and Effect Analysis

Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1-10)	Potential Causes	OCCURRENCE (1-10)	Current Controls	DETECTION (1-10)	RPN	Action Recommended	Resp.	Actions Taken	SEVERITY (1-10)	OCCURRENCE (1-10)	DETECTION (1-10)	RPN
What is the process step, change or feature under investigation ?	In what ways could the step, change or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step, change or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the occurrence of the cause or improving detection?	Who is responsible for making sure the actions are completed ?	What actions were completed (and when) with respect to the RPN?				
The support leg on the gound	*not be long enough*	*tilting*	*10*	*failure in design*	*3*	*Visual Inspection*	*4*	*120*	*observe placement of legs around base of device*	*Caio*	*lengthening of the design of the leg to 1.5 ft.*	*8*	*1*	*3*	*24*
Rotation of Lazy Susan Joint	swivel into nearby furniture	potential safety risk and damage to furniture vicinity	8	lack of observation	8	Visual Inspection	1	64	design minimum amount space for frame to take up.	Josh	demnsions of device are 70"x35"	6	6	1	36
Design of robotic arm and plate supports	not provide enough support for patient's weight	potential safety risk for the patient and damage to the frame	9	failure in design specifications	3	Stress Analysis	1	27	Testing the supports prior to use with patients	Trevor	Stress analysis conducted on Inventor	7	2	1	14
The frame slider	not provide enough support for patient's weight	potential safety risk for the patient and damage to the frame	9	failure in design specifications	3	Stress Analysis	1	27	Testing the slider prior to use with patients	Trevor	Stress analysis conducted on Inventor	7	2	1	14
The choice of the motor	Motor not provide enough power to she system	System's main functions may be compromised	8	Failure in required power calculation	2	Calculation double check and trust on member responsible for it	4	64	test the motor's response to th system's requirements	Cooper	Hand calculations developed by trustworthy member	7	2	3	42
Selection of motorized actuators	Actuator not having enough power to move the frame	Damage to frame and possible patients safety risk	8	Failure in power calculation	2	Stress Analysis and hand written calculations	2	32	Calculate amount of power necessary to move the frame with patients on it	Trevor	Stress analysis conducted on Inventor	7	1	2	14
The control system	Device not responding correctly to controls	Inoperance of system	8	Failure in controls logic	4	Controls logic diagram	4	128	Visual and rational inspection of control logic diagram	Cooper	Completion of controls logic diagram	7	4	4	##
The frame design	Frame not being able to hold patients' weight	Potential safety risk and damage to the frame	8	Failure in materials choice and design specifications	3	Stress analysis and selection of safety factor	3	72	Researching materials properties and proposed specifications	Caleb	Stress analysis and safety factor analysis conducted on Inventor	6	2	2	24

A risk register and management plan was developed. The matrix shown above was generated accordingly. The assessment of risk involves two factors: the probability of occurrence and the impact on the project. The probability factor is a measure of certainty that the event will occur. It is graded from 1 to 5, in the following manner:

1- Frequent
2- Likely
3- Occasional

4- Seldom
5- Improbable

The impact of the event on the project is letter graded in the following manner:

A- Catastrophic
B- Critical
C- Moderate
D- Minor
E- Negligible

The two factors are then combined in a single grade. According to this grade, a response is developed by the group. The team's response for the risks identified was to mitigate them, since they are not completely avoidable. The plan and matrix also include a contingency plan to each risk, in case it happens, and the cost that it would add to the project.

Table 6: Risk Assessment

RISK	OVERALL IMPACT	MITIGATION	CONTINGENCY	COST
An oversight of a specific part that is needed but not readily available. Team had not ordered or considered the purchase of this tool or part. A problem comes that dictates the need for new part to be purchased	4C	create a check list tab in the BOM that can be marked off as parts come in.	Parts that are missing will be re ordered. Parts that have broken or wrong parts that have come in will be assessed either for repurpose or re order	Depending on part importance, may set back build time by 2-4 weeks. Add to expenditures for another part.
Running analysis on prototype and discover a miss calculation in design.	3B	Discuss among members before and after each test the purpose and expected outcome of the results. Do a calculation assessment before starting each analysis	Review calculations, assess system. if no solution can be understood, escalate issue to expert or advisor.	Time setting back by length of issue.
A part or assembly during build time, breaks and is unusable.	3A	Before each action in build, consider what is being done to the part and why. Make sure all members are trained with any equipment necessary in the build.	reorder component and educate team on the situation so that it may be avoided	Add to expenditure
the power supply is draining too much power	2C	Keep batteries charged. Review electrical diagram before adding new components	Test voltage across each component.	loss of time
the back plate shears off from frame	2A	Keep all analysis from CAD design on this section. Review before testing. Consider material, angle, and power of the system.	Redesign back plate. Repurchase necessary parts	This is a major concern. The arm will have to be re designed to avoid shear. This would set this part of the project back by 3-6 weeks at least
the prototypes tilts and falls during test	2A	Before running prototype test, tether prototype to save it from full collapse on floor.	Assess for any damage. Relook at root principles of the design. Make adjustments as needed.	If prototype is damaged, then cost will be equal to damage. System will be considered for redesign.
Team mate falls ill or sick and their responsibility must be picked up.	2D	Open communication of responsibility and health through the term of the project. Shared files and understandings of each responsibility	split responsibility among rest of team members	time

Final Testing Results

Table 7: Required Testing

Date	Item (Device)	Max Extent Limitation	Test Procedure
Scheduled: 1/20/2020 – 1/21/2020 **Completed: 2/27/2020**	**Large and Small Linear Actuators (1st phase)**	**N/A**	**When actuators are received test them by supplying power to see if they extend and retract.**
Scheduled: 2/17/2020 – 2/19/2020 **Completed: NA**	**Large Linear Actuator** **(2nd phase)**	**Rating of 1000 lbf**	**When actuator is placed on metal frame and upper assembly, test to see if it will hold and move the upper assembly with 157.5 lbs. of force from the two max extents of 0 to 45-degree range of motion.**
Scheduled: 2/05/2020 – 2/06/2020 **Completed: NA**	**Small Linear Actuator (2nd phase)**	**Rating of 400 lbf**	**When actuator is attached on the aluminum base board and lower assembly, test to see if it will hold and move the lower assembly with 78.75 lbs. of force from the two max extents of 0 to 30-degree range of motion.**
Scheduled: 1/20/2020 – 1/21/2020 **Completed: NA**	**Turn Table Swivel Bearing (1st phase)**	**Rating of 1000 lbf**	**To test the turn table swivel bearing, a load of 800 lbs. will be placed on it before placing on RPTD to ensure it will be able to take the load of the frame and patient.**

Scheduled: 2/10/2020 – 2/12/2020 **Completed: NA**	**Hip Support Plate and Track System**	**Rating of 180 lbf on each extended extension slider device.**	**Place 288.75 lbs. on the hip support plate and track system to make ensure it can withstand the max extent of weight placed on it.**
Scheduled:3/11/2020 – 3/13/2020 **Completed: NA**	**Robotic Arm Upper Torso Assembly**	**Rating of 200 lbf**	**Place 184 lbf against the back plate as it is attached to a test Rod to test the functionality**
Scheduled: 3/7/2020 – 3/11/2020 **Completed: NA**	**Robotic Arm Lower Leg Assembly**	**Rating to 100lbf against rod**	**Hang 100 lbf over lower arm as it is attached to test Rod then apply power to actuator**
Scheduled: 2/10/2020-2/14/2020 **Completed: 3/5/2020**	**Continuity Testing**	**N/A**	**After all Components are soldered, continuity tests will be applied to ensure no shorts are present.**
Scheduled: 2/17/2020-2/21/2020 **Completed: NA**	**Logic Signal Test**	**N/A**	**View logic digital logic signals on an oscilloscope to ensure their quality**
Scheduled: 3/9/2020-3/13/2020 **Completed: NA**	**Full Load Test**	**Full Load(5A)**	**The board will be run at full load(5A) to ensure temperature remains at rated value for all components**
Scheduled: 3/16/2020-3/31/2020 **Completed: NA**	**Variable Load Test**		**Apply varying loads to full system to ensure it safely operates with its limits**

Scheduled: 3/11/2020 – 3/16/2020 **Completed: NA**	**RPTDS (Tilting)**	**N/A**	**When RPTD is completely built, the robotic arms and hip support plate will be placed at its maximum extent with the maximum amount of weight to ensure that the device is stable.**
Scheduled: 3/16/2020 – 3/31/2020 **Completed: NA**	**Evaluation of RPTD**		**Physically test RPTD by lifting 525 lbs. from wheelchair to device and transferring it from device to bed and vice versa.**

There were issues ordering and receiving the parts for this project which pushed our assembly back to the week of March 9th. Due to complications caused by the Covid-19 the assembly of the project was not completed and thus, none of the planned testing was executed. To supplement this information additional simulation on the system was completed and is featured in the next section.

Simulation Testing Results

To check the strength of the arms, the team ran a stress analysis. The parameters of the stress analysis included a force of 135.5lb on both of the arms (upper and lower) as seen in figure 12, and a 250lb force on the hip slider assembly in figures 10 and 11. These weights were derived from a project target of 350lb and 1.5 safety factor. This safety factor pushes desired capacity to 525lb.

This stress analysis not only checked the strength of the extendable portion of the device, but also the looked at the stresses on the mounting points to the base plate while under load to ensure that nothing was overstressed which would cause failure in implementation.

The analysis compiled tons of helpful data to check the feasibility of the final design. The max Von Mises Stress was 245.6 ksi. The principal stresses were 287.9 ksi and 16.5 ksi respectively. The max displacement was found to be 0.2853in which is very reasonable considering the amount of weight being applied.

Hip Plate Bending

Below are images of the stress analysis and Safety Factor analysis of a single 250lb load on the Hip slider portion of the frame. This analysis verifies that the Hip Slider design is feasible and can bear the load put on it.

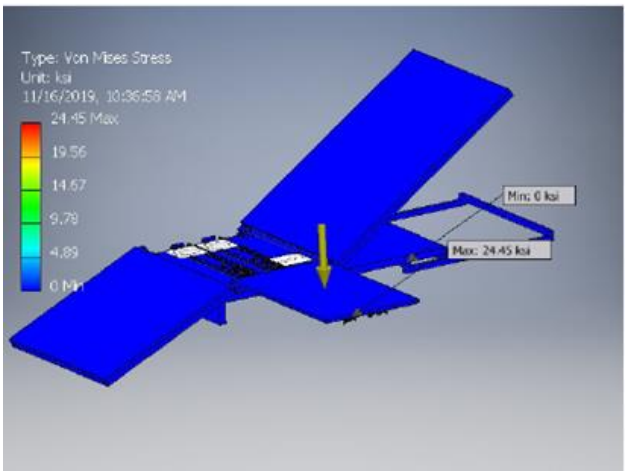


figure 10:Stress Analysis of Hip Plate

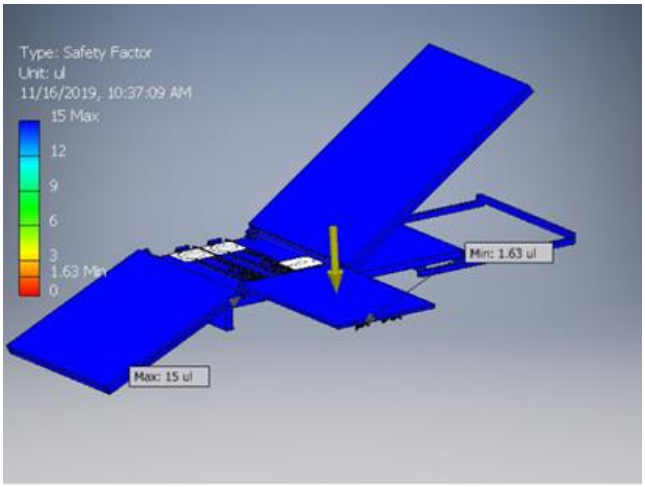


figure 11: Safety Factor

Arm Torque Analysis

Figure 16 simulates that a patient being held in a sling during transfer from device to a chair. This shows that the design is within specification of 1.5 or higher.

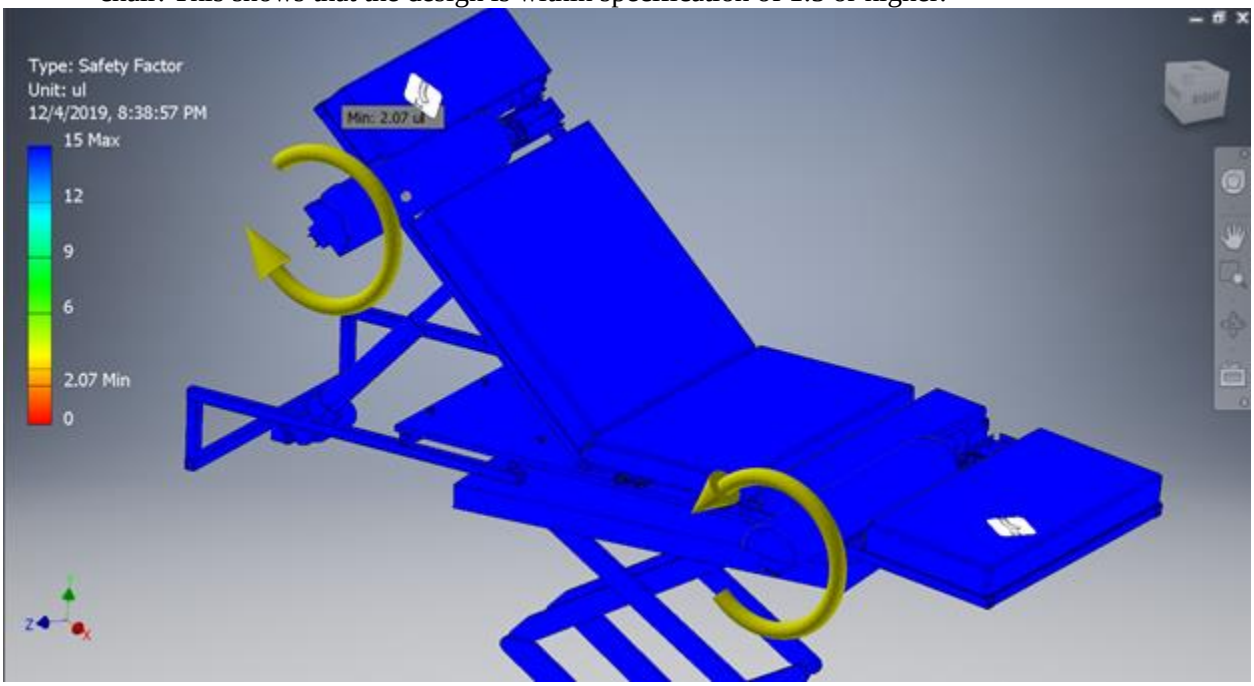


Figure 12: Arm Torque Safety Factor

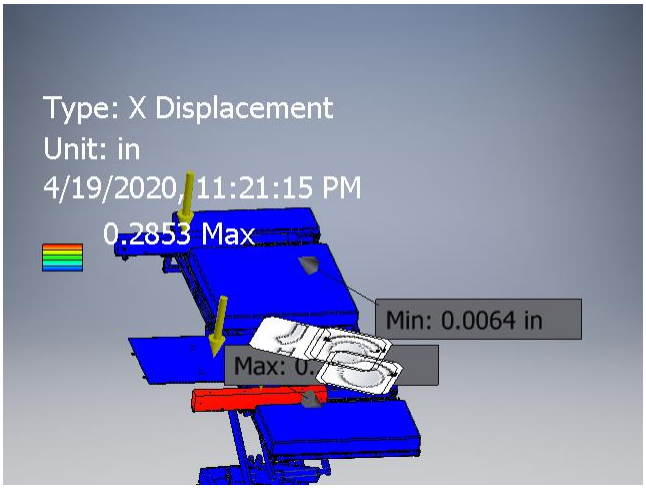


Figure 13:Displacement

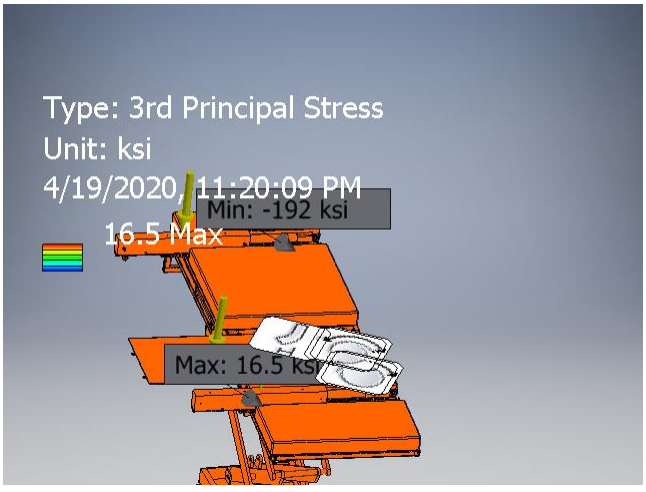


Figure 14: 3rd Principal Stress

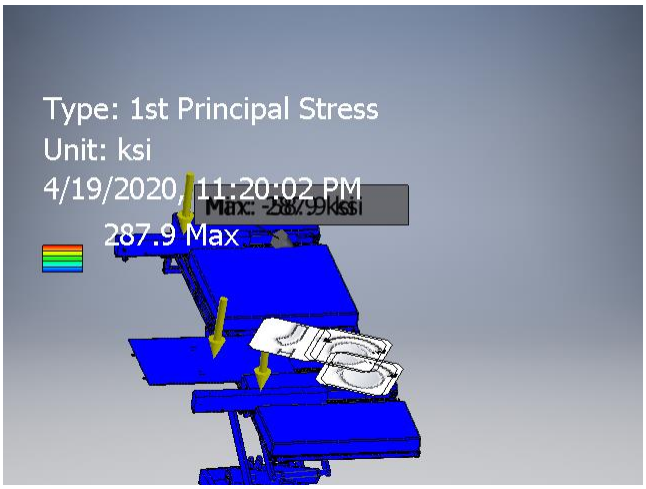


Figure 15: 1st Principal stress

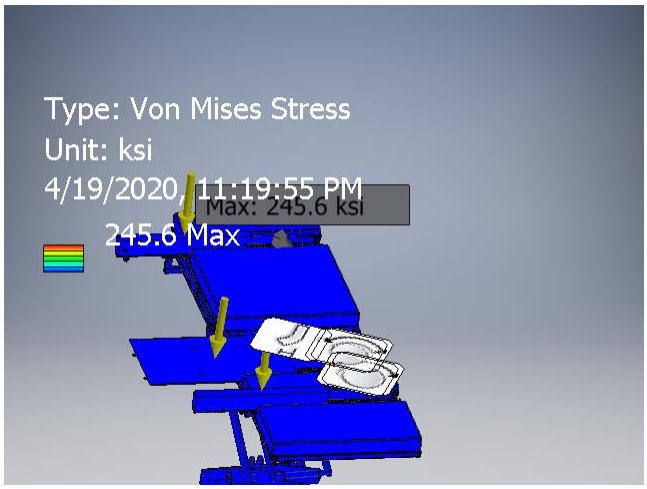


Figure 16: Von Mises Stress

Overall, the results from the stress analysis confirmed that the team's design met the standards set forth by the target specifications. With these met, physical testing of the device would begin to then compare the two to ensure the model matches that of the physical device. However, with the outbreak around the world this will not be possible for this iteration of the device.

BOM and Budget

Budget:
List of all expenses this semester

Table 8

Quantity	Description	Price Per Unit	Tax	Shipping	Total Cost
1	Microcontroller	$21.00	$0.00	$9.66	$30.66
3	H-Bridge Integrated Circuit	$7.29	$0.00	$7.99	$29.86
10	12V Zener Diode	$0.14	$0.00	$0.00	$1.41
2	5V Zener Diode	$0.19	$0.00	$0.00	$0.38
2	3.3 V Zener Diode	$0.19	$0.00	$0.00	$0.38
4	100 Micro F Capacitor	$2.64	$0.00	$0.00	$10.56
30	10k Ohm Resistor	$0.75	$0.00	$0.00	$22.59
6	Tactile Switch	$0.11	$0.00	$8.99	$9.63
1	LCD Display	$11.53	$0.00	$0.00	$11.53
3	Push Button	$1.42	$0.00	$0.00	$4.26
20	.033 Micro F Capacitor	$0.04	$0.00	$0.00	$0.74
25	.1 Micro F Capacitor	$0.03	$0.00	$0.00	$0.78
6	1-2 Demux	$0.37	$0.00	$0.00	$2.22
20	1k Ohm Resistor	$0.06	$0.00	$0.00	$1.22

2	**Heat Sink**	**$5.74**	**$0.00**	**$0.00**	**$11.48**
10	**1 Micro F Capacitor**	**$0.04**	**$0.00**	**$0.00**	**$0.38**
10	**LED**	**$0.36**	**$0.00**	**$0.00**	**$3.63**
2	**15 Pin Female Connector**	**$1.05**	**$0.00**	**$0.00**	**$2.10**
10	**5 Pin Female Connector**	**$0.14**	**$0.00**	**$5.99**	**$7.39**
10	**5 Pin Male Connector**	**$0.27**	**$0.00**	**$0.00**	**$2.70**
1	**PCB**	**$47.90**	**$0.00**	**$0.00**	**$47.90**
2	**Linear Actuator**	**$259.98**	**$0.00**	**$27.11**	**$547.07**
2	**Castor**	**$44.99**	**$0.00**	**$4.45**	**$94.43**
1	**Battery Holder**	**$9.45**	**$0.00**	**$0.00**	**$9.45**
2	**Bracket for Rod Actuator**	**$9.00**	**$0.00**	**$19.45**	**$37.45**
1	**Mini Actuator**	**$160.00**	**$0.00**	**$0.00**	**$160.00**
1	**Bracket for Mini Cctuator**	**$4.00**	**$0.00**	**$0.00**	**$4.00**
4	**Bearing Pillow Block**	**$46.80**	**$0.00**	**$37.40**	**$224.60**
1	**24" Steel Linear Shafting**	**$16.70**	**$0.00**	**$0.00**	**$16.70**
1	**36" Steel Linear Shafting**	**$25.04**	**$0.00**	**$0.00**	**$25.04**
1	**Heavy-Duty & Full Extension Drawer Slide 24" Extension**	**$107.33**	**$0.00**	**14.28**	**$121.61**
5	**1 X 1 X 14 GA (.083 wall) 6'**	**$13.00**	**$0.00**	**$63.25**	**$128.25**

NA	**Aluminum Welding**	**$150.00**	**$0.00**	**$0.00**	**$150.00**
	2" x .75" Aluminum Rectangle Bar	**$12.56**	**$0.00**	**$0.00**	**$12.56**
2	**2" x 3" Aluminum Rectangle Bar**	**$81.87**	**$0.00**	**$169.99**	**$333.73**
1	**0.19" Aluminum Sheet**	**$77.81**	**$0.00**	**$0.00**	**$77.81**
2	**0.08" Aluminum Sheet**	**$59.64**	**$0.00**	**$0.00**	**$119.28**
1	**0.19" Aluminum Sheet**	**$75.54**	**$0.00**	**$0.00**	**$75.54**
2	**Motor Control Boards**	**$19.25**	**$4.61**	**$17.32**	**$60.43**
NA	**Miscellaneous Components**	**$25.00**	**$0.00**	**$0.00**	**$25.00**
1	**Safety Straps**	**$28.74**	**$0.00**	**$5.00**	**$33.74**
12	**Carabiner**	**$278.40**	**$0.00**	**$0.00**	**$278.40**
1	**Safety Harness**	**$203.96**	**$0.00**	**$8.95**	**$212.91**
1	**EA Display**	**$31.90**	**$0.00**	**$0.00**	**$31.90**
				Total	**$2,981.69**

BOM:
Cost of all components included in final design not including tax.

Table 9

1	**Micro controller**	**$21.00**	**$0.00**	**$9.66**	**$30.66**
2	**3.3 V Zener Diode**	**$0.19**	**$0.00**	**$0.00**	**$0.38**
25	**.1 Micro F Capacitor**	**$0.03**	**$0.00**	**$0.00**	**$0.78**
6	**Tactile Switch**	**$0.11**	**$0.00**	**$8.99**	**$9.63**
20	**1k Ohm Resistor**	**$0.06**	**$0.00**	**$0.00**	**$1.22**
30	**10k Ohm Resistor**	**$0.75**	**$0.00**	**$0.00**	**$22.59**
1	**PCB**	**$47.90**	**$0.00**	**$0.00**	**$47.90**
2	**Linear Actuator**	**$259.98**	**$0.00**	**$27.11**	**$547.07**
1	**Battery Holder**	**$9.45**	**$0.00**	**$0.00**	**$9.45**
2	**Bracket for Rod Actuator**	**$9.00**	**$0.00**	**$19.45**	**$37.45**
1	**Mini Actuator**	**$160.00**	**$0.00**	**$0.00**	**$160.00**
1	**Bracket for Mini Actuator**	**$4.00**	**$0.00**	**$0.00**	**$4.00**
4	**Bearing Pillow Block**	**$46.80**	**$0.00**	**$37.40**	**$224.60**
1	**24" Steel Linear Shafting**	**$16.70**	**$0.00**	**$0.00**	**$16.70**
1	**36" Steel Linear Shafting**	**$25.04**	**$0.00**	**$0.00**	**$25.04**
1	**Heavy-Duty & Full Extension Drawer Slide 24" Extension**	**$107.33**	**$0.00**	**14.28**	**$121.61**

5	**1 X 1 X 14 GA (.083 Wall) 6'**	**$13.00**	**$0.00**	**$63.25**	**$128.25**
1	**2" x .75" Aluminum Rectangle Bar**	**$12.56**	**$0.00**	**$0.00**	**$12.56**
2	**2" x 3" Aluminum Rectangle Bar**	**$81.87**	**$0.00**	**$169.99**	**$333.73**
1	**0.19" Aluminum Sheet**	**$77.81**	**$0.00**	**$0.00**	**$77.81**
2	**0.08" Aluminum Sheet**	**$59.64**	**$0.00**	**$0.00**	**$119.28**
1	**0.19" Aluminum Sheet**	**$75.54**	**$0.00**	**$0.00**	**$75.54**
2	**Motor Control Boards**	**$19.25**	**$4.61**	**$17.32**	**$60.43**
NA	**miscellaneous components**	**$25.00**	**$0.00**	**$0.00**	**$25.00**
1	**Safety Straps**	**$28.74**	**$0.00**	**$5.00**	**$33.74**
12	**Carabiner**	**$278.40**	**$0.00**	**$0.00**	**$278.40**
1	**Safety Harness**	**$203.96**	**$0.00**	**$8.95**	**$212.91**
1	**Scissor Lift**	**$2,090.00**	**$0.00**	**$85.22**	**$2,175.22**
				Total	**$4,791.94**

There are a few items included in the design but not completed. The carabiners bought were too large and heavy duty, so they should be replaced with smaller ones that can be purchased from Home Depot or any other alternative. The sling was ordered and paid for, but was not received. Attempts were made to contact the company, but no response was received. Additionally the design incorporated padding for patient comfort. We had not reached that stage of the project when we ceased assembly. Due to this a padding and adhesive will be required by future iterations.

Economic Feasibility

As depicted in Appendix B, the price per unit could be brought down slightly by mass production. The price may also be brought down slightly by the lower prices of bulk purchasing raw materials which was not considered in this analysis. The prototype cost approximately $5,100 to create. With an estimated overhead cost of $30,000, a lowered price per unit would be reached at 1,000 units. Without considering bulk discount, there is not much of an advantage to mass production considering that labor would be an expense not experienced through the prototyping.

There are several factors contributing to the project's suspect economic feasibility. One primary factor is the device's cost when compared to that of its competitors. The market value for a patient transfer device using the hoist mechanism ranges from approximately $1,200- $4,700. Considering production without the cost of logistics or profit is more expensive than the higher end alternatives does not bode well for its marketability. While the RPTD does have several key advantages in its current state, it does have some disadvantages. It is bulkier, less mobile, and harder to operate in the confined spaces of a hospital compared to its competition. With the market saturated with other dependable cheaper solutions, it may be difficult to secure a large enough market share to be producing 1,000 units annually. In order for this product to be mass-producible, the price of production must be brought down.

There are several key factors leading to this inflated cost of production. The primary reason being the scissor lift base. It contributes $2,100, or approximately 44% of the total material cost. Another contributor is the different thicknesses required for each component. Each plate was constructed of different gauge aluminum sheets. If these sheets of aluminum were the same gauge, the plates could be cut from the same source which would result in less scrap metal.

Overall this iteration of the Robotic Patient Transfer Device is a proof of concept rather than the final product to be brought to market. Thus, there are several areas that can be adjusted to reduce the cost per unit and increase its economic feasibility.

Flow Charts of Software

The flow chart in figure 13 was the basis for the software developed in appendix H. It is a simple loop of logical checks monitoring user input. The controller locks and unlocks by holding down the linear actuator control buttons for 2 seconds. The user interface operates on a menu-based system. The arms and back plates will not be maneuvered at the same time, so the buttons can be consolidated. The user will select which function to control and the corresponding linear actuators will be activated and tied to the input of the linear actuator control buttons. To exit the control mode, the back button is pressed. This will restart the loop of checking for specific inputs. The button inputs are prioritized in the following order: lock button, menu navigation, select/back button, and then actuator control buttons. Once a button is pressed, the Arduino interprets the intended command and distributes the PWM and enables signals to the correlating inputs on one of the motor control boards. This software is written in C++ as it combines the simplistic nature of C with the functionality of an object oriented programming language. Our group members' familiarity with the language also contributed to reduced time to develop the software.

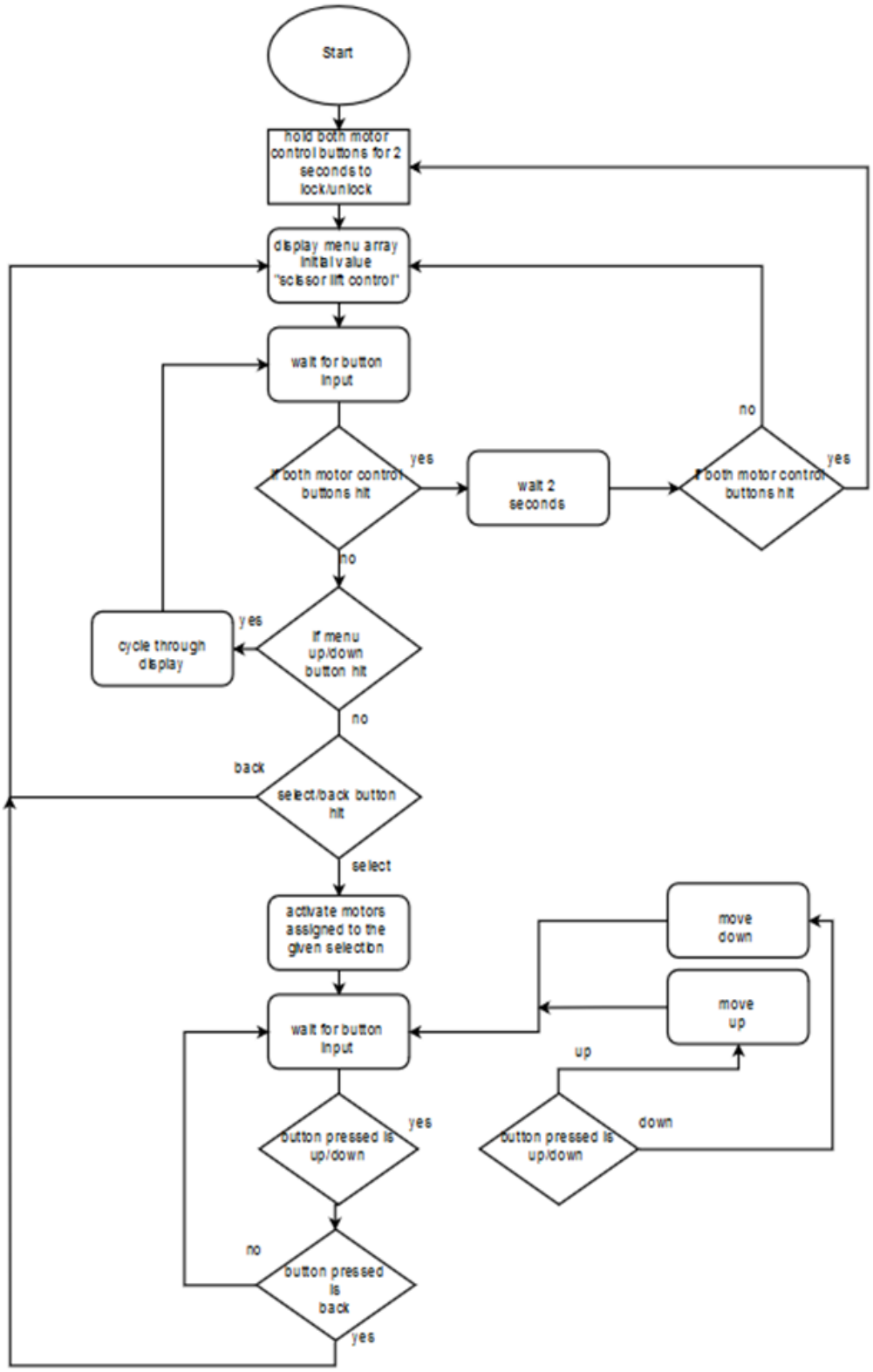


Figure 17: Software Flow Chart

Acceptance Criteria and Success-Metrics

Table 10 describes the acceptance criteria that is involved with this project. In order for the design to be successful, both the customers and the faculty staff have to approve it. Taking that into consideration, the following table was developed:

Table 10: Acceptance Criteria

Acceptance Criteria
Transfer patients from bed to device
Transfer patients from device to bed
Transfer patients from chair to device
Transfer patients from device to chair
Adjustable height (scissor lift performance)
Transfer 350 lbs patients plus 1.5 safety factor
Proof that design works (FEA)
Build a working prototype

All the efforts and design components are implemented in order to achieve these criteria.

Discussion

All projects are limited by their feasibility. The primary goal of the RPTD is to reduce the strain on the lower back of nursing staff with machine assisted Transfer. There are many devices on the market that accomplish this goal, but the RPTD has several key features that set it apart. It is designed to be a patient centric transfer device that focuses safety and comfort for both the patient and the operator. The Devices key concerns in feasibility are centered on the robotic arms and the device maintaining balance. When a heavy load is placed extended from the base it can cause a tilt. This is a major concern for a device intended to carry patients. This tilting was a primary concern, which was remedied by extended support legs. The support legs are to be extended whenever a patient is held by the arms in their extended position. The length of these support legs was calculated so that with a max load the center of mass remained over the base. The center of mass test displayed in figure 17 shows that the device will maintain its balance at a load of 525lbs.

Figure 18: Center of Gravity/Mass

The second predicted point of failure was the robotic arms. There were questions as to whether they would support the downward and rotational force. For the downward force the drawer sliders used to extend the arms are rated to 600lbs. For the Rotational force a stress analysis was done in inventor. When the distributed forces were applied downward on each arm a safety factor of 1.63 was determined. The calculation can be viewed in the calculations sections. This test produced a safety factor on the arms of 2.09.

Manufacturing for the device was halted due to the COVID-19 outbreak. Further testing on the device was halted when shelter-in-place laws went into effect. No major testing was done to the prototype but some observations were made. The need for the Lazy Susan as the main joint in the device is not needed. After surveying a simulated hospital wing on the UT Tyler Campus and a nursing facility in the area, having a device that can swivel would not be necessary and possibly over engineering the device. That swivel motion would be cumbersome in those working environments because of the tight spaces that the device must slide in and out of.

Recommendations

For future generations of this project, the goal is to make it easier to operate, once there is a working design produced by the team. The main recommendation is to incorporate wireless controllers for the manipulation and different settings of the device. Feedback in the control loop would enable the device to be programmed to perform actions rather than have user input control each motor. Motorization of the wheels would increase the movability of the product. Consider adding a second battery in parallel to increase the device's battery life. In the mechanical point of view, future investments should aim to allow the sliders go in both directions. That would address the problem of having to rotate the frame in constrained spaces such as hospital rooms in order to transfer the patient from one location to another. Remove the Lazy Susan turning component and incorporate the frame to the scissor lift another way. Turn all four wheels of the scissor lift to be fully rotational and possibly have them powered to move the weight of the device with ease. Do a second generation for the arm assemblies that will involve more sophistication and functionality to the device.

Conclusion

The Robotic Patient Transfer Device (RPTD) purpose is meant to mitigate the injuries among healthcare workers by automating the transfer of the patients. To conclude it was proven that the Robotic Patient Transfer Device is a feasible system for the transferring of a patient in all four desired situations. Those situations being from bed to device, device to chair, chair to device, and device to bed. The analysis done on the arm design shows its ability to support a patient weight while maintaining safety factor throughout the system above the specifications tolerance of 1.2-1.5. It does this with robotic arm sliders and a sling mechanism. As the design is completed and feasibility is confirmed, the next steps were assembly and testing.

Most of the assembly was completed before the Covid-19 pandemic halted manufacturing of the device. The frame and arm assemblies done but the actuators and wiring the device were not completed before the pandemic. Because of this, prototype testing was limited to CAD simulation using inventor. No major changes were done to the design of the arms, frames, and parts that the team had designed for this project.

References

[1] 36,000 musculoskeletal disorder (MSD) cases involved health care patient handling in 2008 (9/14). (2011, July 6). Retrieved December 8, 2019, from https://www.ishn.com/articles/90400-36-000-musculoskeletal-disorder-msd-cases-involved-health-care-patient-handling-in-2008-9-14 (Introduction) (#2)

[2] Work-Related Musculoskeletal Disorders & Ergonomics. (2018, February 1). Retrieved December 8, 2019, from https://www.cdc.gov/workplacehealthpromotion/health-strategies/musculoskeletal-disorders/index.html (Introduction #)

APPENDICES

A. Poster



The University of Texas at TYLER
COLLEGE OF ENGINEERING

COLLEGE OF ENGINEERING
Phone: 903.566.6121
Fax: 903.566.7148
uttyler.edu/engineering

Department of Mechanical Engineering

B.

Senior Design Project II

MENG 4216 / EENG 4315

Project Robotic Patient Transfer Device Delivery and Acceptance

Senior design team Triple C JT Robotics, from UT-Tyler College of Engineering, has worked with the sponsors: Dr. Colleen Marzilli and Dr. Neil Dong to design, construct, and deliver a robotic patient transfer device that is capable of safely transferring a patient from a bed to a chair, and from a chair to a bed. The Robotic Patient Transfer Device i a f e e de academic work during the academic year of 2019-2020. This document includes the sign-off list and D . C ee Ma a d D . Ne D g final approval of the outcome of the Robotic Patient Transfer Device delivered by Triple C JT Robotics, based on the previously set and mutuallyapproved scope and specifications of the project. An authorized signature indicates this approval.

Table 1: Sponsor Sign OFF list for Deliverables of the Senior Project Robotic Patient Transferring Device

Item	Description of Deliverable	Comments:	Sponsor Sign Off: Authorized Initials
Motor Control board	2 NXP motor drivers provided with logic by Arduino Nano BLE		XND CM
User Interface	36mm x 12mm Newhaven Display and 6 button inputs		XND CM
Control Programming	C script that interprets button inputs and activates the corresponding motors		XND CM
Production Model Documentation	Technical Documentation		XND CM
B.O.M.	Bill of Materials		XND CM
Circuit Schematics	Schematics depiction layout and components of the circuits		XND CM

Testing	Testing of system	Could only perform simulated testing due COVID-19 stay-at-home order.	XND	CM to
EMG	Electromyography used to prove design reduced load on skeletal muscles in lower back	Could not perform due to COVID-19 stay-at-home order.	XND	CM
Actuator Upper Back Plate	Full range movement with simulated load	The Back Plate should be able to end parallel with the floor	XND	CM
Actuator Lower Leg Plate	Full range of motion	The Leg Plate should be able to end parallel with the floor	XND	CM
Hip Slider	S de 20 simulated load		XND	CM
Actuator Upper Arm	Fully extend and retract with simulated load		XND	CM
Actuator Lower Arm	Fully extend and retract with simulated load		XND	CM
Steel Bed Frame foot print	25 70		XND	CM
User Interface	Functional and Responsive to User		XND	CM

The following signatures indicate that both Dr. Colleen Marzilli and Dr. Neil Dong approves of the completion of this project and deliverables stated above which included all sponsor changes from original design and any consequent changes in the project, as mutually approved by all signing parties. Also indicated is the acknowledgement by both Dr. Colleen Marzilli and Dr. Neil Dong of reception of the final product of the project.

Chung Hyun Goh — 04/23/2020

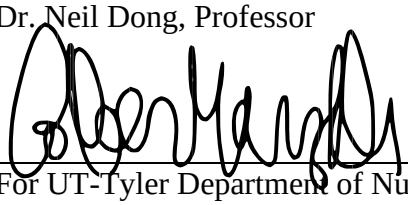
For UT-Tyler Mechanical Engineering: — Date

Dr. Nael Barakat Dr. Chung Hyun Goh, Assistant Professor

4/17/2020

Xuanliang Dong

For UT-Tyler Health and Kinesiology:
Dr. Neil Dong, Professor — Date



4/14/2020

For UT-Tyler Department of Nursing,
Dr. Colleen Marzilli, Assistant Professor — Date

caleb Hutchings — 4/14/2020

For the Senior Project Student Caleb Hutchings — Date

Triple C JT Robotics Team Captain

C. Economic Feasibility chart

Labor:

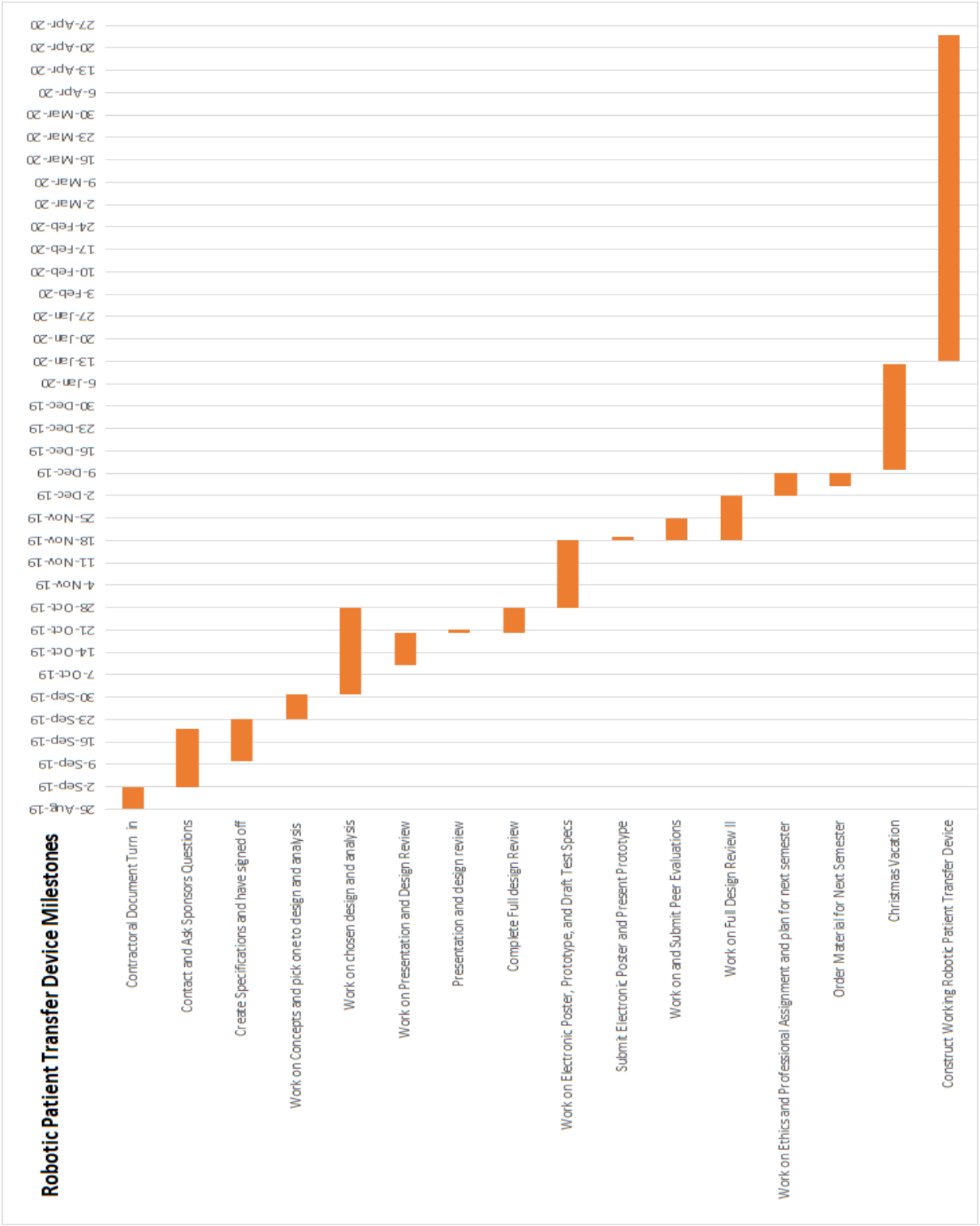
	Assembly	Machining	Soldering	Tig Welder
Hours	2.00	6.00	2.00	4.00
Wage	$14.00	$19.54	$14.28	$18.66
Cost Per Unit	$28.00	$117.24	$28.56	$74.64
Total Cost per Unit	$248.44			

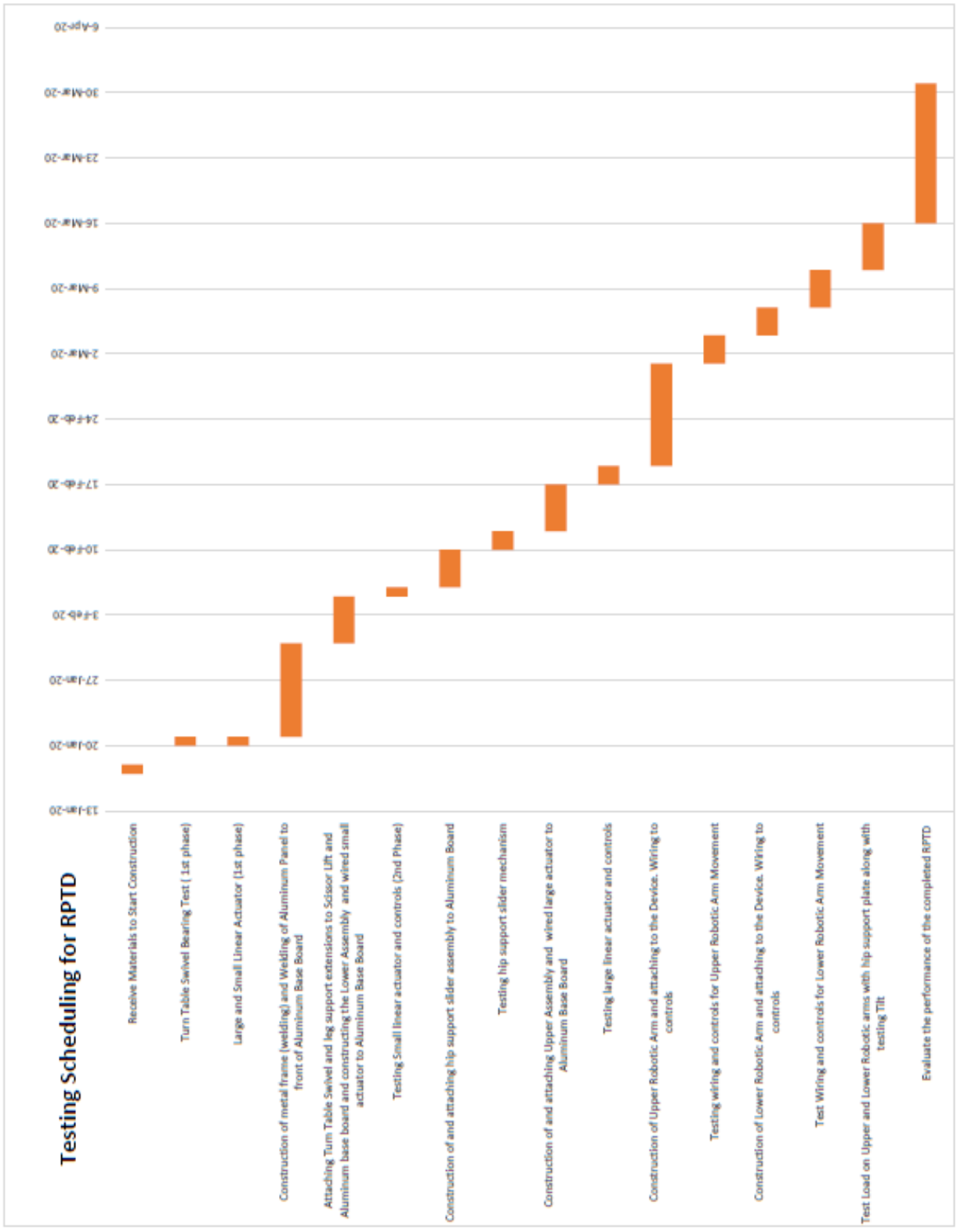
*All wage values are taken from payscale.com

Manufacturing Cost:

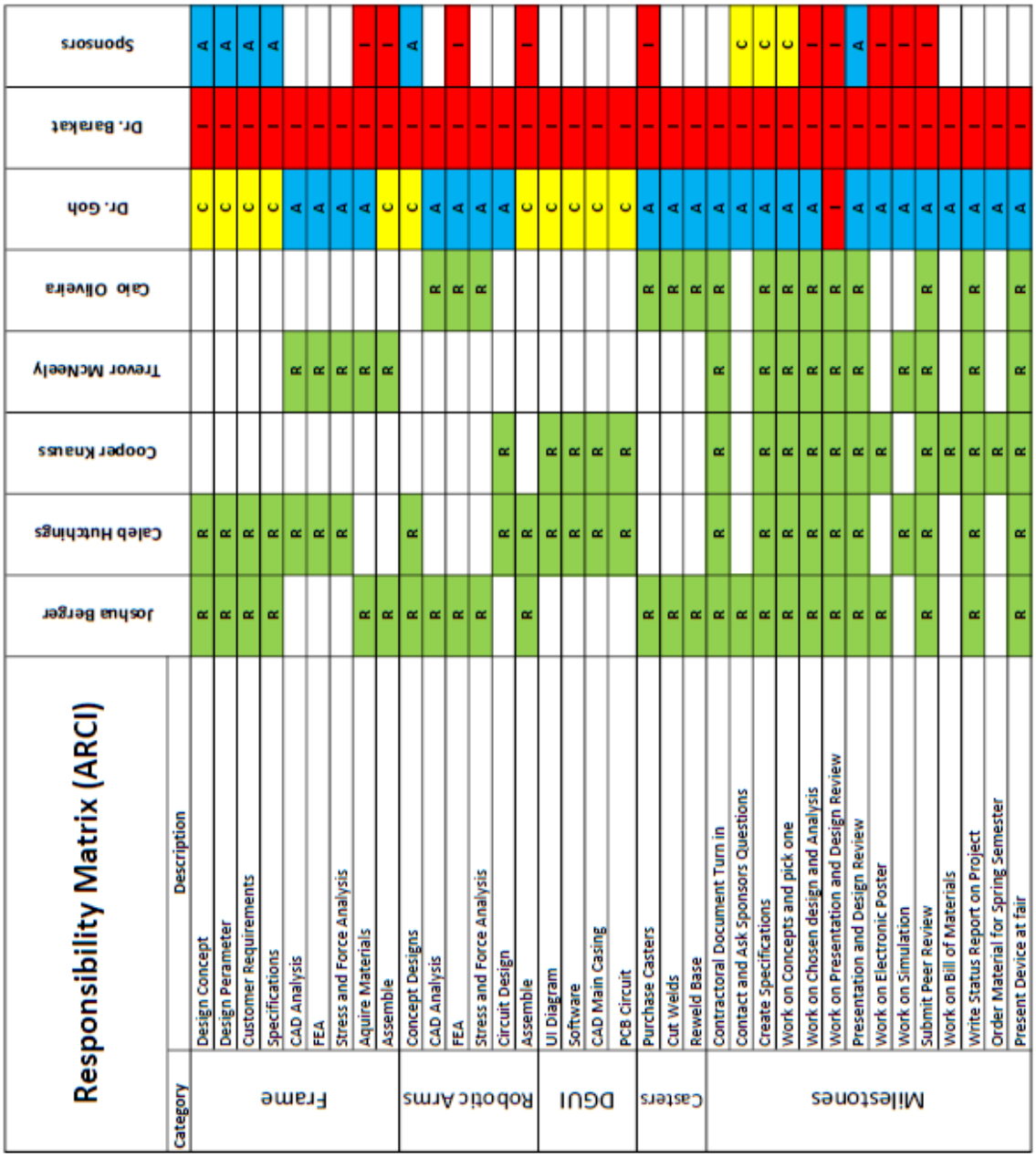
Quantity	Materials	Labor per unit	Overhead	Total	Price per Unit
1	$4,791.94	$248.44	$30,000.00	$35,040.38	$35,040.38
10	$47,919.40	$2,484.40	$30,000.00	$80,403.80	$8,040.38
100	$479,194.00	$24,844.00	$30,000.00	$534,038.00	$5,340.38
1000	$4,791,940.00	$248,440.00	$30,000.00	$5,070,380.00	$5,070.38
10000	$47,919,400.00	$2,484,400.00	$30,000.00	$50,433,800.00	$5,043.38
1				Prototype	5125.01

D.Timelines and Milestones

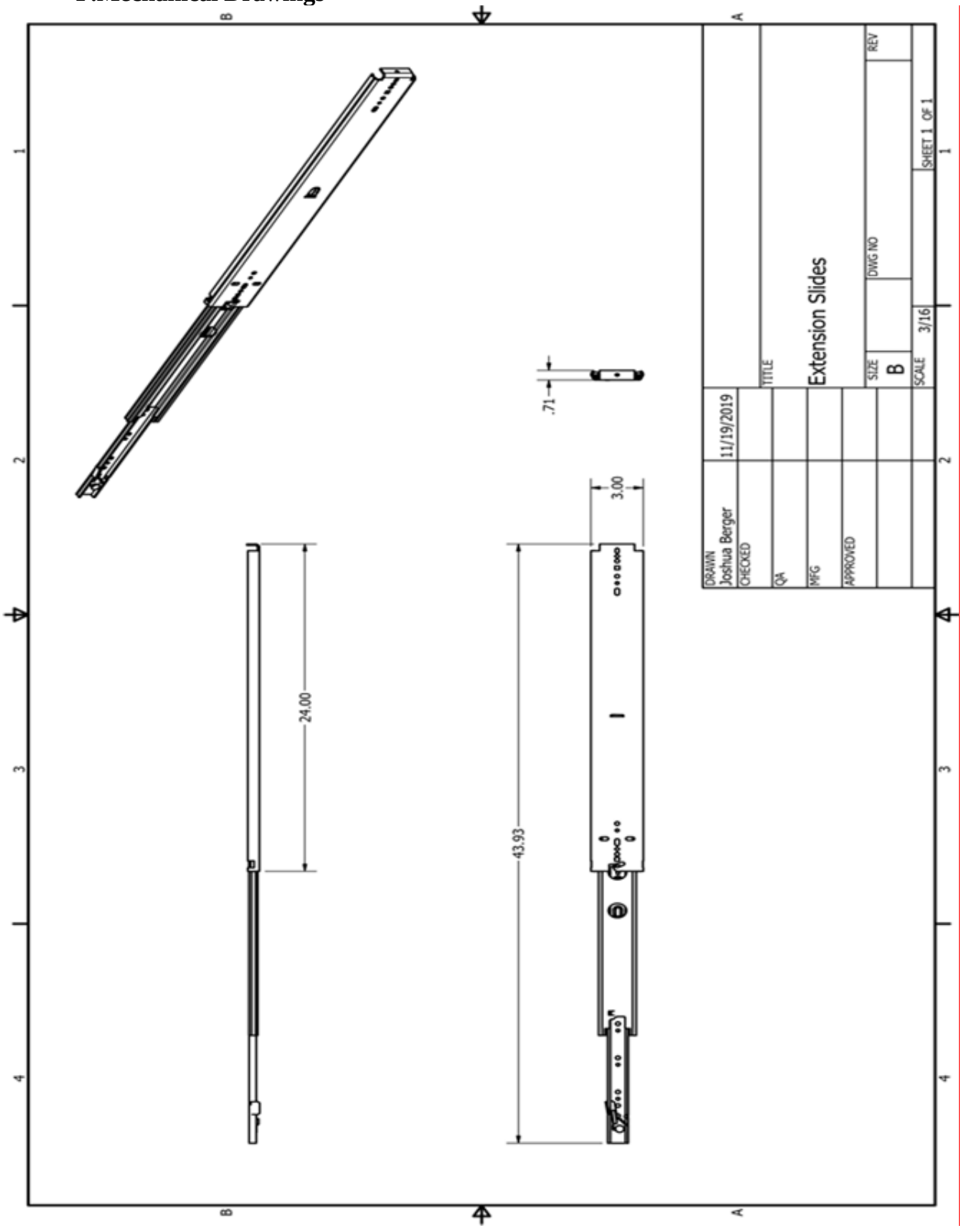


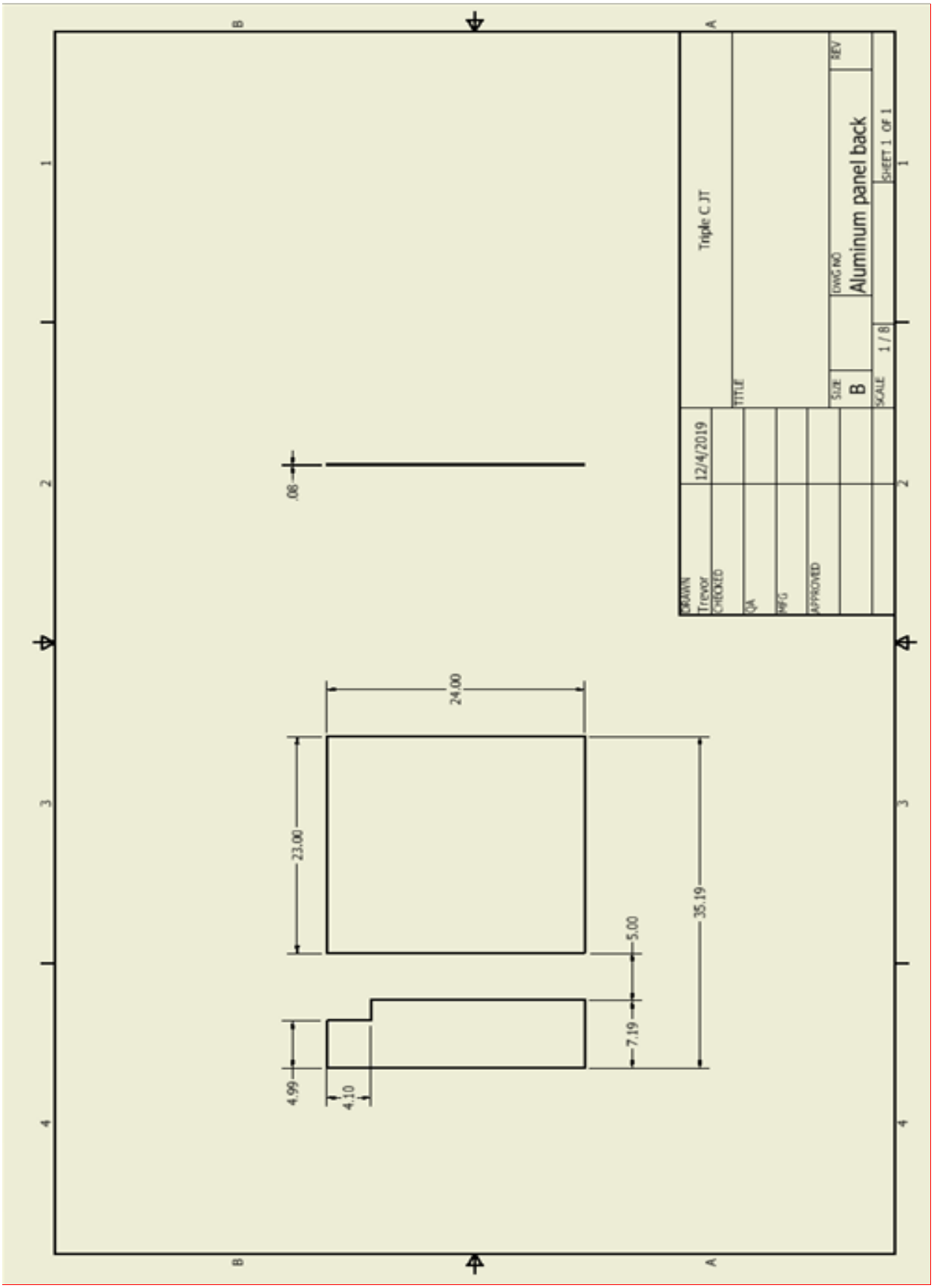

Testing Scheduling for RPTD
13-Jan-20
20-Jan-20
27-Jan-20
3-Feb-20
10-Feb-20
17-Feb-20
24-Feb-20
2-Mar-20
9-Mar-20
16-Mar-20
23-Mar-20
30-Mar-20
6-Apr-20
Receive Materials to Start Construction
Turn Table Swivel Bearing Test (1st phase)
Large and Small Linear Actuator (1st phase)
Construction of metal frame (welding) and Welding of Aluminum Panel to front of Aluminum Base Board
Attaching Turn Table Swivel and leg support extensions to Scissor Lift and Aluminum base board and constructing the Lower Assembly and wired small actuator to Aluminum Base Board
Testing Small linear actuator and controls (2nd Phase)
Construction of and attaching hip support slider assembly to Aluminum Board
Testing hip support slider mechanism
Construction of and attaching Upper Assembly and wired large actuator to Aluminum Base Board
Testing large linear actuator and controls
Construction of Upper Robotic Arm and attaching to the Device. Wiring to controls
Testing wiring and controls for Upper Robotic Arm Movement
Construction of Lower Robotic Arm and attaching to the Device. Wiring to controls
Test Wiring and controls for Lower Robotic Arm Movement
Test Load on Upper and Lower Robotic arms with hip support plate along with testing Tilt
Evaluate the performance of the completed RPTD

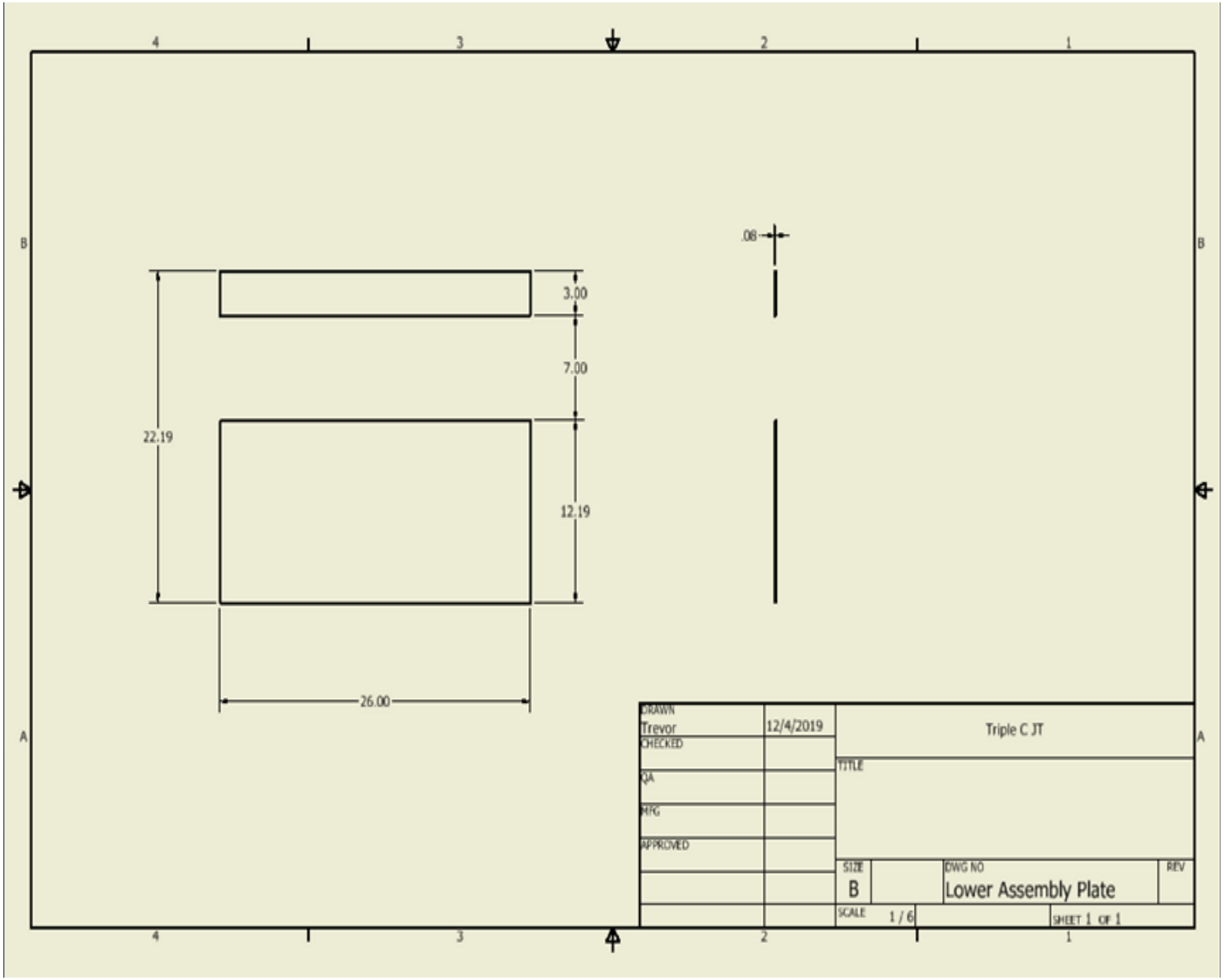
E.ARCI Chart

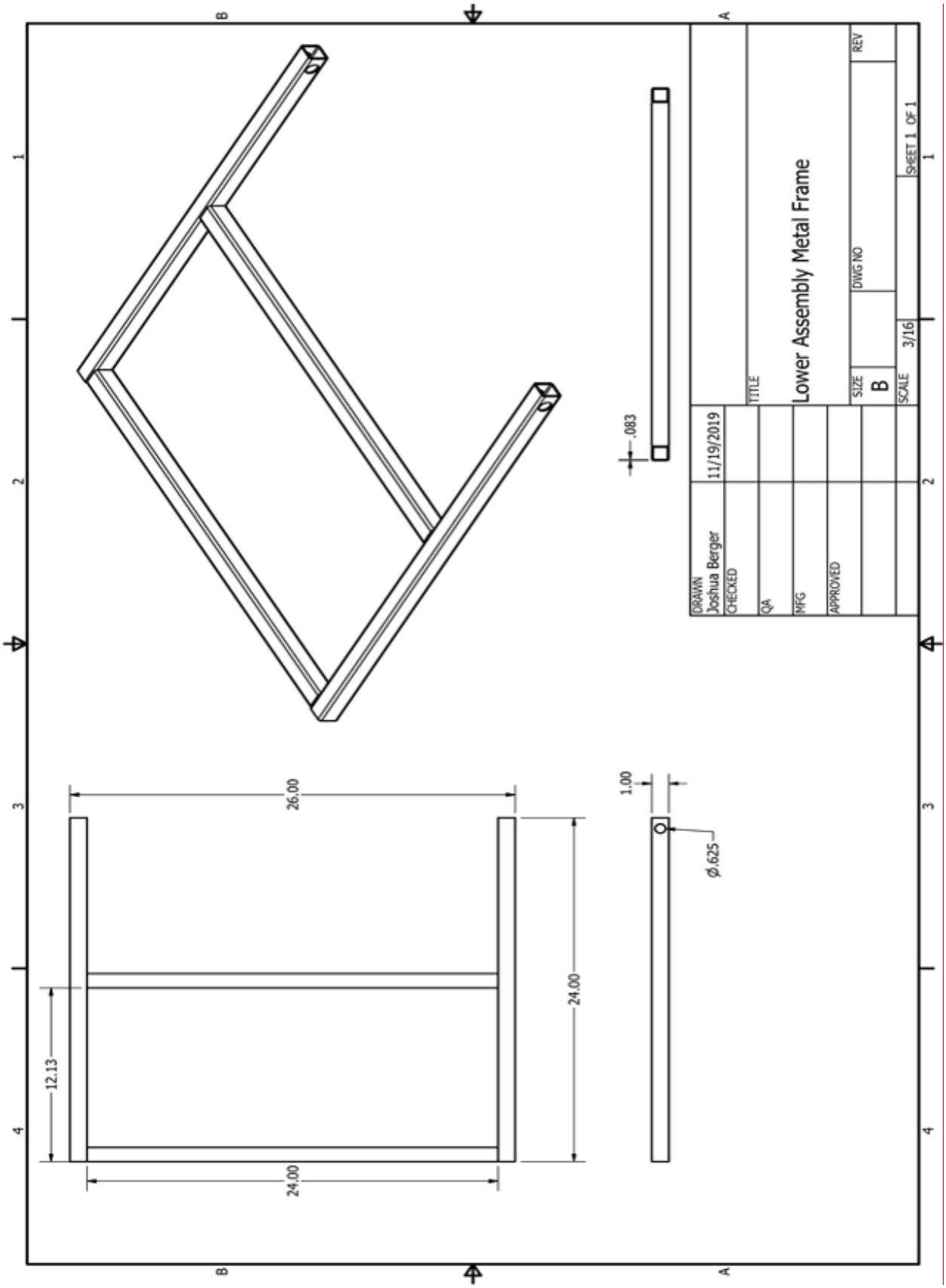

A Accountable
R Responsible
C Consulted
I Informed
Responsibility Matrix (ARCI)
Category
Description
Joshua Berger
Caleb Hutchings
Cooper Knauss
Trevor McNeely
Caio Oliveira
Dr. Goh
Dr. Barakat
Sponsors
Frame
Design Concept
Design Perameter
Customer Requirements
Specifications
CAD Analysis
FEA
Stress and Force Analysis
Aquire Materials
Assemble
Robotic Arms
Concept Designs
CAD Analysis
FEA
Stress and Force Analysis
Circuit Design
Assemble
DGUI
UI Diagram
Software
CAD Main Casing
PCB Circuit
Casters
Purchase Casters
Cut Welds
Reweld Base
Milestones
Contractoral Document Turn in
Contact and Ask Sponsors Questions
Create Specifications
Work on Concepts and pick one
Work on Chosen design and Analysis
Work on Presentation and Design Review
Presentation and Design Review
Work on Electronic Poster
Work on Simulation
Submit Peer Review
Work on Bill of Materials
Write Status Report on Project
Order Material for Spring Semester
Present Device at fair

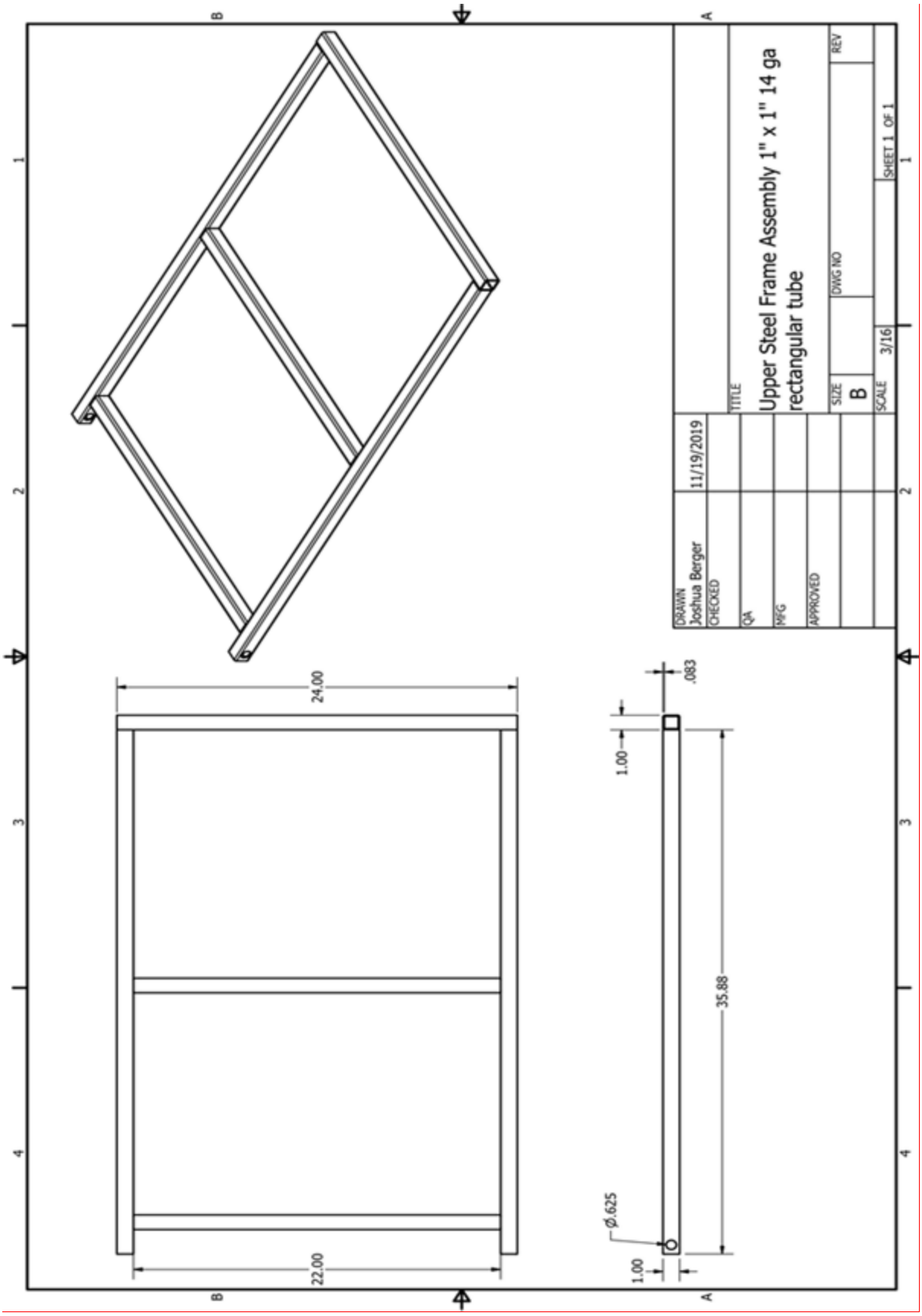
F.Mechanical Drawings

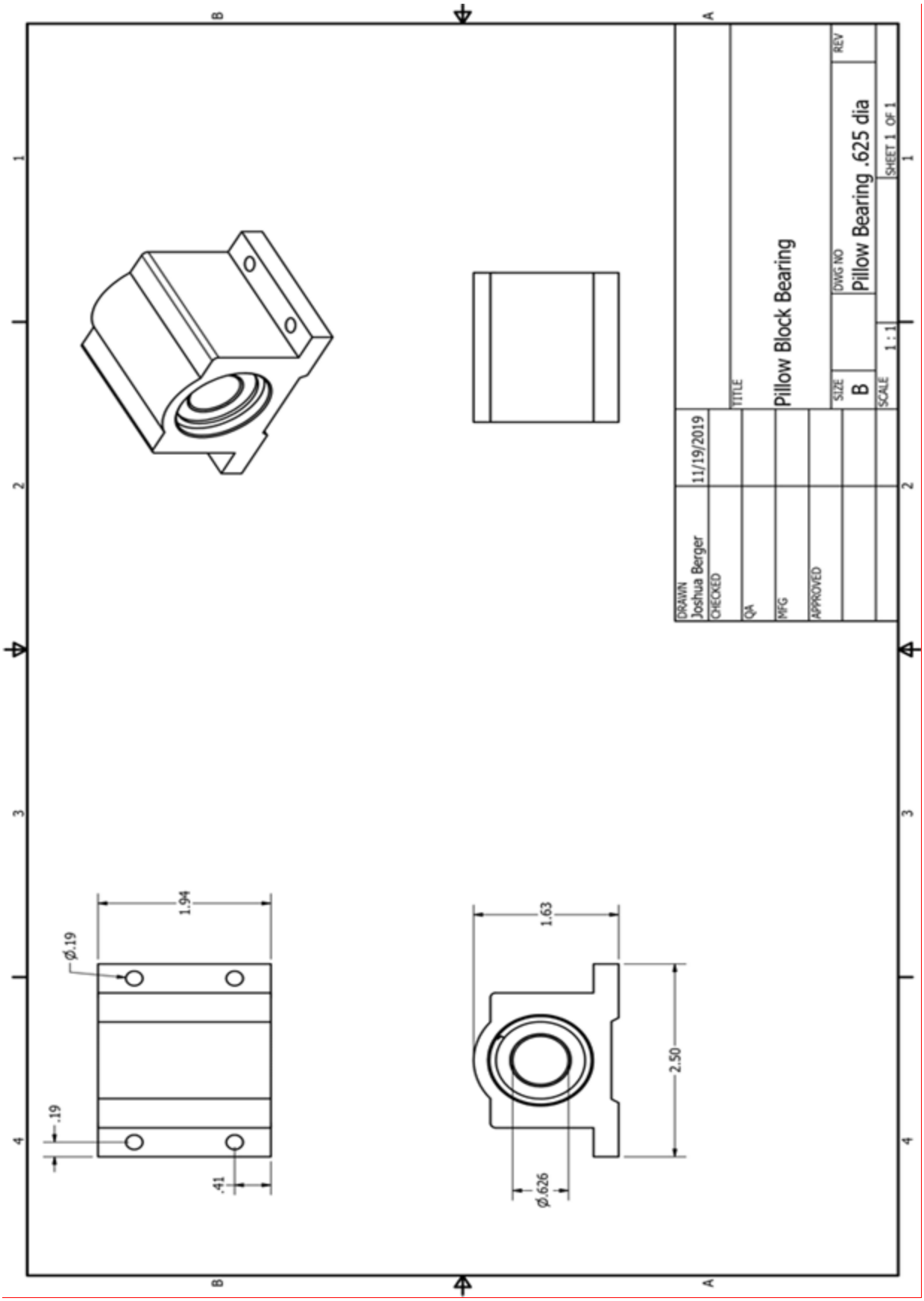


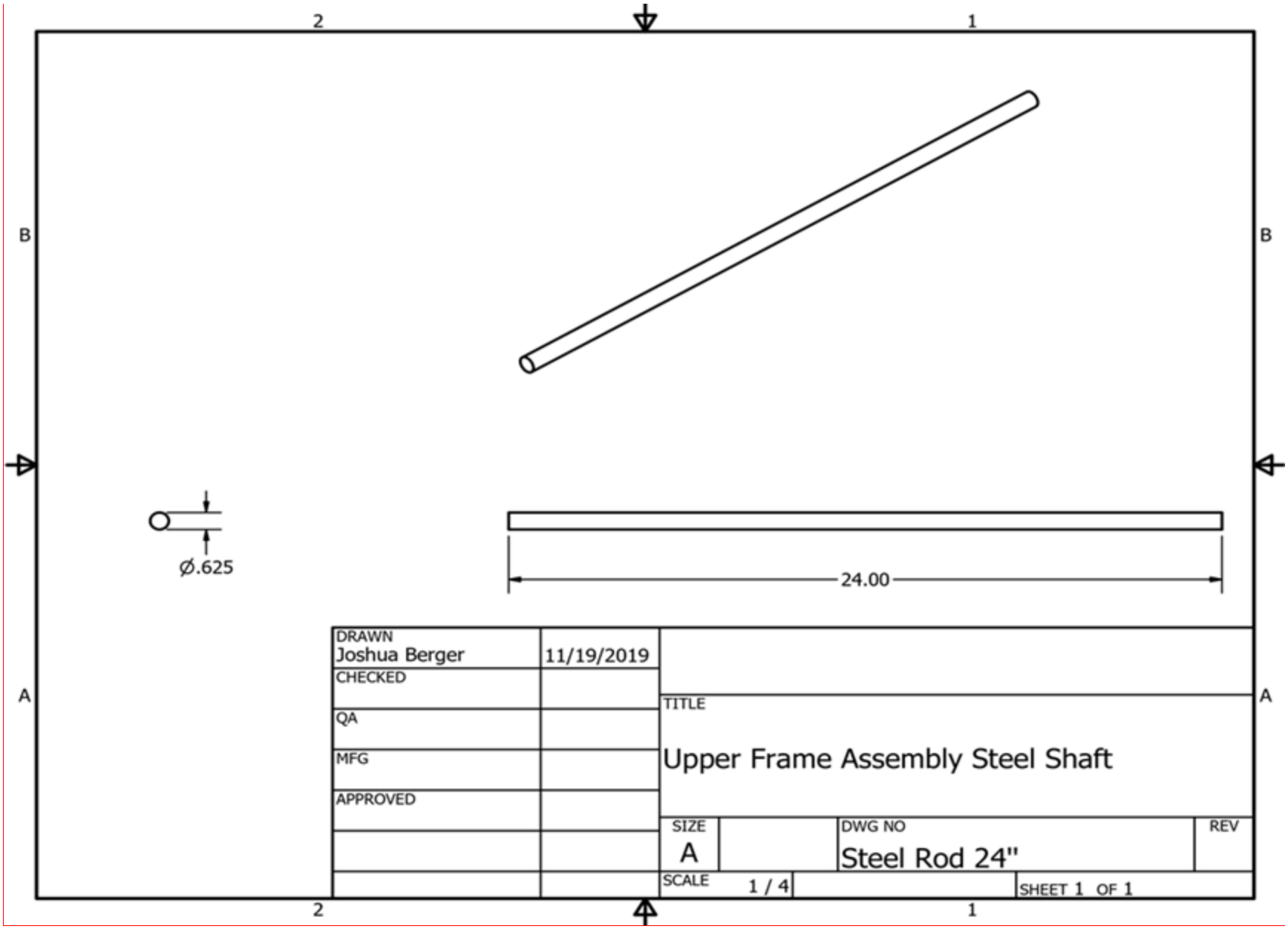

.08
24.00
23.00
35.19
5.00
7.19
4.99
4.10
DRAWN
Trevor
CHECKED
QA
MFG
APPROVED
12/4/2019
TITLE
Triple C JIT
SIZE
B
DWG NO
Aluminum panel back
REV
SCALE 1 / 8
SHEET 1 OF 1

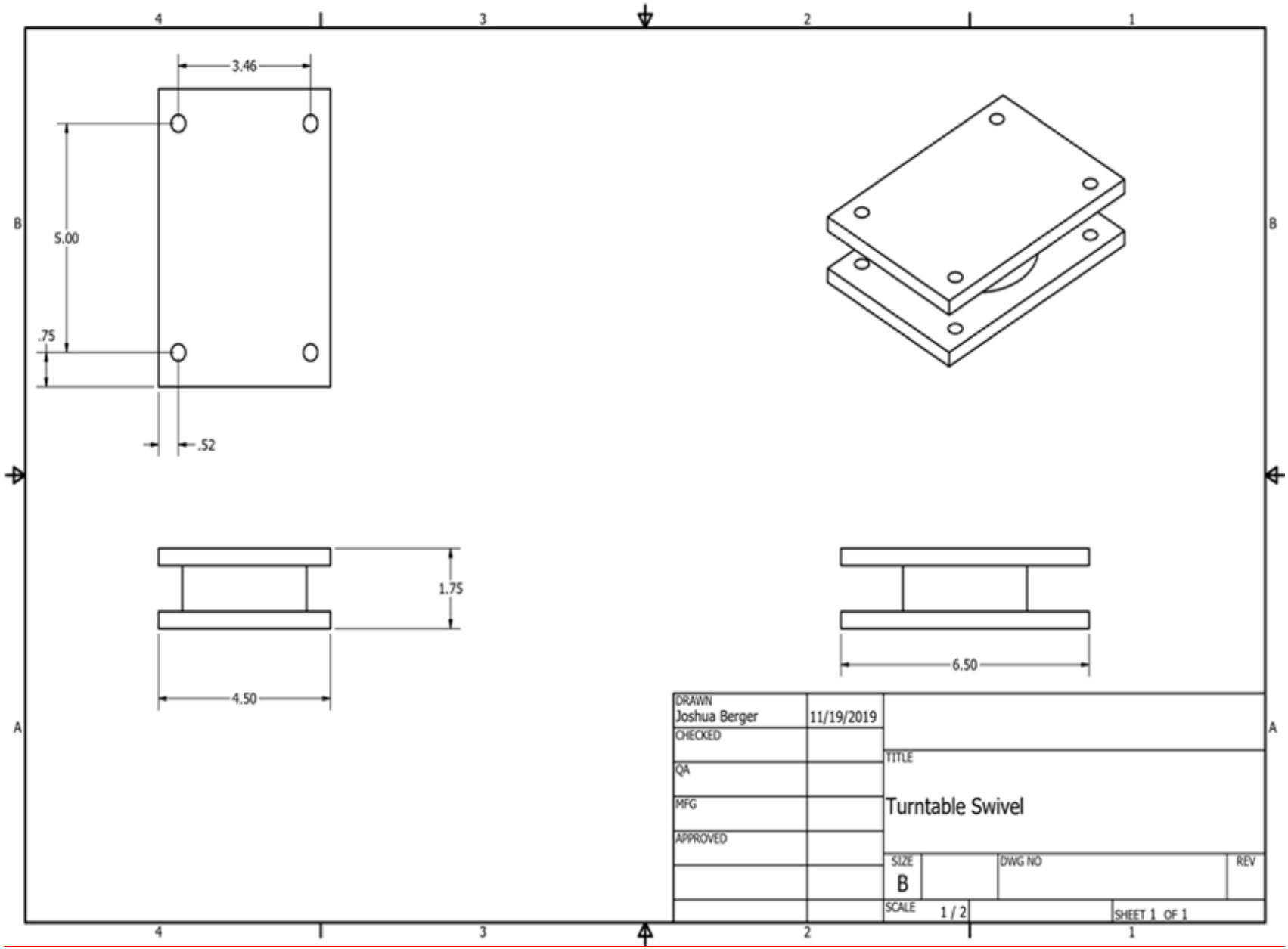

4
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2
1
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A
.08
3.00
7.00
22.19
12.19
26.00
DRAWN
Trevor
12/4/2019
CHECKED
QA
MFG
APPROVED
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SIZE
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DWG NO
Lower Assembly Plate
REV
SCALE
1 / 6
SHEET 1 OF 1

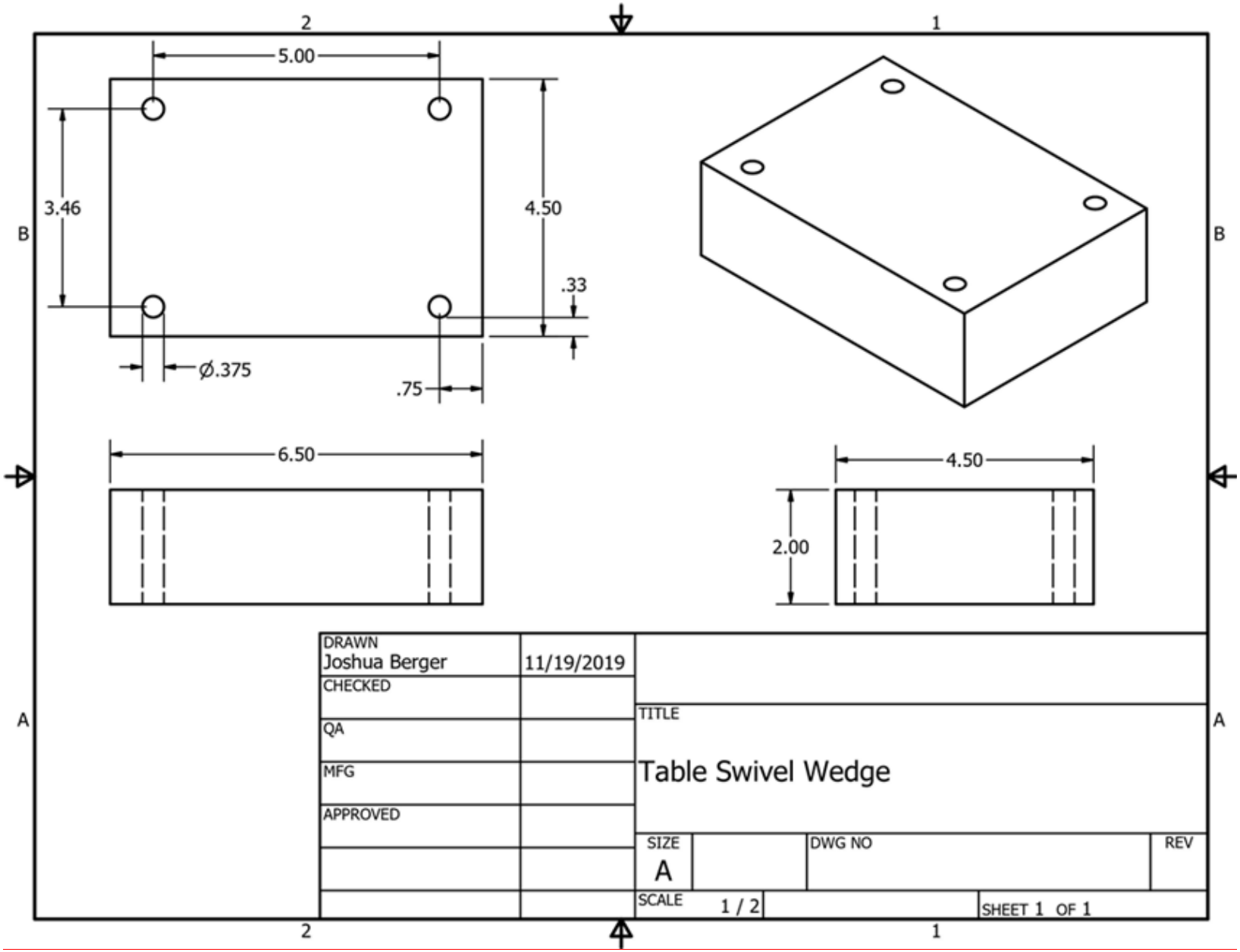

Lower Assembly Metal Frame
DRAWN
Joshua Berger
11/19/2019
CHECKED
QA
MFG
APPROVED
TITLE
SIZE
B
DWG NO
REV
SCALE
3/16
SHEET 1 OF 1
.083
26.00
24.00
12.13
24.00
1.00
Ø.625


DRAWN
Joshua Berger
11/19/2019
CHECKED
QA
MFG
APPROVED
TITLE
Upper Steel Frame Assembly 1" x 1" 14 ga rectangular tube
SIZE
B
DWG NO
REV
SCALE
3/16
SHEET 1 OF 1
24.00
22.00
.083
1.00
35.88
Ø.625
1.00


DRAWN
Joshua Berger
11/19/2019
CHECKED
QA
MFG
APPROVED
TITLE
Pillow Block Bearing
SIZE
B
DWG NO
Pillow Bearing .625 dia
REV
SCALE
1 : 1
SHEET 1 OF 1
1.94
Ø.19
.19
.41
1.63
2.50
Ø.626


2
1
B
A
Ø.625
24.00
DRAWN
Joshua Berger
11/19/2019
CHECKED
QA
MFG
APPROVED
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Upper Frame Assembly Steel Shaft
SIZE
A
DWG NO
Steel Rod 24"
REV
SCALE
1 / 4
SHEET 1 OF 1


3.46
5.00
.75
.52
1.75
4.50
6.50
DRAWN
Joshua Berger
11/19/2019
CHECKED
QA
MFG
APPROVED
TITLE
Turntable Swivel
SIZE
B
DWG NO
REV
SCALE
1 / 2
SHEET 1 OF 1


2
1
5.00
3.46
4.50
.33
Ø.375
.75
B
6.50
4.50
2.00
A
DRAWN
Joshua Berger
11/19/2019
CHECKED
QA
MFG
APPROVED
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Table Swivel Wedge
SIZE
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DWG NO
REV
SCALE
1 / 2
SHEET 1 OF 1

G.Electrical Circuit Diagrams

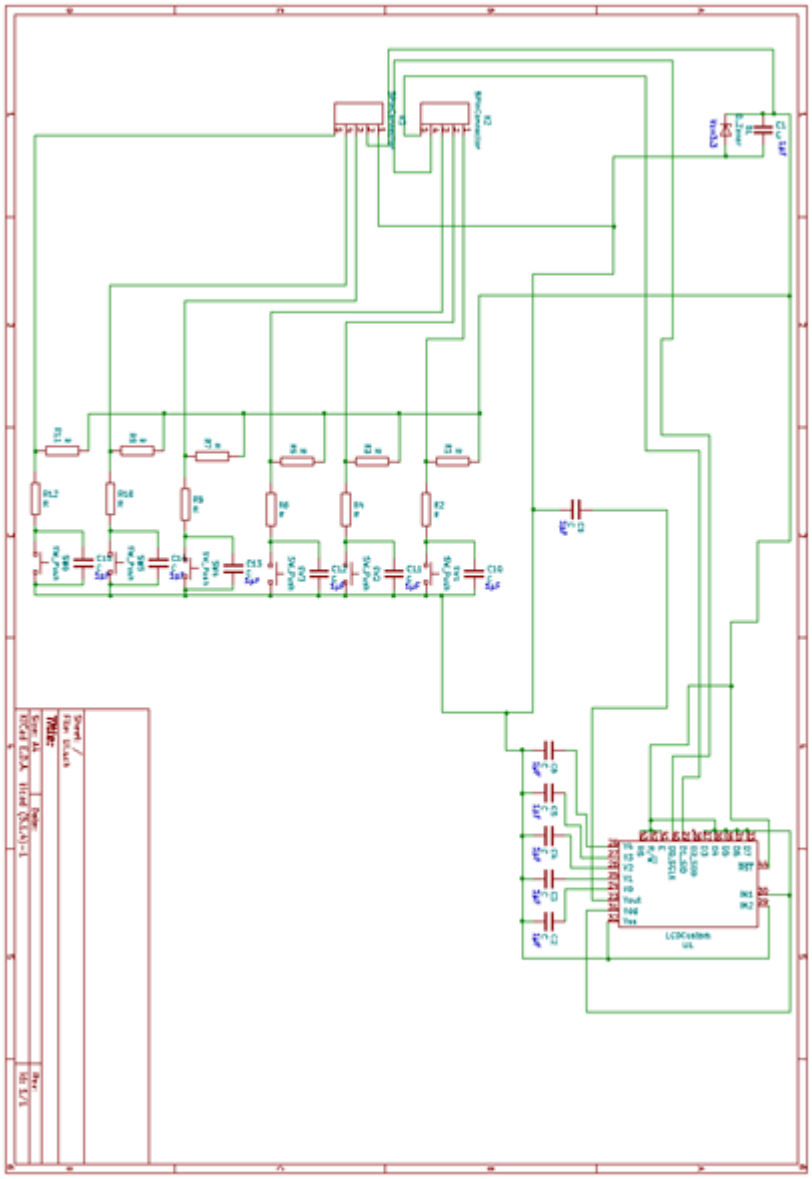


Figure 1

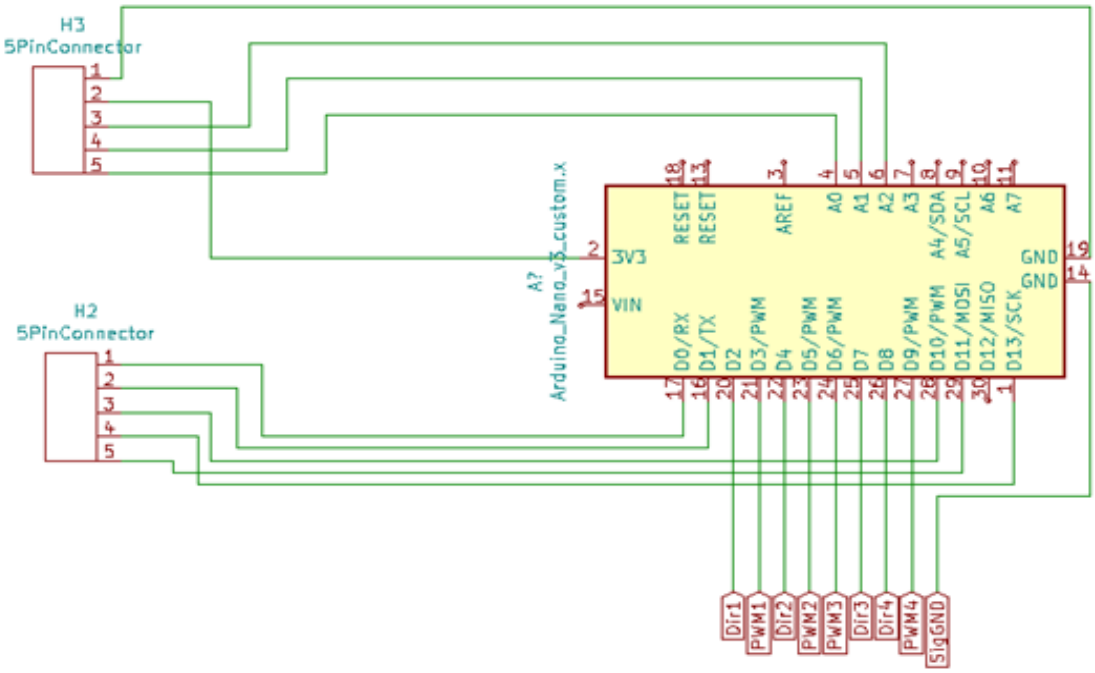


Figure 2

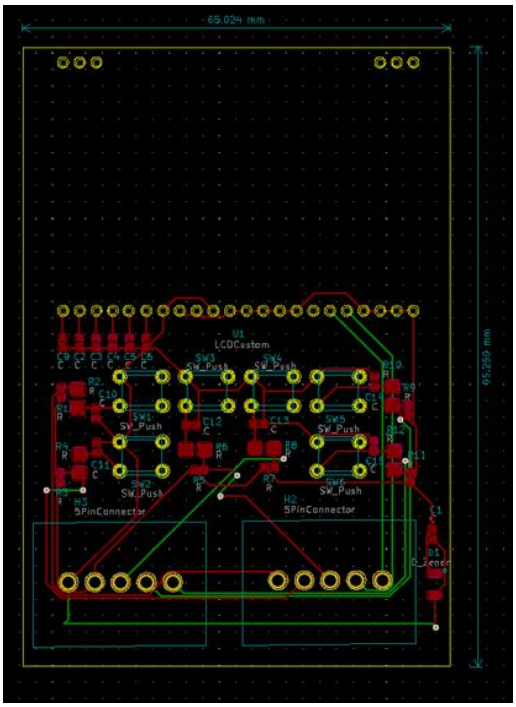


Figure 3

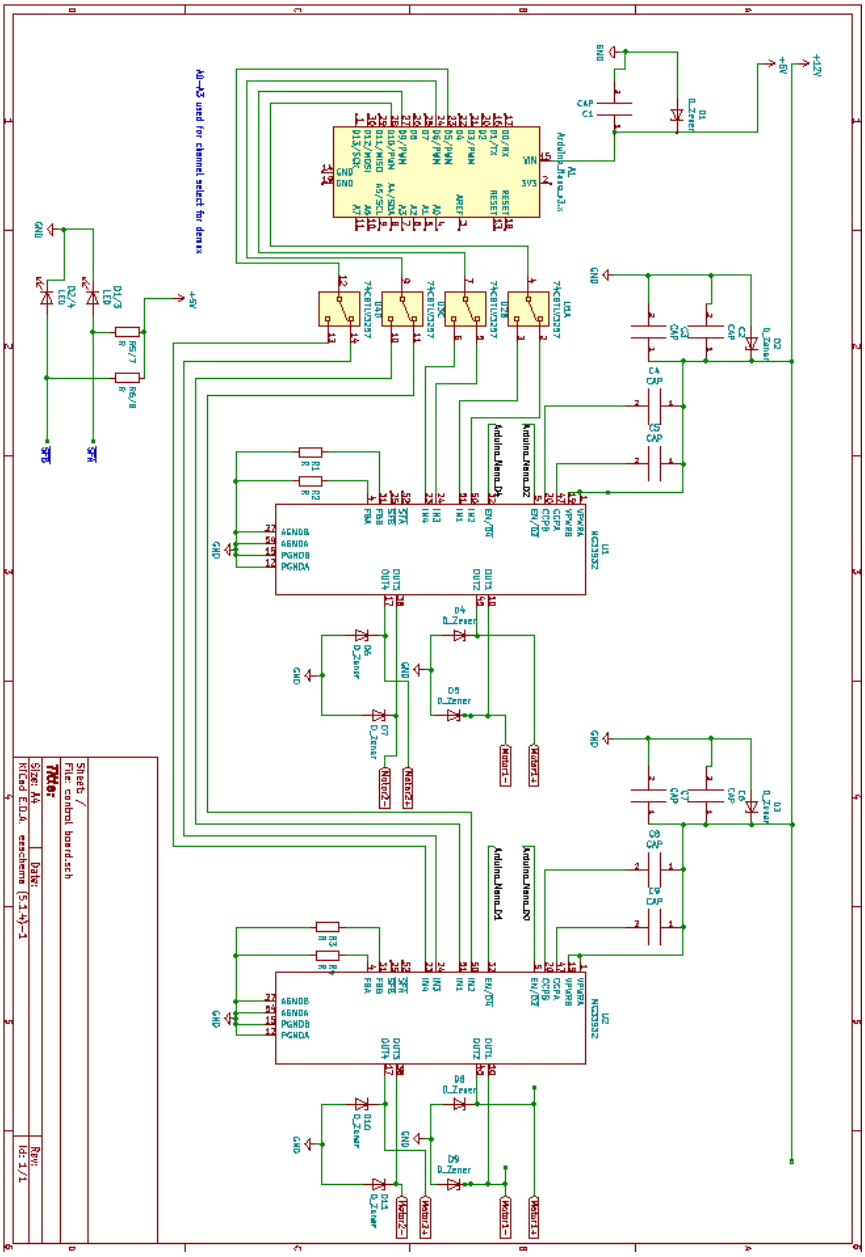

A0-A3 used for channel select for demux
Sheet: /
File: control boardsch
Title:
Size: A4
Date:
KiCad E.D.A. eeschema (5.1.4)-1
Rev:
Id: 1/1

Figure 4

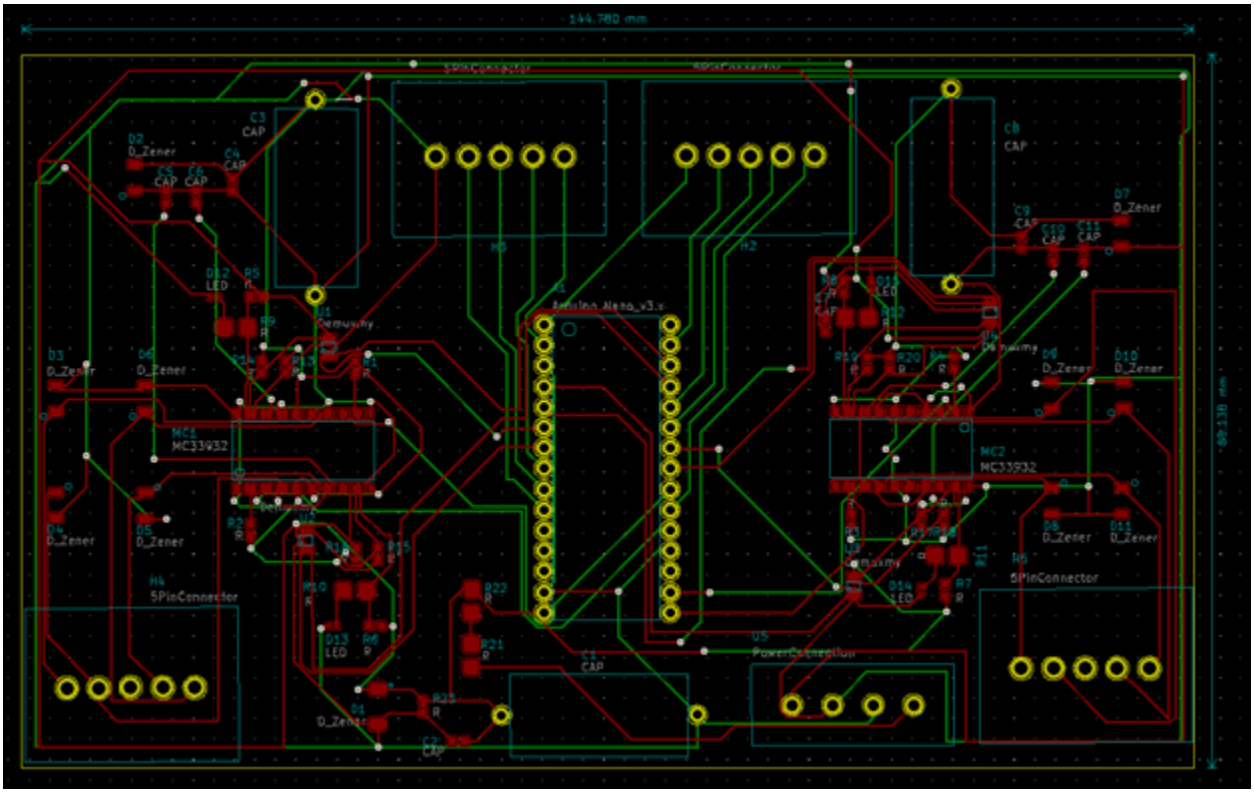

144.780 mm
5PinConnector
5PinConnector
C3
CAP
D2
D_Zener
C4
CAP
C5
CAP
C6
CAP
C8
CAP
C9
CAP
C10
CAP
C11
CAP
D7
D_Zener
D12
LED
R5
R
R9
R
H3
H2
A1
Arduino_Nano_v3.x
D1
D_Zener
D3
D_Zener
D6
D_Zener
R14
R
R13
R
C1
R
MC1
MC33932
R19
R
R20
R
R4
R
D6
D_Zener
D10
D_Zener
MC2
MC33932
D4
D_Zener
D5
D_Zener
R2
R
R1
R
R15
R
R10
R
R22
R
R21
R
D13
LED
R6
R
H4
5PinConnector
C7
CAP
U5
R23
R
D1
D_Zener
C2
CAP
D8
D_Zener
D11
D_Zener
R7
R
D14
LED
H5
5PinConnector
80.138 mm

Figure 5

H.Any Code or Program listing

```
#include <stdio.h>
#include <time.h>
#include <SPI.h>
#include <cstddef>


/*writes data from char arrays to the display*/
void write2Display(char contents[] , int len)
{
  SPI.beginTransaction(SPISettings(2500000, LSBFIRST, SPI_MODE0));
  for(int i=0;i++;i< len)
        SPI.transfer(*(contents+i));
}

/*creates delay in milliseconds*/
void delay(int milli_seconds)
{
        clock_t start_time = clock();
        while (clock() < start_time + milli_seconds)
        ;
}
/*class used to create objects for menu options. it has fields motor 1 and motor 2 as well as the direction pin for each of these
pwm motor drivers. In future iterations I would make the dual motor control a seperate class that extends this one*/
class Menu_Options
{
  public:
  char message[25];
  int motor1;
  int motor2;
  int dualflag;
  int direction_pin1;
  int direction_pin2;
  /*default constructor*/
  Menu_Options()
  {
        motor1 = 0;
        motor2 = 0;
        direction_pin1 = 0;
        direction_pin2 = 0;
        dualflag = 0;
  }
  /*other constructor*/
  Menu_Options(char data[],int len, int motorone, int motortwo, int dir1, int dir2)
  {
```

```
        for(int i=0;i++;i<len)
        {
        message[i] = *(data+i);
        }
        motor1 = motorone;
        motor2 = motortwo;
        direction_pin1 = dir1;
        direction_pin2 = dir2;
        set_dual_activated();
}
/*set methods*/
void set_message(char data[], int len)
{
        for(int i=0;i++;i<len)
        {
        message[i] = *(data+i);
        }
}
void set_motor_activated(int motorone)
{
        motor1 = motorone;
}
void set_motor_activated(int motorone, int motortwo)
{
        motor1 = motorone;
        motor2 = motortwo;
        set_dual_activated();
}
void set_direction_pin(int dir1)
{
        direction_pin1 = dir1;
}
        void set_direction_pin(int dir1, int dir2)
{
        direction_pin1 = dir1;
        direction_pin2 = dir2;
}
/*determines if dual motor control is activated*/
void set_dual_activated()
{
        if (motor2 != 0)
        {
        dualflag = 1;
        }
}
/*get methods*/
int get_direction_pin1()
{
        return direction_pin1;
}
int get_direction_pin2()
```

```
  {
        return direction_pin2;
  }
  int get_motor_activated()
  {
        return dualflag;
  }
  int get_motor1()
  {
        return motor1;
  }
  int get_motor2()
  {
        return motor2;
  }
  /*writes message data to display*/
  void send_message()
  {
        write2Display(message, sizeof(message));
  }
};
/*node class for linked list*/
class Node
{
  public:
  Menu_Options* data;
  Node* forward;
  Node* backward;
  Node* up;
  Node* down;
};


/*initializes all settings on display*/
void setup_display()
{
  const int mosi = 29;
  const int sclk = 1;



  pinMode(mosi, OUTPUT);
  pinMode(sclk, OUTPUT);



  const int back_button = 27;
  const int select_button = 6;
  const int menu_up = 28;
  const int menu_down = 26;
  const int motor_forward = 5;
```

```
  const int motor_backward = 4;


  pinMode(back_button, INPUT);
  pinMode(select_button, INPUT);
  pinMode(menu_up, INPUT);
  pinMode(menu_down, INPUT);
  pinMode(motor_forward, INPUT);
  pinMode(motor_backward, INPUT);

  SPI.beginTransaction(SPISettings(2500000, LSBFIRST, SPI_MODE0));
  digitalWrite(65, LOW);
  /*8 bit message length*/
  SPI.transfer(58);
  /*4 line display*/
  SPI.transfer(9);
  /*bottom view*/
  SPI.transfer(6);
  /*BS1=1*/
  SPI.transfer(30);
  /*8 bit data length extension*/
  SPI.transfer(57);
  /*BS0=1 -> Bias=1/6*/
  SPI.transfer(27);
  /*Devider on and set value*/
  SPI.transfer(110);
  /*Booster on and set contrast (DB1=C5, DB0=c4)*/
  SPI.transfer(87);
  /*Set contrast (DB3-DB0=C3-C0)*/
  SPI.transfer(114);
  /*8 bit data length extension Bit RE=0;IS=0 */
  SPI.transfer(56);
  /*Display on, cursor off, blinker off  12*/
  SPI.transfer(15);
}



int main()
{
  setup_display();

  const int mosi = 29;
  const int sclk = 1;



  pinMode(mosi, OUTPUT);
  pinMode(sclk, OUTPUT);
```

```
/*initialzes pins for respective outputs*/
const int back_button = 27;
const int select_button = 6;
const int menu_up = 28;
const int menu_down = 26;
const int motor_forward = 5;
const int motor_backward = 4;

/*sets up pins for input*/
int unlock_flag = 0;
pinMode(back_button, INPUT);
pinMode(select_button, INPUT);
pinMode(menu_up, INPUT);
pinMode(menu_down, INPUT);
pinMode(motor_forward, INPUT);
pinMode(motor_backward, INPUT);

/*creates menu option objects*/
char locked_array[] = {'L','o','c','k','e','d'};
char first_array[17] = {'B','e','d',' ','A','n','g','l','e',' ','C','o','n','t','r','o','l'};
char second_array[11] = {'A','r','m',' ','C','o','n','t','r','o','l'};
char third_array[] = {'U','p','p','e','r',' ','P','l','a','t','f','o','r','m',' ','A','n','g','l','e',' ','C','o','n','t','r','o','l'};
char fourth_array[] = {'L','o','w','e','r',' ','P','l','a','t','f','o','r','m',' ','A','n','g','l','e',' ','C','o','n','t','r','o','l'};
char fifth_array[] = {'U','p','p','e','r',' ','A','r','m',' ','C','o','n','t','r','o','l'};
char sixth_array[] = {'L','o','w','e','r',' ','A','r','m',' ','C','o','n','t','r','o','l'};
char seventh_array[] = {'C','o','m','b','i','n','e','d',' ','A','r','m',' ','C','o','n','t','r','o','l'};
Menu_Options* first = new Menu_Options(first_array,sizeof(first_array),0,0,0,0);
Menu_Options* second = new Menu_Options(second_array,sizeof(second_array),0,0,0,0);
Menu_Options* third = new Menu_Options(third_array,sizeof(third_array),21,0,20,0);
Menu_Options* fourth = new Menu_Options(fourth_array,sizeof(fourth_array),23,0,22,0);
Menu_Options* fifth = new Menu_Options(fifth_array,sizeof(fifth_array),24,0,25,0);
Menu_Options* sixth = new Menu_Options(sixth_array,sizeof(sixth_array),27,0,26,0);
Menu_Options* seventh = new Menu_Options(seventh_array,sizeof(seventh_array),24,27,25,26);

/*creates node objects*/
Node* first_node = new Node();
Node* second_node = new Node();
Node* third_node = new Node();
Node* fourth_node = new Node();
Node* fifth_node = new Node();
Node* sixth_node = new Node();
Node* seventh_node = new Node();

/*sets up layout of the menu*/
first_node->data = first;
first_node->forward = third_node;
first_node->backward = NULL;
first_node->up = second_node;
first_node->down = second_node;

second_node->data = second;
```

```
  second_node->forward = fifth_node;
  second_node->backward = NULL;
  second_node->up = first_node;
  second_node->down = first_node;

  third_node->data = third;
  third_node->forward = NULL;
  third_node->backward = first_node;
  third_node->up = fourth_node;
  third_node->down = fourth_node;

  fourth_node->data = fourth;
  fourth_node->forward = NULL;
  fourth_node->backward = first_node;
  fourth_node->up = third_node;
  fourth_node->down = third_node;

  fifth_node->data = fifth;
  fifth_node->forward = NULL;
  fifth_node->backward = second_node;
  fifth_node->up = seventh_node;
  fifth_node->down = sixth_node;

  sixth_node->data = sixth;
  sixth_node->forward = NULL;
  sixth_node->backward = second_node;
  sixth_node->up = fifth_node;
  sixth_node->down = seventh_node;

  seventh_node->data = seventh;
  seventh_node->forward = NULL;
  seventh_node->backward = second_node;
  seventh_node->up = sixth_node;
  seventh_node->down = fifth_node;
  Node* curr = new Node();
  curr = first_node;

  while (1)
  {
        /*records initial values of inputs*/
        bool list[6] = {digitalRead(motor_forward), digitalRead(motor_backward),
digitalRead(menu_up), digitalRead(menu_down), digitalRead(select_button), digitalRead(back_button)};
        /*checks if unlock*/
        if (list[0] && list[1])
        {
        delay(1000);
        if (!list[0] && !list[1])
        {
        delay(1000);
        if (!list[0] && !list[1])
        {
```

```
unlock_flag++;
}

}

}
delay(3000);
if (unlock_flag % 2)
{
/*writes data of current menu option to display*/
curr -> data -> send_message();
bool cont = true;
/*provides option to relock*/
while (cont)
{
if (!list[0] && !list[1])
{
delay(1000);
if (!list[0] && !list[1])
{
delay(1000);
if (!list[0] && !list[1])
{
write2Display(locked_array,sizeof(locked_array));
cont = false;
unlock_flag++;
}
}
}
/*checks for menu up*/
else if (!list[2])
{
if (!digitalRead(menu_up))
{
curr = curr -> up;
curr -> data -> send_message();
}
}
/*checks for menu down*/
else if (!list[3])
{
if (!digitalRead(menu_down))
{
curr = curr -> down;
curr -> data -> send_message();
}
}
/*checks for selction of menu option*/
else if (!list[4])
{
if (!digitalRead(select_button))
```

```
{
if (curr -> forward != NULL)
{
curr = curr -> forward;
}
curr -> data -> send_message();
}
}
/*checks for back button to move out one layer in menu*/
else if (!list[5])
{
if (!digitalRead(back_button))
{
if (curr -> backward != NULL)
{
curr = curr -> backward;
}
curr -> data -> send_message();
}
}
/*checks for motor forward*/
else if (!list[0])
{
if (curr -> data -> get_motor1() != 0)
{
/*sets direction of motors*/
bool dual_flag1 = false;
digitalWrite(curr -> data -> get_direction_pin1(), HIGH);
if (curr -> data -> get_motor_activated() != 0)
{
dual_flag1 = true;
digitalWrite(curr -> data -> get_direction_pin2(), HIGH);
}
/*pwm motor control adjust on off time to adjust speed. I didn't account for time spent to execute code, but should be insignificant since they are in the microsecond range*/
while (!digitalRead(motor_forward))
{
if (dual_flag1)
{

digitalWrite(curr -> data -> get_motor1(), HIGH);
digitalWrite(curr -> data -> get_motor2(), HIGH);
delay(2);
digitalWrite(curr -> data -> get_motor1(), LOW);
digitalWrite(curr -> data -> get_motor2(), LOW);
delay(0);
}
else
{
digitalWrite(curr -> data -> get_motor1(), HIGH);
delay(2);
```

```
        digitalWrite(curr -> data -> get_motor1(), LOW);
        delay(0);
        }
        }
        }
        }
        /*checks for motor backward*/
        else if (!list[1])
        {

        if (curr -> data -> get_motor1() != 0)
        {
        /*sets direction of motors*/
        bool dual_flag2 = false;
        digitalWrite(curr -> data -> get_direction_pin1(), LOW);
        if (curr -> data -> get_motor_activated() != 0)
        {
        dual_flag2 = true;
        digitalWrite(curr -> data -> get_direction_pin2(), LOW);
        }
        /*pwm motor control adjust on off time to adjust speed. I didn't account for time spent to execute
code, but should be insignificant since they are in the microsecond range*/
        while (!digitalRead(motor_backward))
        {
        if (dual_flag2)
        {

        digitalWrite(curr -> data -> get_motor1(), HIGH);
        digitalWrite(curr -> data -> get_motor2(), HIGH);
        delay(2);
        digitalWrite(curr -> data -> get_motor1(), LOW);
        digitalWrite(curr -> data -> get_motor2(), LOW);
        delay(0);
        }
        else
        {
        digitalWrite(curr -> data -> get_motor1(), HIGH);
        delay(2);
        digitalWrite(curr -> data -> get_motor1(), LOW);
        delay(0);
        }

        }
        }
        }
        }
        }

  }
}
```

I.FEA Images

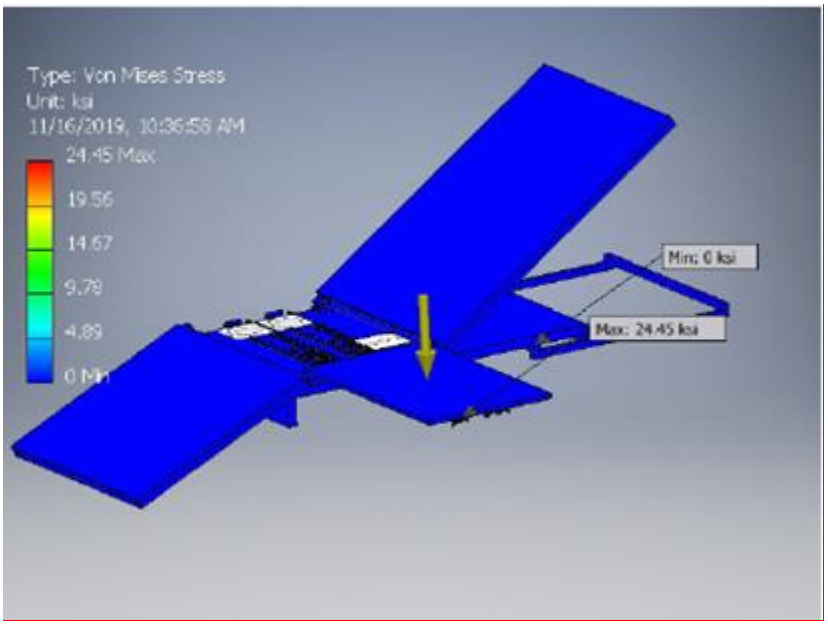


Figure 6

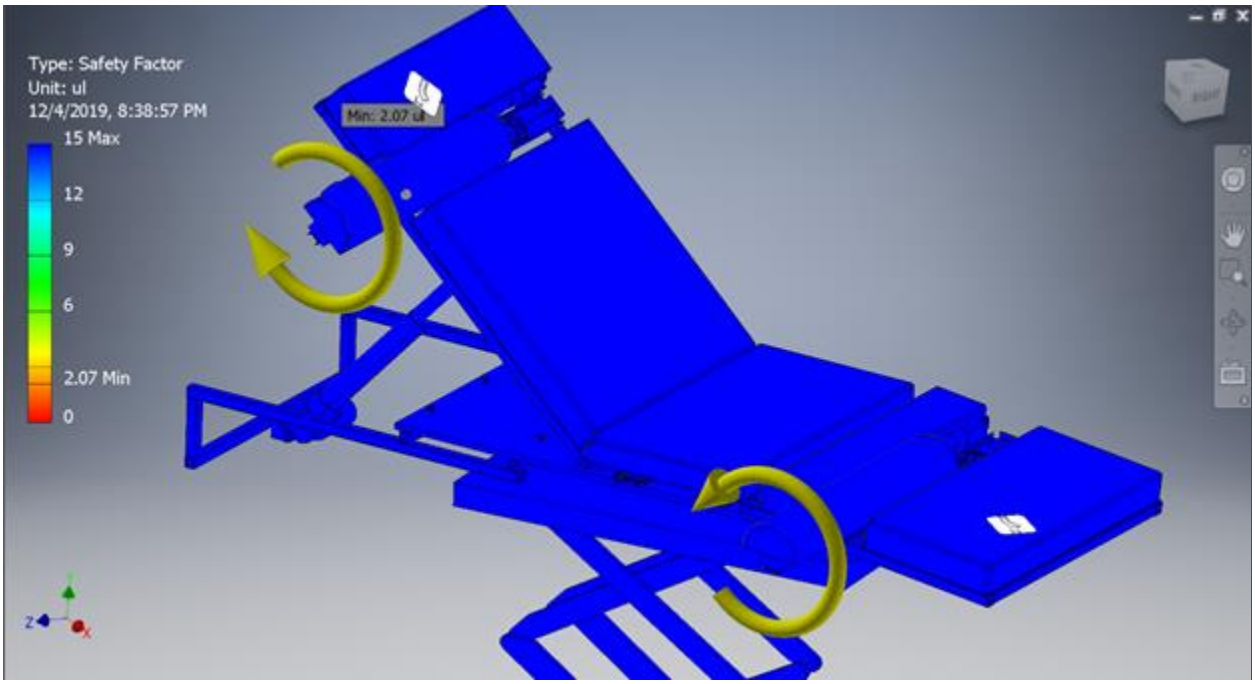


Figure 7

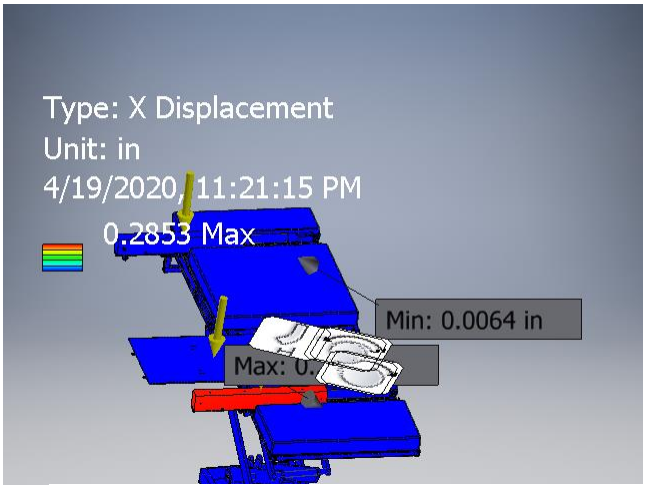


Figure 8

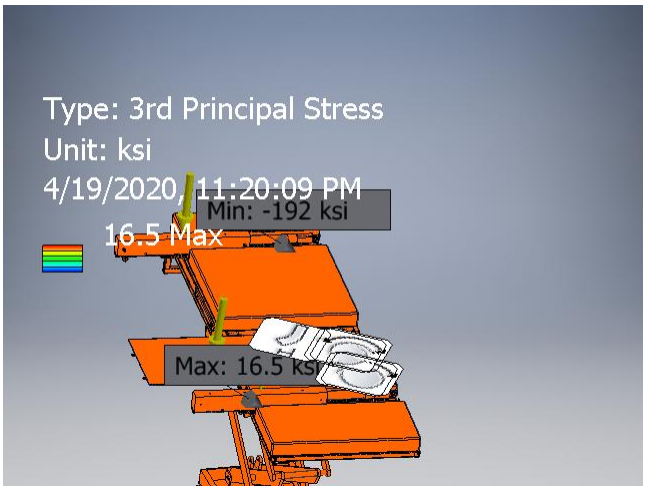


Figure9

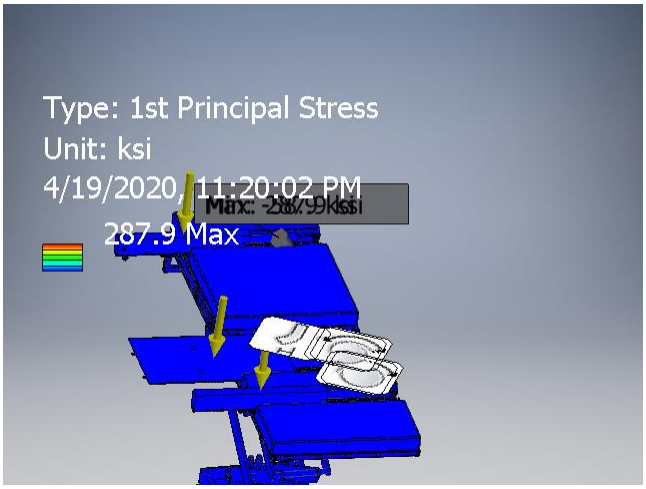


Figure 9

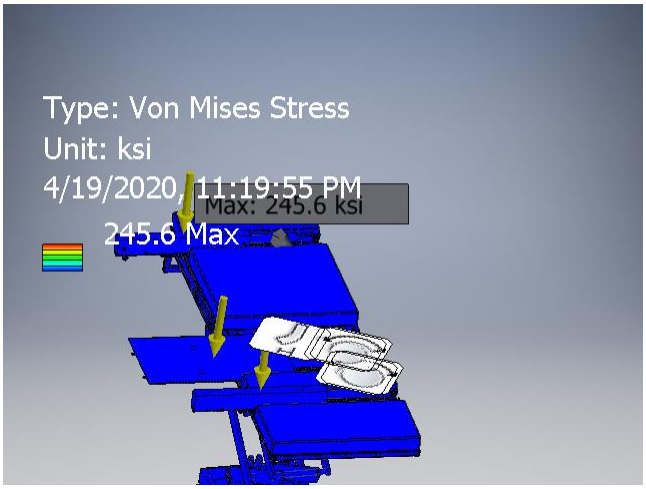


Figure 10

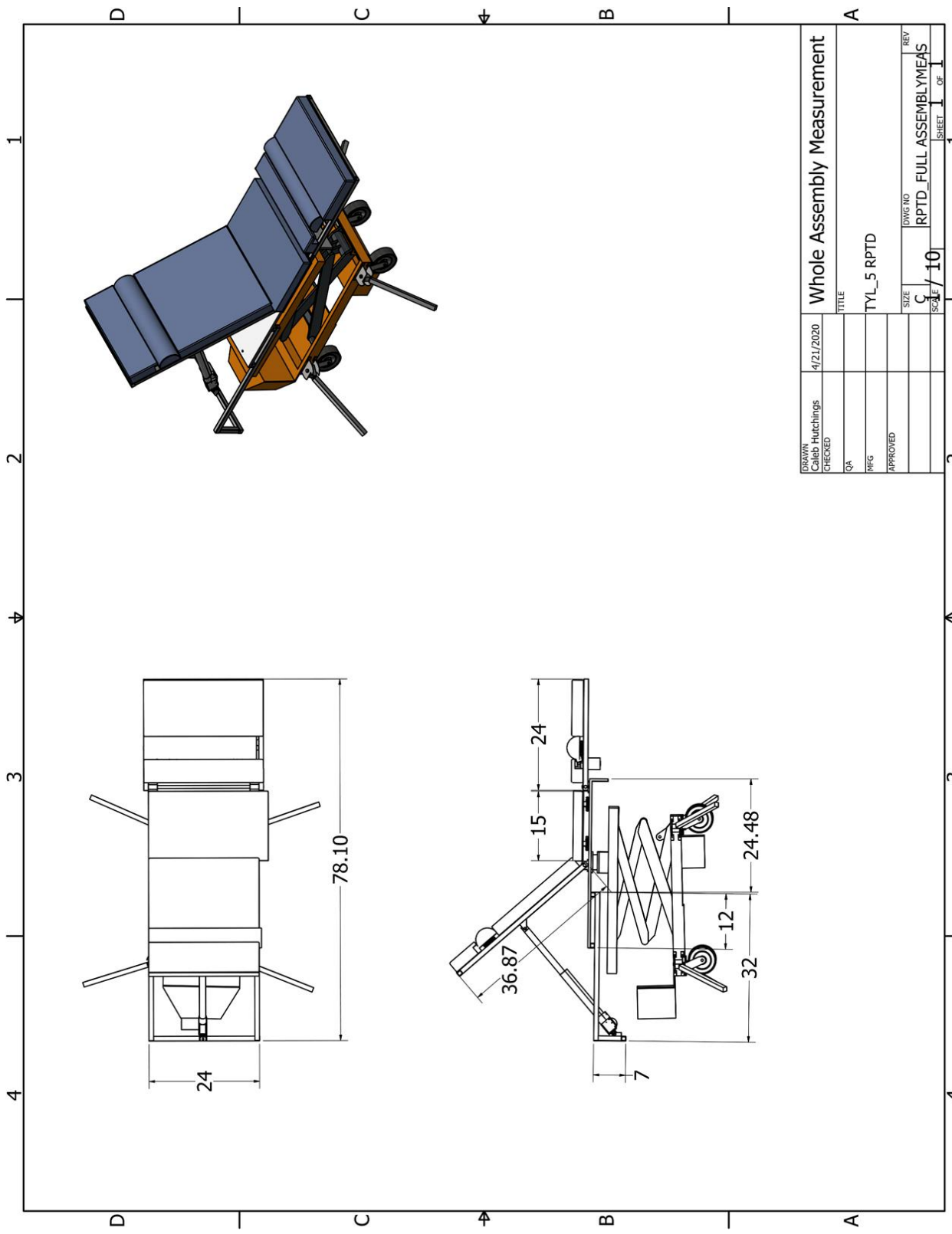
J.Design of Experiments, Experimental Procedures, and Results

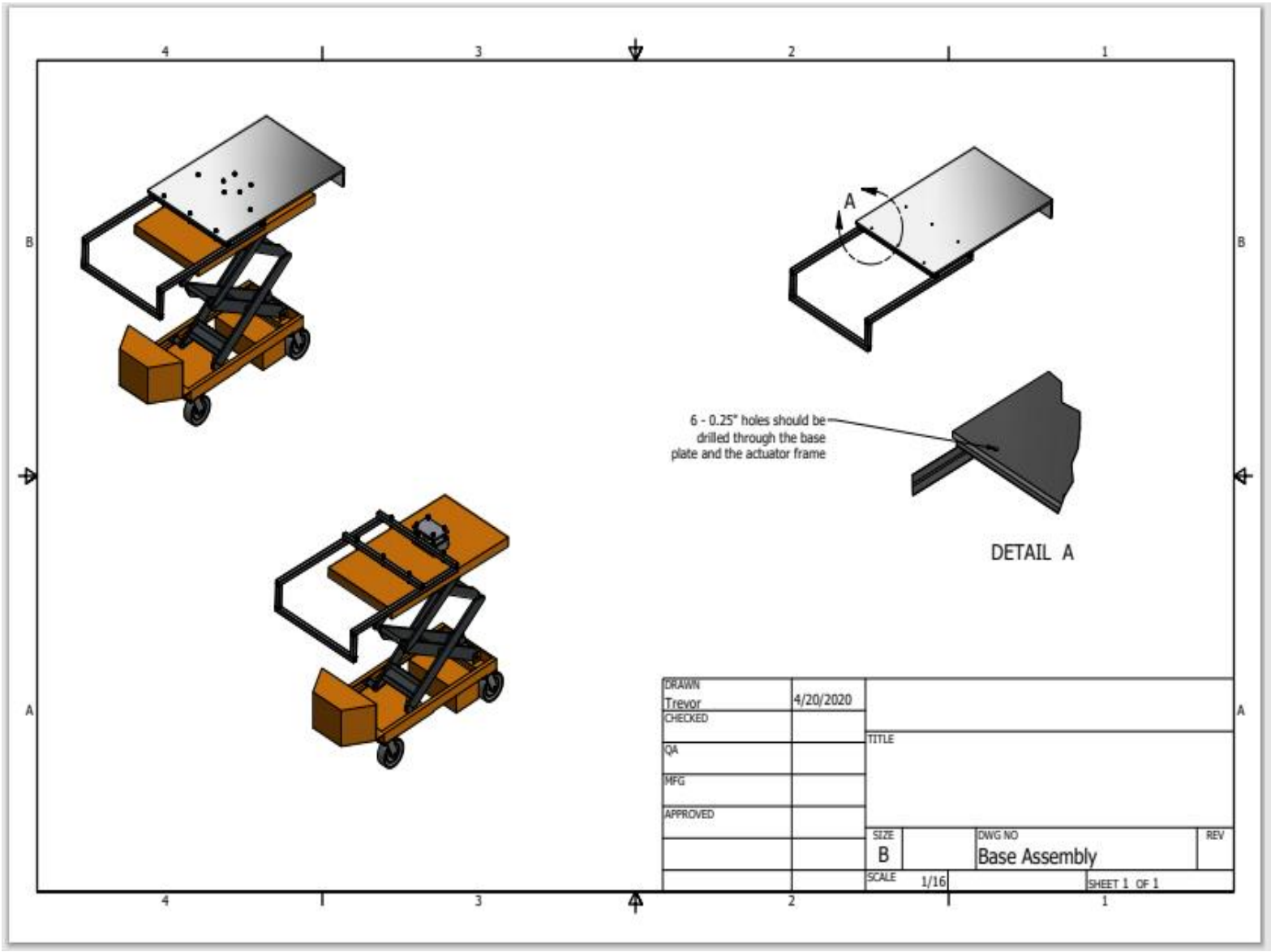
Date	Item (Device)	Max Extent Limitation	Test Procedure
Scheduled: 1/20/2020 – 1/21/2020 Completed:2/27/2020	**Large and Small Linear Actuators (1st phase)**	**N/A**	**When actuators are received test them by supplying power to see if they extend and retract.**
Scheduled: 2/17/2020 – 2/19/2020 Completed:	**Large Linear Actuator (2nd phase)**	**Rating of 1000 lbf**	**When actuator is placed on metal frame and upper assembly, test to see if it will hold and move the upper assembly with 157.5 lbs. of force from the two max extents of 0 to 45-degree range of motion.**
Scheduled: 2/05/2020 – 2/06/2020 Completed: NA	**Small Linear Actuator (2nd phase)**	**Rating of 400 lbf**	**When actuator is attached on the aluminum base board and lower assembly, test to see if it will hold and move the lower assembly with 78.75 lbs. of force from the two max extents of 0 to 30-degree range of motion.**

Scheduled: 1/20/2020 – 1/21/2020 **Completed: NA**	**Turn Table Swivel Bearing (1st phase)**	**Rating of 1000 lbf**	**To test the turn table swivel bearing, a load of 800 lbs. will be placed on it before placing on RPTD to ensure it will be able to take the load of the frame and patient.**
Scheduled: 2/10/2020 – 2/12/2020 **Completed: NA**	**Hip Support Plate and Track System**	**Rating of 180 lbf on each extended extension slider device.**	**Place 288.75 lbs. on the hip support plate and track system to make ensure it can withstand the max extent of weight placed on it.**
Scheduled:3/11/2020 – 3/13/2020 **Completed: NA**	**Robotic Arm Upper Torso Assembly**	**Rating of 200 lbf**	**Place 184 lbf against the back plate as it is attached to a test Rod to test the functionality**
Scheduled: 3/7/2020 – 3/11/2020 **Completed: NA**	**Robotic Arm Lower Leg Assembly**	**Rating to 100lbf against rod**	**Hang 100 lbf over lower arm as it is attached to test Rod then apply power to actuator**
Scheduled: 2/10/2020-2/14/2020 **Completed: NA**	**Continuity Testing**	**N/A**	**After all Components are soldered, continuity tests will be applied to ensure no shorts are present.**
Scheduled: 2/17/2020-2/21/2020 **Completed: NA**	**Logic Signal Test**	**N/A**	**View logic digital logic signals on an oscilloscope to ensure their quality**

Scheduled: 3/9/2020-3/13/2020 Completed: NA	**Full Load Test**	**Full Load(5A)**	**The board will be run at full load(5A) to ensure temperature remains at rated value for all components**
Scheduled: 3/16/2020-3/31/2020 Completed: NA	**Variable Load Test**		**Apply varying loads to full system to ensure it safely operates with its limits**
Scheduled: 3/11/2020 – 3/16/2020 Completed: NA	**RPTDS (Tilting)**	**N/A**	**When RPTD is completely built, the robotic arms and hip support plate will be placed at its maximum extent with the maximum amount of weight to ensure that the device is stable.**
Scheduled: 3/16/2020 – 3/31/2020 Completed: NA	**Evaluation of RPTD**		**Physically test RPTD by lifting 525 lbs. from wheelchair to device and transferring it from device to bed and vice versa.**

K.Manufacturing Drawings

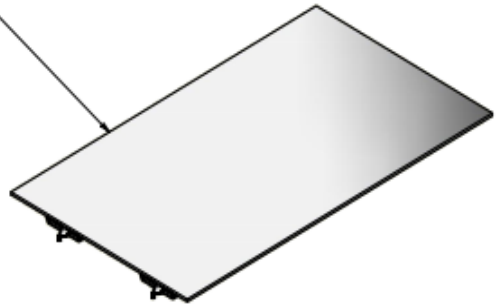


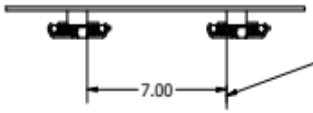

4
3
2
1
B
A
A
6 - 0.25" holes should be drilled through the base plate and the actuator frame
DETAIL A
DRAWN
Trevor
4/20/2020
CHECKED
QA
MFG
APPROVED
TITLE
SIZE
B
DWG NO
Base Assembly
REV
SCALE
1/16
SHEET 1 OF 1

A hole should be drilled through each of the spacer blocks to allow them to be secured between the hip plate and the sliders.



Attach the sliders to the base plate prior to fitting the hip plate to ensure proper spacing between the sliders.





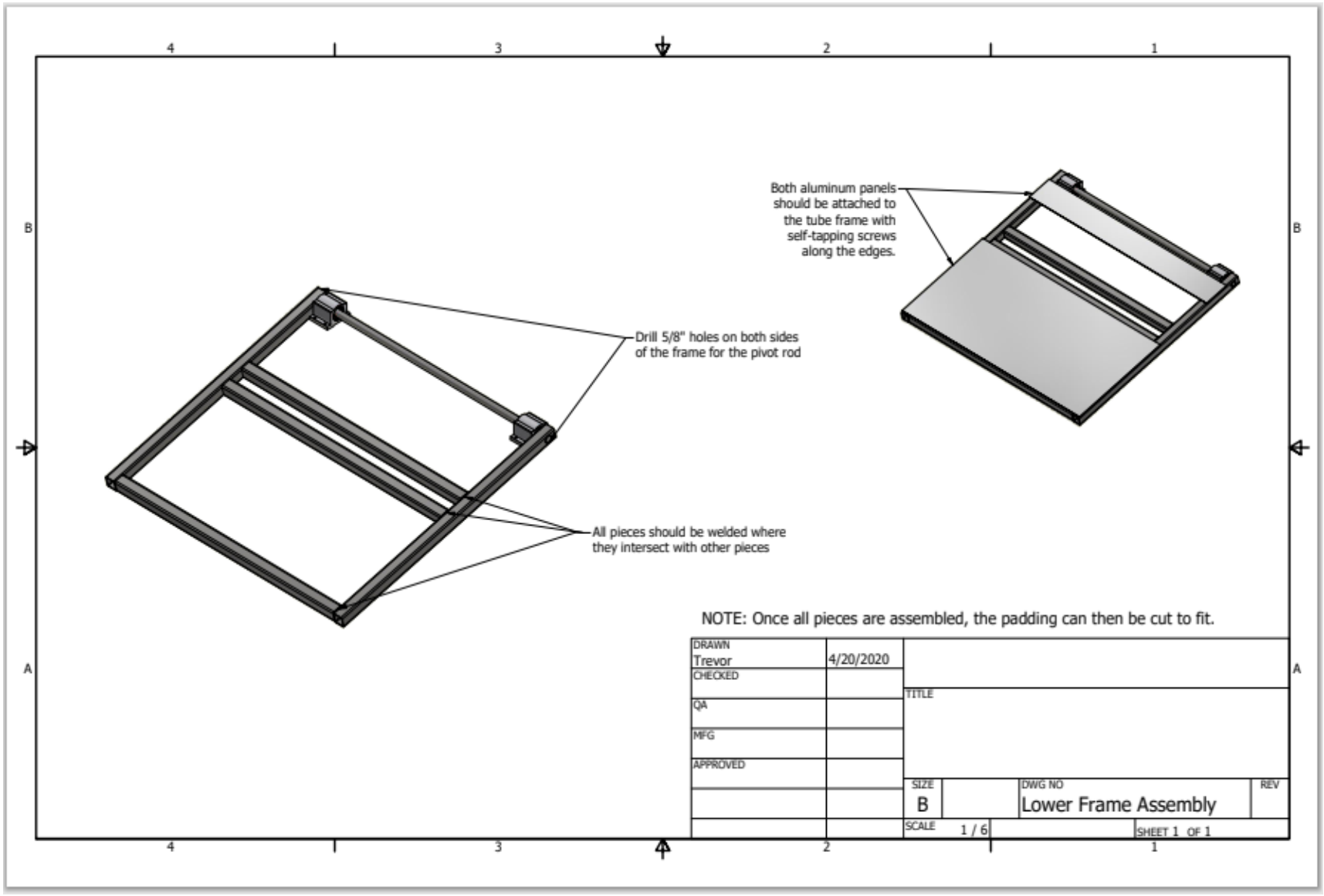
This should be the distance between the spacers once mounted on the device.

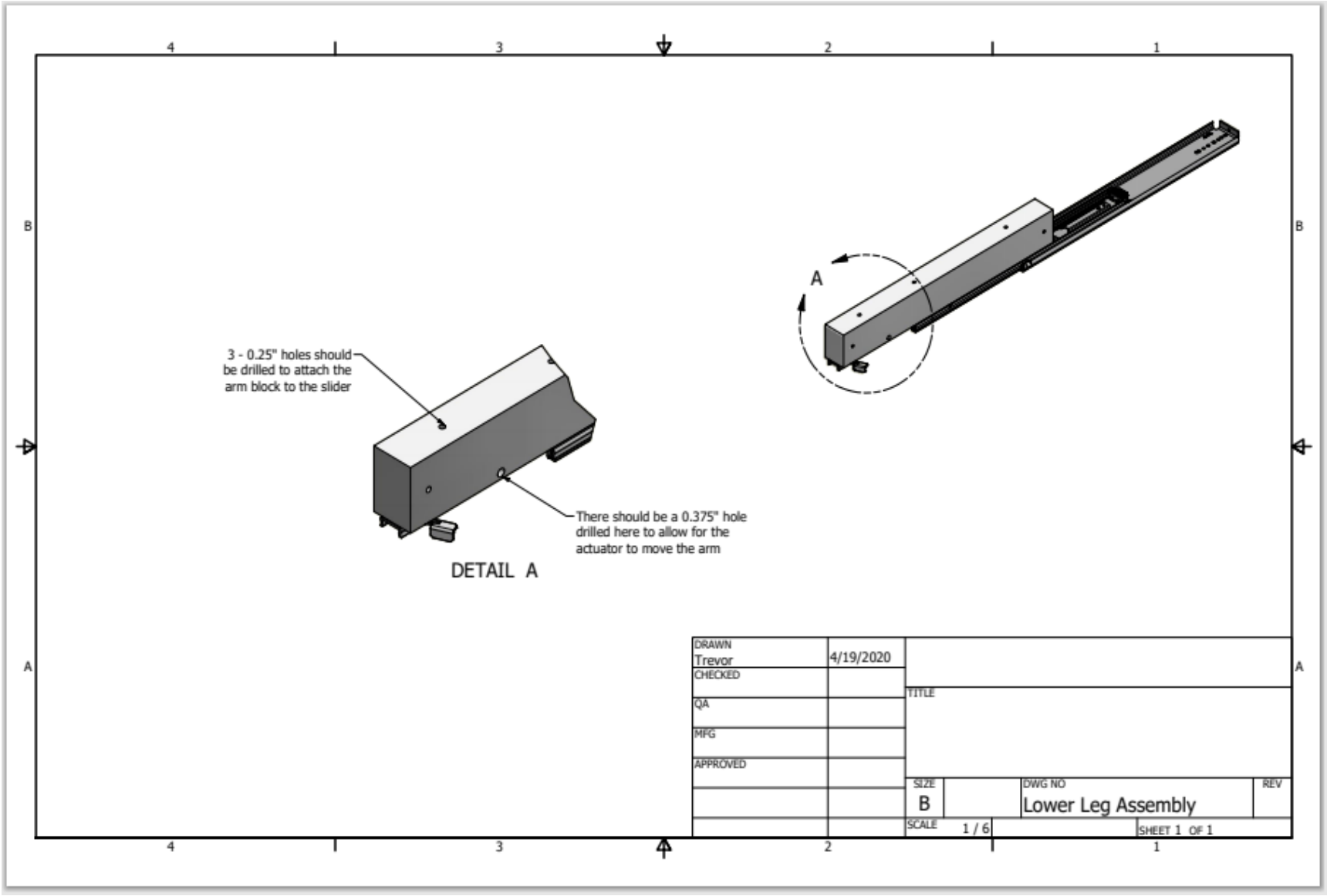
DRAWN	Trevor	4/20/2020
CHECKED		
QA		
MFG		
APPROVED		

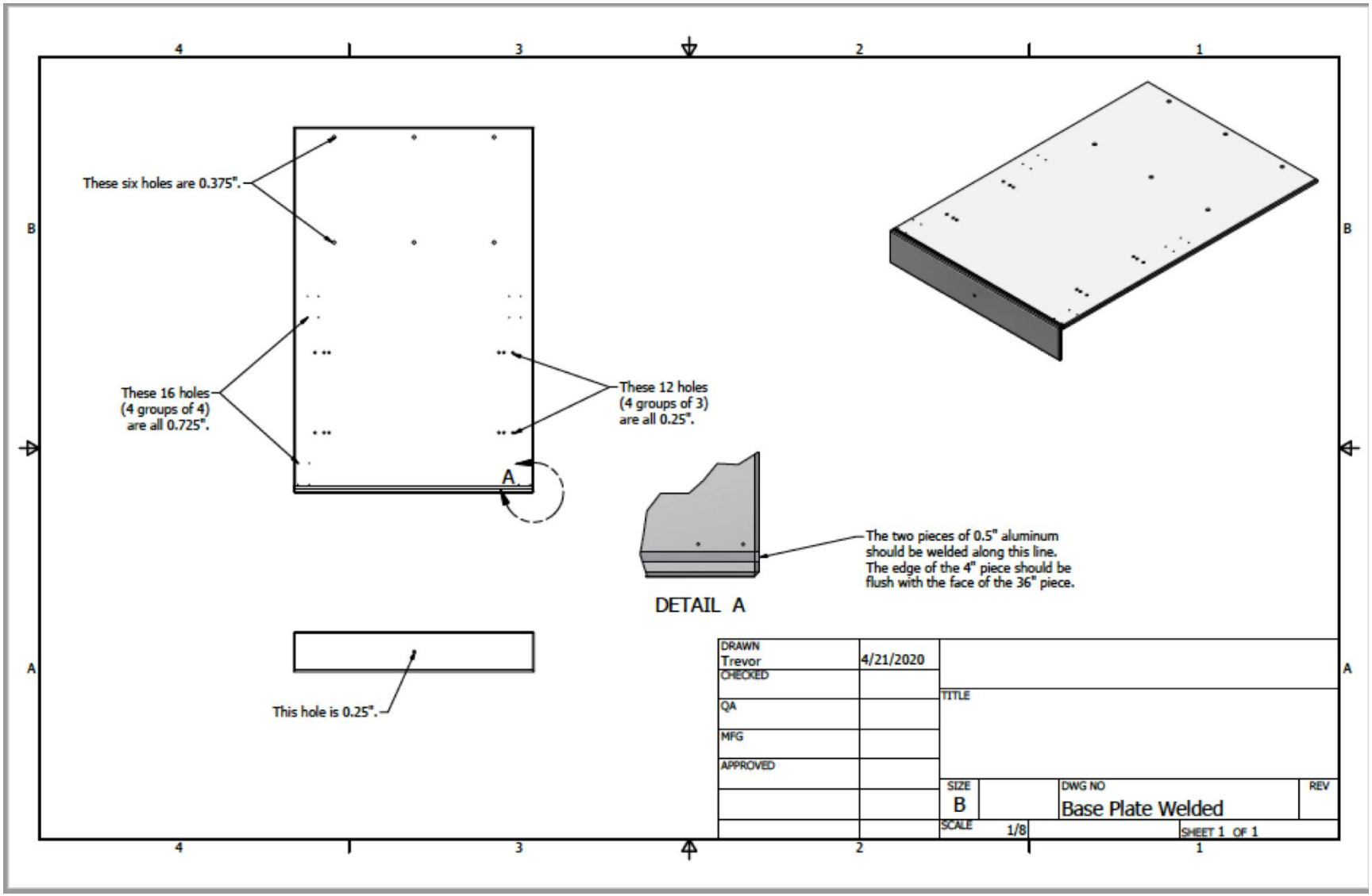
TITLE

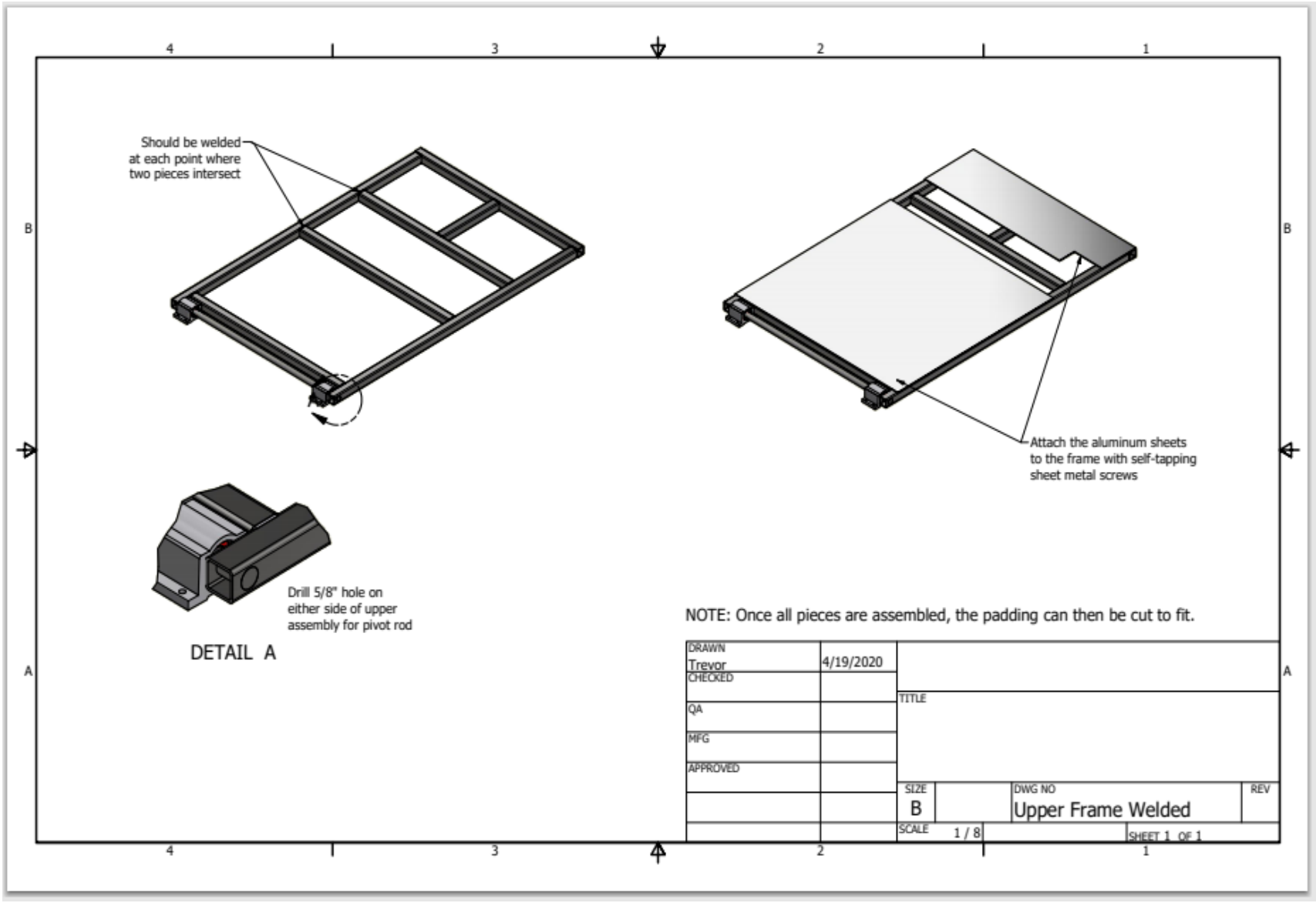
SIZE	DWG NO	REV
B	Hip Plate Assembly	

SCALE 1 / 6 SHEET 1 OF 1

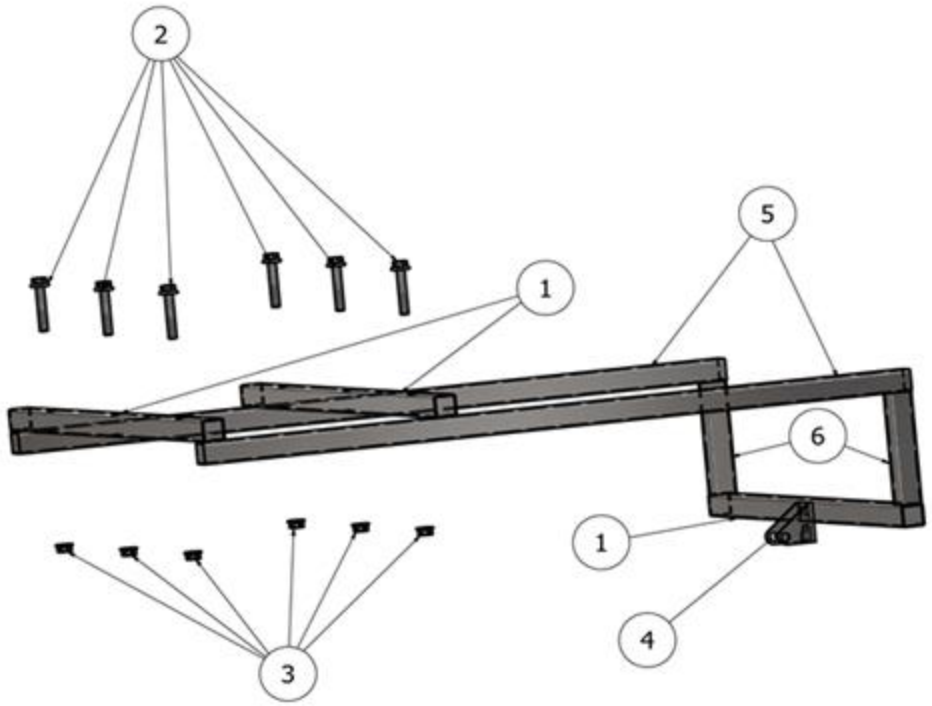

Both aluminum panels should be attached to the tube frame with self-tapping screws along the edges.
Drill 5/8" holes on both sides of the frame for the pivot rod
All pieces should be welded where they intersect with other pieces
NOTE: Once all pieces are assembled, the padding can then be cut to fit.
DRAWN
Trevor
4/20/2020
CHECKED
QA
MFG
APPROVED
TITLE
SIZE
B
DWG NO
Lower Frame Assembly
REV
SCALE
1 / 6
SHEET 1 OF 1


4
3
2
1
B
A
A
3 - 0.25" holes should be drilled to attach the arm block to the slider
There should be a 0.375" hole drilled here to allow for the actuator to move the arm
DETAIL A
DRAWN
Trevor
4/19/2020
CHECKED
QA
MFG
APPROVED
TITLE
SIZE
B
DWG NO
Lower Leg Assembly
REV
SCALE
1 / 6
SHEET 1 OF 1


These six holes are 0.375".
These 16 holes (4 groups of 4) are all 0.725".
These 12 holes (4 groups of 3) are all 0.25".
A
The two pieces of 0.5" aluminum should be welded along this line. The edge of the 4" piece should be flush with the face of the 36" piece.
DETAIL A
This hole is 0.25".
DRAWN Trevor
4/21/2020
CHECKED
QA
MFG
APPROVED
TITLE
SIZE B
DWG NO Base Plate Welded
REV
SCALE 1/8
SHEET 1 OF 1

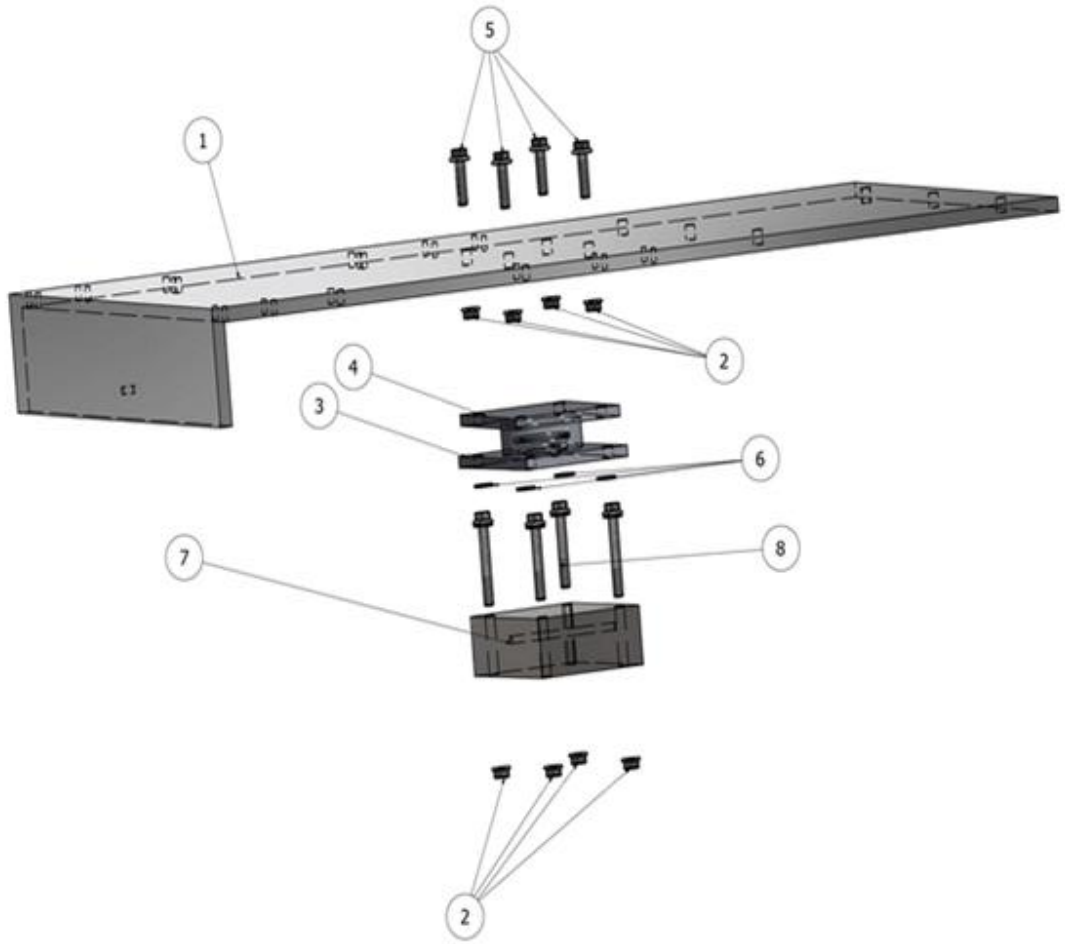

Should be welded at each point where two pieces intersect
Attach the aluminum sheets to the frame with self-tapping sheet metal screws
Drill 5/8" hole on either side of upper assembly for pivot rod
DETAIL A
NOTE: Once all pieces are assembled, the padding can then be cut to fit.
DRAWN
Trevor
4/19/2020
CHECKED
QA
MFG
APPROVED
TITLE
SIZE
B
DWG NO
Upper Frame Welded
REV
SCALE
1 / 8
SHEET 1 OF 1

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	3	Rect Tube 1inx1in 24in	
2	6	IFI 111 - 3/8-16 UNC x 2	Hex Flange Screw - Regular Thread - Inch
3	6	IFI - I0.375 - 16	Hex Flange Nut
4	1	Actuator Connector	
5	2	Rect Tube 1inx1in 34 in	
6	2	Rect Tube 1inx1in 5in	
7	2	small 1 in actuator bracket	



DRAWN Joshua Berger	11/18/2019	
CHECKED		TITLE: Metal Frame Assembly
QA		
MFG		
APPROVED		SIZE C / DWG NO / REV
		SCALE 5/16 / SHEET 1 OF 1

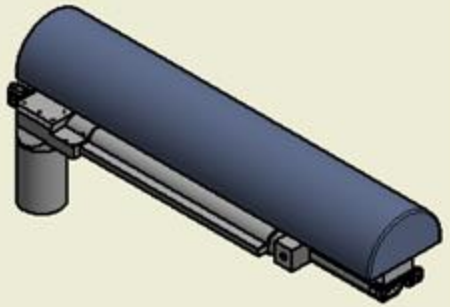
PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Aluminum panel back	
2	8	IFI - I0.375 - 16	Hex Flange Nut
3	1	bearing support	
4	1	bearing Frame	
5	4	IFI 111 - 3/8-16 UNC x 1.5	Hex Flange Screw - Regular Thread - Inch
6	4	SAE J773b - 3/8. SAE Type L. narrow	Conical Spring Washer
7	1	Lazy Susan Wedge Plate	
8	4	IFI 111 - 3/8-16 UNC x 2.5	Hex Flange Screw - Regular Thread - Inch

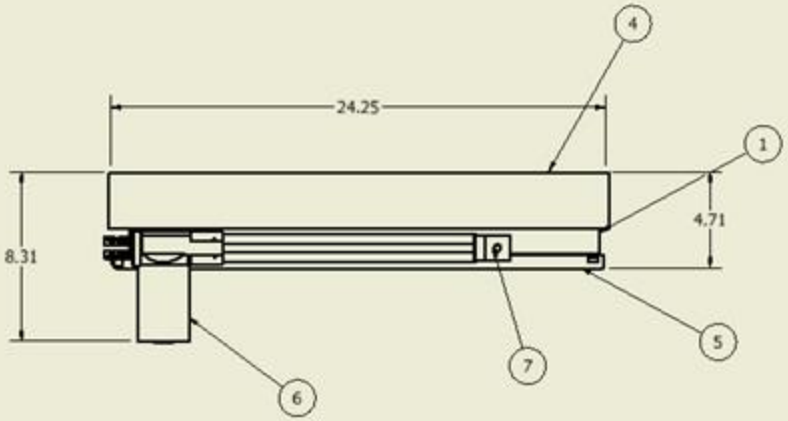


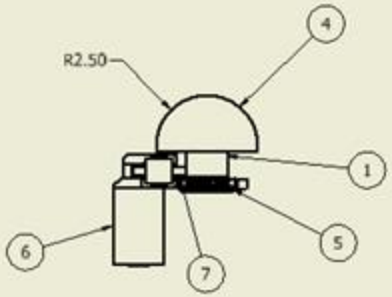
Base Plate and Swivel Bearing

SIZE D | SHEET 1 OF 2

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Arm-Lower Rod	
4	1	Arm-Lower Leg Pad	
5	1	Accuride_9308-E24_Good Other Side	
6	1	12" Actuator	
7	1	Actuator pin for slider	

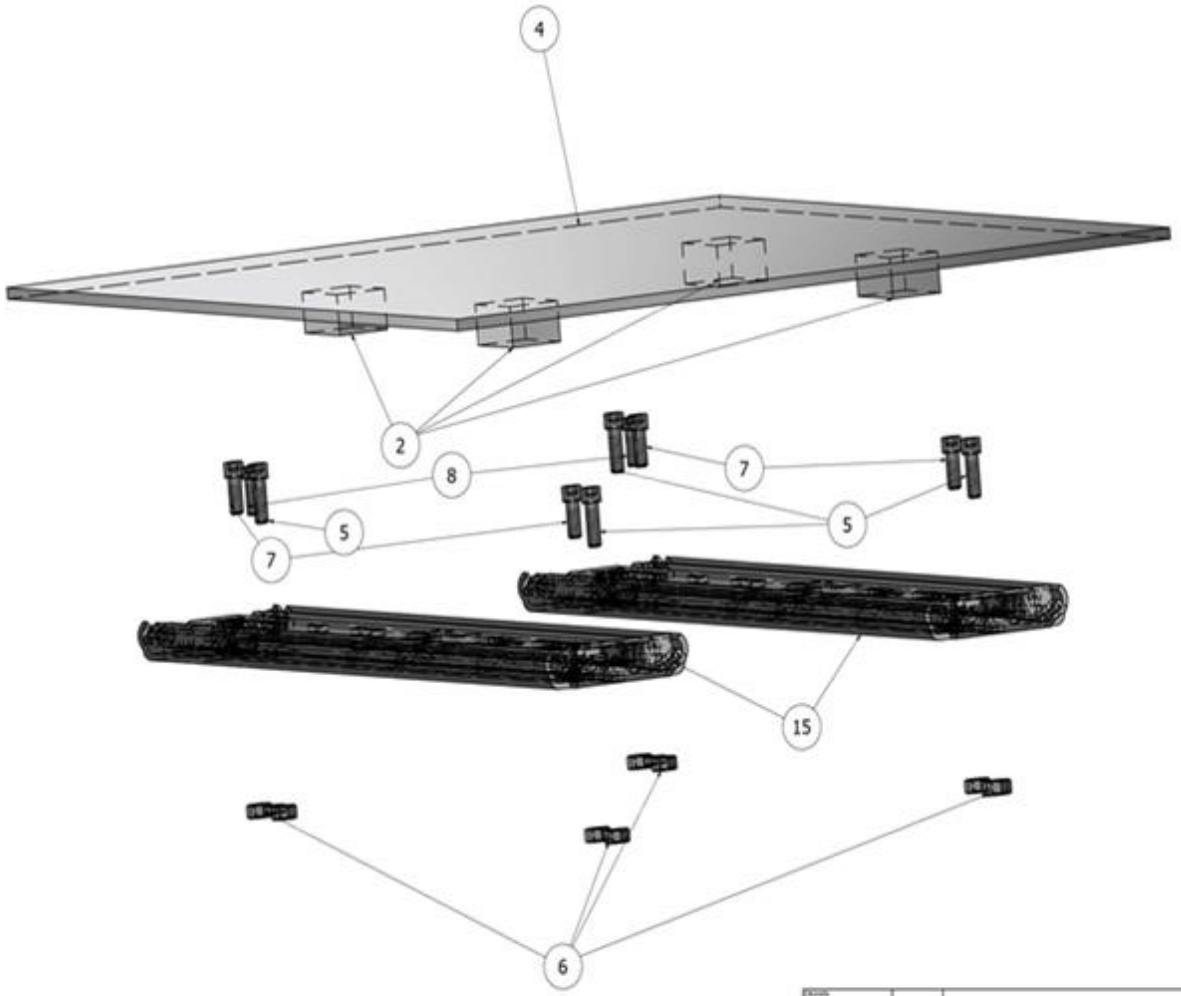






DRAWN Trevor	12/4/2019	Triple C JT
CHECKED		TITLE
QA		
MFG		
APPROVED		
SIZE B	DWG NO Lower Leg Assembly with Actuator	REV
SCALE 1 / 5	SHEET 1 OF 1	

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	9308-E24 L Open	
2	2	plate 3.8	
3	2	plate 3.9	
4	1	hip plate	
5	4	ANSI B18.3 - 1/4 - 20 UNC - 3/4 HS HCS	Hexagon Socket Head Cap Screw
6	8	ANSI B18.2.2 - 1/4 - 20	*Varies*
7	4	ANSI B18.3 - 1/4 - 20 UNC - 5/8 HS HCS	Hexagon Socket Head Cap Screw
8	2	ANSI B18.3 - No. 10 - 24 UNC - 5/8 HS HCS	Hexagon Socket Head Cap Screw
9	2	ANSI B18.2.2 - 10 - 24	Hex Machine Screw Nut



Hip Slider Extension Assembly

Hip Plate Extension Assembly

L.User Manual- Safety Operations

Robotic Patient Transfer Device

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Introduction

Intended Use:

The purpose of this product is to provide a Robotic Transfer Patient Device which safely transfers a patient from bed to wheelchair and from the wheelchair back to bed while making the transfer ergonomically friendly for the nurse or caretaker. The device also doubles a gurney for patient transfer exceeding the area of the room. This device was designed for a maximum patient weight of 350 pounds, and thus no load exceeding 350 pounds is considered to be within the scope of its designed operation.

Precautions:

- The device may be prone to tilting, so avoid moving the device without the patient fully retracted.
- The device is designed for a maximum load of 350 lbs, so no weight above that may reduce the reliability and stability of the device.
- The device may lose power if the batteries are not fully charged, so be sure to follow recommended maintenance(Featured in the next section)
- Device is heavy and relies on support legs when in use, so be sure the device is used on a clear and level floor.

Features:

- Rotating base and adjustable angles provide a versatility regarding compatible products
- Safety belts and harness provide a safe and secure experience for the patient
- Handheld controller with display and menu interface
- Rechargeable battery for ease of use and increased portability
- Doubles as a gourney for overall reduction of medical equipment required
- Incorporates support legs to stabilize the system and create a safer environment for both the patient and the healthcare provider

Maintenance and Cleaning

Battery Health and Charging:

Batteries should be inspected for voltage drain monthly to ensure the long term health of the battery. When the device is idle, plug in the scissor lift battery charger to a 120 volt receptacle to charge. The actuator batteries may be recharged using any car battery charger so long as they are not allowed to die completely. As a precaution, it is recommended to charge them bimonthly(every 2 months) .

Recommended Cleaning Procedure:

Abide by your facilities cleaning standards. Avoid use of excess water as it may cause complications with the electronics on board. The surface will not be damaged by liquid and the use of alcohol wipes and other generic disinfectants is permitted.

Troubleshooting Guide:

Movement unresponsive to user input:

1. Ensure Linear actuator cables are still connected to the motor controller stored near the battery. Make sure the battery is disconnected before any adjustments are made to the wires.
2. Check that the battery is still supplying 12 V DC using a multimeter.
3. Check the function of the actuators by removing the pins connecting them to the arm and trying to retract them once again. If this works, check that the sliders of the plate are not bent and are properly lubricated.
4. If all else fails, troubleshooting of the microcontroller is required. To do this, you will need to sniff the busses transmitting control signals from the microcontroller to the motor control board using an oscilloscope to ensure data is being sent. If no data is being sent, replace the microcontroller. If data is being sent, replace the motor control board.

Display is not responsive:

1. Check that the microcontroller is powered, if not replace AAA Batteries.
2. Troubleshooting of the microcontroller is necessary
3. If the microcontroller is still powered, sniff the busses transmitting control signals from the microcontroller to the user interface using an oscilloscope to ensure data is being sent. If no data is being sent, replace the microcontroller. If data is being sent, replace the user interface.

Patient Care Procedure

Bed to Device:

1. Place the device parallel to the bed with pressed together as closely as possible.
2. Extend the support legs.
3. Assuming a sling is already in place under the patient, roll the patient onto their right side.
4. Slide out the hip plate so that it is pressed against the patient.
5. Roll the patient onto the plate and use the sling to slide their hips completely onto it.
6. Adjust the hospital bed and the transfer device so that they are both in the semi upright position.
7. Lean the patient forward slightly and fully extend the upper arm so that it is positioned on the patient's neck/upper shoulder area.
8. Position the patient's legs with their heels a foot from their hips.
9. Extend the lower robotic arm so that it is on the underside of their knee.
10. Ensure the patient is securely fastened and raise the scissor lift slightly.
11. Retract the hip slider and robotic arms to transfer the patient onto the device.
12. Retract the support legs if necessary.

Device to Bed:

1. With a patient on the device roll it parallel to the bed with as little space between the two as possible.
2. Check that the device and bed are holding the patient in the same angle.
3. Extend the support legs.
4. Ensure that the device is raised 6 inches above the bed.
5. Extend all three segments of the device and check that the sling is connected properly.
6. Retract the hip plate sliding it out from under the hips of the patient.
7. Lower the patient to bed level.
8. Disconnect the sling from the two arms.
9. Lean the patient forward slightly and retract the upper arm.
10. Finally, remove the lower leg, and place the patient's legs in a downright resting position.
11. Retract the support legs if necessary.

Chair to Device:

1. Maneuver the sling as that it is positioned properly on the patient.
2. Adjust the backplate and lower plate so that the device is in the same position as the wheelchair.
3. Pull the wheelchair parallel to the device and extend the support legs.
4. Lower the device to the height of the chair.
5. Attach the sling to the upper arm.
6. Lean the patient forward slightly and extend the upper arm, so that it is positioned on the patient's neck/upper shoulder area.
7. Place the patient's legs on the ground and disengage footholds of the wheelchair.
8. Extend the lower robotic arm so that it is on the underside of their knee.
9. Attach the lower end of the sling to this arm.
10. Fasten the safety belts
11. Ensure the patient is securely fastened and raise the scissor lift approximately one foot.
12. Slide the hip plate underneath the patient applying pressure to their hips from below to help it along its path.
13. Retract the hip slider and robotic arms to transfer the patient onto the device.
14. Retract the support legs if necessary.

Device to Chair:

1. Adjust the backplate and lower plate so that the device is in the same position as the wheelchair.
2. Pull the device parallel to the wheelchair and extend the support legs.
3. Raise the device to one foot above the arms of the chair.
4. Ensure the sling is connected securely.
5. Fasten the safety belts.
6. Extend all three segments of the device.
7. Remove the hip plate before the device reaches the level of the arm rest.
8. Lower the device until the patient's hips have contacted the seat of the wheelchair.
9. Disconnect the sling from the lower arm and retract the arm.
10. Disconnect the sling from the upper arm.
11. Lean the patient forward and retract the upper arm.
12. Retract the support legs if necessary.

Control

Menu Options and Description:

Command	Layer	Description
Bed Angle Control	1	Takes you to a sub menu containing controls for the angle of the upper and lower sections of the device.
Arm Control	1	Takes you to a sub menu containing controls for the extension of the arms.
Upper Platform Angle Control	2	Enables control of the angle of recline for the upper portion of the device.(Contained within Bed Angle Control)
Lower Platform Angle Control	2	Enables control of the angle of recline for the lower portion of the device.(Contained within Bed Angle Control)
Upper Arm Control	2	Enables Control of the upper arm(contained within Arm Control)
Lower Arm Control	2	Enables Control of the lower arm(contained within Arm Control)
Combined Arm Control	2	Enables Control of both arms combined (contained within Arm Control)

Buttons and Description:

Button	Identifier	Description
Menu Up	SW1	Cycles upward through the current layer of the menu
Menu Down	SW2	Cycles downward through the current layer of the menu
Back	SW3	Goes to the outer layer of the menu
Select	SW4	Goes to the inner layer of the menu
Motor Forward	SW5	Begins extending actuators if their operation has been unlocked by the menu navigation
Motor Backward	SW6	Begins retracting actuators if their operation has been unlocked by the menu navigation
Lock/Unlock	SW5& SW6	If both motor control buttons are selected simultaneously and held for 2 seconds the inputs to the controller will be locked/unlocked depending on their current state

*The controls for the height of the device are on a separate controller attached to the scissor lift.