Swing Away Medial Thigh Support

Rehabilitation Centre for Children

Team 13

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Executive Summary

The Rehabilitation Centre for Children has a need for a customizable medial thigh support, also known as a pommel. There are multiple problems with current commercial options available and they have commissioned a design that serves there most critical problems. Critical problems are: access to the wheelchair is blocked by the pommel, positioning of the pommel does not prescribe physical therapy treatment, this meaning the placement of the pommel cushioning does not provide sufficient lower body support or alignment. The way of attachment is not compatible with all wheelchair designs, the mechanism to engage and disengage the pommel is not intuitive, durability of pommel is insufficient and finally pommels are expensive to purchase.

Objectives for this project were to create a pommel design that corrects al critical problems highlighted above. The final deliverables for this project were to design a functional and cost effective pommel support, produce a feasible and manufacturable CAD model with engineering drawings of the final design, provide a detailed bill of materials with cost analysis and a finite element analysis to ensure structural integrity of design.

The final design completed by Team 13, addressed all the critical problems expressed by R.R.C. The design is composed of a customizable cushioning reinforcement with three different sizes designed, an adjustable arm connecting the cushioning reinforcement to the hinge mechanism, which allows for 210 degrees of rotation, locking mechanisms for when the pommel is engaged and disengaged. The engagement lock is spring loaded plunger and the disengagement lock is a magnet that holds the pommel at 210 degrees, completely under the wheelchair. Finally the mounting component uses four fasteners and pre drilled holes in the wheelchair's sit plate to secure the pommel.

All critical problems seen with commercial pommels were solved and accounted for. The 210 degree rotation of the pommel allows for easy access to the wheelchair from any angle, because pommel can be moved and secured completely under the wheelchair seat. The pommel allows for adjustability in the vertical and horizontal direction because of adjustable slot and screw features located along the arm and under the cushioning reinforcement. This adjustability will allow for correct positioning of the pommel to align and support the patient's lower body. Space below the arm and mounting component allow the wheelchair to be mounted to but straight edge and curved lip wheelchair seat plates and is therefore compatible with multiple wheelchair designs. The easy pull handle to disengage the pommel, is recognizable, easy to use and intuitive to users. The durability of the pommel has been analyzed using Solidworks finite element analysis (FEA). The maximum predicted force applied was applied to the head of the pommel, where the inner thighs of the patient would applied force to the pommel. The results from the FEA analysis show the durability of the pommel will be satisfactory. Finally, the final predicted cost analysis showed the manufacturing cost to be $288.91 per pommel.

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1. Introduction & Background

The Rehabilitation Center for Children (R.C.C.) has asked team 13 to design a swing away medial thigh support. A medial thigh support, commonly called a "pommel", is a device that separates and restricts the legs, which is recommended to clients who have been diagnosed with neuromuscular disorders such as Parkinson's disease, Cerebral Palsy, and Multiple Sclerosis, as well as hip diseases such as femoral anteversion, developmental dysplasia of the hip and slipped capital femoral epiphysis. Patients with these diagnosis's experience muscular spasms and misalignment of the lower body, which causes discomfort and immediate or long term harm. The pommel allows the patients to correct their asymmetric or improper sitting posture by aligning the heads of the femurs with the acetabulum, providing symmetrical hip abduction [1].

The typical pommel, shown in Figure 1, can be separated into the following components: pommel cushion, internal cushion reinforcement, arm, hinge mechanism, locking mechanism and the attachment piece. The primary function of the cushion is to provide comfort, restrict lower body movement and redistribute the load into the internal reinforcement component and the arm. The pommel is typically mounted underneath the wheelchair's sit cushion, by the attachment piece.

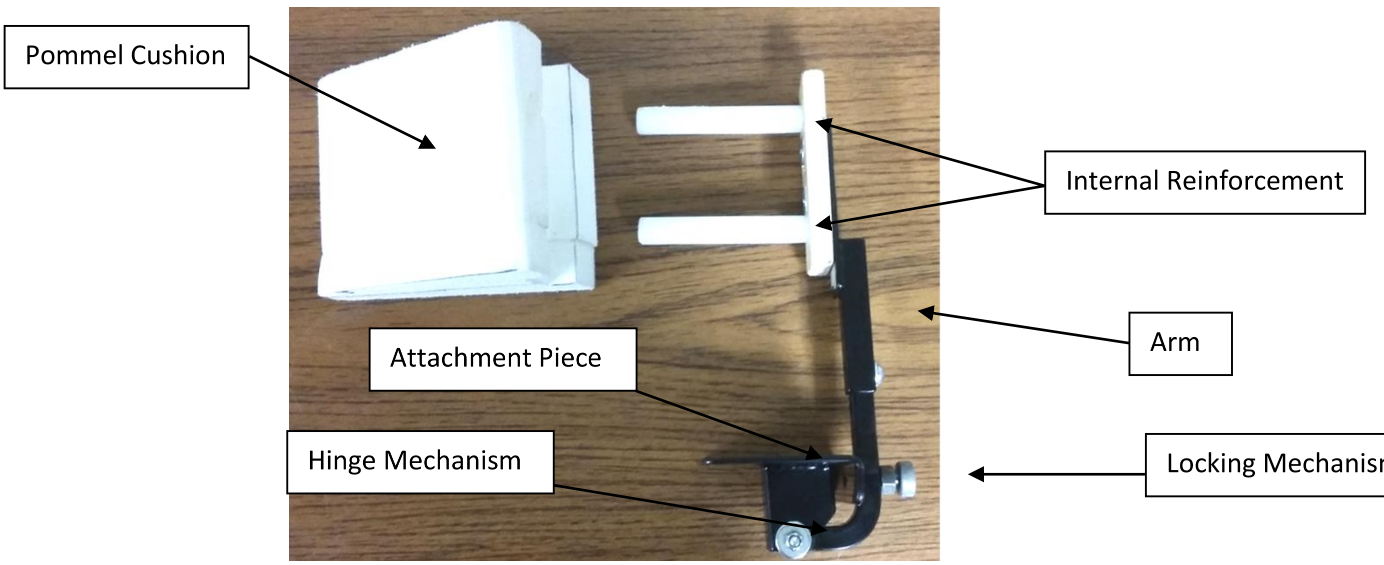


Figure 1: Pommel manufactured by R.C.C. with pommel cushion removed.

The first pommel prototype the R.C.C. has developed, seen in Figure 1, uses a spring loaded pin as the locking mechanism. When the pin is pulled away from the arm the pommel is unlocked and free to move from the hinge. Two plastic pillars are used as the internal reinforcement for the pommel cushion, which is cut from foam. The majority of the parts for the prototype were manufactured and assembled in the R.C.C. workshop with materials that were already purchased. However, the design needs refinement. Some of the complaints are hinge mechanism doesn't allow pommel to move completely under the chair, locking mechanism is not intuitive to all caregivers and pommel cannot be mounted to the bottom of all wheelchairs.

The purpose of this report is to define the project's goal and scope, give an in-depth look at the customer needs and target specifications of the end product, show the conceptual design and screening processes, and finalize which of the designs will be further developed and optimized.

2. Problem Definition

In the first stage of the project, all aspects of the problem were clearly defined to get a full understanding of R.C.C.'s expectations of the final design. This section will define the problem statement, highlight project goals and deliverables, classify the scope of the project and identity constraints and limitations.

2.1 Problem Statement

The Rehabilitation Centre for Children (R.C.C) requires a customizable pommel that is adaptable for each patient. Current designs used, which are either purchased off the market or manufactured by R.C.C., are not suitable to patient needs because of a combination of critical problems, which are highlighted below.

- Access to the chair is blocked by the pommel.
- Position of thigh support does not support prescribed physical therapy treatment. These needs include correct placement of the pommel cushioning to support and aligned patient' slower body. Ideal placement of the pommel cushioning is a third of the way, from the knee joint, up the upper thigh.
- Pommel attachment to the chair is not compatible with all wheelchairs. Attachment mechanism should be compatible with a straight edge and curved lip seat plate.
- Design of locking mechanism is not intuitive to all caregivers.
- Durability of support is insufficient.
- Expensive to purchase.

2.2 Objectives

The goals of this project were to design a pommel support that satisfies the most important customer needs and to deliver high quality and completed final deliverables on schedule. The final deliverables, agreed upon by Team 13 and R.C.C. are as followed;

- Functional and cost effective design of a swing away medial thigh support.
- Feasible and manufacturable CAD model and drawings of final design.
- Detailed bill of materials with respective specifications.
- Finite element analysis (FEA) to ensure device does not fail during normal usage.

2.3 Scope

The finalize scope of the report will cover the design of the internal cushion reinforcement, arm, hinge mechanism, locking mechanism and the attachment piece. Outside of the scope is the pommel's cushion, which includes the shape and fabrication of the cushion. Reasoning for omitting the pommel cushion from the report is to allow freedom and customization for each patient. Each cushion will be created on a case-by-case basis to best suit the patient's physical needs. The cushion will be created using self-skinning foam and a customized mold. Therefore, the method of cushion development will need to be taken into consideration when designing the internal cushion reinforcement.

2.4 Constraints

Constraints of the project have been categorized into subsections: time, cost, resources and space. These constraints will influence the way this project will be managed and conducted. We have a strict timeline to complete the project by December 7th, 2017. The cost to manufacture the final design must be under $300, to be considered feasible by the R.C.C. This cost will include materials, labor hours, outsourced parts, machining and equipment costs. Design FEA analysis will be limited to SolidWorks and Ansys software. The design space for the pommel is limited by the frame geometry of the wheelchair. Constricting elements of the frame are the size and geometry of the wheelchair sit plate, the edge of the sit plate (straight or curved), distance between the wheels and space between the sit plate and foot support (*h*). and show a wheelchair with the sit cushion removed and a straight sit plate. This wheelchair has the smallest possible geometry that should be considered when designing.

Figure 2: Front design view

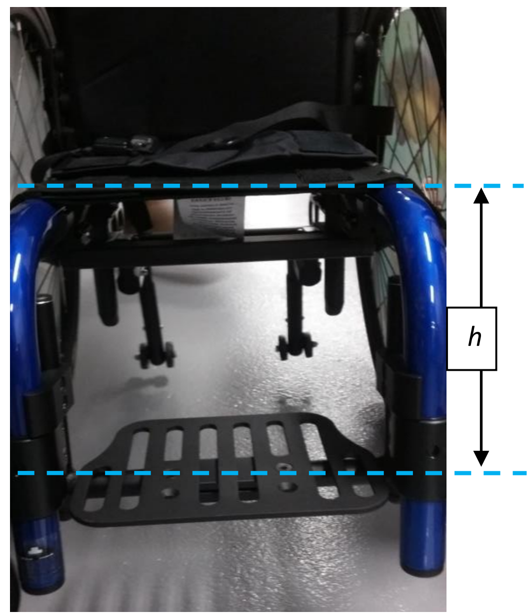


Figure 3: Front design view with height between sit and foot rest indicated

3. Methodology

Design process was initiated by determining the methodology/approach to generating different design concepts. Methodology to generating concepts includes individual brainstorming, group brainstorming, concept fusion and client feedback. Our team decided to perform individual brainstorming to allow everyone their pace to research and develop concepts. Individual brainstormed concepts were then discussed in team brainstorming session to enhance creativity and further concepts were developed. Following team meetings focused on design components, best components of various concepts were combined and fusion concepts were created. Lastly, concepts were discussed with client and according to their feedback further concepts were developed. Total of nine conceptual designs were finalized and further analyzed to select final design(s). Concept analysis and design selection is briefly discussed in Appendix section 8, concept analysis and selection.

4. Final Design

This section shows the final design of the swing away pommel. Features and mechanisms of the design will be discussed with the aid of CAD models for reference. The overall dimensions of each component can be found in the engineering drawings located in the Appendix: Section 7.

4.1 Swing Away Pommel

The swing away pommel design, seen in Figure 4, is composed of two major components, the pommel head and the swing away arm. There are three pommel head sizes, small, medium and large, where the dimensions of each were determined using commercial product average sizes and feedback from the client. These sizes can be seen in Figure #. While there are three different pommel heads, the swing away arm can accommodate all head sizes and remains constant. The swing away arm features an attachment plate for the pommel head, adjustable settings in the vertical and horizontal directions, locking mechanisms to stabilize pommel when engaged and disengaged and wheelchair mounting mechanism that is compatible with both straight and curved edge seat plate designs. The engaged and disengaged positions can be seen in Figure 5 and Figure 6.

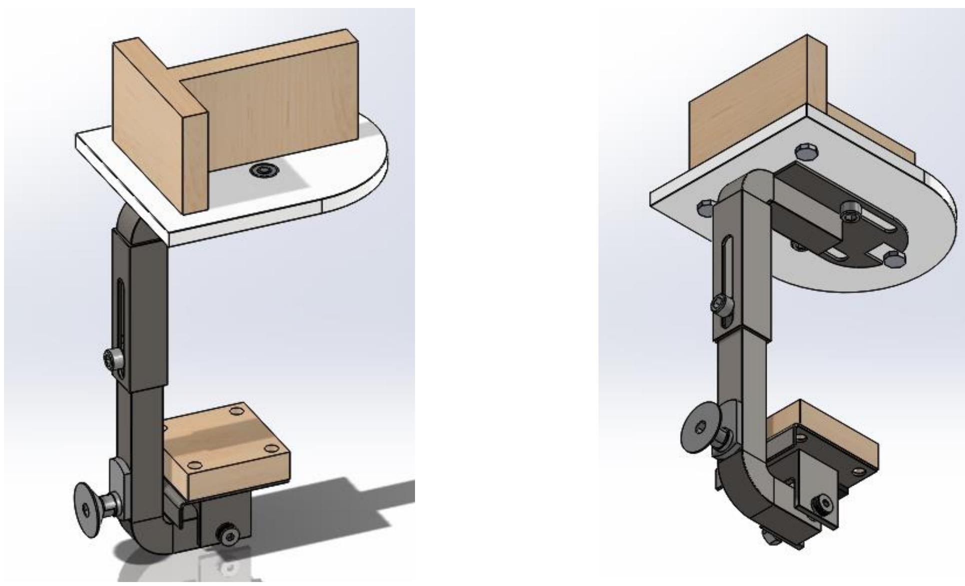


Figure 4: Final swing away pommel design

Figure 5: Engaged pommel position   Figure 6: Disengaged pommel position

4.1.1 Swing away arm

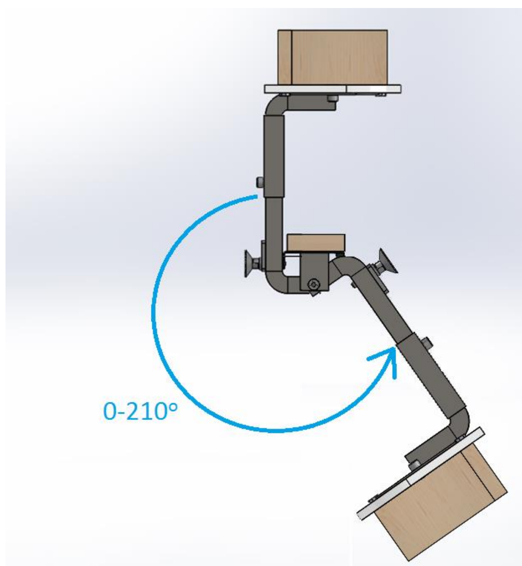


Figure 7: Maximum swing angle of the swing away pommel

As shown in Figure 7, the swing away system used by the arm allows a 210° swing to engage and disengage the pommel. The arm is engage by locking the spring loaded plunger onto the lower attachment plate as seen in Figure 8. The arm can be disengage by pulling the plunger and swing the arm 210° under the seat, the arm is then magnetically locked into place by magnets as the arm reaches 210° as shown in Figure 9.

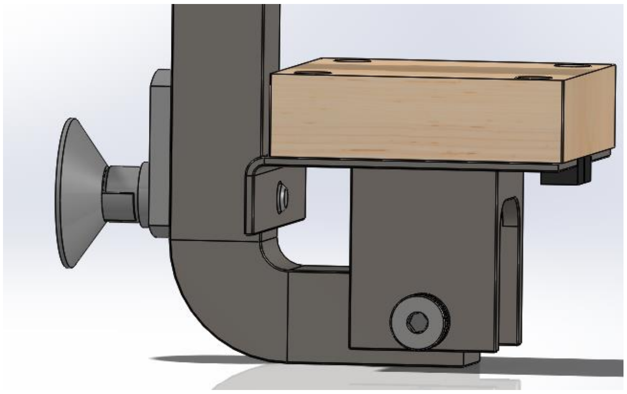


Figure 8: Swing away arm at the engaged state.

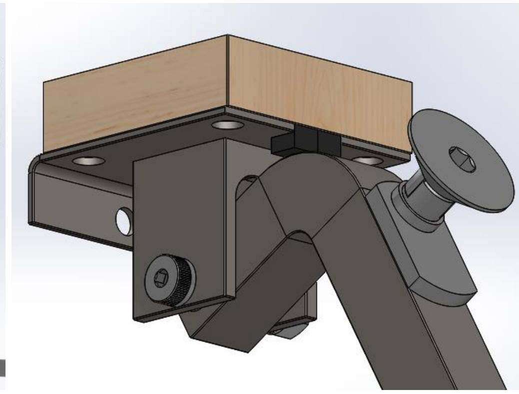


Figure 9: Swing away arm at the disengaged state.

4.1.2 Adjustability

The swing away pommel offers both vertical and horizontal adjustability. The horizontal adjustability is done by the fastener interaction between the upper plate and the bed plate. It allows one inch adjustability away from the wheelchair. Figure 10 shows interaction between the upper plate and the bed plate.

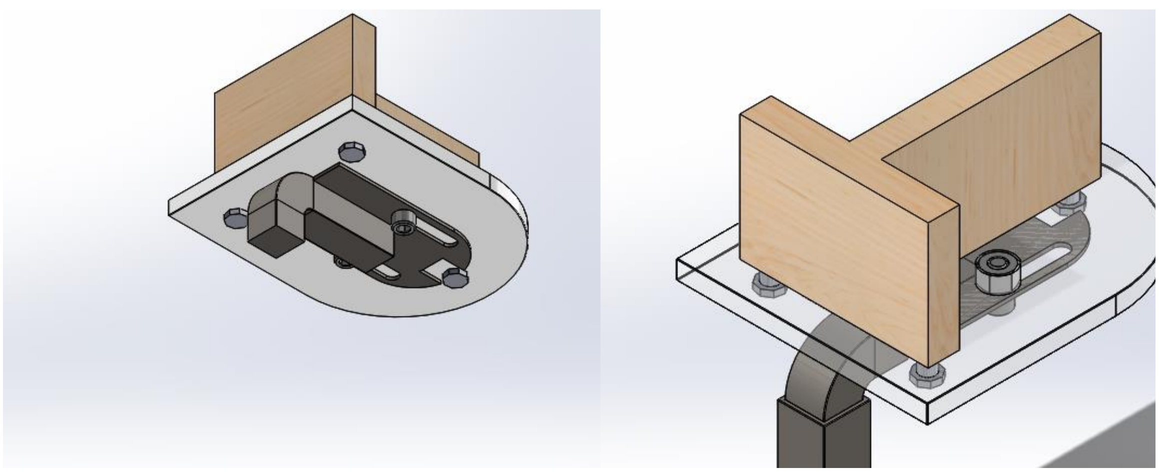


Figure 10: Horizontal adjustability.

The vertical adjustability is done by the fastener interaction between the upper hollow arm and the lower arm. It allows 2 inch adjustability away from the wheelchair, which allows the pommel to be compatible with a cushion height of 4.66 inch to 2.55 inch. Figure 11 and Figure 12 shows interaction between upper hollow arm and the lower arm.

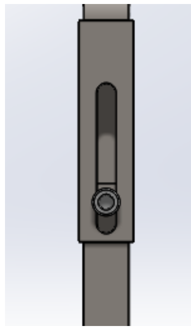


Figure 11: Iinteraction between upper hollow arm and the lower arm.

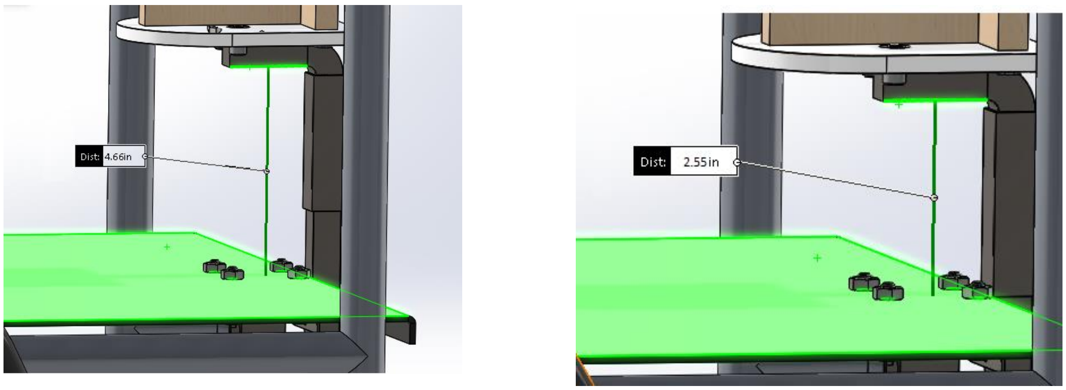


Figure 12: Vertical adjustability.

4.2 Pommel Head

In ordered to adapt to different client need, the pommel head is designed in three different sizes. The smallest pommel have an overall dimension of 2.5" by 3.75", it is suitable for clients between the ages of 0-5. The medium pommel have an overall dimension of 3" by 4", it is suitable for clients between the ages of 6-14. The large pommel have an overall dimension of 4" by 5", it is suitable for the clients between the ages of 15 to 21. Figure 13 shows all three sizes of the pommel head. The pommel head was designed to match the natural position of the thighs when seated and knees are slightly separated. The negative space between the inner thighs creates an inverted triangle with slightly rounded edges, therefore the shape of the pommel head mimic this shape.

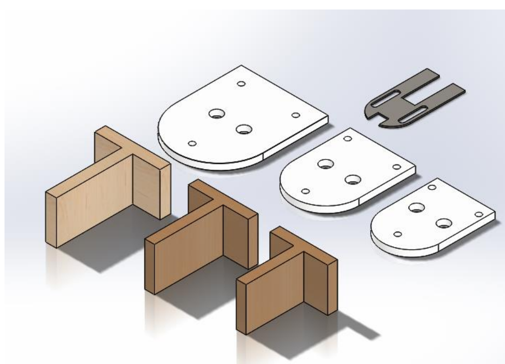
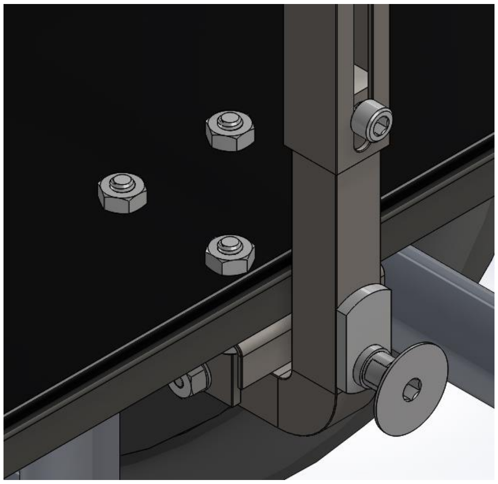


Figure 13: Different size of Pommel Head and Head plate

4.3 Mounting

As shown in Figure 14, the swing away system is mounted on to the wheel chair plate with four fasters and nuts. The fasters are connected through the pre-drilled holes on the wheelchair plate, the nuts on the upper surface holds the entire system in place. As shown in Figure 15, the lip clearance plate allows the spring loaded plunger to function properly with the lipped wheelchair plating design.



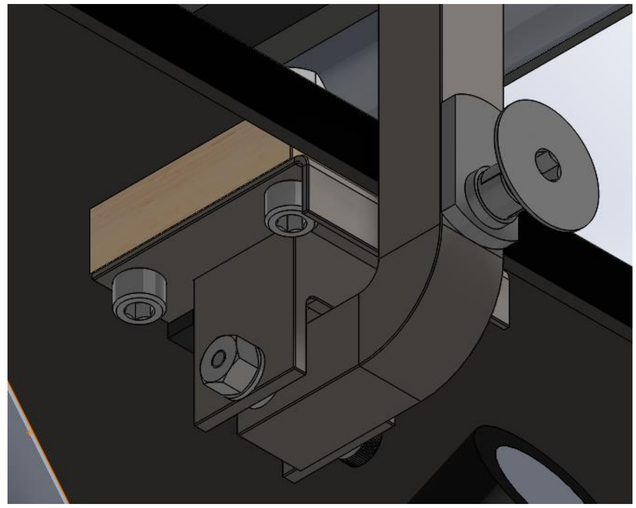


Figure 14: System mounting bolts and nuts

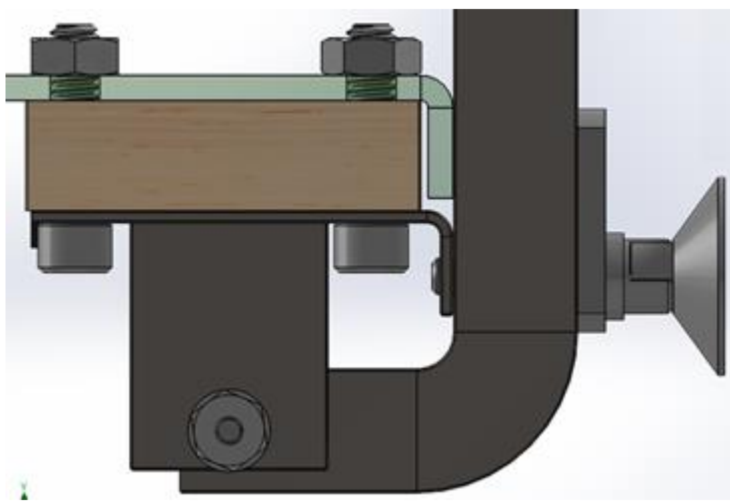


Figure 15: Pommel at engaged stated while mounted on a lipped wheelchair plate

5. Final Cost Analysis

5.1.1 Raw Material Cost

Our product cost was divided in to three main categories, raw material cost, machining cost and assembly cost. Raw material cost was derived from raw material dimensions required to make a necessary part. McMaster Carr website allowed for flexibility of raw material selection and instant quote for selected material. Hence, that was used to estimate raw material cost. Detailed list of materials required for part and corresponding cost is shown in TABLE I. A reference image is shown below, Figure 16. The part names shown in Figure 16, are referencing the engineering drawing location in the appendix in Section 7.

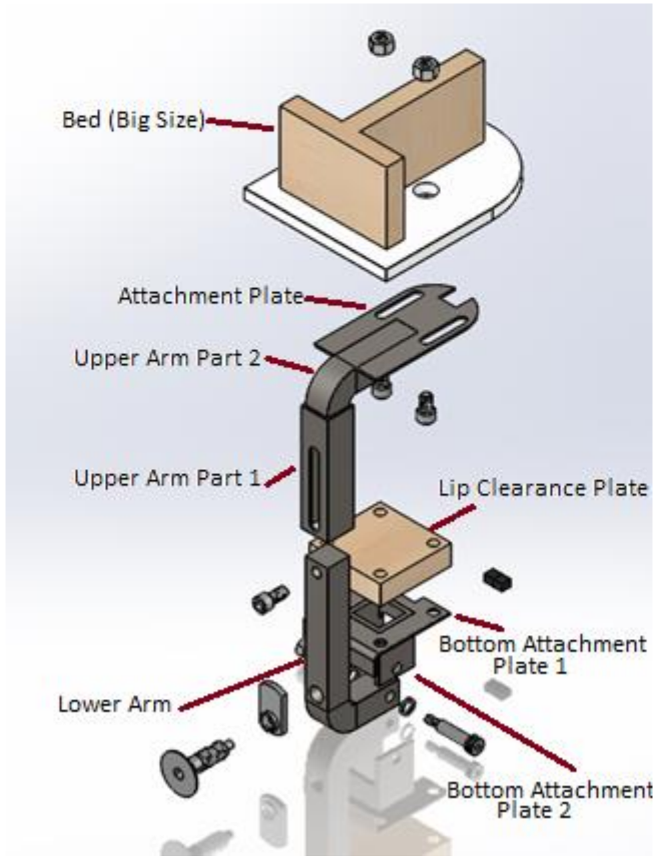


Figure 16: Componets Map

TABLE I: RAW MATERIAL COST

Part	Raw Material	Size [in]	Raw Material Cost
Bottom Attachment Plate Part 1	Standard Stainless-Steel Sheet	2.43 x 2.01, 0.06	$2.45
Bottom Attachment Plate Part 2	Stainless-steel Square bar	0.75 x 0.75, 1.30	$2.30
Lower Arm	Stainless-steel Square bar	0.625 x 0.625, 5.15	$7.06
Upper Arm Part 1	Stainless-steel Square Tube	0.75 x 0.75; 0.62 x 0.62, 3	$2.79
Upper Arm Part 2	Stainless-steel Square bar	0.625 x 0.625, 3	$2.92
Attachment Plate	Standard Stainless-Steel Sheet	1.75 x 3.375, 0.06	$2.96
Bed (Big Size) Part1	Plywood Sheet	4 x 5, 0.30	$4.09
Lip Clearance Plate	Standard Stainless-Steel Sheet	2 x 2, 0.62	$9.44
Total			**$35.71**

5.1.2 Manufacturing Cost

Manufacturing cost was derived by determining the types of machining required for each part and amount of time required to manufacture each part. *Anything Custom* and *Pritchard Machine* were approached for machining cost quotes. Based on the quotes received the approximate machining cost to machine all the parts were $200.00. Quotes received were based on the fact that 10 or more of each part would be ordered for machining. Detailed list of operations required for each part is summarized in TABLE II. It was assumed that machining quotes received from the market would be equivalent to cost of in house manufacturing including the cost of in-house manufacturing labour.

TABLE II: MANUFACTURING COST

Part	Machining	Source
Bottom Attachment Plate Part 1	Drill Press	In House
	Manual Mill	In House
	Metal Chop Saw	In House
	Sheet Bender	Out Source
Bottom Attachment Plate Part 2	Drill Press	In House
	Metal Chop Saw	In House
	Manual Mill	In House
Lower Arm	Tube Bender	Out Source
	Metal Chop Saw	In House
	Drill Press	In House
Upper Arm Part 1	Manual Mill	In House
	Metal Chop Saw	In House
Upper Arm Part 2	Tube Bender	Out Source
	Metal Chop Saw	In House
Attachment Plate	Manual Mill	In House
	Metal Chop Saw	In House
Bed (Big Size) Part1	Manual Mill	In House
	Band Saw	In House
	Drill Press	In House
Bed (Big Size) Part 2	Band Saw	In House
	Screwdriver	In House
Lip Clearance Plate	Metal Chop Saw	In House
	Drill Press	In House
Total Estimated Machining Cost		**$200.00**

5.1.3 Out Sourced Component Cost

The last category of cost, Assembly cost of final design was derived from the list of fasteners required to assemble the product. McMaster Carr was again used as a source to estimate the cost. Internal labour cost to assemble parts were determined by determining time required to assemble the pommel. Since, estimated time of assembly was one hour and internal labour was $25/hr; the assembly process was estimated to be 1hour, which yields the labour cost of $25.00. Detailed cost breakdown can be seen in TABLE III.

TABLE III: OUTSOURCED COMPONENT COSTS

Assembly Component Cost	Column1	Column2
PVC Nut	2	$0.45
PVC Screw	2	$0.39
Washer	2	$3.21
Magnet	1	$3.71
Shoulder Screw	1	$3.03
Hex Shoulder Cap	2	$0.24
Height Adjustment Screw	1	$0.11
Bottom Plate Mounting Screw	4	$0.65
Bottom Plate Mounting Nut	4	$0.92
Wood Screw for Bed	3	$0.54
Locking Mechanism	1	$14.95
Total Assembly Component Cost		**$28.20**
Total Assembly Labor Cost		**$25.00**

5.1.4 Total Cost

Our total cost to manufacture the product combining all three categories of cost came to $ 288.91, which was within a given budget of $ 300.

TABLE IV: TOTAL COST

Category	Cost
Raw Material Cost	$35.71
Manufacturing Cost	$200.00
Out sourced component cost	$28.20
Internal Labor Cost	$25.00
Total Cost	**$288.91**

6. Conclusions

Objectives for this project were to design a pommel support that satisfies the most critical customer needs and to deliver high quality and completed final deliverables on schedule. The final completed deliverables for this project are a functional and cost effective pommel design, a feasible and manufacturable CAD model with engineering drawings, a detailed bill of materials with cost analysis and a finite element analysis to ensuring structural integrity of the design.

The final design completed by Team 13, addressed all the critical problems expressed by R.R.C. The design is composed of a customizable cushioning reinforcement with three different sizes designed, an adjustable arm connecting the cushioning reinforcement to the hinge mechanism, which allows for 210 degrees of rotation, locking mechanisms for when the pommel is engaged and disengaged. The engagement lock is spring loaded plunger and the disengagement lock is a magnet that holds the pommel at 210 degrees, completely under the wheelchair. Finally the mounting component uses four fasteners and pre drilled holes in the wheelchair's sit plate to secure the pommel.

All critical problems seen with commercial pommels were solved and accounted for. The 210 degree rotation of the pommel allows for easy access to the wheelchair from any angle, because pommel can be moved and secured completely under the wheelchair seat. The pommel allows for adjustability in the vertical and horizontal direction because of adjustable slot and screw features located along the arm and under the cushioning reinforcement. This adjustability will allow for correct positioning of the pommel to align and support the patient's lower body. Space below the arm and mounting component allow the wheelchair to be mounted to but straight edge and curved lip wheelchair seat plates and is therefore compatible with multiple wheelchair designs. The easy pull handle to disengage the pommel, is recognizable, easy to use and intuitive to users. The durability of the pommel has been analyzed using Solidworks finite element analysis (FEA). The maximum predicted force of 300 lbs was applied to the head of the pommel, where the inner thighs of the patient would applied force to the pommel. The results from the FEA analysis show a deflection of 5 mm. Therefore, the durability of the pommel was considered to be acceptable. Finally, the final predicted cost analysis showed the manufacturing cost to be $288.91 per pommel.

This final design will allow R.C.C. the freedom to produce and customize medial thigh supports for patients that meets all critical design requirements, no matter their size or wheelchair type. With the consistent swing away arm design, this component can be manufactured in large quantities and the pommel head can be customized for the patient, shortening the lead time. This design will greatly improve the manufacturing process and eliminated time spent finding suitable commercial products.

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Table AVI: Loading Case Summary...A35
Table AVII: Raw Material Cost.. A**Error! Bookmark not defined.**
Table AVIII: Manufacturing Cost .... A**Error! Bookmark not defined.**
Table AIX: Out sourced component cost .... A**Error! Bookmark not defined.**
Table AX: Total Cost .... A**Error! Bookmark not defined.**

1. Patent Info

After extensive searching only a single patent related to a wheelchair medial thigh support was found. The patent application number is US06529517, it was filed on September 6, 1983, and publication date was October 21, 1986 and was granted October 21, 1986. The inventor was Robert B, Suhre of Theradyne Corporation. The claim was a leg support for a wheelchair, which included a V-shaped pad with a U-shaped rod supporting the pad as seen in Figure A2, with a coupler supporting the U-shaped rod relative to the chair in order adjust the distance of the V-shaped pad from the back of the chair. What is also claimed is the apparatus of an axle which permits rotation of the U-shaped rod seen in Figure A2 between a first position in which the V-shaped pad is in proper adjustment above the seat of the chair for supporting the individual, and a second position wherein the V-shaped pad is located beneath the chair seat; and releasable locking means for preventing rotation between the first and second position except when such rotation is desired.

Figure A1: V-shaped pad with U-shaped support rod [10]

Figure A2: Axle connected to U-shaped support rod under seat [10]

The background of the invention is that the fixture employs independently adjustable posture pads for applying supporting and counteracting forces to the body of a seated individual. The primary purpose of the thigh support is to maintain a desired separation between the thighs of a seated patient and to prevent the patient from slouching. Since this desired separation varies from patient to patient, the angular orientation of the two sides of the V-shaped thigh support are adjustable via right and left linkage arms 60 in Figure A1.

1.1 Conclusion

The devices we have generated as potential concepts do not infringe on this patent due to the fact that this patents legal status is expired – free related. Even if the patent was currently active, the mechanisms by which our designs swing away to make room from the patients are so different we would not be infringing on this design.

2. FDA Classification

2.1 Background

Since this is a relatively new field for medical device, we were not able to find Canadian standards for our medical device we chose to use the classification and standards given under the Food and Drug Administration (FDA), since American standards for medical devices are usually similar to, or ahead of Canadian standards. Under the FDA, medical devices our product would be classified as a wheelchair accessory due to the fact that a wheelchair accessory is defined as a device intended for medical purposes that is sold separately from a wheelchair and is intended to meet the specific needs of a patient who uses a wheelchair. Some wheelchair accessories include but are not limited to an arm board, lapboard, pusher cuff, crutch and cane holder, overhead suspension sling, head and trunk support, and blanket and leg rest strap. The device classification in this category is class 1, which is the lowest class, meaning there are very few form submissions and regulations to adhere to.

2.2 Regulations

If we wanted to register our device under the FDA regulations to take it to market we would only need to adhere to requirements concerning records section (820.180) and complaint files (820.198), and we would be exempt from a submission of a 510(k) and GMP regulation. A 510k requires demonstration of substantial equivalence to another legally U.S. marketed device.[11] Substantial equivalence meaning that the new device is at least as safe and effective as a currently used market device that is up to FDA regulations. A GMP or CGMP refers to the Current Good Manufacturing Practice regulations enforced by the US Food and Drug Administration. CGMPs provide for systems that assure for proper design, monitoring, and control of manufacturing processes and facilities. Section (820.198) of FDA regulations refers to the proper procedures for maintaining, receiving, reviewing and evaluation complaints. Section (820.180) of FDA regulations refers to the keeping of records maintained by the manufacturing establishment, by which all records kept by the inspected establishment must be made readily available for review and copying by FDA employees. The records of a particular product must also be kept for the duration that the particular design is being used by the public.

3. Conceptual Designs

After research of common pommel designs, conceptual designs were created individually by team members. Afterward, a concept sharing meeting was held to further brainstorm and develop concepts. Nine practical concept designs were developed. In this section, illustrations are shown and the advantages and disadvantages are discussed for each conceptual design.

3.1 Design #1 - Straps Attachment Design

Design #1, shown in Figure A3, consists of a pommel cushion attached to the sit plate and arm rests of the wheelchair via nylon straps with bolts. The nylon straps are adjustable in length, using slider buckles. The two horizontal straps have heavy duty plastic clips, to release the pommel cushion. When two clips are unbuckled, the pommel cushion can hang beneath the chair, shown in Figure A4.

An advantage of this design was that it was very cheap and easy to manufacture due to simple construction and material choice. Disadvantages include: over restriction of the patient's thighs, clips may be too accessible to the patient who may unclip accidentally, and confusion with other wheelchair straps. The problem with using straps in the design, was many patients already may have a harness with straps for upper body alignment and a pommel with additional straps was not an attractive option.

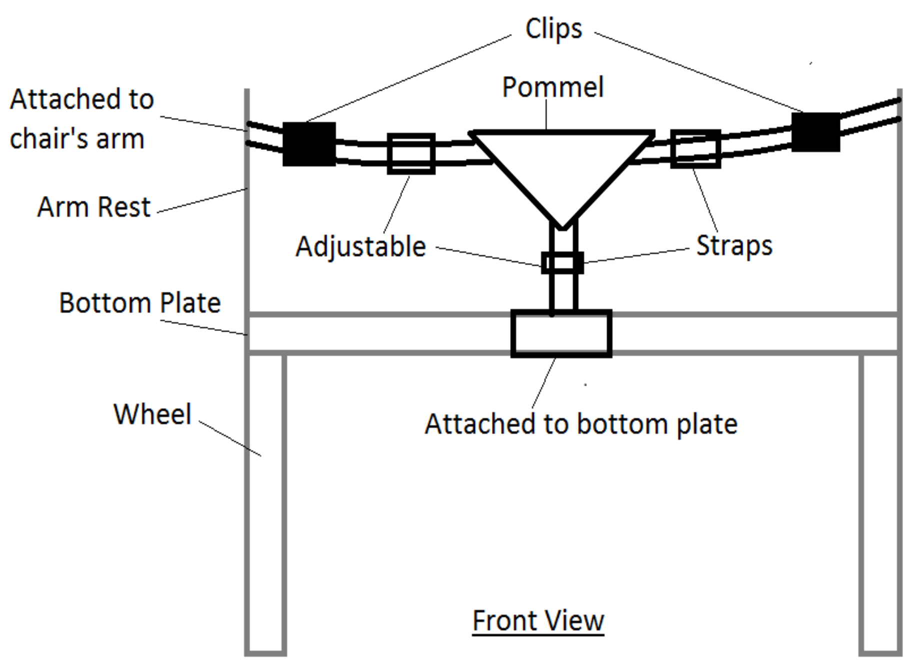

Figure A3: Straps design front view

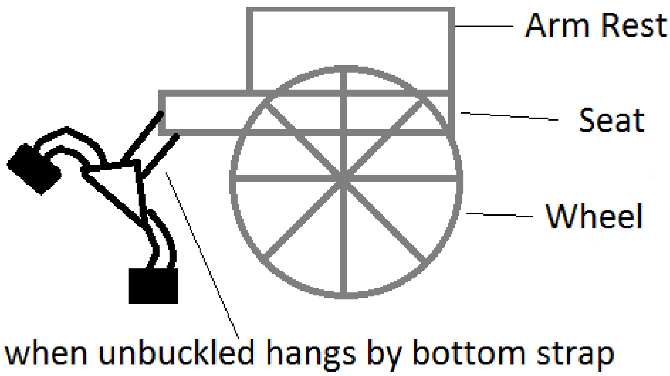

Figure A4: Straps design side view

3.2 Design #2 - Push Back Design

Design #2 uses a rectangular slider rail bolted underneath the sit plate of the wheelchair, seen in Figure A7. The pommel shaft is then attached to the slider rail with a hinge connected to a compression lock release lever or a tightening hinge/screw knob on a bolt, seen in Figure A5. When the screw knob is untightened or the release lever unlocked, there will be no more friction between the rail flanges and locking device, allowing the pommel and shaft to swing at the hinge. The pommel shaft can then be pushed between the open spaced between the two sides of the rail, seen in Figure A6, creating space for movement in and out of the chair.

Advantages that come with this type of design, were that it was easy to manufacture, easy to operate and the bulk of the device was hidden beneath the chair when stowed away. The only disadvantage to this design was the strength of the locking mechanism, which may need to be changed if the device was used as the final design.

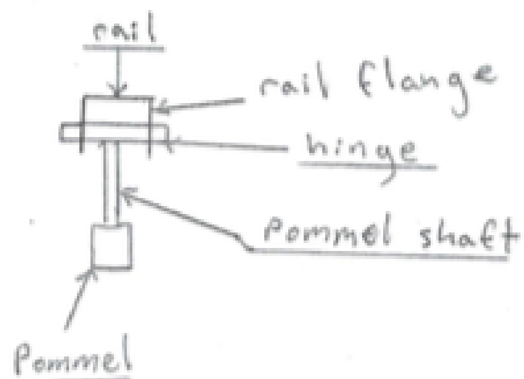

Figure A6: Sliding rail design front view of pommel and rail

Figure A5: Compression lock release lever [8]

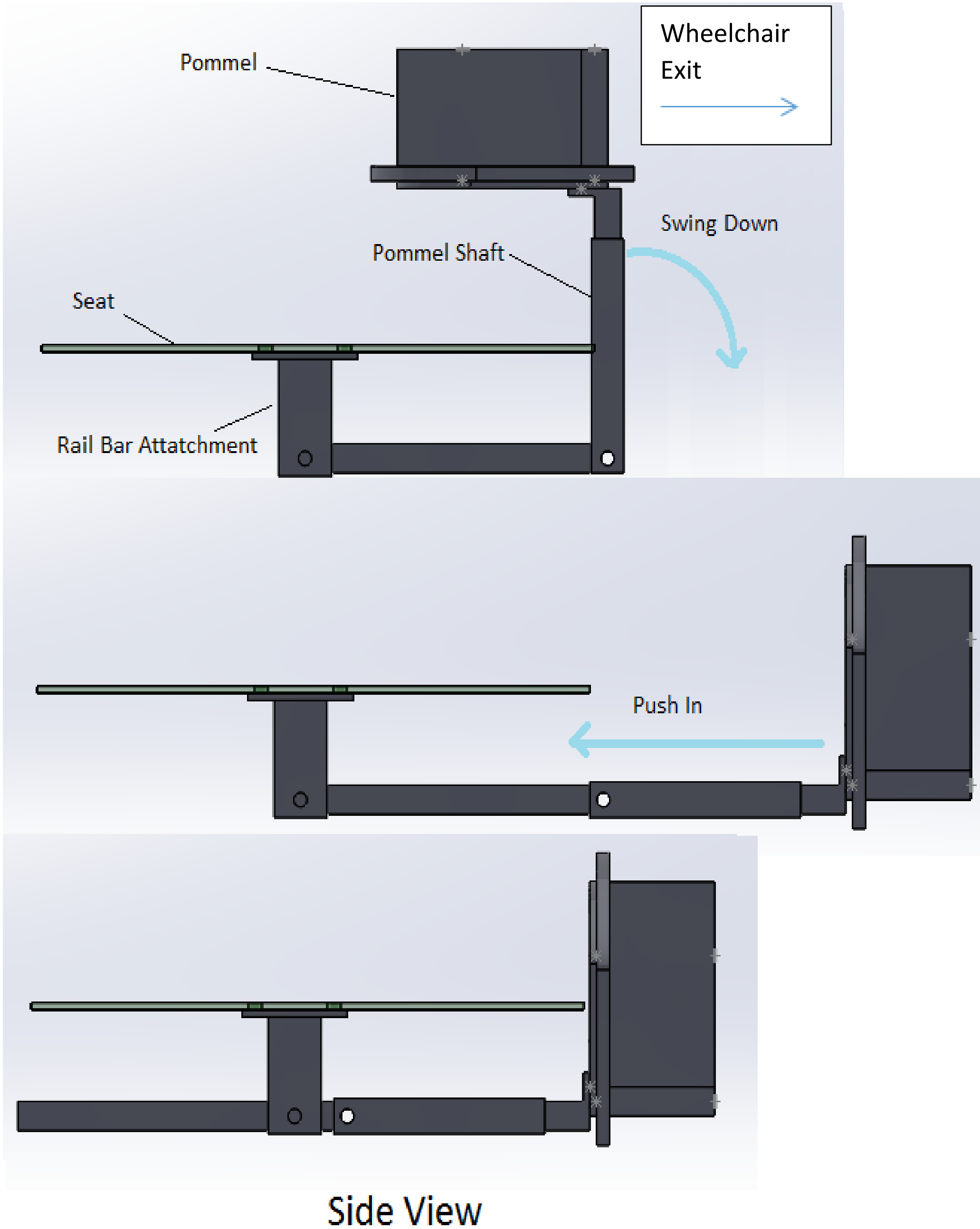

Figure A7: Sliding rail design side view

3.3 Design #3 - Sideway Arm Design

In Design #3, the pommel is attached to an arm which is then attached to the side of the chair, shown in Figure A8. The arm extends out from the side of the chair and turns at a right angle toward the center of the chair. The arm then makes another right angle extending again towards the center of the chair with the pommel attached. The arm is made up of 3 steel tubes. The first tube, which is attached to the chair, is the largest in diameter and extends half way between the first right angle and the side of the chair. This halfway point where the first and second smaller tube connects has a swivel attachment quick release clamp as seen on bicycle seat posts, which can be seen in Figure A9. When this clamp is released it will allow for the arm to swing 270 degrees to the side of the wheelchair as seen in Figure A10 or extend the arms attached to the pommel cushion forward and backward towards the patient. The second part of the arm, which has the elbow joint, has a quick release clamp, or locking push pin which allows for the tube attached to the pommel cushion to slide between the patient's legs.

Advantages of this design were its adjustability, being able to move side to side, as well as being able to swing completely out of the way of the patient. The biggest disadvantages were that it was large, bulky and was very aesthetically unpleasing. Its bulky nature may get in the way of narrow doorways and bump into objects.

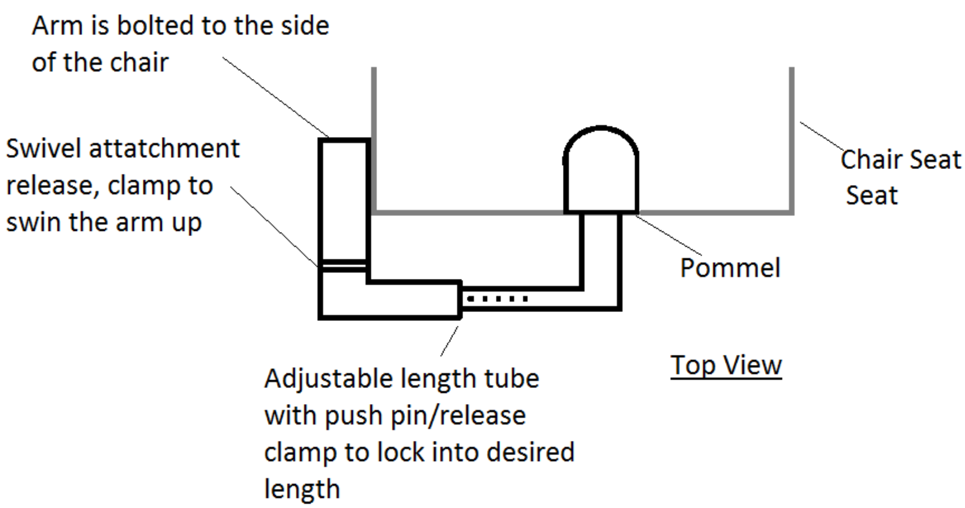

Figure A8: Swing side arm design top view

Figure A9: Quick release clamp [9]

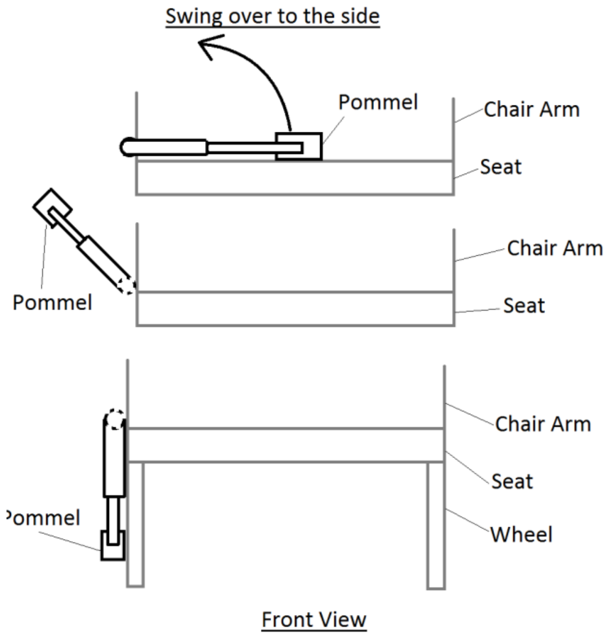

Figure A10: Swinging side arm design front view

3.4 Design #4 - Push Down Design

Design #4 is made up 2 steel tubes and a metal piece, which is attached to the bottom chair plate with bolts and is extending downward towards the ground as seen in Figure A11 and Figure A13. The first tube is the smallest in diameter and is attached to the pommel head. The first tube extends through the larger second tube, which is attached to the bar under the seat by a 90-degree angle. At the point where tube one and tube two meet is a quick release clamp as seen on bicycle seats seen in Figure A9, that when unclamped allows the pommel to swivel away from the patient and allows the first tube to slide up and down through the second tube lowering the pommel below seat level. The bar attached to the second tube with the 90-degree bend has small circular holes cut into it and is inserted through the metal piece attached to the bottom of the chair plate. The spot where the bar attached to the second tube meets the metal piece will have a push/ pull latch pin spring as seen in

Figure A12, which allows for the pommel to slide and lock under the chair out of the way of the patient.

The main advantage to this design was that it would be very cheap and easy to manufacture. It would also be easy to replace or fix broken parts without having to replace the entire device. The disadvantage was that it was not the most aesthetic and took multiple steps in order to get the pommel under the chair as opposed to a design where the pommel swings under in a single motion.

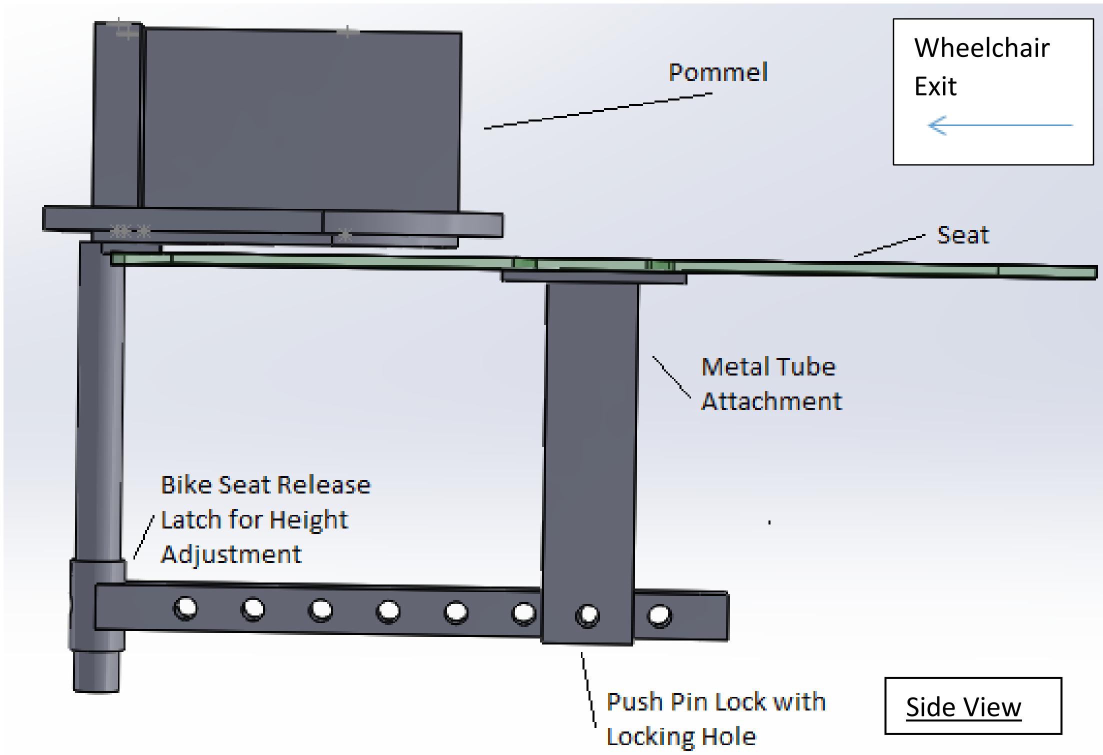

Figure A11: Push down design side view

Figure A12: Push/pull latch spring pin

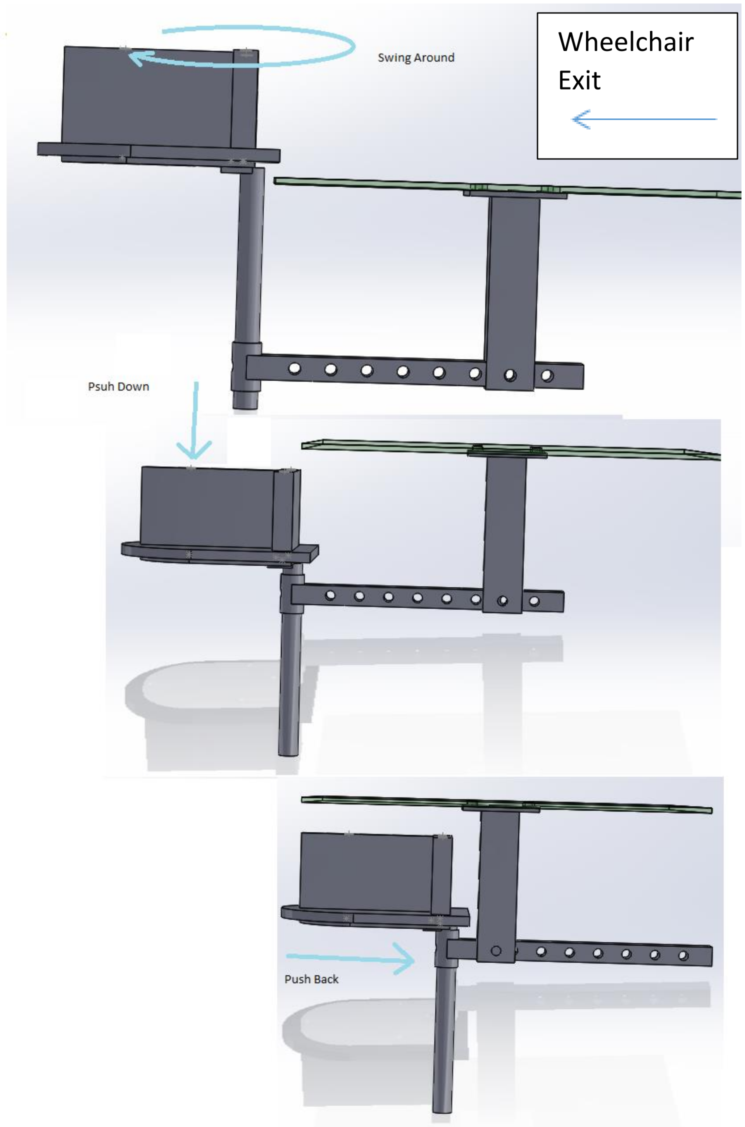

Figure A13: Push down design side views

3.5 Design #5 - Locking Disk Design

Design #5 operates by having a metal piece with a 90-degree angle attached to the bottom plate of the chair by bolts or screws. For up and down adjustment of the pommel, the pommel shaft is made up of 2 steel tubes, with the tube attached to the pommel being smaller in diameter seen in Figure A14. Where the two tubes connect is a quick release clamp as seen in Figure A9. When the clamp is released the pommel may be adjusted up and down. The piece with the 90-degree angle protrudes to the front of the seat and is then attached to a wheel by an axle, which passes through it by a hole. In the front of the metal piece attached to the wheel is a spring latch pin, seen in Figure A15, which locks into the hole that passes its position. The wheel is a thick disk with small holes spaced at equal distances from each other in a circular pattern around the center axle. The wheel is attached to the pommel on the left side. When the latch pin is out of the locked position, the pommel is free to rotate on the wheel till it reaches a position under the seat that grants the patient easy movement in and out of the chair.

A positive aspect of this design was its locking mechanism, which allows the pommel to be locked completely underneath the chair, as well as at various other positions. The other advantage of this design was that its different parts were easily bought or made for a low price. A disadvantage to this type of design was that it may not completely be hidden from view when under the chair.

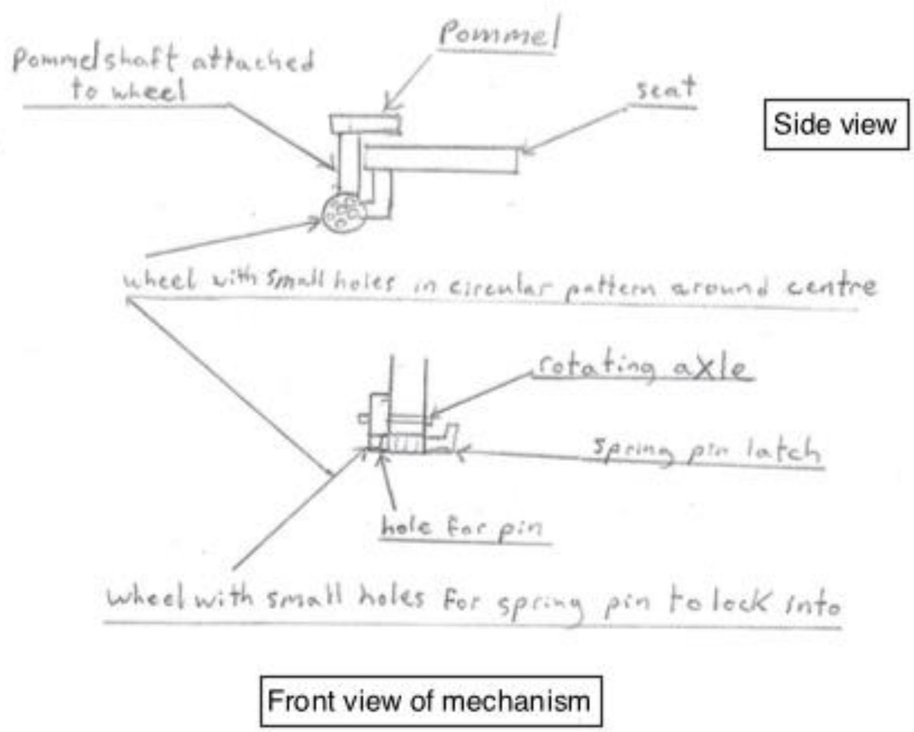

Figure A14: Wheel design with spring latch pin

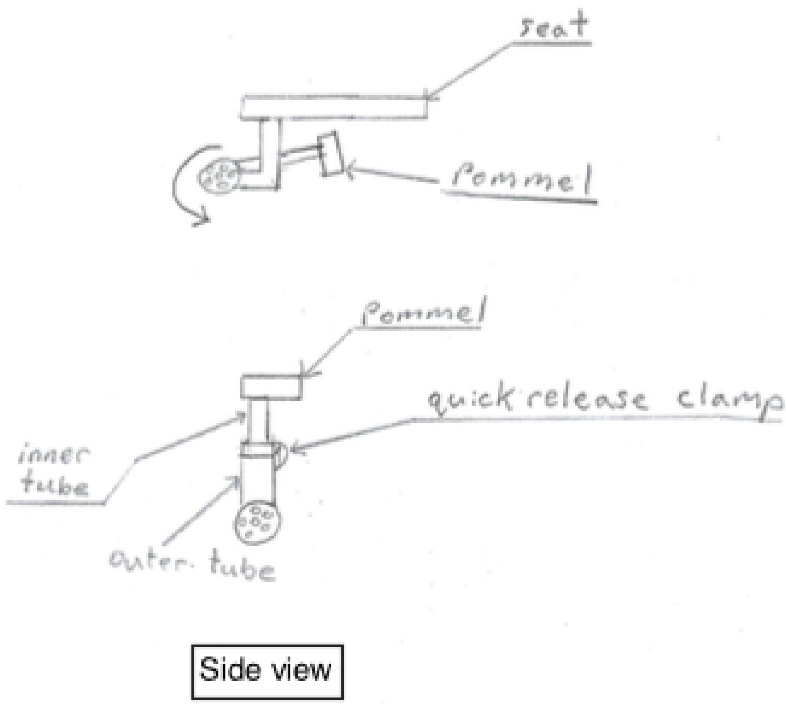

Figure A15: Wheel design with quick release clamp on pommel shaft

3.6 Design #6 - Four Bar Linkage Design

In Design #6, the design consists of 4 bars linked together with swivel, as shown in Figure A16, Figure A17 and Figure A18. The four-bar linkage design allows the pommel to perform a 180^o swing to engage and disengage the pommel. The main bar consists of multiple mechanisms, such as the locking mechanism to engage the pommel and an extending mechanism to allow vertical adjustment of the pommel to account of different cushion height.

One of the advantage of the design was the majority of the part can be mass produced by CNC machine. However, a potential risk in this design was the required precision when installing the system onto the wheelchair, if the system is not aligned correctly the swing away motion would be skewed.

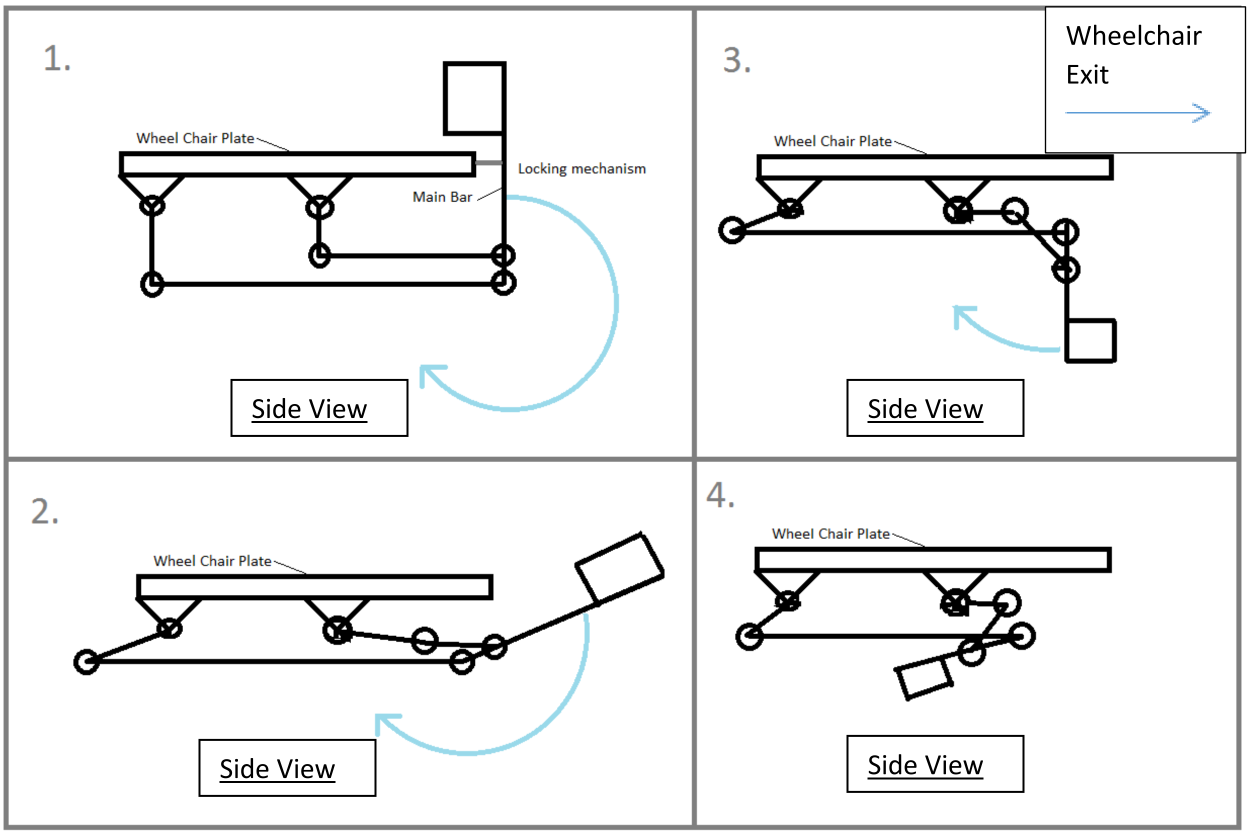

Figure A16: Four bar linkage motion

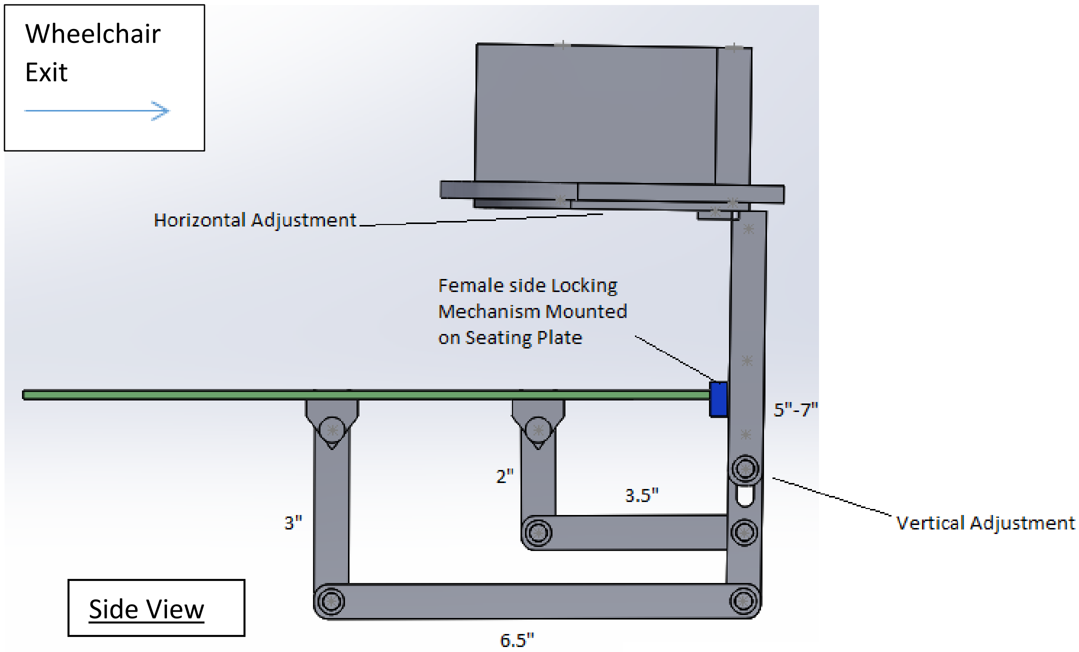

Figure A17: Initial geometry and dimension

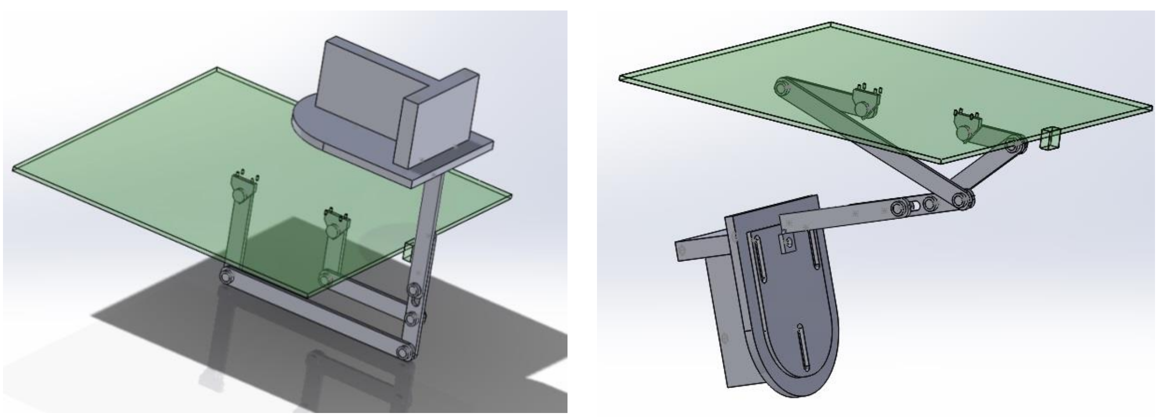

Figure A18: Four bars linkage system

3.7 Design #7 - Restructuring R.C.C. Prototype Design

Design #7 is focused on improving the overall performance of the existing R.C.C. prototype as shown in Figure A19, which allows the modified prototype to meet the client's specification.

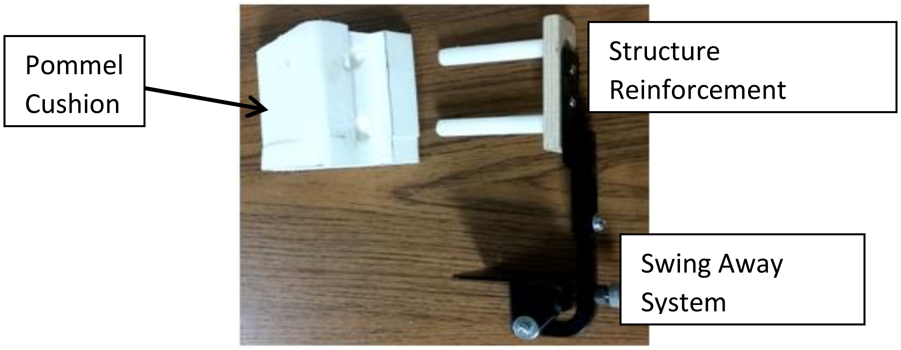

Figure A19: R.C.C. prototype

As shown in Figure A20 and Figure A21, the three major modifications to the design were redesigning the pommel reinforcement structure (bed), separating the design into a more modular version and parts re-dimension.

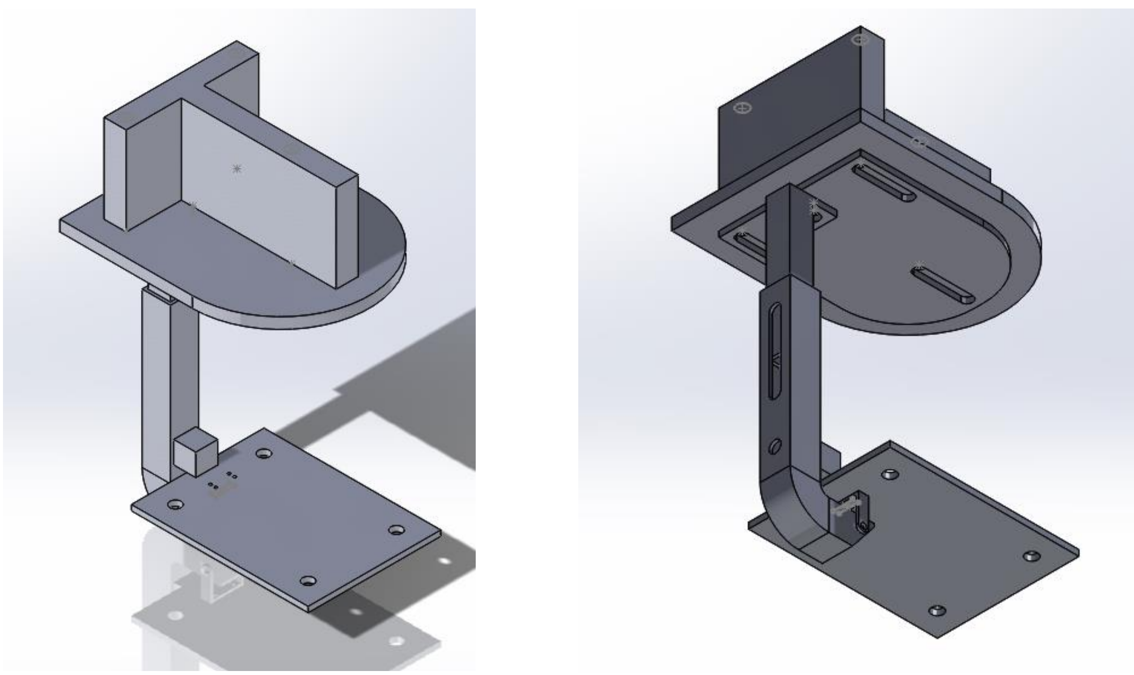

Figure A20: Restructuring R.C.C. prototype

3.7.1 Bed

The redesigned pommel reinforcement structure is separated into an upper attachment plate section and the structure reinforcement section (bed), the combination of the bed and the attachment plate allowed a new forward and backward adjustment of the pommel. In addition, the redesigned bed was structured horizontally, it allowed the bed to provide support to the pommel cushion more evenly, which allowed an even stress distribution to reduce the chance of the cushion detaching from the bed.

3.7.2 Modular Design

The old design was divided into 3 main component see Figure A19, in order to allow easy maintenance and part replacement, the new design selected a modular approach. As seen in Figure A 31, the new design was separated into 7 different components. This is specifically important for users between the ages of 3-14, because the size of the pommel' s cushion will have to increase as the user grows and the modular design allowed the client to upgrade their pommel cushion without replacing the entire pommel. In addition, due to the lifetime difference in between the pommel cushion and the support system, a modular design allowed the user to simply swap out the easily worn out component such as the pommel cushion (bed) and the lower support arm instead of replacing the entire system.

3.7.3 Parts Re-dimensions

The parts re-dimension allowed the design to meet the client's specification. This included a longer arm that allowed a clearance for seat cushion between the heights of two inches to four inches, a thicker bottom attachment plate that accounted for a lip clearance of 11 to 13 mm, and a 180^{o} swing away bracket that allowed the pommel to be fully hidden under the wheelchair when it is not active.

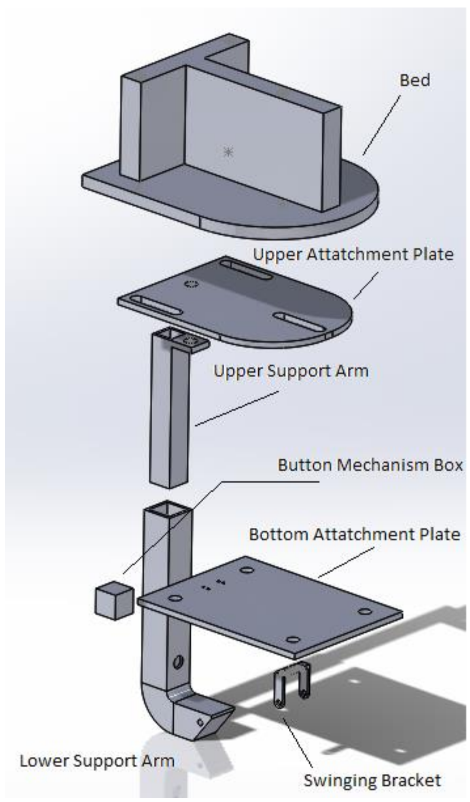

Figure A21: Restructuring R.C.C. prototype components

3.8 Design #8 - Snap-Fit Design

Design #8 consists of two square L shaped members attached under a wheelchair seat, a circular shaft connecting two L shaped members and a square bar (Arm) with pommel cushion support as shown in Figure A22. The slot profile in End 1 of L shaped members allows shaft to move up and down allowing for adjustability. Similarly, the slot profile in pommel cushion support allows for a forward and backward adjustability. The bearing joint to circular shaft allows an Arm to swing 180 degrees, which will enable a smooth transfer. The holder bracket will have a magnetic feature to hold the arm in place when it's in the use and upon a pull force it will release the arm.

The advantage of the design was the ability to reduce the need of a complicated locking mechanism.

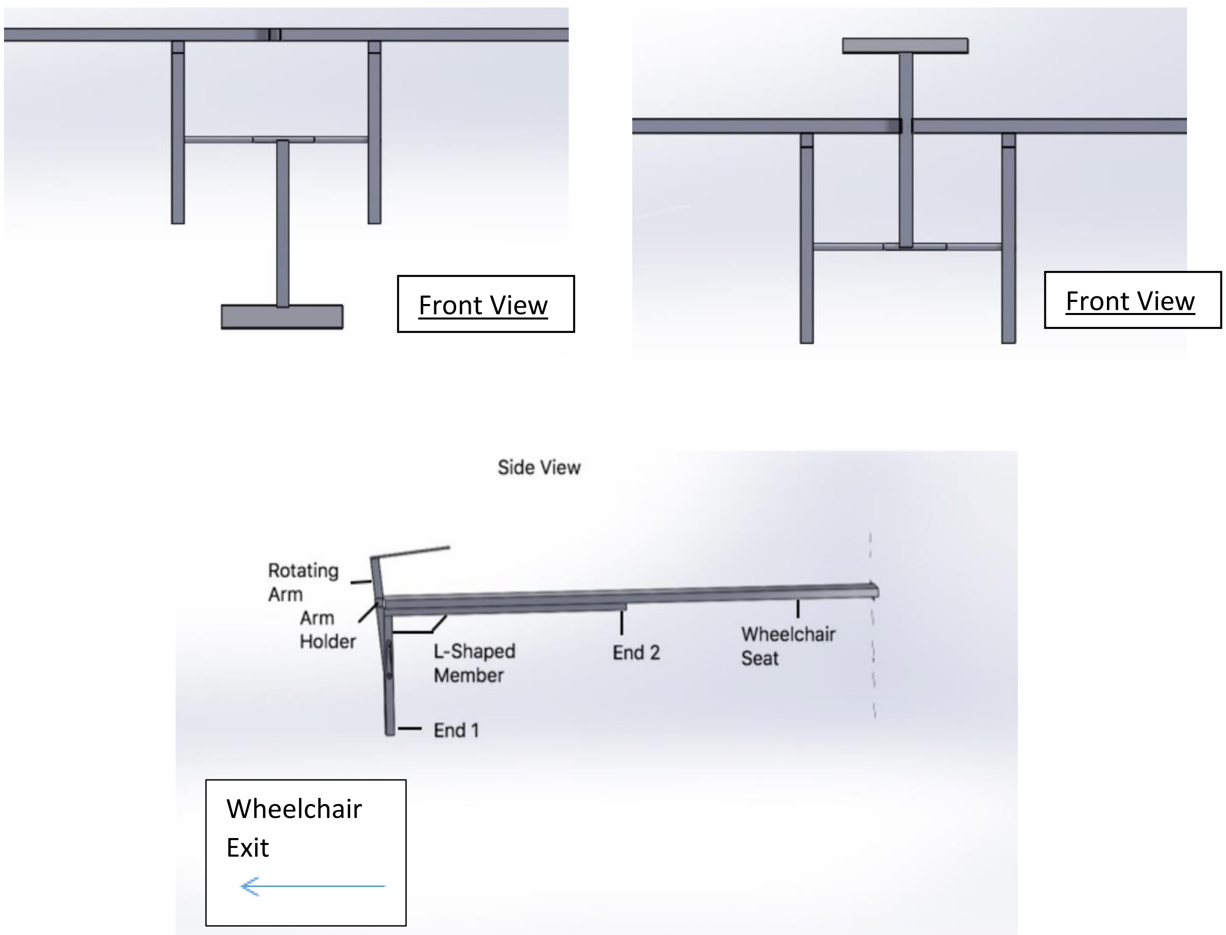

Figure A22: Snap fit design

3.9 Design #9 - Tube in to Tube Design

Design #9, shown in Figure A23, consists of a square L tube welded to the plate (Part 1) that is attached under the wheelchair seat, 2 square tubes with holes profile welded together with a pin release mechanism (Part 2), and a square tube with holes profile welded to pommel cushion support plate (Part 3). The end 1 of part 1 can slide into end 1 of part 2 to allow for a forward and backward adjustability with aligning to holes and locking with pin. Similarly, end 1 of part 3 can slide into end 2 of part 2 to allow for an up and down adjustability. Pin release mechanism will allow an assembly joint at end 2 of part 2 to swing 180 degrees.

The advantage of the design was the ability to reduce the need of a complicated locking mechanism and the high amount of adjustability it provided.

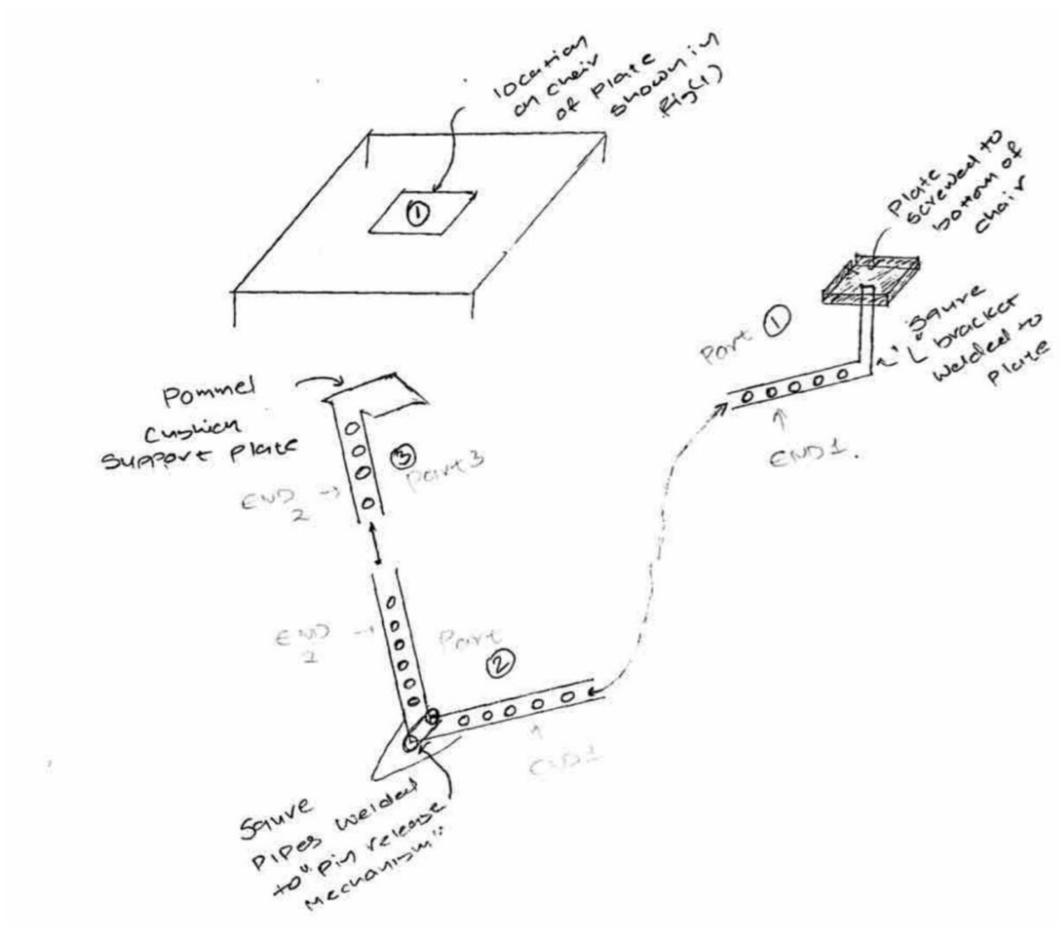

Figure A23: Tube-in-to-Tube Design

3.10 Conceptual Design Summary

Team 13 came up with nine designs as potential solutions to the problem. These nine designs were summarized in the table below. These nine designs were further analyzed by concept screening and concept scoring and best design(s) were selected.

Materials listed in the conceptual designs were subject to change and refined moving forward to the final steps of the project.

4. Concept Analysis and Selection

Now that nine conceptual designs have been developed, this section shows the selection process. First, all nine designs will be compared against the reference, Design #7, in a screening matrix. This will narrow down the three best designs. Secondly, the top three designs will be evaluated based on weighted criteria. This will determine the two designs we will be moving forward with in phase three.

4.1 Selection Criteria

In order to properly evaluate the generated concepts, proper design criterion was established. Criterion was developed using the technical specifications. General criteria, shown in Section 4.1.1, takes into account the design concept as a whole. Component specific criterion was generated and is shown in Section 4.1.2. This breaks down the basic design into modular components, which allows for more in-depth analysis.

4.1.1 General Criteria

- Safety – the design must operate without compromising user safety (i.e. exposing sharp corner, exposing pinch point, etc.).
- Cost – the cost of the material selection and the manufacture process should be reasonable.
- Aesthetics – the design should have a professional appearance.
- Manufacturability – the design should be manufacturable with in-house equipment given if in-house manufacture is more cost efficient.
- Client satisfaction – The client should be satisfied with the design.
- Durability – The design has to last two years.
- Strength/Rigidity – the design should not fail under the spastic load from the user.
- Interchangeable/replaceable – the component should be interchangeable to allow component upgrade or repair.

4.1.2 Component Specific Criteria

4.1.2.1 Hinge/Locking Mechanism

- Degree of rotation – the hinge should be able to perform a swing beyond 180°.
- Intuitive user interaction – the design should be intuitive to use.
- Position (in use) – A locking mechanism should be engaged while the pommel is in use.
- Position (out of use) – A locking mechanism should be engaged while the pommel is out of use.

4.1.2.2 Cushion Reinforcement & Bracket Attachment

- Compatibility with self-skinning foam (pommel cushion material) – the design geometry and selected material should be compatible with foam forming technique.
- Backward and forward adjustment – the design should allow a backward and forward adjustment of 0 to 3”

4.1.2.3 Attachment to Chair

- Position/mount location – the mounting location should be under the seating plate of the wheelchair.
- Lip clearance – the design should be able to operate properly without the interference of the 11-13mm lip on the edge of the seating plate.
- Easy installation – the design should be easy to install and allow in house installation.

4.1.2.4 Arm

- Vertical adjustability – the design should have a vertical adjustment to allow a seating cushion height of two to four inches.
- Intuitive user interaction - the design should be intuitive to use.

4.2 Concept Screening Matrix

To start the selection process, a concept screening was used. Designs (referred to in Table AI) were compared to the reference design (REF), which was selected to be Design #7 because it is the most similar to the initial prototype developed by R.C.C. For each criteria point, one of the following three score was given:

+ : Better than REF
- : Worst than REF
0 : Equivalent to REF

Final scores were totaled, in Table AII, and designs with negative scores were eliminated and designs with positive or scores of zero moved onto further analysis.

To determine the design concepts to move forward to the scoring stage, a concept screening matrix was developed under the selection criteria listed in section 4.1. The performances of the concepts were compared with a reference design, concepts with negative scores were eliminated, and the concepts with positive score and zeros were selected to perform further concept selection analysis. Design 7 was selected to be the reference design due to the similarity with the current R.C.C. prototype. The team developed matrix is shown in Table AII.

Table AI: LIST OF DESIGN

Design #	Design Name	Reference
Design 1	Straps Attachment Design	Section 7.1
Design 2	Push Back Design	Section 7.2
Design 3	Sideway Arm Design	Section 7.3
Design 4	Push Down Design	Section 7.4
Design 5	Locking Disc Design	Section 7.5
Design 6	Four Bar Linkage Design	Section 7.6
Design 7	Restructuring RCC Prototype Design	Section 7.7
Design 8	Tube into Tube Design	Section 7.8
Design 9	Snap Fit Design	Section 7.9

Table AII: CONCEPT DESIGN SCREENING MATRIX

	Concept Designs								
Selection criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7 (REF)**	**8**	**9**
Safety	+	0	0	0	0	0	0	0	0
Cost	+	0	0	0	0	0	0	0	0
Aesthetics	-	+	-	+	0	0	0	0	0
Manufacturability	+	+	0	+	+	+	0	+	+
Client Satisfaction	-	+	-	-	0	0	0	-	-
Durability	-	0	0	0	0	0	0	0	0
Strength/Rigidity	-	0	0	0	0	0	0	0	0
Interchangeable Parts	0	0	0	0	0	0	0	0	0
Hinge/ Locking Mechanism									
Degree of rotation	0	0	0	0	0	-	0	0	0
Intuitive User Interaction	+	-	0	-	-	0	0	0	-
Positioning (In Use)	0	0	0	0	0	0	0	0	0
Positioning (out of Use)	-	0	-	0	0	-	0	0	0
Cushioning Reinforcement & Bracket Attachment									
Compatible with self-skinning foam	0	0	0	0	0	0	0	0	0
Backward and forward adjustability	+	0	0	0	0	0	0	0	0
Attachment to chair									
Positioning/ Mount Location	0	0	0	0	0	0	0	0	0
Lip Clearance	0	0	0	0	0	0	0	0	0
Easy Installation	0	0	-	0	0	-	0	0	0
Arm									
Vertical Adjustability	0	0	0	0	0	0	0	0	0
Intuitive User interaction	+	-	0	-	-	0	0	0	-
PLUSES	5	3	0	2	1	1	0	1	1
SAMES	8	14	15	14	16	15	19	17	15
MINUSES	6	2	4	3	2	3	0	1	3
NET	-1	1	-4	-1	-1	-2	0	0	-2
RANK	3	1	5	3	3	4	2	2	4
CONTINUE?	No	Yes	No	No	NO	No	Yes	Yes	No

The three concepts that will move on are the Push Back Design, Restructuring R.C.C. Prototype Design and Tube into Tube Design.

4.3 Selection Criteria Weighting

Before scoring the selected concepts, the selection criteria were weighted. In order to determine the weight of each of the criteria, the team assigned a rating value based on the importance of the criteria. Each criterion was assigned a value ranging from one to five for each concept, one being the lowest and five being the highest rating. The weight of each criterion is then ranked and calculated based on comparing with other criterion. Table AIII shows the weight of each criterion.

Table AIII: CRITERIA WEIGHTING

Selection Criteria	Score	Weight (%)
Safety	5	5.95
Cost	5	5.95
Aesthetics	4	4.77
Manufacturability	4	4.77
Client Satisfaction	5	5.95
Durability	3	3.57
Strength/Rigidity	4	4.77
Interchangeable/replaceable	5	5.95
Hinge/ Locking Mechanism		
Degree of rotation	5	5.95
Intuitive User Interaction	5	5.95
Positioning (In Use)	5	5.95
Positioning (out of Use)	4	4.77
Cushioning Reinforcement & Bracket Attachment		
Compatible with self-skinning foam	5	5.95
Backward and forward adjustability	5	5.95
Attachment to chair		
Positioning/ Mount Location	3	3.57
Lip Clearance	5	5.95
Easy Installation	2	2.38
Arm		
Vertical Adjustability	5	5.95
Intuitive User interaction	5	5.95
Total	84	100

4.4 Concept Scoring

The next step of the concept selection is to evaluate the three concepts with the weighted criteria. For each design, criterion was given a score ranging from one to five, one being the lowest and five being the highest rating. The scores were multiplied by their weights and summed together for a design score. The each team member rated the concepts individually and finally scores were averaged to obtain the final design score. Table AIV shows the average scoring for the top three concepts.

Table AIV: CONCEPT SCORING MATRIX

		Concepts					
		Design 2		Design 7		Design 8	
Selection criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Safety	5.95	5	5.95	5	5.95	3	3.57
Cost	5.95	4	4.76	3	3.57	3	3.57
Aesthetics	4.77	5	4.77	4	3.82	4	3.82
Manufacturability	4.77	5	4.77	4	8.82	4	3.82
Client Satisfaction	5.95	5	5.95	5	5.95	2	2.38
Durability	3.57	5	3.57	5	3.57	5	3.57
Strength/Rigidity	4.77	5	4.77	5	4.77	3	2.86
Interchangeable/Replaceable parts	5.95	5	5.95	5	5.95	5	5.95
Hinge/ Locking Mechanism							
Degree of rotation	5.95	5	5.95	5	5.95	5	5.95
Intuitive user interaction	5.95	3	3.57	5	5.95	3	3.57
Position (in use)	5.95	5	5.95	5	5.95	5	5.95
Position (out of use)	4.77	5	4.77	3	2.862	3	2.86
Cushioning Reinforcement & Bracket Attachment							
Compatible with self-skinning foam	5.95	5	5.95	5	5.95	5	5.95
Back & Forth adjustability	5.95	5	5.95	4	4.76	4	4.76
Attachment to chair							
Positioning/ Mount Location	3.57	5	3.57	5	3.57	4	2.85
Lip Clearance	5.95	5	5.95	5	5.95	5	5.95
Installation Ease	2.38	5	2.38	5	2.38	5	2.38
Arm							
Increment Adjustability	5.95	4	4.76	4	4.76	5	5.95
Intuitive User interaction	5.95	3	3.57	5	5.95	3	3.57
Total Score		92.86		91.43		79.28	
Rank		1		2		3	
Continue?		Yes		Yes		No	

After conducting the concept scoring for the three selected concepts, the Push Back Design achieved the highest score of 92.86 with the Restructuring R.C.C. Design achieved the second highest score of 91.43, and the Tube into Tube Design achieved a score of 79.28. Since the different between the second and third scoring designs is more than 10% apart, a scoring sensitivity section is not needed to justify the second selection. Therefore, the Push Back Design and the Restructuring Design are the selected as the final concept designs to move forward.

Both design will then undergoes materializing design section to transform the conceptual design into a realistic and feasible design. The modified designs are then presented to the clients for feedbacks.

5. Materializing Design

For the purpose making the designs more feasible and realistic, we further evaluated and adjust the components of both the Push Back Design and the Restructured R.C.C Design.

5.1 Push Back Design

For the push back design, we kept the plate fixture that attaches to the bottom of the chair and the rail bar attachment extending from it the same as seen in Figure A24.

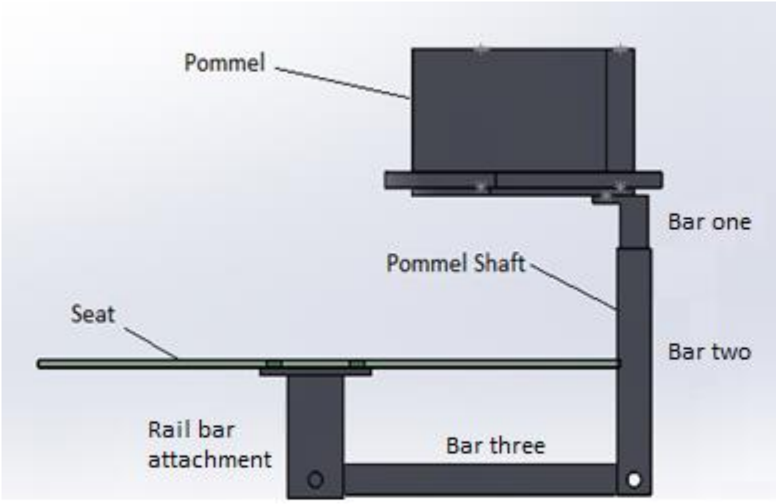

Figure A24 Push Back Design before modifications

The first modification was made to reduce the overall length of the design, the tube two was modified to a hollow square cross-section with a slightly smaller cross section than tube three to allows tube three to conceal tube one and two.

A hinge was added with flush-mount press-fit ball-nose spring plunger so that when tube one and two are aligned the ball nose can be pressed to allow for tube one to slide into tube two. Another hollow square cross section tube was added in the design to fit into tube one with a guide rail just wide enough for a screw to fit into so that the pommel height could be adjusted to a maximum of 4 inches as seen in Figure A25.

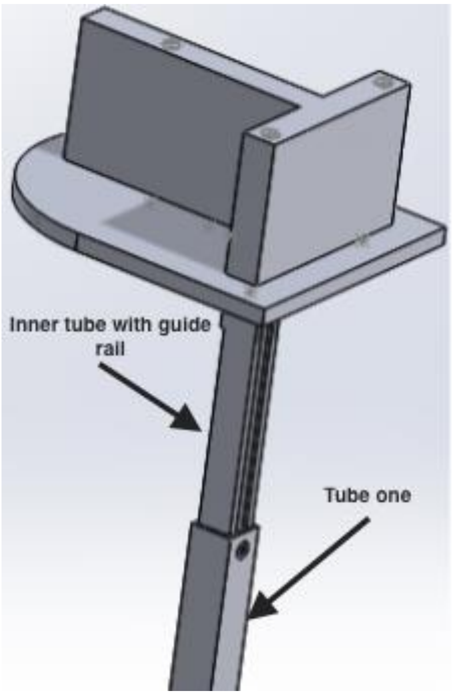

Figure A25: Tube one with adjustable height tube pommel attachment

In addition, the locking mechanism had to be re-designed due to the inconvenient of the location. The problem was solved by welding an L shaped piece of flat metal to tube two hinge point, with a small hole drilled into it. Together with a small hole drilled into tube one that flushed with the hole, a nut with a spring-loaded pull-pin would then be welded to this piece allowing for the hinge to lock in the 90-degree position as seen in Figure A26 and Figure A27.

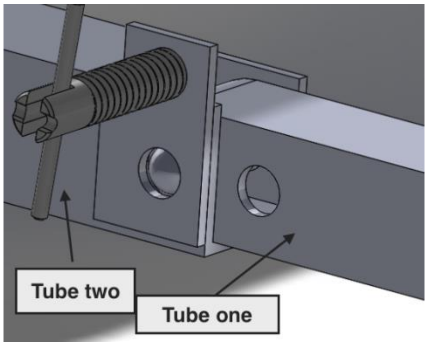

Figure A26: Flat metal piece with pull pin locking mechanism and hole for hinge spring ball nose joint

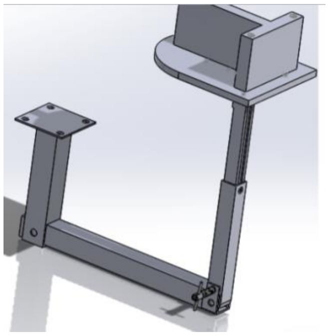

Figure A27: Push Back Design locked in 90 degree position

In Figure A28 shows an exploded view of the materialized Push-Back design and Figure A29 shows how the device is stored under the chair.

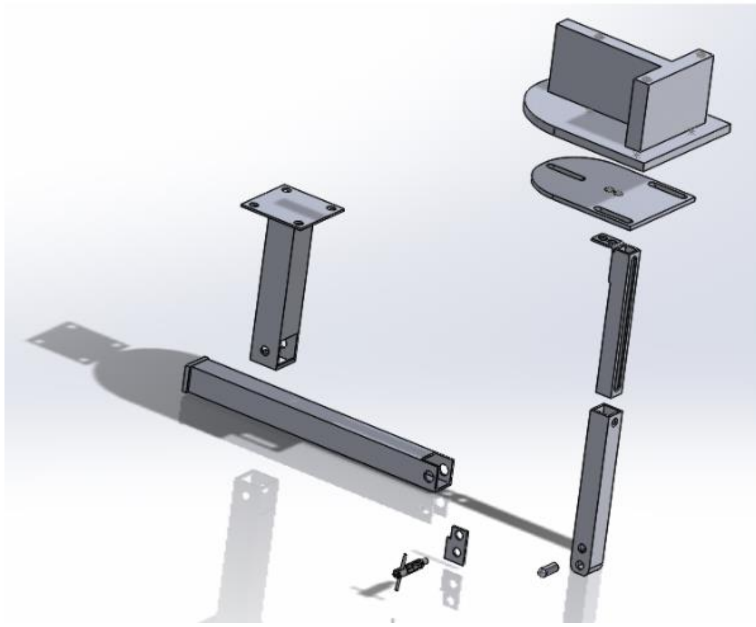

Figure A28: Exploded view of pieces of Push Back Design

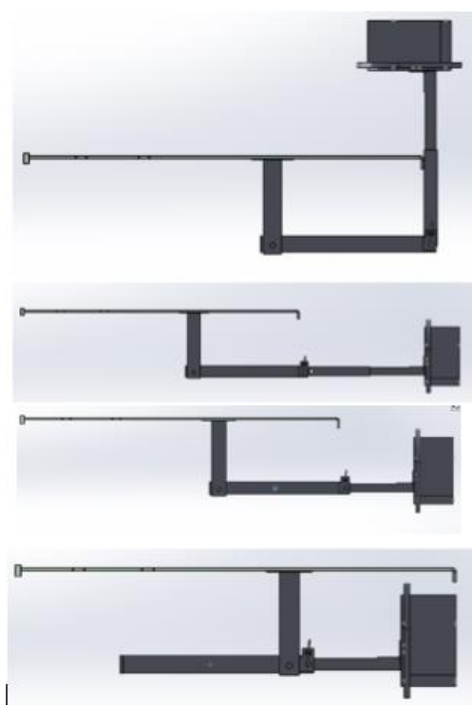

Figure A29: Shows the steps by which the Push Back Design stores under chair

After meeting with the client the design was further evaluated for possible design flaws that would need to be considered before the design was finalized. The major concerns of the design are listed as follows:

1. The force on the locking mechanism might be too great for the welding.
   - The client was worried the shear force produced by the moment of the arm might be enough to break off the locking flat plate.
2. The friction between tube two and three can cause the sliding motion difficult.
   - The concern is mainly due to tube two carries the entire weight of the pommel and tube one, as a result tube two may lean forward.

5.2 Restructured R.C.C Design

The restructured R.C.C design remains very similar to the original design, due to the benefit of utilizing the parts as R.CC's prototype which they manufactured onsite. However, new parts and modifications are needed to allow the design to perform within target specification.

As shown in Figure A30, a 0.56-inch block spacer that was attached at the front center of the chair to accommodate the gaps between the lip of the wheel chair plate. It also allow for a sturdier mounting base with a stronger hinge mechanism with less bending stress applied to it. In addition, the mounting block also allow for a more conveniently placed locking mechanism.

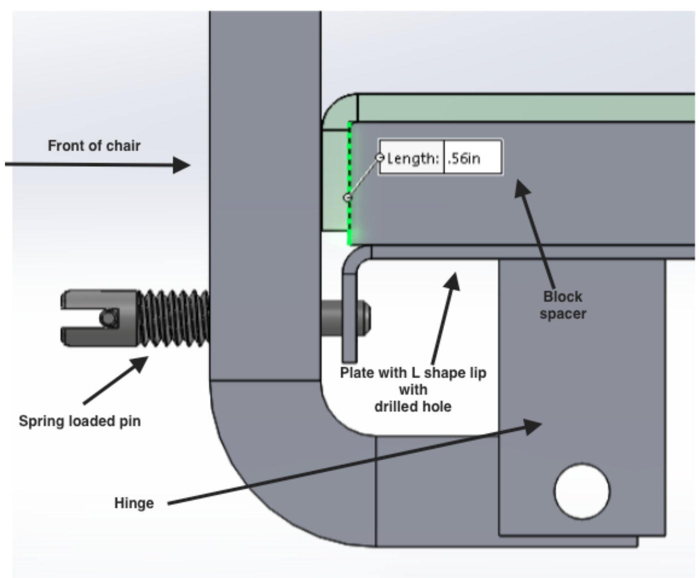

Figure A30: R.C.C prototype restructured with added components

In the meeting with our clients at R.C.C the design was further evaluated and suggestions were given to avoid possible problems while the design is in use. The suggestions are listed as follows:

1. The L-bracket that attached the pommel shaft to the head as seen in Figure A31 should be replaced by directly welding the attachment plate to the headpiece for greater strength.

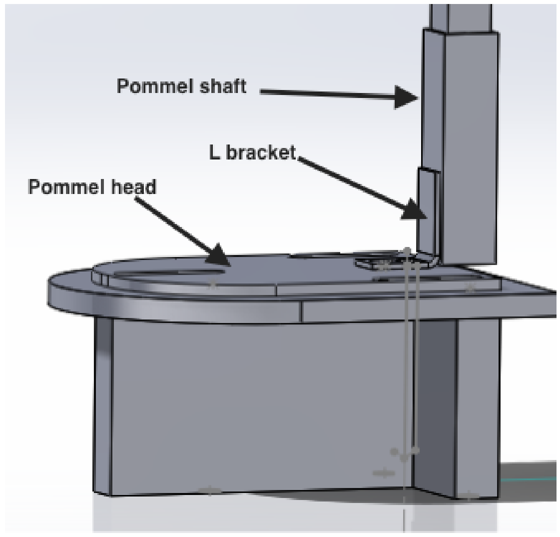

Figure A31: Pommel head attached by L bracket

2. The spring loaded-plunger for the locking mechanism should not be directly welded on to the pommel shaft, due to it increases the difficulty of replacing the locking mechanism.
3. A latch mechanism to hold the pommel lightly under the chair.

5.3 Pommel Head

The different dimension of the pommel head attachment that held the foam in place was also finalized. The bed sizes for the head attachment were in the sizes of large medium and small and their shapes and dimensions can be seen in Figure A32, Figure A33 and Figure A34 shows the pommel beds and their plates next to each other for each size.

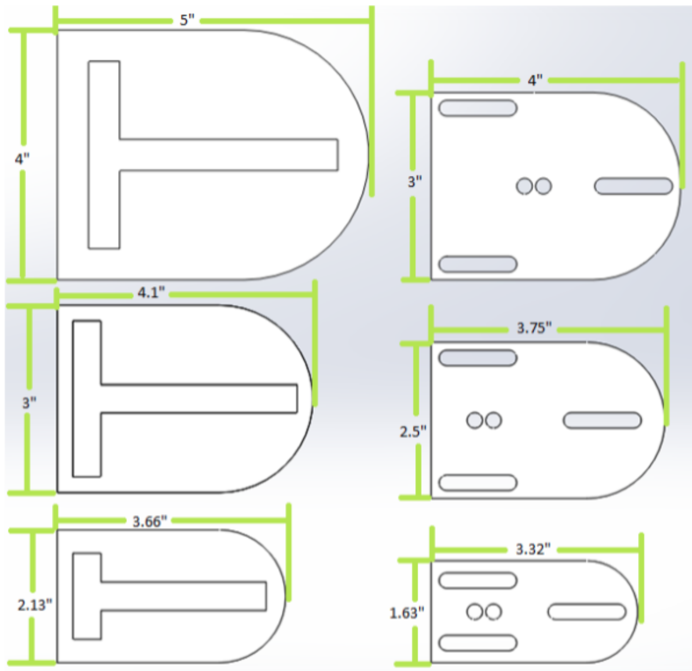

Figure A32: Pommel head attachment bed dimensions

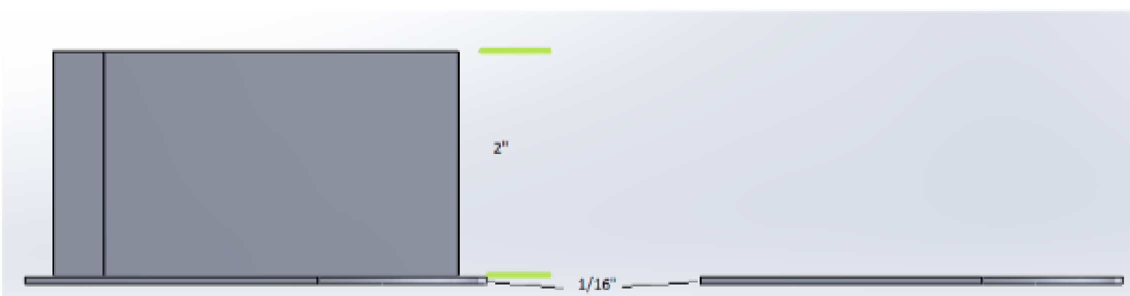

Figure A33: Bed and pommel foam head attachment height

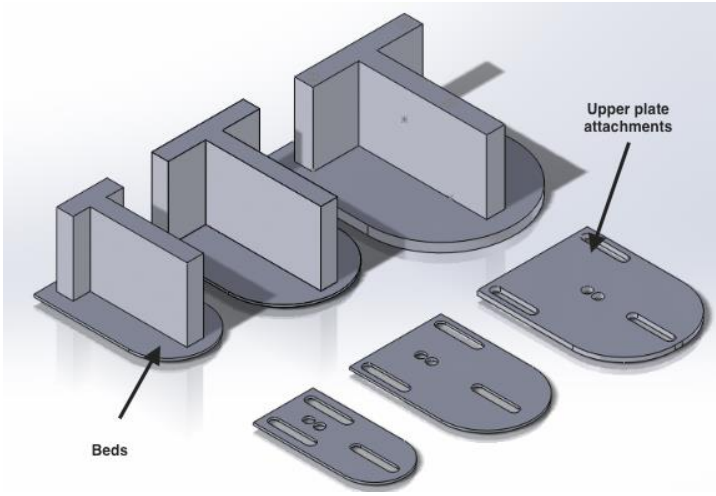

Figure A34: Array of bed sizes for pommel head attachment

In the meeting with our clients at R.C.C the design was feedback was provided by the clients, the client feedback as listed as follows:

1. A standard size upper plate that attached to all the bed sizes.
2. Due to wearing out between the wooden pommel and screws, the wooden pommel head mounting method might become a problem for younger patient.
    - For a younger patient, the size of the pommel head needs to be replaced frequently. A standard size upper plate can reduce the need of replacing multiple parts due to patient growth.

5.4 Conclusion

After evaluation of both the modified versions of the push back design and the restructured R.C.C design with the client, the team and the client have decided that the design flaws for the push back design were difficult to complete within the time limit, therefore the push back design would not be further optimize. And the restructured R.C.C design along with the client suggestion is our final design. The solutions to the provided suggestion are listed in Section 6. A List of client suggestions is shown as follows:

- Weld pommel shaft directly onto top plate of pommel head.
- Spring loaded locking pin should not be welded direction onto the shaft.
- Standardize the size of the upper plate that fits all pommel bed sizes.
- Different wooden pommel head mounting methods.
- A latch mechanism to hold pommel under chair when stowed away.

6. Design Optimization

For the purpose of optimizing manufacturability, design feasibility and accommodating client suggestions, the restructured R.C.C. design is further optimized with the section listed below.

6.1 Manufacturing Optimization

Final design consists of 9 parts, which require machining and assembly. Machining operation required to manufacture these parts are: Drilling, Manual Milling, Metal Chopping, Sheet Bending, Tube Bending, and Bend Saw. Manufacturing optimization was performed by considering the processes required to perform these operations on our part such as machine setup, tool changing, face switching, standard raw material.

6.1.1 Single face milling

Milling operation is required for most of the parts, 7 out of 9 parts required milling operation. We have optimized design to single face milling for 4 out of 7 parts that required milling. This will eliminate frequent turning of parts and resetting of machine, and saves time and effort milling the parts. This can be seen in Figure A35.

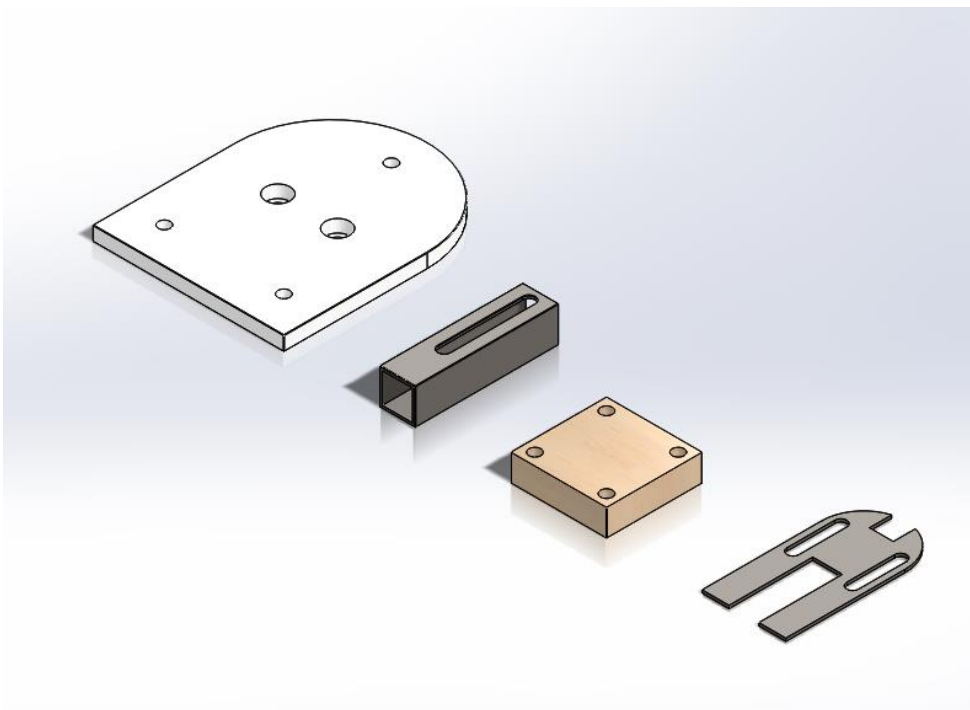

Figure A35: Single face milling possible components

6.1.2 Unified drill size

Another operation that is required for most parts is drilling, 5 out of 9 parts required drilling with total of 17 holes to drill. In order to make the operation process easier and faster standard size drill holes were used on parts, 14 holes out of 17 are designed to be ¼”. This will eliminate need of changing drill bit and machine setup time. Another benefit of using standard size drill hole is that drill bit is readily available within shop, there is no need to make or buy new drill bit for the job.

6.1.3 Standard size raw/stock material

Parts dimensions were modified to reflect available standard sizes of raw materials such as sheets, bars and tubes. This will eliminate raw material waste, excess unnecessary machining and need of customization. Which resulting an easier, faster and cost-effective manufacturing of parts.

6.1.4 Welding spot guide line feature

Lastly, assembling the parts together has been optimized by assembly plan. Assembling requires welding and fasteners as main operations. Welding spot guideline feature has been implanted for easier, faster and defect free welding of components. This feature will eliminate the need of manual alignment between parts, which increase precision of welding. The welding guide feature design in parts can be seen in the Figure A36.

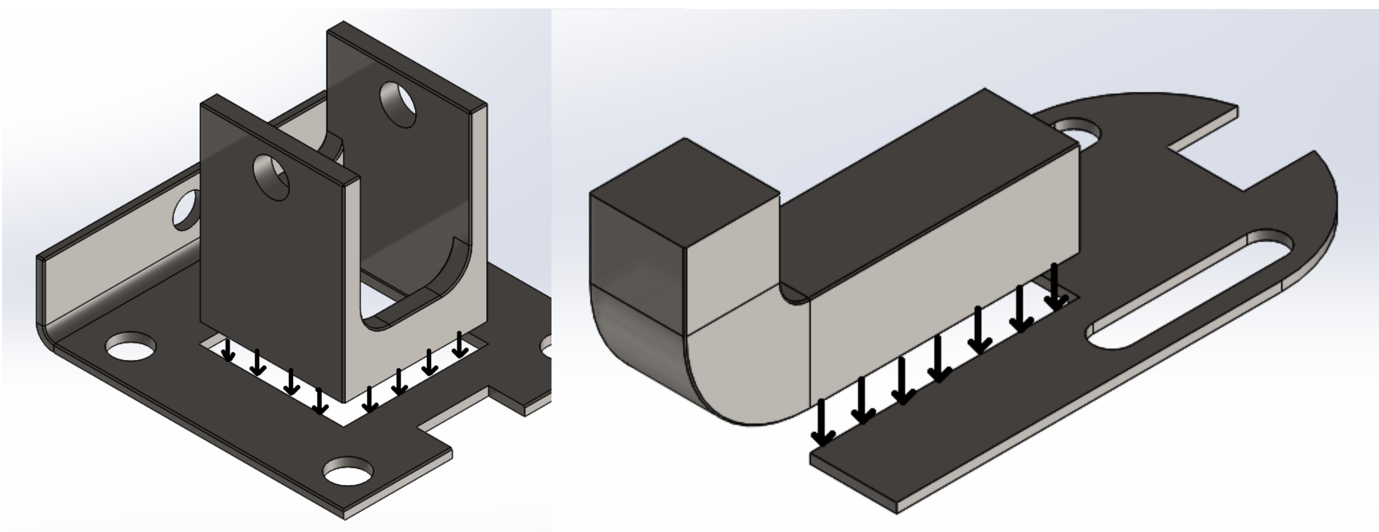

Figure A36: Welding guide line

6.2 Component Optimization

Component optimization is focus on implementing client suggestions into the design as listed in Section5.4 to improve the performance and client satisfaction of the design.

6.2.1 Attachment joint strengthening

To adjust client concern with the lack of structural strength of the L-bracket attachment plate, the L-bracket plate is replaced with L-joint solid shaft as seen in Figure A37 and Figure A38.

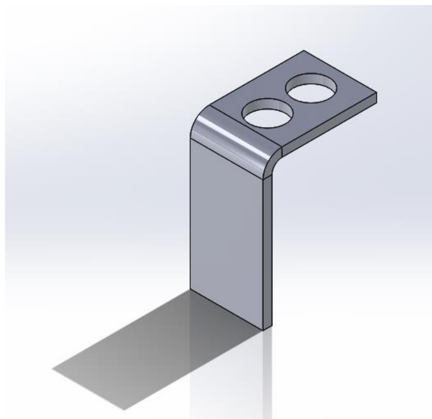

Figure A37: L-bracket attachment plate

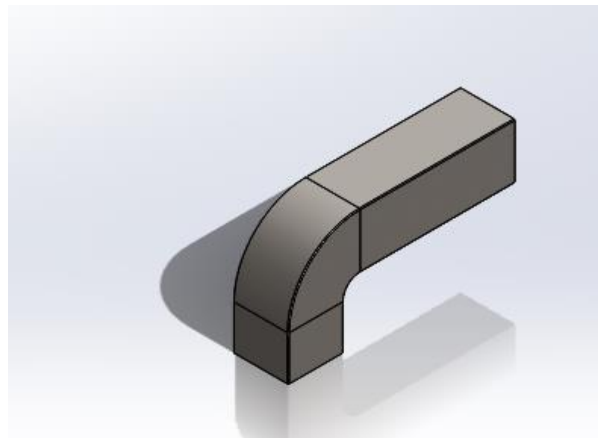

Figure A38: L-joint solid shaft

As seen in Figure A38, L-solid shaft is inserted in the upper arm and weld it in place, while the other end is welded to upper plate directly. The change was performed to strengthen the joint between the upper arm and the upper plate. As shown in Figure A39 and Figure A40, the newly implemented L-joint had successfully distributed the load under the same load case.

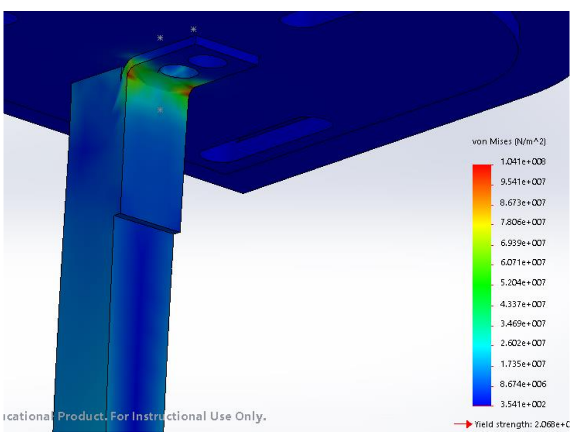

Figure A39: FEA of the L-bracket plate

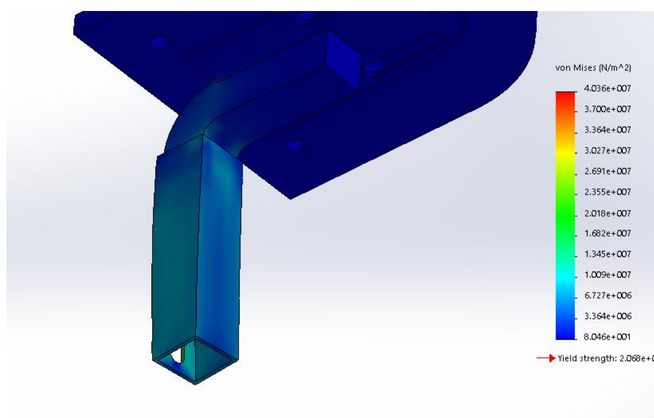

Figure A40: FEA of the L joint

6.2.2 Optimization of bed assembly

The repetitive wearing force between wooden bed and bed frame assembly was listed to be problematic by client. Original design consists of one set of screws to fix the wooden bed, bed frame and upper plate in to one piece as seen in Figure A41. If this is subject to repetitive changing of wooden bed, the wooden holes are easy to wear out over time. The solution was optimized by assembling the wooden bed and bed frame into one piece by a set of wooden screw and a separate set of fastener and nut to locating bed assembly on to upper plate.

Another client suggestion was to standardize the upper attachment plate to eliminating the need to replace upper plate as the client requires an upgrade in pommel size. The optimized component can be seen in Figure A42.

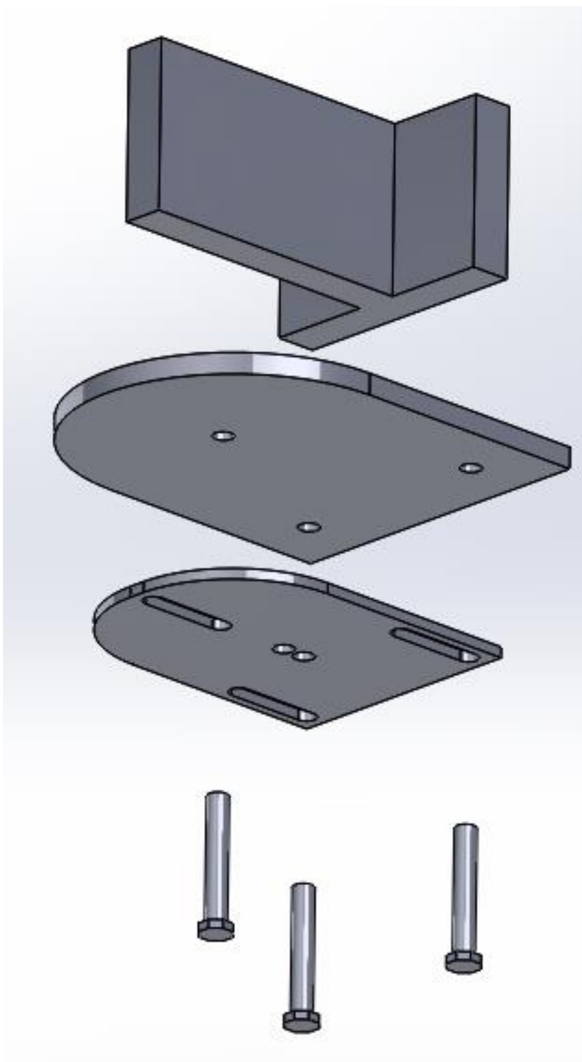

Figure A41: Bed assembly before optimization

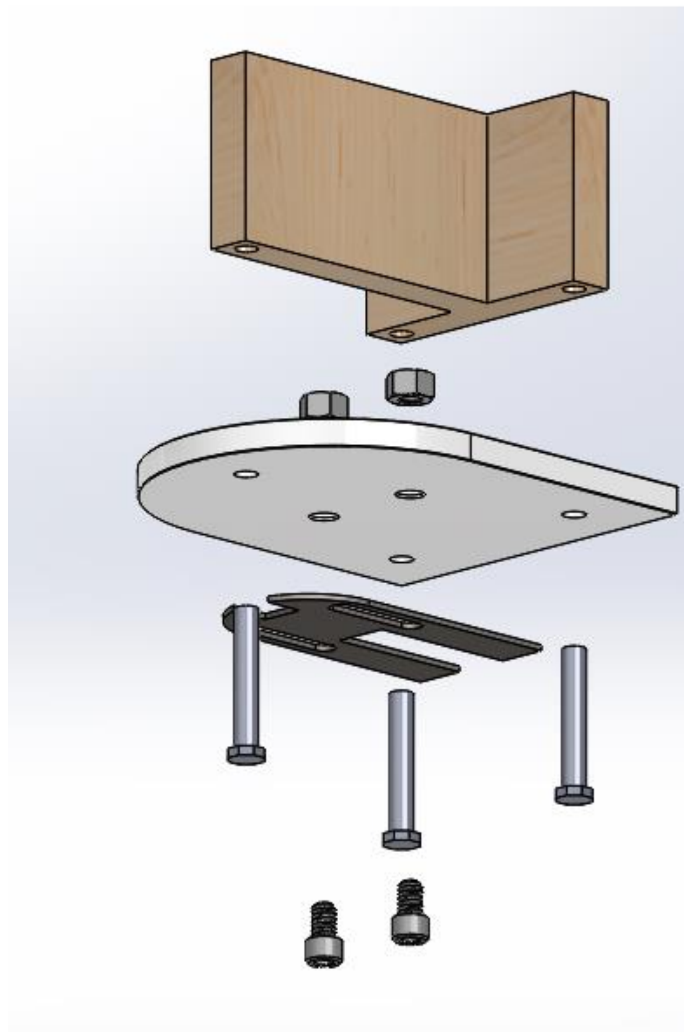

Figure A42: Bed assembly after optimization

6.2.3 Overall structure strength reinforcement

Lastly, after discussion with the engineering drawing consultant, the ratio between the size of the hole with the locking mechanism housing and the width of the lower arm is not realistic. The consultant recommended increasing the width of the lower arm to 5/8" to improve the overall structural strength around that hole. Since the dimension of the lower arm tube has been increased, the rest of the components also have to be increased to the next available stock size. The detailed list of revised dimensions is listed in the Table AV.

Table AV: Parts with revised dimensions

Parts	Before	After
Lower arm	½" x ½"	5/8" x 5/8"
Upper arm 1	5/8" x 5/8" OD ½" x ½" ID	¾ x ¾ " 5/8" x 5/8"
Upper arm 2	½" x ½"	5/8" x 5/8"
Lower attachment plate 1	Welding guild hole ¾" x ¾"	Welding guild hole ¾" x ¾"
Lower attachment plate 2	¾" x ¾" OD 5/8" x 5/8" ID	1" x 1" ¾" x ¾"
Upper attachment plate	Width of the welding guild hole ½ "	Width of the welding guild hole 5/8"

6.3 Geometry and Stress Analysis

Finite element analysis was conducted to ensure the pommel will not fail under set load. The study will simulate loading similar to spastic muscle.

6.3.1 FEA model

In order to improve the analysis efficiency, accuracy and remove the mesh problems, the model was simplified by performing the following procedures:

1) Replacing the spring loaded plunger with a similar size pin with the same material.
2) Removes threads on fastener.
3) Joining welded items into a single body.
4) Vertical setting of the pommel is set to max to allow analysis of the maximum bending stress.

6.3.2 Loading Case

The loading case was designed to similar a spastic load cause by interaction between the knee and swing away pommel. All of the force is assumed to be transmitted evenly across the pommel head, due to the effect of the pommel cushion. Table AVI summarizes the two types of load case were performed to the swing away pommel.

Table AVI: Loading Case Summary

Case	Fixture	Load
1	Lip Clearance Plate	300lbf applied directly to the left side of the pommel head.
2	Lip Clearance Plate	300lbf applied directly to the left side of the pommel head with 16° outward from the pommel.

6.3.3 Result

6.3.3.1 Case 1

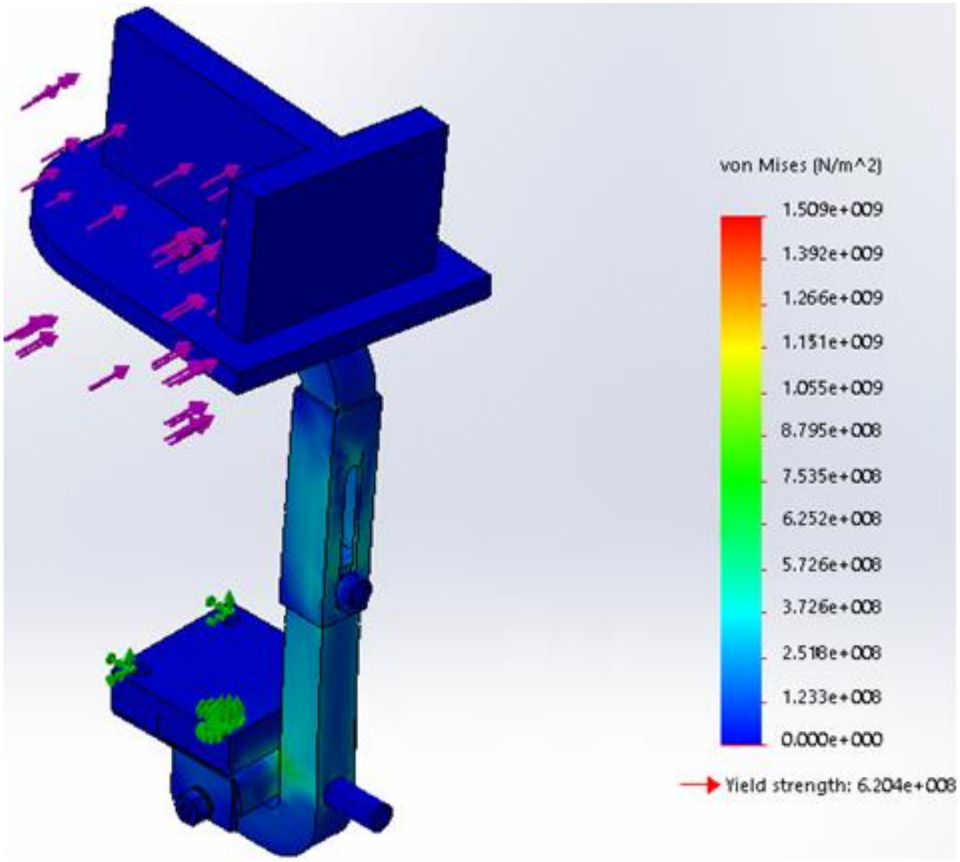

Figure A43: Von Mises stress distribution model for case 1

The model experiences an average stress of 2.5 to 3.7 MPa with a maximum deflection of 6.63mm, as shown in the Figure A43 and Figure A45, which is well below the yield strength of 304 steel alloy. Similar to the current prototype experience most of the wearing at the locking plate, as seen in Figure A44, which remain as the stress concentration spot.

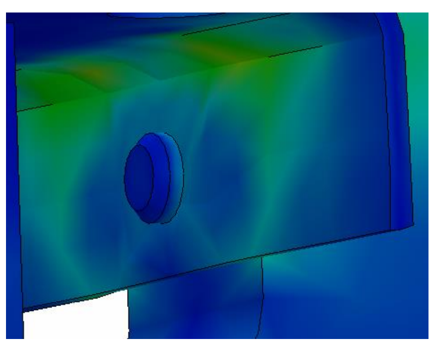

Figure A44: Stress concentration around locking plate

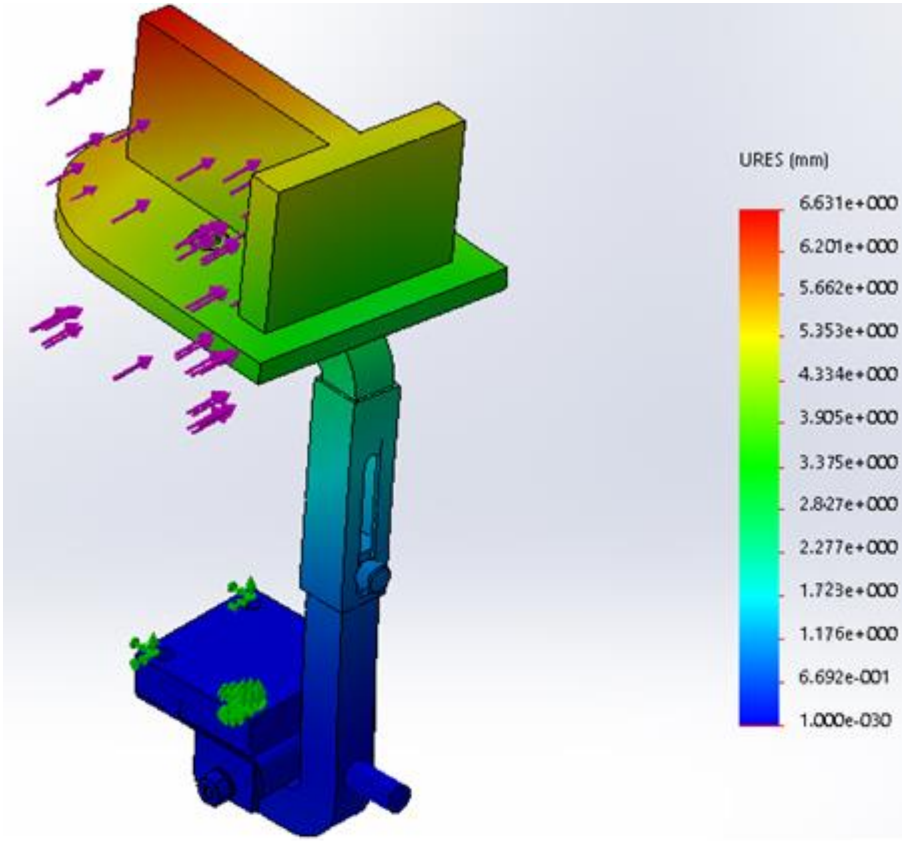

Figure A45: Overall deformation model for case 1

6.3.3.2 Case 2

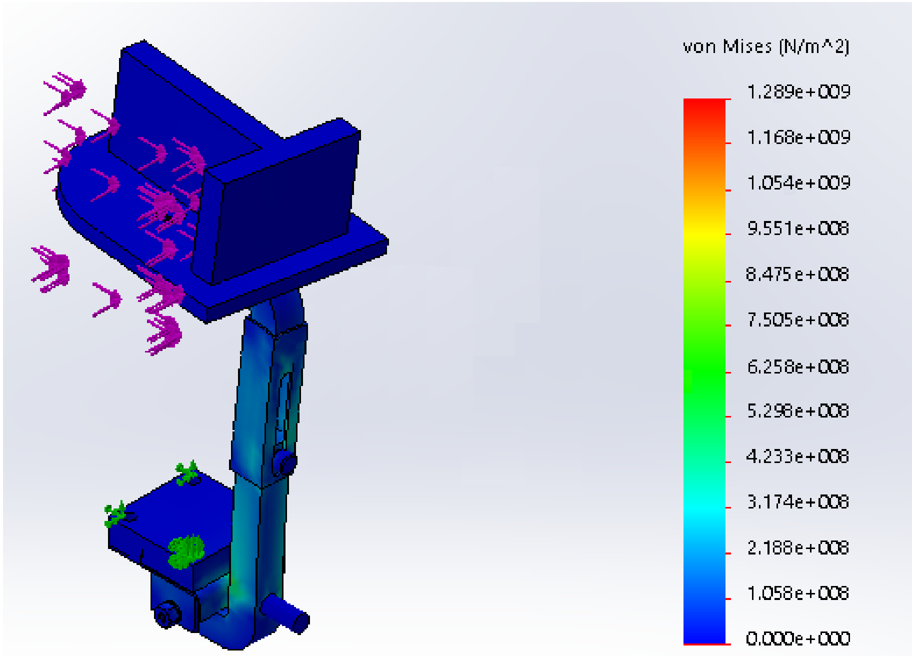

Figure A46: Von Mises stress distribution model for case 2

In the case 2, the model experiences an average stress of 2.1 to 3.17 MPa with a maximum deflection of 5.22mm, as seen in Figure A46 and Figure A47, which is well below the yield strength of 304 steel alloy.

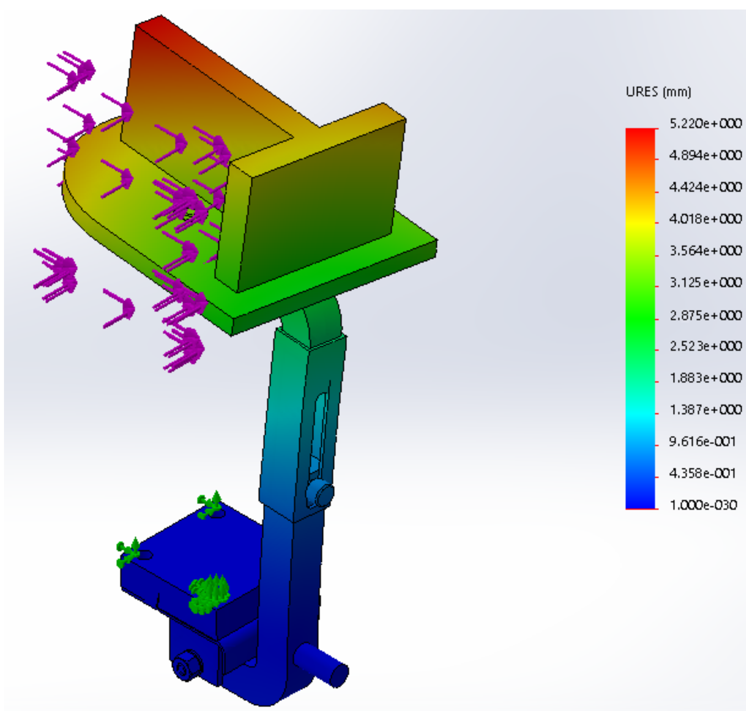

Figure A47: Overall deflection model for case 2

6.3.4 Conclusion

The pommel will not fail under a typical spastic muscle load with a maximum deflection of 6.6mm.

7. Preliminary Engineering Drawings

8. References

[1] Stealth's User Manual and Maintenance Guide for Medial Thigh Support, 2016 ed., Stealth Products, Burnet, TX, 2017,pp. 2-3.

[2] SPEX Medial Thigh Support Installation And User Manual.Pommel20170320 ed., Medifab Ltd, Rolleston 7675, New Zealand, 2017.

[3] SPEX Seating. (2017). Standard Medial Thigh Support. [online] Available:http://www.spexseating.com/products/medial-knee-support/standard-medial-thigh-support [September 30, 2017].

[4] Stealth's User Manual and Maintenance Guide for Medial Thigh Support, 2016 ed., Stealth Products, Burnet, TX, 2017,pp. 2-3.

[5] DMEShoppe Accessibility O complex Rehab O Mobility. DmeShoppe.com [Online]. Available: http://dmeshoppe.com/pediatric-tilt-in-space-/convaid-safari-tilt-wheelchair.html [September 17, 2017].

[6] SPEX Medial Thigh Support Installation And User Manual.Pommel20170320 ed., Medifab Ltd, Rolleston 7675, New Zealand, 2017.

[7] Nuera trailer parts. (2017). Nueratrailerparts.com [Online]. Available: https://www.nueratrailerparts.com/5-8-spring-latch-tube.html [October 21, 2017].

[8] Knee Walker Shop. (2017). Kneewalkershop.com [Online]. Available: http://www.kneewalkershop.com/knee-walker-universal-compression-lock-with-release-lever-for-knee-platform-replacement-part-fits-most-knee-scooters/ [October 21, 2017].

[9] Seatpost and seatpost clamp. (2017, January 24). Bike-manual.com [Online]. Available: http://www.bike-manual.com/brands/trek/om/hybrid/seatpost.htm [October 21, 2017].

[10]Wheelchair with posture supports, by Robert B. Suhre. (1986, October 21). Patent US06529517 [Online]. Available: https://patents.google.com/patent/US4617919A/en?q=medial&q=thigh&q=support&q=wheelchair [October 22, 2017].

[11] Product Classification. (2017, October 16). FDA.gob [Online]. Available: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpcd/classification.cfm?ID=5070 [October 27, 2017]

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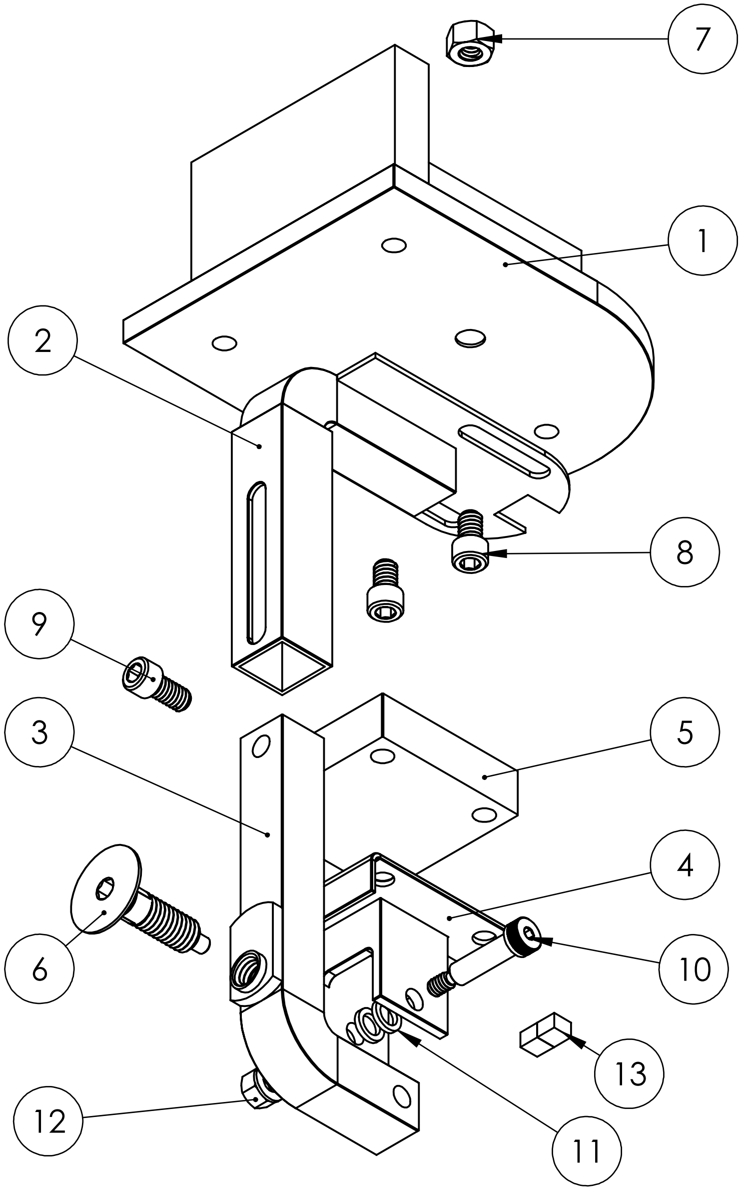

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2	1	A01-02	UPPER ARM
3	1	A01-03	LOWER ARM WITH WELD NUT
4	1	A01-01	BOTTOM ATTACHMENT
5	1	P01-0	LIP CLEARANCE PLATE
6	1	2375A332	KNOB-STYLE RETRACTABLE SPRING PLUNGER 3/8"-16
7	2	95036A012	HEX NUT 1/4"-20
8	2	91251A535	SOCKET HEAD SCREW 1/4"-20, 3/8 LONG
9	1	91251A537	SOCKET HEAD SCREW 1/4"-20, 1/2 LONG
10	1	91259A541	SHOULDER SCREW 1/4' DIAMETER 7/8' LONG SHOULDER, 10-24
11	2	97022A535	.06' THICK, 1/4" ID WASHER
12	1	94909A011	FLANGE LOCKNUT 10-24
13	2	Magnet	HIGH-PULL RARE EARTH MAGNET

B

A

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

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CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

Final Assembly

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SCALE: 1:4 WEIGHT: SHEET 1 OF 1

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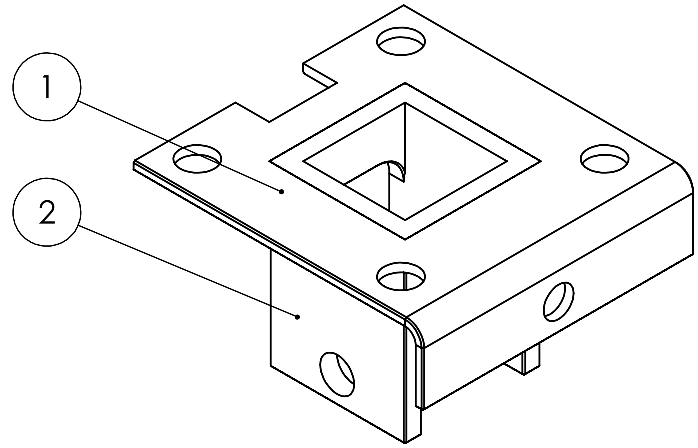
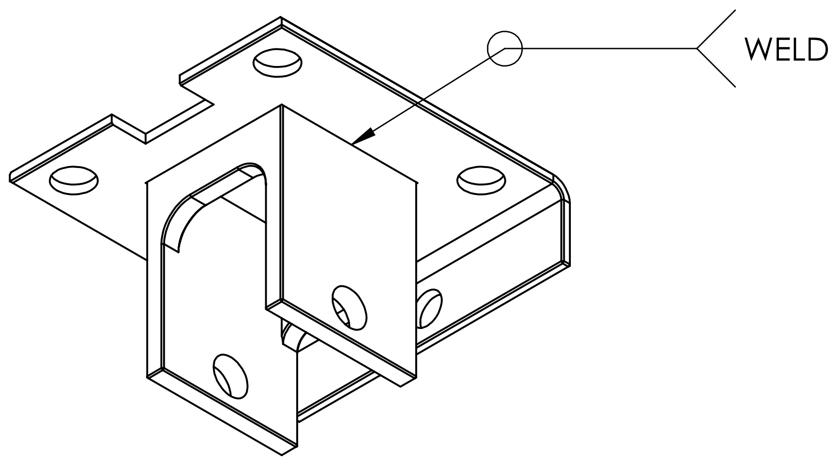
NEXT ASSY	USED ON
APPLICATION	





ITEM	QTY	DWG. NO.	TITLE
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1	1	P01-1-01	BOTTOM ATTACHMENT PLATE PART 1

UNLESS OTHERWISE SPECIFIED:

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TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH Black Power Coated

DO NOT SCALE DRAWING

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DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

NEXT ASSY	USED ON
A01	A01

APPLICATION

TITLE:

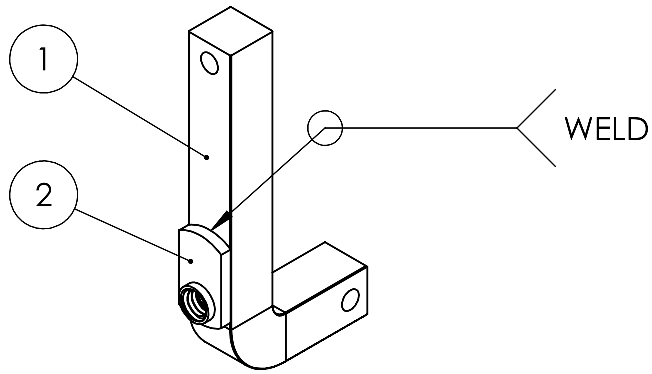
Bottom Attachment Assembly

SIZE A | DWG. NO. A01-01 | REV A

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

2 1

B B



ITEM	QTY	DWG. NO.	TITLE
2	1	94581A148	1-18 STAINLESS STEEL BARREL WELD NUT
1	1	P01-2	LOWER ARM

A A

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH Black Power Coated

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

NEXT ASSY	USED ON
A01	A01

APPLICATION

PROPRIETARY AND CONFIDENTIAL

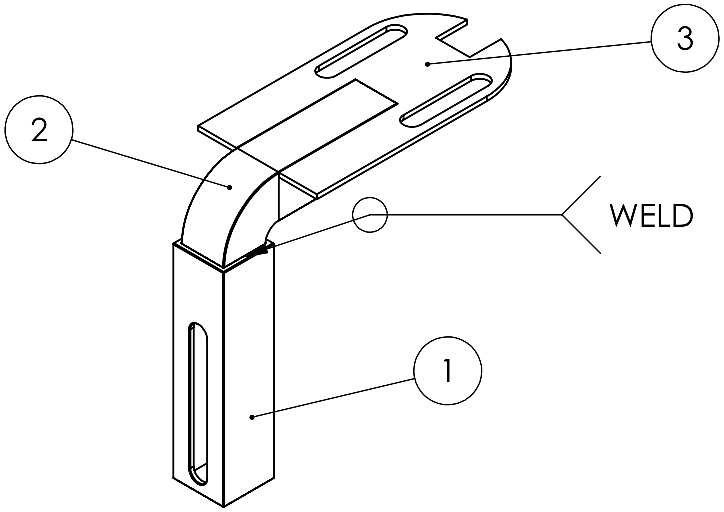
TITLE:

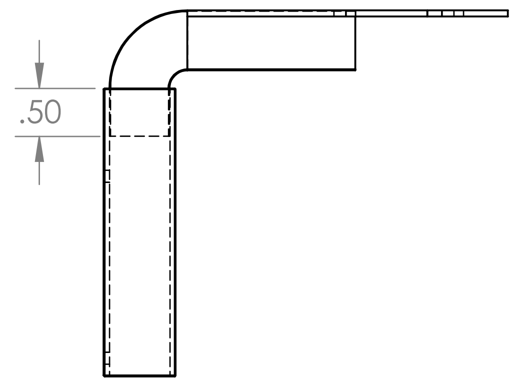
Lower Arm Assembly

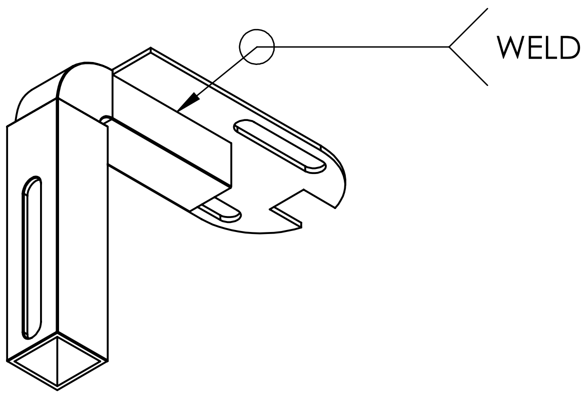
SIZE A DWG. NO. **A01-03** REV A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2 1







ITEM	QTY	DWG. NO.	TITLE
3	1	P01-4	ATTATCHMENT PLATE
2	1	P01-3-02	UPPER ARM PART 2
1	1	P01-3-01	UPPER ARM PART 1

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH
Black Powder Coated

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
A01	A01

APPLICATION

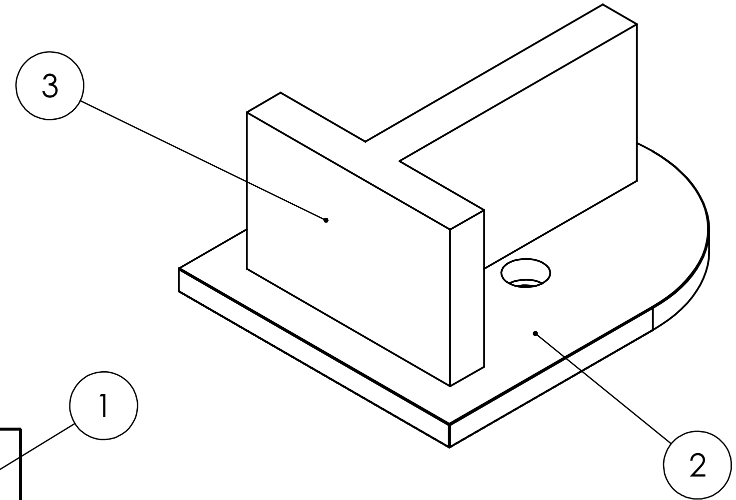
TITLE:

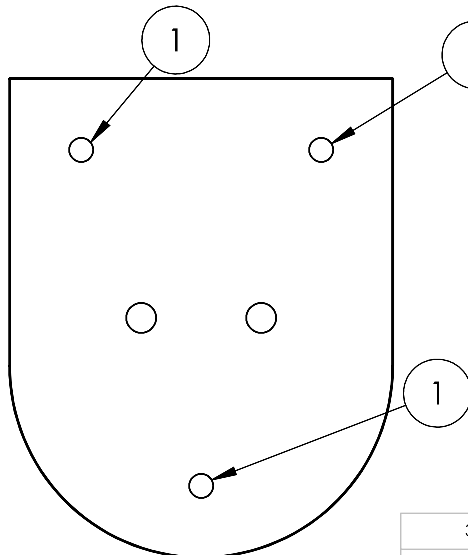
Upper Arm Assembly

SIZE	DWG. NO.	REV
A	A01-02	A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

1. SOCKET HEAD FLANGED SCREWS 1/4', 1.5' LONG ARE INSERTED AT LOCATION "1"





ITEM	QTY	DWG. NO.	TITLE
3	1	P02-1-002	BED (BIG SIZE) PART 2
2	1	P02-1-001	BED (BIG SIZE)PART 1
1	3	-	SOCKET HEAD FLANGED SCEWS 1/4", 1.5" LONG

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
A01	A01

APPLICATION

TITLE:

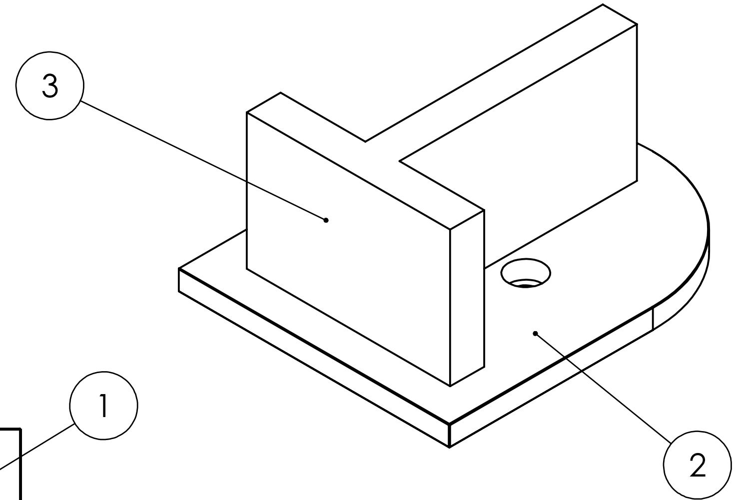
Bed Assembly (Big Size)

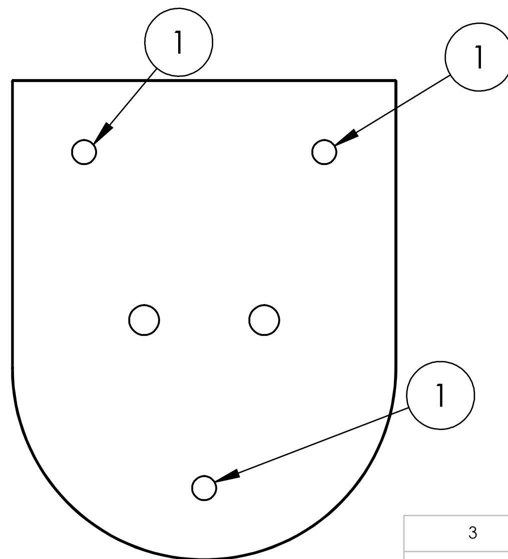
SIZE A | DWG. NO. A02-01 | REV A

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

2 | 1

1. SOCKET HEAD FLANGED SCREWS 1/4', 1.5' LONG ARE INSERTED AT LOCATION "1"





ITEM	QTY	DWG. NO.	TITLE
3	1	P02-2-002	BED (MID SIZE) PART 2
2	1	P02-2-001	BED (MID SIZE)PART 1
1	3	-	SOCKET HEAD FLANGED SCEWS 1/4", 1.5" LONG

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

A01	A01
NEXT ASSY	USED ON
APPLICATION	

TITLE:

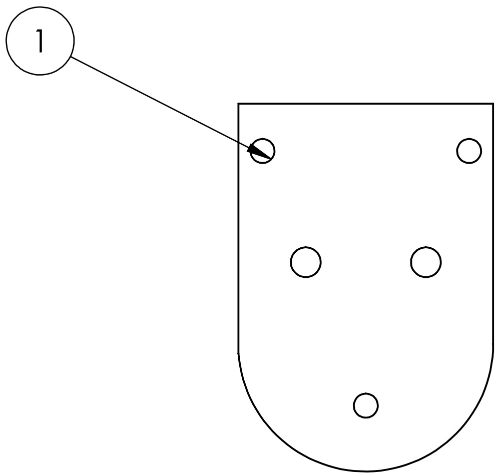
Bed Assembly (Mid Size)

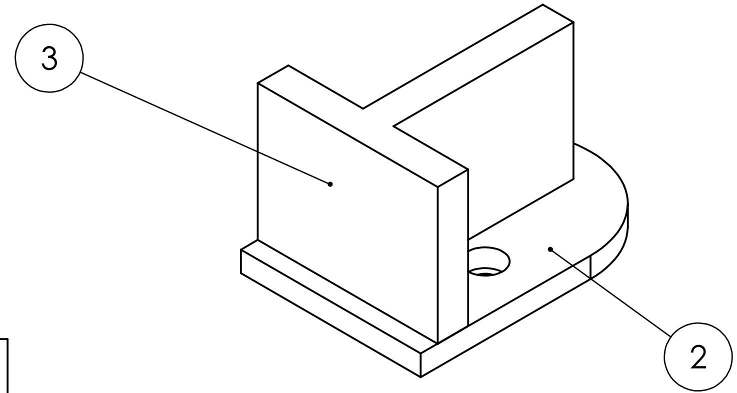
SIZE	DWG. NO.	REV
A	**A02-02**	**A**

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

2 | 1

1. SOCKET HEAD FLANGED SCREWS 1/4', 1.5' LONG ARE INSERTED AT LOCATION "1"





ITEM	QTY	DWG. NO.	TITLE
3	1	P02-3-002	BED (SMALL SIZE) PART 2
2	1	P02-3-001	BED (SMALL SIZE)PART 1
1	3	-	SOCKET HEAD FLANGED SCEWS 1/4", 1.5" LONG

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
A01	A01

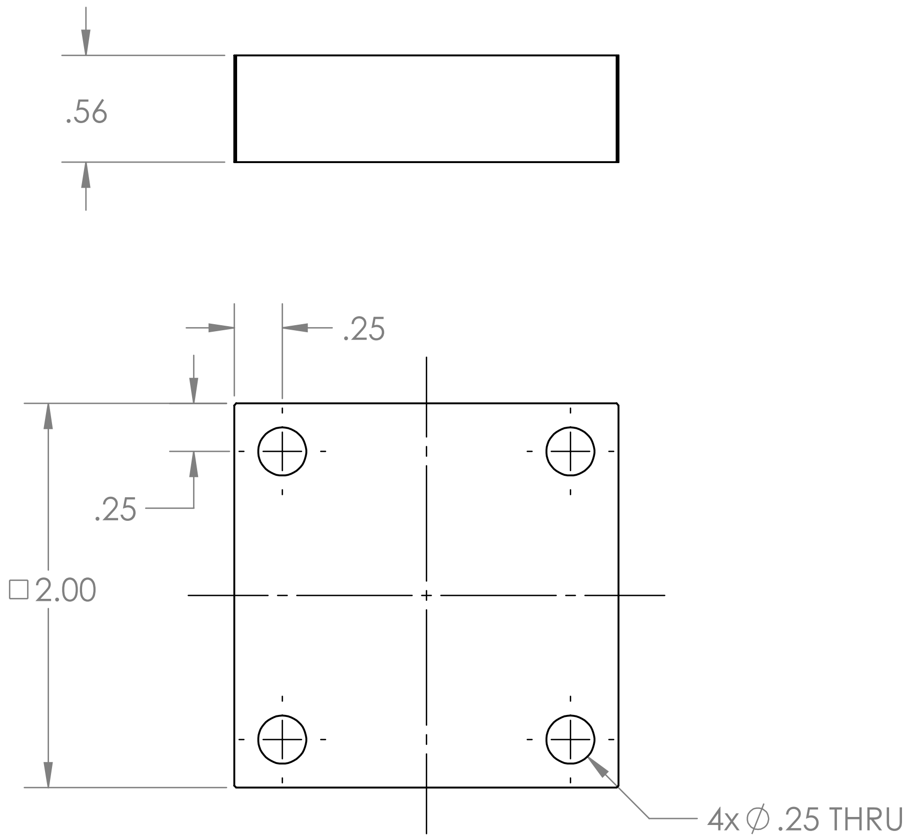
APPLICATION

TITLE:

Bed Assembly (Small Size)

SIZE: A | DWG. NO. A02-03 | REV A

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

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NEXT ASSY	USED ON
A01	A01

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Wood

FINISH

DO NOT SCALE DRAWING

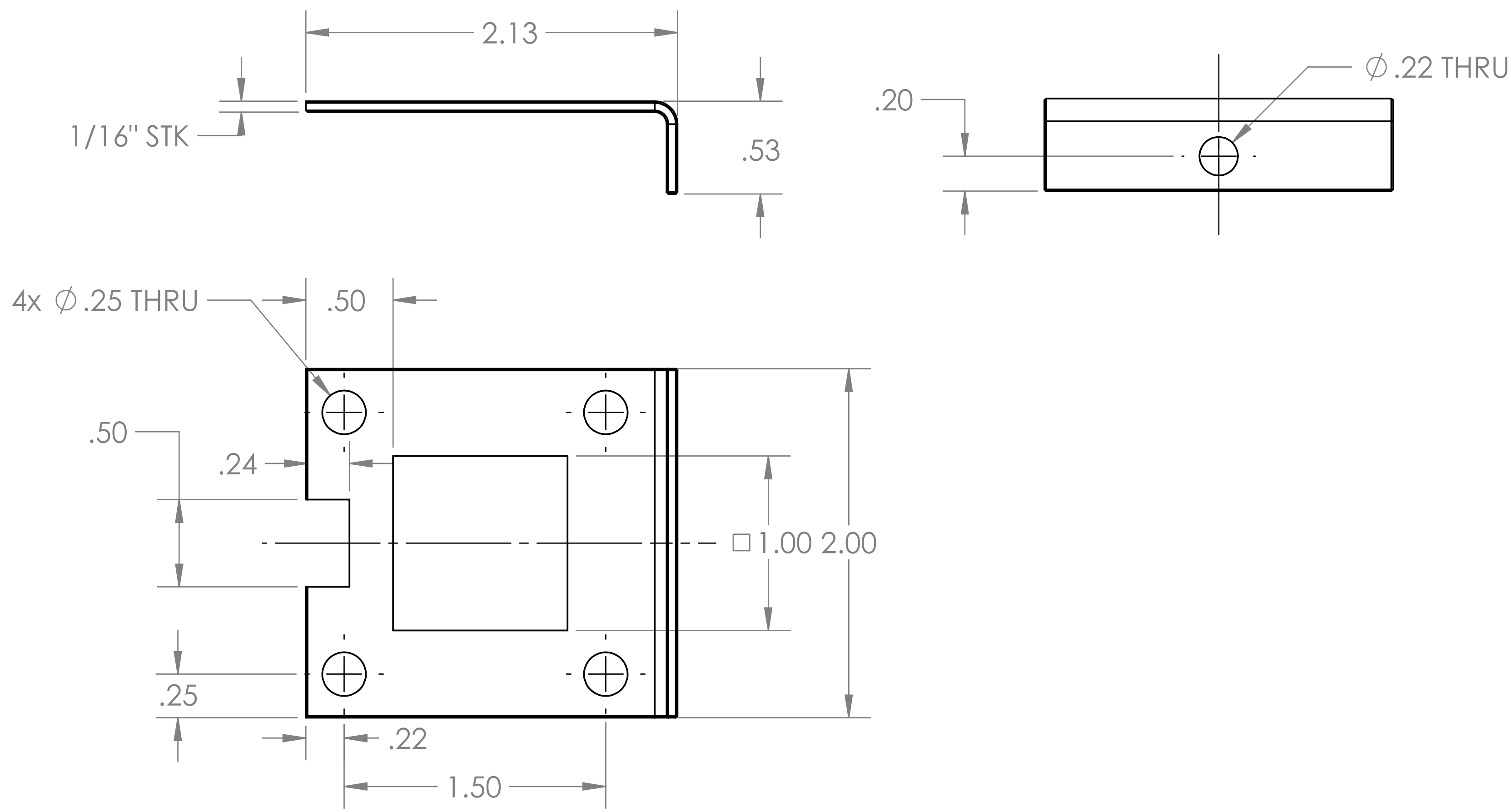
	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE: Lip Clearance Plate

SIZE	DWG. NO.	REV
A	**P01-0**	**A**

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± .1 ANGULAR: MACH ± 1° BEND ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005
		INTERPRET GEOMETRIC TOLERANCING PER:
A01-01	A01-01	MATERIAL 304 Steel
NEXT ASSY	USED ON	FINISH
APPLICATION		DO NOT SCALE DRAWING

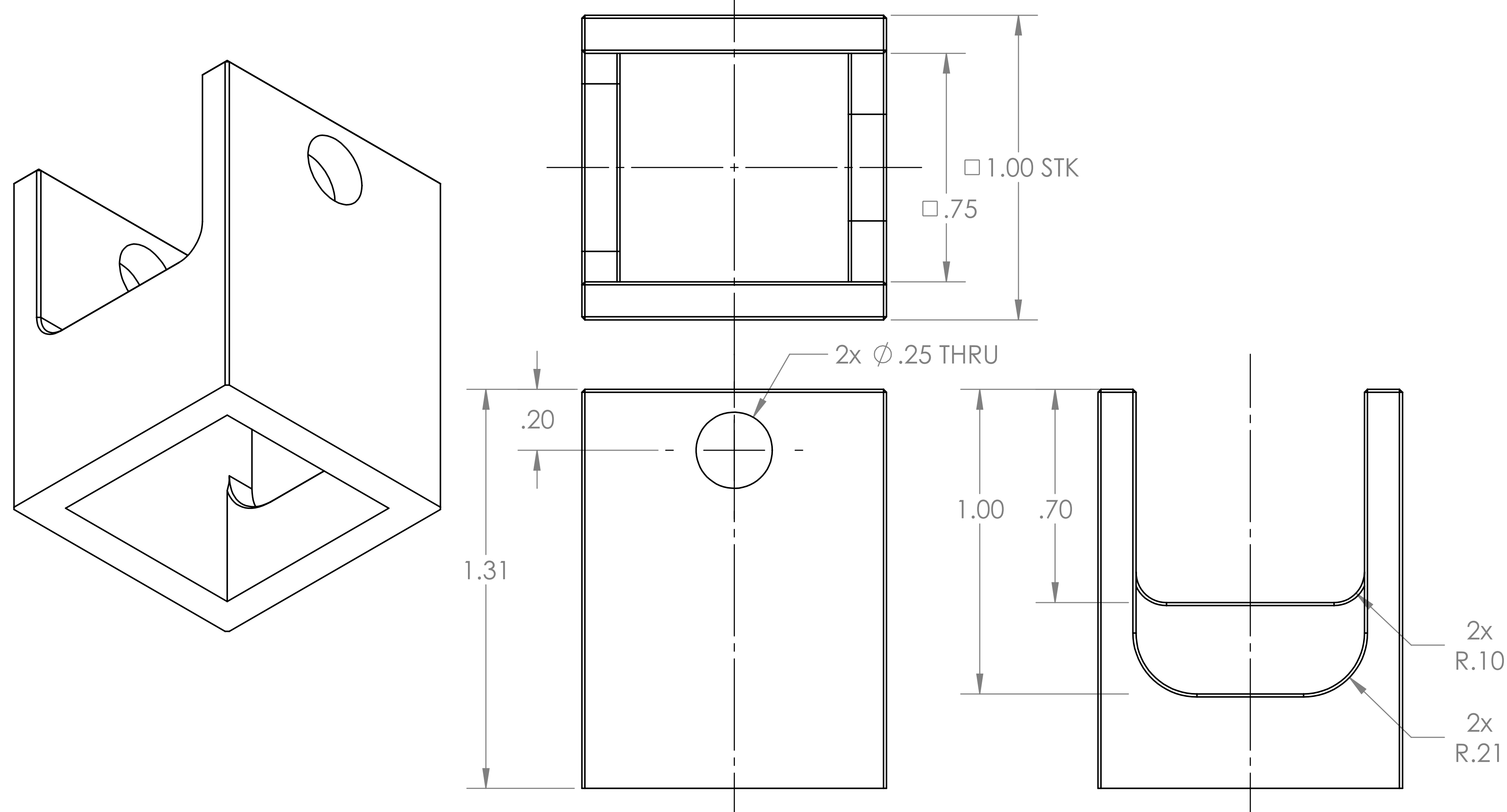
	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

Bottom Attachment Plate Part 1

SIZE	DWG. NO.	REV
A	P01-1-01	A

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



A01-01	A01-01	
NEXT ASSY	USED ON	
APPLICATION		

PROPRIETARY AND CONFIDENTIAL

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 304 Steel

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

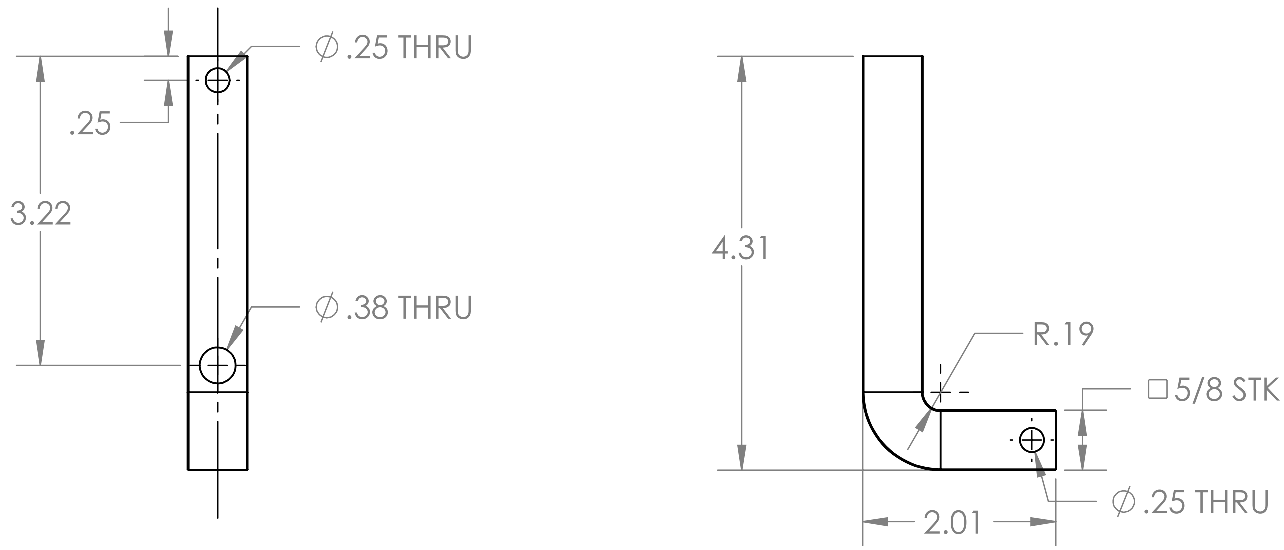
Bottom Attachment Plate
Part 2

SIZE	DWG. NO.	REV
A	**P01-1-02**	**A**

SCALE: 2:1 WEIGHT: SHEET 1 OF 1

2 1

B B



A A

PROPRIETARY AND CONFIDENTIAL

A01-03	A01-03
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 304 Steel

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

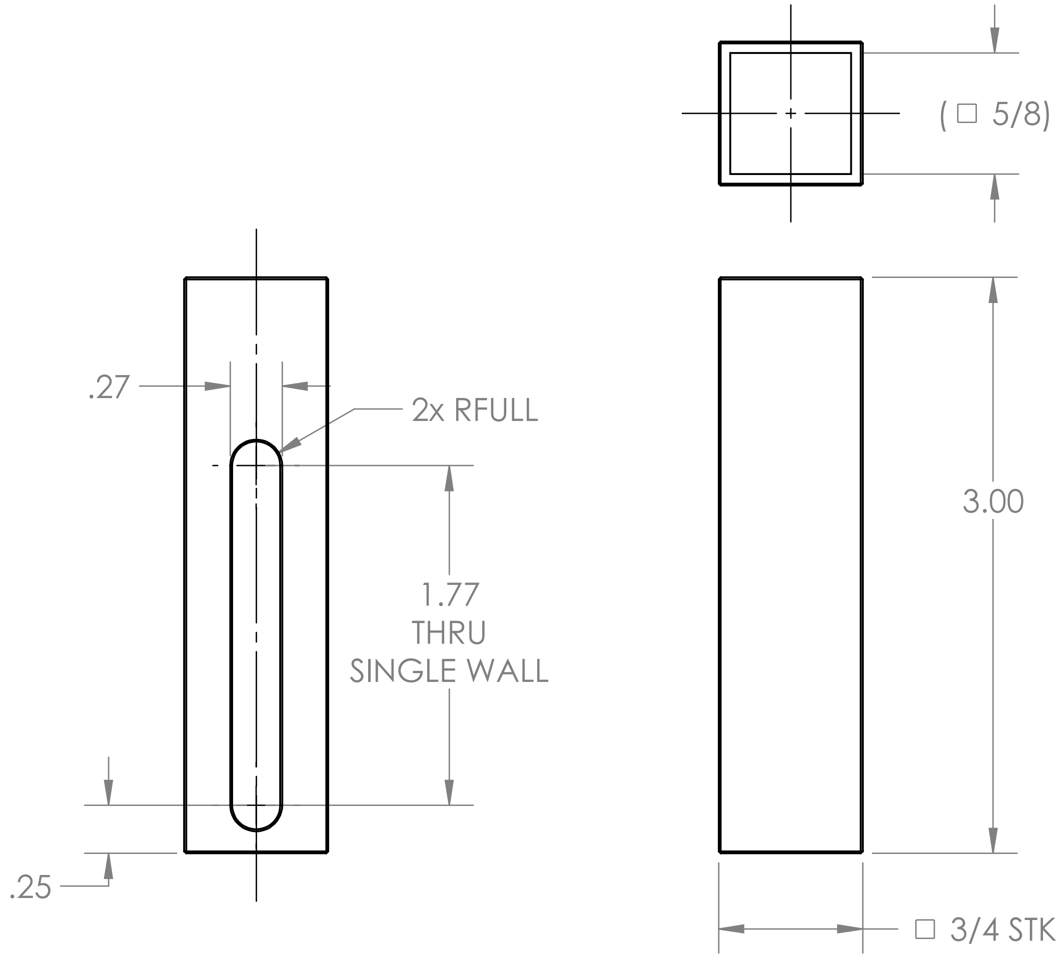
COMMENTS:

TITLE: Lower Arm

SIZE	DWG. NO.	REV
A	**P01-2**	A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1

2 1



A01-02	A01-02	MATERIAL 304 Steel
NEXT ASSY	USED ON	FINISH
APPLICATION		DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

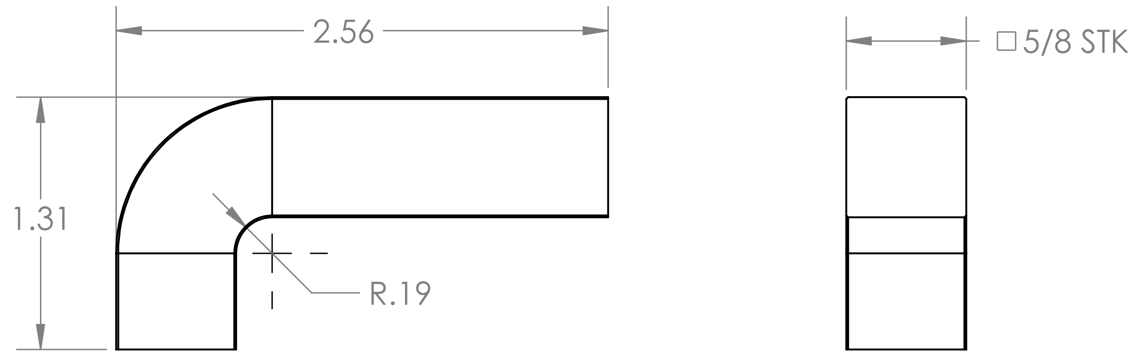
COMMENTS:

TITLE:

Upper Arm Part 1

SIZE	DWG. NO.	REV
A	P01-3-01	A

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

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NEXT ASSY	USED ON
A01-02	A01-02

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 304 Steel

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

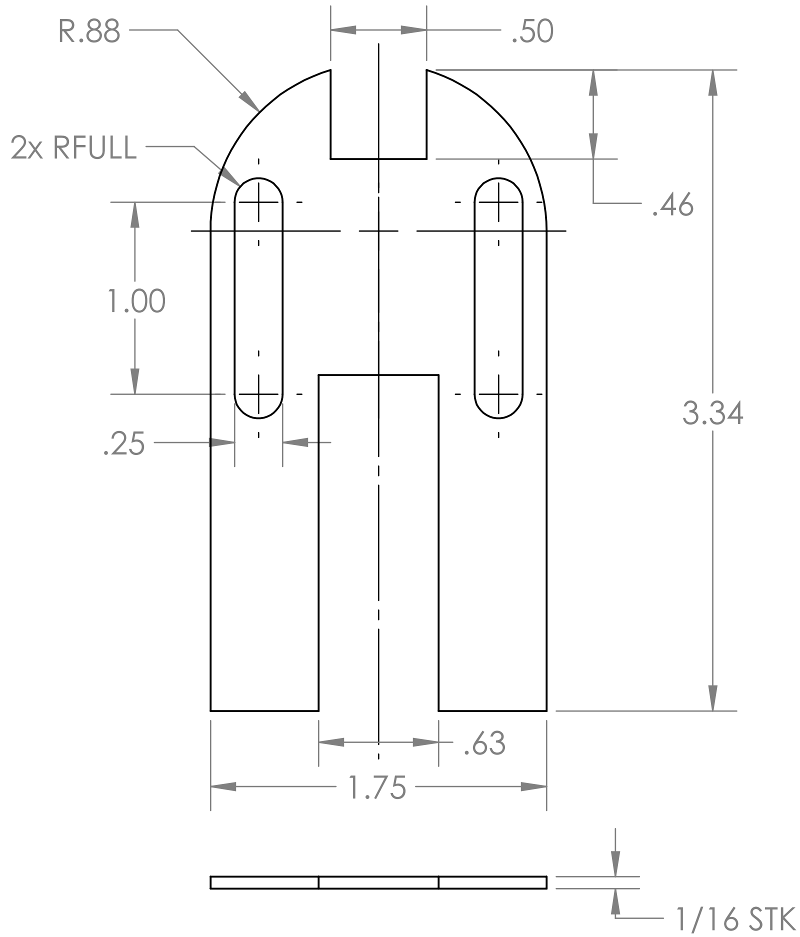
COMMENTS:

TITLE:

Upper Arm Part 2

SIZE	DWG. NO.	REV
A	P01-3-02	A

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



NEXT ASSY	USED ON
A01-02	A01-02

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 304 Steel

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

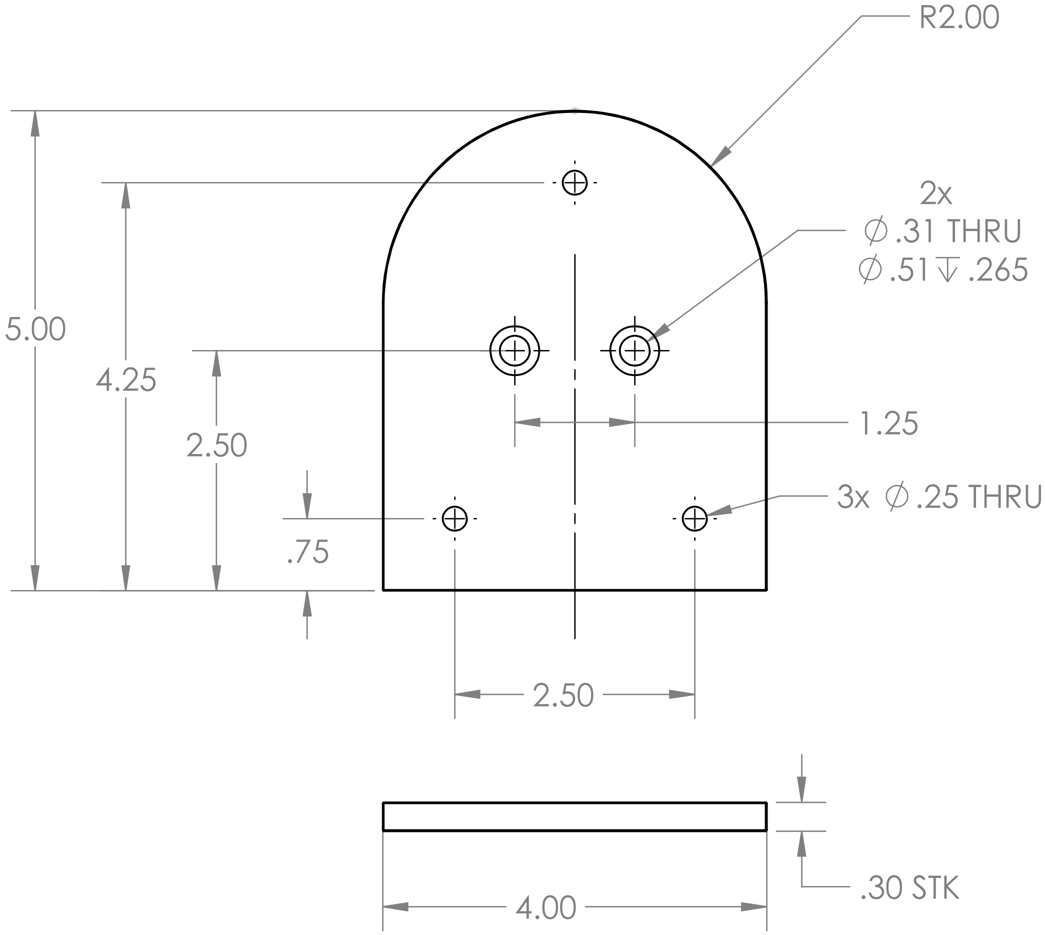
COMMENTS:

TITLE:

Attatchment Plate

SIZE	DWG. NO.	REV
A	P01-4	A

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

A02-01	A02-01
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: PVC

FINISH

DO NOT SCALE DRAWING

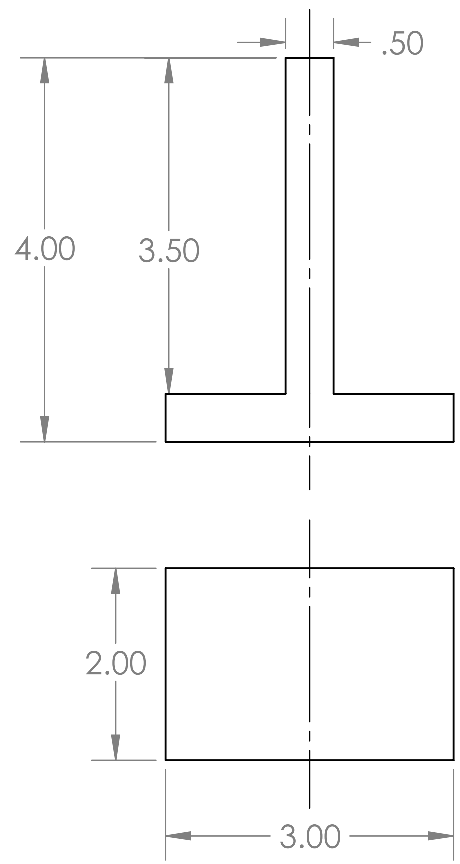
	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

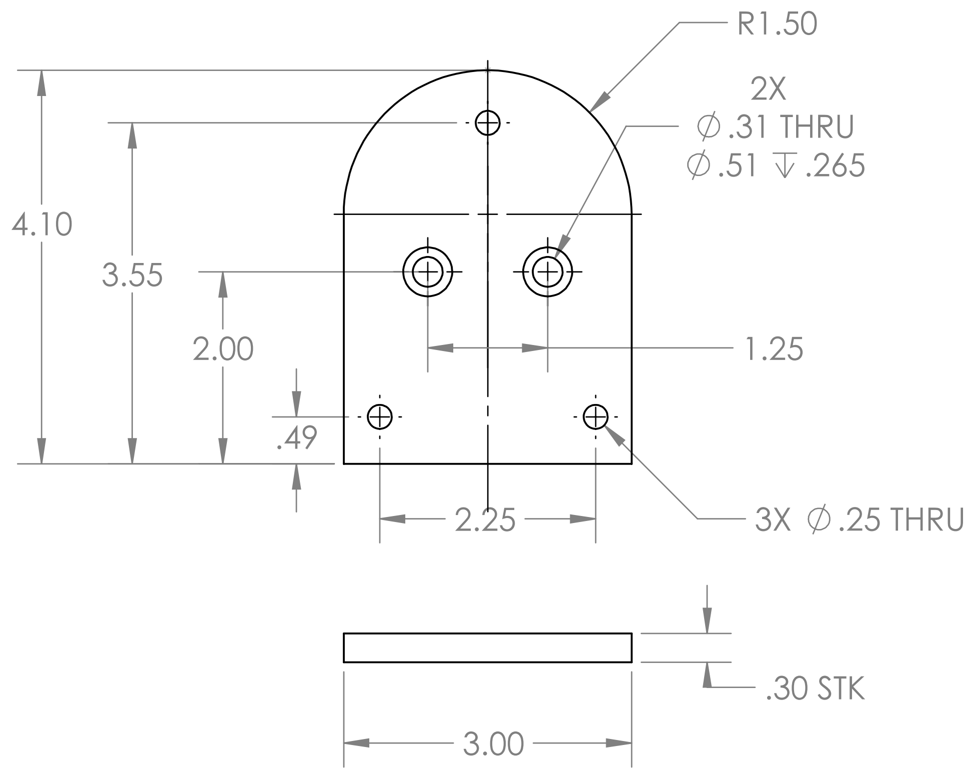
TITLE: Bed (Big Size) Part 1

SIZE	DWG. NO.	REV
A	P02-1-001	A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± .1 ANGULAR: MACH ± 1° BEND ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005	DRAWN	T.C.	2017-12-03	
			CHECKED			TITLE: Bed (Big Size) Part 2
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
A02-01	A02-01	MATERIAL Wood	COMMENTS:			SIZE A · DWG. NO. P02-1-002 · REV A
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 · WEIGHT: · SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

NEXT ASSY	USED ON
A02-01	A02-02

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: PVC

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

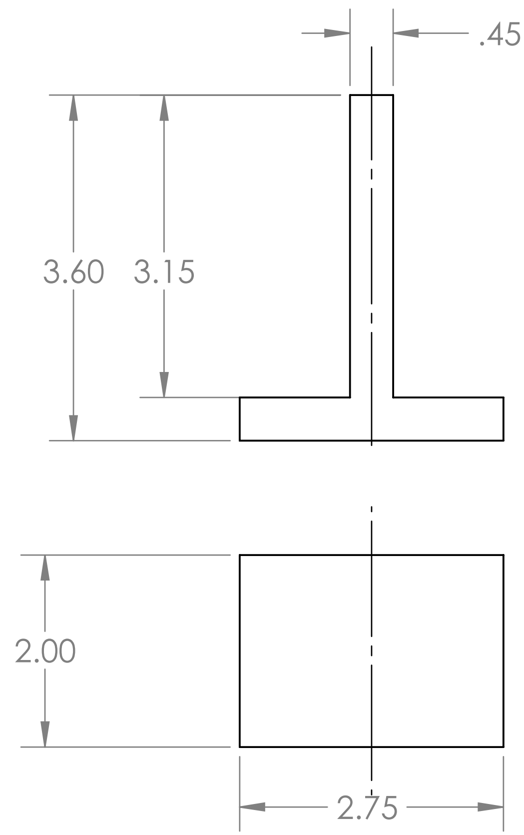
COMMENTS:

TITLE:

Bed (Mid Size) Part 1

SIZE	DWG. NO.	REV
A	P02-2-001	A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1



A02-01	A02-02
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Wood

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

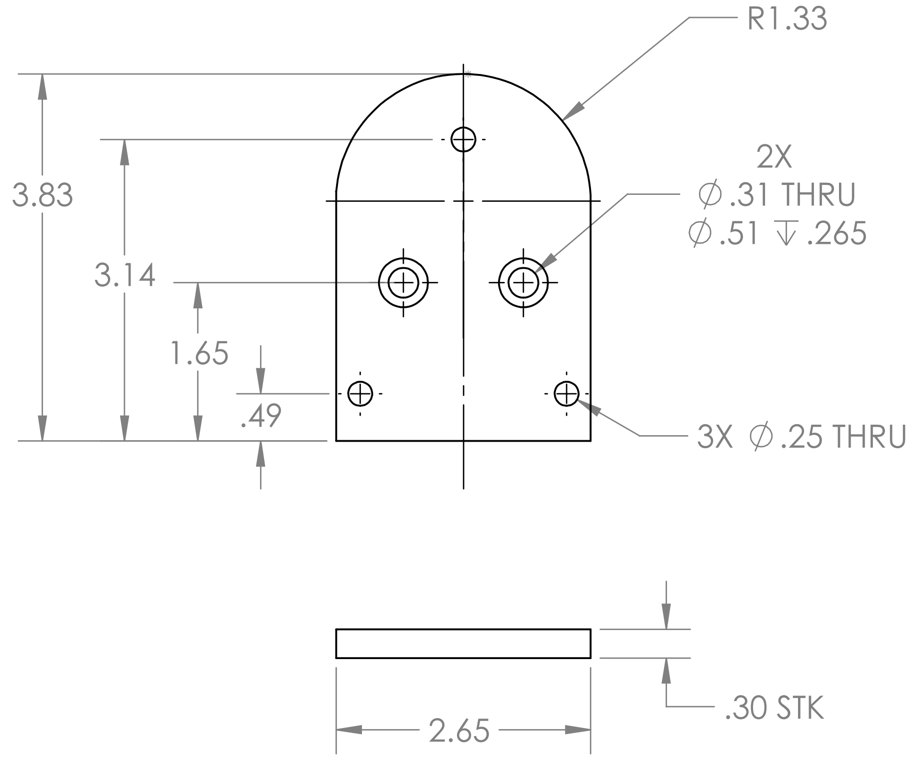
COMMENTS:

TITLE:

Bed (Mid Size) Part 2

SIZE	DWG. NO.	REV
A	P02-2-002	A

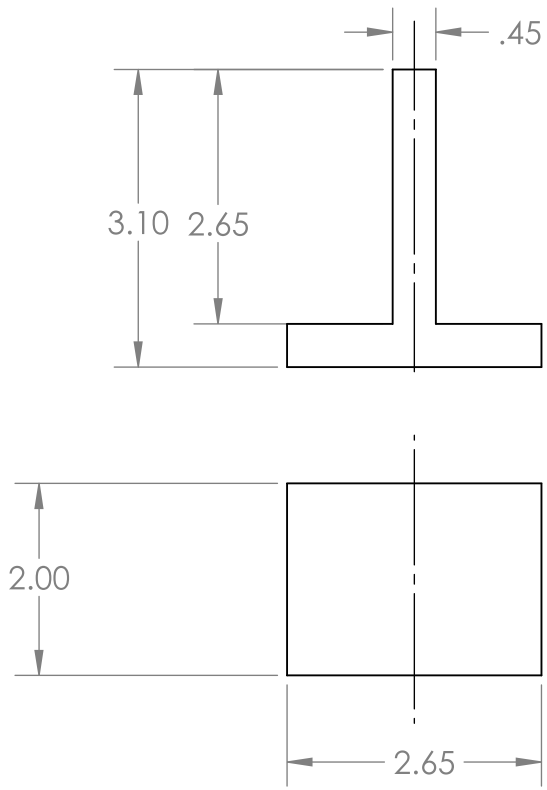
SCALE: 1:2 WEIGHT: SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± .1 ANGULAR: MACH ± 1° BEND ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005	DRAWN	T.C.	2017-12-03	
	CHECKED			TITLE: Bed (Small Size) Part 1
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL PVC	COMMENTS:			
FINISH				
DO NOT SCALE DRAWING				

A02-01	A02-03
NEXT ASSY	USED ON
APPLICATION	

SIZE	DWG. NO.	REV
A	**P02-3-001**	A
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



PROPRIETARY AND CONFIDENTIAL

NEXT ASSY	USED ON
A02-01	A02-03

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± 1°
BEND ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: Wood

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	T.C.	2017-12-03
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE: Bed (Small Size) Part 2

SIZE	DWG. NO.	REV
A	P02-3-002	A

SCALE: 1:2 WEIGHT: SHEET 1 OF 1