ENGINEERING

McMaster University

Project Four – Power in Community

The Supporter

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial T05

Tues-22

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Executive Summary:

Our client loves to paint but has some difficulty using her arms or hands for long periods of time without any pain due to her lymphedema. Bearing the own weight of her arm causes fatigue and she struggles to paint with ease. So, our team designed a solution that would allow the client to paint more comfortably and with a wide range of motion without having to bear the weight of her own arm. Our final prototype is an adjustable wooden tripod which holds up a linkage connected to an arm rest as shown in Figure 1. The height of the tripod and the linkage is adjusted through wide ergonomic tightening knobs which do not put a strain on the client's hands as shown in Figure 10 and Figure 11. The knobs for the legs are positioned at the client's waste to ensure she doesn't need to bend down, preventing any strain in her back. The arm rest can be adjusted from left to right as well using the tightening knob. Some benefits of the prototype are that it is lightweight, cost efficient, and easy to set up. In addition, our design has been accommodated to ensure that our client can use our device in several positions since the legs and arm rest are adjustable. Additionally, our device can be used for loading the dishwasher, sculpting, and any other activities involving weight bearing of her arm making our device multipurpose. The little triangular gaps in the arm rest can be place holders for her brushes as well. Looking at materials, we chose to add memory foam lined with silk to the arm rest since it is gentle and comfortable on her skin considering her Fibromyalgia. It is also removable so she can clean it periodically since painting can get messy. We understand that every day is unpredictable for our client and so we built our device to adapt to her changes.

Figure 1: The Supporter at its lowest height and linkage fully extended.

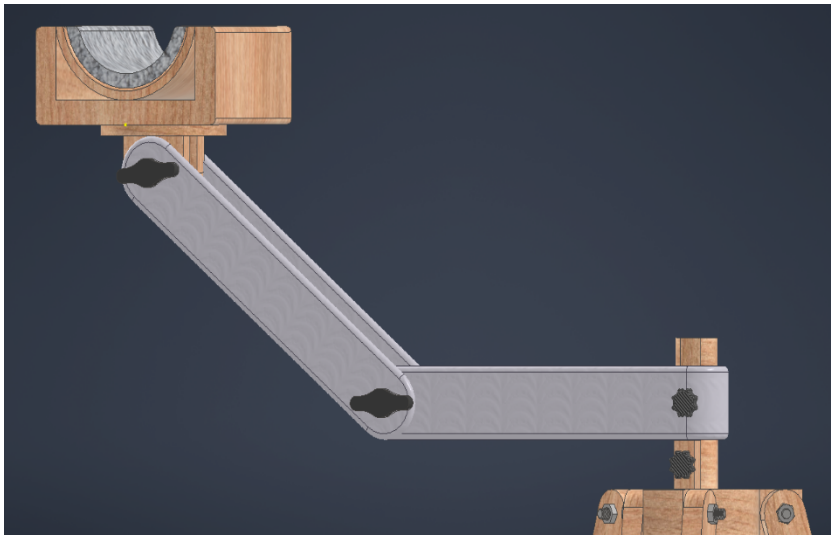


Figure 2: Close up of arm rest and linkage

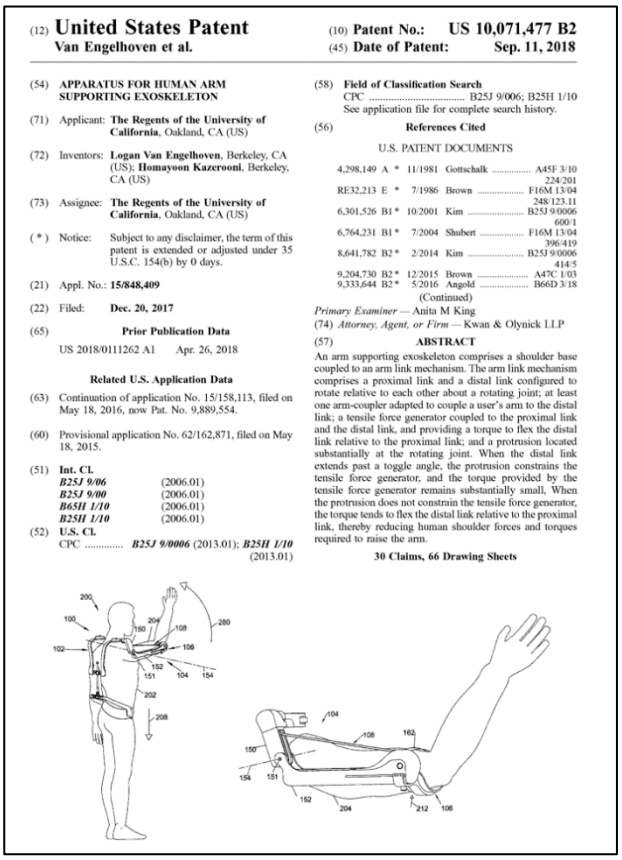
Moving forward, if we had more time and money, we wanted to test out other alternatives of height adjustment of the legs including the use of linear actuators attached to the bottom of the legs. When the client pushes a button with her foot, the legs would rise or fall and that would eliminate any bending at the waist in

consideration of her spondylitis. Additionally, we would like to consider adding a tray for the client to put her paints and paint brushes on but that would take time since we would need to work out the weight distribution of the tripod and the client's arm. Finally, if we had more time and money, we would refine our physical prototype by changing the wooden linkage to a stainless-steel one since it would increase stability and durability and line the arm rest with memory foam and silk. These were all parts of our final CAD design. We also would want to work on finding more people who have conditions similar to Allana's to test out our device, allowing us to improve our design further. With the time and budget available to us, we were unable to try to incorporate all of these ideas.

Introduction:

Our client has lymphedema, a condition that is developed after cancer treatment. It can cause severe swelling and pain in her arms and hands. There are several factors that trigger lymphedema including, straining of the hands or arms, when the affected area is under compression, if the skin is cut, cracked, or damaged, or if her arms are left hanging for too long [3]. In addition, her hands and arms feel fatigued easily if she bears too much weight for long periods of time, which makes it very difficult for our client to carry out a task involving lifting, the use of fine joints (due to arthritis) and applying pressure on her hands [3]. So, the problem we wanted to solve for our client was to design a system that reduces weight bearing on the client's biceps, triceps, arms, and peck muscles to minimize the weight applied on their upper body and increase its functionality to allow for painting and sculpting with ease. This led to our main objectives of our device being: reliable, multipurpose, ergonomic, and cost efficient. We have tested for reliability through physical and Autodesk testing to show range of motion and ensure that our device is safe, sturdy, and long lasting. It is multipurpose, since our client can use the device when painting in several positions, due to the adjustability of the legs and the arm rest. It can also be used to carry out other tasks involving weight bearing of her arm. Our device was made ergonomically through the use of wide tightening knobs and memory foam padded arm rests lined with silk, which is a material our client mentioned is gentle on her skin. As for cost efficiency, our device was made of inexpensive and easily accessible materials. We used ash wood to build the tripod legs and the arm rest which are sealed with a topcoat to prevent damage and wearing down. The linkage is built of stainless steel and the knobs, nut and bolts, and screws are low cost. In the process of making our device, our team viewed a few patents to see other existing ideas and solutions that could help us improve upon our design.

We looked at several different designs of adaptable arm rests including exoskeletons and linkage type designs, similar to ours to help understand the restrictions, portability, price, and range of motion achievable of these designs. In Figure 3, an exoskeleton arm connected to a back brace provides a good range of motion, but the back brace could potentially put a strain on the clients back considering her spondylitis and increase fatigue. It also restricts the client to only standing and painting where instead she needs a device that adapts to her daily changes and allows her to paint in many different positions. Although a price is not given for the device in Figure 3, the general price for an arm exoskeleton is approximately $180 and higher. Figure 4 shows a tripod arm rest with limited range of motion, lack of support, and a non-ergonomic design since the knobs are not adaptable to individuals with a wider grip. Its price ranges from approximately $90 to $170. Another arm rest found is one that needs to be mounted to a platform as shown in Figure 5. It must be attached to a surface such as a table to be used and can allow for only horizontal movement of the arm. It is restricted to one position which is not convenient when painting. Its price varies between $30 and $100. Although the price of our device is $120 or less and is about the mid-range price of the three devices below, our design incorporates aspects that current devices do not have including range of motion, comfort, portability, and multifunctionalities, which makes it optimal for our client.



(12) **United States Patent**
Van Engelhoven et al.

(10) **Patent No.: US 10,071,477 B2**
(45) **Date of Patent: Sep. 11, 2018**

(54) **APPARATUS FOR HUMAN ARM SUPPORTING EXOSKELETON**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Dec. 20, 2017**

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(60) Provisional application No. 62/162,871, filed on May 18, 2015.

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B25J 9/06 (2006.01)
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B25H 1/10 (2006.01)

(52) **U.S. Cl.**
CPC ***B25J 9/0006*** (2013.01); ***B25H 1/10*** (2013.01)

(58) **Field of Classification Search**
CPC B25J 9/006; B25H 1/10
See application file for complete search history.

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(57) **ABSTRACT**

An arm supporting exoskeleton comprises a shoulder base coupled to an arm link mechanism. The arm link mechanism comprises a proximal link and a distal link configured to rotate relative to each other about a rotating joint; at least one arm-coupler adapted to couple a user's arm to the distal link; a tensile force generator coupled to the proximal link and the distal link, and providing a torque to flex the distal link relative to the proximal link; and a protrusion located substantially at the rotating joint. When the distal link extends past a toggle angle, the protrusion constrains the tensile force generator, and the torque provided by the tensile force generator remains substantially small. When the protrusion does not constrain the tensile force generator, the torque tends to flex the distal link relative to the proximal link, thereby reducing human shoulder forces and torques required to raise the arm.

30 Claims, 66 Drawing Sheets

Figure 3: Patent showing an arm exoskeleton connected to a back support for stability

Figure 4: Tripod armrest with limited range of motion and support

Figure 5: Mountable armrest restricted to one position

Conceptual Design:

During the ideation stage of the design process, we generated solutions to our problem statement through researching existing solutions, brainstorming, sketching, and prototyping. We refined our solutions through the usage of decision matrices and accounting for feedback from design evaluations. Initially, our team examined characteristics and functionality of current arm-rest solutions to our problem statement to identify why the problem still exists, which helped us to develop more effective solutions. After our examination, we found that all existent arm-rest solutions allowed for a limited range of motion of the arm while they provided support; thus, providing full range of arm-movement for our client was our main objective during the ideation process. Then, we performed a functional analysis with a morphological chart, which allowed us to identify all the main functions the solution should perform as well as several different means of carrying out each function. Our main functions included height adjustment, stabilizing the arm, allow for gripping paintbrush horizontally, bearing the weight of an arm, does not restrict movement, and provides comfort. Based on our functions and means, each team member produced two initial concept sketches. Next, each team member created an initial refined prototype of one concept sketch. The first initial refined prototype was an AutoCAD model of a device resembled a tripod like structure with three adjustable legs, using large tightening knobs (for easy grip) and a concave padded arm rest (with a non-irritable material) to bear the weight of our client's arm. The second was an AutoCAD model of a device resembling a linkage attached to an armrest, which, through joints, would move as our client's arm moves, allowing her to rest her dominant arm while painting. This device would mount to the easel used by our client. The third was an AutoCAD model of a multi-functional device which allowed our client to paint on the ground or standing up. This device would allow for a canvas to be placed underneath while painting on the ground. While on the ground, an arm rest (padded with memory foam), free to rotate and lock about an axis, would bear weight and an adjustable strap for stabilization. The arm rest is attached to a rod which can move up and down and lock into the desired position. The mechanism also vertically attaches to an easel through the two holes on the supporting bars. Lastly, our fourth was an AutoCAD model of a device with a built an arm rest

Function	Mean 1	Mean 2	Mean 3	Mean 4
Height Adjustment	Lever	Clamp tightening knob	Motors	Hinge/ Flexible joints
Stabilize her arm	Arm rest	Strap	Arm cuffs	Wrist mat (memory foam)
Gripping paintbrush horizontally	A large ergonomic grip that can hold any paintbrush	Using a hook	Storage compartment that can hold any size paintbrush	Wearing a glove that holds the paintbrush
Hold the weight of her arm	Arm rest	Tripod	Strap that comes down from the ceiling	Arm brace (connected to her waist as a belt)
Doesn't restrict movement	Has wheels	It isn't attached to her so she can move away from it easily	Slidable arm rest	Rotatable
Provide Comfort	Comfortable materials (no sharp or objects)	Using memory foam	Can take the shape of her body	Can provide heating

Figure 6: Morphological Chart

attached to a height adjustable stand that can be used while painting standing up. The arm rest can rotate 360 degrees and up and down about a hinge and the legs are easily adjustable by becoming locked at the height a preferred height. The arm rest could also be removed and attached to a sliding rectangular base plate to allow for painting while laying down.

Next, we evaluated each prototype against criterions using weighting established in a decision matrix. Our criterions in ascending order of weighting were multi-purpose, easy to assemble, ease of use, does not restrict movement and ability to bear weight as seen in Figure 1. Ability to bear weight was weighted the most, as it was the main intended function of our device. According to our problem statement, weight bearing while painting was the issue our solution would address. Secondly, does not restrict movement, since a wide range of motion is necessary during the painting process. Multi-purpose, easy to assemble, and ease of use tied in weighting. Easy to assemble and ease of use are important because our client has various medical conditions that restrict her from any labor-intensive physical activity that may be required with complex devices. Finally, multi-purpose is crucial since our client paints in various positions in accordance with her physical limitations, therefore our device must allow her to do so.

	Multi-purpose	Does not restrict movement	Easy to assemble	Ability to bear weight/Reliability	Ease of use /Simplistic design/ Realistic	**Score**
Multi-purpose	1	0	1	0	0	2
Does not restrict movement	1	1	1	0	1	4
Easy to assemble	0	0	1	0	1	2
Ability to bear weight/Reliability	1	1	1	1	1	5
Ease of use/Simplistic design/Realistic	1	0	0	0	1	2

Figure 7: Decision matrix

After evaluation, our first and second prototypes ranked highest, as seen in Figure 2, therefore, we decided to present them during our first design evaluation interview. Feedback in regard to the first design was to ensure the arm-rest device linear and rotary motional freedom so that the client can paint in different positions without feeling constraint. In addition, bending down to the level of tightening knob for height adjustment could potentially cause strain on her back, therefore we were advised to incorporate her leg for adjusting height of the tripod since she is leg dominant. Feedback in regard to the second design was to position the arm rest and device such that is to the side of our client to avoid

	Weight	Tripod-Like Design		Linkage-Like Design		Canvas Holding Design		Arm-Rest Design	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Multi-purpose	2	4	8	3	6	4	8	3	6
Does not restrict movement	4	3	12	4	16	3	12	4	16
Easy to assemble	2	5	10	4	8	3	6	4	8
Ability to bear weight/Reliability	5	5	25	4	20	4	20	2	10
Ease of use/Simplistic design/Realistic	2	5	10	4	8	3	6	3	6
TOTAL			65		58		52		46

Figure 8: Design evaluation

it interfering with her ability to paint. Also, we were recommended to add tightening knobs to prevent a joint from giving out when weight is applied.

As a result of our received feedback and the outcomes of the decision matrix, we decided to combine the linkage arm design and the tripod arm rest design to create one design which was the linkage arm design attached on top of the tripod arm design. The linkage component allowed for a wide range of linear and translational motion, which was not possible with the tripod arm design. The tripod component provided proper structural support for the linkage component, which would prevent any failures due to weight bearing. Also, we positioned the tightening knobs at arm level for the adjustable legs of the tripod component to prevent strain as mentioned in the feedback.

During our second design evaluation, we were told to make the memory foam padding the arm rest can removable to ensure it can be cleaned. Consequently, we made a removable silk cover, which is her preferred material, for the memory foam padding.

Final Proposed Design:

The final proposed design is an adjustable arm rest that the client could use throughout the day for various tasks such as painting or washing the dishes. Named, “The Supporter”, this design is a tripod that has a linkage and arm rest tightened to it which all can be adjusted to any position with the goal of “supporting” the client’s arm.

Figure 9: The Supporter

Starting off with the tripod seen in Figure 10, this design includes a central plate in which the tripod legs and central rod are tightened to. When undoing any of the three tightening knobs on the bottom of the legs, they can be adjusted up or down however the client would like, to give the best height adjustment for them. When undoing the fourth tightening knob on the central rod, this allows for the rod (which has the linkage attached to it) to be shifted up and down.

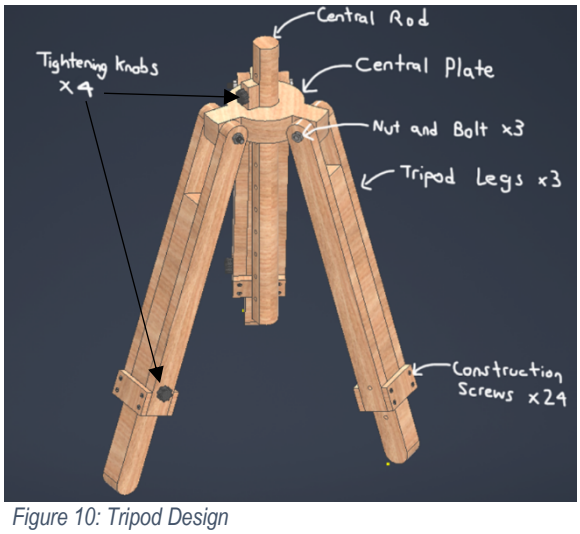

Figure 10: Tripod Design

Moving on to the linkage arm rest in Figure 11, this whole component is what the client is supposed to rest their arm on to give them additional support. The linkage is tightened to the central rod by means of another tightening knob, this allows for the linkage to also be adjusted to any height along the central rod. When undoing the large tightening knob between the linkage arm and linkage rod, it allows for the arm to be rotated to any position.

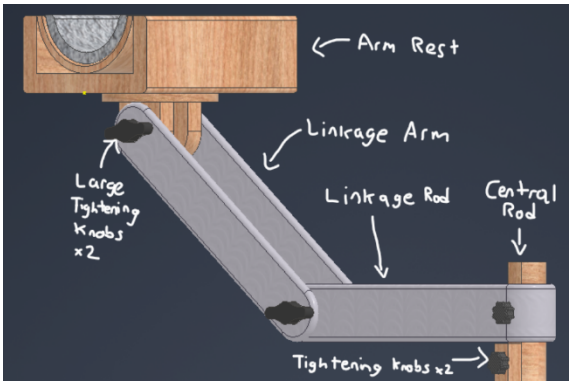

Figure 11: Linkage Design

Finally, when undoing the large tightening knob between the linkage arm and arm rest, it allows for the arm rest to be adjusted to any position.

Overall, the way this mechanism is designed allows for arm support at essentially any place she wants. We believe this would be very helpful when doing certain tasks such as painting as her position would change time to time which is why support at any position is a crucial part of the design.

In the initial stages of the project, a main objective of the design was that it should be ergonomic. This objective was met by using proper dimensions that would be appropriate for the client we were working with as well as taking note of materials used for whatever will contact her skin. When looking at the design's dimensions of the height and arm rest, height can be adjusted in many ways as described above and the arm rest is shaped properly like an arc to allow her arm to rest on it, having a radius 77.43mm. When looking at materials used, the device includes a silk material over a memory foam providing comfort and therefore meeting the objective and being as ergonomic as we could make it. Another objective was the design's reliability which would be met by testing the weight that the mechanism can bear. When testing the prototype made in real life with different weights, the mechanism and it's tightening knobs withstood well over the amount of weight of a human arm and more, therefore meeting the objective. Finally, cost efficiency was the last main objective of the design that was met by using cost effective materials and looking at the cost of the final prototype that was made. This is talked about below.

The mechanism was constructed out of inexpensive and easily accessible materials. The tripod, and arm rest within the mechanism are made from ash wood, which ranges from $6-$15 per 2 in. x 4 in. x 8 ft. plank [2]. They are sealed with a clear polyurethane topcoat that costs approximately $11 per container. Stainless steel sheets that would be used for the linkage range from $30-$50 [2]. In addition, yellow zinc construction screws were used, which are approximately $0.11 per screw. Aluminum knob tightening screws were extensively in the mechanism, which cost approximately $1.30 per knob. Stainless steel hex nuts and bolts were used throughout the mechanism, which totalled to $0.52 per hex nut and $0.27 per bolt. Lastly, the memory foam blocks with our desired dimension would range from $15-$25 and a silk roll with our desired dimensions would cost $12-$28 [2]. Our current prototype (using a wood linkage instead of steel and no memory foam) has cost us approximately $80, and the finalized mechanism would not exceed $110. The machines and tools used to construct the design include planer, jointer, a table saw, mitre saw, jigsaw, belt sander, drill, drill bits, ratchets and sockets, clamps, wood glue and epoxy. Final engineering drawings are included on page 38 of the design report.

Figure 12: The Supporter, Real Life Model

Conclusions:

In the future, when given more time, our group would like to refine our physical prototype to a high-fidelity prototype by building it using the same materials as our CAD model. This includes the stainless-steel linkage and adding memory foam lined with silk on the arm rest. Furthermore, we would like to explore the idea of using linear actuators with a pedal for the foot where when it is pressed, the height of the tripod can be raised or lowered (just like a chair at the salon). We could also possibly consider adding a foldable tray on the device for her paints and paint brushes, so they are easily accessible to her. Another concept we would like to test would be the idea of having wheels at the bottom of each tripod leg with locks to increase ease of portability and movement. All these ideas could be accomplished and further tested for safety and convenience if we were given more time.

Looking back at this project, we have learned a lot about the design process and how not everything can be pre-planned. Our group learned to be open to new ideas, changes, and solutions throughout the design process. We understood that all our planning, ideas, and designs are not the final solution; there could be other changes along the way. When we were prototyping, we went back to the select and brainstorm part of the design process

many times as we were coming up with possible solutions to support the joint on the linkage while still providing a wide range of motion. This taught us that it is possible to go backwards in the design process and re-evaluate certain aspects of our design. We learned through design failure and feedback as we faced challenges such as supporting the linkage from giving out and preventing the tripod from tipping over. This was an important learning experience, as it tested our creativity and taught us to find alternative solutions within a given time constraint. One aspect our whole team took away from the experience of working on this project together is that communication and openness to new ideas is crucial in coming up with an optimal design that will meet the needs of our client. Through thorough communication we were able to portray several different ideas and solutions and worked through our challenges. We also planned ahead of time for what will be done and split the work between each team member, focusing on assigning work to each person in their area of strength. Building off of this, we learned the importance of applying critical feedback from each other or from science students to our design to improve upon parts of our device that could have been a problem or re-evaluating our design to enhance it. This allowed us to consider all of the clients' needs and view certain aspects of our design with a different perspective.

We would structure the design process differently by spending more time prototyping and refining our device to find potential issues or improvements that could make our design better. This includes prototyping physically for testing purposes. Physical testing brings up issues and benefits of the design that cannot be seen on CAD which is why we would want to spend more time on it as it is important in ensuring that our device is safe and durable. Additionally, incorporating feedback or thoughts from the client about our design after prototyping would be a step we would add in the design process because she is the one who would be using the device. Getting her thoughts and comfort level about certain aspects of our design such as the tightening knobs and the materials used would allow us to build a device that would adapt to her very well.

If we were to work together as a team again, the one thing we would change would be for all of us to be able to work on building the physical model together and making the CAD components with each other instead of having only 2 people do it. This would allow everyone to understand how the physical model is built and for each team member to be able to fully explore the different kinds of tools and materials used to build it. Other than that, all group members were understanding, open-minded, and well organized which helped us complete our work on time. Each individual communicated their thoughts for every stage through the progression of this project which resulted in a well-designed device given the amount of time we had.

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Appendices

Appendix A

Medical Documents:

Autoimmune diseases are very painful and stressful. There are over 80 types and they affect parts all over the body and cause a wide variety of symptoms [18]. That is why I want to know how these diseases affect our client Alanna's physical capabilities, very specifically ergonomics. As our team has been tasked with designing a device to improve Alanna's daily life [1], it is very important to know which body and limb positions can cause pain and discomfort, so we avoid the need for these positions to interact with our device. First, I will discuss Ankylosing spondylitis (AS), a rare type of arthritis that causes pain and stiffness in the spine [19]. AS can also cause pain and stiffness in the hands, ribcage, hips, thighs, feet, and shoulders; it could even cause fusion of the vertebrae [19]. So, how does AS affect your everyday ergonomics? Let us look at the example of working an office job, what are the dos and don'ts of managing AS. Since AS can make your back stiff and painful, you want to make sure you are sitting with your thighs at a 90-degree angle while planting your feet flat, and the chair ought to support your spine [20]. If you are typing on a keyboard, or maybe in Alanna's case holding a paintbrush, you should hold your wrists and arms level and maybe consider a wrist cushion or mat (perhaps this is something our device could include) [20]. Some other things to consider are having the correct eye level with your work (monitor or easel is at eyelevel) and keeping items close so you do not repeatedly overstretch (as AS affects tendons and ligaments too).

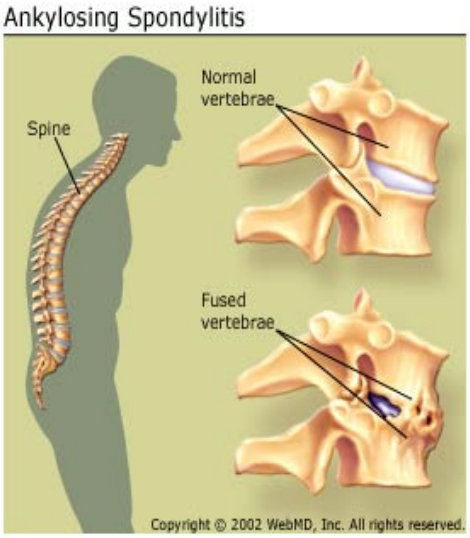


Figure 13: Effects of Anylosing Spondylitis on the Vertebrea [38].

Furthermore, Lymphedema is another autoimmune disease defined as swelling most frequently in the arm(s) and/or leg(s) [21]. Common symptoms are partial or full swelling in your arms, legs, fingers, toes, heaviness, restricted motion and thickening of skin [21]. To accommodate the discomfort caused by Lymphedema, it is very important to avoid injury to the skin from sharp objects and tools [22]. Positional supports like pillows, armrests and braces are crucial to elevate swollen limbs [22]. Additionally, small parts may be tough to work with because of finger swelling, so using speech recognition instead of a keyboard and having large diameter handles are something our client would appreciate [22].

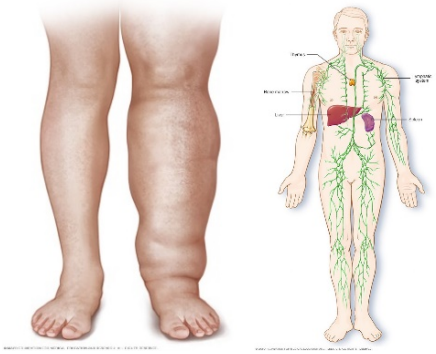


Figure 14: Leg lymphedema (on the left) and the Lymphatic system (on the right) [21].

Lastly, let us look at Fibromyalgia, where lightweight and rest is the 'name of the game'. Fibromyalgia is a disorder where broad musculoskeletal pain, fatigue, sleep, memory, and mood problems occur [23]. Fibromyalgia causes these symptoms because the disorder amplifies pain processing in the Nervous System [23]. If our device is to be wearable, it is important for Fibromyalgia patients to wear lightweight, warm, and layered fabrics [24]. Resting and not overworking yourself it important as this could cause flares. Therefore, it is important to not lift very heavy objects (our device must be lightweight!). Like the other auto-immune disorders, positional rests, mats and even feet cushions (could be insoles, a mat, or slippers) relieve a great deal of pain [24].

Lymphedema is a disease that is mainly caused by removal of the lymph nodes during cancer treatment. It causes swelling in the arms and legs, specifically fingers and toes. When swelling occurs, it can cause heaviness, pain, and limited range of motion [33]. If too much fluid is built up in the soft tissues under your skin or if lymph fluid cannot drain well which causes a blockage in the lymphatic system, flare ups will occur [33]. This is triggered by air travel due to the changes in air pressure, injury or infections to the specific limb or area, exposure to excessive heat, lifting heavy weights, and applying too much pressure to the area [31].

Constriction or squeezing of the arms or legs will increase blood pressure and fluid flow near those lymph vessels. This will cause swelling since those vessels may not exist or are damaged [34]. This is why it is important to wear loose clothing that does not apply pressure to the given area [32]. Compression sleeves have known to help reduce swelling and pain; however, they need to be fitted well [30].

Figure 15: Compression pump for the arm [39].

Flare ups can occur if arms or legs are left hanging for too long. They need to be kept elevated so that any fluid build-up flows back into the body to prevent swelling and increase circulation [32]. A lymphedema compression pump has been found to be very helpful with allowing the fluid to properly flow throughout the body [30]. A comfortable sleeve easily

connects to your arms, legs, or torso as needed. It inflates and deflates, applying appropriate pressure to the area and pumping the fluid back into your body to exercise proper circulation [29].

Flare ups can also occur if the skin has been damaged, cut, or cracked. This is because white blood cells move to the limb that is injured to try and heal it, but this will cause fluid buildup since those vessels are missing or damaged which again causes swelling and pain [44]. So, it is important to keep those limbs protected. It is encouraged to bandage the area appropriately when doing certain activities to prevent any cuts or scrapes [28]. Bandaging with gauze, stockinette, or tubular bandages are the most recommended materials since they are gentle on the skin but still provide protection and relief [26].

Figure 16: Bandaging using gauze [36]

Repetitive movements and over exertion of the affected limb will cause flare ups as well, however, small exercise like movements is important in keeping fluid flow throughout the body and most importantly for the affected limb [27]. Soft stress balls, finger stretchers, and 1-to-3-pound weights are good tools to help regain strength in hand muscles and fine joints [26].

To conclude, there are several factors that trigger flare ups for individuals with lymphedema, however, devices such as compression sleeves, bandages, and lymphedema compression pumps for the arms, legs, and torso are important devices used to reduce pain, swelling, and fluid build-up.

Commercial Products:

Supplies made for artists with disabilities often use materials and geometry that would have properties which would help the condition. For example, artists with uncontrolled hand movement would prefer a device that would be lightweight and easy to hold/balance with whatever body part they would hold it with. Or artists with weight bearings may prefer a device that would use allow the use of other body parts, thus having durable or biocompatible materials [39]. These materials and geometric properties will be discussed in this summary by looking at previously designed art supplies.

A common art supply used by people who have neurological disorders, cerebral palsy, spinal cord injuries or upper extremity disabilities is a mouth stick [35]. This stick is commonly made from lightweight materials, such as aluminum or stainless steel [36]. Aluminum is a material that is lightweight, soft, ductile corrosion resistant and has a high electrical conductivity [37], and since the mouth stick is held by the mouth, the lightweight and soft properties of aluminum are very useful in allowing the user to hold this art supply for extended periods of time. Stainless steel is a material that is durable, has a long-life span, high tensile strength, corrosion resistance, and is environmentally friendly [38], and since the stick is something used daily, the long-life span and durability of it is very beneficial. The other component is the mouthpiece that attaches to the aluminum stick [39]. These mouthpieces are made from thermoplastic materials with low melting points to mold to the mouth easier. They are biocompatible to not leave a taste in the mouth and are thin to comfort the user of the device [39].

Another common art supply used are the egg-handled paint brushes. This is often used by people who have trouble gripping onto things, fine motor, or arthritis [40]. These brushes have more focus on the geometric/ergonomic design rather than materials, having handles shaped in an urn-shape [40]. This is what helps the artist grip onto the paintbrush easily and allows them to have a steadier hand when completing their artwork.

Overall, lightweight, durable, high tensile strength materials and ergonomic designs are the main properties that were seen to help people with disabilities in creating art as these properties did a good job in assisting the user with their disability. In our initial problem statement, we specified in creating an everyday system that reduces the weight bearing on the client's upper body to help with her condition, meaning lightweight, and durable materials should be considered when designing a solution. So, in theory, aluminum, and stainless steel would great options for materials in devices to be designed if they fit the criteria. Also mentioned was the feasibility of the system, as it should be easy for the client to use. Thus, modifying ergonomics in a way that would help the client's upper body is crucial in assisting her with creating the best art she can in a comfortable position.

Figure 17: Egg handled paint brushes [41].

Using art as a form of therapy can often provide disabled individuals a sense of personal accomplishment. Art can help to improve one's outlook on life, voice unexpressed emotions, and allows for communication with the world, especially in the case of those with physical disabilities. Artists that deal with disabilities in their everyday lives have found various methods to produce beautiful and intricate art pieces regardless of the adversity that they face. Art and sculpting supplies often need to be tailored specifically for persons with disabilities for support and to ensure their success. However, it can be difficult and highly expensive to find or purchase such tools, therefore; "big box" retailers, which offer bargain prices, are the only option. Thus, it is crucial to consider the generic dimensions of art supplies during the design process of our solution.

Floor easels are an essential tool for large-scale painters. They are commonly designed with upper and lower canvas support so they can hold large canvases, up to 100" and 25lbs, while adjusting up to 15 to 30 degrees [42], [43]. The height of floor easels is typically adjustable and ranges from a maximum of 122" to a minimum of 74", with a base width and depth of 30". Shelf width and depth are commonly 27.5" and 3" respectively [42], [43]. This tool additionally often features non-skid rubber feet for stability [42], [43].

Popular painting surfaces include canvas panels and canvas boards since they are more stable and portable and can be set up easily within a studio [44]. Canvas boards and panels are usually covered with cotton or linen canvas that is secured to a wood, wood fiber, or MDF backing [44]. Canvas panels and canvas boards are available in a multitude of sizes varying from 40" by 12" to 72" by 48" with a depth ranging from 18mm to 38mm [44].

Artists' paintbrushes come in an array of sizes, shapes, and hairs. Brushes with longer handles are up to 12″ are helpful for easel work, while the short ones are around 6″ and are used detailed work [45]. Round brush diameters range from 1/64" to 11/16", while flat, bright, and filbert brush widths range from 1/32" to 31/32" [45]. Foam brushes are also used for a wide variety of art applications. Common dimensions include 3" for foam rollers and 1" to 3" for foam brushes [46]. In addition, paint wedges are ergonomically designed painting tools utilized by many artists. They are offered in various shapes with an approximate width of 102 mm and length of 76mm [47].

A commonly used sculpting tool such as sculpting, and armature wire has dimensions of 0.13" by 20ft [48]. Another tool is palm carvers, which are 4 to 3/4" with wooden handles[49].

Although accessible and affordable adaptive art supplies exist, there is not a wide variety. Egg handled brushes are ergonomically designed paintbrushes with a rounded handle to allow for gripping and a flat side on the handle to prevent rolling when not in use [49]. Mop brushes, which are shaped like a shaving brush, and grip brushes, which have a knob-shaped end, are also other easy-to-hold designs for those with physical limitations[48].

Patents:

US 20160081871A1

(19) **United States**

(12) **Patent Application Publication**

Doyle

(10) **Pub. No.: US 2016/0081871 A1**

(43) **Pub. Date: Mar. 24, 2016**

(54) **ADAPTIVE ARM SUPPORT SYSTEMS AND METHODS FOR USE**

(71) Applicant: **LEVITATE TECHNOLOGIES, INC.**, San Diego, CA (US)

(72) Inventor: **Mark C. Doyle**, Del Mar, CA (US)

(21) Appl. No.: **14/960,243**

(22) Filed: **Dec. 4, 2015**

Related U.S. Application Data

(63) Continuation of application No. 13/353,268, filed on Jan. 18, 2012, now Pat. No. 9,205,017.

(60) Provisional application No. 61/433,840, filed on Jan. 18, 2011, provisional application No. 61/507,535, filed on Jul. 13, 2011.

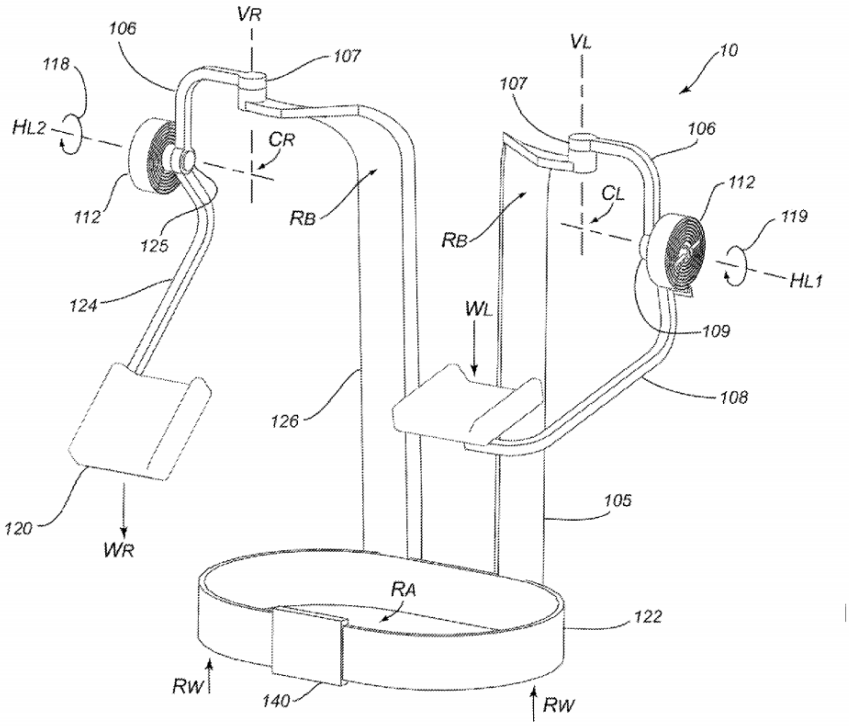
Publication Classification

(51) **Int. Cl.**
A61H 1/02 (2006.01)

(52) **U.S. Cl.**
CPC *A61H 1/0274* (2013.01)

(57) **ABSTRACT**

A system is provided for supporting an arm of a user that includes a harness configured to be worn by the user, and an arm support coupled to the harness and including an arm rest to support an arm of the user. The arm support is configured to accommodate and follow movement of the arm without substantially interfering in such movement. The arm support may at least partially offset a gravitational force acting on the arm as the user moves and the arm support follows the movement of the user's arm. For example, the arm support may transfer at least a portion of the weight of the user's arm to the torso or other region of the user's body and/or may apply an opposing force to at least partially offset the gravitational force acting on the arm.



[50]

(12) **United States Patent**
Van Engelhoven et al.

(10) **Patent No.: US 10,071,477 B2**
(45) **Date of Patent: Sep. 11, 2018**

(54) **APPARATUS FOR HUMAN ARM SUPPORTING EXOSKELETON**

(71) Applicant: **The Regents of the University of California**, Oakland, CA (US)

(72) Inventors: **Logan Van Engelhoven**, Berkeley, CA (US); **Homayoon Kazerooni**, Berkeley, CA (US)

(73) Assignee: **The Regents of the University of California**, Oakland, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/848,409**

(22) Filed: **Dec. 20, 2017**

(65) **Prior Publication Data**

US 2018/0111262 A1 Apr. 26, 2018

Related U.S. Application Data

(63) Continuation of application No. 15/158,113, filed on May 18, 2016, now Pat. No. 9,889,554.

(60) Provisional application No. 62/162,871, filed on May 18, 2015.

(51) **Int. Cl.**

B25J 9/06	(2006.01)
B25J 9/00	(2006.01)
B65H 1/10	(2006.01)
B25H 1/10	(2006.01)

(52) **U.S. Cl.**

CPC ***B25J 9/0006*** (2013.01); ***B25H 1/10*** (2013.01)

(58) **Field of Classification Search**

CPC B25J 9/006; B25H 1/10

See application file for complete search history.

(56) **References Cited**

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(Continued)

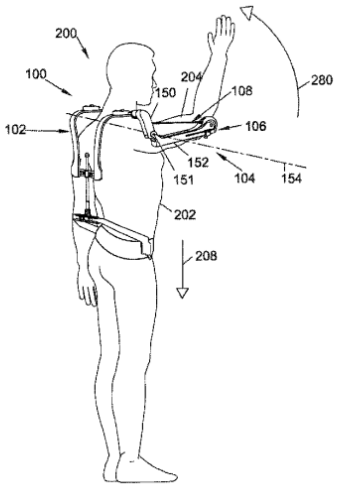
Primary Examiner — Anita M King

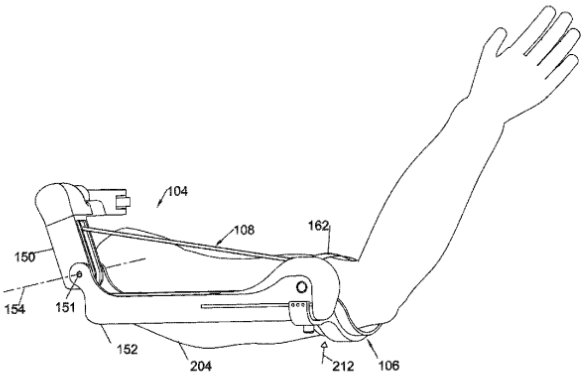
(74) *Attorney, Agent, or Firm* — Kwan & Olynick LLP

(57) **ABSTRACT**

An arm supporting exoskeleton comprises a shoulder base coupled to an arm link mechanism. The arm link mechanism comprises a proximal link and a distal link configured to rotate relative to each other about a rotating joint; at least one arm-coupler adapted to couple a user's arm to the distal link; a tensile force generator coupled to the proximal link and the distal link, and providing a torque to flex the distal link relative to the proximal link; and a protrusion located substantially at the rotating joint. When the distal link extends past a toggle angle, the protrusion constrains the tensile force generator, and the torque provided by the tensile force generator remains substantially small, When the protrusion does not constrain the tensile force generator, the torque tends to flex the distal link relative to the proximal link, thereby reducing human shoulder forces and torques required to raise the arm.

30 Claims, 66 Drawing Sheets





[51]

US 20050012376A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2005/0012376 A1**

Siminovitch et al. (43) **Pub. Date: Jan. 20, 2005**

(54) **ERGONOMICALLY NEUTRAL ARM SUPPORT SYSTEM**

(75) Inventors: **Michael J. Siminovitch**, Berkeley, CA (US); **Jeffrey Y. Chung**, Walnut Creek, CA (US); **Steven Dellinges**, Pacifica, CA (US); **Robin E. Lafever**, Oakland, CA (US)

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(21) Appl. No.: **10/612,716**

(22) Filed: **Jul. 1, 2003**

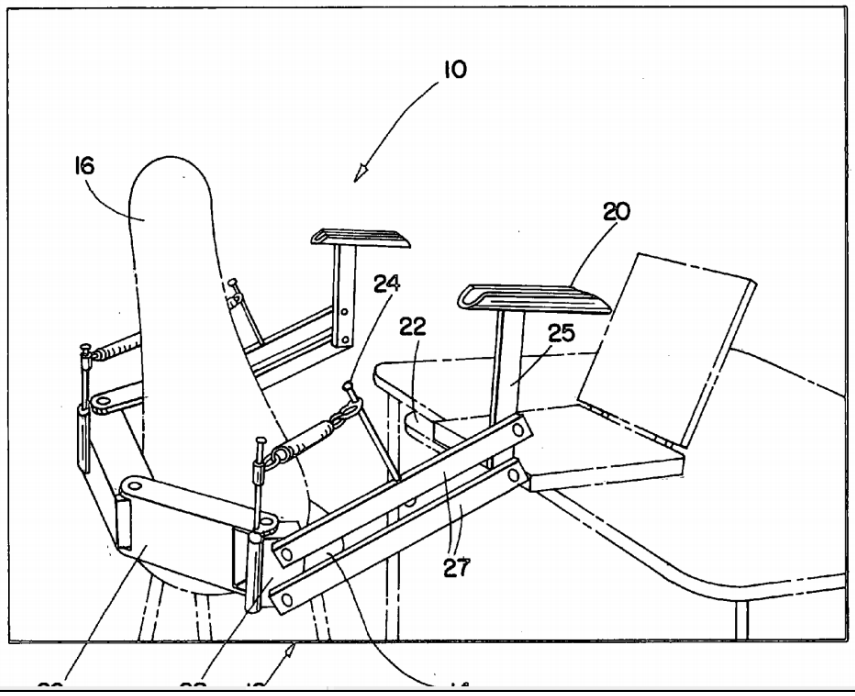
Publication Classification

(51) **Int. Cl.**[7] **A47C 7/54**

(52) **U.S. Cl.** **297/411.35**; 297/411.2; 297/411.36

(57) **ABSTRACT**

An ergonomic arm support system maintains a neutral position for the forearm. A mechanical support structure attached to a chair or other mounting structure supports the arms of a sitting or standing person. The system includes moving elements and tensioning elements to provide a dynamic balancing force against the forearms. The support structure is not fixed or locked in a rigid position, but is an active dynamic system that is maintained in equipoise by the continuous operation of the opposing forces. The support structure includes an armrest connected to a flexible linkage or articulated or pivoting assembly, which includes a tensioning element such as a spring. The pivoting assembly moves up and down, with the tensioning element providing the upward force that balances the downward force of the arm.



[52]

US009204730B2

(12) **United States Patent**
Brown

(10) **Patent No.: US 9,204,730 B2**
(45) **Date of Patent: Dec. 8, 2015**

(54) **ARTICULATED HUMAN ARM SUPPORT**

(76) Inventor: **Garrett W. Brown**, Philadelphia, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 189 days.

(21) Appl. No.: **12/674,731**

(22) PCT Filed: **Aug. 28, 2008**

(86) PCT No.: **PCT/US2008/074554**
§ 371 (c)(1),
(2), (4) Date: **Feb. 23, 2010**

(87) PCT Pub. No.: **WO2009/029693**
PCT Pub. Date: **Mar. 5, 2009**

(65) **Prior Publication Data**

US 2011/0127390 A1 Jun. 2, 2011

Related U.S. Application Data

(60) Provisional application No. 60/968,974, filed on Aug. 30, 2007.

(51) **Int. Cl.**
A47C 7/54 (2006.01)
B43L 15/00 (2006.01)
F16M 11/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ... ***A47C 7/54*** (2013.01); ***A47C 1/03*** (2013.01); ***A47C 7/52*** (2013.01); ***A61B 19/26*** (2013.01); ***A61F 5/3761*** (2013.01); ***B43L 15/00*** (2013.01); ***F16M 11/04*** (2013.01); ***F16M 13/04*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC A47C 1/03; A47C 7/54; B43L 15/00; F16M 11/04; F16M 13/04; A61B 2019/265; A61B 19/26
USPC 248/118, 118.1, 118.3, 118.5; 297/411.21, 411.22, 411.23, 411.32, 297/411.33, 411.34, 411.35, 411.37, 297/411.39, 411.2, 411.46, 423.39, 423.43, 297/411.25, 411.29, 411.31, 411.38, 297/411.36; 5/621, 623, 624, 646, 648
See application file for complete search history.

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Information Disclosure Statement dated Jan. 13, 2010 for U.S. Appl. No. 11/859,526.
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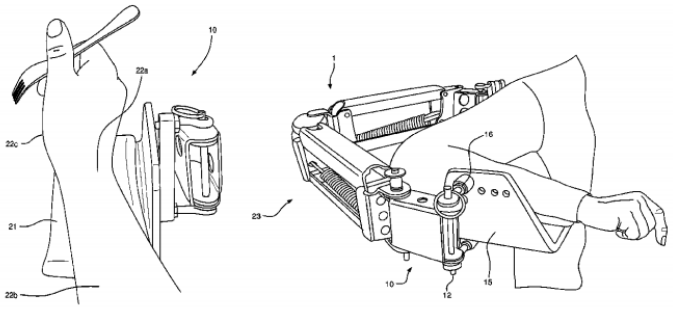
Primary Examiner — Terrell McKinnon
Assistant Examiner — Eret McNichols
(74) *Attorney, Agent, or Firm* — Barnes & Thornburg LLP; Joan T. Kluger

(57) **ABSTRACT**

An upper body appendage support apparatus having an articulating parallelogram support structure connected to an articulating upper body appendage support structure, the latter accommodating a user's forearm, wrist, and/or heel-of-hand. The apparatus analogously jointed to the human arm and moving synchronously therewith.

29 Claims, 23 Drawing Sheets



[53]

US006877813B2

(12) **United States Patent**
Caruso et al.

(10) **Patent No.: US 6,877,813 B2**
(45) **Date of Patent: Apr. 12, 2005**

(54) **ADJUSTABLE ARMREST**

(75) Inventors: **Jerome C. Caruso**, Lake Forest, IL (US); **Steven J. Caruso**, Antioch, IL (US); **Bruce R. Gezon**, Caledonia, MI (US); **Marc A. Gierz**, Hudsonville, MI (US); **Jack R. Nyenhuis**, Jenison, MI (US)

(73) Assignee: **Herman Miller, Inc.**, Zeeland, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/611,002**

(22) Filed: **Jul. 1, 2003**

(65) **Prior Publication Data**

US 2004/0104611 A1 Jun. 3, 2004

Related U.S. Application Data

(60) Continuation of application No. 10/140,440, filed on May 6, 2002, now Pat. No. 6,598,937, which is a continuation of application No. 09/833,311, filed on Apr. 11, 2001, now Pat. No. 6,386,636, which is a division of application No. 09/234,291, filed on Jan. 20, 1999, now Pat. No. 6,250,715.

(60) Provisional application No. 60/078,938, filed on Mar. 20, 1998, and provisional application No. 60/072,111, filed on Jan. 21, 1998.

(51) **Int. Cl.**[7] **A47C 7/54**

(52) **U.S. Cl.** **297/411.36**

(58) **Field of Search** 297/353, 411.36, 297/284.7, 344.14; 248/230.2, 125.1, 246, 412

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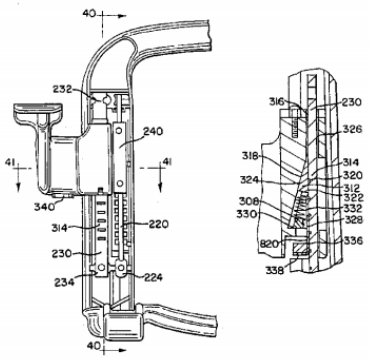
Primary Examiner—Peter R. Brown
(74) *Attorney, Agent, or Firm*—Brinks Hofer Gilson & Lione

(57) **ABSTRACT**

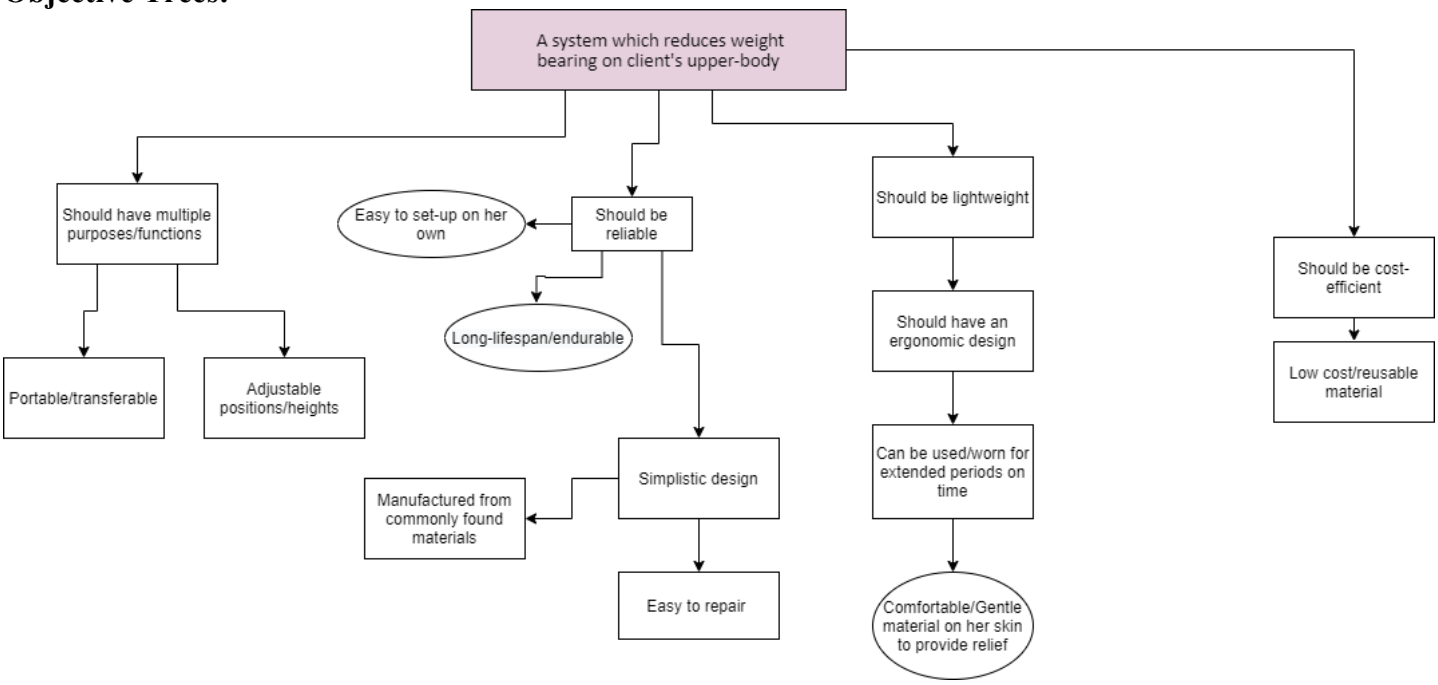
An adjustable armrest for a chair includes a housing having a cavity defined by a wall and a latch member slideably mounted in the cavity. The latch member includes a wedge shaped portion having a first and second surface forming a oblique angle between them. One of the first and second surfaces engages the wall of the housing at least when the latch is in the engaged position.

17 Claims, 26 Drawing Sheets



[54]

Objective Trees:



We have chosen to use the objective tree as our design tool since it allows us to map out the objectives and constraints in a more organized and visually pleasing way. Although both the how/why ladder and objective tree answer the questions of why going up and how coming down, we feel that seeing the objectives, and constraints more clearly through the different shapes is easier for us. In addition, the how/why ladder is restricted to only moving in an up or down direction whereas the objective tree allows us to branch out our thoughts from one idea.

Client Meeting Notes:

Meeting 1:

Issues while painting include/general notes about her process of painting:

- In order to paint for long periods of time, client uses her other arm to stabilize her dominant arm to minimize the weight applied.
- Client often experiences muscle spasms while holding paint brushes.
    - Thus, she struggles to hold paint brushes in horizontal position/like a pen.
    - Leads to her gripping the paint brushes.
    - For larger brushes she grips it from the bottom and uses vertical movements.
        - **Would likely need a mechanism/system which allows her to maintain the position she would prefer to paint with.**
- While painting the client inconveniently rests her arm on the canvas (which is placed on a stool), while resting on her knees.
    - After long periods of time client lies on the floor with her arm resting on the ground or resorts to sitting on the ground while her arm rests on the canvas (which is placed on a shorter stool) (This option is inconvenient since the canvas is prone to break or bend)
    - Sits on the ground so she does not carry the weight of herself.
        - **Would likely need a mechanism/system which supports her arm while painting.**
- **Wants a solution that provides relief for the inconsistent/unpredictable issues she faces on a daily basis.**
    - **Something that will make it easier to make her paint will bring her comfort!**
- Prefers to be moving whilst she is painting.
- Small detail-oriented work is difficult due to constrains in movement of her hands.
- Struggle with weight-bearing on biceps triceps and peck muscles.
- Struggles with opening paint jars.
    - Uses food jars instead of typical paint containers.
    - Uses acrylic flip-top paints.
        - If dried paint is preventing top from opening, she struggles to fix this issue.
- Does not use a palette since it is too heavy to hold with her other arm.
    - Prefers not to use a palette.
    - Uses paint directly from food jars.

General Issues in day-to-day activities:

- Difficult daily tasks/movements include bending of her waist, picking up things left on the ground.
    - Claw-like mechanism works for picking up large objects but not smaller ones.
- Often forgets to utilize tools whilst in the struggles that need them.
    - **May need a mechanism that is convenient to always have on hand or a mechanism that cannot be misplaced easily.**
- Washing dishes and food preparation is difficult due to constrained movements of her hands.
    - For example: cannot cut squash.
    - Often utilizes use of blender due to this issue.
- During COVID-19 she trained some Jiu Jitsu. Also, has shifted to learning yoga, took teacher training to learn how to adapt yoga poses to be safe for her body. Online yoga classes made her frustrated because she had difficulty getting adaptations from instructors online.
- Has extensive meditation practices and movement helps manage challenges that come along with such practices.
    - **A mechanism/system which utilizes movement as part of the solution.**

Specific Positions she finds comfortable/difficult:

- Crouching and squatting are relatively comfortable positions. Bending at waist very difficult/painful. Any motions up and down is difficult and causes her to be dizzy.
    - **A mechanism/system that can be used in a comfortable position is essential. Preferably crouching, sitting, or squatting.**

Solutions/tools she has tried:

- Uses canes, tens machine, body pillows, rolling walker, vibrating heat belt on SI joint, acupuncture, self-acupressure, cupping, traditional Chinese medicine approaches, exercise, and movement.
- Wear's lymphedema compression gear during painting and exercise.
- **Potentially implement a solution that could be used simultaneously and with ease with these tools.**

Medical Condition:

- Spondylitis (affects mobility, she does better when she is moving)
- Lymphedema in arms and trunk (impacts ability to weight bear, must wear medical devices)
- Fibromyalgia (Causes pain in muscles, impacts her hands, detailed work is challenging)

About Her:

- Alanna is an artist who enjoys making paintings, sculptures, and other things that have meaning. Painting especially is important for her as it gives an outlet for all the things that her illnesses and disabilities implicate on her life. She also enjoys Jiu Jitsu, yoga, meditation and gardening as other hobbies. Allana is also a mother who continuously pushes through and adapts to the challenges put in front of her to help her cope with her disabilities.

Struggles:

- Forearm and hand flaring/pain affects her the most when painting
- Can only paint in short periods of time
- Harder to work with smaller brushes, but it adds detail to her paintings
- Biggest challenges at home are things that involve bending at the waist, picking up things from the ground, using tools that are child-proof
- Being tired makes her condition more difficult
- When stress goes up, pain goes up, and the ability to adapt goes down
- Stress causes her ability to think go down (starts forgetting the tools and resources she has)
- Managing the dishwasher is difficult
- Washing by hand hurts arms and hands
- Food prep is harder; she needs to get precut stuff because cutting is a challenge
- Bottles with a flipping joint are easy at first but when paint gets stuck its harder to open
- She does not use a paint pallet because it is something heavier
- Instead, she uses a tray and places her small jars side by side, she likes having the shelf hold the paint rather than herself

Supports Currently Being Used:

- Tens Machine
- Vibrating Heat Belt
- Canes
- Compression Gear (vest arms and hands)

- Arthritis Gloves (ordered lymphedema gloves)
- Sacroiliac Joint Brace (helps for walking long distances)
- Body Pillows

Client's Name?
- Alanna

What's the client's longest art piece (time to complete)?
- Took 8 months to complete.
- Can only work for short periods of time.

Anything that would make the client's healing process better?
- Lives with constant unpredictability with how her body feels.
- Level of comfort in unpredictability would be incredible, as it would be easier to paint while her body hurts.

Favourite art pieces?
- Frida Kahlo, The broken column.
- Client's paintings, Hope Cocoon (painted while in a state of chronic pain and struggling).

Client's mediums used in painting.
- Acrylic on canvas.
- Prefers large pieces as small canvas is hard to work with.
- Oil paints with cold wax.
- Collage
- Sculptures (found objects like wire, staples, metal etc.)

How the client paints?

- Arthritis affects client's joints.
- Ability to sit and stand affected.
- Although she loves to move and stand while painting.
- Wears compression sleeves on arms,
- Has pain in muscles, specifically hands/wrists.
- Small, detailed painting is difficult.

Any specific body part that gets fatigued?

- Forearm feels as if on fire.
- Has muscles spasms in hand.
- Struggles with weight bearing in her, biceps, triceps, and pectoral muscles.

Would setup time of a device matter?

- Not really, time is not a factor.
- If she can set the device up on her own.

How long each week does the client normally paint, and do other activities (yoga, meditation etc.)?

- Varies base on how her body feels.

- Wants to do so much more than she can physically do.
- Meditation helps, she has a meditation spot/space which she uses to calm herself.
- Has been home since March 2020.
- Has an idea wall to brainstorm her next art pieces.

What drew the client to art?

- Struggling to learn to be her new self, drew the client to art.
- Stopped painting in 2001 due to her midwifery job.
- The stopped being a midwife due to struggling with her painful body.
- Client then started painting to cope.

How does the client hold utensil?

- Holds larger squeezy and square brushed in palm.
- Client holds up her right forearm with left hand.
- Likes to work on the floor and holds wrist.
- Leans on canvas while sitting on stool.

Does the client find any everyday tasks to be difficult?

- Picking things up and bending by the waist.
- Difficult to cook, cuts vegetable in specific ways as she is vegan/vegetarian.
- Struggles to open paint and gravitates towards specific paint brands.
- Large lid jars are preferred over flip top.
- Struggles with unpredictability because there is no constant part of her body that is always O.K.

Does the client use a painting palette or an easel, any other devices?

- She does not use a painting palette to hold paints as it would be an extra weight to hold.
- Her system works for her, as she keeps here paints on the shelf of her easel.
- Uses a cane and sometimes a rolling walker.
- Uses lymphedema compression gear during activities, on her torso, arms, and hands.
- Loves movement because her pain is decreased during movement.
- Has flares cause by her conditions which totally stop all her movement.

When recovering what helps the client?

- Body pillows, Epson salts and fake sun light.

How does the client use painting to improve her future?

- An outlet for all the client's emotions causes by the client's disabilities.
- Painting helps propel the client forwards during her painful states and allow the client to be a more balanced parent.
- Painting helps the client teach her children perseverance.
- This also helps McMaster engineering students be better engineers in the future, to tackle diverse problems of any clients we may encounter.

✷ Important note: Improving the client's painting ability will subsequently improve her ability to perform her other activities like yoga, jujitsu, meditations, cooking and time with her children.

What does the client's website name represent or symbolize?

- "In a Power Failure".
- Symbolizes her how the client's life felt.
- As if she was in a power failure due to her conditions she was diagnosed with and situations she experienced.

Meeting 2:

- Dimensions of a mechanism being placed on the floor for your art-space?
  - Space between desk and easel 4 ft.
  - Sink to chalkboard is 7 ft.
- Height of Client
  - 5'1.5"
- Size of Wrists
  - 5' ¾"
- Length of hand (From middle finger to base of wrist)
  - 6.5'
- Width of hand
  - 3' ¼" (straight across).
  - 4' (straight across to her thumb but hand it a little bent).

Client Notes mainly focus on issues associated with painting process since our problem statement is addressing this.

- When drawing with crayons and charcoal pencils cannot allow hand to rest on surface, she experiences pain on the entire side of her dominant arm (right arm) and hand.
- Angled brushes to allow for maneuverability with brush and paint.
  - Only possible with smaller brushes.
  - Smaller the brush bigger the cramp as she holds them.
  - Pain in armpit or axial area after a few minutes no matter what the side of the brush.
- Grip of her paintbrushes is ideally loose and holding wider grips instead of smaller ones.
- One hand dominant so cannot paint with left hand.
  - Often uses left hand to hold right hand to balance the weight of both arms centrally, which allows her to paint for longer periods of time.
- Must wear vest, sleeve, and gauntlet during painting and any weightbearing activities.
  - **Solution must consideration compression gear.**
  - Sleeve: has 20-30mm compression level.
  - Texture of her compression gear are thick-tight material.
  - Vest is nylon and spandex material.
- Would like to keep painting in bed for instances when she must be in bed and rest.
  - **Solution must be functional for use in bed.**
- Fine with Velcro material as long as it does not touch her skin.
  - Prefers things that are adjustable (likes the idea of Velcro usage).
- Largest size for a canvas that she typically uses 39.5" by 39.5".
- Does not prefer extreme temperatures since they aggravate lymphedema.
  - Prefers heat rather than cold.
  - Warm temperature is fine.
  - She has temperature instability in her body.
- Struggles with running errands.
  - Cannot drive, limited walking ability, limited ability with carry things.
- Favourite color is turquoise/red.

  - **Make it her favourite color!**
- Materials containing gluten and rough edges are not preferable.
  - Prefers cotton and silk as materials.
  - **Use padding between undesirable materials if needed for solution.**
- Standing, seated, to the side or turning the painting canvas itself (to allow for her to work on every portion with a seated position) during painting process.
  - **Solution must allow for this range of motion.**
- When outstretching her arm to pain the position that provides her with least amount of discomfort is when her wrist is in line with arm
  - No bending
- Outstretching her fingers is easier and less painful than bringing her finger in (ie. Like holding a pen).
- Small and detailed work is challenging for her joins and muscles.
- Does not want to paint on floor if it was not needed however there are benefits.
  - Increases her feeling of stabilization since she does not feel nauseous and allows her to focus on the task at hand.
  - Floor can hold her weight and does not force her to weight bear her whole body.
  - Makes her feel less nauseous and dizzy-being on the floor mitigates these feelings.
  - **Solution should allow her to paint on floor since this is the ideal position.**
- When she is standing up and painting her arm fatigues her first instead of weight bearing her whole body.
- To relieve pain after painting or when hands hurt, shaking her whole hand brings relief to the nerve shock.
- Has difficulties with pushing and pulling motion.
  - Pushing is easier as she uses torso to bear the weight of pushing.
  - Pulling is difficult for lymphopenia affected areas.
- Wearing something such as a belt on the shoulder must consider posture, must be symmetrical, straps must not be constructive as she has lymphedema at the lower posterior edge of her shoulder .
- More use of her palm easier it is to grip something.
- Open and likes the idea using of a painter's mahl stick.

Appendix B

Morph Charts:

Choice: Morphological chart

Rational: We chose the morph chart because it allows us to write out and identify all the main functions the design should perform. It also allows us to come up with several different ways of carrying out each function which displays what our optimal design should have as well as ideas that may or may not work.

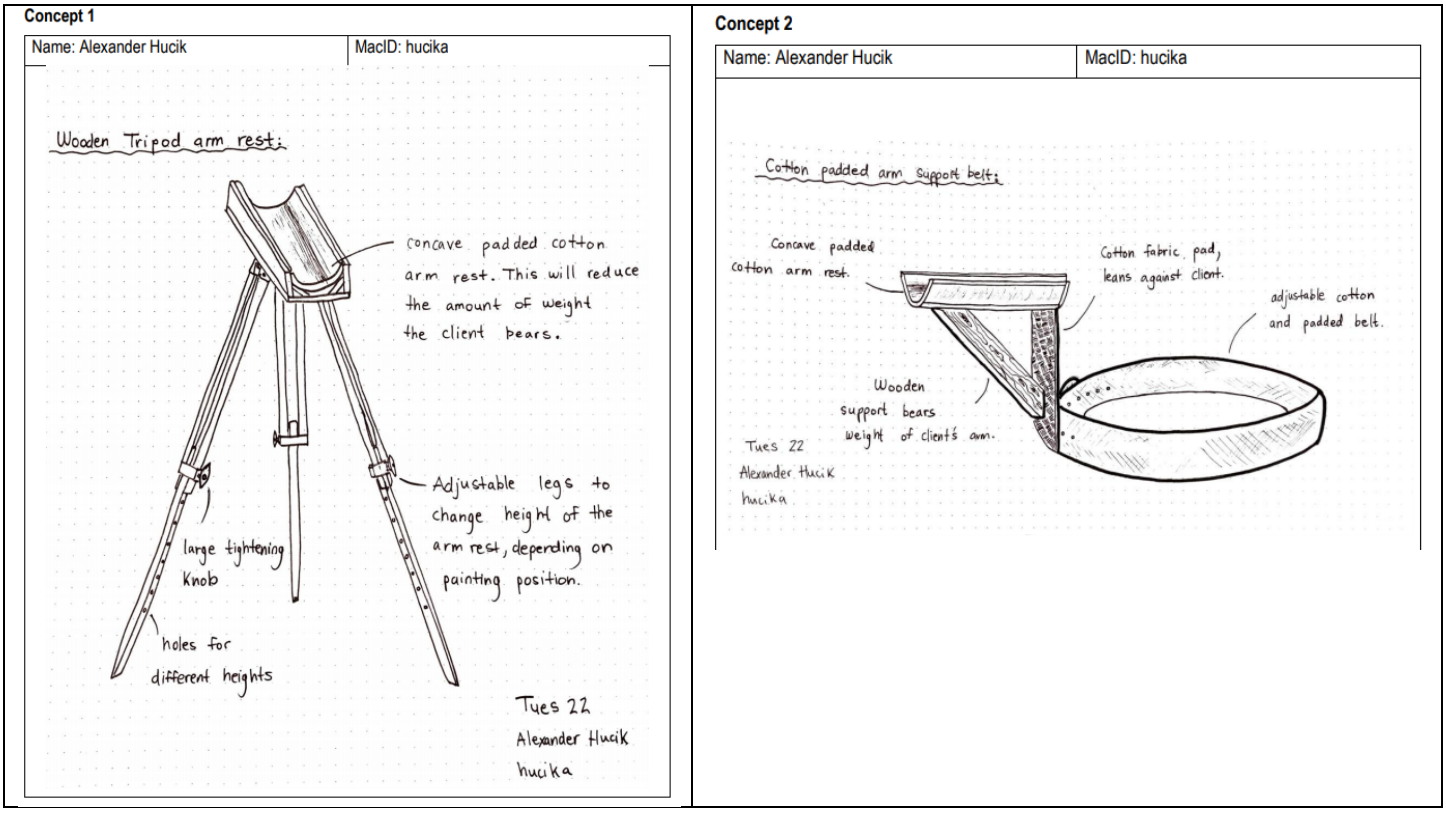
Function	Mean 1	Mean 2	Mean 3	Mean 4
Height Adjustment	Lever	Clamp tightening knob	Motors	Hinge/ Flexible joints
Stabilize her arm	Arm rest	Strap	Arm cuffs	Wrist mat (memory foam)
Gripping paintbrush horizontally	A large ergonomic grip that can hold any paintbrush	Using a hook	Storage compartment that can hold any size paintbrush	Wearing a glove that holds the paintbrush
Hold the weight of her arm	Arm rest	Tripod	Strap that comes down from the ceiling	Arm brace (connected to her waist as a belt)
Doesn't restrict movement	Has wheels	It isn't attached to her so she can move away from it easily	Slidable arm rest	Rotatable
Provide Comfort	Comfortable materials (no sharp or objects)	Using memory foam	Can take the shape of her body	Can provide heating

Decision Matrices:

	Multi-purpose	Does not restrict movement	Easy to assemble	Ability to bear weight/Reliability	Ease of use /Simplistic design/ Realistic	**Score**
Multi-purpose	1	0	1	0	0	2
Does not restrict movement	1	1	1	0	1	4
Easy to assemble	0	0	1	0	1	2
Ability to bear weight/Reliability	1	1	1	1	1	5
Ease of use/Simplistic design/Realistic	1	0	0	0	1	2

	Weight	Tripod-Like Design		Linkage-Like Design		Canvas Holding Design		Arm-Rest Design	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Multi-purpose	2	4	8	3	6	4	8	3	6
Does not restrict movement	4	3	12	4	16	3	12	4	16
Easy to assemble	2	5	10	4	8	3	6	4	8
Ability to bear weight/Reliability	5	5	25	4	20	4	20	5	25
Ease of use/Simplistic design/Realistic	2	5	10	4	8	3	6	3	6
TOTAL			65		58		52		61

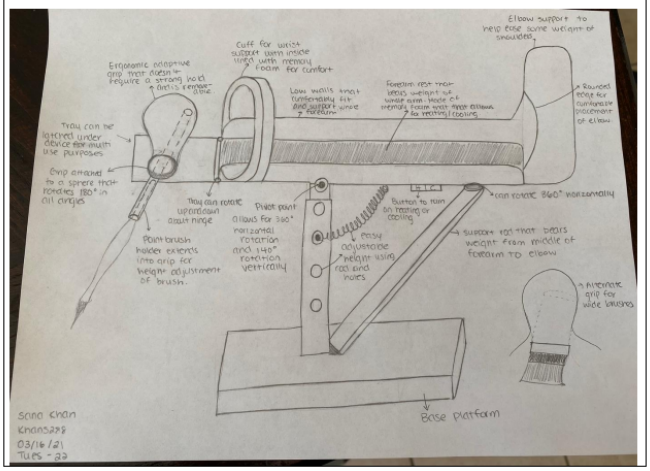
Sketches:



Concept 1

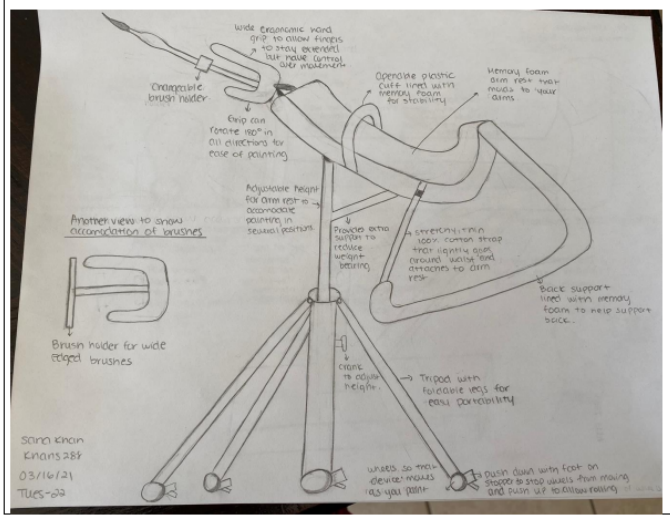
Name: Sana Khan	MacID: khans288

Insert screenshot(s) of your concept below.



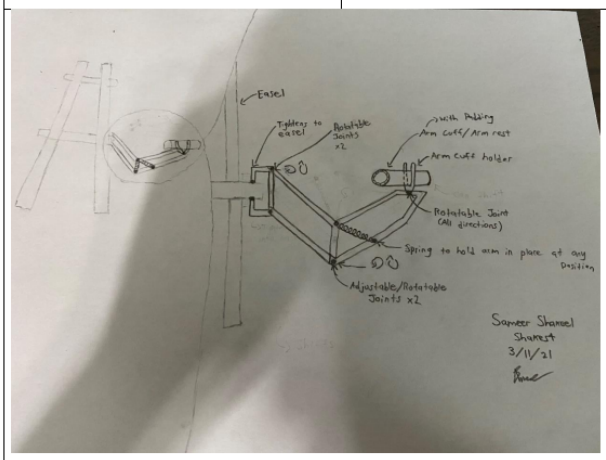
Name: Sana Khan	MacID: khans288

Insert screenshot(s) of your concept below.



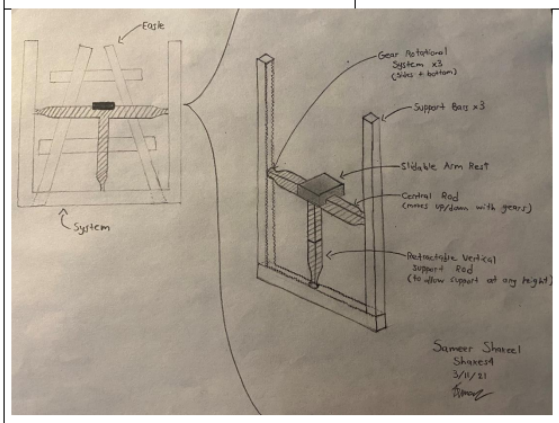
Concept 1

Name: Sameer Shakeel	MacID: shakes4



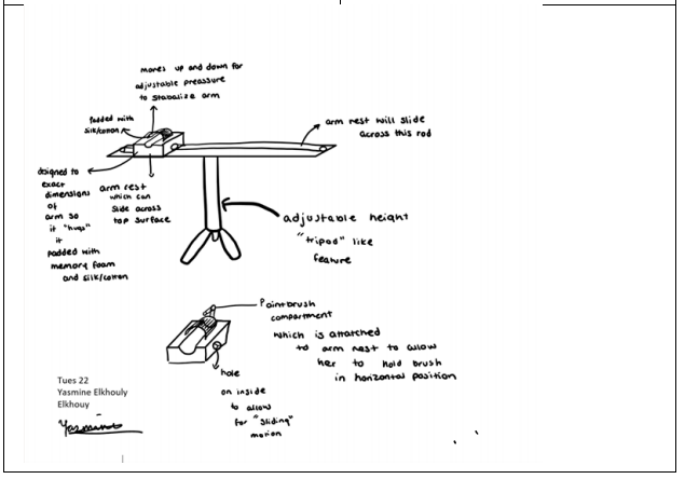
Concept 2

Name: Sameer Shakeel	MacID: shakes4



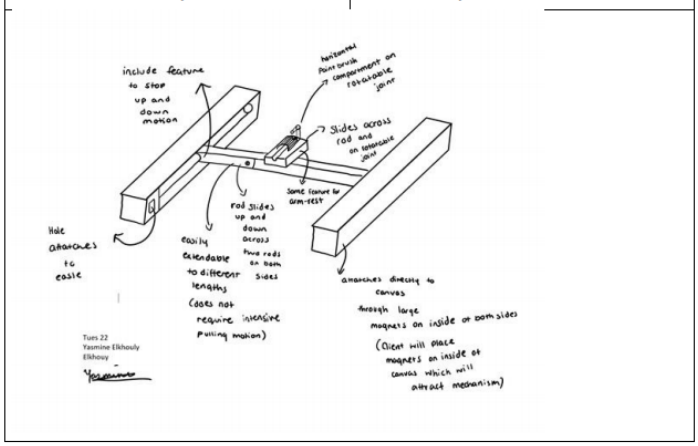
Concept 1

Name: Yasmine Elkhouly	MacID: elkhouy



Concept 2

Name: Yasmine Elkhouly	MacID: elkhouy



Design Review Notes:
The notes on the left are feedback from our first design review and the notes on the right are feedback from our second design review.

Name:	MacID:

Include feedback from peers in this row.

Tripod-Like Design

- Consider up and down motion.
- Consider changing the tightening knob to something that will not cause her strain.
  - Consider adjusting height with a mechanism that uses her foot (she has good lower body strength)

Canvas Holding Design

- How comfortable is it for her when she is painting on the ground?
- Consider changing the size of the supporting side-bars.
- Consider how difficult it would be to attach the mechanism to the canvas (can she bear the weight of setting it up?)

Linkage-Like Design

- Extend arm rest.
- Attach mechanism to a pole that allows for 180 degrees of rotation along the z axis.
- Add tightening knobs to prevent a joint from giving out and having the mechanism drop down when weight is applied.
- Adjusting the position of the mechanism so it is not an obstacle in her way as she paints

Include feedback from science students in this row.

Tripod-Like Design

- Incorporate hinge in the arm rest so she can have multiple degrees of freedom.
  - Specifically, movement from left to right.
- Consider leg components on a smaller scale for painting on the floor.
- Removable strap for adjusting pressure on her arm for stabilization.
- Bending down to level of tightening knob may cause strain on her back.
  - Use something that incorporates her leg more than upper body (since she is leg dominant)
  - Potentially the use of an actuator

15 Project-4

ENGINEER 1P13 – Project Four: *Power in Community*

Canvas Holding Design

- Consider where she would be positioned when she is painting.
- If she is positioned on her shoulder this may cause strain

ENGINEER 1P13 – Project Four: *Power in Community*

MILESTONE 4.2 – DESIGN REVIEW

Team Number: TUES-22

Include feedback from peers in this row.

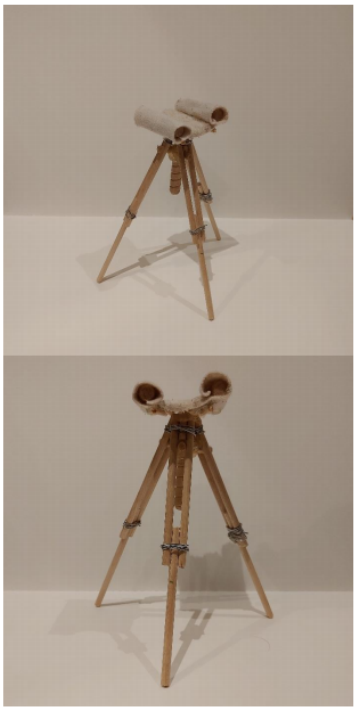
Include feedback from science students in this row.

- Make sure the tightening knobs are at arm level.
- Make sure it is not too heavy but durable/stable.
- Make sure the memory foam can be removed to ensure it can be cleaned.
- Do not use glue since she is allergic.
- Consider adding a weight to counter the weight of her arm so the tripod doesn't tip over.

If applicable, include feedback from the client in this row.

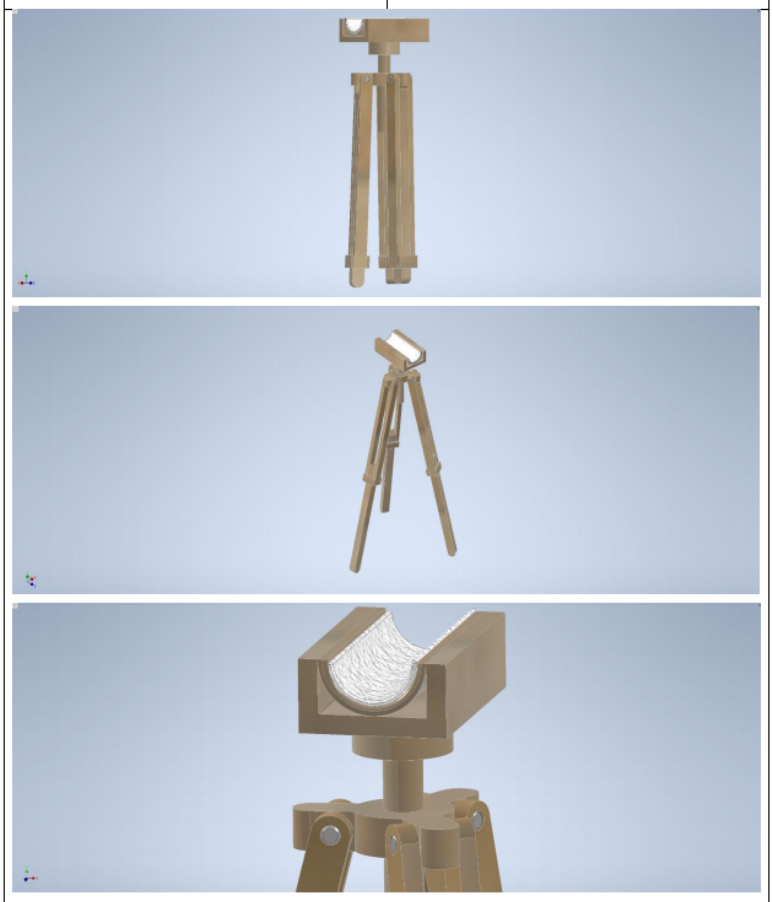
Initial Prototype/Prototype Iteration pictures:

Basic Prototype:

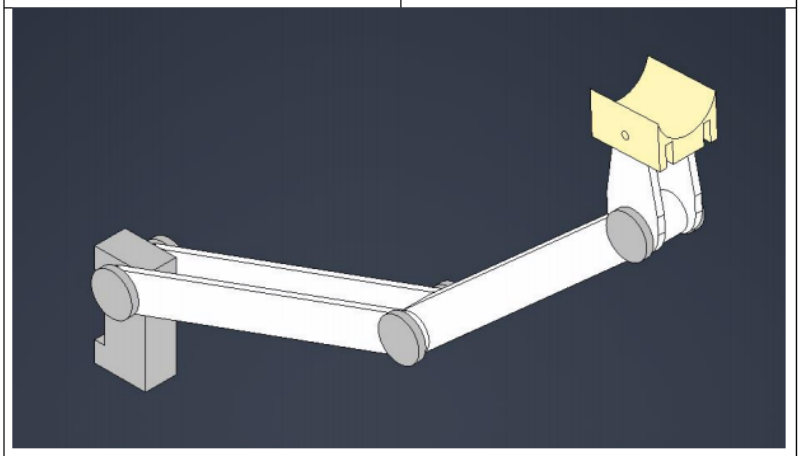


Basic Prototype:

Name: Alexander Hucik | MacID: Hucika

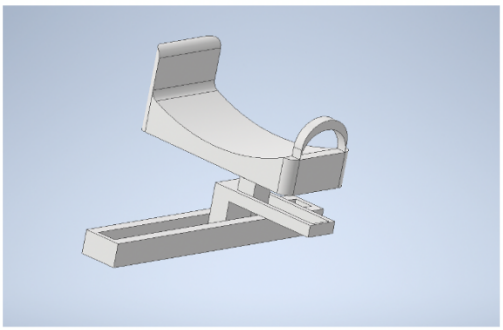


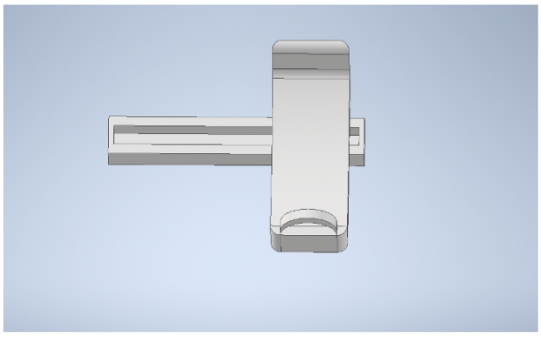
Name: Sameer Shakeel | MacID: shakes4

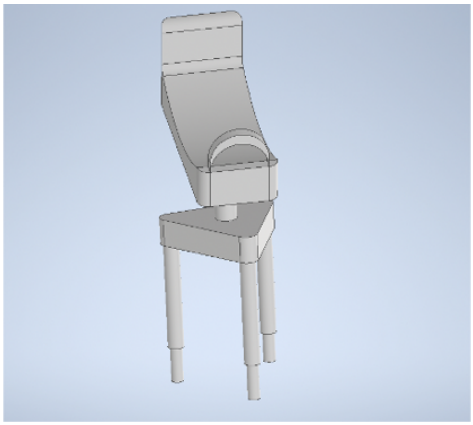


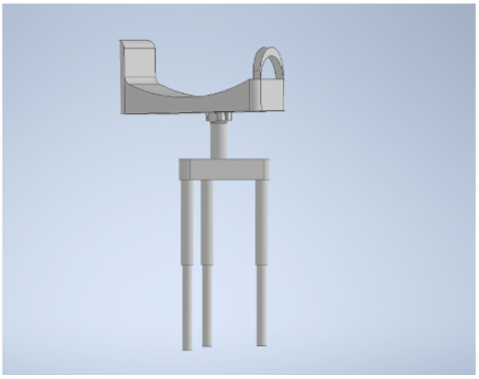
Name: Sana Khan	MacID khans288

Insert picture(s) of your refined concept (initial prototype) below.



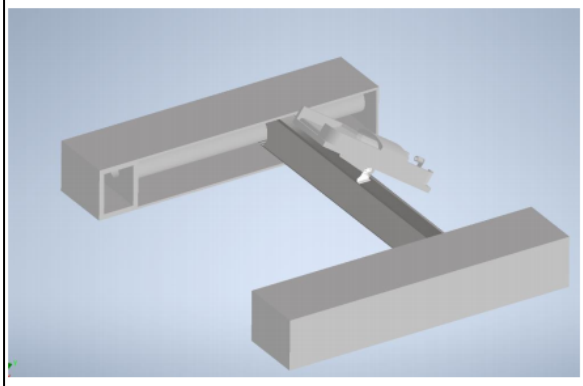


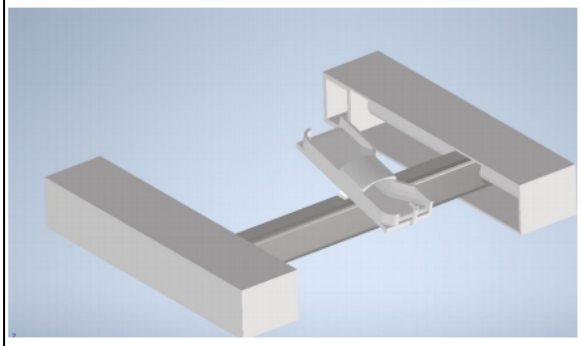


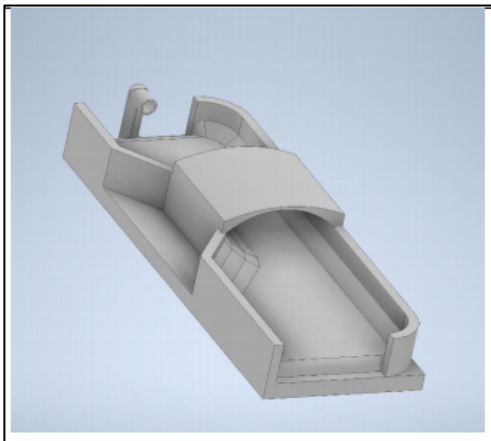


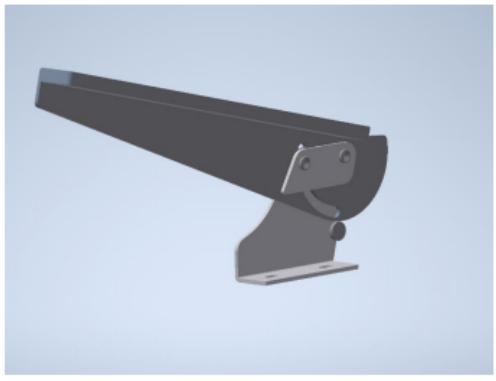
Name: Yasmine Elkhouly	MacID: Elkhouy

Insert picture(s) of your refined concept (initial prototype) below.





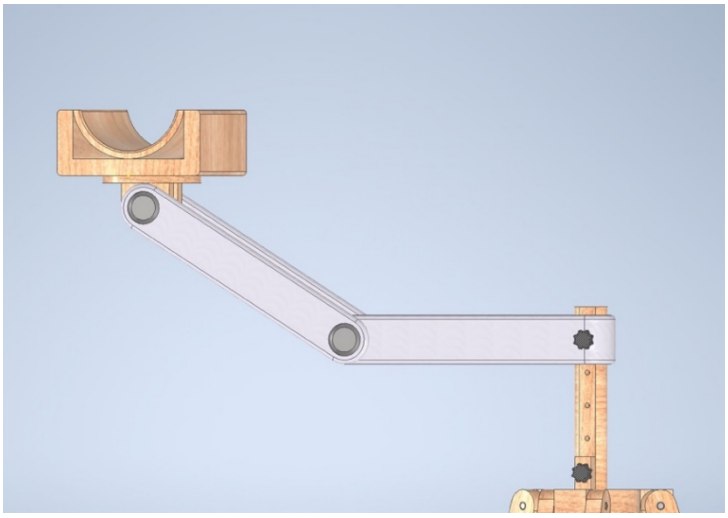


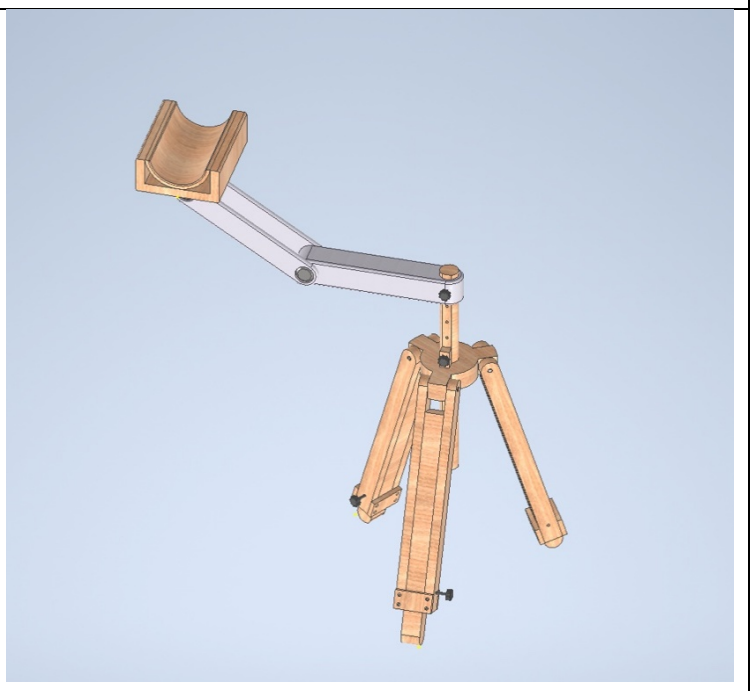


Appendix C

Final Prototype:

The following images are the final prototype from Milestone 4.



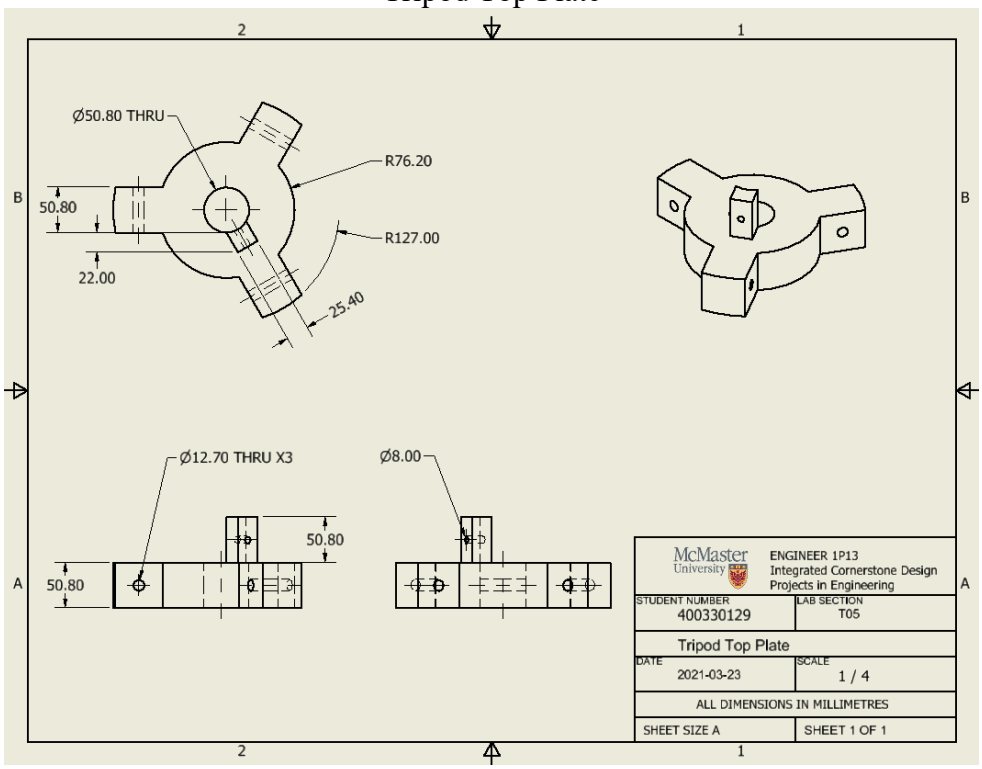


The following images are our final refined prototype.

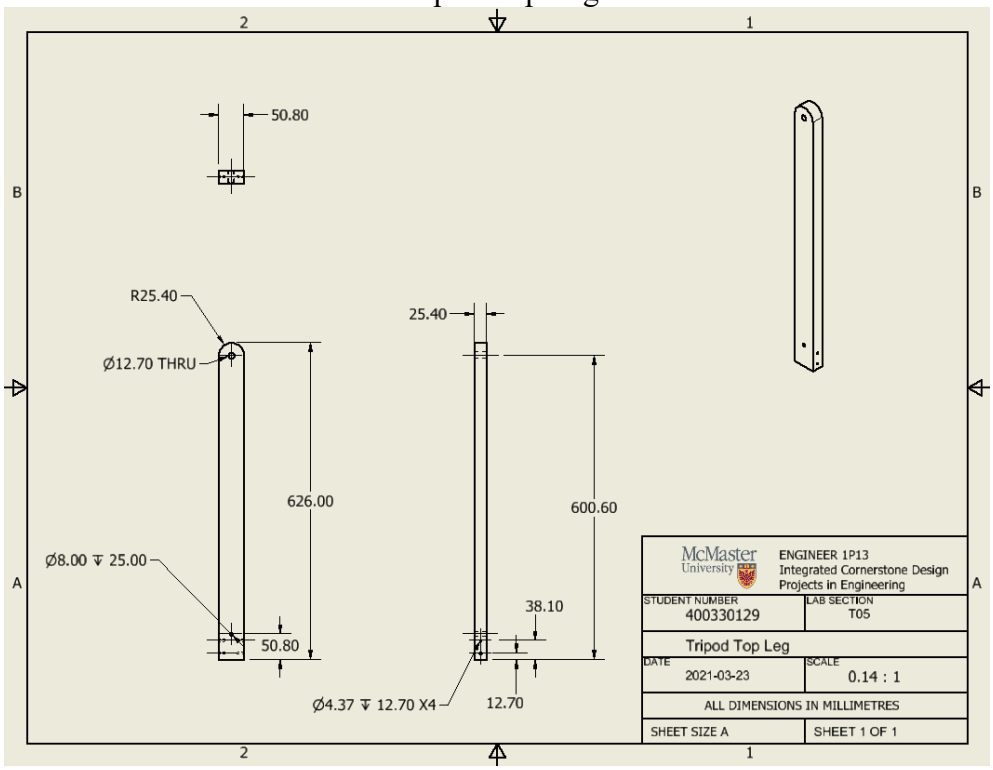
The following images are our final physical prototype.

Final Engineering Drawings:

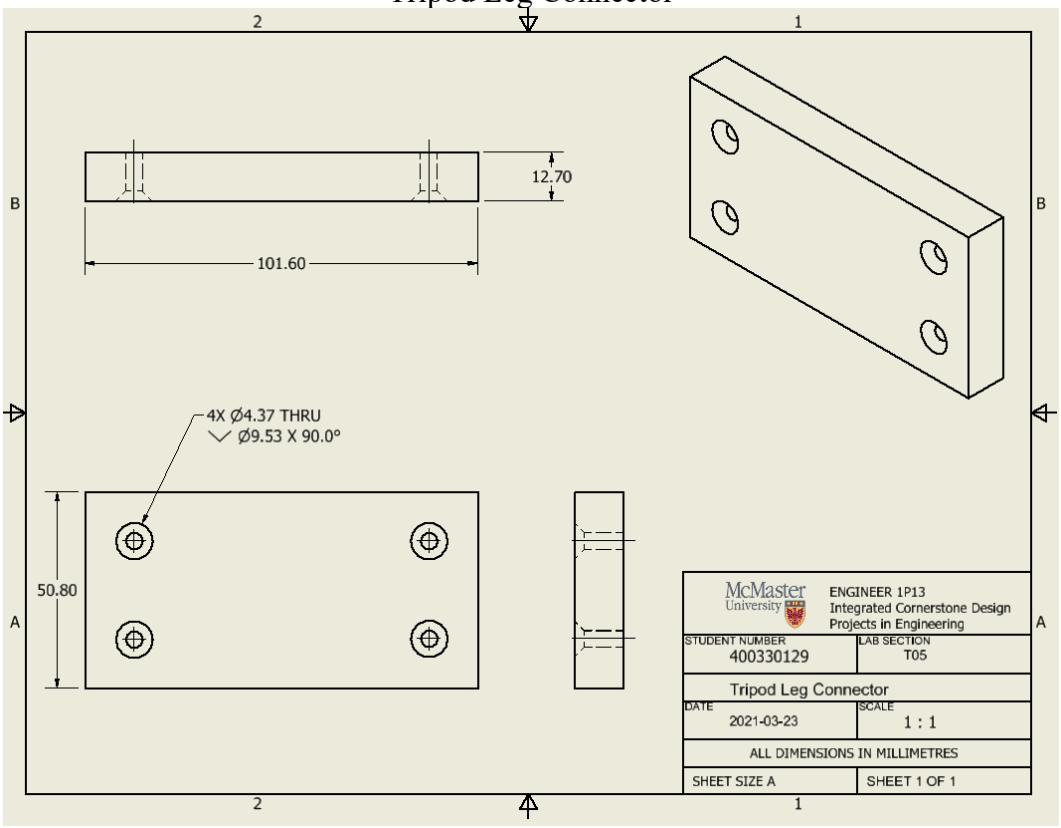
Tripod Top Plate



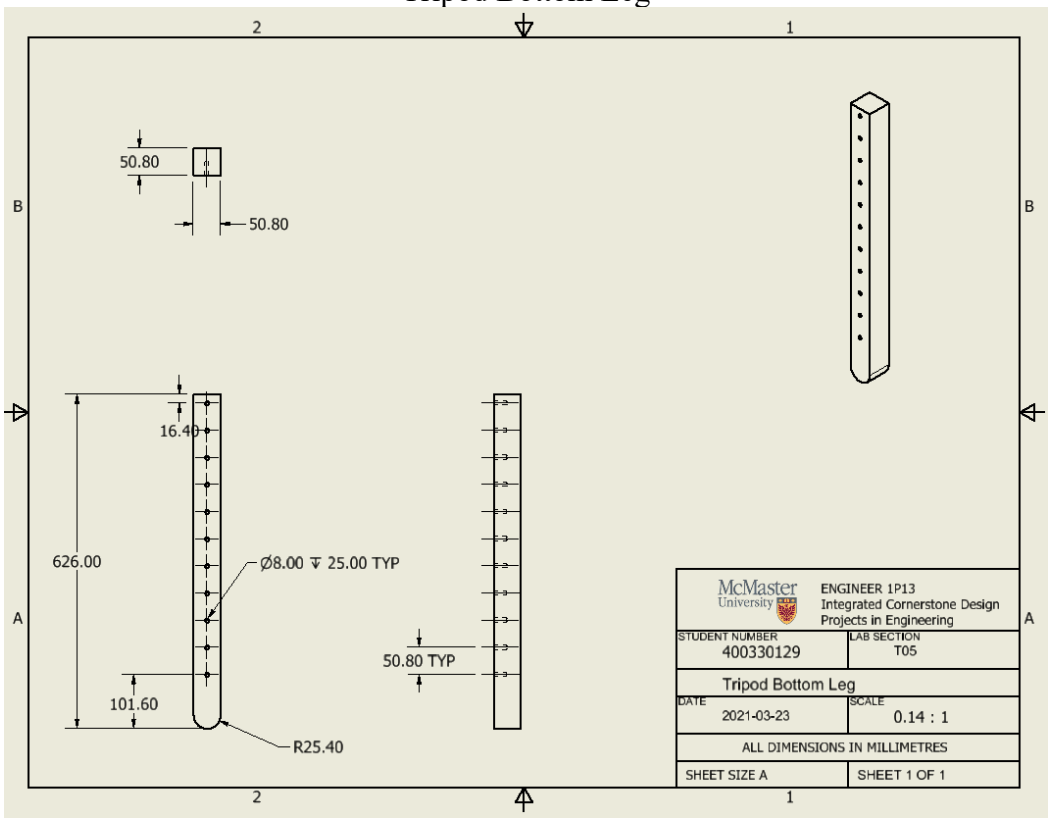
Tripod Top Leg



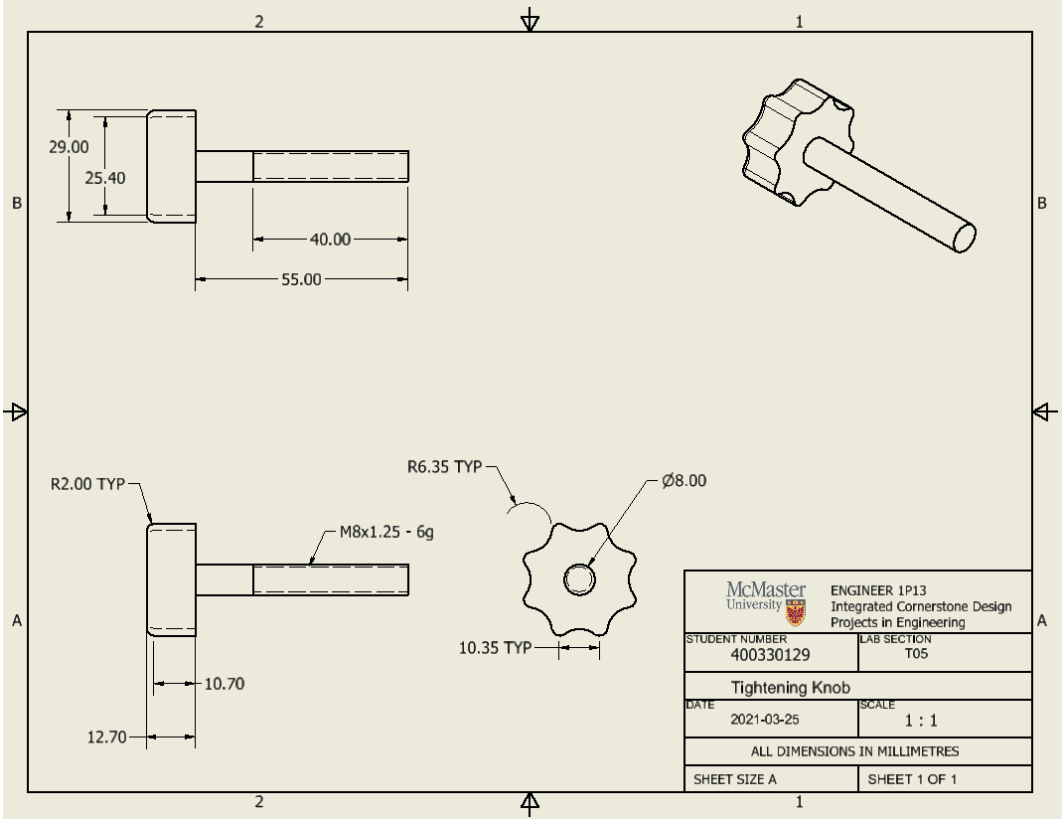
Tripod Leg Connector



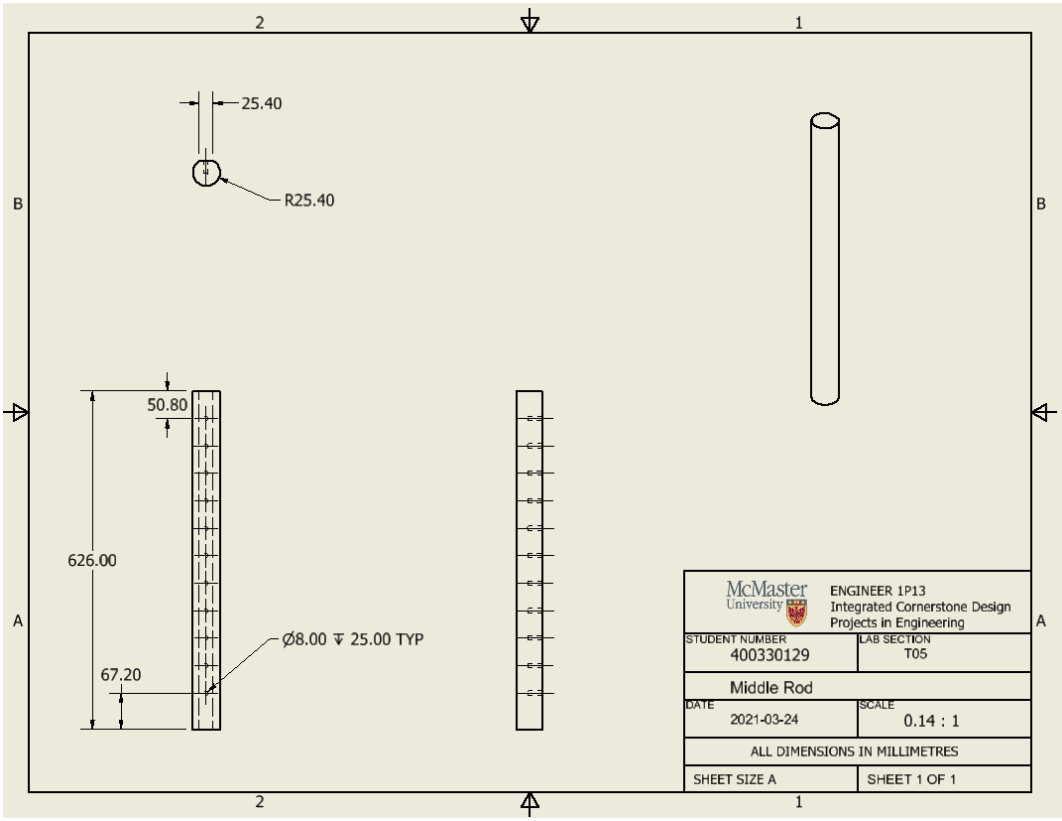
Tripod Bottom Leg



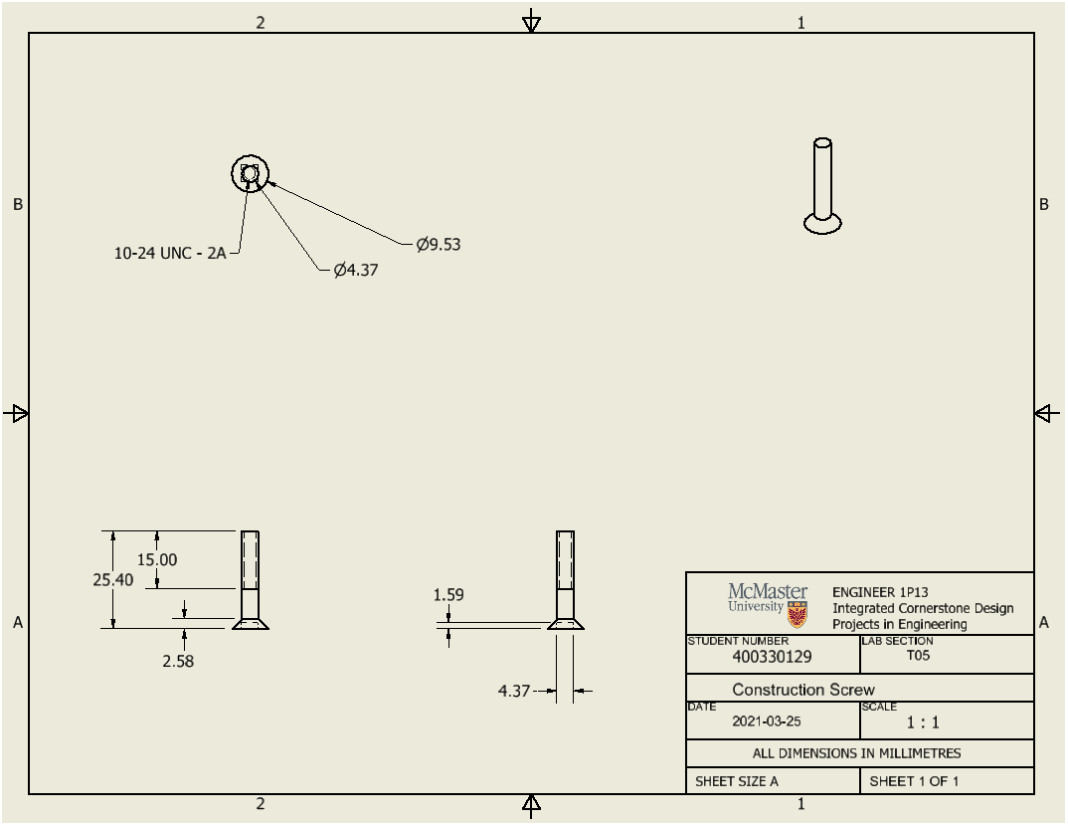
Tightening Knob



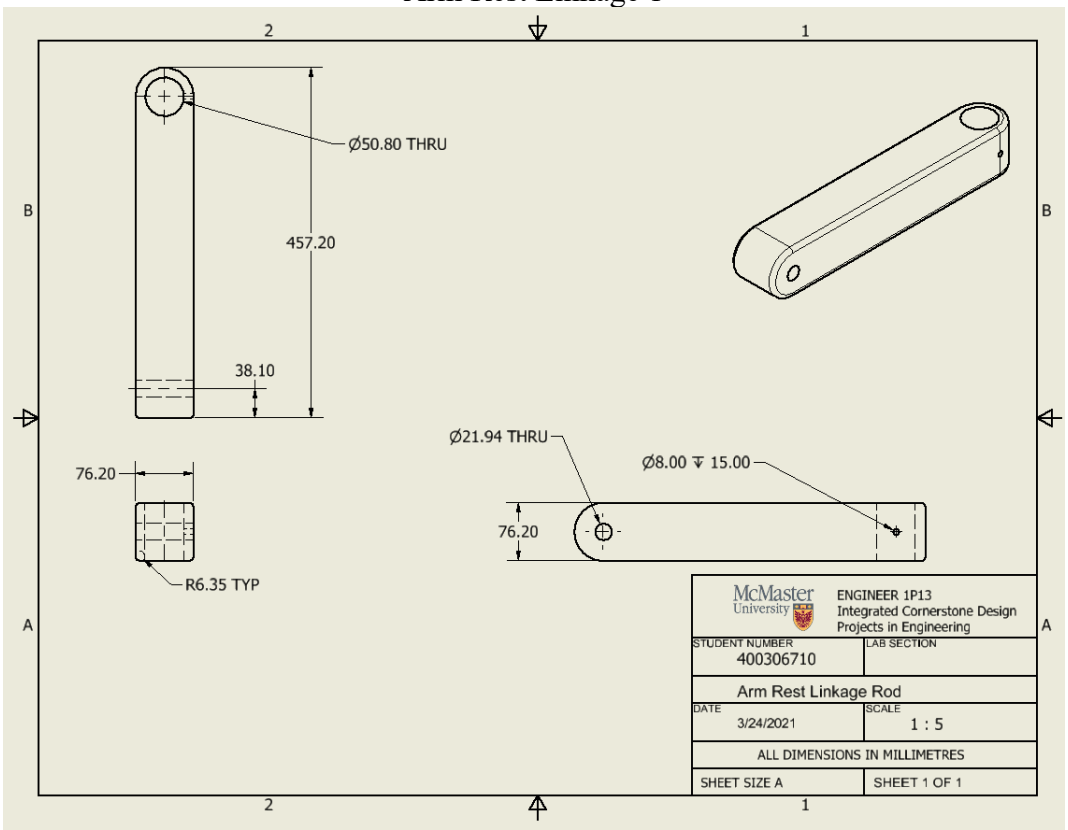
Middle Rod



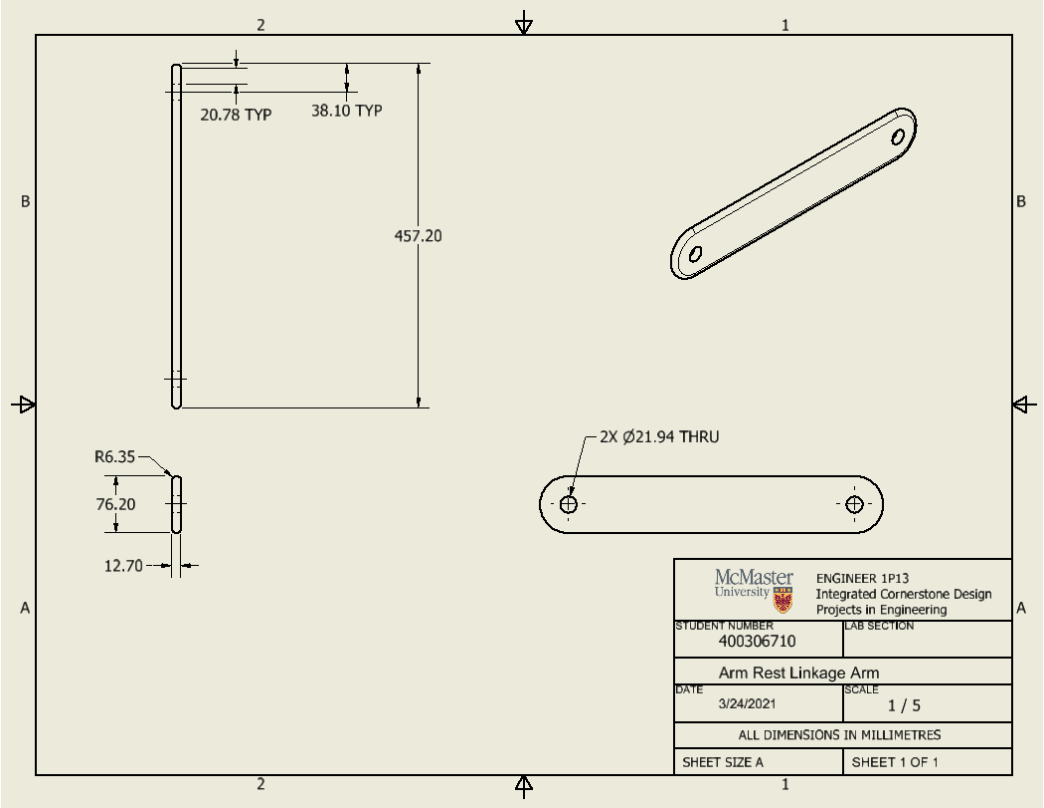
Construction Screw



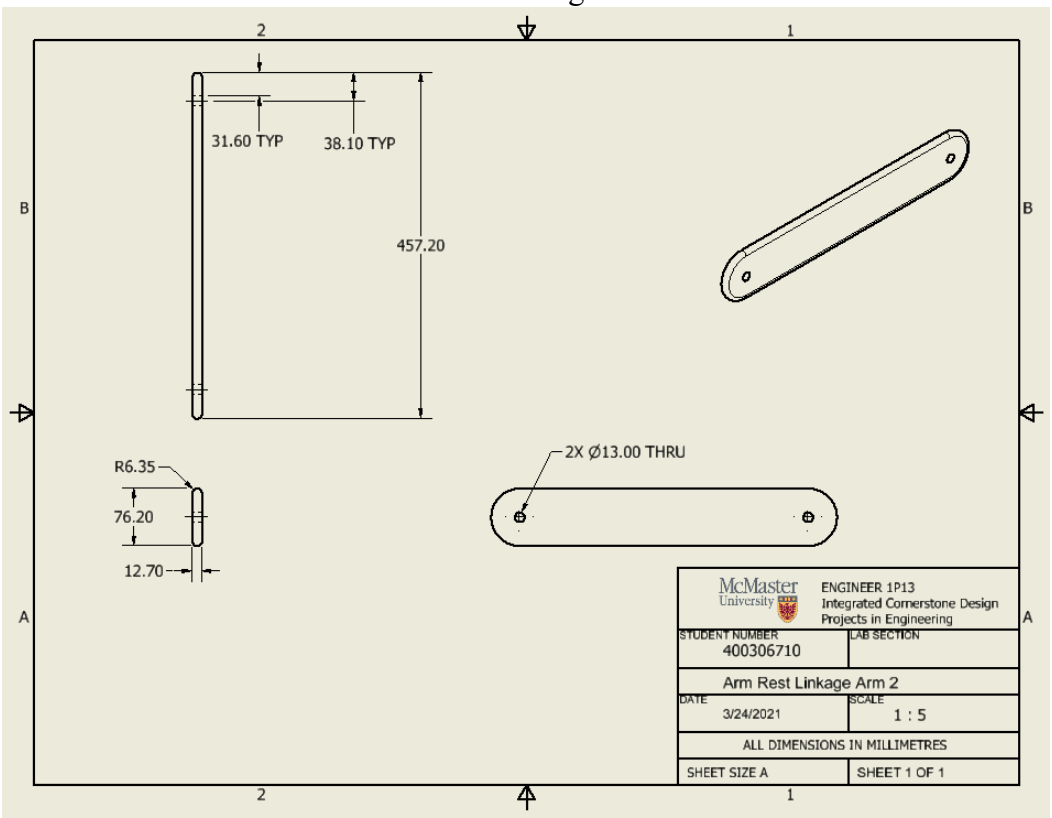
Arm Rest Linkage 1



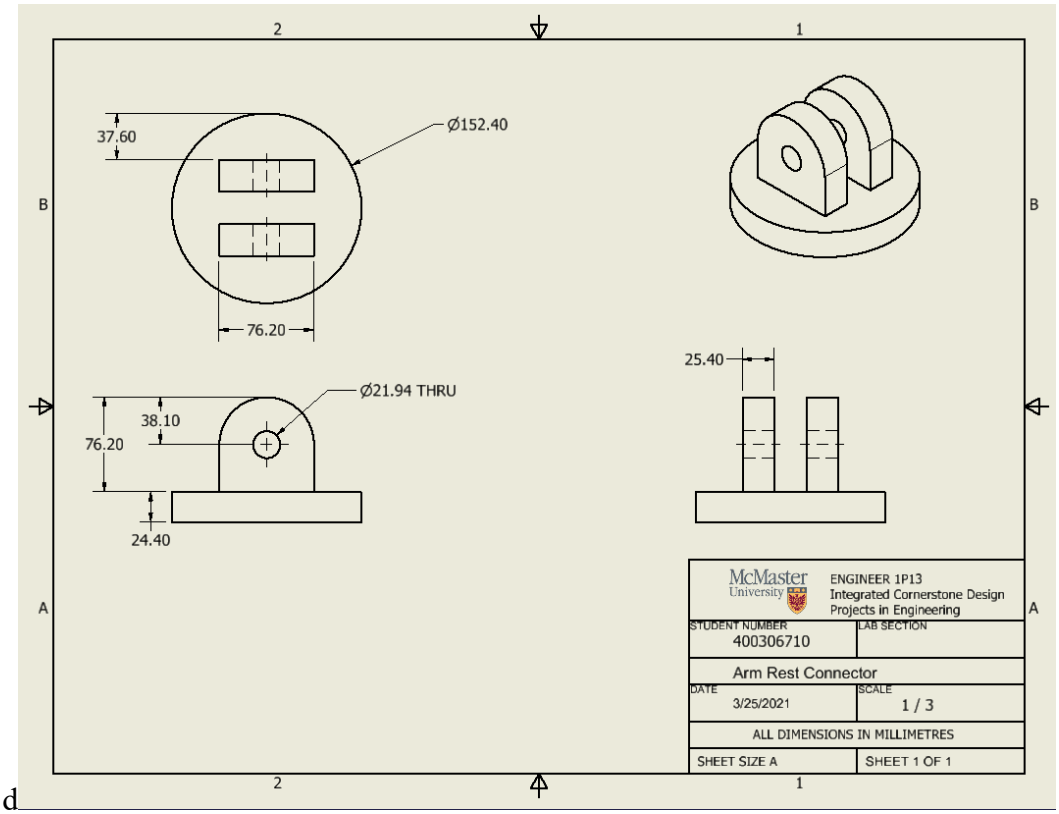
Arm Rest Linkage Arm



Arm Rest Linkage Arm 2

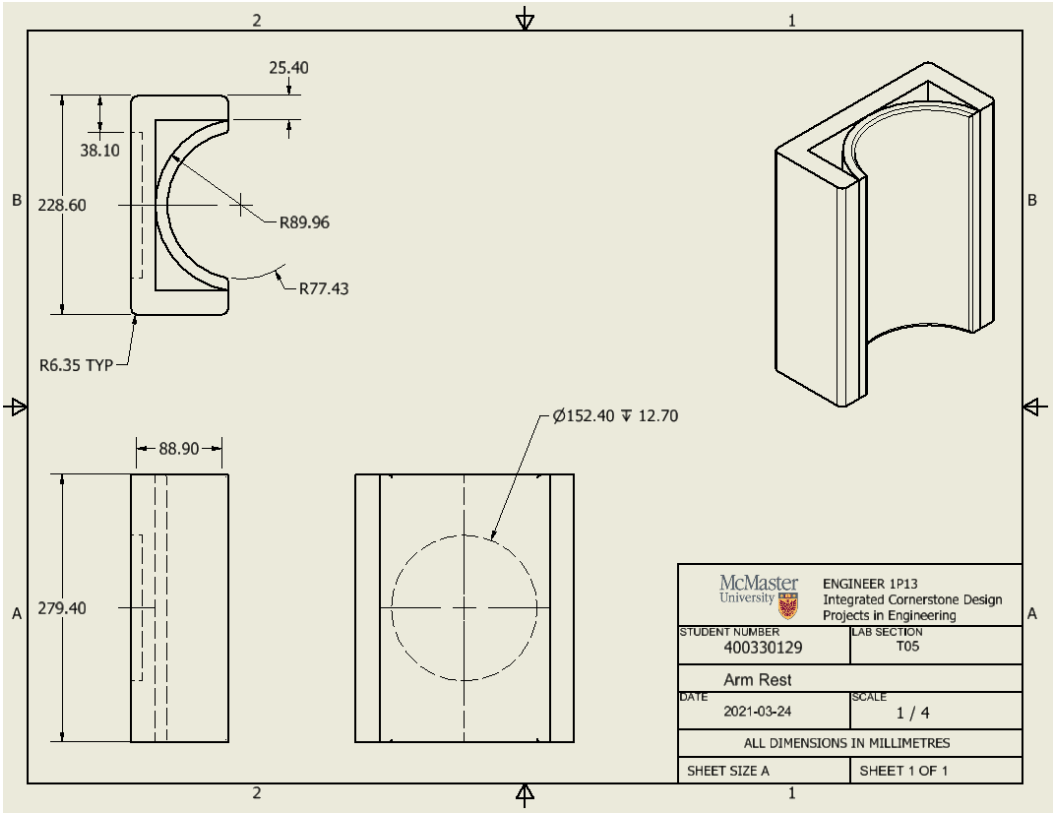


Arm Rest Connector

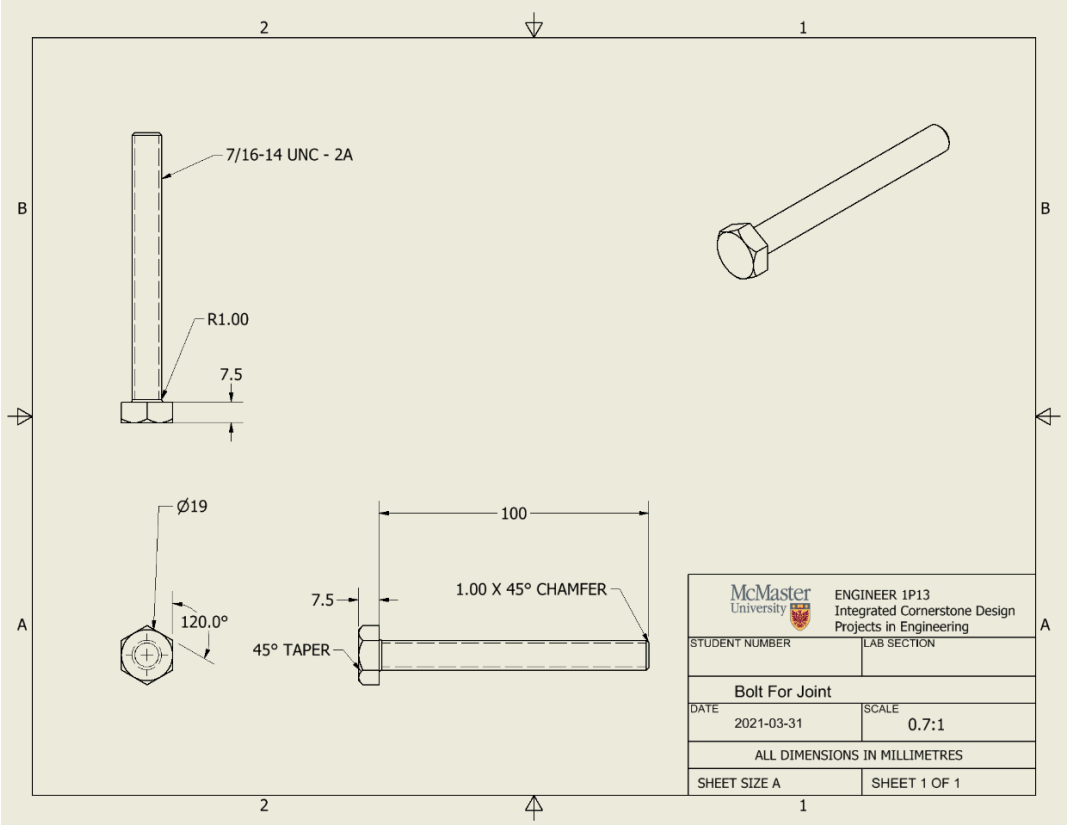


d

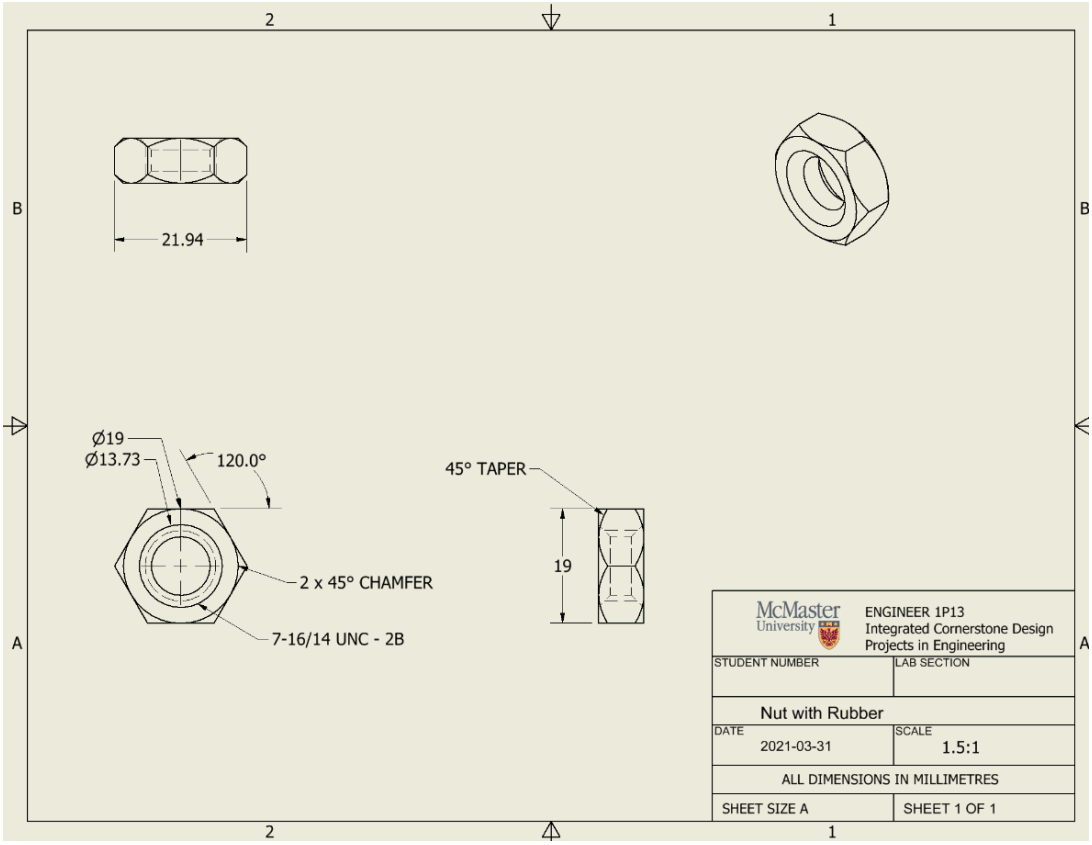
Arm Rest



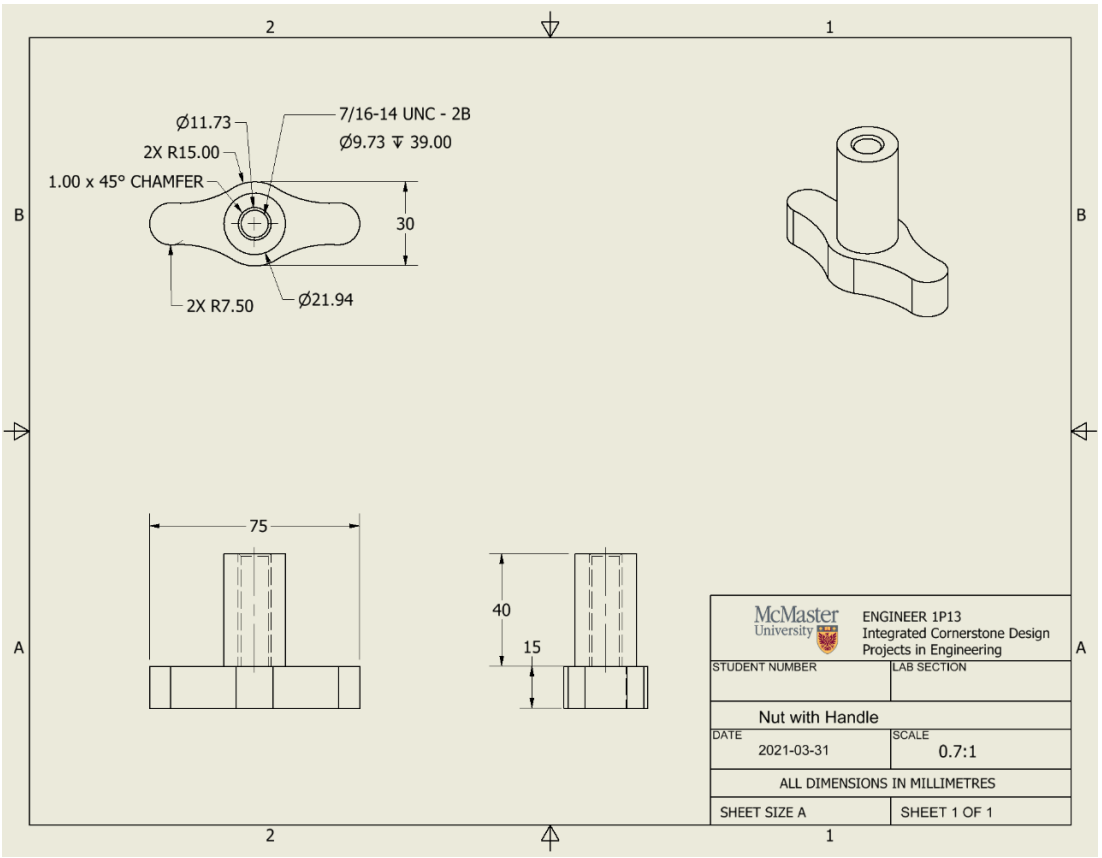
Bolt for Joint



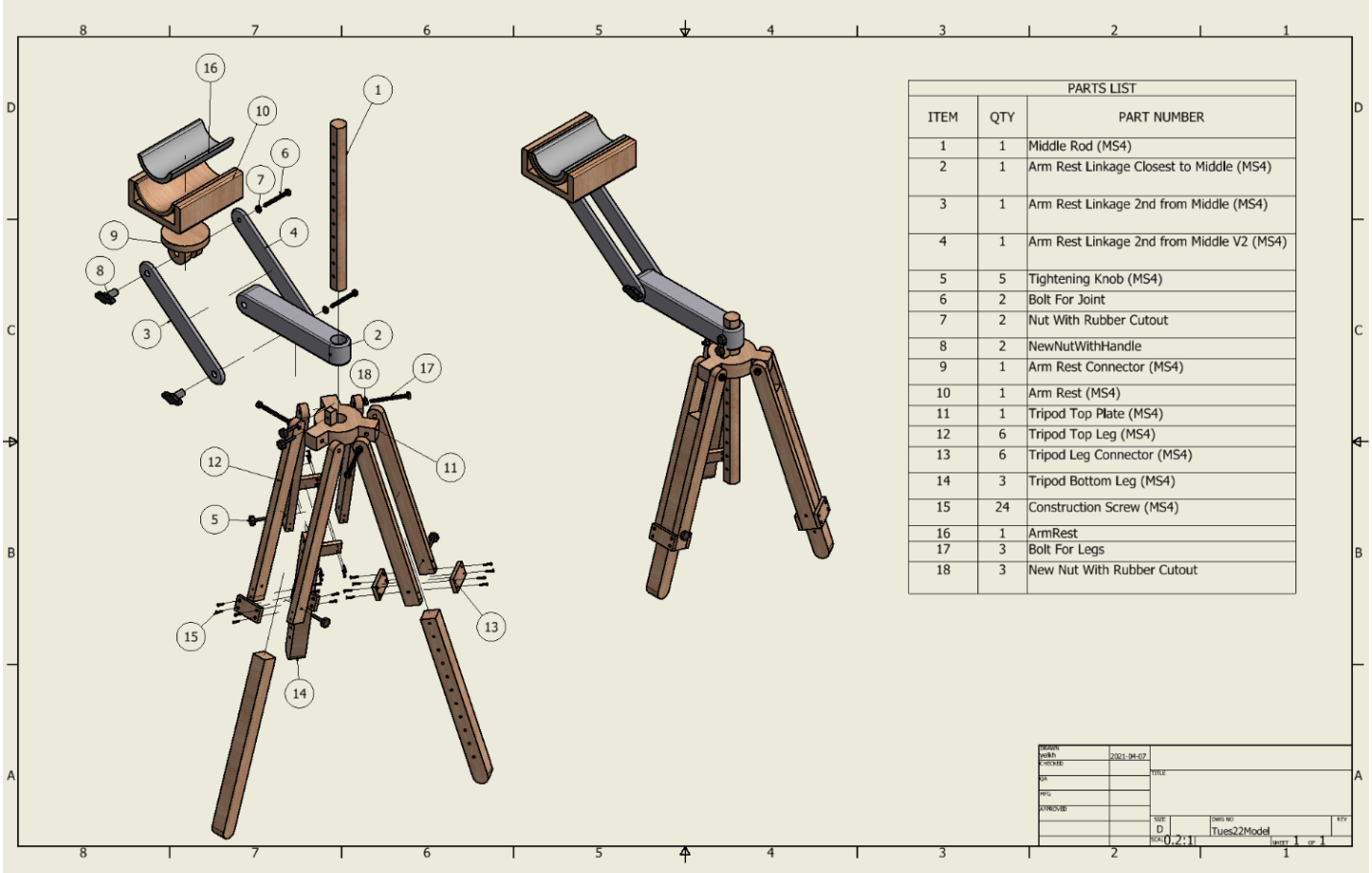
Nut with Rubber



Nut with Handle



Exploded Assembly



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Middle Rod (MS4)
2	1	Arm Rest Linkage Closest to Middle (MS4)
3	1	Arm Rest Linkage 2nd from Middle (MS4)
4	1	Arm Rest Linkage 2nd from Middle V2 (MS4)
5	5	Tightening Knob (MS4)
6	2	Bolt For Joint
7	2	Nut With Rubber Cutout
8	2	NewNutWithHandle
9	1	Arm Rest Connector (MS4)
10	1	Arm Rest (MS4)
11	1	Tripod Top Plate (MS4)
12	6	Tripod Top Leg (MS4)
13	6	Tripod Leg Connector (MS4)
14	3	Tripod Bottom Leg (MS4)
15	24	Construction Screw (MS4)
16	1	ArmRest
17	3	Bolt For Legs
18	3	New Nut With Rubber Cutout

Bill of Materials:

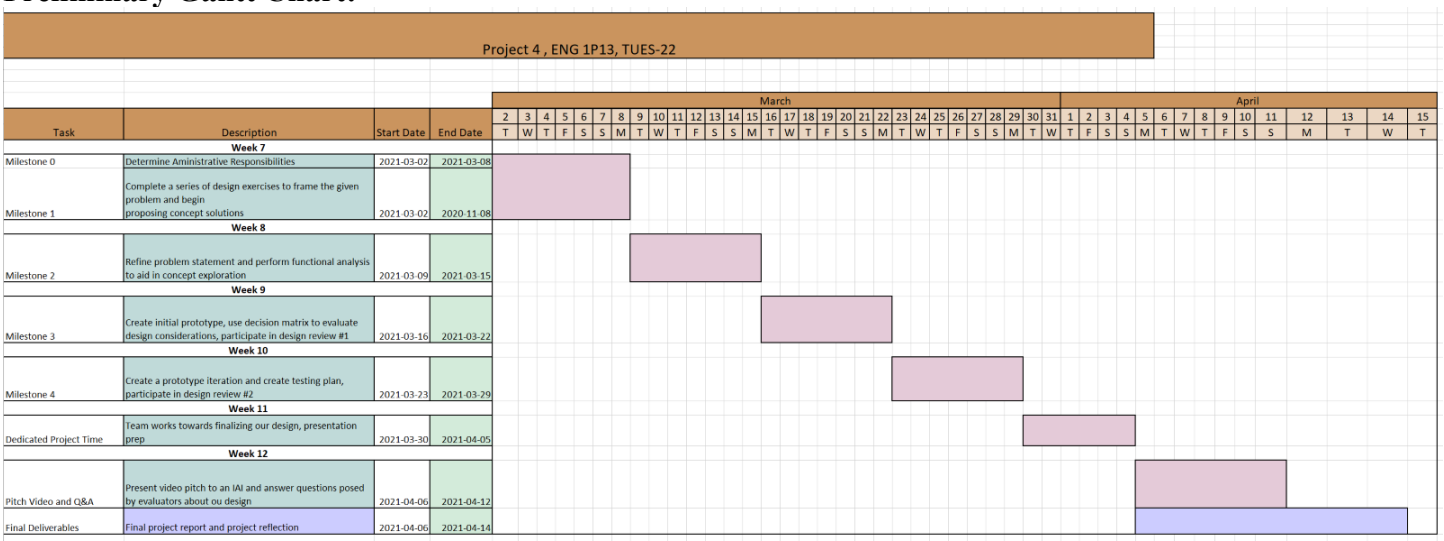
PARTS LIST			
ITEM	QTY	PART NUMBER	PART COST
1	1	Middle Rod (MS4)	4.00
2	1	Arm Rest Linkage Closest to Middle (MS4)	9.00
3	1	Arm Rest Linkage 2nd from Middle (MS4)	4.00
4	1	Arm Rest Linkage 2nd from Middle V2 (MS4)	2.00
5	5	Tightening Knob (MS4)	1.30
6	2	Bolt For Joint	0.27
7	2	Nut With Rubber Cutout	0.52
8	2	NewNutWithHandle	1.00
9	1	Arm Rest Connector (MS4)	8.00
10	1	Arm Rest (MS4)	6.00
11	1	Tripod Top Plate (MS4)	7.00
12	6	Tripod Top Leg (MS4)	4.00
13	6	Tripod Leg Connector (MS4)	2.00
14	3	Tripod Bottom Leg (MS4)	5.00
15	24	Construction Screw (MS4)	0.11
16	1	ArmRest	20.00
17	3	Bolt For Legs	0.27
18	3	New Nut With Rubber Cutout	0.52
		Total Cost	98.78

Appendix D

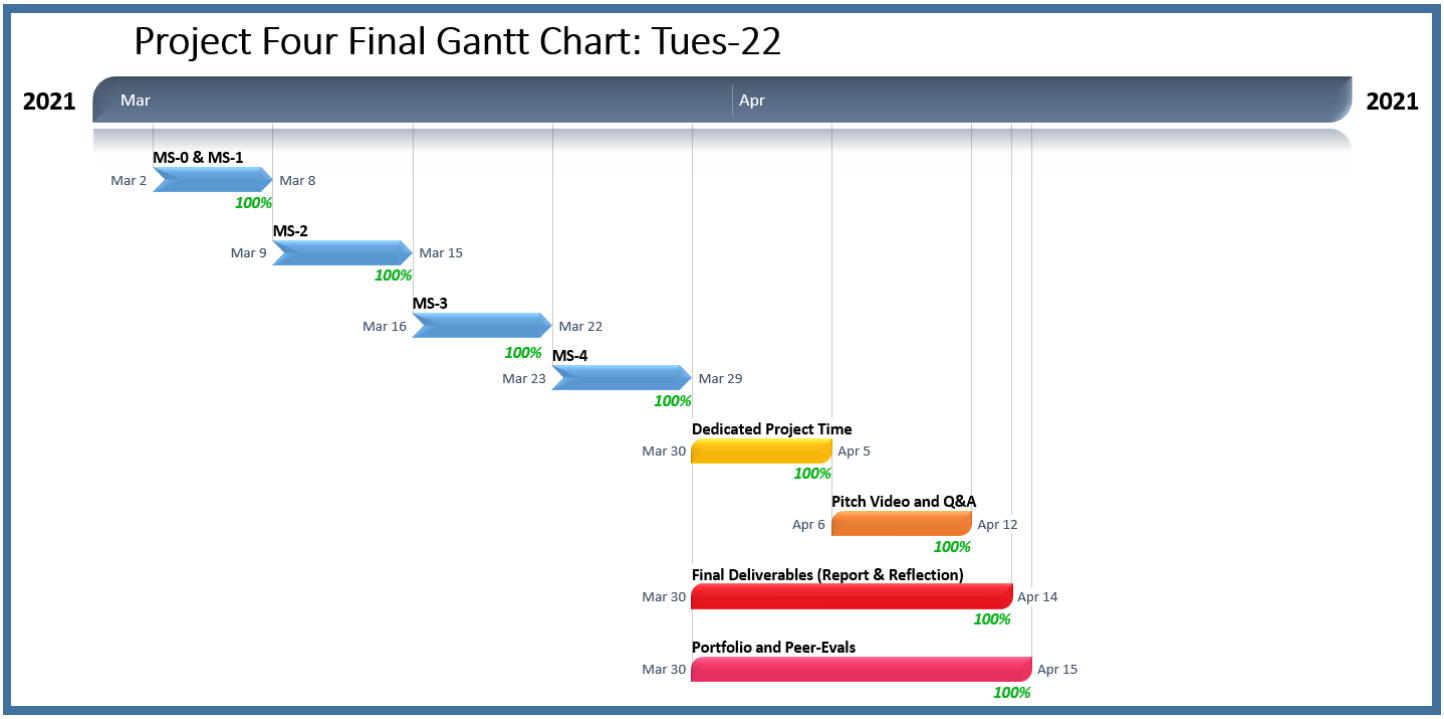
Preliminary Gantt Chart:

Project 4 , ENG 1P13, TUES-22

Task	Description	Start Date	End Date
	Week 7		
Milestone 0	Determine Aministrative Responsibilities	2021-03-02	2021-03-08
Milestone 1	Complete a series of design exercises to frame the given problem and begin proposing concept solutions	2021-03-02	2020-11-08
	Week 8		
Milestone 2	Refine problem statement and perform functional analysis to aid in concept exploration	2021-03-09	2021-03-15
	Week 9		
Milestone 3	Create initial prototype, use decision matrix to evaluate design considerations, participate in design review #1	2021-03-16	2021-03-22
	Week 10		
Milestone 4	Create a prototype iteration and create testing plan, participate in design review #2	2021-03-23	2021-03-29
	Week 11		
Dedicated Project Time	Team works towards finalizing our design, presentation prep	2021-03-30	2021-04-05
	Week 12		
Pitch Video and Q&A	Present video pitch to an IAI and answer questions posed by evaluators about ou design	2021-04-06	2021-04-12
Final Deliverables	Final project report and project reflection	2021-04-06	2021-04-14



Final Gantt Chart:



Logbook of Additional Meetings and Discussions:

Logbook of Additional Meetings and Discussions

Date	Time	Meeting For	What Was Completed
March 2, 2021	12:30-2:20	Design Studio	**Milestone 0 and Milestone 1** ○ Assigned administrative roles ○ Added in individual client notes ○ Worked on initial problem statement ○ Started objective tree ○ Section 1.1, 1.2, and 1.3
March 4, 2021	11:30-2:20	Lab B	**Milestone 1** ○ Finished up objectives, metrics, and justifications ○ Recorded individual experience and approach for the project ○ Section 1.3 and 1.4
March 9, 2021	12:30-2:20	Design Studio	**Milestone 2** ○ Worked on refined problem statement and morph chart ○ Section 2.3 and 2.4
March 11, 2021	11:30-2:20	Lab B	**Milestone 2** ○ Added all of our research, combined client notes, and worked on our preliminary sketches ○ Section 2.1, 2.2, and 2.5
March 16, 2021	12:30-2:20	Design Studio	**Milestone 3** ○ Put criteria for decision matrix ○ Started modelling design in AutoCAD ○ Section 3.1 and 3.2
March 18, 2021	11:30-2:20	Lab B	**Milestone 3 /Design Review** ○ Got feedback from design students ○ Finished decision matrix and decided on final design ○ Recorded feedback ○ Section 3.2 and 3.3
March 23, 2021	12:20-2:20	Design Studio	**Milestone 4** ○ Whole team worked together to refine the protype and fix some issues in the design ○ Finished the testing plans ○ Section 4.1
March 25, 2021	11:30-2:20	Lab B	**Milestone 4 /Design Review** ○ Got feedback on design from science students ○ Finished up the final prototype
			○ Recorded feedback ○ Section 4.1 and 4.2
March 30, 2021	12:30-2:20	Design Studio	**Finalizing design** ○ Got feedback and advice from TA's on design
April 1, 2021	11:30-2:20	Lab B	**Final Deliverable** ○ Started final deliverable- worked on adding images/formatting ○ Assigned sections of deliverable for each person to do
April 4, 2021	8:00-9:45	Final Presentation video	○ Working out who will say what part, and making the slides

Appendix E

Source Materials Database:

[1] "1 – P4 Project Module," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[2] Autodesk Inventor Pro software, Autodesk Inc., San Rafael, California, USA, 2021 (www.autodesk.com)

[3] Ansys Granta EduPack software, Granta Design Limited, Cambridge, UK, 2020 (www.grantadesign.com)

[4] "Wk-8 Design Studio & Lab B (Winter) – P4 Milestone 2 Slides," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[5] "Wk-9 Design Studio & Lab B (Winter) – P4 Milestone 3 Slides," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[6] "Wk-10 Design Studio & Lab B (Winter) – P4 Milestone 4 Slides," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[7] "Wk-11 Design Studio & Lab B (Winter) – P4 Slides," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[8] "Getting Started – Gantt Chart," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[9] "1P13 Template Engineering Drawing (mm)," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[10] "1P13 – Agenda and Meeting Minutes Template," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[11] "Lecture 48, Feb 24 - Project 4 Intro & Client Visit," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[12] "Lecture 49, March 1 - Review of Design Process," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[13] "Lecture 51, March 8 — Review from Conceptual Design to Prototyping," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[14] "Lecture 52, March 10 — Client visit and IMPACT lecture," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[15] "ENG 1P13 - Lecture 53 - March 15 - Designing for Ability," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[16] "Feb. 24th Client Visit Q&A," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[17] "Mar. 10th Client Visit Q&A," class notes for ENGINEER 1P13, Department of Engineering, McMaster University, Winter, 2021.

[18] "What Are Common Symptoms of Autoimmune Disease? | Johns Hopkins Medicine." https://www.hopkinsmedicine.org/health/wellness-and-prevention/what-are-common-symptoms-of-autoimmune-disease (accessed Mar. 09, 2021).

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[20] "Manage Ankylosing Spondylitis at Work." https://www.webmd.com/arthritis/ankylosing-spondylitis-17/daily-life/slideshow-ankylosing-spondylitis-work (accessed Mar. 09, 2021).

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[22] C. Maheu, R. Cashman, K. Johnson, and M. Parkinson, "Lymphedema | Cancer and Work." https://www.cancerandwork.ca/healthcare-providers/cancers-impact-on-work/effects-lymphedema/ (accessed Mar. 09, 2021).

[23] "Fibromyalgia - Symptoms and causes - Mayo Clinic." https://www.mayoclinic.org/diseases-conditions/fibromyalgia/symptoms-causes/syc-20354780 (accessed Mar. 09, 2021).

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[25] "Learn More About Fibromyalgia Symptoms." https://www.practicalpainmanagement.com/patient/conditions/fibromyalgia/fibromyalgia-symptoms-diagnosis (accessed Mar. 09, 2021).

[26] "Products for Lymphedema." https://jeanlamantia.com/cancer-bites-diet-blog/products-for-lymphedema/ (accessed Mar. 11, 2021).

[27] "Arms in Motion." https://www.curetoday.com/view/arms-in-motion (accessed Mar. 11, 2021).

[28] "Treating Lymphedema | Johns Hopkins Medicine." https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/treating-lymphedema (accessed Mar. 11, 2021).

[29] "Lymphedema Compression Pump | Care-Med LTD." https://care-med.ca/lymphedema-compression-pump/# (accessed Mar. 11, 2021).

[30] "Lymphedema - Diagnosis and treatment - Mayo Clinic." https://www.mayoclinic.org/diseases-conditions/lymphedema/diagnosis-treatment/drc-20374687 (accessed Mar. 11, 2021).

[31] "Risk factors and triggers." http://www.lymphoedemanz.org.nz/About+Lymphoedema/Risk+Factors+and+Triggers.html (accessed Mar. 11, 2021).

[32] "Lymphedema - Symptoms and causes - Mayo Clinic." https://www.mayoclinic.org/diseases-conditions/lymphedema/symptoms-causes/syc-20374682 (accessed Mar. 11, 2021).

[33] "Lymphedema in Legs & Arms: Symptoms, Causes, & Treatment." https://www.webmd.com/a-to-z-guides/what-is-lymphedema (accessed Mar. 11, 2021).

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[38] "Stainless Steel Characteristics: Grades, Properties & Applications." https://eagletube.com/about-us/news/stainless-steel-characteristics/ (accessed Mar. 10, 2021).

[39] "(PDF) A new Approach to Mouth Sticks Material selection for Additive Manufacturing of personalizable Mouth Pieces." https://www.researchgate.net/publication/342353959_A_new_Approach_to_Mouth_Sticks_Material_selection_for_Additive_Manufacturing_of_personalizable_Mouth_Pieces (accessed Mar. 10, 2021).

[40] “Find specific products for children or parents with disabilities. Larimer County, Colorado.” https://larimer.co.networkofcare.org/aging/assistive/list.aspx?indexingterms=painting-tools (accessed Mar. 10, 2021).

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[44] “Treating Lymphedema | Johns Hopkins Medicine.” https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/treating-lymphedema (accessed Mar. 11, 2021).

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