Cooking Hand Multi-Tool

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Challenger: Jorge Segura

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Executive Summary

The purpose of this project was to devise a solution for Jorge Segura, a US Marine who was wounded in Afghanistan and had to have his non-dominant arm amputated above the elbow. His current prosthetic attachments are not suited to cooking tasks, so he needed a way to cook more effectively with either prosthetic attachments or accessibility devices. The main tasks that he needed help with was holding down food on cutting boards and stabilizing pots, pans, and bowls especially when stirring. After background research, exploring commercially available devices, and talking with our challenger, our solution was to design three prosthetic attachments with a quick-change wrist to enable Jorge to stabilize pots, pans, and bowls, as well as hold food down on a cutting board and switch between the attachments efficiently.

The quick-change wrist operates in a twist-and-lock fashion, with the wrist inserts mating into the wrist receiver and locking into place with magnets on each component. The wrist receiver easily mates with Jorge's current wrist so that he can efficiently and easily install our quick-change wrist into his existing wrist. The wrist is predominantly made from delrin to reduce weight and improve component machinability. The prototyping process for the wrist cost $144.58 to develop our functional prototypes, while the estimated mass production cost is only $13.99 per wrist assembly.

The clamp attachment interfaces with Jorge's current body powered prosthetic arm through a connector plate mounted on the attachment body. Jorge is able to engage the cable to open the clamp so that it can fit over various sizes of pots and bowls, and release the tension in the cable to allow it to close over the pot or bowl. The clamp is also fully adjustable, with a trifold face designed with springs to conform to different diameters, and an angled guide that is adjustable with thumb screws to allow Jorge to angle the trifold to fit on curved bowls. It also includes a set of angled and straight inner prongs that can be removed for easier cleaning. The clamp is predominantly made from aluminum to reduce weight and has an estimated cost of $209.55 to develop our functional prototypes, while the estimated mass production cost is only $43.25 per clamp assembly.

The sleeve attachment allows Jorge to stabilize shallow pans with long handles. The design includes a simple diamond-shaped opening to fit over a variety of pan sizes, and has no moving parts for simplicity. Made from a 3D printed core and sheet metal inserts and connections, the sleeve is relatively lightweight and easy to manufacture. Design development to make our sleeve prototypes cost $124.91, while the estimated mass production cost of one sleeve is only $8.05.

The cutting tool attachment enables Jorge to secure various sizes of food onto a cutting board. It is made of clear acrylic to allow Jorge to receive visual feedback from what he is cutting. The design of the cutting tool attachment includes several ridges to allow for better grip, and a narrow slit on the base to allow for perpendicular knife cuts. The cutting tool has an estimated development cost of $70.86 for the prototypes, with an estimated mass production cost of $4.72 per assembly.

For future manufacturing of the wrist, we recommend that the wrist inserts be made from aluminum instead of delrin to improve the strength of the epoxied and press-fit joints. This would increase the weight of the device and decrease the cost slightly. We recommend that future iterations of the clamp include a more robust prong design, and a more secure connection for the angle guides. To manufacture more copies of the sleeve, we recommend adding a key to both sides of the connecting rod to fully restrain the rotation of the connecting rod. This would increase the weight and cost of the sleeve marginally. Finally, for future iterations of the cutting tool we recommend looking into a solid construction cast from food-safe resin in order to improve cutting tool durability with respect to impact loads.

1. Introduction

The challenger for this project is Jorge Segura, a US Marine who was wounded in Afghanistan. After 7 years and 26 surgeries to try and save his arm, he decided to amputate his right arm above the elbow. The goal of this project was to provide Jorge with a way to cook independently and efficiently with his amputated arm. This was solved with a functional device that allows him to increase his ability to navigate various tasks in the kitchen. Jorge needed a device to help him open jars, as well as enable him to stir while preventing the pot or bowl from moving away. Additionally, a new device to help with chopping or cutting was needed because his current one-handed cutting board is unreliable.

Our team on this project consisted of four Cal Poly engineering students: Amanda Meares (mechanical engineering), Amy Wilson (mechanical engineering), Duania Evans (general engineering) and Ethan Littlejohn (general engineering). Additional information on the team can be found in the About the Team section at the end of the report. Throughout the design process, we worked closely with our challenger, Jorge Segura, our QL+ advisors, Barb Springer, Vanessa Salas, Art Yeager, and Alan Strasburgh, and our lab advisor, Jim Widmann. In addition to completing this project, various requirements for the interdisciplinary senior project courses at Cal Poly were completed and shared with our QL+ advisors and challenger.

1.1) Management Plan

The following three flowcharts [show a general overview of our process of working on this project, and what was accomplished. We also developed a tentative timeline of work conducted throughout the project, which is displayed in the form of a Gantt chart (Appendix 4).

We have been working closely with Jorge to ensure our design concepts match his needs. Occasional phone calls or video chats have occurred to help ensure this. Additionally, we shared our progress with our QL+ sponsor and project advisor on a weekly basis and at key points throughout the quarters we shared design documentation to ensure all requirements were met.

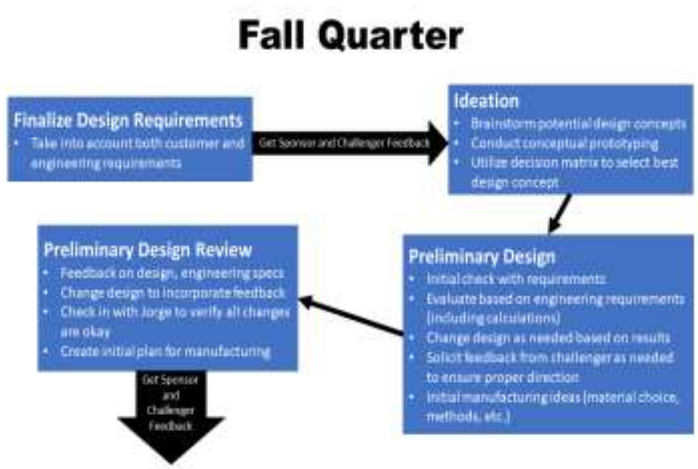

Figure 1.1) Flowchart of work throughout fall quarter

For the first quarter of the project, we came up with a preliminary design. The overall workflow for fall quarter can be seen in Figure 1.1, and included finalizing design requirements, conducting ideation of potential designs, choosing and developing the preliminary design, and developing a preliminary design review presentation. Key deliverables included the project requirements document, project schedule, and a preliminary design review and this preliminary design report.

Figure 1.2) Flowchart of work throughout winter quarter

By incorporating the feedback from the preliminary design review, we updated our preliminary design during the first half of winter quarter in order to develop a detailed design. We then presented this detailed design in a critical design review, which included proof-of-concept prototypes, finalized materials, and manufacturing and testing details. After the critical design review, we began to manufacture functional prototypes. By the end of Winter Quarter, we had prototypes of the wrist, sleeve and cutting tool sent to Jorge for preliminary ergonomic feedback. The overall goals and steps for winter quarter can be seen in Figure 1.2.

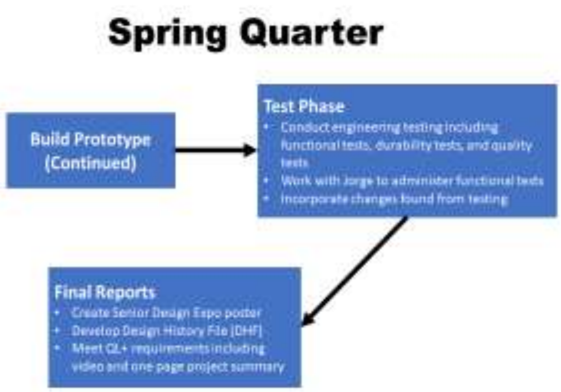

Figure 1.3) Flowchart of work throughout spring quarter

Prototype building continued through the first few weeks of spring quarter. After this stage, we performed system testing. These included engineering tests to verify engineering requirements, as well as functional tests with our challenger Jorge to ensure the device meets his specifications. After successful testing and interactive design changes, we developed a fully functioning prototype to send Jorge. To finalize the project, we then developed final documentation to share what we have accomplished, including a Design History File, Senior Design Expo Presentation, and video for QL+. The overall project plan for spring quarter can be seen in Figure 1.3.

2. Background

There are three different types of prosthetics above-elbow amputees can choose to use —passive, body-powered, and myoelectric. Passive prosthetics are purely for aesthetic purposes and are used to provide the user with a sense of normalcy in appearance. Body-powered prosthetics are mechanically controlled through various harnessing systems, which allow the user to control the motion of the prosthetic through shoulder and upper body movements. These prosthetics are functional devices and often have split hooks, prehensors (devices with thumb component and finger component), or other mechanical devices as the terminal. The final type is myoelectric prosthetics, which is another type of functional prosthetic. Myoelectric prosthetics are controlled through sensors that measure electrical impulses of the nerves in the residual limb. That signal is then passed through a microcontroller which regulates motor-powered joints within the prosthetic.

Figure 2.1) Body-powered prosthetic (left) and myoelectric prosthetic (right) made by Ottobock (Ottobock Prosthetics)

Of these prosthetic types, 90% of upper limb amputees who use prosthetics choose to use a body-powered prosthetic (Cupo & Sheredos 1998). This is most likely due to some key advantages of body-powered prosthetics. Typically, they have a lower initial and repair costs. Additionally, they are lighter and provide the user with some tension feedback due to their mechanical design similar to hand brakes on a bicycle. Myoelectric prosthetics have some advantages as well, such as no uncomfortable harnessing and stronger, more sensitive grip strength. Many myoelectric hands are modeled after the human hand, allowing them to handle items more similarly to a human hand. Some artificial hands even have sensors in them, which sense the needed grip force and automatically adjusts to prevent items from being dropped by accident (Bowers 2014).

One example of a functional prosthetic for an above elbow amputee is the AdVAntage Arm, which is a body-powered prosthetic detailed in the "Clinical Evaluation of a New Above-Elbow, Body-Powered Prosthesis Arm" by Mary E Cupo and Saleem J Sheredos. This prosthetic was specifically designed for people with low shoulder mobility and/or short residual limbs. In these cases, traditional body-powered prosthetics provide less mechanical advantage and lower lift forces. The AdVAntage arm has a separation mechanism, which allows the terminal device to lock when the elbow is being controlled, and conversely allows the elbow to lock when the terminal device is being controlled. A lock cable is used to switch between the two modes and increases the range of positions the prosthetic can be used in. Traditional body powered prosthetics limit the motion of the elbow and terminal device, such that when the elbow is bent the terminal device cannot be fully actuated. The AdVAntage Arm prosthetic helped to fix that issue, while still using standard sockets and conventional dual cable harnessing. This specific prosthetic had a large learning curve for both the prosthetist and prosthesis user, but once the learning curve was overcome it had relatively successful results. One of the biggest complaints was that the device was not compatible with quick release wrists that allow for specialized terminal devices, such as attachments for athletics. Overall, clinical trial was conducted on 16 patients and 10 of those chose to continue using the AdVAntage Arm over their previously used prosthetic (Cupo & Sheredos 1998). This result was better than the average rejection rate of 50% for body-powered prosthetics (Kate, Smit, & Breedveld 2017).

Within passive and body-powered prosthetics, there are also a variety of wrist joints that can be used in order to give the user specific functionality. The standard option, shown in Figure 1.2 on the left, is a simple friction wrist. Fixed in place on the prosthetic device, this wrist has interior threads where the user can screw a terminal device into place. The terminal device can then rotate with friction about one axis, allowing the user to rotate the terminal device into the desired position. The interior friction plates provide a locking mechanism that prevents the terminal device from rotating freely. A more complex option, shown below in Figure 1.2 on the right, is a flexion friction wrist. This type of wrist has the same single axis of rotation as previous, in addition to a second axis of rotation. This second axis can be adjusted manually by the user, and the terminal device is locked into place by pushing the tab. More complex wrist joints can provide three axes of rotation, but these are not standard. One main drawback with these different wrist attachments is the time needed to thread the terminal device into the wrist, and the alignment issues that stem from this method of attachment (Bajaj, et. al).

Figure 2.2) Hosmer Dorrance Friction Wrist (left), Hosmer Dorrance Flexion Friction Wrist (right), from (Bajaj, et. al)

For customers that want more precision out of their devices, there are myoelectric options available that offer more functionality and simpler controls than body-powered devices. There are several styles of myoelectric arm prosthetics, the lightest of which being the Boston Elbow (Toledo 2009).

First introduced in 2001, the Boston Elbow consists of a modular, lightweight forearm attached to a simple elbow joint with myoelectric sensors. It is compatible with a variety of terminal attachments, such as the electronic Otto Bock Hand, or a cabled hook/prehensor. The Boston Elbow itself only weighs less than half a pound, while attachments like the Ottobock Hand weight just over a pound (Toledo 2009). This prosthetic provides significant weight-savings and comfort for the wearer. The Utah Arm has been around since 1981 and has made many performance gains in the early 2000s to allow for greater loading at the terminal device and the ability to control multiple functions at once since there are two microprocessors on the prosthetic. However, these performance gains come at a cost of weight, since the Utah Arm weighs two pounds without a terminal attachment.

As seen above, there are many options available for arm prosthetics, but user retention is still a pressing problem. A study from the Journal of Hand Therapy found that 56% of upper-arm amputees rarely or never used their prosthetics, and that those who used their prosthetics rated their quality (in terms of comfort, ease of use, amount of sweating) to be fair or unacceptable (Davidson 2002). It is worth noting that the sample size in this study was only 70 upper-arm amputees, but similar trends were seen in the other sources listed above. Thus, designing a prosthetic that the user will actually wear regularly and enjoy wearing is of prime importance.

Figure 2.3) North Coast Medical Inc, Stovetop stabilizer (left), EZ Off jar opener (right). (North Coast Medical Inc. & Amazon)

Other cooking aids include devices which stabilize pots, bowls, and other cooking equipment to allow Jorge to continue using his dominant hand for more precise tasks. Specialized mixing bowls with rubber grips on the bottom can be suitable for one-handed mixing, as well as generic bowls placed on top of silicone gripping mats. In addition, there are also wall- or countertop-mounted devices such as flexible vegetable peelers, jar openers, and other specialized cooking tools available (Cisler). One jar opener currently available is the EZ Off Jar opener which attaches to the bottom of a cabinet and grips the lid, so that the jar can be turned by the user. The reviews on this device say that it works well, but it can be very difficult to open jars that haven't been open before. Currently, there are a couple of stovetop pot stabilizers on the market. North Coast Medical Inc. has created a device made of a wire frame that holds the handle of a pot securely. It has suction-cup feet securing the frame on the stove and it is supposed to accommodate different size handles. A similar device is the Sammons Preston Folding Pan Holder. The folding holder device is made of steel with rubber suction-cups that keep the device in place. The adjustable pan holds a 2 quart pan/pot and folds for easy storage in the kitchen drawer. Review on both of these devices claim that the devices do not fit enough pot sizes and the suction-cups touch the burners and don't always stick well.

3. Customer Requirements

Based on conversations with Jorge, he wanted his device to be lightweight, durable, and provide aforementioned cooking support. He struggled with gripping items with his current prosthetics, and was unable to use them for cooking tasks. The customer requirements we derived are as follows, with their matching engineering specifications detailed below.

3.1) ***Customer Requirement 1:*** *Cooking Functionality*

The device needs to help Jorge grip objects, like pots and bowls, and keep them steady when stirring. He also needs to be able to grip and open jars on his own. In addition, his custom cutting board has been unreliable, so a method to improve the stability and reliability of his current food prep environment would be helpful for him as well. The cooking functionality of this device is highly dependent on the ergonomics of the device, as Jorge needs to manipulate the device with ease in order to accomplish cooking tasks. Verifying this requires end-user testing and shipping prototypes to him. To enhance the ergonomics, the device must be designed proportional to Jorge's size in terms of outer dimensions and weight. For safe use in the kitchen, the device must also be resistant to heat and sticky contaminants. Another important quality is the food safety of the parts of the device that come in contact with food. This helps drive the material choice of the terminal device and dictates whether any additional coatings or coverings are needed. The food safety of the device are verified against FDA food safety regulations.

3.2) ***Customer Requirement 2:*** *Lightweight*

Though weight is also an engineering requirement, we included it as a customer requirement as well because it is crucial to the function and ergonomics of the device. The weight must be low enough that it does not put excess strain on Jorge's body, especially around his shoulder and residual limb. Since Jorge has likely experienced muscle atrophy in his residual limb, we designed to the weight of his plastic body-powered hook attachment (0.5 pounds), with an added 5% tolerance for epoxies and finishes. To test this, we carried the material properties through CAD work as well as measure the working prototypes prior to any other testing. Decreasing the weight could increase the overall cost of the device, so optimization of cost and weight played a large role in the design process.

3.3) ***Customer Requirement 3:*** *Waterproof*

Since this device will be used in the kitchen, it must be waterproof. The most crucial areas are around the terminal device and up to the wrist joint, while the rest of the prosthetic may only need to be water-resistant. Whereas the terminal device will be used under running water to clean food or be cleaned itself, the elbow joint up to his socket could face splatter and spills with far less frequency than the wrist joint. Thus, the prosthetic must be resistant to water, and any electrical components must be sealed in a water-tight enclosure. If the solution is not a prosthetic but rather an external device, it still needs to be waterproof. These engineering requirements affect the material choices for the terminal device and the overall packaging of the device. We used FDA regulations and guidelines once more to verify the materials used meet waterproofing needs, and we ran prototype tests with the device submerged in water to verify that critical internal areas remain dry.

3.4) ***Customer Requirement 4:*** *Comfortable**

Comfort is essential for the continued use of a prosthetic. Without a comfortable design, a perfectly functional prosthetic may never be used in the user's daily life. Therefore, the outer dimensions of the prosthetic are critical to creating a seamless fit with his existing socket, or a new socket if needed. We can design for and measure the dimensions of the prosthetic using the dimension of Jorge's socket and remaining arm, as well as his residual limb if a new socket is deemed necessary. Weight is another key factor in this, as excess weight could create strain and pain that would make the device unusable. The same design and test criteria for weight were used as described previously. In addition, prototypes were shipped to Jorge to verify that it is comfortable for him to wear for extended periods of time.

3.5) ***Customer Requirement 5:*** *Robust*

The device must be robust in the kitchen environment in order to withstand abrasion, heat loads, and prolonged contact with water. It will also need to last for several years of daily use, so fatigue of the device and joints were considered as well. The main engineering requirements that correlate to the overall durability of the device are the strength and stiffness compared with the weight. We designed for a factor of safety of greater than two throughout the entire device. To account for stiffness, we performed static load testing to determine the deflection of the arm under rigorous situations. The deflection will need to be imperceptible, as it could be alarming for Jorge to see his arm bending even if it is well within the elastic deformation region. Throughout this process, the weight must be minimized to stay under the maximum set previously.

3.6) ***Customer Requirement 6:*** *Ease of Use*

The device must be easy to use, from installing the device to switching devices and performing different cooking operations. Jorge must be able to put on his prosthetic and change any attachments independently. The primary engineering requirement associated with this is the ergonomics of the device. In designing for usability, we minimized the amount and complexity of the attachment methods. To test the ergonomic factors, we sent prototypes to Jorge and timed how long it takes for him to put on the device, switch attachments, and perform specific cooking tasks.

3.7) ***Customer Requirement 7:*** *Easy to Keep Sanitary*

Since this device will be used in the kitchen, it is crucial that it is easy to clean and maintain a safe cooking environment. Therefore, the outermost material must be nonporous and resistant to exposure to water and cleaning agents. This helped steer the material choice for the exterior of the device. These surfaces must be food safe to FDA standards. The material choices to promote cleaning must also meet the strength and stiffness requirements mentioned above.

3.8) ***Customer Requirement 8:*** *Aesthetics*

Aesthetics is a lower priority for this project, but we still want to address it so that Jorge can have more confidence when cooking for a group, for instance. We also want to encourage Jorge to use the device as much as possible, so adding an aesthetic component to the aforementioned requirements should help bolster prosthetic retention. The main factors affecting the aesthetics are the overall form of the device. We designed dimensions to his other arm as much as possible and verified the similarity of our prototypes. For overall form, we sent prototypes to Jorge and evaluate his aesthetic concerns with a set of questions.

3.9) ***Customer Requirement 9:*** *Safe to Use*

The safety of the device is of prime importance. We considered the attachments between the socket and Jorge's body, the reliability of the device, as well as the sharp terminal devices. The attachment to Jorge will need to be comfortable, so we considered improving upon existing straps and evaluating possible pinch points using FDA guidelines. We verified that pinch point risk has been mitigated by testing the attachment swapping ourselves, and confirmed with Jorge in terms of comfort. We considered the safety of the attachments themselves, as any sharp edges made during manufacturing must be broken. In addition, we ensured that any potential electronics are stored safely to mitigate the risk of electric shock. If needed, we were to design an insulated enclosure for the electronics and ensure that there is no electrical pathway to the socket, where compression and sweat could increase risk of shock. We were to test any electronics prior to installing in the device, as well as after installation and under high loads before sending the prototype to Jorge for functional testing.

3.10) ***Customer Requirement 10:*** *Doesn't Damage Other Cooking Equipment*

We also considered the interaction between the device and other cooking equipment. We want to avoid damage to pots and pans, especially if there is a metal attachment interacting with a non-stick surface. In addition, we considered more fragile equipment such as plastic buttons on blenders and food processors, knobs and handles on stovetops, microwaves, and ovens. This constrained the material choice for the exterior of the device, in addition to the strength, weight, and waterproof needs mentioned above. We designed for interactions between the device and common tools and surfaces in the kitchen and followed FDA guidelines for food safety and material interactions. We tested the terminal devices ourselves and ensure they do not scratch common kitchen appliances.

Note: * denotes requirements that are necessary for prosthetic devices only

4. Engineering Requirements

Using a Quality Function Deployment (QFD) chart (Appendix 1), we translated the above customer requirements into testable engineering requirements. The first column lists each of the customer requirements, and the row along the top of the document shows the engineering requirements that will impact the customer requirements. To determine the most important engineering requirements, we added a weighting system and ranked each engineering requirement by how much it affects the product function. With this chart, we also compared how well Jorge's existing device and other options on the market fulfill the customer requirements.

The results of the QFD chart showed that the most critical engineering requirements are the weight, food safety and ergonomics. The various test methods for the engineering requirements are summarized in Table 1, and are ranked by their order of importance on the QFD chart. The risk column has three different designations which are low (L), medium (M), and high (H). The compliance column describes how each requirement is validated and it includes four methods: Analysis (A), Test (T), Similarity to other designs (S), and Inspection (I).

Table 4.1) Formal engineering requirements

Spec #	Parameter Description	Target	Tolerance	Risk	Compliance
1	Weight (attachment+wrist)	Weight ≤ 0.503	Max	M	A, T, S
2	Food Safety	Meets FDA Requirements	Pass/Fail	M	T, S
3	Ergonomics	Compatibility with Jorge	Pass/Fail	H	T, S
4	Thermal Resistance	Cool from 400°F to 120°F within 10 seconds	Max	M	A, T
5	Strength	Factor of Safety = 2	Min	M	A, T
6	Deflection	0.04 in	Max	M	A, T

The primary engineering requirement is the weight of the device, which we set as a maximum equal to the weight of Jorge's existing body-powered hook attachment. Instead of deriving an overall thermal resistance for each device, we decided to evaluate the components in contact with hot surfaces and ensure the time to cool from 400°F to 120°F (a hot pan temperature to a safe touch temperature) is less than 10 seconds. The strength of the device must also be considered, with a minimum factor of safety of 2 for all components to ensure product safety while also keeping weight as low as possible. The static deflection of the device will be accounted for as well, with a maximum loaded deflection of 0.04 in. This is the maximum deflection for our assumed device length that would remain undetectable to the human eye. All these requirements were designed for and analyzed prior to building and testing a prototype.

The more subjective requirements (food safety and ergonomics) cannot be specifically designed for, but there are existing standards and other products that guided our design. For food safety, we followed FDA standards for compliant materials. For ergonomics, we compared our design to existing market products and improved upon areas where those products fall short. In addition, we sent our prototypes to Jorge for functional and ergonomics testing.

5. Design Development

During the design development process, we used an assortment of household materials to model several preliminary concepts. Each concept was reviewed and rated on how they met the customer requirements. Following the review process, a Pugh Matrix (Appendix 2) was used in order to rank the ideas in terms of functionality compared to a datum. Three of the top rated concepts included the crane bowl holder, the orange sleeve jar opener, and the clamp attachment, all shown in Figure 5.1.

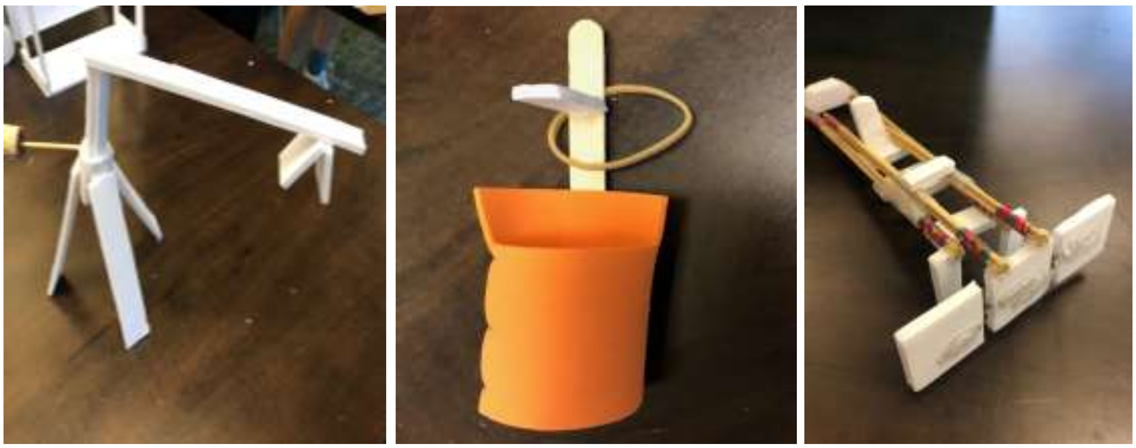

Figure 5.1) Crane bowl holder (left), Sleeve jar opener (middle), Clamp attachment (right)

5.1) Crane Bowl Holder

The crane bowl holder was highly ranked because it had great potential for stabilizing large pots and bowls, which was one of the primary cooking requirements. It had a height adjustment mechanism, modeled with a cork on a skewer, that allowed it to grip many sizes of pots or bowls. Some of the largest drawbacks with the crane design were the large moment arm created with the length between the base and the gripping surface, as well as the poorly defined attachment mechanism between the base of the crane and the countertop. In addition, the design was centered around one contact point, decreasing the stability of the system. This could be mediated with a heavier base, but at the cost of useability.

5.2) Sleeve Jar Opener

The sleeve jar opener was chosen because it met the cooking functionality requirement of opening jars. A benefit of the sleeve was the adjustable opener on the top and the ability to grip a jar. The sleeve would hold the jar and the user would then be able to twist the top of the jar open. After more discussion, we concluded that it also had the possibility of being electric to completely eliminate the user's need to twist the lid open. Some possible issues observed included the need for different sizes of sleeves, or a vacuum/suction mechanism that would tighten the sleeve to accommodate multiple sizes of jars. We decided to not continue with the jar opener idea at the recommendation of occupational therapist Art Yeager, who suggested several devices already on the market to accomplish this task. We noted that the large grip surface of the sleeve could be useful in other applications, and this led to the development of a sleeve attachment for gripping pan handles.

5.3) Clamp Attachment

The clamp attachment was chosen because it provided stability for different size pots and bowls. This design utilized a moveable trifold and two prongs on the outside of the clamp system, with the clamp designed to be operated with a body-powered prosthetic cable. Motion of the shoulder would move the trifold away from the prongs, providing room for the device to be placed over the lip of a pot or bowl. Releasing the tension in the cable would clamp the pot within the trifold and the prongs. This design ranked highly due to its versatility and compatibility with Jorge's existing prosthetic. However, with the trifold on the inside of the clamp, there was a relatively large area of the clamp that could come in contact with food. This was a food safety concern and therefore in our final design we changed the orientation of the prongs and the trifold so that only two small prongs would potentially come in direct contact with food. Additionally, by moving the trifold to the outside of the pot or bowl, smaller diameter items can be clamped on since the length of the trifold is no longer the limiting diameter of the item.

Each of these ideas played a significant role in our final design concepts. The crane arm was the highest ranking tabletop device for stabilizing pots and pans, but it came with many drawbacks in terms of stability, ease of use, and adaptability for use on a variety of sized pots and bowls. This steered us toward designing prosthetic attachments rather than tabletop devices, since most tabletop devices were cumbersome, not easily adjustable, and difficult to clean. The jar opening sleeve inspired the final sleeve design that would hold shallow pan handles. The initial clamp attachment was modified in order to provide better stability and to reduce the surface area coming in contact with food. In addition, the trifold concept from the clamp design was integrated into a device which will help Jorge chop food on a cutting board. Using the trifold idea and removing the prongs, we came up with a clamping device that would enable Jorge to stabilize food on a cutting board and apply enough compression to prevent the cutting board from moving away from him.

6. Design Concept

The overall design is a series of three terminal devices attached to Jorge's existing body-powered prosthetic with the addition of a quick-change wrist mechanism. The three attachments are: a body-powered clamping device to grip the sides of pots and bowls, a passive sleeve to hold long pan handles, and a passive cutting tool to keep food in place on a cutting board. The first iteration of these four devices are shown in detail below.

6.1) Quick Change Wrist

Jorge's current quick change wrist does not meet his needs for easily and quickly changing attachments. Therefore, we needed to design a quick-change adapter to allow Jorge to easily and efficiently switch between cooking tasks. The initial quick-change wrist was composed of two main parts shown in Figure 6.1.

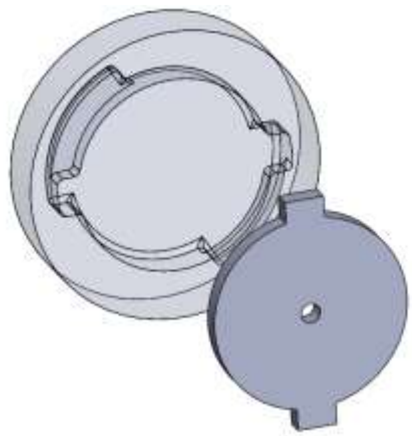

Figure 6.1) Initial quick-change wrist attachment

The larger, grooved piece is to be threaded into Jorge's existing body-powered wrist attachment. The small, circular piece with tabs are then to be inserted into the mating hole and twisted to fit in the groove. Magnets were embedded in both parts, so that when the two sides of the quick-change wrist are brought together, they lock into place. The magnets were sized such that they lock and unlock the attachments without excessive amounts of force. Note that Figure 6.1 is a preliminary CAD model, and the wrist attachment mechanism shown is not a machineable part. The detailed design phase updated this part for manufacturability, resulting in the machining and joining of two separate parts instead of machining a complex interior pocket as shown above.

We verified this mechanism with a functional foam core model, as seen in Figure 6.2 (left). This model showed that an additional locking mechanism, chosen to be magnets in this case, are necessary to keep the terminal device from moving within the slot. The model also drew attention to the need to regulate the tolerances on each part in the detailed design phase, since there was an excess of clearance in the mechanism that has been reduced as much as possible. A second model was also created, pictured in Figure 6.2 (right), in order to further test the design. This model was 3D printed in order to test the modeled geometry and understand how magnet placement within the design would function. Our initial magnet placement did not supply enough force to keep the wrist insert stable in the overall assembly. This is because we placed the magnets so that they disengage with a sliding motion. However, the strong axis for magnets in perpendicular to their contact surfaces, rather than parallel as we designed the initial wrist. This lead to the decision to locate the magnets in the tabs of the wrist insert, as detailed in Section 7.1.

Figure 6.2) Initial models of the quick-change wrist; (left) foam core model; (right) 3D printed model with embedded magnets

This concept achieves the customer requirements of being easy to use, comfortable, and safe. As mentioned above, the quick-change concept allows Jorge to be able to switch between multiple attachments while he is performing his various cooking tasks. He needs to perform many distinct tasks while cooking, and that a single device would not be able to fulfill all his cooking requirements. Therefore, he needs to be able to switch between attachments often during the cooking process. With this quick-change design, Jorge will easily be able to switch between multiple attachments quickly with a very small learning curve.

6.2) Body-Powered Clamp

The first iteration of the clamp shown below in Figure 6.3 is the only body-powered terminal device we made. It is designed to clamp onto the lip of pots without long handles and bowls.

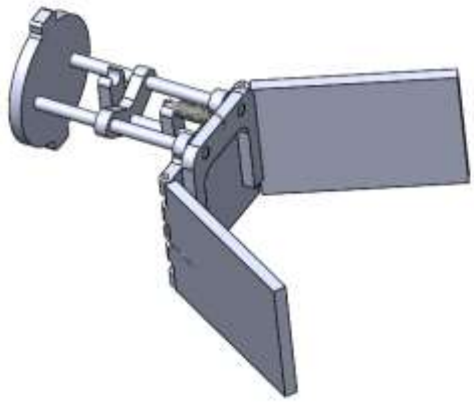

Figure 6.3) Initial body-powered clamp terminal device

Starting from left to right, the clamp features the wrist insert, which is present on all the devices. This is press-fit into two shafts that connect to the trifold subassembly. The extension spring shown is nominally closed, providing the clamp force. The trifold attaches to the body-powered cable, allowing Jorge to pull the trifold toward himself and insert the clamp in place on the rim of a bowl or pot. By releasing the tension in the cable, the trifold moves back towards the two prongs in the interior of the bowl or pot and clamps onto the outside of the rim. Each trifold includes several nominally-bent torsion springs, which allows the clamp to grip onto a multitude of diameters while still providing plenty of grip surface. In addition, the two prongs are the only part of the clamp located inside the pot or bowl, minimizing the surface area of the clamp that will come in contact with food.

We created several iterations of functional prototypes to evaluate this concept, with the final model shown below in Figure 6.4. This design was able to successfully grip full-size pans with a simple mechanism analogous to a body-powered cable. Though the extension spring in the model was not stiff enough to provide the amount of clamp force needed in regular use, it provided proof of concept with simple materials.

Both the initial model and CAD did not account for the fact that bowls have an angle to their curvature. Therefore, further design development was required to allow the clamp to properly accommodate the angle of bowls. This is included in the detailed design for the clamp, found in Section 7.2.

Figure 6.4) Foam core model of the body-powered clamp; (left) picture of clamp model; (right) clamp on lip of pot

This body-powered clamp concept achieves the customer requirements of cooking functionality, along with the device being lightweight, waterproof, sanitary, and robust. This attachment allows Jorge to grip various sizes of pots, pans, and bowls with his prosthetic, allowing him to interact with these items without them slipping or moving away from their desired position. As mentioned, the trifold design allows the clamp to conform to the various sizes of pots, pans, and bowls that Jorge can expect to encounter in the kitchen. To keep this attachment sanitary and easy to clean, we minimized the food contact surface by designing the prongs on the inside and placing the trifold on the outside of pots and bowls. This attachment is designed to be relatively lightweight in order to decrease the strain on Jorge's shoulders body and waterproof to make the tool simple to clean.

6.4) Passive Sleeve

The final terminal device is designed for use on shallow pans with long handles that cannot be gripped by the clamp. This provides Jorge with options and flexibility with respect to how he chooses to cook.

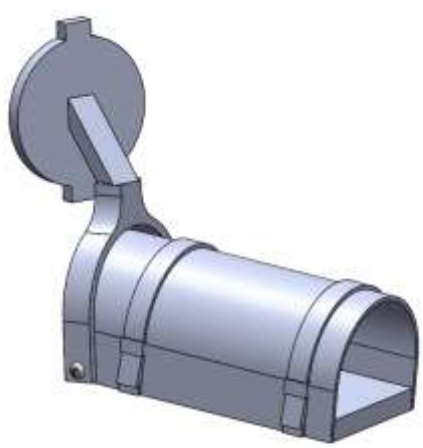

Figure 6.5) Initial passive sleeve terminal device

The sleeve is designed to fit over long pan handles, and is secured in place with the two straps shown. Note that Jorge needs to use his dominant hand to secure the straps, since this is a more complex motion than body-powered prosthetics are capable of achieving. Using multiple straps makes this design well-suited to withstand moment loads from the pan, and increases overall stability. The sleeve is comprised of a flexible material along the outer surface to help with grip, as well as a rigid base to support the load along the length of the sleeve. Note that the sleeve includes two pivoting points, of which only one is shown in this simple CAD model. The first pivot is identical to the one on the cutting tool, allowing the sleeve to rotate relative to the wrist. The second pivot is located at the base of the arch, and allows for rotation relative to the counter to accommodate angled pan handles. In addition, we considered making the pivoting mechanism at the base of the sleeve lock firmly into place to allow Jorge to be able to lift a pan with his prosthetic arm.

We created a rudimentary model for a sleeve-like attachment to verify that the design functions as intended. Initially, our sleeve design included a clamping mechanism on the bottom of the sleeve (shown in Figure 6.6), but testing showed that this was cumbersome to use. Thus, we decided the final sleeve attachment is limited to a single function. While designing this attachment, there was initially no restraining method to keep the pan handle within the sleeve. Therefore, the straps included on the model are necessary for the sleeve to function.

After further testing, we determined that 60° relative to the wrist was the approximate angle which we all held pan handles with respect to the longitudinal axis of the arm. Therefore, instead of the initial idea of a pivoting mechanism to allow comfortable pan handle orientation, the design was simplified to have a fixed angle of 60°.

Figure 6.6) Preliminary sleeve prosthetic model

When we started the detailed design for the sleeve, we realized that there were far too many parts and that the rotating mechanisms were ripe opportunities for the sleeve to rotate unexpectedly while lifting. In addition, it was difficult to strike a medium between easy-to-adjust straps and straps that provide adequate clamping for our purposes. Thus, with invaluable input from Art

Yeager, we simplified the sleeve immensely and removed the need for pivots and straps entirely. These changes to the sleeve are detailed in Section 7.3 and allowed for the design to better meet the customer requirements.

This sleeve design also meets the customer requirements of cooking functionality, along with being relatively simple to use and lightweight. The sleeve allows Jorge an alternative option to stabilize pots and pans with long handles. He can also use it on shallow pans such as frying plans where the clamp design is not as effective. Ideally we would also like this attachment to be able to support the weight of the pot or pan in its grip, whether that be the full weight or just a partial weight while Jorge uses his other arm for additional support. However, this is not one of the main functionalities that Jorge requested, and as such is a goal to reach, rather than a specific engineering requirement. The sleeve is compatible with various sizes of handles by having a large internal diameter at the inlet and utilizing several straps to secure the handle within the sleeve. The adjustable straps allow it to snugly fit over different sizes and widths of pan handles. The sleeve contains few mechanical parts, making it lightweight and easy to maneuver. Jorge can quickly adjust the straps and loosen them for accessibility.

6.4) Passive Cutting Tool

The cutting tool is a passive terminal device utilizing the same trifold and torsion spring mechanism as the clamp. However, the cutting tool lacks cable controlled motion making it a passive system.

Figure 6.7) Initial passive cutting tool terminal device

As seen in Figure 6.7 the cutting tool uses the same trifold design as the clamp, but is placed in a different orientation. Jorge can push down on food with this tool and use a knife in his dominant hand. Note that currently there is a single fixed attachment from the center of the cutting tool to the wrist for an even pressure distribution. In addition, the trifold is made of clear, nonporous material so that Jorge can clearly see what he is cutting. This is very important since Jorge will not have tactile feedback for the device, so visual feedback is important when cutting food.

With the model of the clamp attachment already made, it was simple to duplicate the trifold part and attach it directly to the wrist joint. The foam core model is shown below in Figure 6.8 (left).

We were able to hold down various sized vegetables with this tool, however we realized that a fixed angle of attachment was extremely cumbersome to deal with and required Jorge to use awkward movements to accommodate this. Therefore, a pivoting mechanism was considered to increase the comfort of the device by allowing Jorge to choose which angle is most comfortable for him depending on what he is cutting.

After further prototyping and testing, we determined that 60° relative to the wrist was the approximate angle which we all held food while chopping. Therefore, instead of the initial idea of a pivoting mechanism, the design was simplified to have a fixed angle of 60°. Additionally, the design was changed to no longer have a trifold, but just a fixed triangular groove, as detailed in Section 7.4 and seen in Figure 6.8 (right). This was another suggestion from Art Yeager, which helped immensely to refine our design.

Figure 6.8) Initial cutting tool prototypes; (left) foam core cutting tool model, (right) updated triangular model testing

Like the previous attachment, this passive cutting tool concept achieves the necessary requirements of functionality, along with being lightweight, sanitary, and robust. This attachment allows Jorge to hold down various sizes of food on a cutting board with his prosthetic, as well as to help stabilize the cutting board by providing downward force on the objects he is cutting. The updated triangular design allows Jorge to effectively hold down different sizes of food, ranging from round objects like onions to flat objects like strips of chicken. This attachment is easy to clean since it has no moving parts and is composed of a non-porous, non-stick material. This attachment does not have to be heat resistant as it is used for cutting produce and cold foods.

7. Detailed Design

The design consists of iterations of the four parts detailed in the design concept section. Layout drawings for each subassembly can be found in Appendix 6, and detail drawings of each manufactured component can be found in Appendix 7.

7.1) Quick Change Wrist

The quick change wrist did not drastically change from the preliminary design phase. We finalized the location of the magnets, as well as the method of attachment to Jorge's current prosthetic arm. This wrist design consists of two connecting parts: the insert, which is found on all of the following attachments outlined below, and the wrist receiver, which attaches to Jorge's current prosthetic.

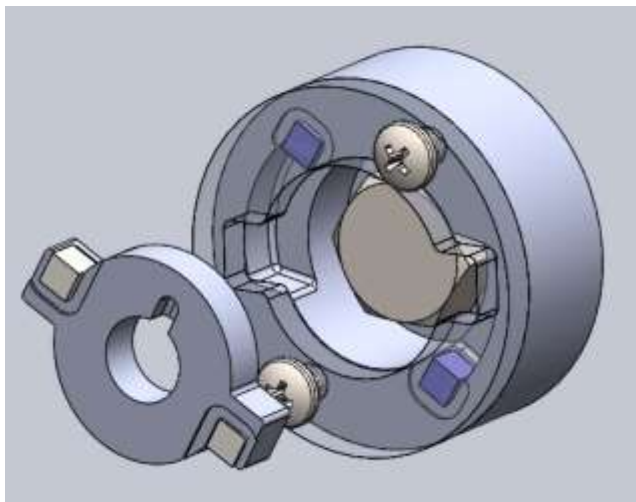

Figure 7.1) Updated quick change wrist

The most prominent change to the wrist was finalizing the magnet location and sizes for the final locking mechanism. We picked 3/16" cube neodymium magnets rated for a pull force of 4 pounds and inserted them in the tabs of the wrist insert, as well as in the slots of the wrist base. Since the neodymium magnets are relatively brittle, we ensured that each magnet has a buffer of wrist material on three sides. This minimized the distance between mating magnets when the locking mechanism is engaged, while also providing load paths through the wrist material itself. These magnets are highlighted in purple and tan in Figure 7.1. The wrist receiver consists of two parts bolted together for ease of manufacturing, as shown in Figure 7.1. The top plate features the outline of the insert, and has two clearance holes for #10-32 bolts. The secondary part is substantially thicker and features slots for the insert tabs to travel, ending with the embedded magnets to receive the insert. There are also two threaded #10-32 tapped holes to connect the two wrist receiver parts. In addition, there is a counterbored hole through the back of the wrist receiver to accommodate a ½-20 hex bolt that threads into Jorge's current "quick" change wrist via the FM Quick Change Wrist Insert manufactured by Fillauer. This allows for Jorge to use this device without making changes to his current prosthetic setup. The larger bore is sized to accommodate a standard ¾" socket head wrench used to install the 1⁄2-20 bolt. Included in the final design is a thin layer of sheet metal cut to the shape of the secondary bottom plate of the wrist receiver to provide clearance for the insert to glide smoothly. This is held in place with the two #10-32 bolts connecting the other two main pieces of the wrist receiver.

Translating the largest expected load (lifting a 10 pound pan with the sleeve), we designed for the wrist to be able to withstand an 80 in-lbf moment at the magnet contact points. To verify this with such complex geometry, we ran a SolidWorks simulation to determine the maximum stress and resultant factor of safety for the wrist. The setup for this simulation is shown in Appendix 5.

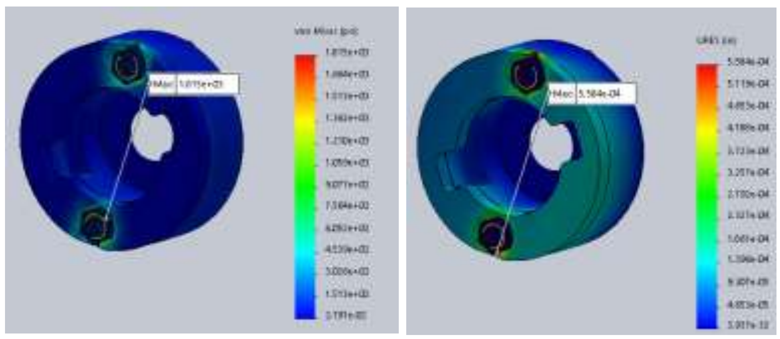

Figure 7.2) SolidWorks FEA results for wrist stress (left) and wrist deflection (right)

As seen in Figure 7.2, the maximum stress in the wrist occurs at the bolt connections. However, compared to delrin's room-temperature yield strength of 10 ksi, this 1.8 ksi stress still yields a minimum factor of safety of 5.6. The wrist also experienced minimal deflection of 0.00056 inches, far less than our maximum deflection requirement of 0.040 inches.

Maintenance and repair needs were considered during final design development. We used standard hardware for the screws in case they needed to be switched out. To address the concerns of the magnets falling out of place after repeated use, we provided our challenger with the epoxy glue (JB Weld) used to secure them in the case that they come out. Additionally, the User Manual (Appendix 14) has a section on maintenance and repairs in case any problems arise.

7.2) Clamp Attachment

There were only a couple of major changes to the clamp design from the preliminary design phase. These changes include fully defining the connection point for the cable that allows for clamp actuation, and adding a mechanism to allow the clamp angle to be adjusted. The rest of the changes made were to make the design manufacturable and to minimize cost.

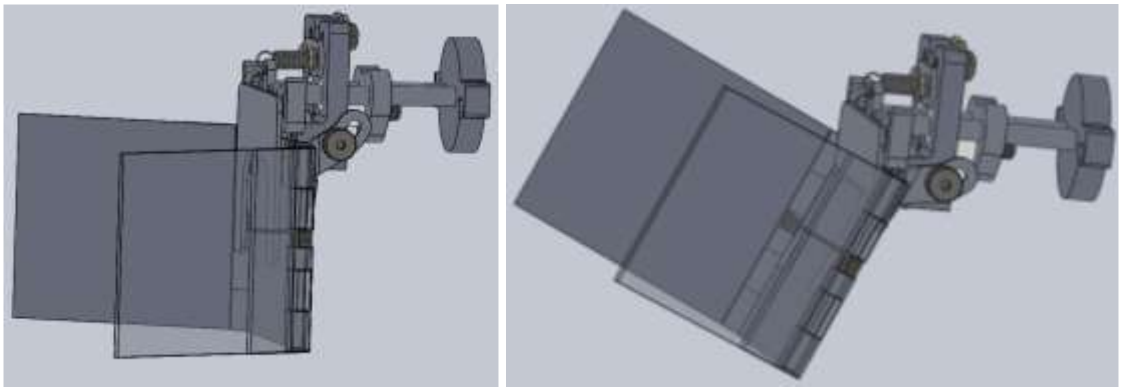

Figure 7.3) Updated clamp design; (left) pan configuration with 90° angle; (right) bowl configuration with 115° angle

The cable connection point uses the same system as on of Jorge's current prosthetics attachments. The mechanism is a small plate that is attached by screws manufactured by ToughWare. This method was chosen largely because our challenger already understands how to use this system, since he currently owns a ToughWare terminal device. This reduces the learning curve required to use this device. Figure 7.4 shows how the plate is to be used in the design and how it connects to the cabling system of body powered prosthetics.

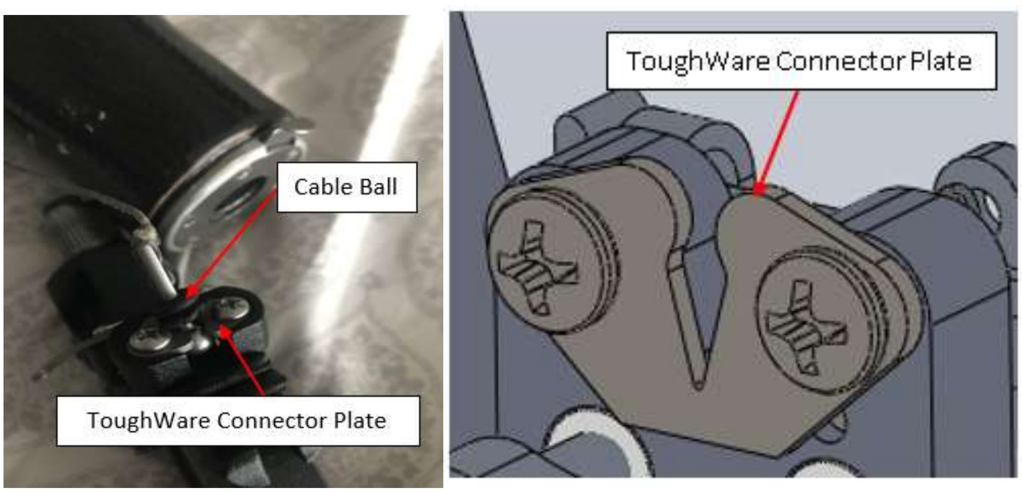

Figure 7.4) Cable attachment point on current prosthetic attachment (left) and clamp cable attachment point (right)

In order to accommodate bowls and pans, the clamp must be able to rotate since bowls have an angled surface and pans are vertical. This led to the addition of a hinge to be added which allows the trifold of the clamp to rotate. The rotation of the hinge is confined by a system of sheet metal guides and thumb screws to lock the trifold at the desired angle. In addition to adding the hinge, the inner prongs had to be modified. There are now two configurations of prongs, a vertical set for pans and a set with tips angled at 115° for bowls. They slide onto the prong attachment point which has tabs on the sides to keep the prongs from sliding laterally.

Another important design feature added to the clamp is a silicone coating. The trifold and prongs may come in contact with hot surfaces and are made out of aluminum, an excellent conductor of heat. By coating the contact surfaces with silicone, we add a significant thermal resistance to the system and decrease the amount of heat the clamp absorbs. This also allows it to cool down much faster and prevent accidental burns of both Jorge and his family.

Figure 7.5) Final assembled clamp prototype

The initial foam core model (Figure 6.5) had problems fully clamping onto pots, since the extension spring force was weaker than the combined torsion spring force which prevented the clamp from providing the necessary grip strength. Therefore, it was determined that the extension spring force needed to be greater than the total torsion spring force. This criteria was considered when choosing the springs and defined which spring constants were allowable. The torsion springs were chosen first since there were less options for these springs, then the minimum spring constant for the extension spring was determined. The hand calculations are shown in Appendix 5. To account for friction and small misalignments in the system, we applied a factor of 5 to the calculations in Appendix 5 so that we would pick stiffer springs capable of overcoming the unavoidable friction and misalignment in our system.

Additional analysis on the trifold was conducted to determine the minimum thickness of the panels. A simplified stress analysis was conducted by hand to get an estimate of the minimum thickness of 0.007 inches. The minimum thickness was very small due to the low forces present in the system, but a thicker material (0.05 inches) was chosen so that it couldn't easily be bent by accidental drops or by hand.

Furthermore, we tested methods of coating the trifold panels and prongs in silicone rubber. Mixing and casting 2-part silicone resin in 3D printed molds yielded coatings that were easily peeled off. Therefore, we decided to use food-safe silicone rubber sheets with a built-in adhesive backing, which we cut this sheet into strips to fit over the trifold panels and prongs.

Finally, during final design development, maintenance and repair needs were considered. We used standard hardware in case parts needed to be switched out. Additionally, we provided our challenger with the epoxy glue (JB Weld) used to secure many of the pieces of the clamp in case they come unattached. Additionally, the User Manual (Appendix 14) has a section on maintenance and repairs in case any problems arise.

7.3) Sleeve Attachment

The sleeve attachment changed dramatically from the preliminary design phase thanks to valuable input from occupational therapist, Art Yeager. He recommended a diamond interior profile rather than a cylinder with external straps to simplify the system and provide reliable contact on pan handles of all sizes. The final geometry is shown in Figure 7.6.

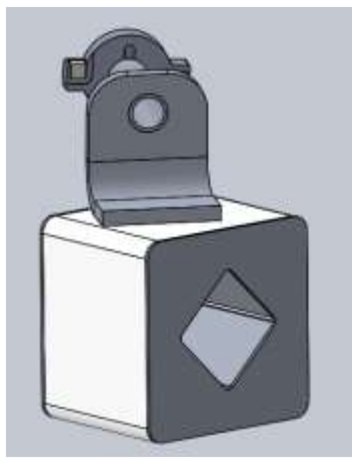

Figure 7.6) Updated sleeve design

The new sleeve consists of a rigid beam, with a diamond profile through the center surrounded by a box for added strength. To minimize the weight of the beam, it was 3D printed. Since the plastic is so soft, however, we added bent aluminum inserts for hardness and applied a silicone coating to the interior of the aluminum to ensure that the sleeve provides enough grip. An aluminum bracket was epoxied to the beam and angled at 60 degrees from the centerline of the wrist in order to be at a comfortable resting position for Jorge. In addition, the L-shape of the bracket is just less than 90 degrees, so that the beam is nominally angled upwards and the clamping is nominally engaged. Jorge can then use his body-powered prosthetic to change the angle of his elbow and slide the wrist over the pan handle. Once in place, Jorge can relax the tension in the cable and grip the pan at a comfortable resting position. From the bracket, there is a short aluminum shaft press-fit into the bracket and wrist insert. Note the addition of a small key, which was added to prevent rotation of the aluminum shaft in the low-friction delrin wrist insert.

To analyze this design, we did some preliminary testing with 3D printed PLA plastic beams of varying infill densities. The test setup, shown below in Figure 7.7, involved stacking weights in a pan to transmit higher-than-expected loads to the beam. However, note that half of the beam is supported by the table, so the strength of the beam shown below is higher than what the actually beam would have in regular use.

Figure 7.7) Preliminary sleeve testing with 75% infill density (left) and 50% infill density (right)

In this test, we saw a fair amount of deflection, but some of this could be explained by the slip of the pan within the relatively smooth sleeve as the load increased. We also noted some damage on the interior of the diamond shape due to previous testing with a cast iron pan denting the soft PLA plastic. Therefore, in order to use the printed beam going forward, we needed to add a metal insert to the interior of the diamond to locally increase hardness. We noticed very little difference in performance between 100%, 75%, and 50% infill densities of PLA. Each beam was able to comfortably support 40 pounds of weight, well over our design parameter. Therefore, we decided to use 50% infill density in our final design.

To analyze the full sleeve, we started with a hand calculation of the expected reactions within the sleeve beam as a result of lifting a 10 pound pan. Due to the large moment arm from the pan, the forces acting on the sleeve were magnified and produced some of the largest load cases in this project. These calculations can be found in Appendix 5. With these loads, we ran a Finite Element Analysis (FEA) using SolidWorks. The resulting stress and deflection plots are shown in Figure 7.8.

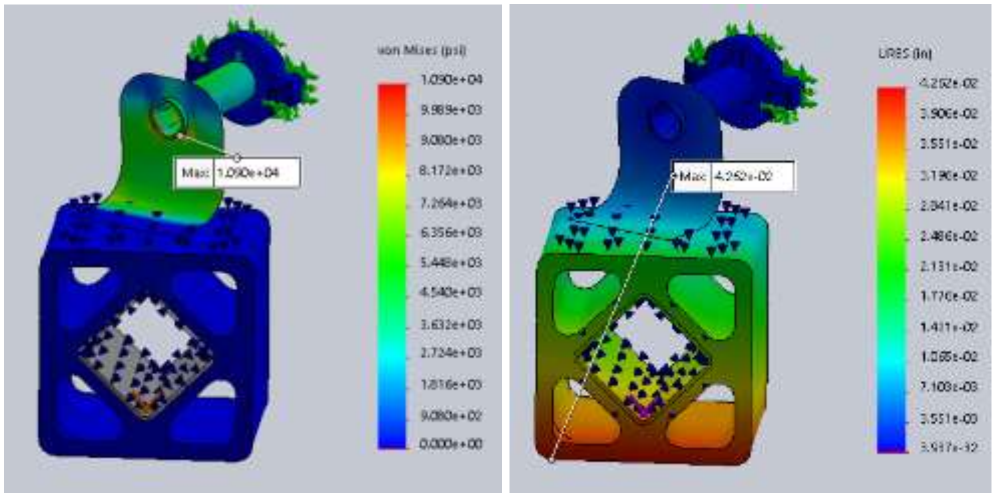

Figure 7.8) SolidWorks FEA results for sleeve stress (Left) and deflection (Right)

The expected point of failure, the connection point between the shaft and the aluminum bracket, was verified with our model as the area of highest stress. The model yielded a maximum stress of 10.9 ksi at this point in the bracket. The yield strength of aluminum is 35 ksi, so this model gives us a factor of safety of 2.55. This meets our required overall minimum factor of safety of 2. The 3D printed beam only experienced a maximum stress of 0.9 ksi, well below the yield strength of PLA (7.5 ksi). This gives the beam a factor of safety of 8.3.

In terms of deflection, the maximum deflection was 0.043 inches. This is slightly above our maximum requirement of 0.04 inches. However, any bending in the aluminum bracket magnifies the overall deflection of the beam as the angle of the bracket increases from 85 degrees. Since the model shows marginal agreement with our requirements, we recommend that the sleeve not be used to lift heavy loads, but rather primarily be used to position shallow pans on the stove. The details of setting up the finite element model are shown in Appendix 5.

Since the sleeve is the only attachment that can lift, we added sections to the User Manual. These considerations include lifting only empty, room-temperature pans, in case the pan slips out of the sleeve and the hot content spill on Jorge or his family. If Jorge does want to lift a lightly loaded pan, we emphasized that he do so only a few inches off the counter or stovetop. Therefore, if the pan does slip, then it will not fall to the floor and cause burns or other injuries.

We added a maintenance section to the User Manual to improve the long-term use of each attachment. These maintenance and repair sections are detailed in the User Manual (Appendix 14). We also sent Jorge a tube of JB Weld, the epoxy we used to attach the bracket and faceplates to the sleeve beam, in the event that they shear off of the sleeve during use.

7.4) Cutting Tool Attachment

The cutting tool also changed from the preliminary design phase due to the input from occupational therapist, Art Yeager. He recommended removing the moving parts that we originally had with the trifold model and to make it static. This simplified our design and in turn make it easier for Jorge to use. He also recommended using a triangular shape, in order to accommodate smaller sized objects. Figure 7.9 shows the final cutting tool design.

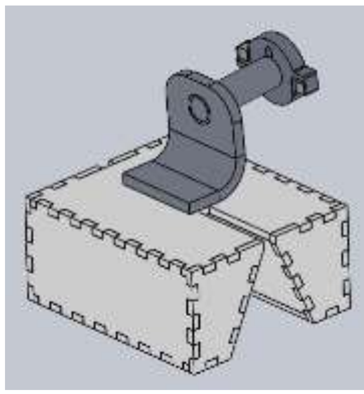

Figure 7.9) Updated cutting tool design

The triangular shape allows Jorge to hold down smaller objects, while the bottom flat surfaces allow him to hold down larger/flat objects (i.e. chicken breast, large bell peppers, tomatoes). The cutting slit allows Jorge to make perpendicular cuts as well as parallel cuts. This comes in handy when cutting smaller objects. The bottom of the cutting tool has extruded bumps/grooves, to improve grip and increase friction. This attachment was made of clear acrylic with clear food-grade resin bumps so that Jorge can receive visual feedback while cutting. The cutting tool was also easy to clean since it has no moving parts and it is made of non-stick materials.

We used the same aluminum bracket as shown in the sleeve attachment to connect to the wrist. It was also oriented at 90 degrees from the centerline of the wrist to be at the same comfortable resting position for Jorge. The wrist was epoxied to the acrylic cutting tool and the same series of press fits connect the bracket to the wrist insert.

With some preliminary testing, we determined that it only takes approximately 5 pounds of compression force to keep food in place with chopping. Since we don't know how much force Jorge can exert with his prosthetic arm, we doubled the force we needed to keep food in place for the loading cases in our analysis. Therefore, a load of 10 pounds at the wrist connection was used for all the cutting tool analysis.

For the analysis of the cutting tool assembly, we created an FEA model in SolidWorks with the wrist connection included. We analyzed the typical loading scenario of 10 pounds of compression acting from the wrist insert and with the bottom surface of the cutting tool fixed (which is the worst case loading we expected to see). The stress and deflection results are shown below in Figure 7.10.

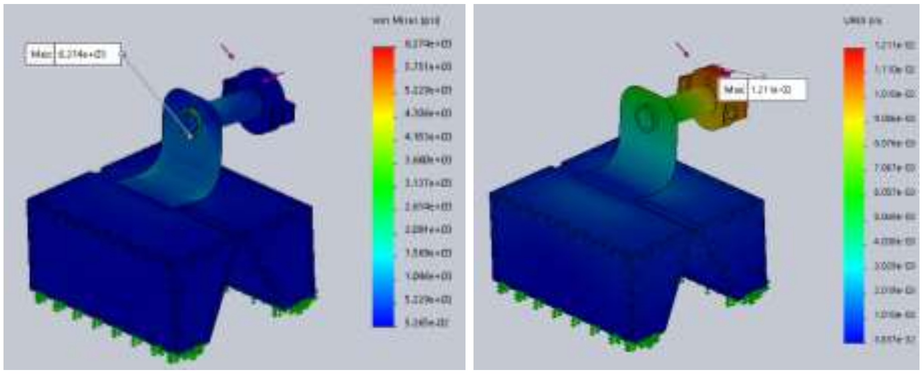

Figure 7.10) SolidWorks FEA results for cutting tool stress (left) and deflection (right)

As verified in the models above, the stresses in the cutting tool are very low under this applied load. The maximum stress of 6.3 ksi was located at the connection point between the bracket and the shaft as expected. With the yield strength of aluminum equal to 35 ksi, this gives a factor of safety equal to 5.6. The maximum deflection was 0.012 inches at the wrist insert, far less than our maximum deflection of 0.040 inches given in the requirements. Additionally, the maximum expected stress in the acrylic is 70 psi and with the yield strength of acrylic equal to 8000 psi, this gives a factor of safety equal to 114. Thus the cutting tool exceeds the minimum factor of safety required.

The cutting tool requires little maintenance, just periodic washing with warm soapy water after each use. It should be dried with a towel and stored in a safe place. The cutting tool is brittle due to the material properties of acrylic, so drops should be avoided. If it is dropped and the cutting tool cracks or splits, it could be repaired by applying acrylic cement to glue the pieces together and then re-sealed with food-safe resin. Food-safe resin can be used to fill in any cracks that may result from drops or everyday wear.

7.5) Cost Analysis

We created a spreadsheet detailing the cost breakdown of each attachment. For shared components, we did not separate the components based on the attachments that use them, but rather kept components together based on ordering sizes. The relative cost of each component is shown in Table 7.1 using values from the detailed cost breakdown and bill of materials found in Appendix 8. The design development cost includes all of the material and manufacturing costs required to develop the prototypes. During design development, we made several iterations of each prototype. This cost includes 5 wrist prototypes, 4 clamp prototypes, 4 sleeve prototypes, 4 cutting tool prototypes and the various costs associated with testing design ideas. The mass production cost includes all the material and manufacturing costs required to develop one set of all the devices.

Table 7.1) Cost breakdown for cooking hand prototypes

Component	Design Development Cost	Mass Production Cost
Wrist	$144.58	$13.99
Sleeve	$124.91	$8.05
Clamp	$209.55	$43.25
Cutting Tool	$70.86	$4.72
General	$102.28	$16.18
Manufacturing	$176.00	$56.67
Total	$828.18	$142.86

7.6) Safety Considerations

The Hazard Identifications Checklist (Appendix 3) identifies a few minor safety concerns. The first concern is that the design has potential pinch points. The body-powered clamp has multiple pinch points which are a necessary part of a clamping device. The forces related to the clamp however are low, so the risk related to these pinch points is also low. The next potential hazard is related to the sleeve attachment. Since the sleeve can be used to lift moderately sized pans, if the load is unevenly balanced the pan could lose contact with the sleeve and fall, possibly causing injury to Jorge or his family. While this is a potential concern, we performed characterization testing with the silicone rubber to ensure that asymmetrical loads do not cause the sleeve to fail (details in Section 9.4). The third risk relates to the stored energy in the springs in the body-powered mechanism that allow the clamp to be controlled. Stored energy can lead to unintended and unexpected releases of energy. However the springs used in the design are relatively weak and therefore store a small amount of energy, and so there is little risk of injury related to this aspect of the design. In addition, two of the attachments (the clamp and sleeve) have the potential to come in contact with high temperatures. This determines material considerations and potentially influence the need for thermal coating to prevent the device from both melting and protect someone touching a hot attachment from injury (testing details in Section 9.2).

8. Manufacturing

8.1) Wrist Manufacturing

The wrist was made from delrin to decrease the weight of the assembly while maintaining strength. In addition, delrin has a low coefficient of friction that allows the wrist insert to slide into place easily. The top plate of the wrist receiver and wrist inserts were water jet cut, and the base of the wrist receiver was CNC machined, as shown in Figure 8.1. In order to machine the keyway and magnet slots in the wrist inserts, we needed the rigid setup of a mini CNC mill. Since the wrist base was not a standard stock thickness, we faced a 2” diameter delrin rod on a manual lathe and cut cylindrical blanks with a bandsaw to expedite the CNC machining process.

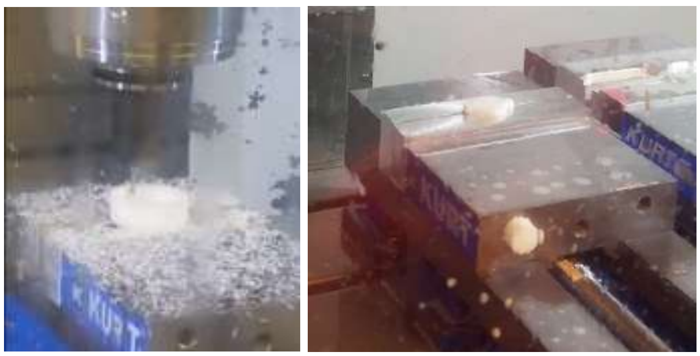

Figure 8.1) CNC machined wrist base process

To assemble the wrist receiver, we bolted the two wrist receiver plates together. However, we noticed that the delrin stock for the wrist inserts was thicker than the nominal size, so we water jet cut a simple sheet metal shim to accommodate this difference without changing the wrist design or re-machining all of the wrist parts. We then threaded the ½-20 bolt through the counterbore and into Jorge’s existing wrist insert. To ensure we have a long-lasting fit, we used loctite thread locking adhesive between the hex bolt and the internally-threaded wrist insert.

To connect the wrist insert to the rest of the attachments, we used a combination of press-fits and adhesives to ensure a tight fit. To prevent rotation of the singular connecting rod in the sleeve and cutting tool configurations of the wrist, we pressed and glued a key into the wrist insert and cut a mating slot in the connecting rod with a dremel. After pressing these pieces together, we added another layer of adhesive to fill the gaps in the connecting rod. Since the clamp configuration uses two connecting rods, we did not have to make any additional changes to prevent rotation.

For future manufacturing, the wrist inserts should be faced to tolerance rather than used at the stock thickness. This would prevent the need for the simple sheet metal shim to accommodate the different insert thicknesses. This would add one less layer of complexity to the design and assembly.

8.2) Clamp Manufacturing

The clamp was the most complex part of the overall design to manufacture. There were five main categories of manufacturing including commercial part modification, sheet metal, manual lathe, CNC mill, manual mill, and final assembly.

The commercial part modification phase was in order to make custom spring loaded hinges and make the clip-on prongs. Making the spring loaded hinges was necessary since we could only find off-the-shelf hinges that were nominally open or closed. For this project we needed hinges that were nominally set at approximately 90° for the trifold. To construct these hinges we disassembled off-the-shelf hinges and cut slots into the center portion of the hinge for the torsion springs using a dremel fitted with a cutoff wheel. With this modification, the torsion spring fit inside the hinges, additionally this allowed us to be able to easily switch out springs as needed if the angle or strength was wrong. Additional commercial part modification was needed to modify clip-on nuts which are used as the attachment method for the clip-on prongs. The design required half the width of the off-the-shelf clip-on nuts, so we used a dremel to cut the nuts in half. Once the nuts were sized properly, we sprayed the clip on nuts with Rustoleum to prevent corrosion. Additionally, since the bushing material purchased was not sized perfectly to the rod diameters, after cutting the bushings to length, the inner diameter of the bushings were sanded with a dremel to provide the necessary clearance.

Most of the flat sheet metal parts were water jet cut using the water jet in the Industrial Technology & Packaging Laboratory Facilities on Cal Poly's campus. The only exception was the panels for the trifold, which were cut using a sheet metal break in the Mechanical Engineering machine shops. All the holes on the water jet part were cut undersized, since the waterjet doesn't have perfect size tolerances on small features. These parts were then post-processed by drilling the holes to the correct diameter for precise hole fits and tapping holes as necessary. Additionally, the sheet metal parts (ie the rotation guides) were bent into the required shape using tools in the Mechanical Engineering machine shops on campus. See the drawings in Appendix 7 to determine how each part was post processed

Initially, it was assumed that the connecting rods were too small to be turned on the manual lathe, and so they were cut to length then using an 8-32 die threads were cut into the rods. This lead to many problems with misalignment since the threads were not aligned properly when cut. With guidance from the shop techs in the machine shops, it was determined that the best solution to this was to cut threads using the mini-lathe in Mustang 60.

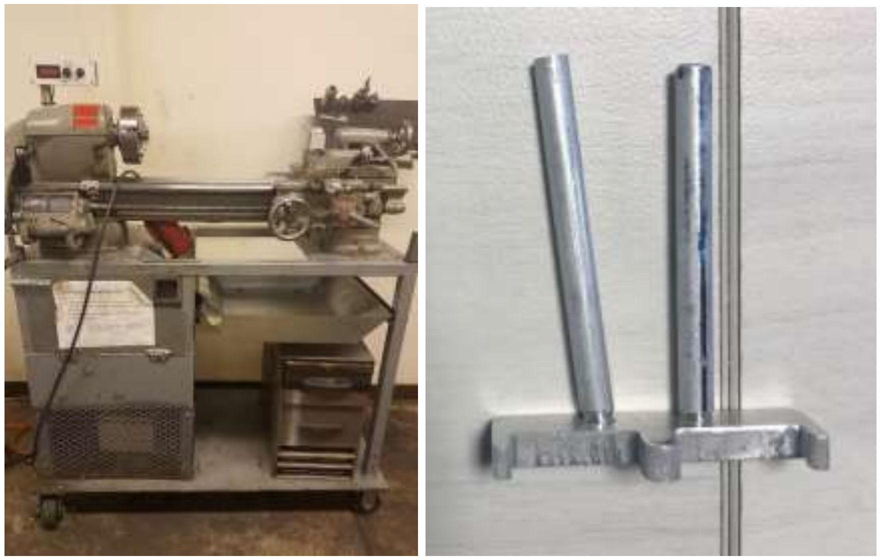

Figure 8.2) Manual lathe manufacturing (left) mini-lathe located in Mustang 60 (right) results of when threads misaligned versus aligned properly

The central attachment point required a CNC mill, which was operated by a Cal Poly Mechanical Engineering machine shop technician. This is the central piece which interfaced with the trifold panels, angled rod guides, connects to one end of the extension spring, and houses the Toughware attachment for the body-powered prosthetic cable. This part had a complex geometry in order to minimize the weight of the device and accommodate all the connection points and functions needed by the design. Thus CNC was the best means to manufacture this part.

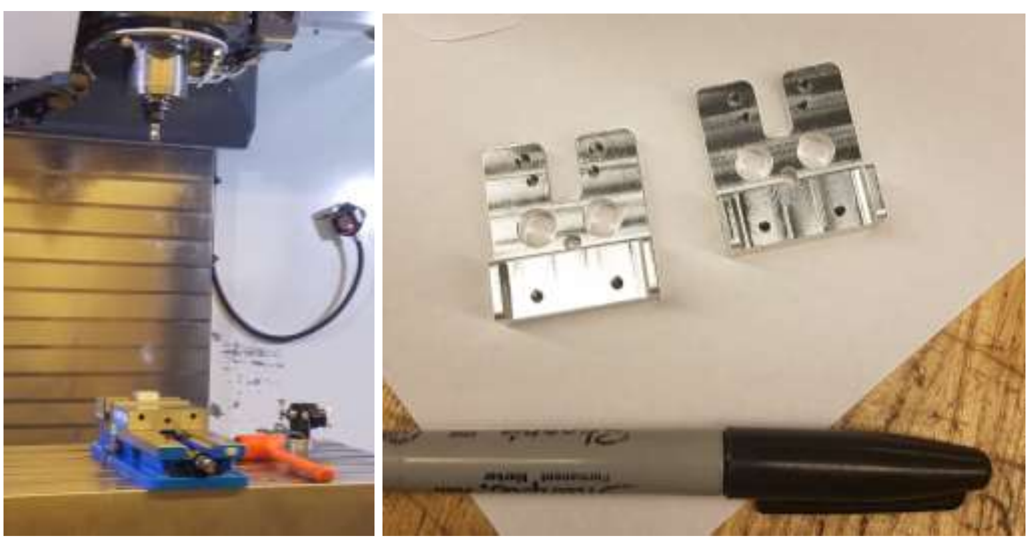

Figure 8.3) Central attachment point manufacturing; (left) CNC setup ready to start machining; (right) finished central attachment points with sharpie for size reference

Using the mini-manual mill located in Mustang 60, the prong attachment point was modified to accommodate loop size on the extension spring. Additionally, a chamfer was added to this part using metal files. This chamfer allows the clip-on prongs so slide on and off easier. And lastly before assembly, we created a fixture to accurately locate the rod guide onto the connecting rods using the manual mill. This part consisted of a small block of aluminum with two through holes which the longer connecting rods slide into. The height of the block determined how far from the ends of the long rods the rod guide was located.

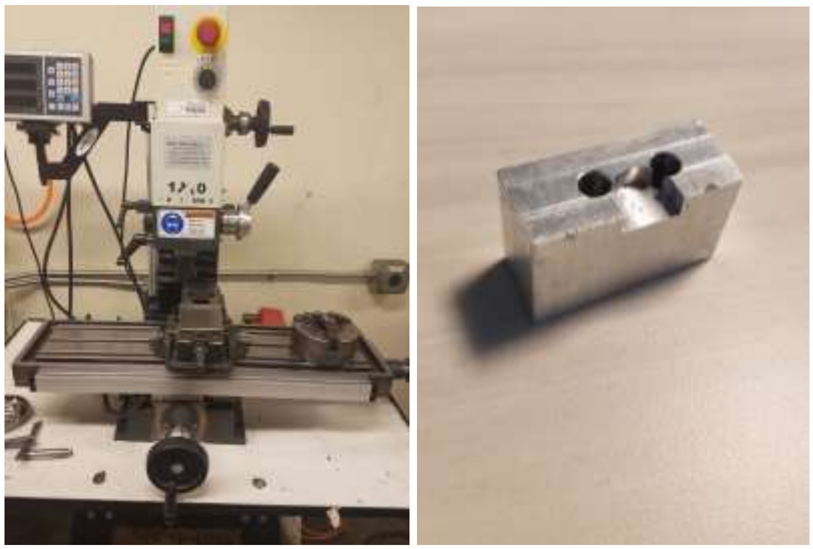

Figure 8.4) Manual mill manufacturing (left) mini-mill located in Mustang 60 (right) assembly fixture made on the mill

Finally, we were ready for clamp assembly. The trifold was epoxied together using JB weld to add the custom made spring loaded hinges to the trifold the panels and to attach the small hinge to the center panel which connects the trifold to the central attachment point. Additionally, the modified clip-on nuts were epoxied to the prongs to create the clip-on prong assemblies. Additionally, the silicone sheets were adhered to both prongs and trifold. Following our initial assembly procedure, the first roadblock we encountered in assembling the clamp was that the hole location in the clamp configuration of the wrist insert were substantially different than what we needed for alignment. Upon noticing this, we updated the files and water jet and re-machined wrist inserts for the clamp as detailed in section 8.1. Next still using the aforementioned procedure, we tried pressing the rod guide onto the connecting rod, however the rod guide kept bending when trying to align the assembly. Instead, we bored the holes in the rod guide further to become clearance holes and epoxied them into place still using the assembly fixture. Refer to Appendix 9 for the detailed clamp assembly procedure. Lastly, the rotation guides were epoxied with JB Weld into place. This was a tricky process since the rotation guides had to be placed very precisely in order to not over constrain the rotation of the trifold.

8.3) Sleeve Manufacturing

We used the water jet and sheet metal cutting tools and bending tools to manufacture the sleeve attachment parts and sleeve inserts, as well as a drill press for the connecting bracket. We started with the water jet parts: the brackets and the faceplates. The only processing needed for the faceplates was breaking the sharp edges that resulted from the water jet cutting process. For the brackets, we broke the sharp edges and then bored the hole to tolerance according to the manufacturing drawing. We had to bend the brackets by hand because stock we used was too thick to fit in the press brake located in the Cal Poly Machine Shops. In manufacturing testing, we noticed that we could not control the bend radius of the sheet using this method and every bracket cracked substantially. To mitigate this, we switch from aluminum 6061-T6 to aluminum 5052-H32, which is much easier to bend. In order to control the bend radius, we used the old, failed brackets as a guide when hammering the new brackets. This method yielded brackets with minimal cracking. A comparison between the two types of brackets is shown in Figure 8.5.

Figure 8.5) Cracked aluminum 6061-T6 sleeve bracket (left) and final aluminum 5052-H32 sleeve bracket (right)

With the brackets completed, we were ready to press the connecting shaft in. We started with the connection between the shaft and the wrist insert, since it was most important that we align the key in the wrist insert with the keyway cut into the connecting rod. With this half of the connection complete and set, we then pressed the connecting rod into the bracket, ensuring that the tabs were level.

The beam was printed using the 3D printers located in the QL+ lab on campus. We designed the part with a tight clearance fit between the interior diamond profile on the printed part and the outer dimensions of the bent sheet metal inserts to ensure a tight fit. Since the sheet metal inserts were much thinner than the brackets, we were able to use traditional sheet metal cutting and bending tools to fabricate them. We then attached the silicone rubber sheets and epoxied the sheet metal inserts into the 3D printed beam.

To protect the PLA plastic beam itself, we lightly sanded the outer surfaces and applied a 2-part smoothing compound to create a barrier between the plastic and the environment. We then sprayed the sleeve with Rustoleum to improve its aesthetic appeal. To prevent oil, sauces, or other contaminants from getting stuck in the sleeve, we added water jet cut faceplates and epoxied them on either side of the sleeve. We covered these plates in silicone as well to make the sleeve easier to clean. With these protections in place, we epoxied the connecting bracket to the sleeve and used excess epoxy to fill any gaps between the sleeve beam and face plates where water could potentially get trapped during cleaning. Finally, we added a layer of resin to prevent the Rustoleum spray from rubbing off during use, and maintaining a smooth, food-safe finish.

Figure 8.6) 3D print smoothing compound used in manufacturing

8.4) Cutting Tool Manufacturing

We laser cut the acrylic parts of the cutting tool with cutouts for ease of assembly. To achieve the textures Jorge requested, we 3D printed the positive of the sheet with grooves, as well as a lip edge, and poured 2-part silicone rubber in to make a mold. With the silicone mold, we prepared 2-part FDA food-safe resin and poured in into the mold. We then covered it with the acrylic sheet to cure together, shown in Figure 8.7. We had to sand the interior angled plate after the resin was applied in order for it to fit on the cutting tool. With the individual pieces completed and the edges roughed, we glued the acrylic sheets together with acrylic cement to create the cutting tool structure. We finished the process with a thin layer of the same food-safe resin along all the edges to seal gaps and prevent water from pooling inside of the tool after cleaning.

We used the same bracket attachment method as described in Section 8.3, the sleeve manufacturing section, to connect the cutting tool to the wrist insert.

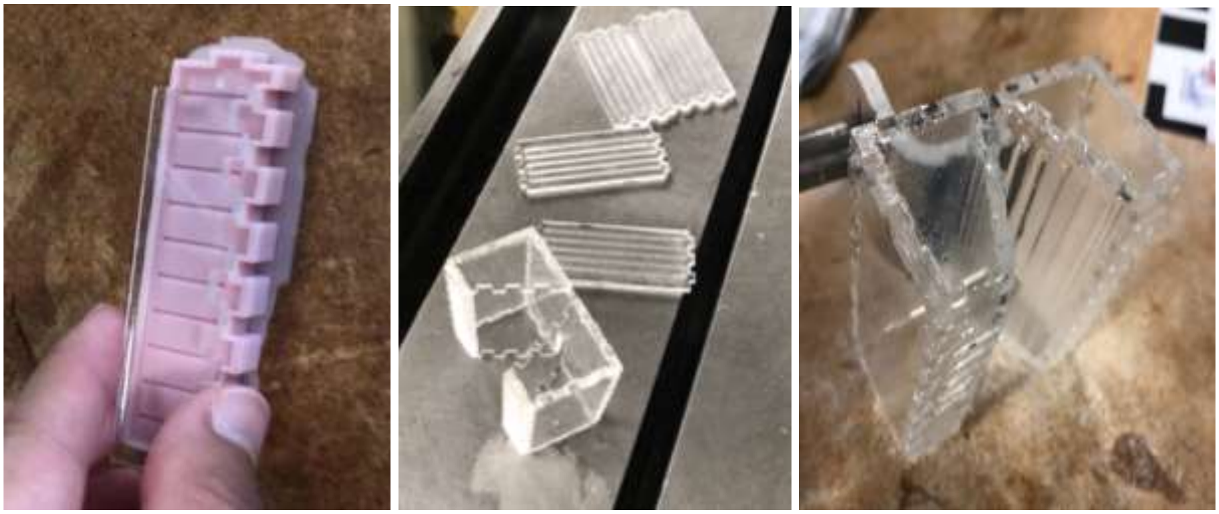

Figure 8.7) Silicone mold of bottom plate with grooves (left), finished interior plates with resin grooves (middle), finished cutting tool (right).

9. Design Verification

For each assembly, we performed a series of common tests to ensure agreement with our requirements. These tests are summarized in Table 9.1. In addition to these tests, specific tests for each prototype were also conducted, and all tests are detailed throughout the rest of Section 9.

Table 9.1) General test plan and results for all subassembly

Test	Criteria	Test Result	Quantity Pass	Quantity Fail
Weight (attachment and wrist)	Weigh ≤ 0.503lb	Clamp: 0.40b, Sleeve:0.502lb, CutTool:0.471lb	Clamp, Sleeve, Cutting Tool	None
FDA Material Compliance	Pass/Fail	N/A	Wrist, Clamp, Sleeve, Cutting Tool	None
User Functional Testing	Min. Survey Score of 80%	31.11%	Wrist	Clamp, Sleeve, Cutting Tool
Drop Test	Pass/Fail	See Section 9.1	Wrist, Clamp, Sleeve	Cutting Tool, Prongs

A complete list of tests, specifications met and criteria for success is shown in the Design Verification Plan and Report (DVP&R) in Appendix 11.

9.1) Drop Test

We performed a standard military-grade drop test that required a series of 4 to 5 devices to be dropped from 3 feet onto two inches of plywood on top of a concrete floor (MIL-STD-810G). These series of devices must be dropped 26 times, with impact being focused on every face, edge, and corner. After each drop, the device must be inspected for damages. Since we only have one prototype of each attachment to test, we modified the test to include only 6 drops, one for each orientation of the device. See Appendix 12 for the full test procedure.

Table 9.2) Drop test results for all attachments

Attachment	Drop Height	Number of Drops	Result
Cutting Tool	3 ft	2	Fail
Sleeve	3 ft	6	Pass
Wrist	3 ft	6	Pass
Clamp	3 ft	6	Pass
Prongs	3 ft	2	Fail

We dropped the sleeve, wrist and clamp from each orientation at least 6 times. Each test resulted in a pass. The failures are detailed below.

The first drop for the cutting tool was made with the cutting tool landing on its top face (that being the face with the bracket in place). After careful examination of each face, this drop resulted in a pass since there were no cracks or breaks. However, the second drop resulted in a complete failure, with the cutting tool splitting in half, as shown in Figure 9.1. In the process, the bracket completely sheared off of the top face of the cutting tool, but the bracket itself was not damaged. The split occurred at the weakest point: the cutting slit. All the other parts of the cutting tool stayed together, which means the glue and the resin used to seal the edges worked very well. For future models, the cutting slit could be removed, which in turn could result in a less brittle top face and help prevent any cracks from propagating.

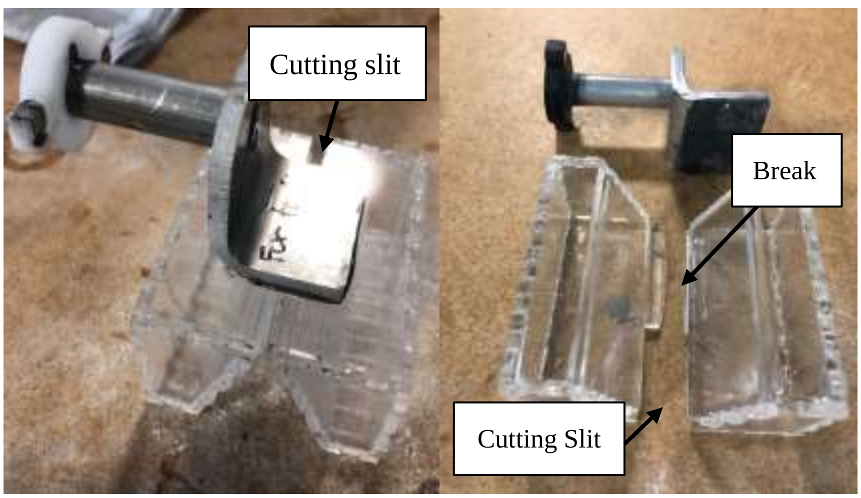

Figure 9.1) Cutting tool before drop (left). Cutting tool after second drop (right). The cutting tool split in half during the second drop, ending the test with a fail.

The prongs were tested while attached to the clamp. During the initial drop, both the clamp and prongs passed the drop test since neither component was damaged. However, during the second drop, the prongs came apart from the clip-on nuts (Figure 9.2), resulting in a fail. We decided to test these separately because the prongs are detachable parts than can be switched by the user. They are also very easy to repair with epoxy (JB Weld). The main body of the clamp sustained no damage in the remaining 4 drops.

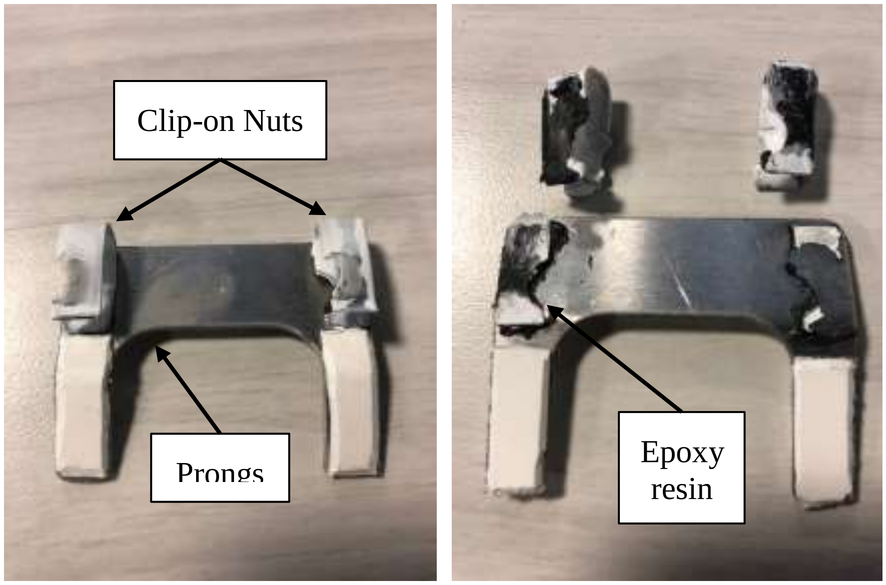

Figure 9.2) Prongs before the drop test (left). Prongs detached from clip-on nuts (right).

9.2) Silicone Coating Thermal Characterization

For the thermal testing, we adhered to the silicone sheets to aluminum coupons test articles and heated them via contact with a hot plate, ensuring the temperature range tested covers the highest temperatures encountered by a pan on a stovetop. We monitored the surface temperature with a laser thermometer and ensured that the coupon cools to a safe touch temperature of 120°F within 10 seconds of being removed from the hot plate. For a hot plate at 400°F, the coupon cooled from a recorded temperature of 172°F as it was taken off to a temperature of 96°F within 10 seconds. For a hot plate at 330°F, the coupon cooled from a recorded temperature of 105°F as it was taken off to a temperature of 92°F within 10 seconds. These times and temperature were all well within our test requirements of cooling to a temperature of 120°F or below within 10 seconds of being removed. Therefore, the silicone coating passed our test requirements as designed, and is deemed safe for use with hot pots and pans on the stove. See Appendix 12 for the full test procedure.

Figure 9.3) Silicone coating thermal characterization test setup

9.3) Clamp Functional Mixing Test

The objective of the clamp functional mixing test was to test how the clamp performed under lateral loading under various loading conditions. For this test, we used a full clamp prototype and a variety of food mixtures to test. We tested three different viscosities of common ingredients including eggs, brownies, and chocolate chip cookie dough, to characterize the clamp's effectiveness with a variety of loading conditions. To run the test, we mounted the clamp and wrist assembly to a rigid fixture, which was the best method to mimic how the system interfaces with a prosthetic without actually using a prosthetic. We then positioned the clamp onto the bowl and mix each of the foods at increasing speeds to determine how well the clamp stays engaged with changes in loading. See Appendix 12 for the full test procedure.

Figure 9.4) Clamp functional mixing test setup

Overall the clamp performed as designed. For all three levels of the test, the clamp was able to stay secured to the bowl and keep it from moving around. There was one small test anomaly near the end of testing when the electric mixer hit the inner prong of the clamp and the prongs came detached from the clip-on nut used to secure it to the clamp. However, the prongs in question was already partially broken since the clip-on nuts had not been properly glued on previously, so during the test only one clip-on nut was securing the prongs. Once the prongs were replaced with a properly assembled set this issue was resolved and did not recur.

9.4) Sleeve Unbalanced Load Testing

To characterize the sleeve's grip, we incrementally loaded one side of the sleeve until it rotated. To run this test, we used a full sleeve assembly and inserted it into the wrist, which was bolted to the test stand. The test stand was secured with 20 pounds of weights to ensure a rigid setup. Then, with the sleeve inserted in the wrist, we added a pan and an extension spring to one side. We then incrementally hung bags of hardware with known weights off the side of the pan until the pan rotated in the sleeve. The full test procedure is shown in Appendix 12. This occurred with 2.52

pounds hanging off the pan, below our requirement of 3 pounds. Though it reached 84% of our required mass, the sleeve failed this test.

Figure 9.5) Sleeve unbalanced load testing setup (left), and maximum load condition (right)

9.5) Sleeve Balanced Load Testing

W tested the maximum evenly-distributed load the sleeve could withstand to determine the maximum lifting capacity of our prototype. With the same test setup, we added objects of known mass into the pan and in-line with the pan handle. The test procedure is shown in Appendix 12. However, the sleeve itself began to rotate as we added the same amount of weight as in the unbalanced loading case. Therefore, the sleeve had already broken in our last test and the maximum load we achieved as also 2.52 pounds. This is only 25% of our design parameter of 10 pounds, and so the sleeve failed this test as well. To mitigate this shortcoming, we clearly specified in the user manual that Jorge not use the sleeve to lift a full pan. Instead, it must only be used to stabilize pans on a stovetop.

Figure 9.6) Sleeve balanced load, maximum load condition

9.6) User Functional Testing

In order to confirm our designs met Jorge's requirements, we sent him the prototypes along with a user manual and a feedback form at the end of Winter Quarter and Spring Quarter. For the first iteration, we sent him a 3D printed wrist and full sleeve and cutting tool attachments. We included several tasks for him to complete with each attachment and rate his satisfaction with each. The survey is shown in Appendix 13. With his results, we calculated a score of 85%, above our minimum threshold of 80% specified in our engineering requirements. From this testing, we learned that the silicone coating in the sleeve was necessary to prevent rotation of the wrist insert about the connecting rod.

For the second set of user functional testing, we sent Jorge a full set of completed prototypes to ensure that each attachment suited his needs. We sent an updated user feedback survey and user manual as well, which are shown in Appendix 13. From the results of the survey, we calculated a score of only 31.11%, far below our requirement of 80%. Out of all attachments, Jorge was only able to use the wrist. He liked how easy it was to install, but none of the connecting attachment passed their functional tests. The clamp arrived to him broken, as seen in Figure 9.7. He attempted to glue the angle guides back on to the main body of the clamp, but was unable to repair it. When using the sleeve, he could not fit any of his pans into the opening. And finally, the bracket on the cutting tool snapped off when he applied significant pressure to try and hold down a potato.

Figure 9.7) Broken prototypes: clamp arrived broken (left), cutting tool bracket came off during use (right)

With more time, we would ask Jorge to remove the silicone sheets from the interior of the sleeve and try to fit the sleeve over his pans. However, for this survey, the overall score shows the attachments failed user functional testing.

10. Conclusions and Recommendations

Based on testing and conversations with occupational therapist Art Yeager, we would make several changes to our designs. For the clamp, we would look into decreasing the size of the trifold panels to improve ergonomics. We would also investigate alternate methods of attaching the angles guides, since the epoxy used in our current design failed during user testing. We would add a key to both sides of the connecting rods in the sleeve and cutting tool to fully prevent rotation. For the cutting tool, we would investigate a solid construction (3D printed or cast from food-safe resin, for example) to make the assembly less brittle and to enable us to embed the connecting bracket within the tool for a more secure fit. For the sleeve, we would consider shortening the bracket to reduce the size of the moment arm and decrease the amount of deflection. In addition, we would make the interior opening larger to better accommodate Jorge's pans. We would also consider adding a key to both ends of the connecting rod to fully prevent rotation of the connecting rod. Finally, we would consider making the wrist inserts out of aluminum instead of delrin to increase the friction between connecting parts and bolster the glued and press-fit joints.

11. Acknowledgements

Special thanks to QL+ for sponsoring this project, and all of our other advisors for providing invaluable advice and guidance—Art Yeager, Jim Widmann, Vanessa Salas, and Alan Strasbaugh. Also thank you to ToughWare and Filaur for donating vital components to our project. Finally, thank you to Jorge Segura for creating this challenge and allowing us to work on this project for him to help him overcome it.

12. About The Team

Every team member was committed to the full participation and completion of the project. Making up the team are Duania Evans, Ethan Littlejohn, Amy Wilson and Amanda Meares.

Duania is a general engineering student doing her concentration in materials engineering. She also has a background in mechanical engineering and this experience combined with her materials knowledge makes her a great asset to the team. She has participated in other challenges, such as the Brocade Challenge and the RC car design challenge here at Cal Poly. These challenges have allowed her to apply what she has learned, as well as help her build her teamwork and communication skills.

Ethan is a general engineering student doing his concentration in materials and electronics. He has a background in electrical engineering, having taken many related classes throughout his studies at Cal Poly. He is also experienced in group organization and taking on large scale projects. As an Eagle scout, he has completed community service projects, including gathering materials and organizing the project from beginning to completion. He has also been working for several years as a manager in the restaurant business, and has insight on the types of tasks and challenges required of the challenger.

Amy is a fourth-year mechanical engineering student with a general concentration. She worked with the QL+ Student Association at Cal Poly last year to help build a tricycle for a local boy named Sam with cerebral palsy, and she has worked for two years as a teaching assistant for mechanical drafting and Computer Aided Design (CAD) courses. She has worked for two summers in the medical device industry, and has experience with navigating an R&D environment as well as the many device regulations in the industry.

Amanda is a fourth-year mechanical engineering student with a general concentration. Over the past two years she has been working for a group on campus called CubeSat, which tests and develops small satellites. With CubeSat, she was the vibrations testing lead, which included responsibilities such as writing test procedures and reports, running tests, and designing supporting mechanisms for specialized testing. Additionally, she interned for an aerospace R&D company and designed a test stand and conducted testing as part of her internship. These skills and past experiences were vital for the testing phase of this project.

In addition, Amanda was the main point of contact for this project. She was in charge of contacting the sponsor and challenger in order to avoid confusion. All communication she conducted with the sponsor and challenger was shared with the group in a timely manner. She kept in contact with our challenger, Jorge, so that he could have input on his device throughout the design process.

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14. Appendices

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[5] Appendix 5: Hand Calculations
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14.1) ***Appendix 1:*** *QFD Table*

Customer Requirements	Engineering Requirements: Weighting (1 to 5)	Equivalent Diameter	Length	Weight	Deflection	Strength	Thermal Resistance	Electrical Resistance	Corrosion	Food Safety	Ergonomics	Benchmarks: Current Prosthetic	AdVAntage Arm	Boston Elbow & Ottobock Hand
Cooking Functionality	5	3	3	3			3			9	3	1	3	9
Lightweight	5			9	3	3						1	9	9
Waterproof	5							1	3			3	3	1
Comfortable	5	3	3	9								1	3	9
Robust	4			3	3	9			1			1	9	1
Easy to Attach/Remove	5			1							9	3	1	3
Easy to Keep Sanitary	3								1	9		1	3	1
Aesthetics	1										3	3	1	3
Safe to Use	5						9	9	1	3		3	3	3
Doesn't Damage Cooking Equipment	3						1		3	3		3	1	3
Units	-	cm	cm	% bodyweight	cm	Safety Factor	K/W	kΩ	Meets ASTM Requirements	Meets FDA Requirements	Compatibility with Jorge			
Targets	-	8.4	18.9	.65	0.1	2+	5	100	pass	pass	pass	`		
Current Prosthetic	-	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD			
AdVAntage Arm	-	Custom to User	Custom to User	460 grams	Unknown	Unknown	Unknown	Unknown	Unknown	Pass	Pass for 62.5% of Users			
Boston Elbow + Ottobock Hand	-	Custom to User	Custom to User	1360 grams	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown			
Importance Scoring	-	30	30	122	27	51	63	50	36	96	63			
Importance Rating	-	5%	5%	21%	5%	9%	11%	9%	6%	17%	11%			

14.2) ***Appendix 2:*** *Pugh Matrix*

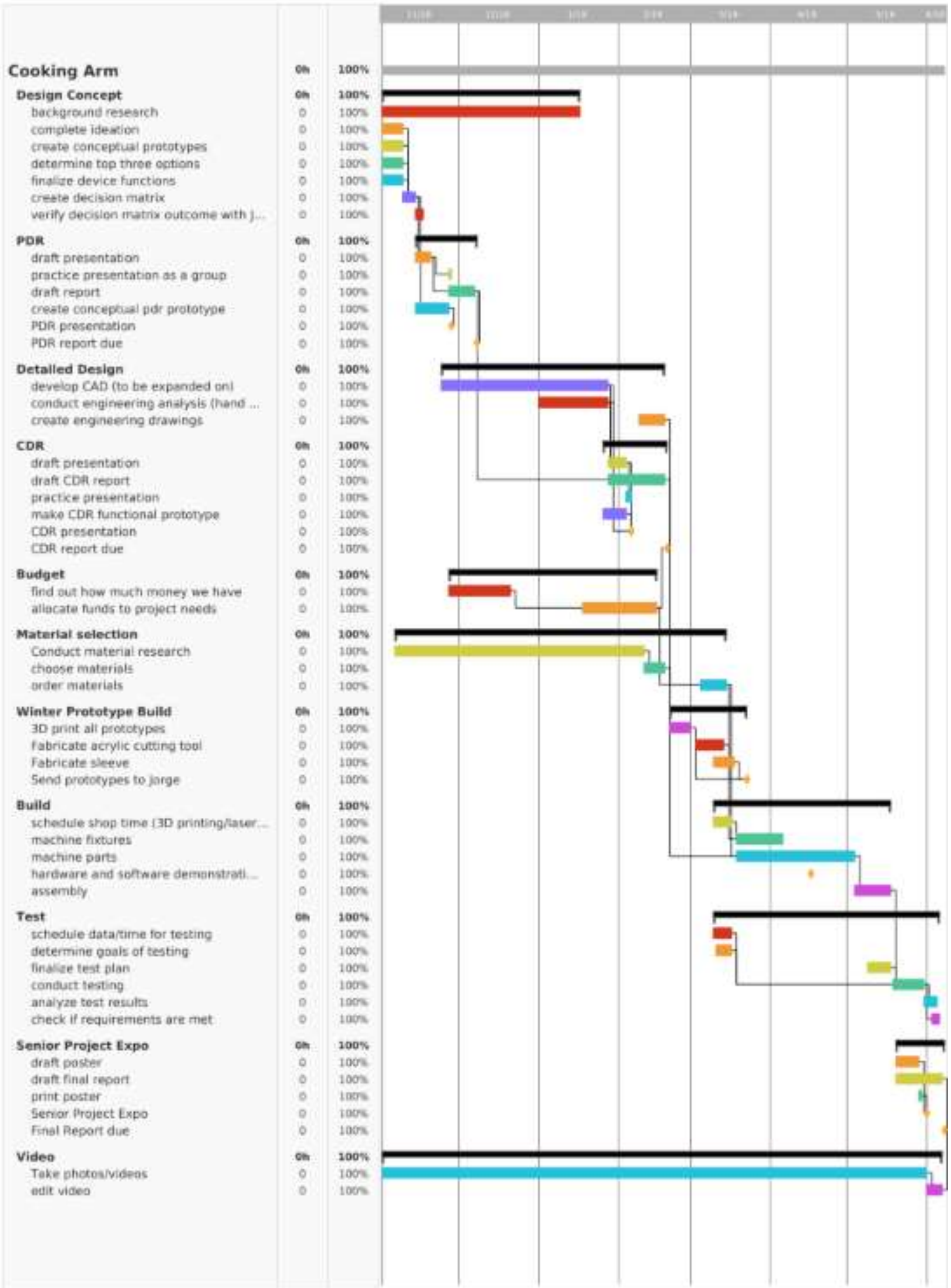
										
Customer Requirements	Strap Hand Attachment	Elastic Expandable Holder	Clutch-Hook Hand Attachment	Curved-Clamp Device	Crane Bowl Holder	Expandable Box Stabilizer	Angled Edge Clamp	Sleeve Jar Opener	Replacement Stove Grate	Clamp Hand Attachment
Cooking Functionality	-	-	D	-	-	-	-	+	-	s
Lightweight	+	+	D	+	+	-	+	+	-	+
Waterproof	-	+	D	s	+	s	s	+	+	s
Robust	-	s	D	+	-	+	-	-	+	-
Easy to Use	-	-	D	+	+	+	-	+	-	+
Easy to Keep Sanitary	-	+	D	+	+	+	s	s	-	-
Aesthetics	s	s	D	s	-	-	-	-	-	s
Safe to Use	s	-	D	+	s	+	-	s	s	+
Size/Shape Adaptability	+	+	D	-	+	s	-	-	-	+
Doesn't Damage Cooking Equipment	+	s	D	s	+	s	-	+	s	+
Σ+	3	4	-	5	6	4	1	5	2	5
Σ-	5	3	-	2	3	3	7	3	6	2
Σs	2	3	-	3	1	3	2	2	2	3

14.3) ***Appendix 3:*** *Safety Identification Checklist*

SENIOR PROJECT CONCEPTUAL DESIGN REVIEW HAZARD IDENTIFICATION CHECKLIST

Y	N	
■	□	Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
□	■	Can any part of the design undergo high accelerations/decelerations?
□	■	Will the system have any large moving masses or large forces?
□	■	Will the system produce a projectile?
■	□	Would it be possible for the system to fall under gravity creating injury?
□	■	Will a user be exposed to overhanging weights as part of the design?
□	■	Will the system have any sharp edges?
⊟ N/A*	⊟	Will all the electrical systems properly grounded? (*No electrical systems)
□	■	Will there be any large batteries or electrical voltage in the system above 40 V either AC or DC?
■	□	Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
□	■	Will there be any explosive or flammable liquids, gases, dust fuel part of the system?
■	□	Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
■	□	Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
□	■	Can the system generate high levels of noise?
■	□	Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc...?
■	□	Will the system easier to use safely than unsafely?
□	■	Will there be any other potential hazards not listed above? If yes, please explain below?

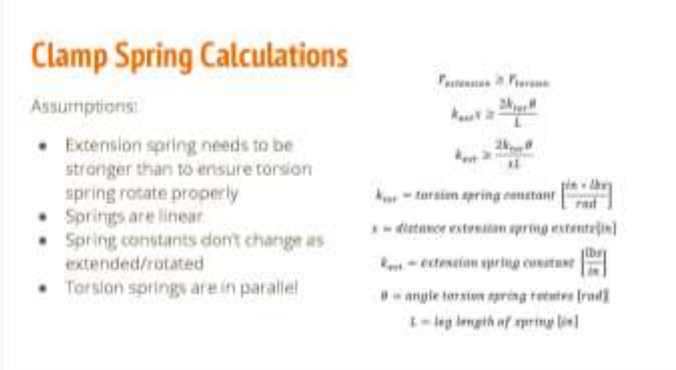
14.4) ***Appendix 4:*** *Gantt Chart*

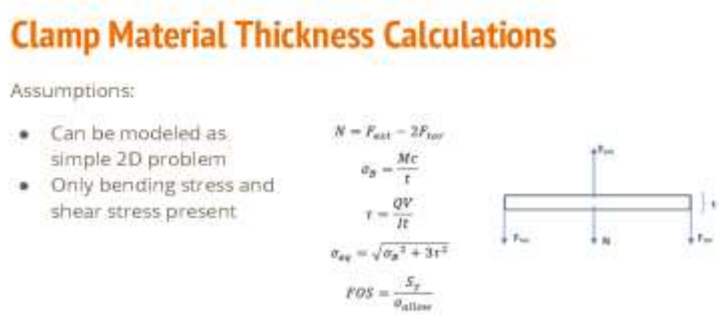


14.5) ***Appendix 5:*** *Hand Calculations*

14.5.1) Clamp Calculations

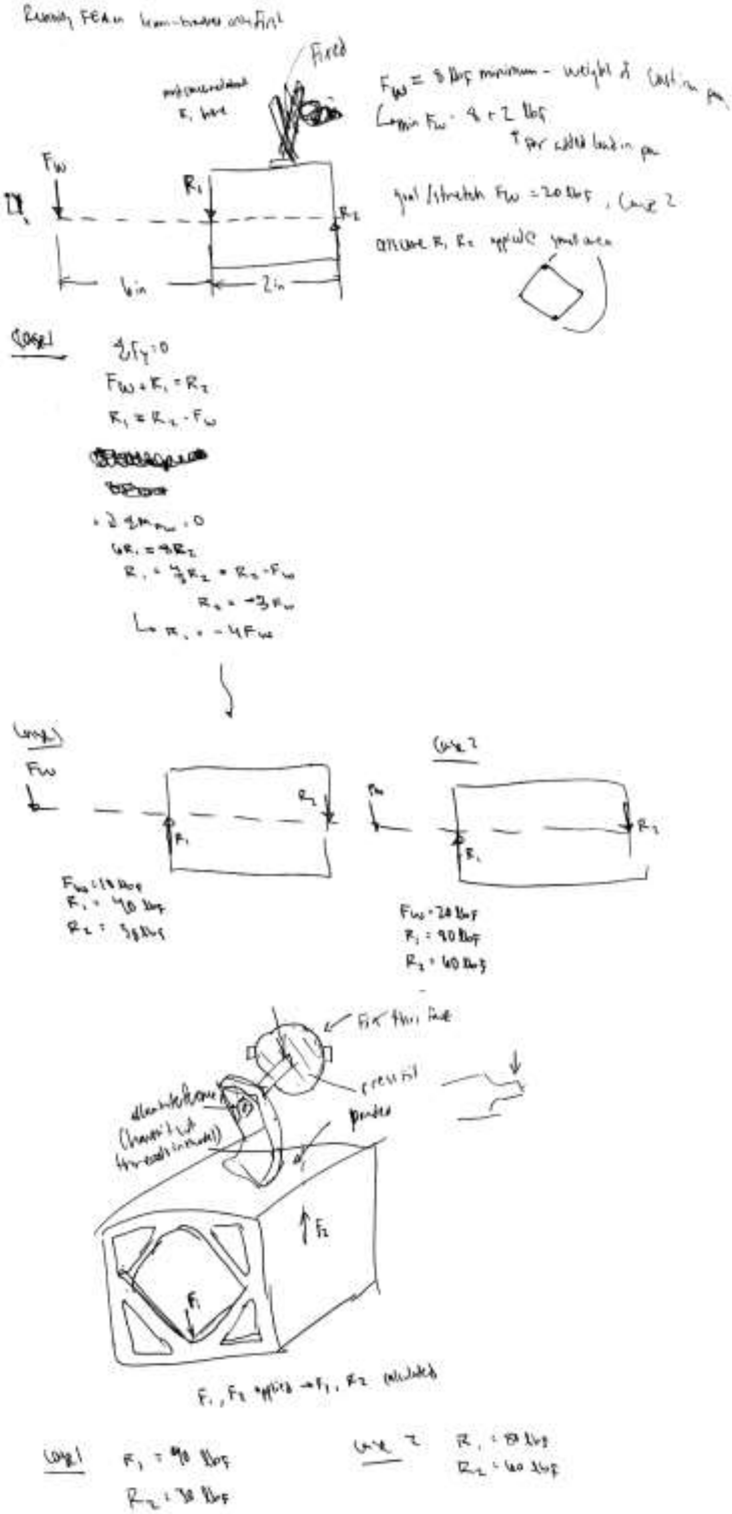
The clamp calculations are summarized below in copies of the CDR presentation.





14.5.2) Sleeve Calculations

To find how the loads were transferred from the pan to the sleeve, we started with a simple statics calculation to find the reactions from the inside geometry of the sleeve. The inverse of these forces became our applied loads for the FEA analysis.

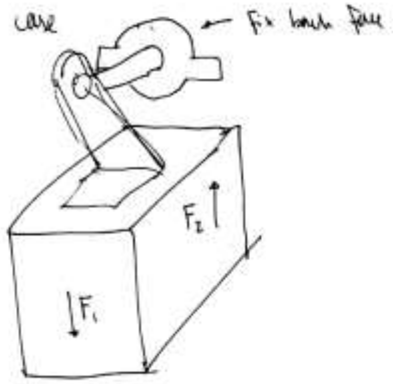


With the loads found, we modeled the sleeve with the wrist piece fixed and the loads applied to the interior of the diamond. To model the worst-case scenario, we located the forces on a small area on the rounded fillets on the inside of the diamond. To model the connections, we removed the press-fits and applied a globally bonded condition to run the simulation. We fixed the back face of the wrist insert, since it would be in contact with the wrist base when in use. To get the simulation to run, we set the sheet metal inserts to be modeled as sheet metal pieces, and applied a "no penetration" contact set between the sheet metal inserts and the plastic sleeve beam. This ensured that the sheet metal inserts moved with the sleeve beam despite small gaps due to differences between bend radius and sleeve diamond radius.

Setup

Eliminate all interferences

- global bonded contact set
- Fix back face of wrist insert
- model sheet metal piece as sheet metal, make rigid
- "no penetration" between sheet metal inserts and sleeve
- 10 pound load case



$F_1 = 40$ lb
$F_2 = 30$ lb

Results

- max stress: 10.9 ksi at press-fit hole for the shaft

$\sigma_{max} = 10.9$ ksi

$\sigma_{yield} = 35$ ksi (Aluminum 5052-H32)

$\rightarrow FS = \frac{\sigma_{yield}}{\sigma_{max}} = \frac{35}{10.1}$

$FS = 2.55 > FS_{min} = 2$ ✓

- max deflection: 0.043 inches at bottom of sleeve, pan-side

$\delta_{max} = 0.043$ inches

$\delta_{req'd} = 0.040$ inches, set by requirements

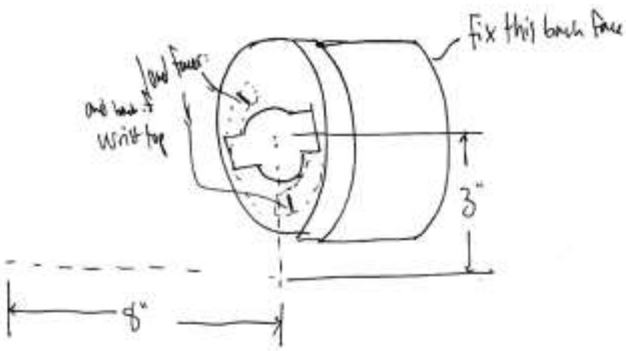
→ less than 10% over our requirement, acceptable marginally

14.5.3) Wrist Calculations

Using the loads found in 11.5.2) Sleeve Calculations, we translated the 10 pound load up to the wrist by translating 8 inches away from the center of the wrist and 3 inches down from the center of the wrist. We applied this load to the magnet contact points and the bottom face of the wrist top. To constrain the model, we fixed the back face of the wrist base and added bolted connections instead of adding the actual hardware. To model hand-tight torque, we estimated 20 in-lb of torque was used to secure each bolt. Finally, all interferences had to be deleted and a global contact set applied for the entire assembly. The summary of the FEA setup and results are shown below.

Setup

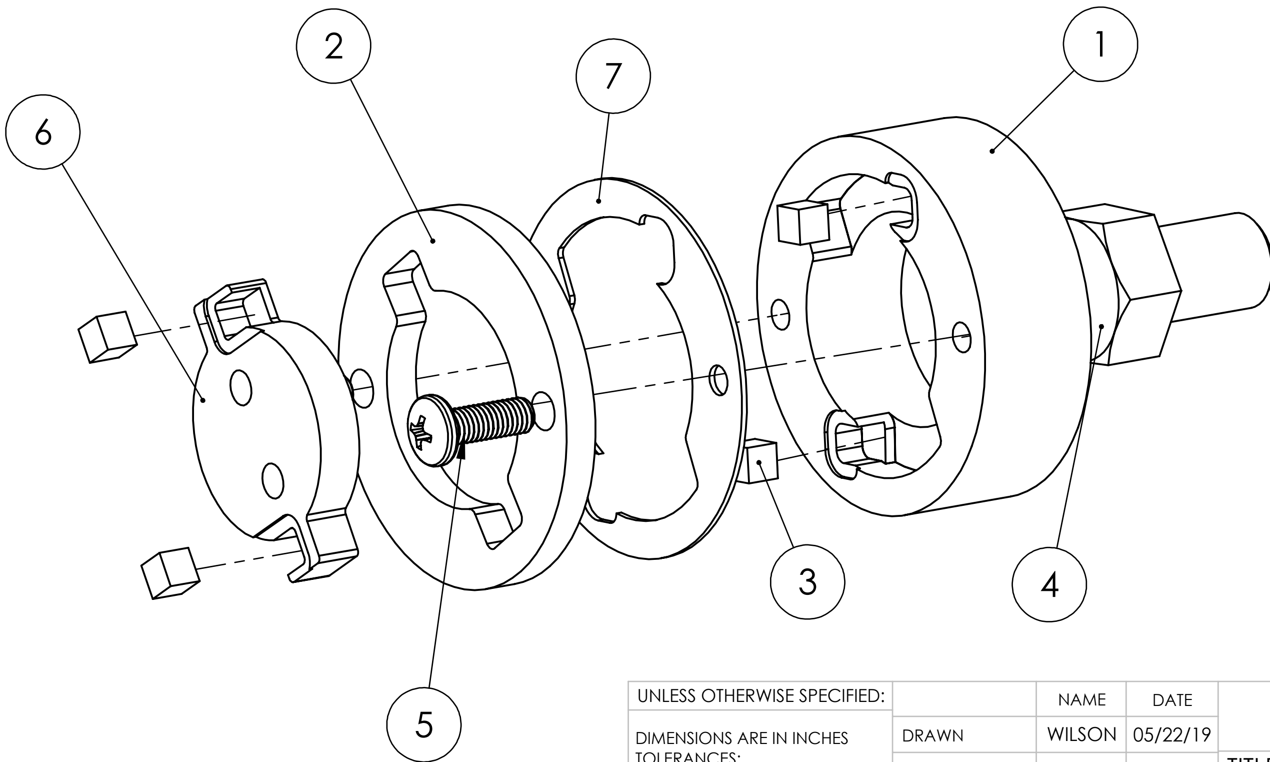
- eliminate all interferences
- globally bonded contact set
- Fix the back face (in contact w/ Jorge's prosthetic)
- apply bolt connections, hand-tight / slightly loose, 20 in-lbf
- apply load at magnets and back face of wrist top
  - magnitude: 10 lbf
  - location: 8" from wrist laterally
  - 3" below center of wrist



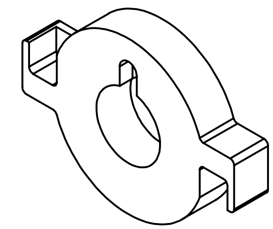
Results

- max stress: 1.8 ksi at bolt connection
  - $\sigma_{max} = 1.8$ ksi
  - $\sigma_{yield} = 10$ ksi @ room temp, worst case $\sigma_y = 4.0$ ksi @ 212°F (wrist itself will never get this hot though)
  - $FS_{min} = \frac{\sigma_{yield}}{\sigma_{max}} = \frac{10}{1.8} = 5.6$
  - $FS_{min} = 5.6 > 2$ → passes strength criteria ✓
- max deflection: 0.00056 inches, relative to maximum value of 0.040 inches
  - $\delta_{max} = 0.00056 \ll \delta_{req} = 0.040$ inches
  - → passes deflection criteria ✓

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MP-203	Wrist Receiver, Bottom Plate	1
2	MP-202	Wrist Receiver, Top Plate	1
3	COTS-204	Cube Magnet	4
4	COTS-207	1/2-20 Hex Bolt	1
5	COTS-206	#10-32 Button Head Screw	2
6	MP-201-01	Wrist Insert, Clamp	1
7	MP-204	Wrist Shim	1



MP-201-02



WRIST INSERT CONFIGURATION FOR CUTTING TOOL AND SLEEVE

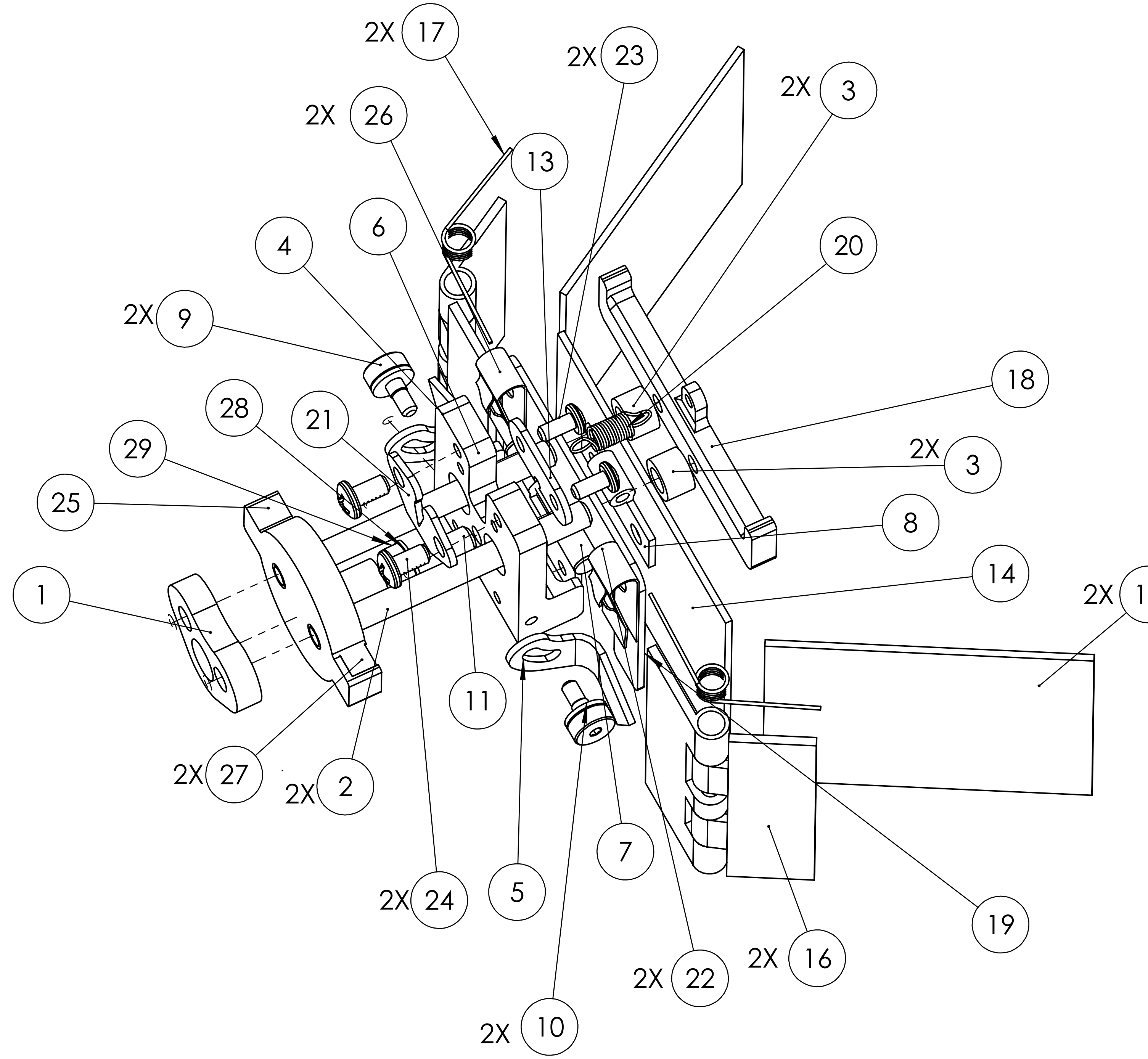
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: N/A	DRAWN	WILSON	05/22/19
	CHECKED	MEARES	05/22/19
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL N/A	COMMENTS: 1. MP-201-01 WRIST INSERT CONFIGURATION SHOWN IN ASSEMBLY AND MP-201-02 DOCUMENTED SEPARATELY		
FINISH N/A			

TITLE:

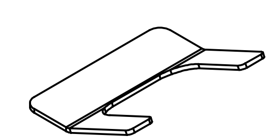
WRIST ASSY

SIZE	DWG. NO.	REV
A	MP-200	
SCALE: 1:1	WEIGHT: 0.22 LB	SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MP-301	Rod Guide	1
2	MP-302	Long Rod	2
3	MP-303	5/16" Short Bushing	2
4	MP-304-01	Rotation Guide, Left	1
5	MP-304-02	Rotation Guide, Right	1
6	MP-305	Central Attachment Point	1
7	COTS-306-01	Mortise-Mount Hinge, Attachment Side	1
8	COTS-306-02	Mortise-Mount Hinge, Trifold Side	1
9	COTS-307	#4-40 Thumb Screw	2
10	COTS-308	#5 PFTE Washer	2
11	MP-309	Short Rod	1
12	MP-310	5/16" Long Bushing	1
13	MP-311	Spring Attachment Point	1
14	MP-313	Trifold Middle Panel	1
15	MP-314	Trifold Outer Panel	2
16	MP-315	Modified Surface-Mount Hinge	2
17	COTS-316	Torsion Spring	2
18	MP-317	Prong Attachment Point	1
19	MP-318-01	Prongs, Straight	1
20	COTS-320	Extension Spring	1
21	COTS-319	ToughWare Vall Connecctor Plate	1
22	COTS-323	#4-40 Stainless Steel Flat Head Screw	2
23	COTS-324	#4-40 Stainless Steel Round Head Screw	2
24	COTS-325	#6-32 Stainless Steel Round Head Screw	2
25	MP-201-01	Wrist Insert, Clamp	1
26	MP-326	Modified Clip-on Nut	2
27	COTS-204	Cube Magnet	2
28	COTS-321	#8 Stainless Steel Washer	1
29	COTS-322	#8-32 Stainless Steel Nut	1



MP-318-02 Prongs, Angled



SCALE 1:2

SECOND CONFIGURATION OF ITEM NO. 19 NOT SHOWN IN MAIN ASSEMBLY

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
TWO PLACE DECIMAL ±.010
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL N/A
FINISH N/A

	NAME	DATE
DRAWN	MEARES	04/17/19
CHECKED	WILSON	04/17/19
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

CLAMP ASSEMBLY

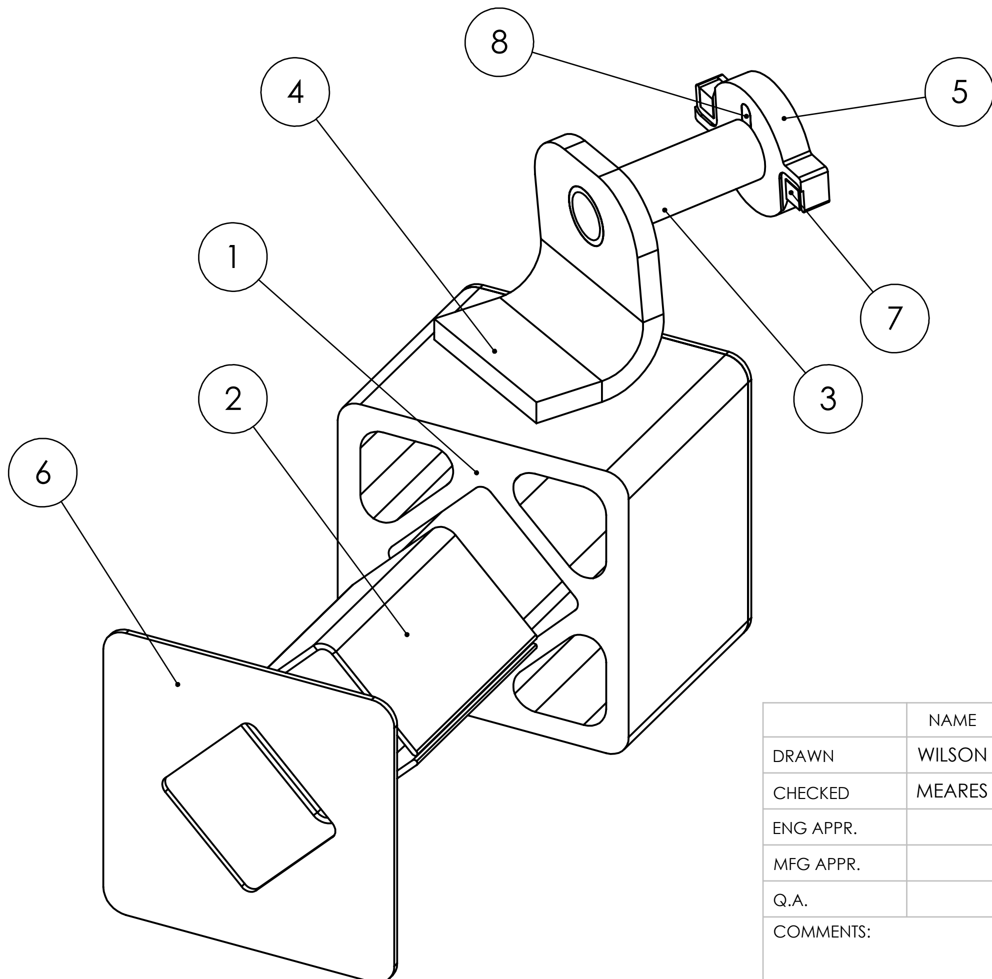
SIZE **B** | DWG. NO. MP-300 | REV

SCALE: 1:1 | WEIGHT: .22 LB | SHEET 1 OF 1

2 | 1

B | B

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MP-401	PLASTIC SLEEVE CASE	1
2	MP-402	SLEEVE INSERT	2
3	MP-102	ATTACHMENT SHAFT	1
4	MP-101	ATTACHMENT BRACKET	1
5	MP-201-02	WRIST INSERT, SLEEVE AND CUTTING TOOL	1
6	MP-403	COVER PLATE	2
7	COTS-204	CUBE MAGNET	2
8	COTS-103	WRIST SHAFT KEY	1



A | A

	NAME	DATE
DRAWN	WILSON	3/10/19
CHECKED	MEARES	3/10/19
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

SLEEVE ASSY

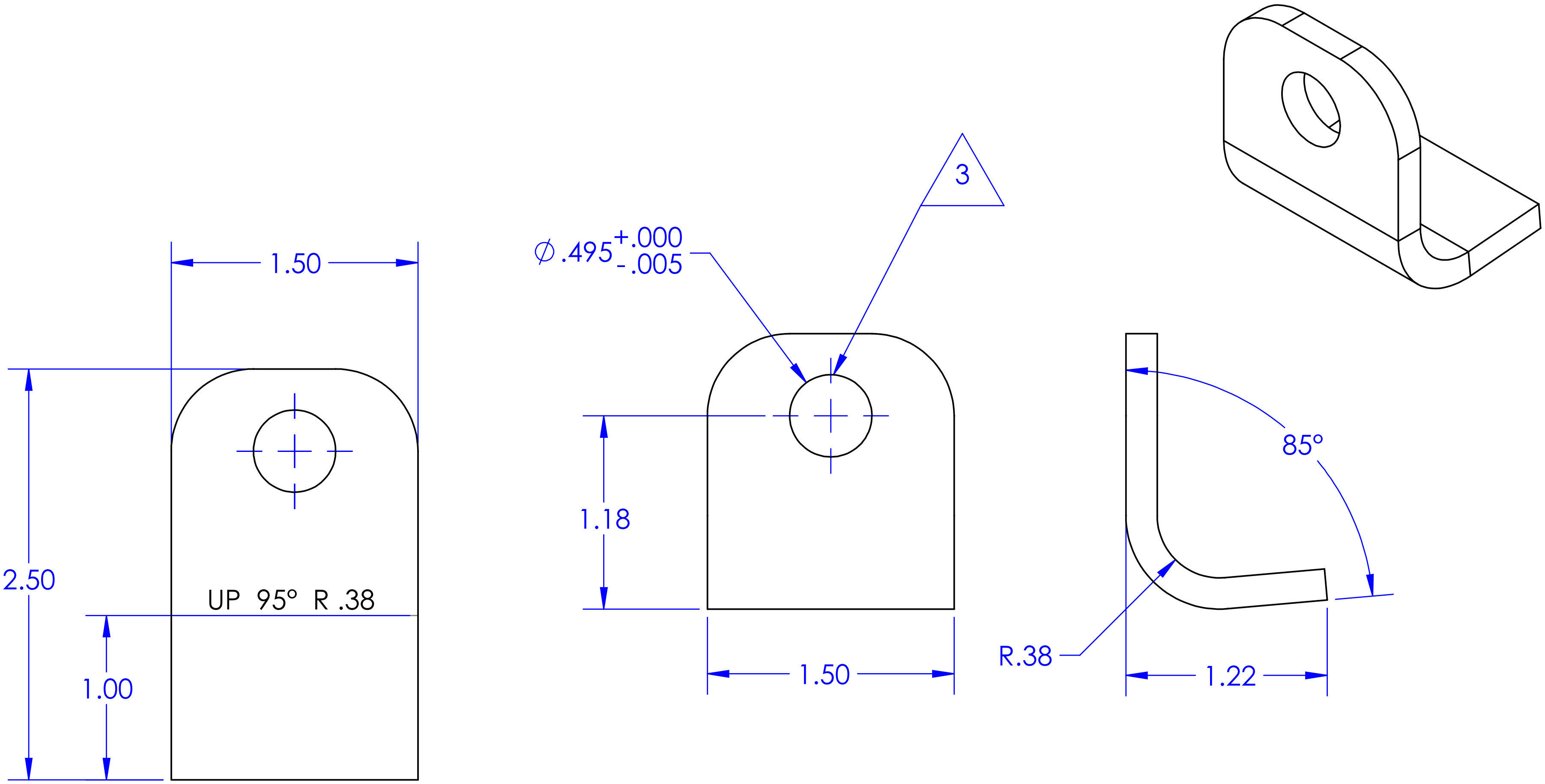
SIZE	DWG. NO.	REV
A	MA-400	

SCALE: 1:1 | WEIGHT: 0.42 LB | SHEET 1 OF 1

2 | 1

2 1

B B



FLAT PATTERN

A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: BEND ±1° TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	WILSON	05/22/19
	CHECKED	MEARES	05/22/19
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL AL 5052-H32	COMMENTS: 1. WATER JET CUT BRACKET PROFILE AND HOLE LOCATIONS 2. BREAK SHARP EDGES 3. POST-PROCESS BORE TO TOLERANCE SHOWN		
FINISH 63			

TITLE:

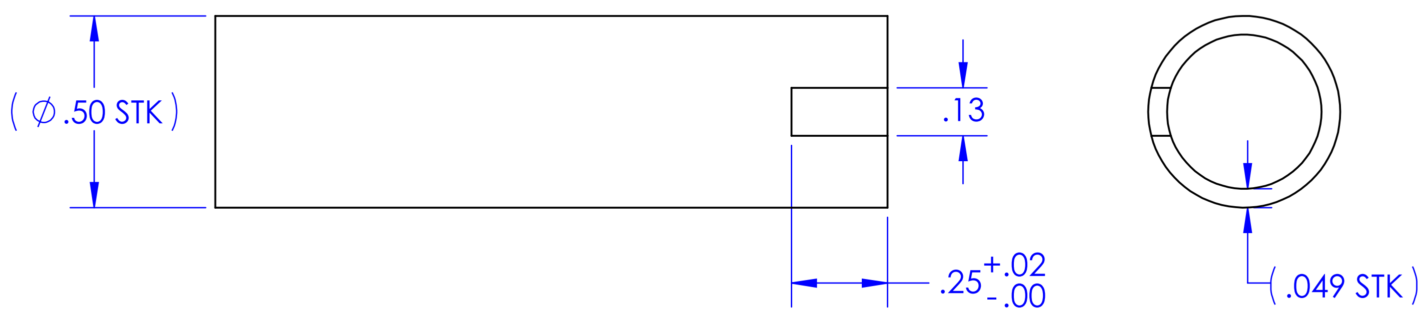
WRIST BRACKET

SIZE	DWG. NO.	REV
A	MP-101	
SCALE: 1:1	WEIGHT: 0.1 LB	SHEET 1 OF 1

2 1

2 1

B B



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
AL 6061-T6

FINISH
N/A

	NAME	DATE
DRAWN	WILSON	05/22/19
CHECKED	MEARES	05/22/19
ENG APPR.		
MFG APPR.		
Q.A.		

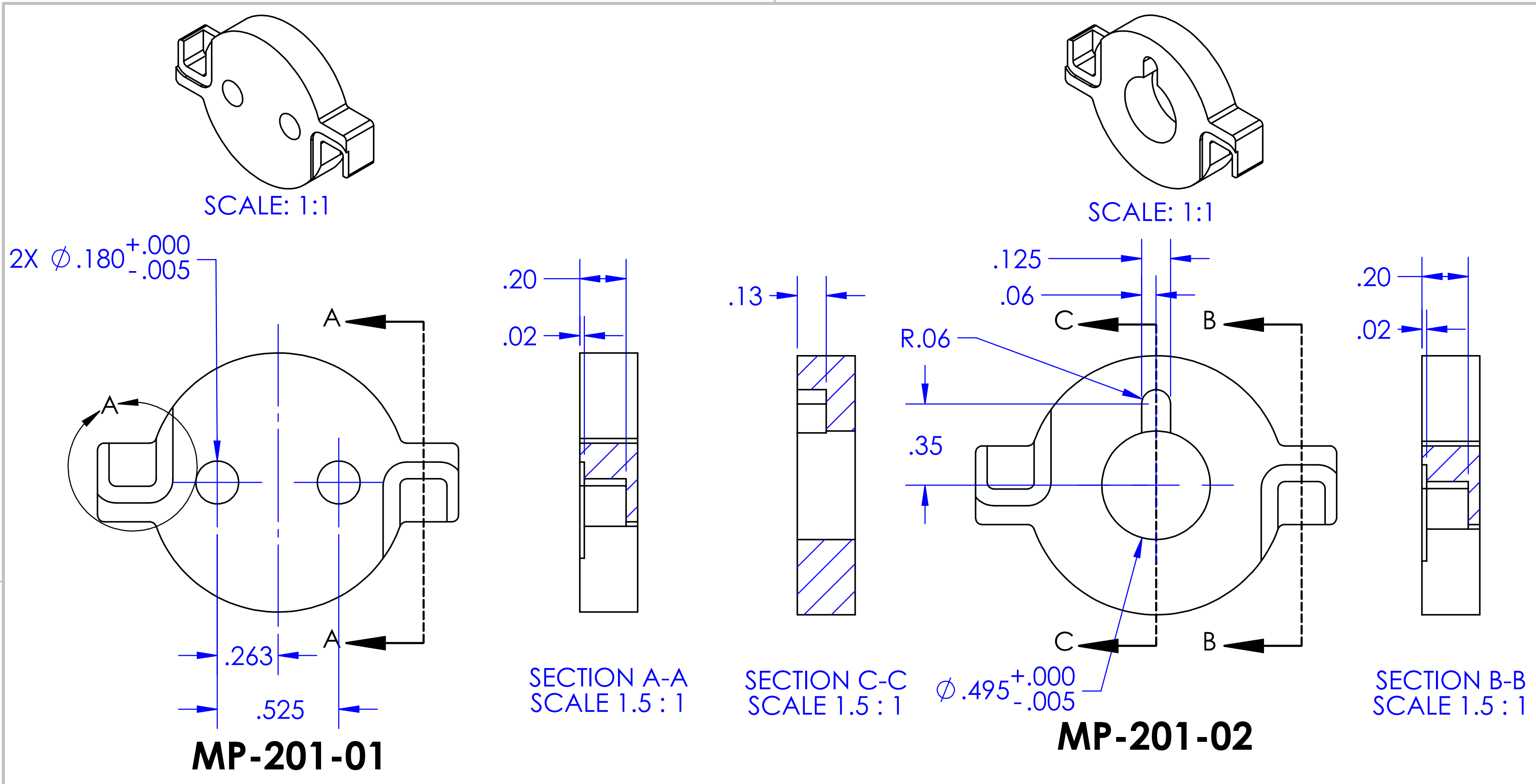
COMMENTS:
1. BREAK SHARP EDGES

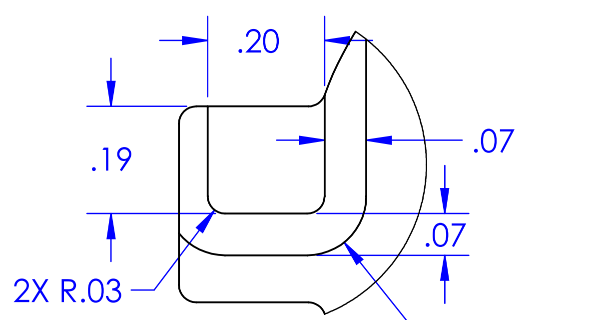
TITLE:
WRIST SHAFT

SIZE **A** DWG. NO. MP-102 REV

SCALE: 2:1 WEIGHT: 0.01 LB SHEET 1 OF 1

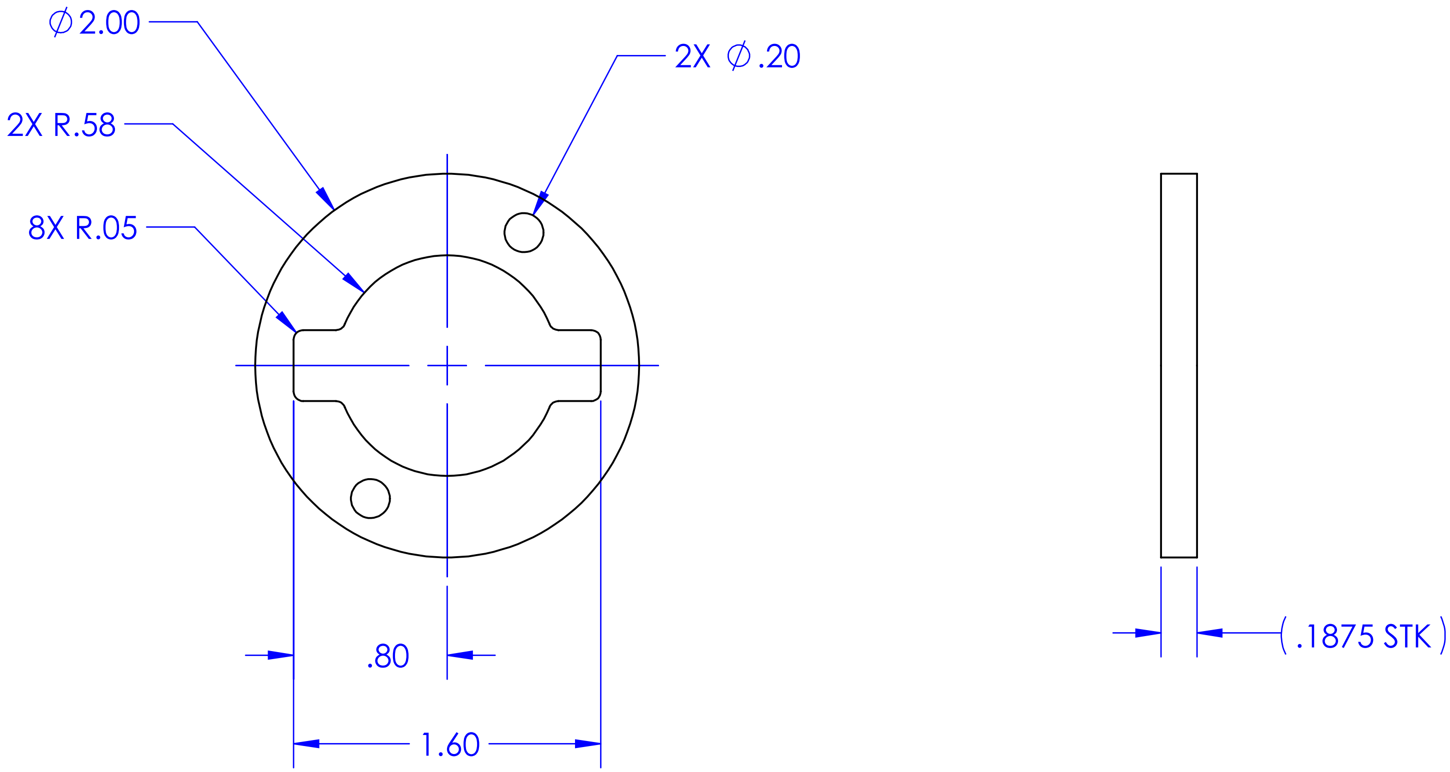
2 1

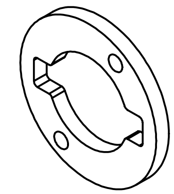




DETAIL A
SCALE 3 : 1

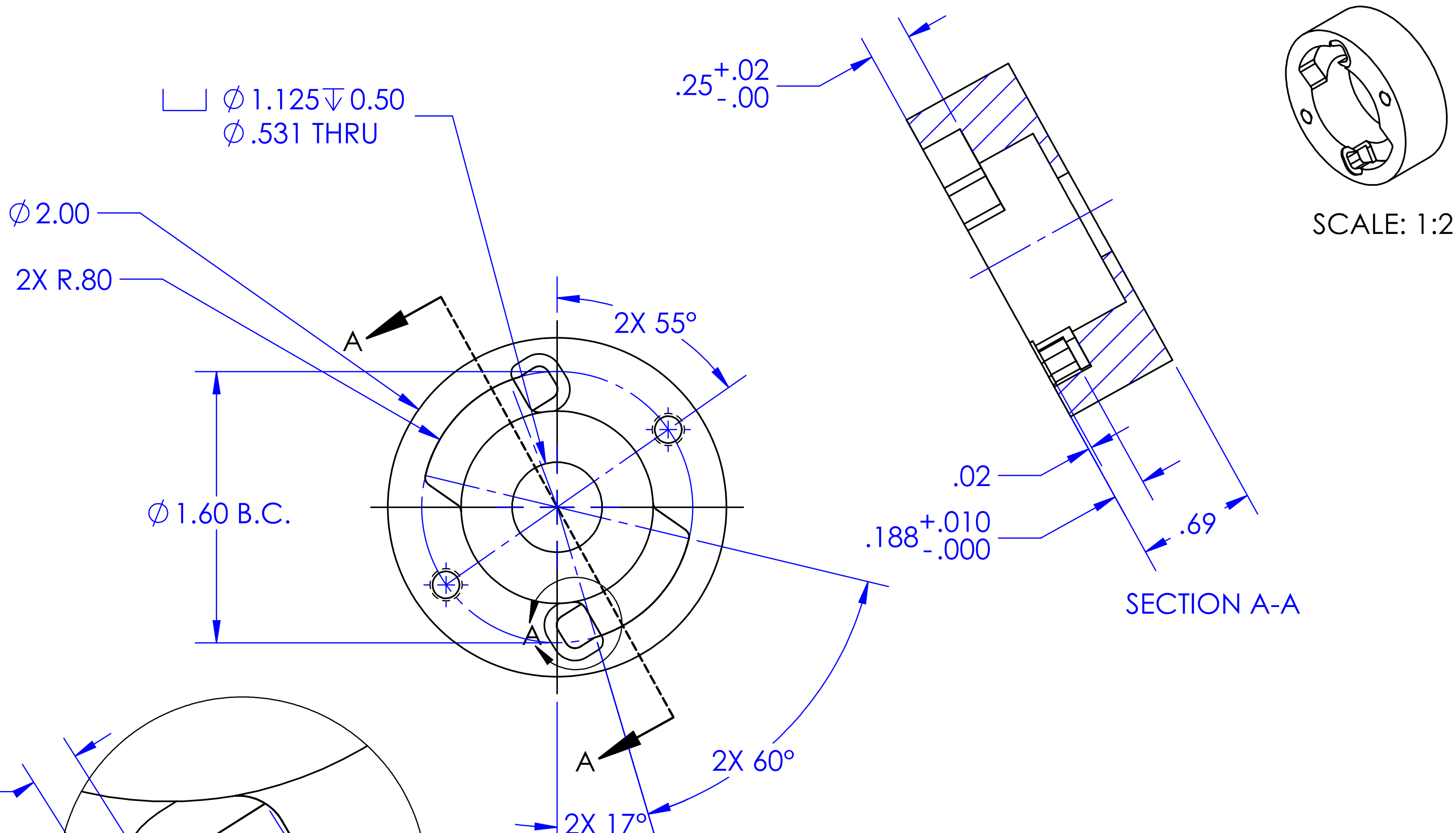
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±1° TWO PLACE DECIMAL ±.010 THREE PLACE DECIMAL ±.005	DRAWN	WILSON	05/22/19	TITLE:
	CHECKED	MEARES	05/22/19	WRIST INSERT
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL DELRIN	COMMENTS: 1. PROFILE AND TABS PRE-CUT WITH WATER JET 2. DETAIL A IS THE SAME FOR EACH CONFIGURATION			SIZE A · DWG. NO. MP-201 · REV
FINISH N/A				SCALE: 2:1 · WEIGHT: 0.01 LB · SHEET 1 OF 1

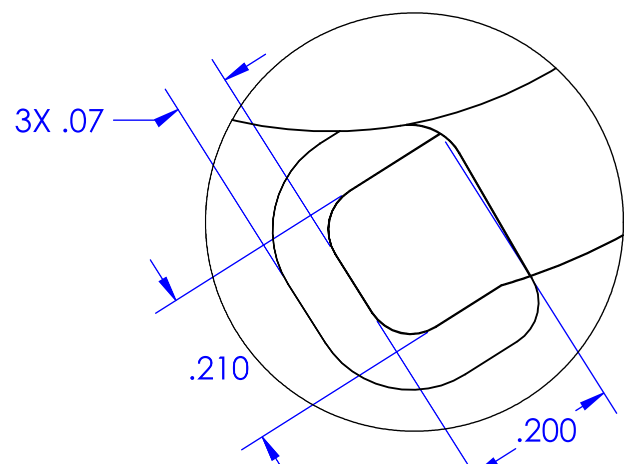




SCALE: 1:2

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±1° TWO PLACE DECIMAL ±.010 THREE PLACE DECIMAL ±.005	DRAWN	WILSON	05/22/19	
	CHECKED	MEARES	05/22/19	TITLE: WRIST INSERT, TOP PLATE
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL DELRIN	COMMENTS: 1. INSERT TO BE WATER JET CUT, PART DIMENSIONS DETERMINED BY .DXF FILE 2. BREAK SHARP EDGES			SIZE A · DWG. NO. MP-202 · REV
FINISH N/A				SCALE: 1:1 · WEIGHT: 0.02 LB · SHEET 1 OF 1





DETAIL A
SCALE 4 : 1

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±1° TWO PLACE DECIMAL ±.010 THREE PLACE DECIMAL ±.005	DRAWN	WILSON	05/22/19
	CHECKED	MEARES	05/22/19
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL DELRIN	COMMENTS: 1. PART TO BE CNC MACHINED 2. BREAK SHARP EDGES		
FINISH 63			

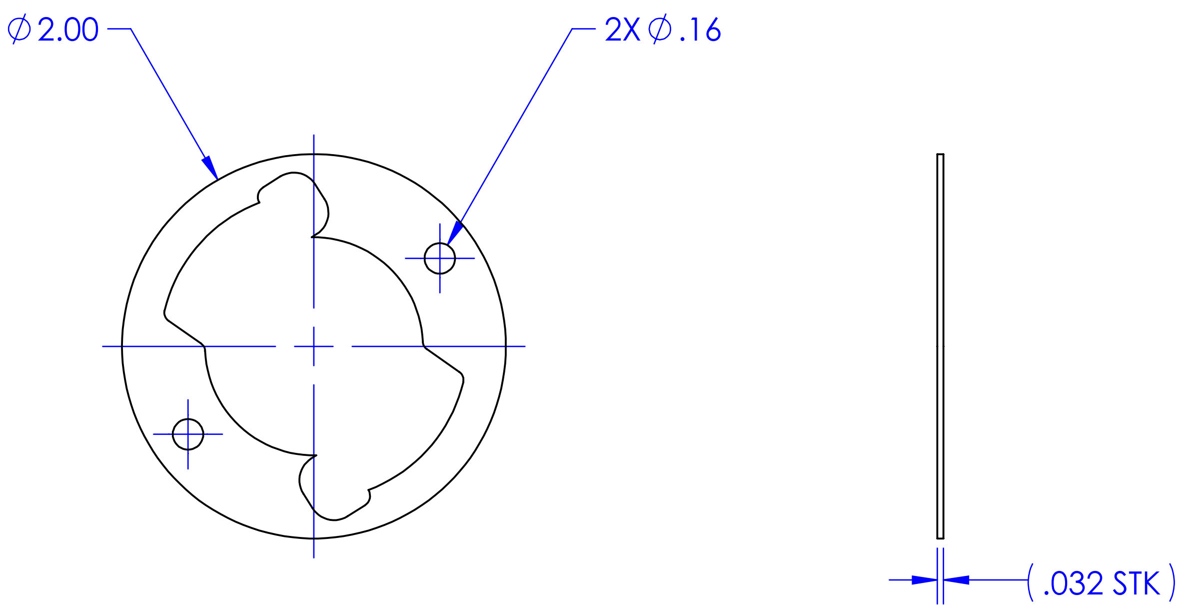
TITLE:

WRIST INSERT, BOTTOM PLATE

SIZE	DWG. NO.	REV
A	MP-203	
SCALE: 1:1	WEIGHT: 0.07 LB	SHEET 1 OF 1

2 1

B B



A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±1° TWO PLACE DECIMAL ±.010 THREE PLACE DECIMAL ±.005	DRAWN	WILSON	05/22/19
	CHECKED	MEARES	05/22/19
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL AL 6061-T6	COMMENTS: 1. PART TO BE WATER JET CUT, MINIMALY DIMENSIONED BECAUSE DIMENSIONS DEFINED BY .DXF FILE 2. BREAK SHARP EDGES		
FINISH N/A			

TITLE: **WRIST SHIM**

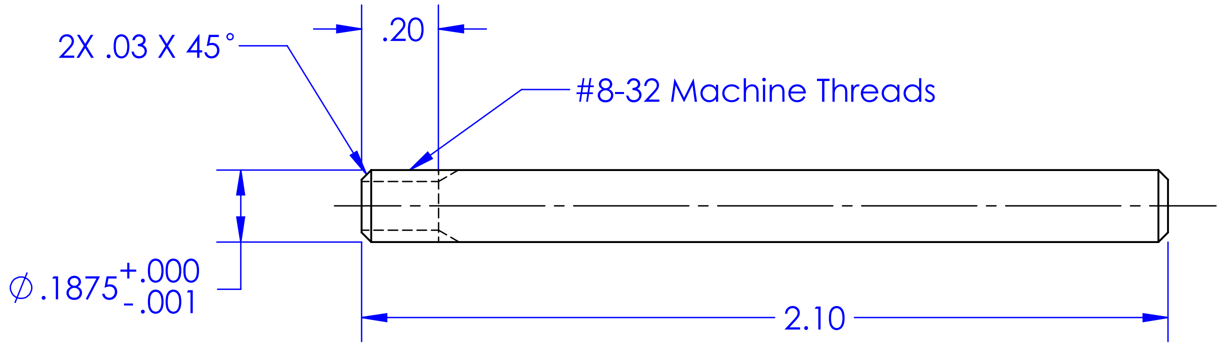
SIZE	DWG. NO.	REV
A	MP-204	

SCALE: 1:1	WEIGHT: .004 LB	SHEET 1 OF 1

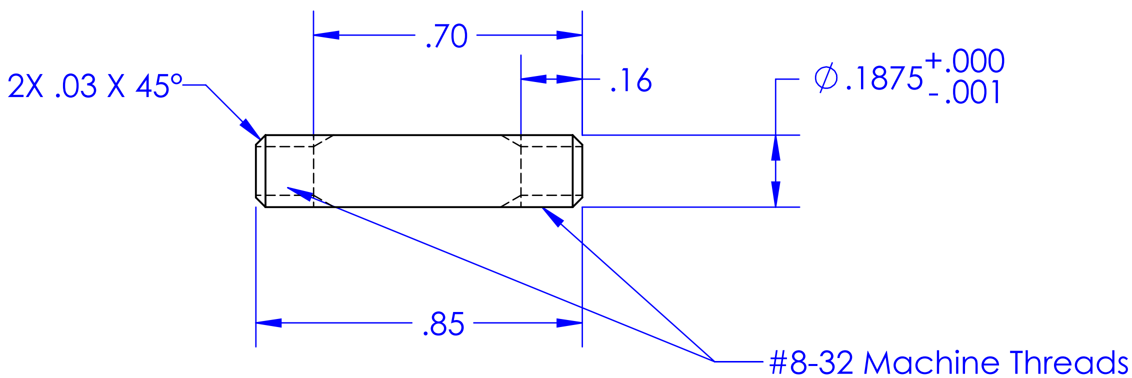
2 1

2 1

B B



MP-302 LONG ROD

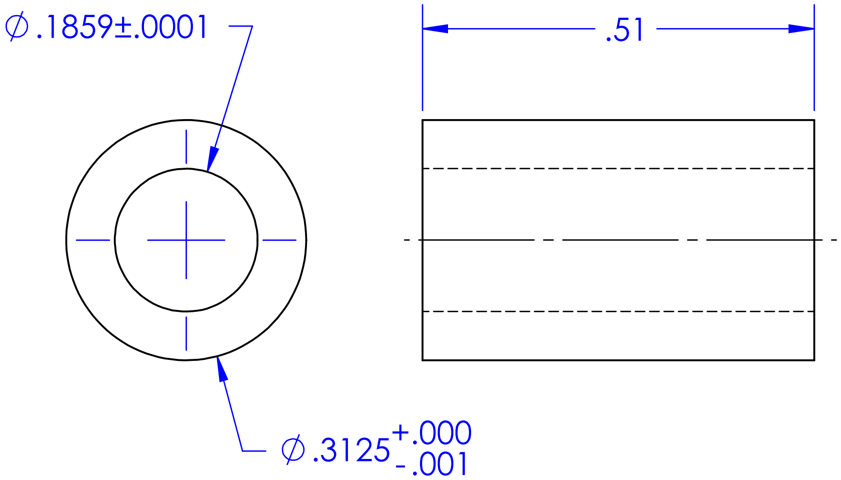


MP-309 SHORT ROD

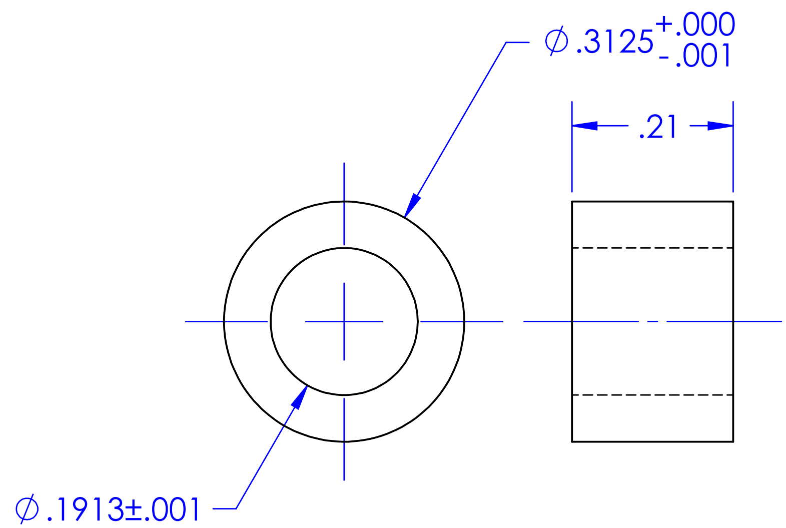
A A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLE ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005	DRAWN	MEARES	02/18/19	TITLE:
	CHECKED	WILSON	04/10/19	CLAMP TURNED PARTS
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL AL 6061-T6	COMMENTS:			SIZE A
FINISH N/A				DWG. NO. MP-302 & MP-309
				REV
				SCALE: 2:1
				WEIGHT:
				SHEET 1 OF 2

2 1

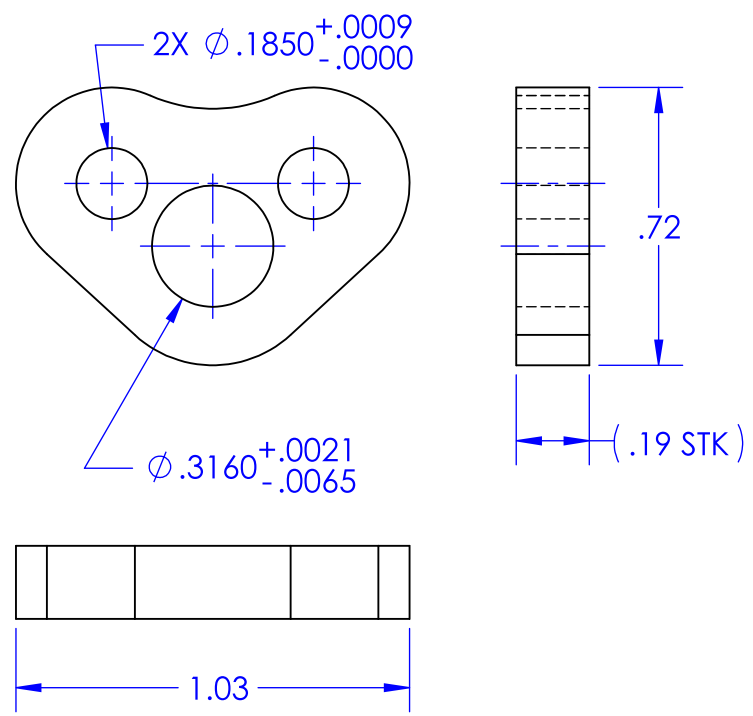


MP-310 Long Bushing

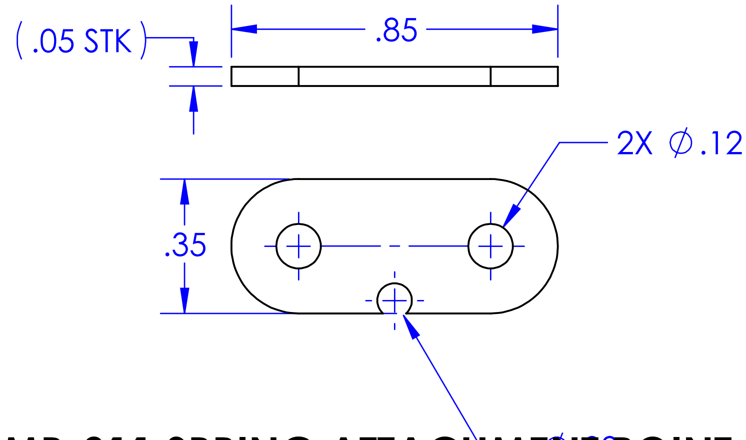


MP-303 Short Bushing

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLE ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005	DRAWN	MEARES	04/09/19	TITLE:
	CHECKED	WILSON	04/09/19	CLAMP TURNED PARTS
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL ACETAL	COMMENTS:			SIZE A DWG. NO. MP-303 & MP-310 REV
FINISH N/A				SCALE: 4:1 WEIGHT: SHEET 2 OF 2

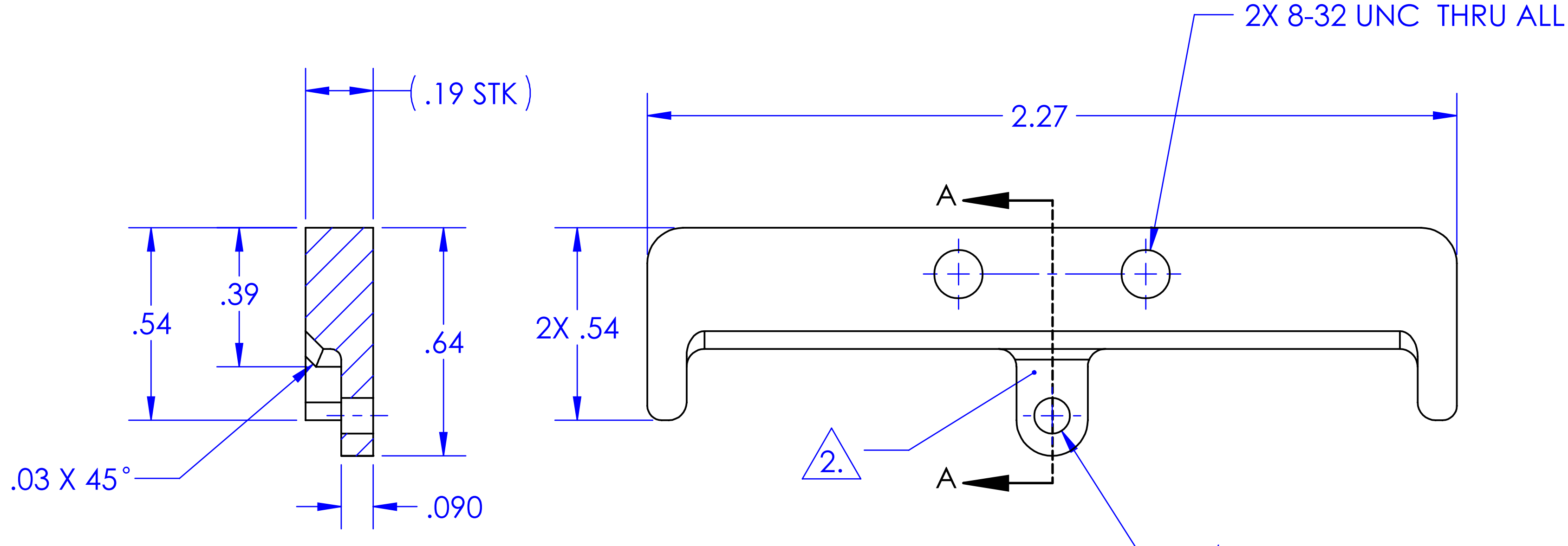


MP-301 ROD GUIDE



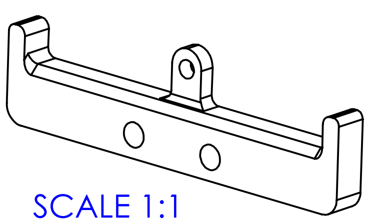
MP-311 SPRING ATTACHMENT POINT

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 1° TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	MEARES	04/17/19	
	CHECKED	WILSON	04/17/19	TITLE:
	ENG APPR.			CLAMP WATER JET PARTS
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL AL 6061-T6	COMMENTS:			SIZE A
FINISH N/A	1. PARTS WATER JET CUT, THEREFORE GEOMETRY AND HOLD LOCATION DEFINED BY DXF FILE 2. POST PROCESSING REQUIRED 3. HOLES BORED TO SIZE			DWG. NO. MP-301&MP-311
				REV
				SCALE: 2:1
				WEIGHT:
				SHEET 1 OF 4



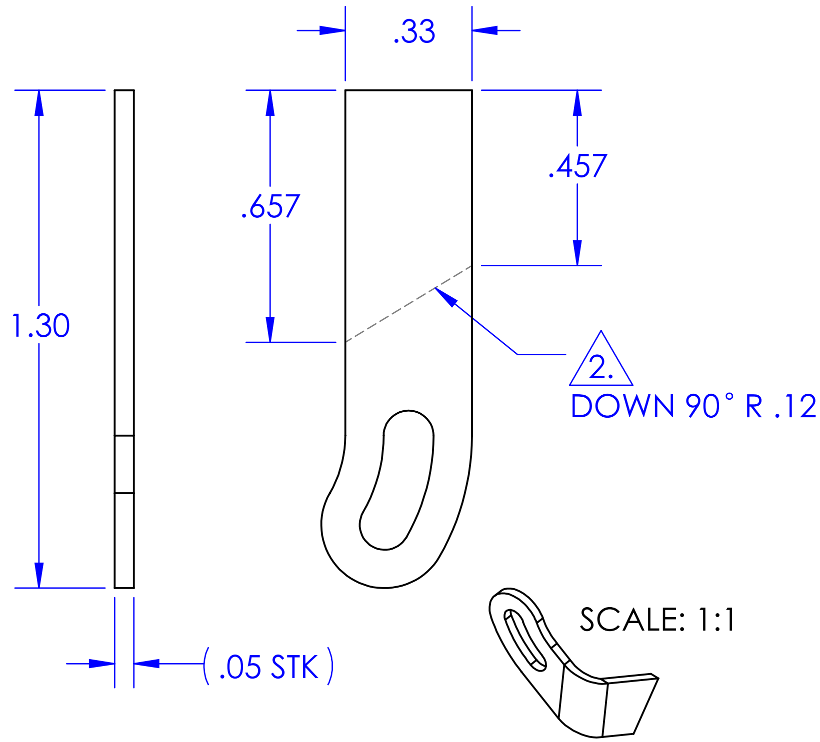
SECTION A-A

MP-317 PRONG ATTACHMENT POINT

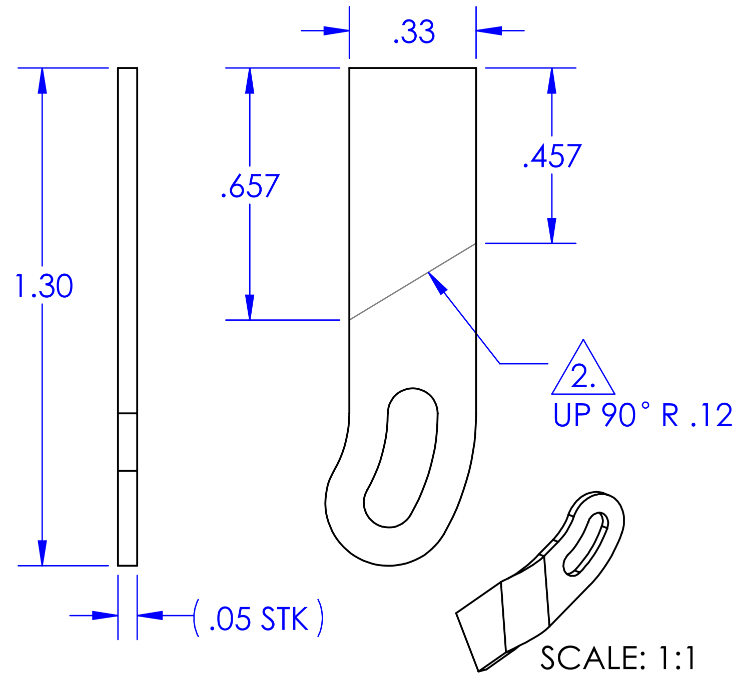


SCALE 1:1

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ±1° TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	MEARES	04/17/19	TITLE:
	CHECKED	WILSON	04/17/19	CLAMP WATER JET CUT PARTS
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL AL 6061-T6	COMMENTS: 1. PARTS WATER JET CUT, THEREFORE GEOMETRY AND HOLD LOCATION DEFINED BY DXF FILE 2. POST PROCESSING REQUIRED 3. HOLES BORED TO SIZE			SIZE: A — DWG. NO. MP-317 — REV
FINISH N/A				SCALE: 2:1 — WEIGHT: — SHEET 2 OF 4

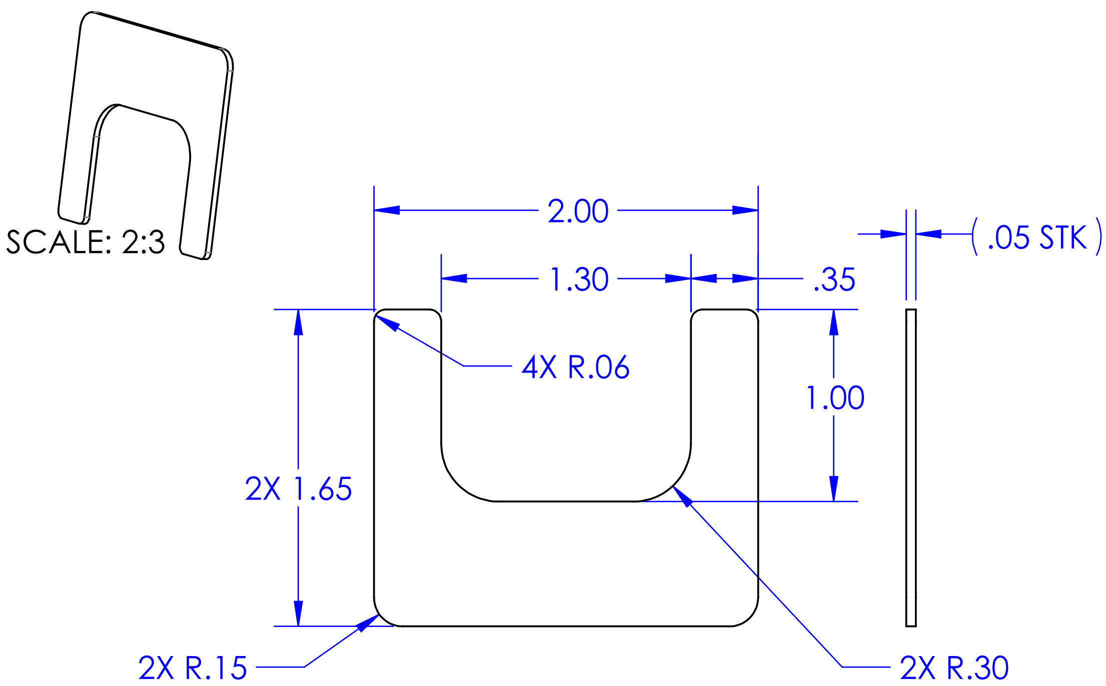


MP-304-01 ROTATION GUIDE, LEFT

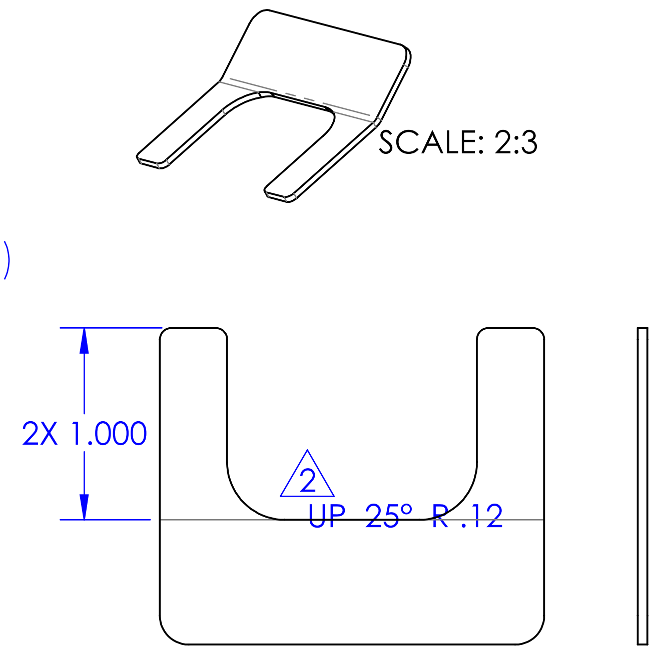


MP-304-02 ROTATION GUIDE, RIGHT

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ±1° TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	MEARES	04/17/19	
	CHECKED	WILSON	04/17/19	TITLE: CLAMP WATER JET PARTS
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL AL 6061-T6	COMMENTS: 1. PARTS WATER JET CUT, THEREFORE GEOMETRY AND HOLD LOCATION DEFINED BY DXF FILE 2. POST PROCESSING REQUIRED 3. HOLES BORED TO SIZE			SIZE A — DWG. NO. MP-304 — REV
FINISH N/A				SCALE: 2:1 — WEIGHT: — SHEET 3 OF 4



MP-318-01 PRONGS, STRAIGHT



MP-318-02 PRONGS, ANGLED

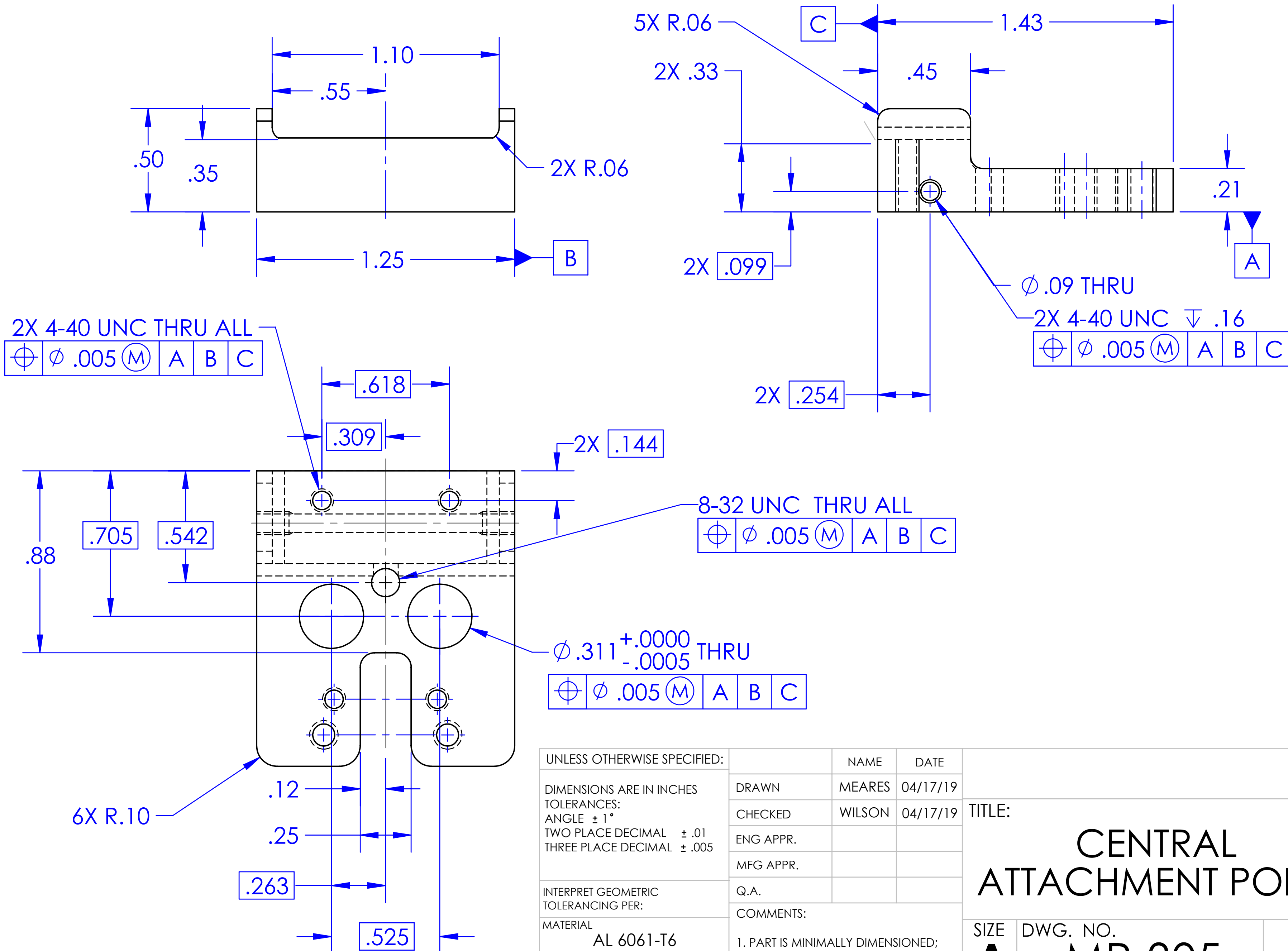
DIMENSIONS SAME AS MP-318-01

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ±1° TWO PLACE DECIMAL ±.01 THREE PLACE DECIMAL ±.005	DRAWN	MEARES	04/17/19
	CHECKED	WILSON	04/17/19
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL AL 6061-T6	COMMENTS: 1. PARTS WATER JET CUT, THEREFORE GEOMETRY AND HOLD LOCATION DEFINED BY DXF FILE 2. POST PROCESSING REQUIRED 3. HOLES BORED TO SIZE		
FINISH N/A			

TITLE: CLAMP WATER JET PARTS

SIZE	DWG. NO.	REV
A	MP-317	
SCALE: 1:1	WEIGHT:	SHEET 4 OF 4

2 1



B B

A A

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGLE ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
AL 6061-T6

FINISH
N/A

	NAME	DATE
DRAWN	MEARES	04/17/19
CHECKED	WILSON	04/17/19
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

1. PART IS MINIMALLY DIMENSIONED; REFER TO PART FILE FOR FULL GEOMETRY

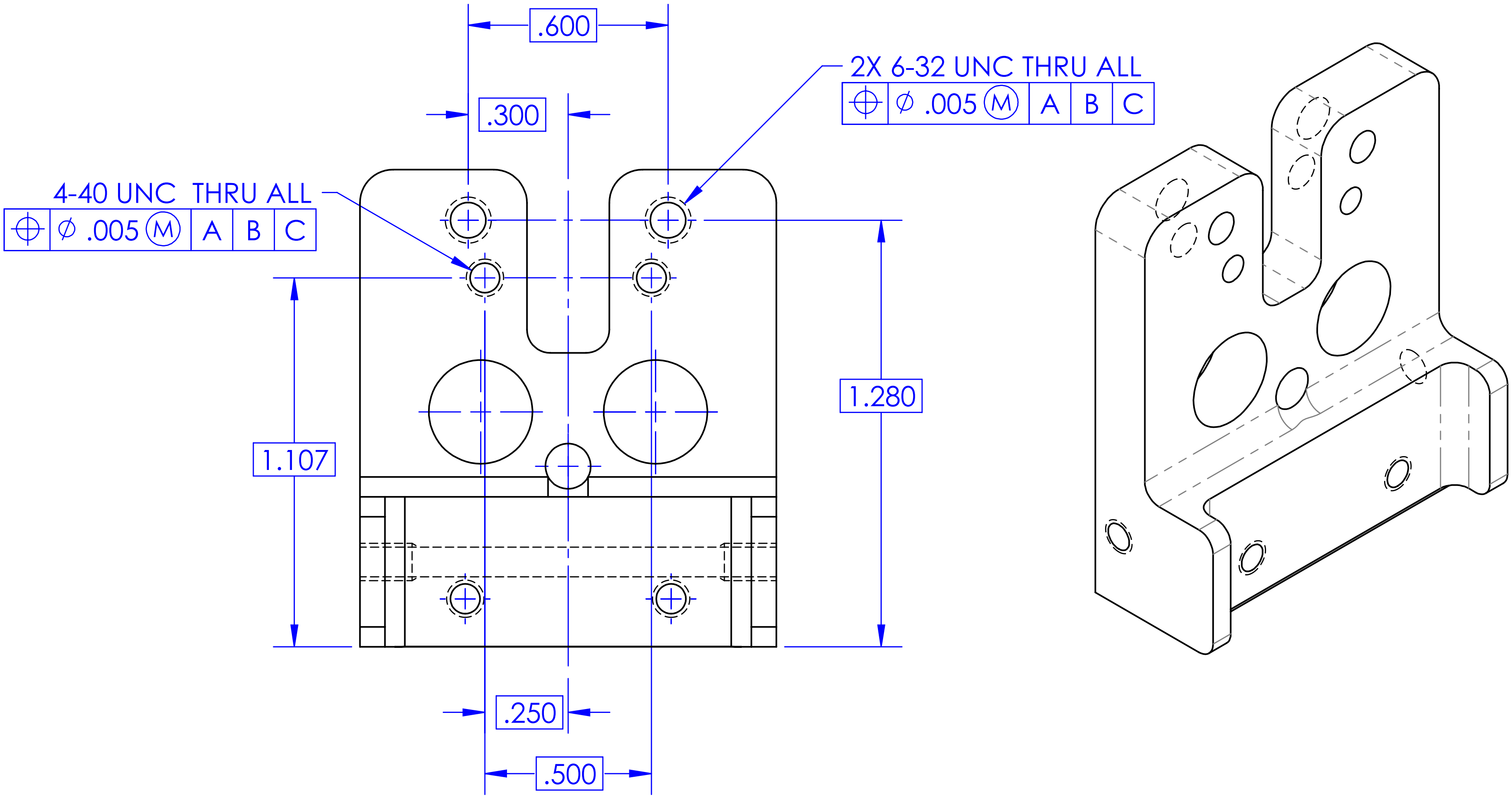
TITLE:

CENTRAL ATTACHMENT POINT

SIZE **A** DWG. NO. MP-305 REV

SCALE: 3:2 WEIGHT: SHEET 1 OF 2

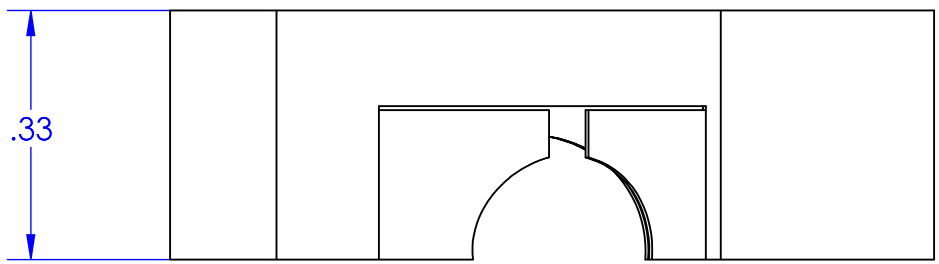
2 1

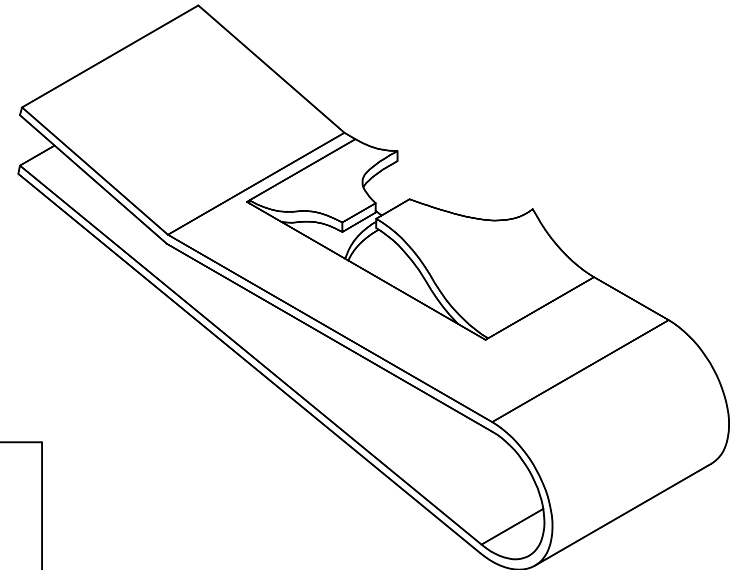


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLE ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005	DRAWN	MEARES	02/18/19	
	CHECKED	WILSON	04/10/19	TITLE:
	ENG APPR.			CENTRAL ATTACHMENT POINT
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL AL 6061-T6	COMMENTS: 1. PART IS MINIMALLY DIMENSIONED; REFER TO PART FILE FOR FULL GEOMETRY			SIZE A — DWG. NO. MP-305 — REV
FINISH N/A				SCALE: 2:1 — WEIGHT: — SHEET 2 OF 2

2 1

B B





A A

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGLE ± 1°
TWO PLACE DECIMAL ± .01
THREE PLACE DECIMAL ± .005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: STEEL

FINISH: N/A

	NAME	DATE
DRAWN	MEARES	04/17/19
CHECKED	WILSON	04/17/19
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

1. PART MADE FROM MCMASTER P/N 94808A350

TITLE:

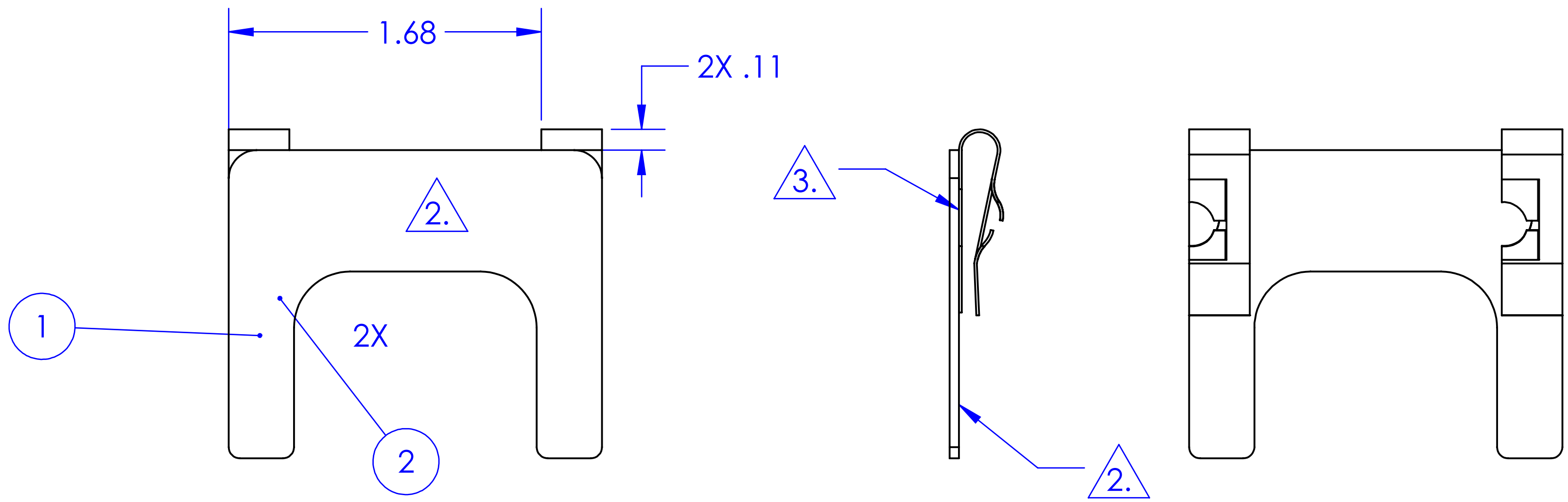
MODIFIED SURFACE-MOUNT HINGE

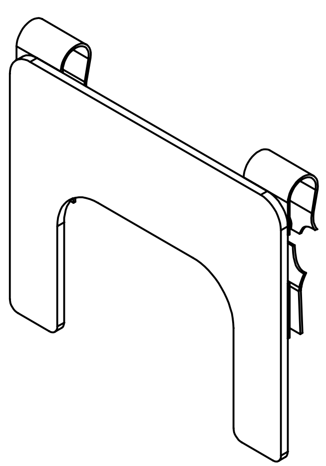
SIZE	DWG. NO.	REV
A	MP-315	

SCALE: 4:1	WEIGHT:	SHEET 1 OF 1

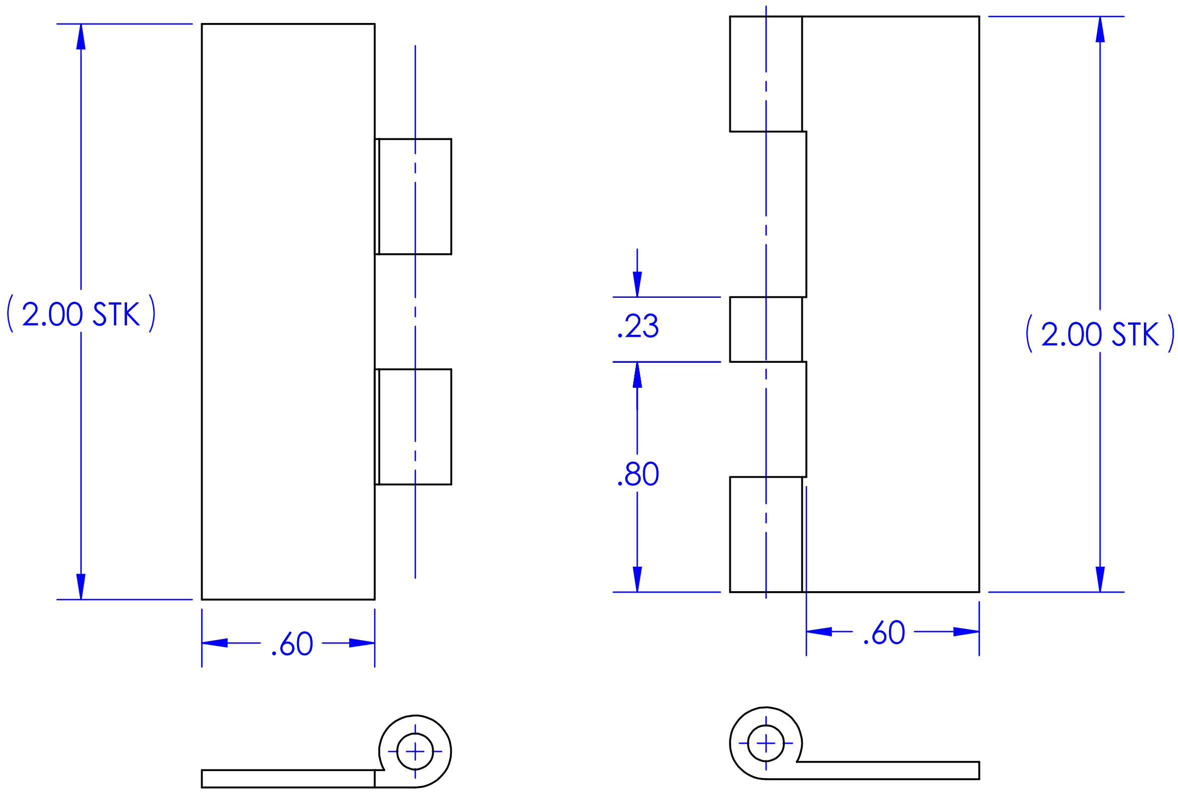
2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MP-318-01	Prongs, Straight	1
2	MP-326	Modified Clip-on Nut	2



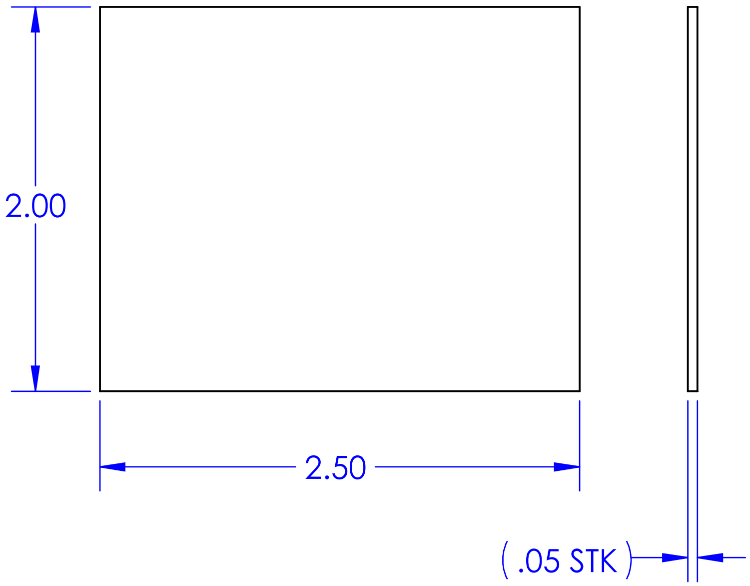


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLE ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005	DRAWN	MEARES	04/24/19	TITLE:
	CHECKED	WILSON	04/24/19	PRONG ASSEMBLY
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL N/A	COMMENTS: 1. MP-318-01 IS TO BE EXCHANGED FOR MP-318-02 FOR OTHER ASSEMBLY CONFIGURATION 2. SILICON SHEETS ARE TO BE GLUED ON THE SURFACES INDICATED 3. USE WELD-ON TO ATTACH PARTS			SIZE A · DWG. NO. MA-327 · REV
FINISH N/A				SCALE: 1:1 · WEIGHT: · SHEET 1 OF 1

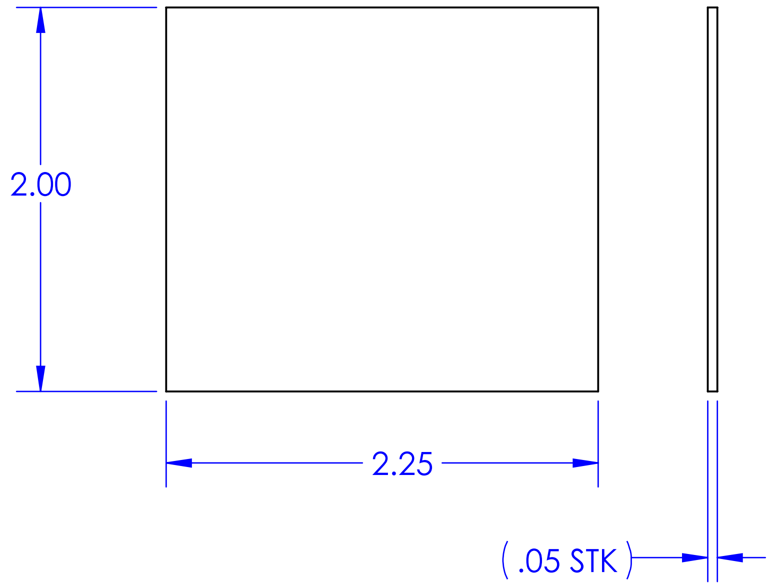


UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLE ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005	DRAWN	MEARES	04/10/19	
	CHECKED	WILSON	04/10/19	TITLE: MODIFIED SURFACE-MOUNT HINGE
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL AL 5052	COMMENTS: 1. PART MADE FROM MCMASTER P/N 1609A41			SIZE A · DWG. NO. MP-315 · REV
FINISH N/A				SCALE: 3:2 · WEIGHT: · SHEET 1 OF 1

B A



MP-313 TRIFOLD MIDDLE PANEL



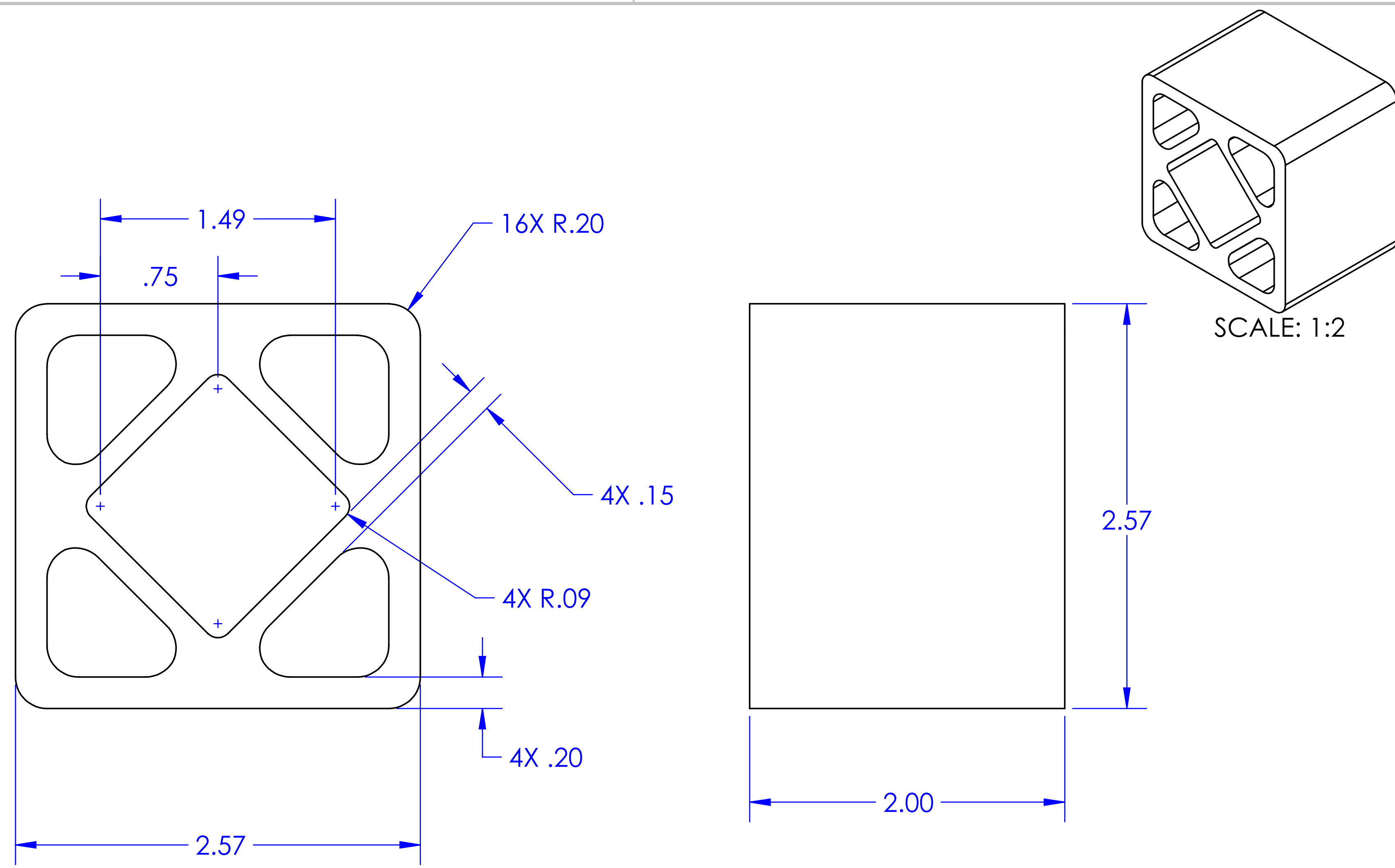
MP-314 TRIFOLD OUTER PANEL

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGLE ± 1° TWO PLACE DECIMAL ± .01 THREE PLACE DECIMAL ± .005	DRAWN	MEARES	04/09/19
	CHECKED	WILSON	04/10/19
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL 6061-T6	COMMENTS:		
FINISH N/A			

TITLE:
TRIFOLD PANELS

SIZE	DWG. NO.	REV
A	MP-313 & MP-314	

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



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
TWO PLACE DECIMAL ±.01

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: PLA

FINISH: N/A

	NAME	DATE
DRAWN	WILSON	3/10/19
CHECKED	MEARES	3/10/19
ENG APPR.		
MFG APPR.		
Q.A.		

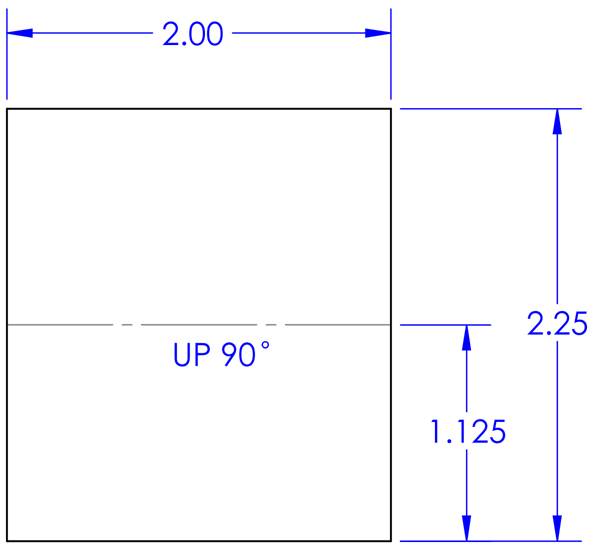
COMMENTS:
1. PART TO BE 3D PRINTED

TITLE:

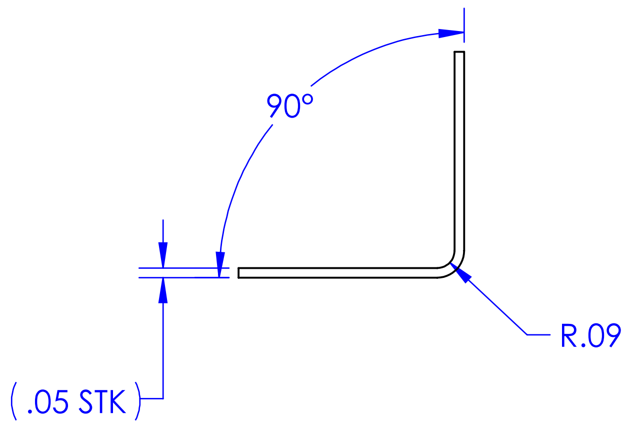
SLEEVE BEAM

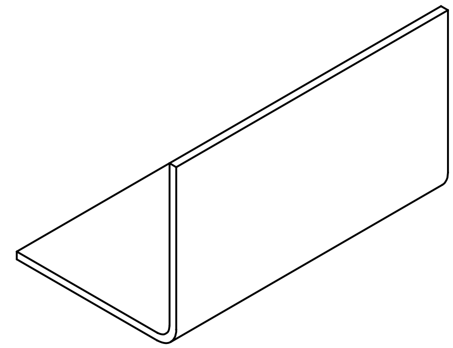
SIZE	DWG. NO.	REV
A	MP-401	

SCALE: 1:1 | WEIGHT: 0.22 LB | SHEET 1 OF 1



FLAT PATTERN





UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±1°
TWO PLACE DECIMAL ±.010
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
AL 6061-T6

FINISH
63

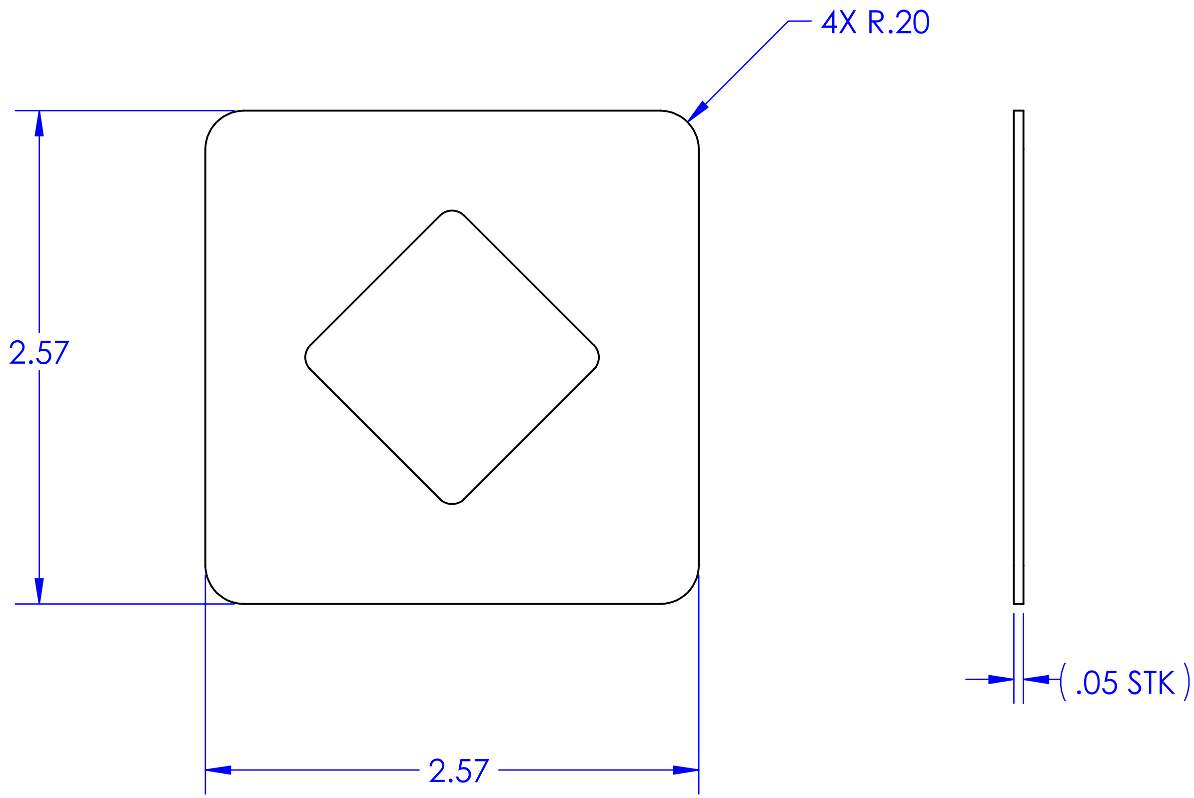
	NAME	DATE
DRAWN	WILSON	05/22/19
CHECKED	MEARES	05/22/19
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
1. BREAK SHARP EDGES
2. MANUFACTURE 2 COPIES PER SLEEVE ASSY

TITLE:
SHEET METAL INSERT

SIZE	DWG. NO.	REV
A	MP-402	

SCALE: 1:1 | WEIGHT: 0.02 LB | SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±1°
TWO PLACE DECIMAL ±.010
THREE PLACE DECIMAL ±.005

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
AL 6061-T6

FINISH
N/A

	NAME	DATE
DRAWN	WILSON	05/22/19
CHECKED	MEARES	05/22/19
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
1. PART TO BE WATER JET CUT, FULL DIMENSIONS DETERMINED BY .DXF FILE
2. MANUFACTURE 2 COPIES PER SLEEVE ASSY
3. BREAK SHARP EDGES

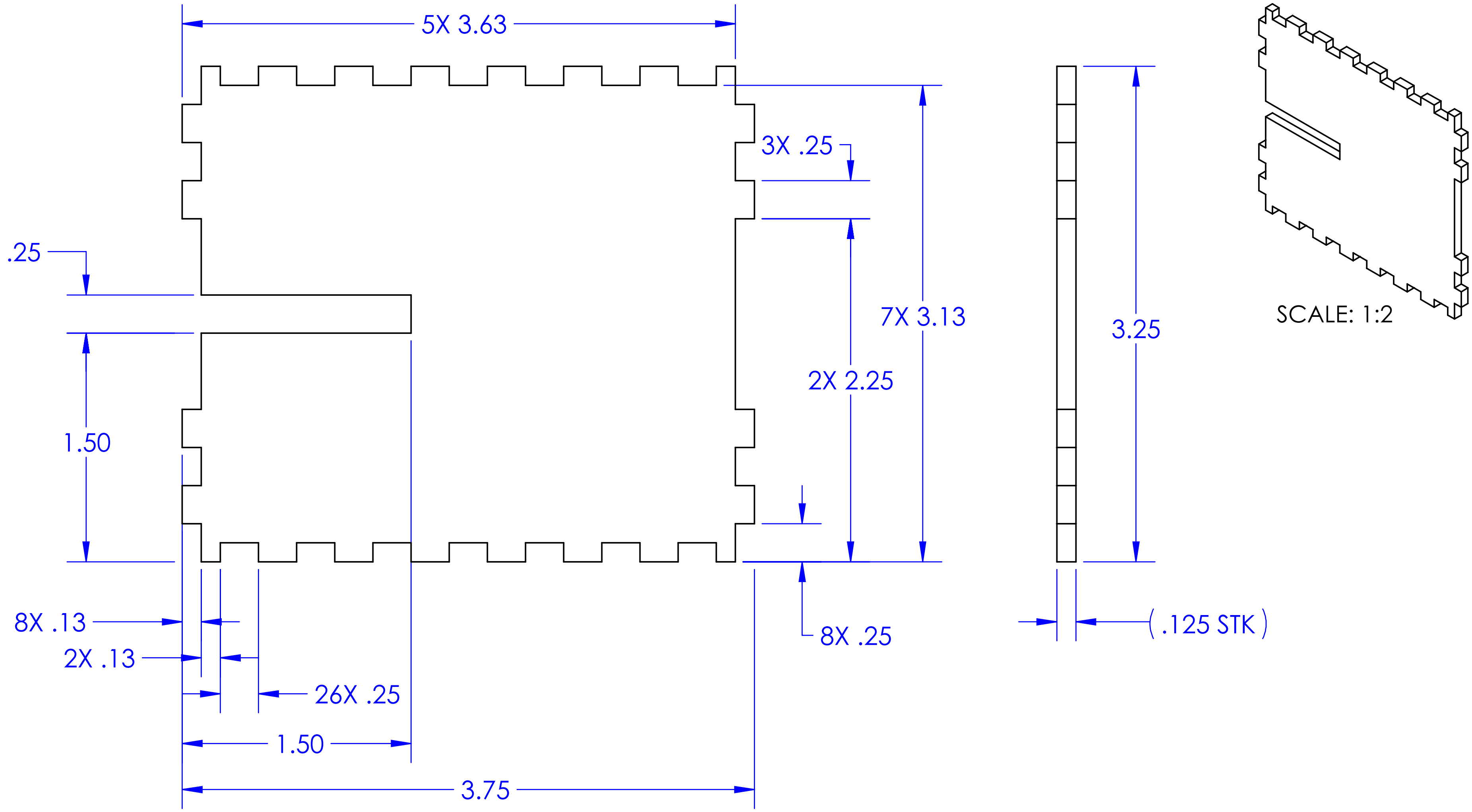
TITLE:
COVER PLATE

SIZE	DWG. NO.	REV
A	MP-403	

SCALE: 1:1 | WEIGHT: 0.02 LB | SHEET 1 OF 1

2 1

B



B

A

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±1° TWO PLACE DECIMAL ±0.20 THREE PLACE DECIMAL ±0.10	DRAWN	WILSON	05/22/19
	CHECKED	MEARES	05/22/19
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL ACRYLIC	COMMENTS: 1. PLATE TO BE LASER CUT 2. BREAK SHARP EDGES 3. MANUFACTURE 1 COPY PER CUTTING TOOL ASSY		
FINISH 63			

TITLE:

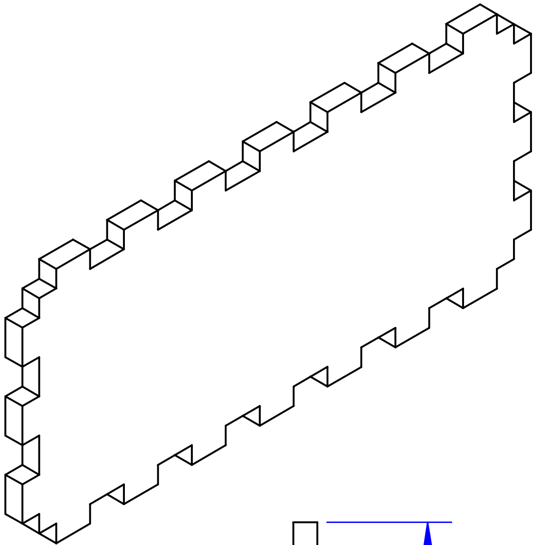
TOP PLATE WITH SLIT

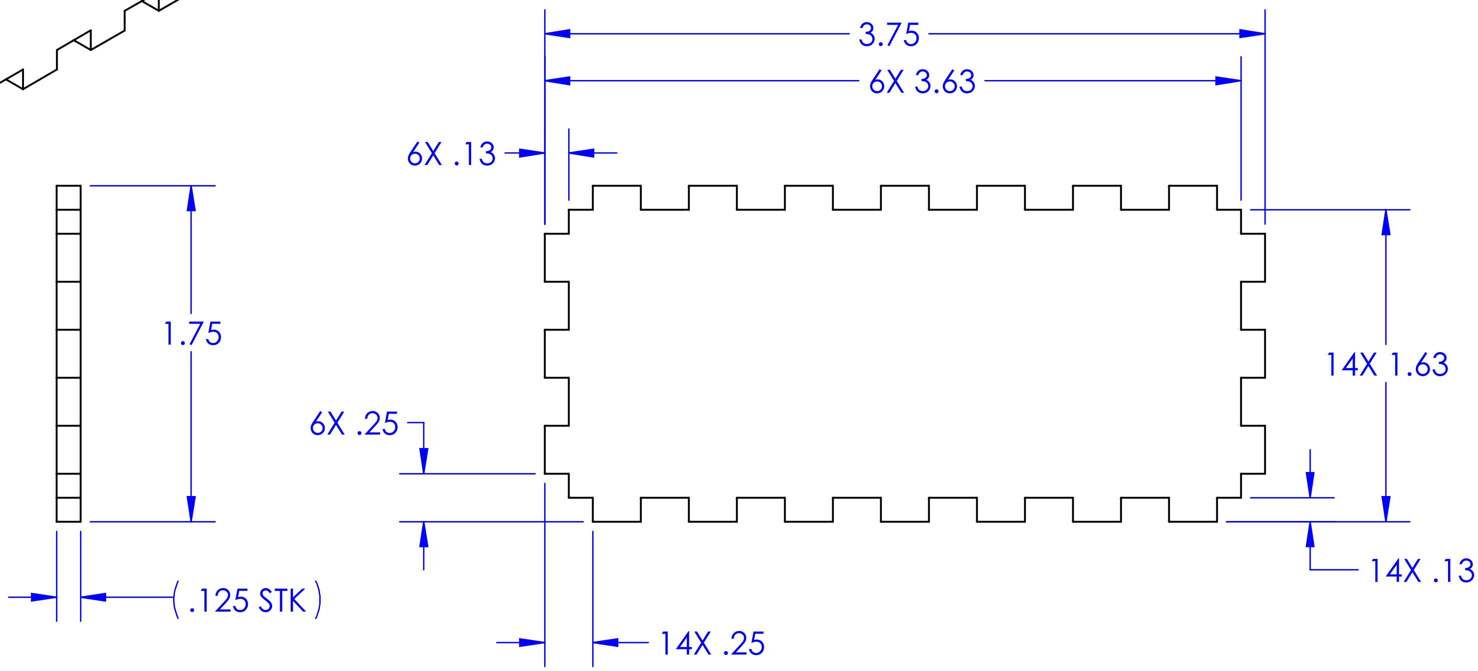
SIZE	DWG. NO.	REV
A	MP-501	

SCALE: 1:1 | WEIGHT: 0.06 LB | SHEET 1 OF 1

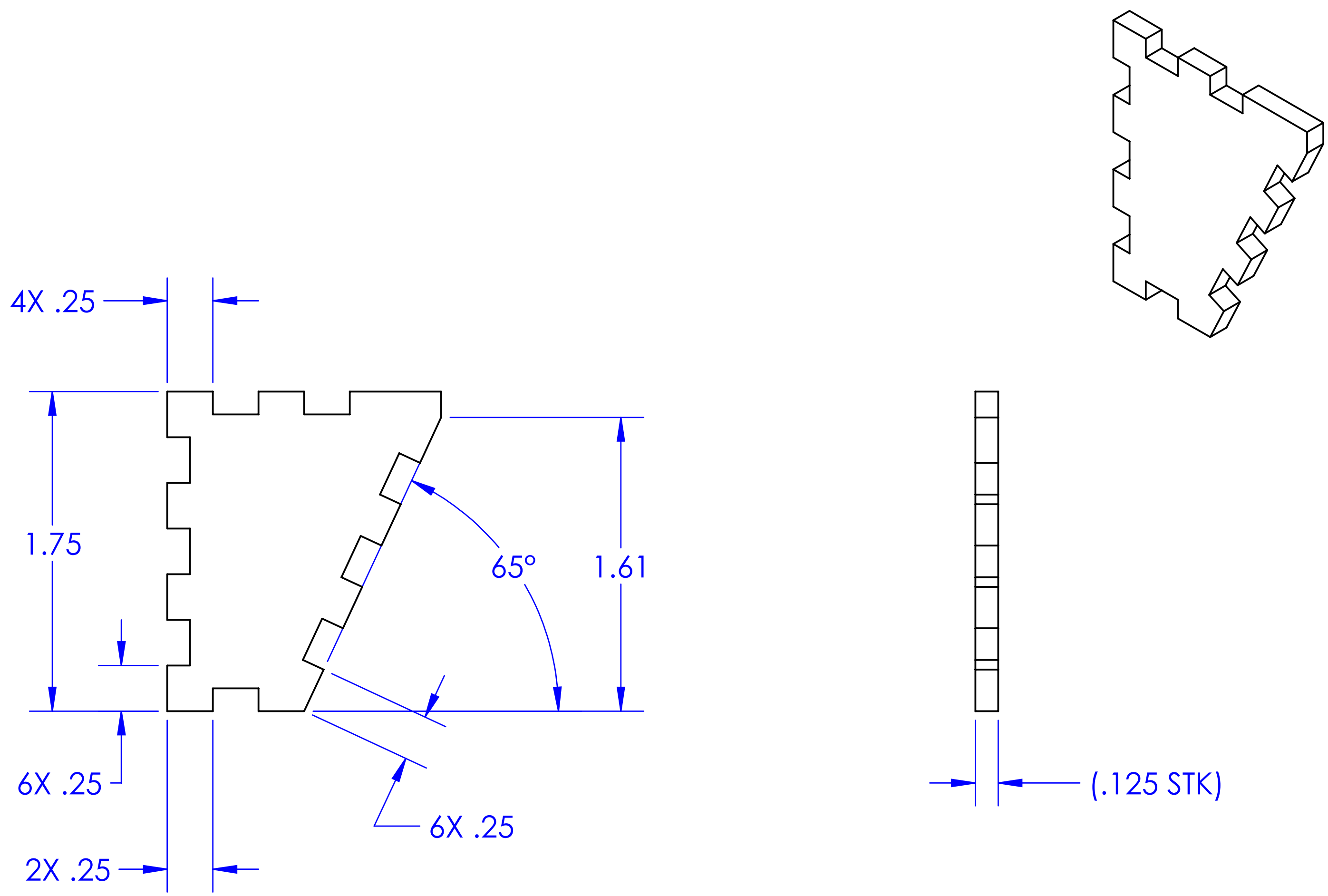
A

2 1





UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±1° TWO PLACE DECIMAL ±.020 THREE PLACE DECIMAL ±.010	DRAWN	EVANS	03/11/19	
	CHECKED	WILSON	03/11/19	TITLE:
	ENG APPR.			SIDE PLATE
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL ACRYLIC	COMMENTS: 1. PLATE TO BE LASER CUT 2. BREAK SHARP EDGES 3. MANUFACTURE 2 COPIES PER CUTTING TOOL ASSY			SIZE A DWG. NO. MP-502 REV
FINISH 63				SCALE: 1:1 WEIGHT: 0.03 LB SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±1°
TWO PLACE DECIMAL ±.020
THREE PLACE DECIMAL ±.010

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: ACRYLIC

FINISH: 63

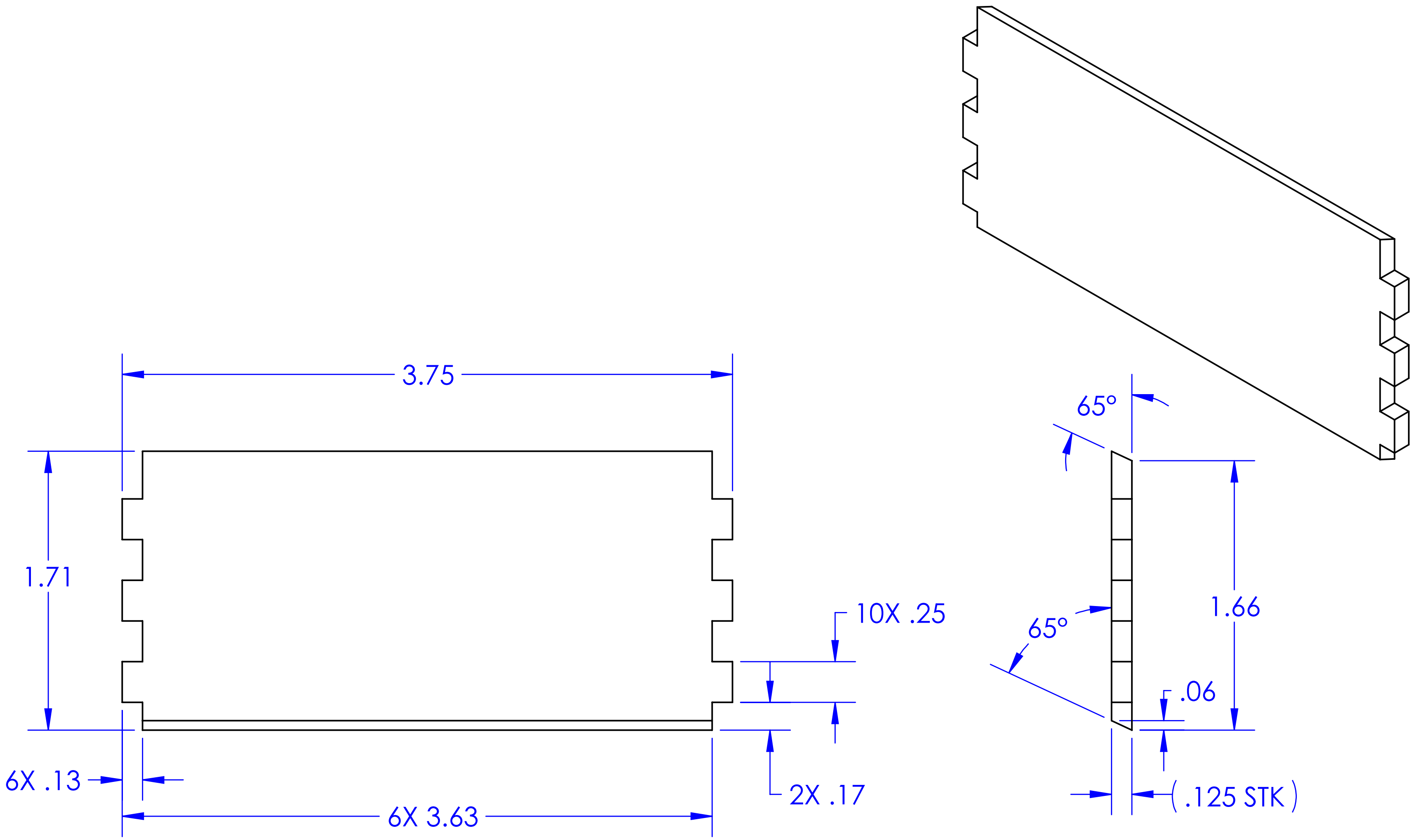
	NAME	DATE
DRAWN	EVANS	03/11/19
CHECKED	WILSON	03/11/19
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
1. PLATE TO BE LASER CUT
2. BREAK SHARP EDGES
3. MANUFACTURE 4 COPIES PER CUTTING TOOL ASSY

TITLE:
TRAPEZOIDAL PLATE

SIZE: A
DWG. NO. MP-503
REV

SCALE: 1:1 WEIGHT: 0.01 LB SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ±1°
TWO PLACE DECIMAL ±.020
THREE PLACE DECIMAL ±.010

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: ACRYLIC

FINISH: 63

	NAME	DATE
DRAWN	EVANS	03/11/19
CHECKED	WILSON	03/11/19
ENG APPR.		
MFG APPR.		
Q.A.		

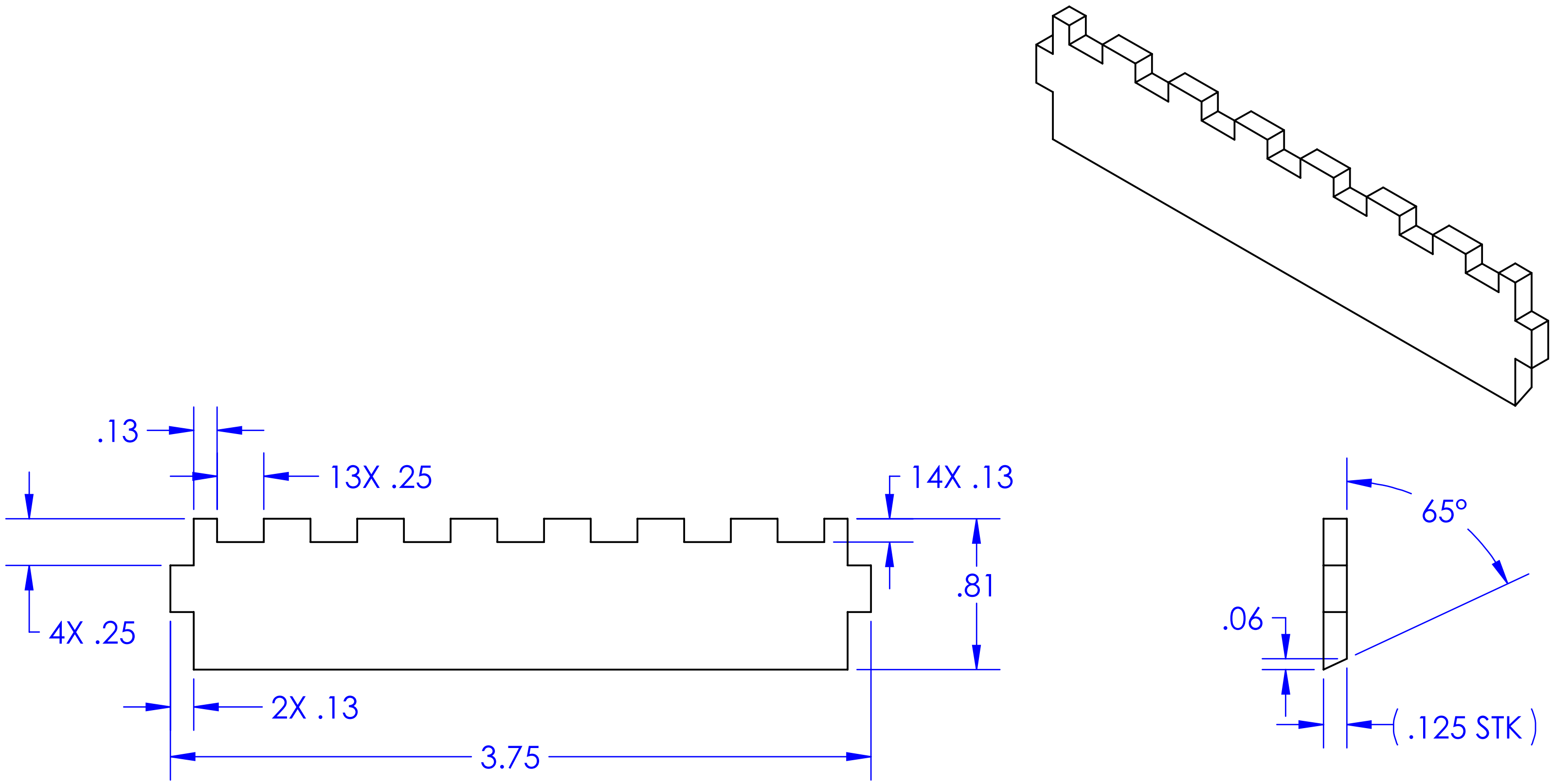
COMMENTS:
1. PLATE TO BE LASER CUT FLAT THEN POST-PROCESSED TO ACHIEVE ANGLES
2. BREAK SHARP EDGES
3. MAKE 2 COPIES PER CUTTING TOOL ASSY

TITLE:

INTERIOR ANGLED PLATE

SIZE	DWG. NO.	REV
A	MP-504	

SCALE: 1:1 | WEIGHT: 0.03 LB | SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ±1° TWO PLACE DECIMAL ±.020 THREE PLACE DECIMAL ±.010	DRAWN	EVANS	03/11/19
	CHECKED	WILSON	03/11/19
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL ACRYLIC	COMMENTS: 1. PLATE TO BE LASER CUT 2. BREAK SHARP EDGES 3. MANUFACTURE 2 COPIES PER CUTTING TOOL ASSY		
FINISH 63			

TITLE:

BOTTOM PLATE

SIZE	DWG. NO.	REV
A	MP-505	
SCALE: 1:1	WEIGHT: 0.01 LB	SHEET 1 OF 1

Appendix 8: Detailed Cost Breakdown and Bill of Materials (BOM)

Subassembly	Item No.	Description	Part Number	Size/Length	Quantity	Price Each	Price Ext	Vendor
Wrist	1	Small rectangular magnets	B633	3/8" x 3/16" x 3/16"	12	$0.61	$7.32	KJ Magnetic
Wrist	2	Small square magnets	B333-N52	3/16" x 3/16" x 3/16"	26	$0.47	$12.22	KJ Magnetic
Wrist	3	FM quick change wrist insert only	51052	1/2-20 internal thread	1	$0.00	$0.00	Fillauer
Wrist	4	delrin, 3/16" thk, 12" x 12" sheet	8573K14	3/16" x 12" x 12"	1	$24.11	$24.11	McMaster
Wrist	5	delrin, 5/8" thk, 6" x 6" sheet	8573K124	5/8" x 6" x 6"	1	$18.37	$18.37	McMaster
Wrist	6	1/2-20x3/4 hex bolt	23LA60	pack of 25	1	$17.51	$17.51	Grainger Supply Co.
Wrist	7	Passivated 18-8 Stainless Steel Pan Head Phillips Screw, 1/4-20 Thread, 5/8" Long	91772A539	pack of 50	1	$7.70	$7.70	McMaster
Wrist	8	Loctite	100371826	0.2 oz tube	1	$6.47	$6.47	Home Depot
Wrist	9	White Delrin® Acetal Resin Sheet, 1/4" Thick, 12" x 12"	8573K15	12" x 12" sheet	1	$25.72	$25.72	McMaster
Wrist	10	Zinc-Plated Steel Machine Key Undersized, 1/8" x 1/8", 1/2" Long	95053A108	pack of 5	1	$6.68	$6.68	McMaster
Wrist	11	White Delrin® Acetal Resin Rod, 2" Diameter	8572K29	2" Diameter, 1 ft long	1	$18.48	$18.48	McMaster
	Total for Wrist:						**$144.58**	
Sleeve	1	6061-T6 Aluminum Sheet, 0.19" Thick, 12" x 12"	89015K31	0.19" x 12" x 12"	1	$36.06	$36.06	McMaster
Sleeve	2	6061 Aluminum Round Tube, 1/8" Wall Thickness, 3/4" OD	9056K33	6" long	1	$27.69	$27.69	McMaster
Sleeve	3	PLA Filament	3D PLA-1KG1.75-BLU	1 kg spool	1	$19.99	$19.99	Amazon
Sleeve	4	6061 Aluminum Round Tube, 0.049" Wall Thickness, 1/2" OD	9056K65	3ft	1	$19.65	$19.65	McMaster
Sleeve	5	Easy-to-Weld 5052 Aluminum Sheet, Highly Corrosion-Resistant, 0.19" Thick	88895K109	12" x 12" sheet	1	$33.72	$33.72	McMaster
Sleeve	6	10-32 bolt, 9x16 thread length	91772A819	pack of 100	1	$10.49	$10.49	McMaster
	Total for Sleeve:						**$147.60**	
Clamp	1	Mortise-Mount Hinge with Nonstandard Hole Pattern, Removable Pin, Square, Zinc-Plated Steel, 1" x 1/2" Leaves	1597A41	Removable Pin, Square, Zinc-Plated Steel, 1" x 1/2"	4	$0.82	$3.28	McMaster
Clamp	2	Thumb-Grip 18-8 Stainless Steel Precision Shoulder Screw, 1/8" Shoulder Diameter, 1/8" Shoulder Length, 4-40 Thread	92952A110	4-40 thread	4	$4.19	$16.76	McMaster
Clamp	3	302 Stainless Steel Corrosion-Resistant Extension Spring, with Loop Ends, 0.625" Long, 0.180" OD, 0.018" Wire Diameter	9065K11	pack of 3	2	$6.51	$13.02	McMaster
Clamp	4	302 Stainless Steel Torsion Spring, 120 Degree Left-Hand Wound, 0.235" OD	9287K211	120 deg left hand	4	$2.18	$8.72	McMaster
Clamp	5	ToughWare Connector Plate	V2P-CPLT-316	3/16" ball	1	$0.00	$0.00	ToughWare
Clamp	6	6061 Aluminum Sheet, 0.05" Thick, 4" x 24"	89015K172	0.05" Thick, 4" x 24"	1	$9.55	$9.55	McMaster
Clamp	7	Moisture-Resistant Acetal Opaque Tubing, 1/8" ID, 1/4" OD, 5 Feet Long	9362T4	5 ft long	1	$8.19	$8.19	McMaster
Clamp	8	Chemical-Resistant PTFE Plastic Washer, for Number 5 Screw Size, 0.15" ID, 0.312" OD	95630A237	pack of 10	1	$3.62	$3.62	McMaster
Clamp	9	6061 Aluminum, 3/16" Diameter	8974K21	2 ft	1	$2.36	$2.36	McMaster
Clamp	10	6061 Aluminum, 5/8" Thick x 1-1/2" Wide	8975K43	0.5 ft	1	$6.50	$6.50	McMaster
Clamp	11	18-8 Stainless Steel Phillips Flat Head Screw, Passivated, 4-40 Thread Size, 1/4" Long	91771A106	Pack of 100	1	$3.75	$3.75	McMaster
Clamp	12	Passivated 18-8 Stainless Steel Pan Head Phillips Screw, 4-40 Thread, 1/4" Long	91772A106	Pack of 100	1	$3.39	$3.39	McMaster
Clamp	13	Passivated 18-8 Stainless Steel Pan Head Phillips Screw, 6-32 Thread, 1/4" Long	91772A144	Pack of 100	1	$4.55	$4.55	McMaster
Clamp	14	18-8 Stainless Steel Hex Nut, 2-64 Thread Size	91841A135	Pack of 100	1	$7.78	$7.78	McMaster
Clamp	15	316 Stainless Steel Washer, for Number 2 Screw Size, 0.094" ID, 0.25" OD	90107A003	Pack of 100	1	$2.64	$2.64	McMaster
Clamp	16	5052 Aluminum Surface-Mount Hinge, Removable Pin, 2" x 1" Door Leaf, 0.064" Leaf Thickness	1609A41	Removable Pin, Square, Zinc-Plated Steel, 1" x 1/2" Leaves	10	$4.28	$42.80	McMaster
Clamp	17	Tube Made From PTFE, 5/16" OD x 3/16" ID	8547K24	1ft	1	$5.21	$5.21	McMaster
Clamp	18	Food-Grade High-Temperature Silicone Rubber Sheet, with Adhesive-Back, 12" x 12", 1/32" Thick,	86045K67	12" x 12" sheet, 60A (medium hard)	1	$15.45	$15.45	McMaster
Clamp	19	Black-Phosphate Steel No-Slip Clip-On Nut, Low-Profile, 1/4"-20 Thread, for 0.18" to 0.19" Thickness	94808A350	pack of 25	1	$9.50	$9.50	McMaster
Clamp	20	Easy-to-Weld 5052 Aluminum Sheet, Highly Corrosion-Resistant, 0.05" Thick	88895K104	12" x 12" x .05" sheet	1	$8.14	$8.14	McMaster
Clamp	21	6061 Aluminum, 3/16" Diameter	8974K21	2 ft	1	$2.36	$2.36	McMaster
Clamp	22	302 Stainless Steel Torsion Spring, 90 Degree Left-Hand Wound, 0.235" OD	9287K18	90 degree, left hand wound, 0.235" OD	6	$3.16	$18.96	McMaster
Clamp	23	302 Stainless Steel Corrosion-Resistant Extension Spring, with Loop Ends, 0.625" Long, 0.240" OD, 0.029" Wire Diameter	9065K111	3 pack	1	$6.51	$6.51	McMaster
Clamp	24	302 Stainless Steel Corrosion-Resistant Extension Spring, with Loop Ends, 0.625" Long, 0.180" OD, 0.022" Wire Diameter	9065K33	3 pack	1	$6.51	$6.51	McMaster
	Total for Clamp:						**$209.55**	
Cutting Tool	1	Clear Cast Acrylic Sheet, 6" x 12" x 1/4"	8560K359	6" x 12" x 1/4"	1	$17.34	$17.34	McMaster
Cutting Tool	2	Weldon #4 with Applicator Bottle - 1/4 Pint - 4oz - 10308 - 1 each	10308	4 oz	1	$10.10	$10.10	Amazon
Cutting Tool	3	Clear Cast Acrylic Sheet, 12" x 12" x 1/8"	8560K239	12" x 12" x 1/8"	1	$9.15	$9.15	McMaster
Cutting Tool	4	Alumilite amazing clear cast epoxy resin 16 ounces	N/A	2x 8oz bottles	1	$25.12	$25.12	Amazon
Cutting Tool	5	Clear Cast Acrylic Sheet, 12" x 12" x 1/8"	8560K239	12" x 12" x 1/8"	1	$9.15	$9.15	McMaster
	Total for Cutting Tool:						**$70.86**	
General	1	HATCHBOX PLA 3D Printer Filament, Blue, 1.75 mm	3D PLA-1KG1.75-BLU	1 kg spool	1	$19.99	$19.99	Amazon
General	2	Smooth-Sil 940 Food Grade Mold Making Silicone Rubber - Trial Unit	SS940	Trial Unit	1	$37.17	$37.17	Amazon
General	3	FM-100s quick change wrist, with insert	51044	1/2-20	1	$0.00	$0.00	Fillauer
General	4	J-B Weld, Two 1 oz. Twin Tube Cold Weld	1002244230	2x 1oz Tubes	1	$5.67	$5.67	Home Depot
General	5	Uncoated Carbide Square-End End Mill, 2 Flute, 1/32" Mill Diameter, 1-1/2" Overall Length	8876A28	2 Flute, 1/32" Mill Diameter, 1-1/2" Overall Length	3	$13.15	$39.45	McMaster
	Total for General Components:						**$102.28**	
Manufacturing	**Item No.**	**Description**			**Hours**	**Fee Rate**	**Price**	Vendor
Manufacturing	1	CNC Machining Clamp Central Attachment Point			6	$16/hr	$96.00	Cal Poly Machine Shop
Manufacturing	2	CNC Machining Wrist Inserts			3	$16/hr	$48.00	Cal Poly Machine Shop
Manufacturing	3	CNC Machining Wrist Base			2	$16/hr	$32.00	Cal Poly Machine Shop
	Total for Manufacturing:						**$176.00**	
						TOTAL	$828.18	

Appendix 9: Clamp Assembly Procedure

1. Screw the 2 long rods into the prong attachment point. The chamfer on the prong attachment point should be facing the same direction as the rods sticking out. Loctite the rods in place.
2. Grid down the length of the long rods so that they are the same length (if necessary).
3. Screw the short rod into the central attachment point and apply Loctite.
4. Put the long bushing on the short rod.
5. Put the rod guide on the short rod.
6. Put the washer and nut on the short rod and apply Loctite.
7. Slide the long rods through the bushings in the central attachment point. The tabs on the prong attachment point should be facing the same direction as the bunny ears of the central attachment point.
8. Use the press-fit fixture to press the long rods through the rod guide. To use this fixture you must first push the long rods through the rod guide such that they protrude only slightly through the rod guide (no more than 0.25 inch). Then the rods can be slid into the fixture and the rod guide can be pressed onto the long rods the rest of the way. The fixture will determine when the rods are fully installed.
9. Press fit the resulting assembly into the wrist insert.
10. Glue magnets in with JB Weld. Be careful of which orientation the poles are. Mark poles with sharpie as needed. (Might want to put this step off until the wrist is done)
11. Glue on rotation guides. (Probably need to develop a specific way to do this)

RETRO CLASSIC HOOK™

ToughWare Prosthetics developed its new Retro Classic Hook to replace older terminal devices popular among farmers and ranchers. We've come up with new innovations of our own to create a wholly new design for the 21st Century. Units are shipped as LEFT or RIGHT from the factory and cannot be reconfigured in the field.

- **Traditional "hoop" digits work securely with heavy equipment and tractor controls.**
- **Aggressive gripping faces and hook contours help when lifting bags and pails or pulling tarps and covers.**
- **Cam-action mechanism increases grip force using "ice-tong" action.**
- **A robust steel spring replaces troublesome latex bands for reliability.**
- **New Twister™ feature lets users set their preferred pinch force by twisting an adjustment knob.**
- **Heavy-duty lubricated bronze bushings and stainless steel parts ensure long life and smooth operation.**
- **Withstands exposure to water, biological fluids, diesel, and many agricultural chemicals.**
- **Accepts standard 9/32" ball cable terminations.**
- **Attaches to the distal forearm using the industry-standard ½-20 UNF threaded boss.**
- **Accepts most commercial quick disconnect (QD) adapters.**


Retro Classic Hook in METAL and in BLACK. Lite, Standard, and Heavy springs available.

Ordering Information

RCH—XXX—X—XX

- Last field (XX): **BK: BLACK**, **MT: METAL**
- Middle field (X): **L: LEFT**, **R: RIGHT**
- First field (XXX): **050: LITE SPRING**, **100: STANDARD SPRING**, **200: HEAVY SPRING**

Length: 5" (127 mm)
Excluding Boss
Width: 1-3/4" (44 mm)
Height: 2-7/8" (73 mm)
Weight: 11.5 oz (327 g)

Boss approximately 5/8" (16 mm) long depending upon pinch force adjustment.

RCH—LITE/STND/HVY—SPRING

Spring kit for the Retro Classic Hook. Lite, standard, and heavy springs available. Includes bushings.

Rotational Wrist

TR TH SD

Product Features

- Cable pull achieves 360° rotation with 18 locking positions

Ordering Information

Description	Material	Diameter	Weight	Thread	Product Number
Rotational Wrist	Al	2 in. (50 mm)	3.7 oz. (104 g)	½-20	**61875**

Quick Disconnect Wrist

TR TH SD

Product Features

- Quick changes and pro-/ supination lock
- 12 Locking positions
- Light pressure indexes pro-/ supination
- Heavier pressure detaches
- Push terminal device in to lock
- Uses Hosmer style laminating ring

61862

62343

61921

61860

Ordering Information

Description	Material	Diameter	Thread	Weight	Product Number
Round	Al	2 in. (50 mm)	½-20	105 g	**61862**
Round	Al	1.75 in. (44 mm)	½-20	89 g	**62342**
Oval	Al	2.25 × 1.63 in. (57 × 41 mm)	½-20	79 g	**61922**
Oval	Al	2 × 1.5 in. (51 × 38 mm)	½-20	92 g	**62343**
Quick Disconnect Insert	SS		½-20	23 g	**61860**
Quick Disconnect Insert	SS		12 mm	23 g	**61861**

Smooth-Sil™ Series

Addition Cure Silicone Rubber Compounds

www.smooth-on.com

PRODUCT OVERVIEW

Smooth-On **Smooth-Sil™** Platinum Silicones cure at room temperature with negligible shrinkage. With different hardnesses to choose from, **Smooth-Sil™** products offer tremendous versatility and are suitable for making production molds of any configuration, large or small. These silicones exhibit good chemical, abrasion and heat resistance. Materials such as plasters, concrete, wax, low-melt metal alloys or resins (urethane, epoxy or polyester) can then be cast into these silicone rubbers without a release agent.

Smooth-Sil™ 936 is a lower viscosity version of Smooth-Sil® 935 platinum silicone rubber (21,000 cps vs. 40,000 cps). It is easier to mix, vacuum degas and pour. **Smooth-Sil™ 945** offers the convenience of a **1A:1B by volume** mix ratio and a fast **6 hour cure time.**

Smooth-Sil™ Platinum Silicones are used for rapid prototyping, wax casting (foundries and candle makers), architectural restoration and for casting concrete. Smooth-Sil™ 940, 950 and 960 are suitable for food related applications. (See separate technical bulletin for usage instructions available at www.smooth-on.com).

TECHNICAL OVERVIEW

	Mixed Viscosity (ASTM D-2393)	Specific Gravity (g/cc) (ASTM D-1475)	Specific Volume (cu. in./lb.) (ASTM D-1475)	Color	Pot Life (ASTM D-2471)	Cure Time	Mix Ratio	Shore A Hardness (ASTM D-2240)	Tensile Strength (ASTM D-412)	100% Modulus (ASTM D-412)	Elongation @ Break % (ASTM D-412)	Die B Tear Strength (ASTM D-624)
Smooth-Sil™ 935	40,000 cps	1.18	23.5	Blue	45 min.	24 hrs.	100A:10B by weight	35A	650 psi	170 psi	300%	115 pli
Smooth-Sil™ 936	21,000 cps	1.21	22.9	Blue	60 min.	24 hrs.	100A:10B by weight	36A	550 psi	180 psi	500%	110 pli
Smooth-Sil™ 940	35,000 cps	1.18	23.4	Pink	30 min.	24 hrs.	100A:10B by weight	40A	600 psi	200 psi	300%	100 pli
Smooth-Sil™ 945	30,000 cps	1.24	22.3	Purple	25 min.	6 hrs.	1A:1B by weight or volume	45A	700 psi	260 psi	320%	120 pli
Smooth-Sil™ 950	35,000 cps	1.24	22.3	Blue	45 min.	18 hrs.	100A:10B by weight	50A	725 psi.	272 psi	320%	155 pli
Smooth-Sil™ 960	30,000 cps	1.25	22.2	Green	45 min.	16 hrs.	100A:10B by weight	60A	650 psi.	280 psi.	270%	110 pli

Useful Temperature Range: -65°F to 450°F (-53°C to 232°C)
Dielectric Strength (ASTM D-147-97a)**:** >350 volts/mil

*All values measured after 7 days at 73°F/23°C
Shrinkage* *(in./in.) (ASTM D-2566):* < .001

PROCESSING RECOMMENDATIONS

PREPARATION... ***Safety*** – Use in a properly ventilated area ("room size" ventilation). Wear safety glasses, long sleeves and rubber gloves to minimize contamination risk. Wear vinyl gloves only. Latex gloves will inhibit the cure of the rubber.

Store and use material at room temperature (73°F/23°C). Warmer temperatures will drastically reduce working time and cure time. Storing material at warmer temperatures will also reduce the usable shelf life of unused material. These products have a limited shelf life and should be used as soon as possible.

Cure Inhibition – Addition-cure silicone rubber may be inhibited by certain contaminants in or on the pattern to be molded resulting in tackiness at the pattern interface or a total lack of cure throughout the mold. Latex, tin-cure silicone, sulfur clays, certain wood surfaces, newly cast polyester, epoxy or urethane rubber my cause inhibition. If compatibility between the rubber and the surface is a concern, a small-scale test is recommended. Apply a small amount of rubber onto a non-critical area of the pattern. Inhibition has occurred if the rubber is gummy or uncured after the recommended cure time has passed.

Because no two applications are quite the same, a small test application to determine suitability for your project is recommended if performance of this material is in question.

To prevent inhibition, one or more coatings of a clear acrylic lacquer applied to the model surface is usually effective. Allow any sealer to thoroughly dry before applying rubber. Note: Even with a sealer, platinum silicones will not work with modeling clays containing heavy amounts of sulfur. Do a small scale test for compatibility before using on your project.

Applying A Release Agent - Although not usually necessary, a release agent will make demolding easier when pouring into or over most surfaces. Ease Release™ 200 is a proven release agent for making molds with silicone rubber. Mann Ease Release™ products are available from Smooth-On or your Smooth-On distributor.

Safety First!

The Material Safety Data Sheet (MSDS) for this or any Smooth-On product should be read prior to use and is available upon request from Smooth-On. All Smooth-On products are safe to use if directions are read and followed carefully.

Keep Out of Reach of Children

Be careful. Use only with adequate ventilation. Contact with skin and eyes may cause irritation. Flush eyes with water for 15 minutes and seek immediate medical attention. Remove from skin with waterless hand cleaner followed by soap and water.

Important: The information contained in this bulletin is considered accurate. However, no warranty is expressed or implied regarding the accuracy of the data, the results to be obtained from the use thereof, or that any such use will not infringe upon a patent. User shall determine the suitability of the product for the intended application and assume all risk and liability whatsoever in connection therewith.

Applying A Release Agent - IMPORTANT: To ensure thorough coverage, lightly brush the release agent with a soft brush over all surfaces of the model. Follow with a light mist coating and let the release agent dry for 30 minutes.

If there is any question about the effectiveness of a sealer/release agent combination, a small-scale test should be made on an identical surface for trial.

MEASURING & MIXING...

Stir Part A and shake Part B thoroughly before dispensing. ***Using a gram scale***, dispense required amounts of parts A and B into a mixing container and mix for 3 minutes. Scrape the sides and bottom of the container several times. Mixing containers should have straight sides and a flat bottom. Mixing sticks should be flat and stiff with defined edges for scraping the sides and bottom of your mixing container. After mixing parts A and B, **vacuum degassing is recommended** to eliminate any entrapped air. Vacuum material for 2-3 minutes (29 inches of mercury), making sure that you leave enough room in container for product expansion.

POURING, CURING & MOLD PERFORMANCE...

For best results, pour your mixture in a single spot at the lowest point of the containment field. Let the rubber seek its level up and over the model. **A uniform flow will help minimize entrapped air.** The liquid rubber should level off at least 1/2" (1.3 cm) over the highest point of the model surface.

Curing / Post Curing - Allow rubber to cure as prescribed at room temperature (73°F/23°C) before demolding. Do not cure rubber where temperature is less than 65°F/18°C. **Optional:** Post curing the mold will aid in quickly attaining maximum physical and performance properties. After curing at room temperature, expose the rubber to 176°F/80°C for 2 hours and 212°F/100°C for one hour. Allow mold to cool to room temperature before using.

Using The Mold - When first cast, silicone rubber molds exhibit natural release characteristics. Depending on what is being cast into the mold, mold lubricity may be depleted over time and parts will begin to stick. No release agent is necessary when casting wax or gypsum. Applying a release agent such as Ease Release™ 200 (available from Smooth-On) prior to casting polyurethane, polyester and epoxy resins is recommended to prevent mold degradation.

Thickening Smooth-Sil™ Silicones - **THI-VEX™** is made especially for thickening Smooth-On's silicones for vertical surface application (making brush-on molds). Different viscosities can be attained by varying the amount of THI-VEX™. See the **THI-VEX™ technical bulletin** (available from Smooth-On or your Smooth-On distributor) for full details.

Thinning Smooth-Sil™ Silicones - Smooth-On's **Silicone Thinner™** will lower the viscosity of Smooth-Sil™ for easier pouring and vacuum degassing. **A disadvantage** is that ultimate tear and tensile are reduced in proportion to the amount of **Silicone Thinner™** added. ***It is not recommended to exceed 10% by weight of total system (A+B).*** See the **Silicone Thinner™ technical bulletin** (available from Smooth-On or your Smooth-On distributor) for full details.

Mold Performance & Storage - The physical life of the mold depends on how you use it (materials cast, frequency, etc.). Casting abrasive materials such as concrete can quickly erode mold detail, while casting non-abrasive materials (wax) will not affect mold detail. Before storing, the mold should be cleaned with a soap solution and wiped fully dry. Two part (or more) molds should be assembled. Molds should be stored on a level surface in a cool, dry environment.

SMOOTH-ON SINCE 1895

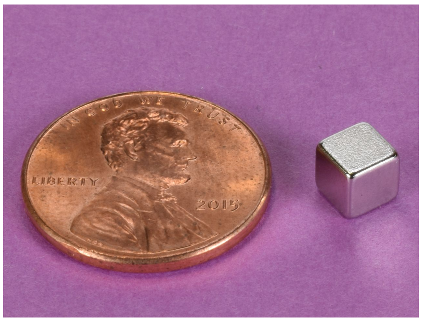
Call Us Anytime With Questions About Your Application.

Toll-free: **(800) 381-1733** Fax: **(610) 252-6200**

The new www.smooth-on.com is loaded with information about mold making, casting and more.

B333-N52 Specification Sheet

Product Specifications



Type:	BLOCK
Dimensions:	0.1875 x 0.1875 x 0.1875 thk (in)
Tolerance:	All dimensions ± 0.004 in
Material:	NdFeB, Grade N52
Plating:	NiCuNi
Max Op Temp:	176ºF (80ºC)
Br max:	14,800 Gauss
BH max:	52 MGOe

Performance Specifications

Pull Force, Case 1, Magnet to a Steel Plate:	2.83 lb

Surface Field values are derived from calculation and verification with experimental testing. These values are the field values at the surface of the magnet, centered on the axis of magnetization. Measurement of the B field with a magnetometer may yield varying results, depending on the geometry of your sensor. Pull Force values are based on extensive product testing in our laboratory. Different configurations of magnets and surrounding ferromagnetic materials may substantially alter your results.

Amazing Clear Cast

80D Clear Epoxy

Product Description:
Alumilite's Amazing Clear Cast is a clear casting and coating system that cures to a rigid, durable, clear plastic. Use Amazing Clear Cast for coating or finishing applications such as bar tops, floors, taxidermy scenery, lenses, and all sorts of other clear casting or coating applications. Amazing Clear Cast is an easy to use, 1:1 mix ratio system that cures overnight which allows time for air bubbles to evacuate prior to curing. Amazing Clear Cast can be colored with Alumilite dyes, alcoholic inks, or other non-water base colorants. Complies with FDA CFR 177.2600

Physical Properties:

Color	Clear
Mixed Viscosity (cps)	2,600
Hardness, (ASTM D-2240) Shore D	80
Specific Gravity	1.08
Shrinkage (in/in)	.003
Tensile Strength (ASTM D-638) (psi)	8,000
Elongation (in/in)	1-3%
Heat Deflection (ASTM D-648) (Degrees F)	N/A
Izod Impact (ASTM D-256) (lb/in)	2.26
Compression (psi)	27,000
Temperature Resistance	Not recommended beyond 130°F

General Properties:

Color	"A" Side	Translucent Lt Blue
	"B" Side	Clear
Mix Ratio		1:1 by vol.
Shelf Life		1 year
Open Time at 75 Degrees F (100g mass)		45-60 minutes
Demold Time at 75 Degrees F (100g mass)		18-24 hours
Full Cure Schedule		72 hours

Packaging:
8, 16, 32 fl.oz.
2 gal
10 gal
Drum Kit

General Instructions

(See Bar top Coating Instructions Below)

Before Starting

Make sure your work area is appropriate for measuring, mixing, and pouring casting resins that can and will stain any porous materials such as carpet and clothing. Also make sure to use and store materials in an area where children cannot reach or access.

Open time & Mixing

Amazing Clear Cast has work time of 30-40 minutes based on 100 gram sample at 70°F. Larger amounts of mixed resin will shorten your work time as will warmer ambient temperatures. Mixing large volumes similar to 1 gallon volumes, you can expect the open time to be cut in half.

The mix ratio of the Amazing Clear Cast is 1:1 by Volume. Using a graduated mixing container, measure out equal parts per side. Varying the mix ratio will alter the cure and change the physical properties in a negative ways such as tackiness or uncured surfaces. When mixing multiple batches, it helps to have a dedicated side A and side B measuring cup, which are then added to a larger mixing container. After the materials have been poured together, mix thoroughly (keeping the stir stick in contact with the bottom of the cup - reduces air from being introduced into your resin) for approximately 3-5 minutes. Make sure to scrape the sides and the bottom of the mixing cup and continue to mix until no swirls are seen. Once no swirls are seen, mix for an additional 2 minutes. Because of the differences in viscosity between the two parts, mixing takes extra time.

Vacuum Degassing

For instances where large surface areas are being coated and drill mixers will be used for mixing, vacuum can be used to remove air from the resin before pouring onto surface. Vacuum puts negative air pressure on the material and expands the air bubbles to a large size which gives them the buoyancy to float to the top and pop. Once mixed thoroughly and placed under vacuum, the air bubbles will come up and then go back down. Once the bubbles go back down under full vacuum and begin to clear up, you may remove the mix container from the vacuum chamber and pour onto surface

Color – Dyes & Painting

Amazing Clear Cast can be dyed or pigmented using non-water base dyes. Alumilite offers a line of translucent dyes in standard colors that react/crosslink chemically with the resin to achieve beautifully translucent cast pieces with no worry of leaching or color ever coming out of the cured piece. Alumilite's Flourescent, White, and Black are not completely transparent as they contain some filler. When used in small quantities, they do not affect the transparency of the piece. However, if used in higher percentages, they can add opacity to the cast piece. Use very small amounts of dye to achieve bright translucent colored castings. If you are looking to use a dye, pigment, or filler that you have not used before, we highly recommend making a small test sample to ensure compatibility before using in resin.

Color Stability - Yellowing

As with all epoxy chemistry, ACC will develop a yellow hue over time. While there are UV inhibitors in our system that help it resist longer than some competitor products, a yellow hue will still develop over time. Many times this is not ever noticed based on the underlying surface color and the relative thin layer. Applications where ACC is applied over bright white surfaces or when pouring thicker layers, yellowing may be more evident. We generally do not recommend ACC for outdoor applications, as the UV exposure will cause the resin to develop a yellow hue rather quickly . There are some instances where it may be reasonable such as adding Alumilite dye or Alumidust to color the resin, which often times negates or minimizes the yellowing. Also applying it over certain toned wood surfaces that have more yellow and orange hues to it would make the yellowing less noticeable.

Shelf Life

ACC has a shelf life of 1 year. Once ACC is opened, this time can be shorter based on moisture contamination from humidity. Amazing Clear Cast B side will naturally yellow over time and when exposure to air. While this can cause a yellow hue to cured coatings, it does not have an effect on the ultimate cure of the product.

Work Area & Clean Up

Cover any surfaces including floors with plastic sheeting, cardboard, or plywood to prevent damage from spilled resin. To clean up unmixed or still liquid material, use rubbing alcohol on a rag or paper towel to quickly clean and remove. Once cured, resin is extremely durable, chemical resistant and nearly impossible to remove.

Bar top Coating Instructions

See next page.

Bar Top Coating Application Instructions

Products used in this application:

* Amazing Clear Cast
* Measuring & Mixing Containers
* Strong & Flat Ended Stir Stick
* Plastic Drop Cloth
* Latex-free Gloves, protective Eyewear
*Paper Towel
* Aluminum Tape
*Good Quality Disposable 2 inch Paint Brush or Foam Applicator
* Propane Torch or Fine Mist Spray Bottle with Isoprolyl Alcohol
* Cutting Blade or Palm Sander

Amazing Clear Cast Resin

Open Time: 30-40 min*
Cure TIme: 24-48 hrs*
Approx. Coverage: 2 gallons of mixed Amazing Clear Cast = 26 sq.ft. in a 1/8" thickness
(*Open time & cure time schedule will vary based on temperature and humidity)

- ***Read all instructions & safety information prior to use.***
- ***Available in 2gal, 10 gal, or 110 gal kits***
- ***FDA CFR 177.2600 Compliant***

****Not Recommended for Outdoor Applications****

SURFACE SEALING: The level of surface prep will depend on the surface being coated. For wood surfaces, we recommend using a sealer such as Mod Podge, which goes on white but dries clear or you can also apply a skim coat of Amazing Clear Cast to the surface 4-6 hours prior to your flood coat. This seals porosity and reduces the amount of air bubbles that can rise out of surface. If any crevices, knots, or holes exist, they should be pre-filled with Amazing Clear Cast and allowed to cure prior to surface coating. Deep or large crevices may require multiple pours of no more than 1/2 inch per pour.

Encapsulations: If encapsulating photos, Mod Podge should be used to glue photo down during the sealing process and should also be coated over top of picture to prevent bleeding of the photo. Remember Mod Podge dries clear and wil not effect the clarity of the picture once coated with Amazing Clear Cast. When encapsulating anything porous, always seal with Mod Pog. Any light items need to be glued down to prevent them from floating to the surface. If you think it might float, glue it down with super glue or clear hot melt glue.

Note: When pouring Amazing Clear Cast over a surface, any gaps, holes, or crevices will be filled with resin. To prevent using excess resin that will flow into, around, and under these areas, we recommend sealing these up with a clear silicone caulk, clear hot melt, or Alumilite Synthetic Clay that will fill these voids.

When to use Aluminum Tape: Most table tops and even bar tops do not contain a lip or border to contain the resin. Aluminum tape allows you to create a temporary dam to contain the resin until it thickens slightly to achieve a thicker & uniform coating when flowing over the edge. The tape can also be left in place during cure if edge coating is not desired, although the inside of the tape must be coated with Alumilite Rubber to Rubber mold release to prevent bonding to the resin. Sharp edges that are formed when the Amazing Clear Cast cures can be sanded, trimmed, or routed to a smooth finish. These edges can be polished to return gloss if desired or a light coat of resin brushed on.

Note: Un-level surfaces can cause resin to pool and ultimately use more resin. In some extreme cases, a uniform coating will not be achieved resulting in thin and thick areas. Pooling resin will create pressure on the tape that can cause the tape to release prematurely. To prevent this, apply tape to a clean surface and press firmly to form a good bond. A supporting piece of trim could also be applied on the outside perimeter to support the tape.

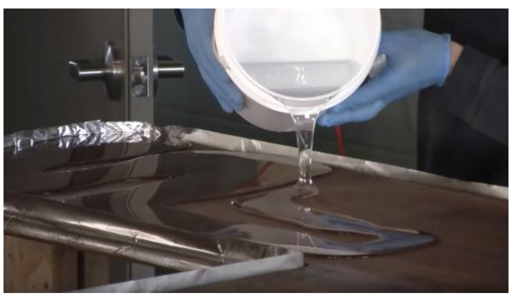
Environment: Prior to pouring your Amazing Clear Cast, thoroughly vacuum the surface and the room where the resin is being applied. Dust in the environment can become air-born and settle onto the surface of the resin. Temperature of the room, surface, and resin will effect how the resin self levels and ultimately cures. Ideal application temperature is 70-80°F. If resin is cold, place resin bottles with caps tightened into a sink or bucket filled with warm water for 10-20 minutes. Temperature of resin should within the 70-80°F range as well. Protect floors/environment with plastic sheets.

Coverage & Application Thickness: A thick coat such as 1/8" thick coating per 1 square foot requires 10 fl oz of volume. This is a good volume estimate to use for your coating project however it does not consider uneven surfaces, edges, absorption, or waste. A thinner coating such as 1/16" will require half the volume per square foot (approximately 5 fl. oz.). Therefore, an approximate coverage of 1 gallon of mixed Amazing Clear Cast is 13 sq.ft. in a 1/8" thickness or 26 sq. ft. for a 2-gallon kit at the same thickness.

Application thicknesses greater than 3/8" in a single pour may shrink, discolor, pull away from surfaces, and/or warp. Where thicker coatings are desired, it is recommended to pour multiple coats. Additional coats can be applied no sooner than 3-4 hours and no longer than 12 hours for optimum adhesion.

Measuring & Mixing: The Amazing Clear Cast has a mix ratio of 1:1 by volume. Therefore use measuring cups with graduations on the side or make your own fill line at the same level on each measuring container. In separate containers, measure out equal amounts of Part A and B. Combine both sides into a large mixing container that has a flat bottom and flat sides to adequately mix resin. Begin mixing resin slowly, ensuring to scrap the sides and bottom. You should also scrap off your stir stick on the lip of the mixing container to dislodge any unmixed resin from the stick. Continue stirring slowly, not to incorporate any more air into the system as possible. Once all striations have dissolved, mix for another 2-3 minutes to ensure adequate mixing. Note: Failure to mix 1:1 by volume or mix thoroughly will result in tacky/soft spots and/or cause the resin not to cure properly.

Vacuum Degassing (if available): Once Amazing Clear Cast has been thoroughly mixed, if you have vacuum degassing equipment, we recommend degassing prior to pouring to minimize air bubbles. If you do not have this equipment, proceed to next step.



Pouring: Once you have properly mixed Amazing Clear Cast, you are ready to pour. Slowly pour resin onto the surface going from side to side (or in a circular pattern if pouring onto a circular shape). Pour strips of resin close enough so that they will self level into one another. If you have areas that do not flow together, simply pour more material in area. Continue this process of mixing and pouring until project has been fully coated. For large applications, it is helpful to have one person measuring and mixing while a second person is pouring and keeping an eye on the surface.

Recesses or encapsulations: Areas of recess or encapsulation should be filled very slowly and poured first. Watch for trapped air bubbles in corners, in the detail of objects, etchings, carvings, or crevices. Ease them out by using a tooth pick or other pointed instrument. Do not pour second coat until 3 or 4 hours later.

Note: We recommend turning off furnaces/fans/air conditioners as long as possible until product has fully cured. This reduces the amount of dust circulating in the air that can settle onto the surface. This may not be possible in cooler/winter climates as a minimum room temperature of 70°F should be maintained to assist with curing.

Popping air bubbles: Amazing Clear Cast cures slowly to allow air bubbles to rise to the surface and pop. To help pop them at or near the surface, you can spray a mist of isopropyl alcohol (93%) over the surface during the first hour after application. You can purchase a fine mist spray bottle under Tools & Equipment. Another option is waving a a propane torch over the surface. The flame should never come in contact with the resin, only the heat from the torch. Do not use alcohol in conjunction with a propane torch or the presence of any flame or ignition source!

Edges: For those that choose not use use tape, pour enough resin onto surface to allow resin to flow over the edges to coat them. A good quality disposable or foam applicator can be used to distribute resin over the surface of the edges. We recommend brushing in one direction only. Excess material may continue to fall from the edge onto the protected floor. A brush or foam applicator can be used to remove excess material from the under edge as well. Painters tape can be used on the underside if resin is not wanted on this area, although it must be removed once resin stops flowing or it may bond to surface.

Aluminum Tape: If Aluminum tape was used, the tape can be removed when resin has thickened slightly, but still flows. Again, use a brush or foam applicator to assist in uniform coverage and removal of excess resin if needed.

Cure: Amazing Clear Cast cures in 24-48 hours. Thinner layers will cure more slowly than thicker layers. As a general rule, the warmer the room, the quicker it will cure.

Removing Drips: Drips off edges can be easily removed with a sharp blade once resin has solidified, but not totally hardened. This usually occurs in 6-10 hrs. If the resin has fully cured and is too hard to remove with a blade, a palm sander can be used. This will create dust, therefore make sure that entire resin surface is completely cured/tack-free. In addition, use a shop vac to collect residual dust during sanding and cover newly pour surface if possible.

WELD-ON
IPS CORPORATION

PRODUCT BULLETIN

4™

ACRYLIC PLASTIC CEMENT

SUBSTRATE RECOMMENDATIONS:

WELD-ON® 4™ is formulated as a blush-resistant cement for bonding acrylic (poly-methyl methacrylate) to itself. It will also form strong bonds with other thermoplastics such as polystyrene, CAB (cellulose acetate butyrate), and polycarbonate to themselves. It is not recommended for cross-linked acrylic.

BONDING RECOMMENDATIONS:

WELD-ON 4 is used extensively in sign fabrication for cementing acrylic letters to flat acrylic presentation panels and trim-capping of cut out acrylic letters. Strong butt joints are made with flat sheets by using the soak method. WELD-ON 4 is also widely used in many applications e.g. fabrication of display and presentation cases, medical equipment assembly, the bonding of plastic containers and pre-forms, and in the manufacture of numerous solvent welded structures and subassemblies using the capillary method.

GENERAL DESCRIPTION:

Weld-On 4 is a water-thin, somewhat flammable cement formulated to quickly develop very clear and high strength bonds for many thermoplastic substrates. The bond is achieved by first softening the surfaces to be joined and then fusing them together with the dissipation of the solvent. The initial bond forms within a matter of minutes and is followed by a significant and continual increase in bond strength over the next several hours. WELD-ON 4 may be preferred by some plastic fabricators because it is less likely to leave white marks (commonly called blushing). For similar applications but faster setting cement, WELD-ON® 3™* is recommended.

*WELD-ON 3 is not available for use in areas regulated by California's South Coast Air Quality Management District (SCAQMD).

TYPICAL BOND STRENGTH †:

SUBSTRATE MATERIAL	Aged Bond Strength, lbs/in² (kg/cm²)		
	2 Hours	24 Hours	1 Week
Acrylic (Cast & Extruded)	800 (56.3)	2000 (140.6)	2500 (175.8)
Polycarbonate	750 (52.7)	1600 (112.5)	2400 (168.7)
Polystyrene	400 (28.1)	1300 (91.4)	2000 (140.6)

† Substrate thickness: 0.25 inch (0.64 cm). Bond area: 1.0 in² (6.45 cm²)

ADHESIVE PROPERTIES AND CHARACTERISTICS:

COLOR:	Clear
VISCOSITY:	Water Thin
TIME TO REACH 80% OF ULTIMATE BOND STRENGTH:	72 hours
SPECIFIC GRAVITY:	1.12 ± 0.04

DIRECTIONS FOR USE:

- **GENERAL** – surfaces to be joined must be clean, dry, and fit intimately without forcing. Apply cement with syringe, eyedropper or brush. Assemble while parts are still wet. If cement is applied to one surface, let the two surfaces be in gentle contact for a few seconds to allow the cement to soften the dry surfaces, then press parts together in firm contact. Initial bonds form very quickly. 65 – 80% of the ultimate bond strength will be obtained within 24 – 72 hours. Strength will continue to increase for several weeks.
- **CAPILLARY METHOD** – Parts are placed lightly together and cement is applied to the edge of the joint with syringe or eyedropper. By capillary action, the cement will flow a considerable distance (approximately 0.25 inch (0.64 cm) between two such surfaces. Allow a few seconds for the cement to soften the surfaces. Press parts firmly together.
- **SOAK METHOD** – vertically dip surfaces until softened (approximately 2 to 5 minutes), then join pieces firmly together.
- Although development of Weld-On 4 bond strength is slightly slower than that of WELD-ON 3, ultimate bond strength will be the same. If crazing is a problem, we suggest you consider annealing before cementing.

AVAILABILITY:

This product is available in 4 oz., pint, quart and gallon metal cans. For detailed information on containers and applicators, refer to the current Product Catalog and Price List.

SHELF LIFE:

2 years in tightly sealed containers. The date code of manufacture is stamped on the bottom of the container. Stability of the product is limited by the evaporation of the solvent when the container is opened. Evaporation of solvent will cause the cement to thicken and reduce its effectiveness. Adding of thinners to change viscosity is not recommended and may significantly change the properties of the cement.

QUALITY ASSURANCE:

Weld-On 4 is carefully evaluated to assure that consistent high quality is maintained. Fourier transform infrared spectroscopy, gas chromatography, and additional in depth testing ensures each batch is manufactured to exacting standards. A batch identification code is stamped on each can and assures traceability of all materials and processes encountered in manufacturing this plastic cement for its intended specific application.

SHIPPING:

For One Liter and Above

Proper Shipping Name: Flammable liquid, toxic n.o.s (Methyl Acetate, Dichloromethane)

Hazard Class: 3 with subsidiary risk 6.1

Identification Number: UN 1992

Packing Group: II

Label Required: Flammable Liquid & Toxic

For Less than One Liter

Proper Shipping Name: Consumer Commodity

Hazard Class: ORM-D

SAFETY AND ENVIRONMENTAL PRECAUTIONS:

This product is a flammable, moderately fast evaporating solvent cement. It is considered a hazardous material. In conformance with the Federal Hazardous Substance Labeling Act, the following hazards and precautions are given. Purchasers who may re-package this product must also conform to all local, state, and federal labeling, safety and other regulations. VOC emissions do not exceed 250 grams per liter.

DANGER! FLAMMABLE. VAPOR HARMFUL.
MAY BE HARMFUL IF SWALLOWED. MAY IRRITATE SKIN OR EYES.

Keep out of the reach of children. Do not take internally. Keep away from heat, spark, open flame and other sources of ignition. Contact with hot surfaces may produce toxic effects. Keep container closed when not in use. Store in the shade below 80ºF (27ºC). Use only in adequate ventilation. Avoid breathing of vapors. Atmospheric levels should be maintained below established exposure limit values. See Sections II and VIII of MSDS. If airborne concentrations exceed these limits, use a supplied air respirator. Do not use a chemical cartridge respirator. For emergencies and other conditions where short-term exposure may be exceeded, use an approved positive pressure self-contained breathing apparatus. In confined areas, use a positive pressure self-contained breathing apparatus (SCBA). Do not smoke, eat or drink while working with this product. Avoid contact with skin, eyes, and clothing. May cause eye injury. Protective equipment such as gloves, safety goggles, and impervious apron should be used. Carefully read Material Safety Data Sheet and follow all precautions.

Contains Methylene Chloride (75-09-2), Methyl Acetate (79-20-9) and Methyl Methacrylate Monomer (80-62-6). Methylene Chloride is considered a cancer causing material. OSHA has established special requirements for work place monitoring and protection. Extent of health risk depends on level and duration of exposure, as well as individual sensitivity. Do not use this product for other than intended use.

"Proposition 65 Warning": This product contains chemicals known to the State of California to cause cancer.

"Title III Section 313 Supplier Notification": This product contains toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and of 40CFR372. This information must be included in all MSDS's that are copied and distributed for this material.

FIRST AID:

Inhalation:	If overcome with vapors, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call physician.
Eye Contact:	Flush with plenty of water for 15 minutes and call a physician.
Skin Contact:	Wash skin with plenty of soap and water for at least 15 minutes. If irritation develops, get medical attention.
Ingestion:	If swallowed, give 1 or 2 glasses of water or milk. Do not induce vomiting. Contact physician or poison control center immediately.

IMPORTANT NOTE:

This product is intended for use by skilled individuals at their own risk. These suggestions and data are based on information we believe to be reliable. Users should verify by test that this product, as well as these methods, is suited to their application.

WARRANTY:

IPS® Corporation ("IPS Corp.") warrants that all new IPS Corp. products shall be of good quality and free from defects in material and workmanship for the shelf life as indicated on the product. If any IPS Corp. product becomes defective, or fails to conform to our written limited warranty under normal use and storage conditions, then IPS Corp. will, without charge, replace the nonconforming product. However, this limited warranty shall not extend to, nor shall IPS Corp. be responsible for, damages or loss resulting from accident, misuse, negligent use, improper application, or incorporation of IPS Corp. products into other products. In addition, any repackaging of IPS Corp. products also shall void the limited warranty. IPS Corp. shall not be responsible for, nor does this limited warranty extend to, consequential damage, or incidental damage or expense, including without limitation, injury to persons or property or loss of use. Please refer to our standard IPS Corp. Limited Warranty for additional provisions.

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CERTIFIED QUALITY MANAGEMENT SYSTEM ISO 9001 2000

DVP&R

Report Date: 6/7/19 | Sponsor: QL+ | REPORTING ENGINEERS: Amy Wilson, Amanda Meares, Duania Evans, Ethan Littlejohn

TEST PLAN / TEST REPORT

Item No	Specification or Clause Reference	Test Description	Device	Acceptance Criteria	Test Stage	SAMPLES TESTED		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	Weight	Weight Measurements	All	mass of attachment + wrist < 0.503 lb	PV	All assy	C	05/22/19	05/22/19	Clamp: 0.40b, Sleeve:0.502lb, CutTool:0.471lb	Clamp, Cutting Tool, Sleeve	None	The sleeve is at our maximum weight limit
2	Food Safety	FDA Material Compliance	All	Pass/Fail	PV	All assy	C	05/23/19	05/23/19	N/A	Wrist, Clamp, Sleeve, Cutting Tool	None	JB weld areas covered in food-safe resin where at risk of coming in contact with food
3	Ergonomics	User Functional Testing 1	All	Min. Survey Score of 80%	DV	All assy	C	3/25/2019	4/1/2019	80.90%	N/A	N/A	see survey results
4	Ergonomics	User Functional Testing 2	All	Min. Survey Score of 80%	DV	All assy	C	5/31/2019	6/6/2019	31.11%	Wrist	Clamp, Sleeve, Cutting Tool	see survey results
5	Thermal Resistance	Coating Material Characterization (Component Level)	Clamp, Sleeve	Max Surface temperature, time to cool	CV	2	A	5/9/2019	5/9/2019	7.5 seconds	All	None	
6	Strength	Drop Test	All	Drop on all sides from 3ft	DV	All assy	C	5/23/19	5/23/19	N/A	Sleeve, Clamp, Wrist	Cutting Tool	Cutting tool failed along the cutting slit, which makes sense since it as made of brittle acrylic
7	Strength	Mixing Test (egg whites, brownies, cookie dough with hand held mixer to test spring strenght)	Clamp	Pass/Fail	DV	Clamp assy	C	5/19/19	5/19/19	N/A	Clamp	None	Broke some already-broken prongs, but worked well with unbroken set of prongs
8	Strength/Deflection	Test to failure	Sleeve	Minimum weight of 4 pounds, then find max	DV	1 sleeve beam	B	3/6/2019	3/6/2019	27 pounds	100% infill	None	Did not yield but concerned with clamping stability and ended test before failure
	Strength/Deflection	Test to failure	Sleeve	Minimum weight of 4 pounds, then find max	DV	2 sleeve beams	C	3/11/2019	3/11/2019	40 pounds	75% infill, 50% infill	None	Again did not yield, but achieved double the maximum load used in design
9	Strength/Deflection	Unbalanced Sleeve Load to Disengage Wrist	Sleeve/Wrist	Minimum weight of 3 pounds, then find max	CV	Wrist/ Sleeve assy	B	5/23/2019	5/23/2019	2.52 pounds	None	Sleeve	Rotated just below our requirement of 3 pounds

Drop Test Procedure

Objective: Determine the durability of each device when subjected to impact loading on all sides.

Materials:

- Completed Cutting tool prototype
- Completed Sleeve prototype
- Completed Wrist prototype
- Completed Clamp prototype
- Plywood, 3" thick
- Table top (3 ft high)

Procedure

1. Lay plywood out on top of a concrete floor.
2. Drop each attachment from table top that is 3 ft high.
3. Record any damage to device after each drop.
4. Repeat so that different faces of attachment hit plywood (6 total drops).
5. Document as pass or fail.
6. Repeat for each attachment.

Silicone Coating Thermal Characterization Procedure

Objective: Determine the thermal characteristics of the silicone rubber and 6061-T6 aluminum assembly.

Materials:

- Food-Grade High-Temperature Silicone Rubber Sheets with Adhesive Backing
- 0.050”-Thick 6061-T6 Aluminum
- Hot plate
- Laser Thermometer
- Safety glasses
- Towel/oven mitt/tongs
- Wire cooling rack

Procedure:

1. Set up the hot plate to reach a temperature outlined above, which is based on average pan bottom temperature readings after 5 minutes of heating on a stovetop.
2. Place the material directly on top of the hot plate and let it sit for 2 minutes (maximum time Jorge’s attachment should be making contact with a hot pan at a time, can increase or decrease if needed).
3. After 2 minutes, immediately record the surface temperature of the material.
4. Remove the material from the hot plate and let it sit on a suspended wire rack to simulate cooling in air at room temperature.
5. Constantly record the surface temperature of the material to form a plot of temperature vs. time. Continue to record until the material reaches a temperature of less than 80 °F).
6. Plot the results, and find the time that it takes for the material to cool to 120 °F.
7. Record this time for each iteration of the procedure.
8. Repeat this procedure 4 times for each temperature in order to determine average time it takes to cool.

Repeat this procedure for all types of materials and for each temperature listed below
275 °F (low), 300 °F (medium), 330 °F (medium high), 375 °F (high), 400 °F (max)

*The maximum surface temperature that is safe for the average person to make skin contact with for up to 5 seconds without sustaining irreversible burn damage is a temperature of 140 °F.

*If one would like to get even more detailed, an actual pan (stainless steel, aluminum, cast iron) can be placed between the hot plate and the tested material to heat up to the temperatures outlined above, the tested material can be cut to the approximate size of the final part.

Clamp Functional Mixing Test Procedure

Objective: Qualitatively evaluate the performance of the clamp when used for stabilizing bowls when mixing various viscosities of ingredients.

Materials:

- 2 eggs
- Ingredients for Chocolate Chip Oatmeal Cookies (homemade)
- 1 packs of commercial brownie mix
  - Associated ingredients listed on the box
- Clamp prototype
- Wrist attachment prototype
- Test Fixture
- Hand held mixer
- Mixing bowl
- Clamp

Procedure:

1. Secure the fixture and wrist attachment prototype to the table with the clamp.
2. Attach the clamp prototype to the configuration.
3. Secure the clamp to the edge of the bowl.
4. Crack two eggs and place them into the bowl.
5. First mix them together with using the electronic hand-held mixer (most likely on low setting). (save the eggs for use in future tests)
6. Record observational data, and any failure.
7. Rinse the bowl and assemble a pack of brownie mix with the required ingredients into the bowl.
8. Mix them together with the mixing electric mixer until thoroughly mixed as described on the packaging.
9. Record observational data, and any failure.
10. Rinse the bowl out again and assemble cookie ingredients as specified in recipe and mix with its required ingredients into the bowl.
11. Mix them together with the electric mixer until thoroughly mixed as described by the recipe.
12. Record observational data, and any failure.

Sleeve Unbalanced Loading Procedure

Objective: Determine the maximum unbalanced load capable of being carried by the sleeve.

Materials:

- Completed wrist prototype
- Completed sleeve prototype
- Test stand
- Scale
- Extension spring
- Weights
- Safety glasses
- Socket wrench
- Crescent wrench

Procedure:

1. Install the wrist prototype into the test stand using a ¾" socket wrench head to hold the ½" bolt and a crescent wrench to hold the nut in place on the back of the test stand. Ensure the bolts in the wrist are vertical and that the wrist insert locks into place in the proper horizontal orientation.
    a. Adjust the wrist as necessary to achieve the proper orientation.
2. Shift the test stand towards the end of the table and add 20 pounds of weights to the back of the test stand to ensure a stable setup.
3. Insert the sleeve into the wrist and ensure it is nominally level. Document this position.
4. Measure the weight of the pan using the scale and insert it into the sleeve.
5. Measure the weight of the extension spring using the scale. Attach the loop of the extension spring to one side of the pan. Document this and each of the following loading steps with pictures.
6. Incrementally take the mass of bags of weights and hang them off the extension spring. Repeat until the sleeve rotates more than 30° from the horizontal. Document the final weight.
7. Remove the weights, extension spring, and pan from the sleeve.
8. Remove the sleeve from the wrist.
9. Remove the wrist from the test stand using the socket wrench and crescent wrench.
10. Remove the weights from the test stand and clean up.

Sleeve Balanced Loading Procedure

Objective: Determine the maximum balanced load capable of being carried by the sleeve.

Materials:

- Completed wrist prototype
- Completed sleeve prototype
- Test stand
- Scale
- Extension spring
- Weights
- Safety glasses
- Socket wrench
- Crescent wrench

Procedure:

1. Install the wrist prototype into the test stand using a ¾" socket wrench head to hold the ½" bolt and a crescent wrench to hold the nut in place on the back of the test stand. Ensure the bolts in the wrist are vertical and that the wrist insert locks into place in the proper horizontal orientation.
    a. Adjust the wrist as necessary to achieve the proper orientation.
2. Shift the test stand towards the end of the table and add 20 pounds of weights to the back of the test stand to ensure a stable setup.
3. Insert the sleeve into the wrist and ensure it is nominally level. Document this position.
4. Measure the weight of the pan using the scale and insert it into the sleeve.
5. Measure the weight the objects used and add them to the center of the pan. Increment with 0.5 to 1.0 pounds of weight, documenting each step with pictures and a corresponding weight.
6. Repeat step 5 until the pan slips out of the sleeve or the sleeve fails. Note this final weight and how the sleeve failed.
7. Remove the weights and pan from the sleeve.
8. Remove the sleeve from the wrist.
9. Remove the wrist from the test stand using the socket wrench and crescent wrench.
10. Remove the weights from the test stand and clean up.

/

Prototype Survey

Please respond to the following questions based on your personal sense of the description. Try to be as accurate as possible so we can identify any issues and develop solutions. Please leave any feedback or comments you may have on each question with a rating describing why you rated it that score. Thank you for taking the time to complete this survey!

This survey will be divided into 4 segments based on **Comfortability, Ease of Use, Aesthetics,** and **General Questions**

1. **Comfortability**: The overall level of comfort you feel when working with the prototype. Take into account its weight, size, cumberance, and any pain level you may feel when interacting with the prototype.

On a scale of 1-10, with 10 being perfectly comfortable and 1 being extremely uncomfortable:

a. How is the comfortability of the wrist prototype attached to your current prosthetic arm? Keep in mind this question is for the wrist attachment only, not the inserts or the other prototypes sent.

1	2	3	4	5	6	7	(8)	9	10

Comments: fit very well, easy to attach

b. How is the comfortability of the cutting tool attachment prototype? Keep in mind the overall comfortability of it attached to the wrist prototype and attached to your existing arm.

1	2	3	4	5	(6)	7	8	9	10

Comments: Had to angle it a bit more to work, but held veggies good

c. How is the comfortability of the sleeve attachment prototype? Keep in mind the overall comfortability of it attached to the wrist prototype and attached to your existing arm.

1	2	3	4	5	6	7	(8)	9	10

Comments:

d. Using the cutting tool prototype as outlined in the manuel, how was the overall comfortability for you? Keep in mind the definition of comfortability outlined above at the start of this section of the survey. Also take into account the fixed angle of the tool in relation to its position on the cutting board.

1	2	3	4	5	6	7	(8)	9	10

Comments: Hold tight on whatever i needed to cut

e. Using the sleeve prototype as outlined in the manuel, how was the overall comfortability for you? Keep in mind the definition of comfortability outlined above at the start of this section of the survey. Also take into account the fixed angle of the tool in relation to its position when holding onto pan handles.

1	2	3	4	5	6	7	8	9	10
					◯				

Comments: pot holder was a little to big. it would angle the pans (cracked cay) forward, and kinda unstable

f. How comfortable are you with specifically the overall weight of the device? Keep in mind both configurations with the attachments.

1	2	3	4	5	6	7	8	9	10
									◯

Comments:

2. **Ease of use**: Your opinion of the ease of use of the prototypes provided. Did they live up to your expectations? Were they difficult to operate in any way? Were they straightforward?

On a scale of 1-10, with 10 being extremely easy to use and 1 being extremely difficult to use:

a. How easy was it to use the quick change feature of the wrist prototype? Did you have any difficulties in attaching the other prototype attachments, or in swapping between the multiple attachments?

1	2	3	4	5	6	7	8	9	10
							◯		

Comments: lightweight, Durable

b. In relation, how easy was it for you to disengage the magnets in the wrist prototype when taking off attachments and swapping between attachments? (This also ties into comfortability)

1	2	3	4	5	6	7	8	9	10

Comments: easy switch on each Device, 5 sec to rotate

c. Using the cutting tool prototype as outlined in the manuel, how was the overall ease of use of operating the attachment?Take into account the fixed angle of the tool in relation to its position on the cutting board, as well as the fixed angle of the tool in relation to the width of food items it can fit over.

1	2	3	4	5	6	7	8	9	10

Comments:

d. Using the sleeve prototype as outlined in the manuel, how was the overall ease of use of operating the attachment? Take into account the fixed angle of the tool in relation to its position when holding onto pan handles.

1	2	3	4	5	6	7	8	9	10

Comments:____

____

____

____

3. **Aesthetics**: Your opinion on the style and overall look of the device. Includes color, design, shape, patterns, and all other aspects of the physical appearance of the device.

On a scale of 1-5, with 5 being definitely agree and 1 being definitely do not agree:

a. The overall aesthetics of this device and attachments are important to me.

1	2	3	4	5

b. I am comfortable with the aesthetics of the quick change wrist and attachments. (Even though these are prototypes, the final product does not currently have any planned changes in aesthetics like colors or patterns)

1	2	3	4	5

Comments:____

____

____

____

Please leave any additional comments on what we can do to improve the aesthetics of the device and make it more appealing to you to have (if any):

____

____

4. General Questions

a. How well were the instructions as presented in the user manual? Were they relatively simple to follow, and were there any unclear sections or areas where you had problems following?

yes very simple pretty much self explanatory

b. For the cutting tool, how was the fixed angle in relation to fitting over various types of food you practiced on? Did it work with all of them, or were there some food items it was not able to hold?

for the most part, each fruit & vegetables held on good

c. For the sleeve, how was the fixed angle in relation to the position of your stove and how you hold pans over it?

I cook mostly on the right burner so access was pretty easy

d. For the cutting tool, were there any difficulties in in slipping or general difficulties in operation?

having to angle a bit

e. For the sleeve, how well did it fit over your pan handles in your kitchen? If it did not fit over some of them, can we get dimensions as outlined in the manuel?

fit a bit to big

f. When washing the cutting tool, did any water get trapped in the hollow sections?

NO

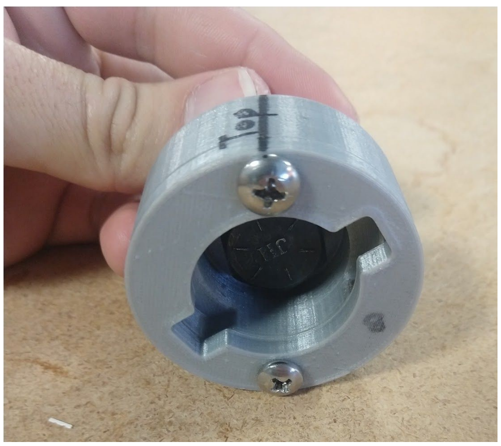
User Functional Testing 2	
Question	Response
How comfortable is it to install the wrist?	9
Any comments or concerns about installing the wrist?	Very simple snap in
How comfortable is it to use the clamp?	3
How effective is the clamp at stabilizing pots?	3
How effective is the clamp at stabilizing bowls?	3
Any comments or concerns about the clamp?	The clamp was broken upon arrival. Tried to reglue it, but to no effect
How comfortable is it to use the sleeve?	3
How effective is the sleeve at stabilizing pans?	3
How effective is the sleeve at lifting pans?	2
Any comments or concerns about the sleeve?	The sleeve did not fit into any of my pans
How comfortable is it to use the cutting tool?	1
How effective is the cutting tool at holding down food?	1
Any comments or concerns about the cutting tool?	Snapped in half as soon as I put pressure on it to hold down a potato
Score:	**31.11%**

Appendix 14: User Manual

Wrist

<u>Attaching the wrist receiver to the body powered arm</u>

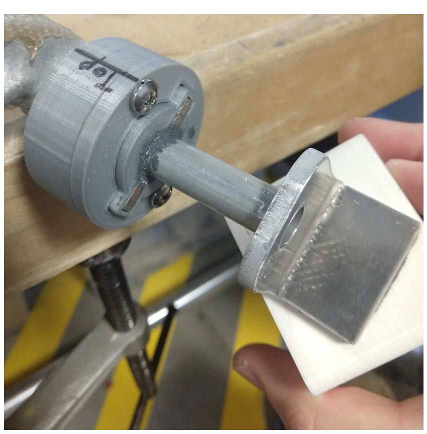
1. Insert and secure the wrist receiver into your current quick change wrist on your body powered prosthetic arm, just as you would with your current hook attachments.
2. Using the line as a guide, make sure that the wrist receiver is locked into place with a horizontal resting orientation for the insert based on its position to the body.
    a. This can also be confirmed by the vertical position of the two screws on the wrist receiver, as shown in the picture.



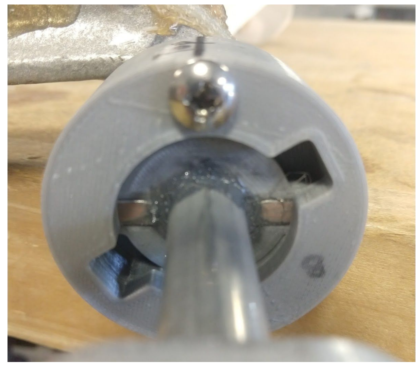
3. Now it is ready to use with your attachments!

<u>Attaching the clamp, cutting tool, and sleeve attachments</u>

1. Using the built in guide on the receiver, insert the tabs of the insert on the desired attachment into the slots in the wrist receiver.
2. Twist the entire attachment clockwise until the magnets engage each other and the insert "locks" into place.




3. Make sure that the insert is sitting at a horizontal resting orientation.
    a. If not, then the wrist receiver needs to be adjusted as outlined above.
4. Make sure the attachment is level and oriented with the surface you wish to use it on (countertop, stove).



Detaching the clamp, cutting tool, and sleeve attachments

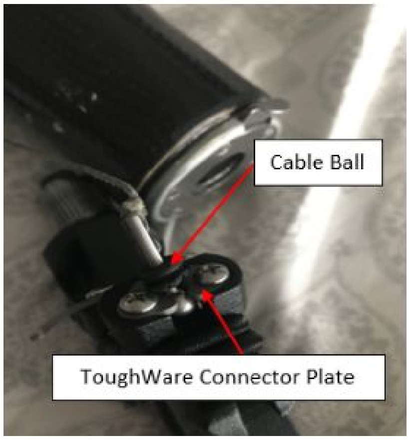
1. When you are ready to detach the attached device, twist the currently attached device counter clockwise to disengage the magnets.

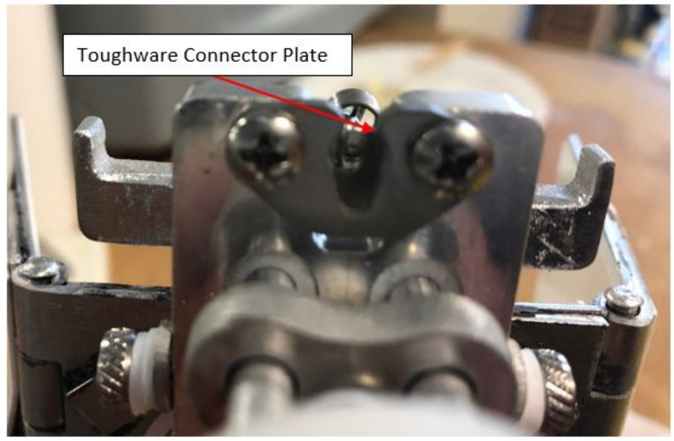
2. Rotate it fully until it is unable to rotate any more, then remove the attached device from the wrist receiver by pulling it out.

Clamp

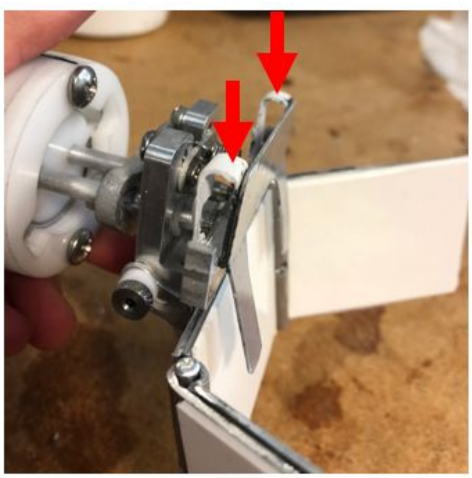
Using the clamp on pans and bowls

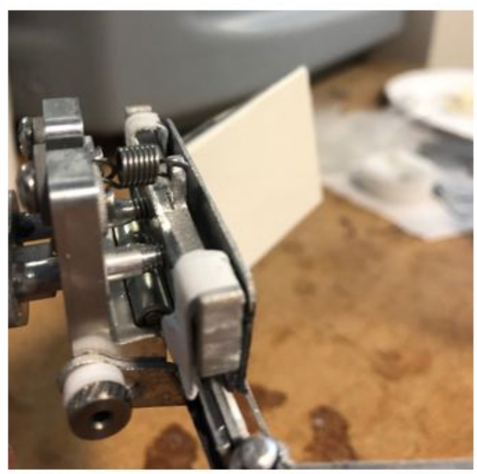
1. Follow the instructions under the wrist section to attach the clamp to the wrist receiver.
2. Attach the ball end of the cable of your prosthetic to the connector plate on the clamp. It should attach the same as one of the existing prosthetic attachments you own.



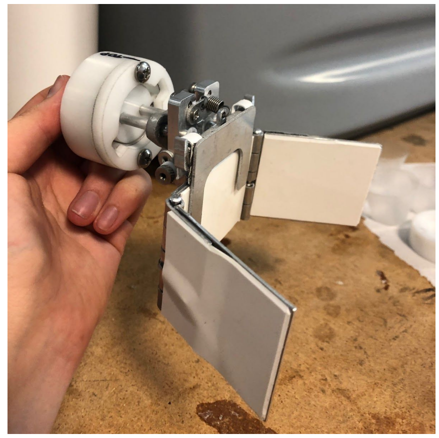


3. To open the clamp apply tension to the cable. This will pull the trifold portion of the clamp towards you and open the clamp.
4. To close the clamp, relax and release the tension in the cable. This will allow the extension spring to pull the clamp closed.
5. To add on the prongs, slide the prongs on the prong attachment point as indicated in the figures below. Apply downward pressure with two fingers where the arrows indicate, until the prongs are pushed on to approximately the location seen in the left figure.

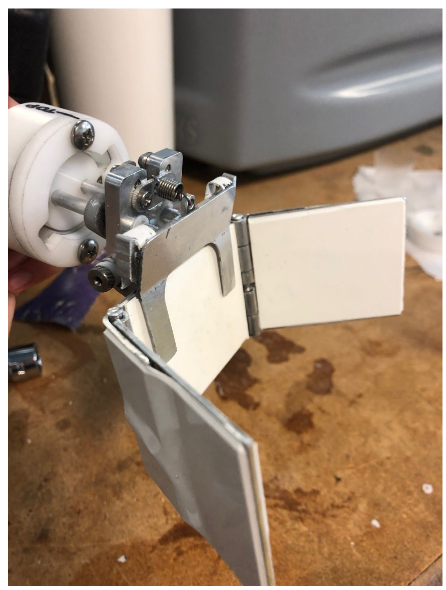




6. FOR PANS: Adjust the angle of the trifold by loosening the thumbscrews on either side of the clamp and rotating the trifold so it is perpendicular to your prosthetic and attach the straight prongs. Be sure to tighten the thumbscrews for the best results.

7. FOR BOWLS: Adjust the angle of the trifold by loosening the thumbscrews on either side of the clamp and rotating the trifold so it is angled to the required angle to accommodate the angle of your bowl and attach the angled prongs. Be sure to tighten the thumbscrews for the best results.

➢ **Warning:** The clamp is not designed to lift pans or bowls, so do not attempt to lift with this device.

Cutting Tool

Using the cutting tool to cut food on your current cutting board

1. Follow the instructions under the wrist section to attach the cutting tool to the wrist receiver.
2. Once it is attached, gather the necessary materials you need for cutting food:
    a. Cutting board
    b. Food item to be cut
    c. Knife
3. To the best of your ability, use the cutting tool to hold down food onto the cutting board by applying slight downward pressure onto the food.

4. Use the slit in the cutting tool to make perpendicular cuts into the food item if needed.

Sleeve

Using the sleeve to hold and stabilize pans with handles

1. Follow the instructions under the wrist section to attach the sleeve tool to the wrist receiver.
2. Once it is attached, slide it over the pan handle you wish to hold on to.
    a. Try to only use on pans with a light/balanced load.

3. Relax the elbow downward to apply the necessary pressure to hold the pan handle securely in place inside of the sleeve.
    a. Experiment with the motion of this if necessary.

4. You can attempt to lift the pan slightly off of the resting surface, but do not lift it more than 4 inches.

➢ **WARNING**: Be careful when lifting the pan, as the pan can rotate inside of the sleeve if the contents are loaded unevenly.

Other

Cleaning the Devices

1. **Do not run any of the devices through a dishwasher!**
2. To clean the cutting tool, rinse it under warm water. You can use a non scratch sponge with dish soap to wash it off.
3. To clean the clamp, detach the prongs and wash them, then wipe down or wash the trifold as needed.

Troubleshooting

1. Do not hesitate to call or text the team any questions you may have on the devices we will get back to you as soon as we can.
2. If the provided attachments are falling out easily while inserted into the wrist, check to see that the insert is sitting at a horizontal resting position and refer to the “Attaching the wrist receiver” section.

Maintenance and Repair

1. For any glued parts that come undone, use the epoxy glue (JB Weld) provided, along with the instructions provided, to make necessary repairs.
2. If any screws fall out of the threads, replace them with new ones and secure with loctite if needed for extra stability.
3. To prevent the silicone strips from peeling off, wipe down with a damp cloth to clean, and do not run under water or in a dishwasher. If the silicone strips do come off, use a food safe standard adhesive or super glue to secure them back into place.
4. Be careful when using this device around electronics or other magnetic surfaces, as the magnets imbedded into the wrist insert and receiver can interact with them and produce harmful results to those devices.