Azelia's Walker

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Statement of Disclaimer

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Executive Summary

A Biomedical Engineering student, KC Balfour, two Mechanical Engineering students, Jayne Benedict and Gabrielle Merkin, and one Industrial Engineering student, Jordan Ramsey, make up the interdisciplinary senior project team of *Azelia's Walker.* The goal of *Azelia's Walker* is to create a custom walker for an 8-year-old girl in the San Luis Obispo Community, named Azelia, who has decreased motor control. Her current walker does not suit her active and energetic lifestyle, so *Azelia's Walker* is challenged to design and manufacture a collapsible all-terrain walker that best suits Azelia's needs. Throughout the academic year, *Azelia's Walker* participated in the brain-storming and iteration process to produce a final design, created a manufacturing plan, and fabricated a prototype. Several key design features of the new walker are its all-terrain ability, height adjustments, portability, and ergonomic features. This report will take you, the reader, through *Azelia's Walker* senior project team's design and fabrication process. This project culminated in a to-scale prototype. Although the final product succeeded in meeting its all-terrain and portability requirements, the walker was deemed unusable for Azelia due to certain safety concerns outlined in the report. The members of *Azelia's Walker* have thoroughly enjoyed this design process and have learned a great deal about the engineering research and design (R&D), analysis, fabrication, and testing process.

1.0 Introduction

This project is a part of the interdisciplinary senior design course at California Polytechnic State University in San Luis Obispo, CA. A Biomedical Engineering student, KC Balfour, two Mechanical Engineering students, Jayne Benedict and Gabrielle Merkin, and one Industrial Engineering student, Jordan Ramsey, make up the team of *Azelia's Walker.* The stakeholders of this project consist of the previously stated four team members, the team advisor: Professor Jim Widmann, the Wentz family, and Azelia.

Azelia's Walker is a team of dedicated problem solvers working to create a walker for Azelia, an eight-year-old girl in the San Luis Obispo community who was born with a rare genetic disorder. This disorder causes Azelia to have decreased motor control similar to that of someone with Cerebral Palsy. Unfortunately, Azelia's current walker does not allow her to go the beach or over curbs, provide her a comfortable seat suited for longer periods of rest, and it is too bulky to be easily transported by her family's Prius. For these reasons and more, Azelia's current walker does not suit her lifestyle and restricts her from living her life fully. By designing a new walker for Azelia that targets these specific problems, the *Azelia's Walker* team hopes to increase Azelia's quality of life by providing her more independence in her daily life.

Over the course of the 2016-2017 academic year, *Azelia's Walker* has researched, designed, and prototyped a walker for Azelia and will manufacture and test a final walker product. Research consisted mostly of understanding current technology and creating the engineering specifications. By designing and prototyping, the team was able to compare and test initial ideas to understand how they meet the engineering specifications. In the last quarter of the academic school year, *Azelia's Walker* will manufacture a final walker to present to Azelia and her parents.

2.0 Background

Azelia has a GNAO1 chromosome mutation. This mutation has caused Azelia to have difficulties controlling her body's muscles resulting in her struggles with speech and movement.[1] To clarify, although Azelia cannot speak, she is cognitively functional, can comprehend all that she hears, and is overall a great listener. This condition is extremely rare; however, one study has proven the link between the genetic mutation and her symptoms of motor development delay and involuntary movements.[2]

In order for Azelia to get around and increase her independence, she uses a walker anytime she is outside of her home. As any eight-year-old girl, Azelia is very active and eager to participate in all activities. She likes to go to the beach with her family and play in the schoolyard with friends, among many other activities. However, Azelia's current walker hinders her abilities. Since she does not communicate verbally, she uses an iPad-like device to communicate.[3] This is another struggle for Azelia as the communication device is not easily accessible while she is using her walker, specifically when she is sitting down in the walker. Azelia and her family like to keep active by going to the beach, hiking, camping, and more. Her parents have fought with health care insurance agencies to help her receive a walker that more adequately suits her needs but due to costs, she was denied approval of a more suitable walker. After just a year or two of growing, Azelia usually needs a new walker. Again, because of the challenges Azelia's family faces when dealing with insurance companies to receive the equipment Azelia needs, it can take up to six months just to receive a new walker. These are all some of the reasons Azelia desperately needs an engineered solution.

Figure 1: Azelia's communication device

Azelia's current walker (see Figure 2) is a basic design. She does not like the vertical handles and does not use them. She prefers to simply rest her arms on the U-shaped armrests without grasping the handles to help aid in maneuvering. The seat is minimal and uncomfortable for sitting for longer periods of time. The walker cannot grow or lengthen and as a result will not be suitable for Azelia after some time. Azelia's current walker cannot be broken down easily in order to transport. Because of the shape of the walker and the

Figure 2: Azelia's current walker

backrest, Azelia is forced to walk into the walker and then turn around, which is difficult for her to do without ‘ping-ponging’ from side to side. The wheels of the walker are unable to conquer curbs or uneven terrain, which make walking around at school extremely difficult for Azelia. This walker does not currently suit Azelia for any terrains other than completely flat pavement. In general, Azelia’s walker cannot match her lifestyle.

Although Azelia’s current walker succeeds in providing her some stability, it lacks in many other categories. For one, Azelia and her family enjoy going to the beach. There are walkers that are designated as ‘Beach Walkers’ but they are costly, visually unappealing, and not specifically for an eight-year-old girl with movement symptoms similar to Cerebral Palsy.

Figure 3: Beach wheelchair

An alternative to a beach walker is a beach wheelchair. These are easier to research, but do not suffice as good substitutes for Azelia. The wheelchair defeats the idea that Azelia is a young, active and independent girl, who just needs a small amount of stability during her activities. Because this is not a power wheelchair, Azelia would be dependent on someone else pushing her. It is also extremely bulky and would not be portable for any sedan sized car. The wheelchair in Figure 3 costs $2,025.00 as of October 17, 2016.[4]

Figure 4: Aluminum beach walker

The Aluminum Beach Walker in Figure 4 costs $1,235.40 as of October 17, 2016. It is clear upon looking at this walker that it would not only be too large for Azelia, but also does not provide the type of stability she needs. This type of walker is geared more towards someone who has full control over their muscles, but is just weak. It has some benefits, such as the basket for storage and the hand brakes. However, handbrakes may not be something Azelia would be able to use regularly. Again, the large wheels imply that this walker will not be easily transportable.[5]

Figure 5: Portable walker

Walkers that suit Azelia’s needs tend to be large and wide as they can provide more stability to her shaky movements. However, this makes them very difficult to transport, especially by her parent’s Prius. Unfortunately, walkers designed to be easily transportable are designed to act as temporary substitutes. In Figure 5, the portable walker shown is small, simplistic, and overall lacks any additional features. This walker specifically does not have wheels on all four legs, just the front two which will not be suitable for Azelia.[6]

Figure 6: Meywalker 2000 walker

One way Azelia can increase her independence is by being able to be more self-sufficient in getting in and out of her assistive devices. Currently, one parent will hold her walker still and the other will hold her arm as Azelia walks into her walker. This can be especially difficult if both parents are not present to help. One walker, the Meywalk 2000, uses a spring suspension and locking buttons in order to make this easier. As seen in Figure 6, there is a bike seat in the middle of the walker. Although this could make it easier for someone to get in and out of the seat, it would not be comfortable to sit in this for a longer period of time. It is also clear that this walker is not portable. From pacificrehab.com, the Meywalk 2000 costs $3,795.00.[7]

Aside from the frame of the walker, one feature that is completely lacking from her current walker is a device that would hold her communication device so that Azelia can easily communicate independently while sitting in her walker. Currently, the company that makes her communication device offers one Wheelchair Mounting kit for the communication device (Figure 7). There are many issues with this device, one of which being that it is currently priced at $675.00. Another is that this is for a wheelchair and not a walker. The bend in the bar would not allow it to be easily compacted in order for the walker to be transported.

Figure 7: Wheelchair Mounting Kit

Other current mount technologies that exist on the market tend to have similar issues. Most of them are made for iPads. A standard iPad is approximately 1/3 the depth and half the weight. Most of these devices are not able to adequately hold Azelia's currently communication device which is not a standard size tablet. An example of the current technology can be seen in Figure 8. A large majority of the current technology would not allow the degrees of freedom necessary to use the device while sitting in a walker but also allow the mount to be moved out of the way when Azelia wants to walk.

Figure 8: IPad Mount

Although these walkers and other technologies each solve one issue that Azelia may have with her current walker, they have many other features that make them undesirable. Almost all of the above are over budget. Health insurance is an option, however, it is debatable that a 'beach walker' or any walker with better technology is not 'necessary' and will not be covered under her insurance plan. For example, the lines of

Medicare insurance are blurred and ‘necessity’ can be vague. “Medicare Part B (Medical Insurance) covers walkers, … that’s medically necessary and prescribed by your doctor or other treating provider for use in your home.”[8]

In general, mechanical walkers on the market are considered Class I - 510(K) Exempt devices by the U.S. Food & Drug Administration (FDA). Class I means that they have been considered low risk. 510(K) exempt, also known as premarket notification exempt, means that there is no FDA review required before they can sell on the market. This is typically because they have predicates that have already been determined safe by the FDA. It should be noted that although the device is 510(K) exempt, it is still required to be suitable for the intended use, be adequately packaged and properly labeled, have establishment registrations and device listings forms on file with the FDA, and be manufactured under a quality system.[9]

Current walkers are held to international standards, per ISO 11199. These standards will be valuable to our team in the future as they outline requirements and testing. More specifically, they give methods for testing static stability, wheels, safety, and ergonomics. Both ISO 11199-1:1999 *Walking Frames* and ISO 11199-2:2005 *Rollators* will be used to inspire and standardize our design and testing methods.[10]

After continuous research on current walkers, it is obvious that the perfect walker for Azelia has not yet been created. *Azelia’s Walker* has come together to design and manufacture this walker.

3.0 Design Requirements and Specifications

The objective of this project is to design a walker suited to Azelia's lifestyle. Azelia and her family have requested a walker with a variety of requirements and desires. Due to her active and energetic personality, Azelia deserves a walker that is all-terrain. This includes the ability to traverse through sand while on the beach, mild hiking trails that may have small rocks and sticks to navigate over, un-maintained and cracked pavement that may present 1 inch or more lips to walk over, and grassy areas at the park and at her Elementary school. Next, the walker needs to be height adjustable. This way the walker will be suitable for Azelia from her current age until she reaches the eighth grade, as requested by Azelia's family. The specific dimensions for height adjustability are listed in the table below. Because Azelia is one-of-a kind, her generic walker is not comfortable for her; specifically, the armrest handles. The armrest hands needs to be tailored towards Azelia's ergonomics, this way she can utilize them more efficiently. Another disadvantage of the generic walker is that it inhibits Azelia's comfortability while sitting. It is crucial that the seat is comfortable for Azelia to use for longer periods of time and it is able to provide trunk support. While sitting, Azelia needs to be able to independently and comfortably use her communication device. Lastly, this walker needs to be easily transportable via the family's Prius. For example, is it required that both groceries and the walker are able to be carried by the car. Table 1 below outlines the formal engineering requirements for this project.

Table 1: Azelia's Walker Formal Engineering Requirements

Customer Specs	Spec #	Engineering Description	Requirement or Target (units)	Tolerance	Risk	Compliance
Safe	1	Factor of Safety	2.5	Min	L	A
All-terrain	2	Clearance	1 [in]	Min	M	T
All-terrain	3	Moves over gravel	Yes	Min	M	T
All-terrain	4	Moves over sand	Yes	Min	M	T
Portable via a Prius	5	Collapsibility	Yes	Min	M	I
Height adjustable	6	Adjustable Height	8 [in]	± 3 [in]	M	T
Height adjustable	7	Lifespan	5 [years]	Goal	L	A
Portable	8	Weight	25 [lbs]	Max	M	T
-	9	Height	3.5 [ft]	Min	M	T
-	10	Width	2.5 [ft]	Min	M	T
-	11	Length (depth)	2 [ft]	Min	M	T
Comfortable Seat	13	Seat Size	18x10 [in]	Min	M	T
Carries Communication Device	14	Carries Comm. Device	Yes	Min	L	T
Better Handles	15	Ergonomic Handles	Yes	Min	L	I

Key: High (H), Medium (M), Low (L)
Analysis (A), Test (T), Similarity to Existing Designs (S), Inspection (I)

The requirements were derived from this project's Quality Function Deployment (QFD) document, attached as Appendix B to this report. In the QFD, team members outlined the customer's requirements, and translated those requirements into quantifiable engineering requirements. The relationships between engineering and customer requirements are explained further.

Although it was not explicitly stated by the customer, safety is of the utmost importance. Factor of safety was based on the durability, and the value was estimated based on our current understanding of the materials likely to be used, the stresses likely to be applied to the walker, the estimated geometry, and the estimated failure theory. These are all based on the rule of thumb method of estimation laid out by David G. Ullman.

In an attempt to define qualities of an "all-terrain" walker, clearance was determined as a requirement to ensure that the walker can maneuver over uneven cracks, grass, rocks, and sand. Adjustability is a key requirement for the walker's ability to grow with Azelia over time. The goal is to allow for the walker to fit Azelia for as long as possible with the target goal being until 8th grade, meaning the walker must last a minimum of 5 years. The team determined that the lifespan should extend beyond the absolute minimum, so a lifespan of 7 years was determined. The target value heights were based on Azelia's current height (52 in) and an estimation of the average height of 13 year olds (60 in). The team took Azelia's current measurements to help in determining walker measurements as seen in Figure 9 below.

Weight is a requirement designed to help define portability, the walker must be light enough to pick up and pack away. A standard medical walker available on the market with a weight of 13.5 pounds was used as a baseline (Rollite Rollator). Azelia's walker will be more involved than the standard medical walker thus 25 pounds was chosen as a maximum weight. It is also important that the walker is heavy enough to withstand obstacles and irregularity in Azelia's motions.

As Azelia is not comfortable utilizing her current armrest handles, our target was to create handles that would be best suited for her. This was a simple Yes/No requirement.

Azelia requires a seat that provides trunk support and comfortability for long periods of time. The seat size was determined from taking measurements of Azelia's body while she rested in a comfortable chair that provided her trunk support.

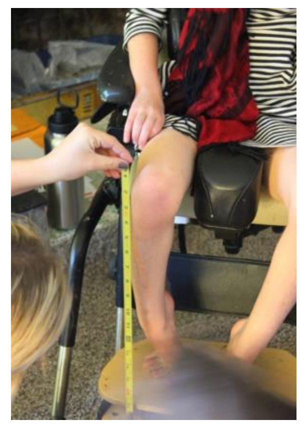


Figure 9: Taking measurements of Azelia while sitting

While sitting, Azelia uses her communication device in order to speak to others. For this reason, it is a requirement that Azelia is able to independently use her communication device while sitting. However, it is very important that this device is also able to be moved out of her way while walking. The requirement for this is based on the dimensions and weight specifications of her current communication device and the space required for her to use it while sitting.

Collapsibility was determined as a requirement based on the desire for portability. The size limits for the walker frame was derived from a combination of multiple factors. The size of the walker needed to be large enough to suit Azelia's size but be small enough to compact. The frame needed to also be tailored to a size that would give an adequate center of mass, in order to confirm safety. The height and width were determined from a combination of all these factors with the goal of producing a safe and effective walker.

4.0 Design Development and Selection

To successfully design and create a walker for Azelia that meet the technical specifications identified, the *Azelia's Walker* team follows the formal design process flow outlined in the Interdisciplinary Senior Project course requirements. To start the design process the team needed to understand all of the specifications and how they fit with specific components. These components were then broken down into how they could be applied to the frame of the walker. Figure 10 below shows how *Azelia's Walker* broke down the frame of the walker into its smaller components.

Figure 10: Idea breakdown

4.1 Frame Style:

Upon understanding how many components would need to be embedded in the frame, it was crucial that *Azelia's Walker* considered multiple frame ideas and choose one which would provide the most structural support, allow the most features to be integrated easily, allow the most collapsibility, and be the most feasible to manufacture at Cal Poly. The Pugh matrix (see Figure 11 on the next page) helped the team compare frame designs to the current walker. Ultimately, Frame 2 was selected with features from Frame 5 incorporated.

	①	②	③	④	⑤	⑥	⑦	CURRENT WALKER [DATUM]
Fits In Pruis Trunk	S	S	S	−	+	−	S	0
Safety - "Pinch Points"	S	−	S	S	−	S	−	0
# of Steps to Collapse	+	−	−	+	+	+	+	0
Ease of Steps to Collapse	+	+	+	+	+	+	S	0
Complexity of Fabrication	−	−	S	−	S	S	S	0
Aesthetic	+	+	S	+	S	S	S	0
Σ-	1	3	1	2	1	1	1	0
Σ+	3	2	1	3	3	2	1	0
Σ S	2	1	4	1	2	3	4	0

Figure 11: Walker frame Pugh matrix

After choosing a general frame design the team looked more closely into the other aspects that would need to be incorporated into the frame. One of which was collapsibility. For collapsibility, *Azelia's Walker* looked into foldable strollers and current medical walkers for inspiration. The team specifically looked into numbers of steps to fold and pinch points in order to standardize the decision process. The least amount of steps and pinch points is the most desirable, as it would make the end product safer and more user-friendly. Ultimately, foldable strollers proved to be most beneficial to the team's research, as strollers were more suited for holding more weight, having a larger seat, and being all-terrain. The following (Figure 12) is a good example of how hinges could be utilized in order to decrease the height of the walker.

Figure 12: Foldable stroller[11]

One issue that arose from researching current foldable walkers was that the majority of them did not meet the support that Azelia requires.[11] However, some aspects of current walkers were still taken into account and used as inspiration. Figure 13 shows an X- or accordion- style which, although not copy-and-pasted into our design, helped lead to the final design. Initially accordion-style was considered, however, upon further inspection it was concluded that the slider mechanism at the bottom of the X would interfere with back of the frame. The interference would cause the X to not be able to fold flat. This component can be seen in the first iteration of the design in Figure 14. Our re-design of the back of the frame is seen in Figure 15. It uses the same idea of pulling the bars up to decrease the width; however, this design does not interference with any other components of the frame. The design itself also auto locks when it is flat, so there is no concern with the walker folding on itself during use. A lock system will be implemented on the top piece of the back in order to make sure the back stays in the flat position during use.

Figure 13: Foldable walker with accordion folding mechanism[12]

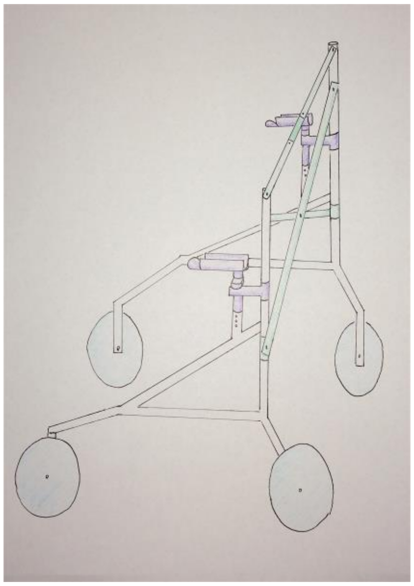


Figure 14: First conceptual walker design

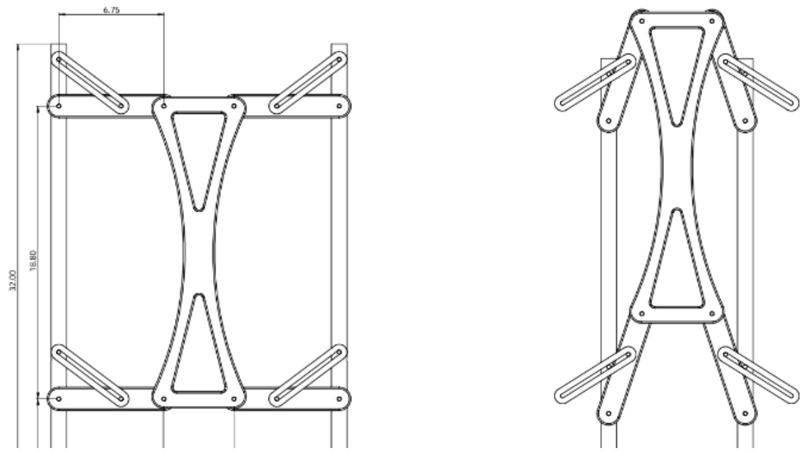


Figure 15: Back of walker, Final design

Another method used to collapse the walker was to have the legs folding up to collapse the height of the walker. The width will also be able to be collapsed in the back of the walker by an H-shaped bar. This is accomplished through hinges that allow this range of motion but are auto-locking for safety.

Overall, the final frame design consists of multiple collapsing mechanisms in order to reach the size requirements while still being safe and easy to use.

4.2 Wheels:

Deciding on wheels proved to be a difficult decision because the walker was requested to go over all-terrain but still needed to be lightweight in order to make traveling convenient. All terrain includes gravel, cracks in pavement, sand, and more. *Azelia's Walker* chose to split the wheels into two different concepts in order to accommodate for most terrain (dirt, gravel, etc.) and sand. This is because going over sand is a distinct challenge when compared to dirt, gravel and other terrain that Azelia would be in contact with more frequently. A decision matrix (Table 2) was constructed to aid in the decision making process.

Table 2: Decision matrix for all-terrain concept ideas

Criteria	Weighting (1-5)	Four 18" Wheels		Four 12" Wheels		Two 12" Wheels in Back, Two 6" Wheels in the Front		Triwheel for All Four Wheels		Suspension System	
Portability / Collapsibility	4	-1	**-4**	0	**0**	0	**0**	-1	**-4**	**-1**	**-4**
Grass	5	1	**5**	1	**5**	0	**0**	1	**5**	**0**	**0**
Rocks	5	1	**5**	0	**0**	-1	**-5**	1	**5**	**1**	**5**

Cracks in Pavement	5	1	**5**	1	**5**	0	**0**	1	**5**	**1**	**5**
Ease of Use	3	0	**0**	1	**3**	1	**3**	0	**0**	**-1**	**-3**
Interchangeable Feasibility	1	0	**0**	0	**0**	-1	**-1**	-1	**-1**	**0**	**0**
Wheel Attachment Manufacturability	3	1	**3**	1	**3**	-1	**-3**	0	**0**	**-1**	**-3**
Obstacle Durability	4	1	**4**	1	**4**	0	**0**	1	**4**	**1**	**4**
Total	-	-	**18**	-	**20**	-	**-6**	-	**14**		**4**

Finding wheels that can travel over gravel, cracks in pavement, and smaller obstacles is not too challenging as many devices are able to accomplish this feet. Initially the team considered a spring system or other type of suspension system, but upon further understanding of Azelia's needs, those concepts were not ideal solutions. A spring system or suspension system would be too complex and heavy. An additional system implemented into the frame would cause difficulties making the walker lightweight and collapsible. The team then began to look into wheels that would allow overcoming obstacles as opposed to an external system.

The team first found a tri-wheel concept (see Figure 16). The concept is currently used in many cart designs to aid in overcoming stairs and other obstacles with no serious impact to the operator's momentum. However, the tri-wheel is a poor design for Azelia as getting over obstacles requires more force using the tri-wheel which is something Azelia cannot provide.

Figure 16: Cart with tri-wheels[13]

After looking into to other wheel options, the team concluded that a large diameter tire would be the best option. A large diameter tire would be easy to purchase, replace, and a simple solution for overcoming small obstacles.

Figure 17: Bicycle tire[14]

The immediate idea was a 12in. bike tire (see Figure 17). This was the first idea because a 12in. bike tire is a common children's bicycle tire. The idea of giving Azelia's family a bike tire that is common on the market was ideal in case anything was to happen in the future where it would need to be replaced.

However, multiple concerns arose from using a pneumatic tire. One concern was pinching. If the tire were to have a tube inside, it could easily be pinched and go flat. In order to avoid this, the team decided to move forward with a tubeless bike tire. However, another concern was the tire slowly going flat over time. Regardless of tube, a flat tire could be catastrophic. For example, if Azelia was at school when her tire went flat, her walker would be completely unusable and she would have to have assistance with her mobility until the wheel was replaced.

Understanding that pneumatic tires could cause disastrous results led the team to other tire alternatives. It was clear from the start that typical walker wheels would not suffice. The diameter would be too small and the materials too stiff to allow any give for getting over small obstacles without additional force from Azelia. This brought the team to a filled or flat free tire (Figure 18). A filled tire would accomplish a larger diameter and all-terrain features, while reducing the maintenance in the future. There are a variety of options for choosing this type of tire; foam and polyurethane for example. Upon researching foam filled options, a multitude of concerns arose. One of these was price. Many foam filled tires that seemed promising (lightweight, all-terrain, the right diameter) were very expensive and would require extra cost to ship or order them directly. The team was also concerned about purchasing a tire that was unfamiliar and that the team would not have adequate time to change the walker design if the flat free tire did not accomplish the specifications. Another issue with the majority of filled tires was that most did not come with a rim. In order to finish this project on time and with the most reasonable amount of fabrication, having to order the tire rim separately and install it on our own was not ideal.

Figure 18: AMERITYRE All Terrain Flat Free Tires

While researching beach wheels, as further described, on Wheeleez.com the team came across a 10in. diameter solid foam wheel, seen in Figure 19. This wheel, upon further inspection, weighed only 9.5 ounces. Other filled tires were usually between 10 to 20 ounces. Additionally, this wheel came with a rim. Although the first design idea for the walker was to use a 12in. diameter wheel, the team came to the conclusion that 10in. would suffice in overcoming obstacles. Using a slightly small diameter wheel would also give the benefit of more collapsibility. This 10in. EVA Solid Foam Wheel created by Wheeleez is the wheel in the final design because it meets the all-terrain requirements while minimizing size and weight, ultimately allowing the best possible collapsibility.

Figure 19: Wheeleez 10in EVA Solid Foam Wheel

An additional idea to aid in safety is to attach an additional bar with a small wheel to the back wheels of the frame. This would keep Azelia from tipping backwards, but still allow for backwards movement of the walker, which Azelia uses when turning (see Figure 20). This concept is available on other walkers, but her current walker has an L-shaped metal bar that catches on obstacles during regular gait. This feature is critical in the safety and maneuverability of the walker.

Figure 20: Anti-Tipping Wheel

Table 3: Decision matrix for sand maneuverability concept ideas

Criteria	**Weighting (1-5)**	**12.5" Balloon Wheels**		**Skis for Wheels**	
Portable	3	0	**-3**	-1	**-3**
Sand	5	1	**5**	0	**0**
Ease of Use	4	1	**0**	0	**0**
Ease of Installation	2	-1	**-2**	0	**0**
Durability	4	0	**0**	1	**4**
Total	-	-	**0**	-	**1**

After continuing to research ideas for the walker to be able to traverse sand, the team was conflicted between interchangeable beach tires or a wheel attachment that resembles a ski (Figure 21). Per Table 3, our decision matrix showed that these options were nearly equivalent benefits. In the case of using the Wheeleez beach tire (Figure 22), the team would need to develop a tire-swapping mechanism, and provide Azelia's family with four Beach tires. The Beach tires were concerning due to the fact that they would require a tire-swapping mechanism; something the team would have to design and fabricate. Additionally, since the tires are pneumatic, there is the concern of them deflating or popping.

There are several companies that design skis for wheels which are used on wheelchairs and strollers. One company that the team is in contact with are WheelBlades. WheelBlades offer relief from the fear of pneumatic tire maintenance. The WheelBlades are also more travel-friendly as they would not require an air pump to install and are easily able to be installed on wheels without additional tools. The main concern with WheelBlades is that turning on sand will be difficult. However, this is something the team will test rigorously upon arrival of the parts.


Figure 21, 22: WheelBladesXL, Wheeleez Beach Tires

4.3 Seat:

Designing a seat that would be out of the way during walking, but also provide Azelia with comfort for a longer rest when she chooses to sit down was clearly conflicting. Additionally, the seat could not interfere with collapsing the walker. *Azelia's Walker* had agreed that this seat should be much larger than her current walker seat and also include a back to the seat. With both of those aspects, it would increase the comfortability exponentially.

One initial idea was to have the seat be two pieces, one on each side. They would be stored on the side of the walker then folded up into the middle and connected to make a full seat.

Figure 23: Walker with foldable seat[16]

Another idea generated was to make the seat out of a more compressible material, such as canvas (see Figure 23). This would give the team flexibility with collapsibility and storage during walking, however it could potentially compromise the comfort of the seat. This is something the team will test for in the future. Figure 24 shows a walker with a canvas seat. The canvas could also be used as a backrest for the seat.

Figure 24: Walker with canvas seat

4.4 Arms:

For the walker design, the arms of the walker play a key role in not only supporting Azelia's weight, but also providing height adjustment. By incorporating adjustable arms, the walker can grow with Azelia for at least five years. One important detail focused on during the design of the arms was to ensure that the adjustability of the arm would be independent of collapsibility. This way the user would not have to re-adjust the height every time they went to fold or unfold the walker.

The initial design solution incorporated the use of telescoping bars, similar to ones used on adjustable tables. Figure 25 shows an example of a telescoping bar, while Figure 26 shows the conceptual design for telescoping arms before further changes to the design were incorporated.

Figure 25: Telescoping bar[17]

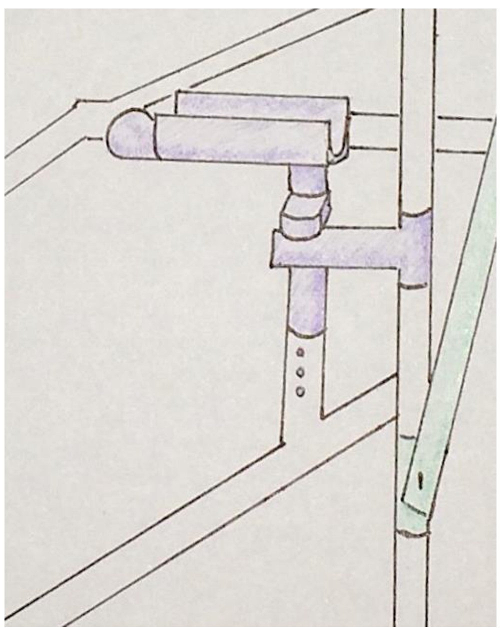


Figure 26: Telescoping bar in concept design

Upon further research into the feasibility of fabrication for telescoping arms, it was discovered that telescoping bars require tight tolerances making fabrication of those bars a high risk for failure. The team attempted to find stock telescoping bars on the market but was not able to do so. As a result, a re-design of the bars took place. The final solution replaced the telescoping bars with a parallel clamp mechanism. The system is comprised of two bars in parallel, one rigidly attached to the frame and the other supporting the arm rests. Two clamps will join the parallel bars and can be loosened with an Allen wrench to adjust the vertical height of the arm support bar. Figure 27 displays this new design solution.

Figure 27: Parallel Clamp Adjusting Bars

4.5 Armrests:

Figure 28 depicts the conceptual design for the armrests. Azelia currently uses the U-shape for her forearms and prefers this armrest to the other armrests she has had in the past. Because this is something the team already knows she likes, the design was kept the same. Additionally, her current walker has handles at the end of the armrest, which Azelia does not like or use often. She cannot grip the handles easily and therefore rarely uses this.

To give Azelia something she would have an easier time grasping, the team designed an ergonomic ball-shape at the end of the armrests. The goal is that she could rest her palms upon the ball-shape to help with her stability and with maneuvering the walker. Figures 29 and 30 show a prototype constructed and carved out of a swimming pool noodle that was testes with Azelia to determine the optimal shape and size of the handle.

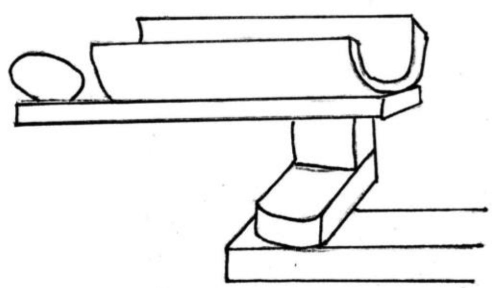


Figure 28: Armrest concept

Figure 29 and 30: Prototyping walker handle designs with Azelia

4.6 Communication Device Holder:

Because Azelia requires her communication device to communicate with others frequently, it was very important to design a walker for her that would allow her to use the device while sitting. The team also wanted to make sure this design would be something that would not interfere with the collapsibility. One concept the team had was to purchase or create something similar to an iPad clamp. This would be a simple way to attach it to the walker, as well as give Azelia the freedom to move it to a location where she would be most comfortable using it.

After researching many iPad or generic device mounts, it was concluded that the majority of mounts would not be acceptable to hold Azelia's communication device. Her device is heavier and has a greater depth than most iPads. However, a promising device, called the TabGrabber, was found and is seen in Figure 31. This device has specifications that allow it to hold the dimensions and weight of Azelia's communication device. Additionally, the connections to the corners of the tablet utilize bungee cables and small plastic pieces, which will help with adjusting to fit her communication device size. In the event the device is not perfectly suited for Azelia's communication device, the team will be able to adjust the original design using 3D-printed parts and/or basic tools from a hardware store. Figure 32 displays how Azelia uses her communication device while seated.

Figure 31: TabGrabber

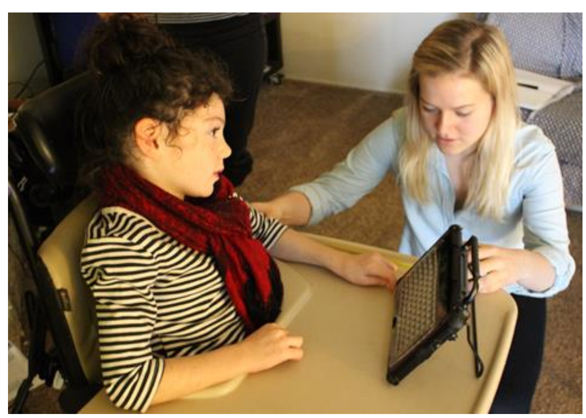


Figure 32: Taking Measurements of Azelia

5.0 Description of Final Design

5.1 Overview

The final design of *Azelia's Walker*, pictured in Figure 33, is comprised of a horizontal collapsing mechanism, folding legs, a folding seat, adjustable armrests, and a communication device holder.

Figure 33: Isometric view of final design

The horizontal collapsing mechanism was designed to collapse in one step. A pull of the top horizontal bar handle causes the mechanism to fold as shown in Figure 34. All folding points will be assembled together with hinges and hard stops to ensure the mechanism stays in the desired position.

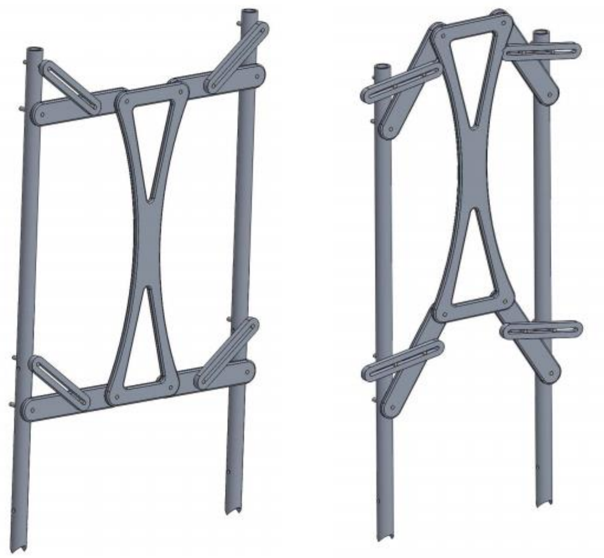


Figure 34: Walker collapsible accordion back state diagram

To ensure that the final design is compact enough to meet requirements, the legs are designed to fold into the body of the walker when being transported. Both legs will fold back as shown in Figure 35. The legs will be connected to the walker frame by rotating Variloc hinges with a limited range of motion. The hinges will lock into place with a hard stop to ensure that they are positioned correctly for use.

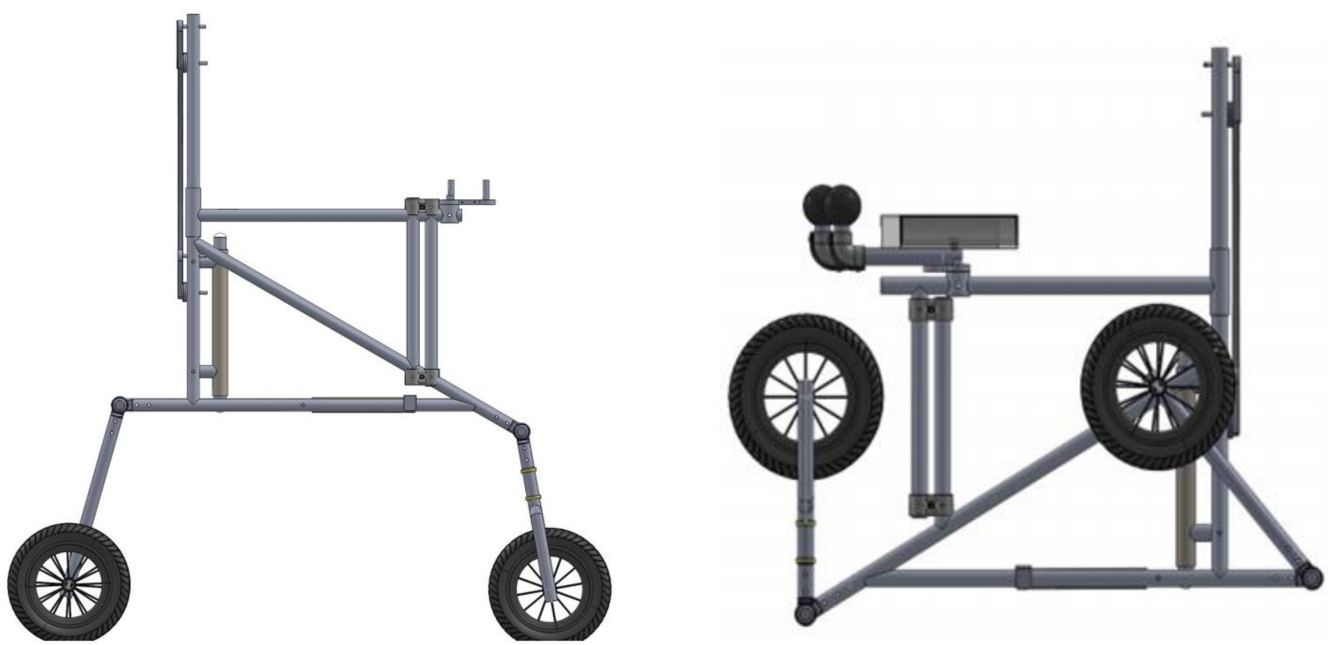


Figure 35: State diagram of walker wheel collapsibility

The armrests (Figure 36) will adjust in height using parallel clamps to accommodate the customer as she grows. Multiple pivots will be used to allow armrests to adjust forward and inward in a rotating motion. The armrest component will be fixed to the parallel bars and attached to the back of the frame with sliders to allow vertical movement when height adjustments are made. The horizontal bar

Figure 36: Armrest design

The seat is designed for both comfort and functionality (Figure 37). The seat will be made out of a sturdy mesh material that is sewn onto aluminum tubing. To keep the seat back from interfering with the back collapsible mechanism, spacers will be welded onto the vertical bars of the back seat support. These spacers will then be mechanically fastened to the frame. To not interfere with the welded spacers, the mesh fabric will be sewn and then laced over the back of the supporting bars. The mesh material of the seat will allow the seat to fold as the walker collapses. The bottom of the seat will be attached with pivots to allow the seat to fold up while in use to ensure that Azelia has plenty of room to walk. Seat drop hooks (Figure 38) will be fastened onto the middle of the bottom seat frame bars which will allow the bottom seat to be supported by the horizontal frame bars and avoid a cantilevered system. Calculations for the beam analysis of the seat were conducted and located in Appendix E.

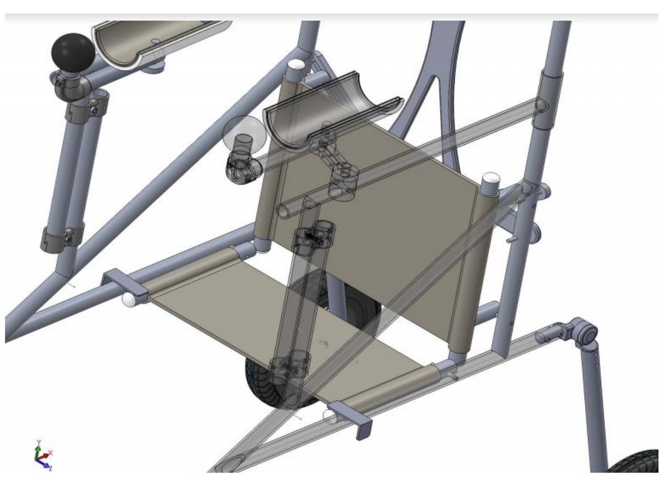


Figure 37: Seat design

Figure 38: 1" Drop Seat Hooks

Azelia will not be using her communication device while walking, thus the communication device holder can and will be folded away while the walker is being used for mobility. While Azelia is sitting on the walker seat, the communication device holder will be pulled from the side of the walker and provide easy access for the communication device. Azelia works best with an angled surface; therefore, the device holder will be angled to allow the most comfort while being used. The communication device holder will be designed and modified by Joel Hitchen from Mob Armor, a mobile tech company based in Santa Maria, with the assistance of the team. Figure 39 shows current Mob Armor products which are similar to the final mounting device that the team will use. This mounting device will allow adjustability of where the mount can be placed on the frame as well as being able to hold Azelia's unique tablet.

Figure 39: Mob Armor current products

5.2 Design Justification

In order for this design to be successful, it must meet all customer requirements, so the design is multifaceted to accommodate the requirements set by the customer.

Frame:

In order to fabricate a walker that could support Azelia's weight, the frame has a center triangle design. A drawing of the frame can be found in Appendix C. The frame consists of four aluminum tubes welded together, three to create the triangle support and a fourth that serves as the point of attachment for the walker arms.

Back Hinge Mechanism:

In order to design a walker that would meet the collapsed size requirements the team needed to find solutions that would allow both the width and the height of the walker to decrease. For the width of the walker, the team chose a design similar to the accordion style previously mentioned because of its simplicity and ease of use.

The walker will primarily collapse in the horizontal direction. The design that was chosen due to the simplicity of collapsibility for the user. With a single pull in the upwards direction, the width reduces to approximately half of its original size. The design also supports the top and bottom halves of the walker and holds the two halves together. This will be a place of significant stress. This design only needs four points of connection per bar. The brackets used to mount the back mechanism to the frame were chosen to reduce the degrees of freedom created by mounting the flat horizontal bars to the round tubing of the frame. There were also slots added to the corners of the center back bar that the horizontal bars slide into before being bolted. This allows the horizontal bars to move freely in the vertical direction while having support in the front and back directions. The goal of this is to reduce the amount of walking that the bolts do while the walker is in use. An overall drawing of the back mechanism and individual part drawings can be found in Appendix C.

Wheels:

After safety, the primary goal of the design was to allow Azelia to have more independence by allowing her to go over more terrain. The wheels chosen are 10in pneumatic tires. The large diameter will allow the tires to overcome small obstacles while still being small enough to be collapsible. The size was chosen in order to increase the clearance of going over obstacles. The size had to be a balance between being too large and interfering with Azelia's feet as she used the walker and large enough to traverse over larger obstacles; the larger the wheel the smoother the path of the walker over any given obstacle.

Front Legs:

In order to make the walker maneuverable, the front legs need to swivel. Given the large wheel diameter, the team opted to make a custom caster as casters on the market for 10-inch wheels are fairly heavy and rated for 500-1000 pounds, a rating significantly stronger than this design requires.

The custom caster is made from three pieces of sheet metal, a tube, and a bike headset. A headset, simply put, is two bearings that allow a larger diameter tube to rotate around a smaller diameter tube. The front legs are welded to the larger diameter tube that will swivel about the smaller tube connected to the sheet metal. The wheels purchased have built in bearings, a bolt and spacers are used as an axle for the assembly. Figure 40 below depicts the front wheel subassembly.

Figure 40: Front Wheel Subassembly

Back Legs:

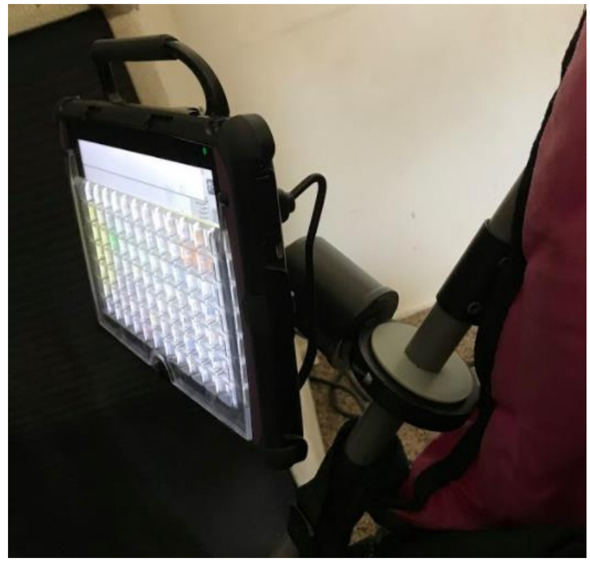
The back legs of the walker serve to help maintain balance and stability of the walker during movement. As the back legs did not need to swivel, like the front legs, no bike headset was required. The back leg sub assembly comprised of the aluminum tubing from the frame, a custom attachment piece, a wheel shaft, spacers, and the wheel which includes ball bearings. These parts were chosen for their simplicity as well as efficacy. The custom attachment piece served to connect the 1" diameter frame tubing to the ½" inch diameter wheel shaft.

Seat:

The seat is meant to be a way for Azelia to be able to rest safely and comfortably while out and about. The current design for the seat was chosen for its ability to collapse with the walker and to be stored away while the walker is in use. With the drop hooks mounted in the middle of the seat, this will allow the seat to be able to lift out of the way when it is not in use. The incorporation of a back support allows to the seat design will allow Azelia to have trunk support which improves upon her current walker's seat which is a small hard rubber seat with no back support.

Communication Device Holder:

The communication device holder will be a customer modified device from Mob Armor. The mounting device will be able to hold Azelia's communication device so that she can use it while sitting in the walker. This device is made up of three primary components: frame attachment, rotational joint, and the device attachment. The frame attachment is a two piece shaft collar held together by two set screws. Inside the collar is a firm plastic that is able to grip onto the aluminum tubing of the frame. The rotational joint is able to be adjusted so that the difficulty of rotating the joint can be increased or decreased. This allows the user to easily move the joint to the desired location then tighten to keep it in place. The device attachment is a small place that is bolted into the back of the communication device using the existing bolt pattern on the device. On this plate is a Mob Armor attachment piece that easily fits onto the rotational joint. Azelia's device can be seen attached to the communication device holder/mount in Figures 41 and 42.

Figures 41and 42: Azelia's communication device attached to the tailored Mob Armor tablet mount

5.3 Analysis

As seen in Appendix E, the team performed a simplified Finite Element Analysis on the frame in order to predict deflections. 60 pounds was applied at the end of each of the armrest supports and the location of the wheel axles were fixed as boundary conditions. This was a good way for the team to understand where the most deflection would occur. It is important to note that the total load applied was 120 pounds, which is heavier than the client's predicted weight at 13 years old (5 years after the client will receive her walker). The FEA yielded the following results:

Maximum Stress: 9055 psi
Maximum Deformation: 0.055 inches

The frame will be fabricated with 6061 aluminum alloy, which has a yielding stress of 35 ksi, well below the maximum stress the FEA analysis produced. According to the analysis, the largest deflection will occur where the load is applied, which is 0.055 inches. Further analysis will be performed on the back collapsing mechanism to ensure that the slotted hard stops will not fail under loading; currently the walker hinge is over designed with ¾ inch aluminum plates to withstand extreme loading conditions.

5.4 Cost Breakdown

The manufacturing of the walker was estimated to cost $2,230.21 which can be seen in Table 4 on the next page. The overall cost of the walker came out to $2,476.25 as seen in Table 5. Vendor information for the specific items selected are located in Appendix D: Vendor Information, Specifications, and Data Sheets. The items in the cost estimate and breakdown that equal zero dollars are parts or labor that have been donated to the team.

At the beginning of the project, the team submitted a proposal for interdisciplinary project funding through CPConnect. The proposal was accepted and the team was granted funding. A rough cost estimate was created for this proposal but a more detailed and accurate cost estimate below showed that the team planned to spend more than the funding that was granted. The team also applied for and was granted additional funding from the Hannah-Forbes Project Fund.

Table 4: Bill of Materials/Cost Estimate

		Item Description	P.N.	Qty	Price per	Shipping	Total	Source
Subassembly	Armrest/Handles	Forearm Supports		2	$65.00	$0.00	$0.00	R82 Inc. - Crocodile Walker
		Ball-joint handles		2	$30.00	$0.00	$0.00	URise Products - StandUp Walker
		Aluminum Slip-on Rail Fitting, 90 Degree Elbow Connector for 1" Rail OD	4698T31	2	$10.03	$6.00	$20.06	McMaster Carr
	Collapsing Back	3/8" Thickness Aluminum Bare Plate 6061 T651 8X8		1	$21.00	$9.00	$21.00	www.onlinemetals.com
	Front Wheels	Set of 10" foam wheels		1	$18.00	$4.00	$18.00	Wheeleez
		Ball Barring - Double Sealed, for 3/16" Shaft Diameter, 1/2" OD	60355K861	4	$3.12	$6.00	$12.48	McMaster-Carr
		Variloc Heavy duty alloy steel locking hinges - 360 offset degrees rotation		2	$95.00	$20.00	$190.00	Adjustable Locking Techniques (ATL)
		Bike headset		2	$30.00	$0.00	$60.00	Amazon
		Children's bike fork		2	$40.00	$0.00	$80.00	Cyclery Foothill Bike Shop
	Back Wheels	Set of 10" foam wheels		1	$18.00	$4.14	$22.14	Wheeleez
		Anti-tip wheel, set		1	$160.00	$15.00	$175.00	R82 Crocodile walker
		Ball Barring - Double Sealed, for 3/16" Shaft Diameter, 1/2" OD	60355K861	4	$3.12	$5.00	$17.48	McMaster-Carr
		Heavy duty alloy steel locking hinges - 360 degrees offset rotation		2	$95.00	$25.00	$215.00	Adjustable Locking Techniques (ATL)
		Anti-reverse wheel locks		2	$40.00	$15.00	$95.00	R82 Inc. - Crocodile Walker
	Frame	6061-T6 Bare Aluminum Tube,1" OD X 0.125" - 8ft long		4	$45.98	$25.00	$208.92	www.onlinemetals.com
		1/4-20 Bolts, pkg of 50	1170005	1	$12.89	$10.00	$22.89	Fastenal
		Ribbed Finishing Plug for Tubing, Fits 1" Tube OD and 0.84"-0.95" Tube ID	9283K14	1 pack	$12.30	$5.00	$17.30	McMaster Carr
		Nylon bushings		20	$2.33	$11.65	$58.25	Igus
	Adjusting Arms	Dimart 1" Hole Dia Double Port Pipe Clamp Clip Lean Tube Connector		4	$3.90	$0.00	$15.60	Amazon
		6061 Aluminum Round Tube,1-1/4 OD x 0.065 wall x 1.120 ID - 2ft		1	$4.78	$16.31	$21.09	www.MetalsDepot.com
	Seat	Canvas material, 4yds		4	$5.00	$20.00	$40.00	
		Spacers, acrylic plastic bar stock		2	$11.00	$0.00	$20.00	Amazon
		Rivets, price per pack		1	$11.00	$0.00	$10.00	Amazon
Manufacturing/Labor		Welding					$0.00	Assisted by Professor Kevin Williams
		Water Jet Cutting					$300.00	Central Coast Creative Cutting
		Industrial Sewing					$50.00	Central Coast Industrial Sewing
		Powder Coating					$100.00	Central Coast Powder Coating
Miscellaneous		Communication Device Holder			$75.00	$15.00	$90.00	Safe T Mate - TG1 Tab Grabber
		Sand Skis					$0.00	Premier Ski - Stroller Ski
		Bike Rack					$250.00	Thule
		Prototype Material					$100.00	
						Total	**$2,230.21**	

Table 5: Final Cost Breakdown

Expenditures Description	Vendor	Category/Where Used	Cost
Raw Materials and Hardware			
Forearm supports	R82	Armrests	$0.00
Ball hand grips	URise Products	Armrests	$0.00
Skis for over wheels	PremierSki	Front Wheels, Back Wheels	$0.00
Honey-Can-Do Cart	Amazon	Prototype	$32.25
KneeRover Jr. 10 inch Replacement Pneumatic Wheel	KneeRover	Back Wheel, Front Wheel	$179.96
Variloc Heavy dutylocking hinges - 360 offset	ALT	Back Wheel, Front Wheel	$357.00
Uxcell 29mm Hole Double Port Clamp Tube Connector	Amazon	Armrests	$29.28
Clamp on frame fitting	McMaster-Carr	Armrests	$22.56
Dura-Ace Headset 7410	Shimano	Front Wheel	$186.98
Aluminum 6061 1" tubing	Valley Iron	Frame	$47.00
Crocodile Forearm Support 86860	R82	Armrests	$317.00
Crocodile Anti-Reverse Wheel Stop, set 86828	R82	Back Wheel	$38.40
Anti-tip device, swing-away, set 86815-3S	R82	Back Wheel	$149.00
Sheet Plate Metal and 3" Square Bar Stock	Onlinemetals.com	Frame, Armrests, Back Wheels	$439.28
Caster top plate metal, Arm adapter block metal, rod, stock tubing for sliding arms	Onlinemetals.com	Front Wheel, Armrests, Frame	$145.63
Tight-Tolerance 6061 Aluminum Rod 1/2" Diameter, 1 Foot Long	McMaster Carr	Back Wheel	$10.38
Stainless Steel External Retaining Ring for 1/2" Shaft Diameter, Packs of 10	McMaster Carr	Back Wheel	$17.01
Acetone and spray bottle	Rite Aid	Frame	$12.19
Sheet Plate Metal for back brakcets	Onlinemetals.com	Frame	$17.71
Nylon Tubing	McMaster Carr	Frame	$38.96
Nylon Tubing for spacers and shaft collars	McMaster Carr	Frame, Back Wheels	$70.31
Clamping Shaft Collar for 1" Diameter, 303 Stainless Steel	McMaster Carr	Front Wheels	$20.92
Friction-Lock Tag Rings 1-1/2" ID, Packs of 50	McMaster Carr	Front Wheels	$10.20
6061 Aluminum Round Tube 0.065" Wall Thickness, 3/4" OD, 1/2 Feet Long	McMaster Carr	Front Wheels	$5.89
Rotary Shaft 1566 Carbon Steel, 1/2" Diameter, 12" Long	McMaster Carr	Front Wheels	$17.44
Dremel bits	ACE Hardware	Frame	$34.43
Snap-in Round Plugs with Flexible Ridges, for 0.710" -0.820" ID, Packs of 100	McMaster Carr	Frame	$18.47
Fasteners	Fastenal	All	$258.00
Fasteners	ACE Hardware	All	$19.47
Poster board	Michaels	Poster	$11.63
Labor and Services			
Welding	Kevin Williams, Cal Poly IME Department Professor	Frame, Front Wheels, Armrests	$0.00
Water jet cutting	Central Coast Creative Cutting	Front Wheels, Frame, Armrests	$0.00
		Total	**$2,476.25**

5.5 Safety Considerations

Through completion of the safety checklist (Appendix G), safety concerns that are addressed in the design were identified. With the chosen concept of the back collapsing mechanism of the walker and the folding wheel legs, several possible pinch points are present. With this design the team accepts a reasonable level of risk and these pinch points are expected for the chosen design. As a similar design of an accordion front to a walker exist per research, the team believes that with proper training for users on how to collapse the walker safely and to avoid the pinch points then the issue of the pinch point safety will be adequately addressed.

6.0 Product Realization

6.1 Manufacturing Process

Successful completion of this project requires a functional prototype that Azelia can safely rely on for five years. As such, much consideration was put into feasibility of fabrication when designing all components of the walker. In addition, consideration was put into aesthetics as the client will be growing into her pre-teenage years with the walker and appearance was deemed fairly important. The planned fabrication and assembly of the walker has been broken down into subassemblies and tabulated in Table 6 below. Through the manufacturing process, several methods of manufacturing were adjusted due to feasibility of manufacturing, time constraints, and adjustments for error in manufacturing. These adjustments are further discussed in the next sections

Table 6: Broken down manufacturing plan

Collapsible Back	Collapsible Legs	Front Wheels	Back Wheels	Adjusting Arms	Armrests	Seat	Communication Device Holder
Raw Material Purchased	Raw Material Purchased	Raw Material Purchased	Raw Material Purchased	Raw Material Purchased	Raw Material Purchased	Raw Material Purchased	Purchased online
3/8" 6061 Aluminum sheet	Variloc locking hinges	Wheels, Bike Headset, Bike Fork Purchased	Wheels, Anti-Tipping Wheel/Bar Purchased	Hinges and Clamps Purchased	Parts Purchased or Donated	Canvas material, rivets, spacers	Can be installed upon final assembly
Work with Central Coast Creative Cutting to water jet cut the material	Hinges attached to frame and wheel subassemblies	Bike Headset and Fork Installed with Help of Foothill Cyclery	Bolt on Anti-Tipping Wheel	Water Jet Cut Rotating Components	Fabricate joint between adjusting mechanism and Armrest: Mill / CNC	Work with Central Coast Industrial Sewing on pattern	
Subassembly attached by welding to frame		Subassembly Attached to Frame via Hinges	Assemble	Weld Support Bar to Frame	Assemble	Use equipment to sew seat	
				Assemble		Attach via rivets to tubing. Attach to walker	

Frame:

The frame was fabricated with 6061 1"OD 0.75"ID aluminum alloy tubing, cut to size in campus machine shops. Rough cuts were made using a horizontal band saw, the tubes were then brought to exact dimensions on the lathes. In order to notch the tubes such that they would fit together for welding, a machine tool called a "Tube Shark" was utilized. The tube shark uses hole saws, selected to match the tubing diameter, to drill the notches.

The frame was then welded together with the help of Kevin Williams, an Industrial and Manufacturing Engineering (IME) Department Lecturer at Cal Poly. To ensure that the tubing would not warp or shift during the welding process, the frame was clamped together on a specialized table in the IME welding lab. This table allows for placement of clamps to create a custom welding jig with relative ease. Figure 43 on the next page shows the frame in the welding jig set up.

Figure 43: Walker Frame in Custom Jig

Holes in the frame were all marked after welding and drilled using a drill press. Toe clamps were utilized to hold the frame secure during drilling. Drilling holes proved to be harder than expected, as most holes did not drill straight through both sides of the tubing. During assembly the team had to enlarge the majority of the holes using a dremel in order to ensure that bolts would go through straight. Figures 44 and 45 show the frame set up in a drill press.

Figures 44 and 45: Frame in drill press for drilling holes.

Collapsible Back:

The collapsible back is fabricated from 6061 aluminum plate and sheet metal. Due to the curved design, the back cannot be cut using technology found in the shops on campus. To solve this a water jet cutter was used. Ian Goodyear of Central Coast Creative Cutting kindly donated his time and work space to help us water jet cut the back center bar, the horizontal back bars, and the slotted hard stops which can be seen fully assembled in figure 46.

Figure 46: Back assembly attached to the frame assembly

These pieces came out to the exact specification of the drawings sent to the water jet cutter. This is important to note since all the holes needed to be clearance fit and instead they were all too small. To correct for this the holes were all reamed out with a drill press and the slots in the hard stops were grinded down with a file or dremel.

The slots in the center vertical bar were made after the piece had been waterjet cut. The original plan was to mill out the slot, only to discover that the long drill bits weren't supplied by the shop. The team bought our own, only to learn that it is only feasible to remove around 0.002in of material on any pass without excessive chatter and risking breaking the tool. Since the depth of the slot was over 1.5in deep the team discontinued this method. Instead, the slot was made on a mill using a circular slotting saw. The process can be seen in figure 47**.** This process worked well, but it should be noted that the accuracy in the z-direction (the width of the slot) was fairly poor. The saw had a wobble in the z-direction that cut slightly more on the bottom then it did on the top. Luckily this didn't cause too much of a problem since the slot was small enough.

Figure 47: Circular Slotting Saw on a mill used to cut the slot in the center piece where the horizontal bars connect

The brackets attaching the horizontal back bars to the frame were originally intended to be milled out of a block of aluminum. Again, the team discovered that the long end mills were very slow to use on a manual mill. Instead the team used eighth inch aluminum sheet metal. This metal was cut down to size on a band saw (Figure 48) and the edges were ground down on a belt sander.

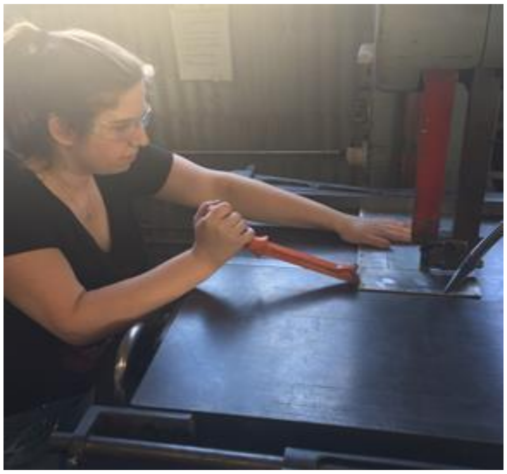


Figure 48: Cutting the sheet metal on a band saw for the back brackets.

Bending the brackets went through a few iterations and attempts. The first attempt to bend the brackets we choose to anneal the aluminum and then bend it. To anneal the metal an acetylene torch was used by first coating the metal in the black soot of the burning acetylene and then burning the soot off with an oxidized flame (Figure 49).

Figure 49: Annealing of the sheet metal using an Acetylene torch.

This failed because even after the annealing the metal was strong when cooled to bend. The second attempt was more successful. In the second attempt the two vice grips were attached to the piece of metal before it was heated. As soon as the metal was hot enough to just barely start bending, the piece was handed off to another group member to bend (so that the torch could be safely turned off). It was challenging to keep the bottom edges of the brackets parallel with each other. In order to bend the sheets, a piece of scrap tubing was put into a vice (Figure 50). This was then used to wrap the hot metal around. To keep the bottom edges parallel, the metal was held down against the vice as the metal was wrapped around the tube. For the most part this worked. The bottoms of the bracket stayed relatively parallel. The trouble was that the planes of the metal being wrapped around the pole also had to stay parallel (this was determined by the amount around the tube that the sheet was wrapped). This rarely come out parallel enough.

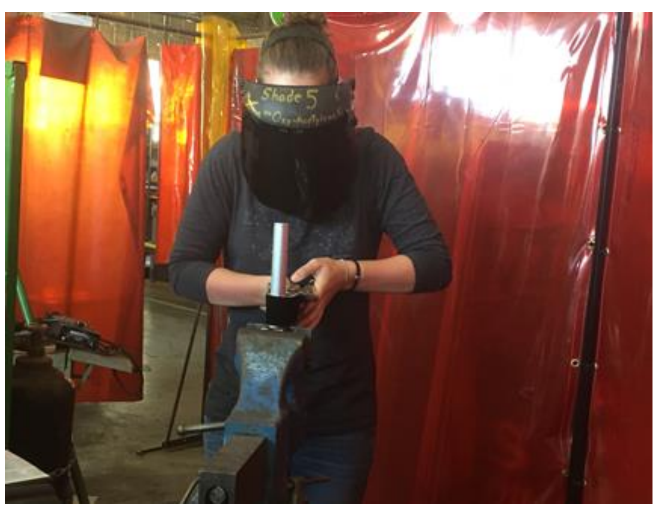


Figure 50: Set-up to bend the back brackets. One inch tubing is held in the vice while the metal sheet is held by two vice grips.

The breakthrough came when the team put a one inch square of wood inside the bracket with the tube and clamped it down using a vice. This forced the gap in the bracket to be exactly one inch while maintaining the one inch diameter bend to fit the tube.

The spacers were made of a machine-able nylon tubing. They were bought oversized to have a clearance fit around the bolts. A lathe was then used to part the tubing to the appropriate length sizes. Troubles arose when trying to maintain parallel surfaces. The tools were too dull to get an accurate cut, so the nylon ended up deforming quite a bit and ended up with slightly rounded faces. Spacers for the back mechanism and brackets were made from the stock nylon tubing. The nylon tubing inner and outer diameters were turned down and then cut to length as to make custom spacers. The spacers can be seen implemented in the final design in Figure 51 below.

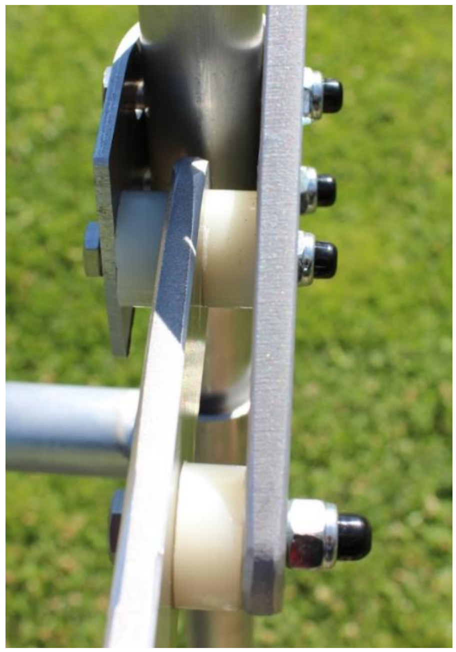


Figure 51: Spacers on the back mechanism

Front Legs:

The legs were fabricated using the same 6061 1"OD 0.75"ID aluminum tubing. Similarly to the frame, bars were rough-cut to dimensions using a horizontal band saw then brought to specified dimensions using a lathe. The most difficult part of fabricating the front legs was bending them. The team opted to curve the front legs for ease of attachment to the headset as well as for aesthetics. Given that the tubing was relatively thick, it took some muscle power to bend them. The two front legs were placed side-by-side in a vise grip, then annealed using an oxy-acetylene torch in order to soften the metal. After annealing the tubing, it was heated up again with the oxy-acetylene while simultaneously being bent with the help of a generous shop tech. Figure 52 and 53 below shows the front legs being heated and in its final bent shape.

Figure 52: Team member Jayne heating up the front legs, the black layer of ash was used as an indicator that the metal had been annealed.

Figure 53: Bending the front legs

The three pieces of the caster were fabricated using a water jet, then welded together by Mr. Williams. Figure 54 depicts the welded caster assembled with wheels.

Figure 54: Welded and Assembled Front Caster/Wheel

Back Legs:

The main focus of manufacturing for the back legs was creating an attachment piece that would connect the 1” diameter frame tubing to the ½” inch diameter shaft. This part was initially designed to be CNC milled, however, due to resource constraints, it was manually milled. The part began as stock aluminum and was cut down as much as possible using a horizontal bandsaw. After that, the piece was put on the mill in order to take off a large portion of material, giving the block an “L” shape. This could have been done on a vertical bandsaw to save time, however the mill provides much more consistency and precision. Next on the mill, the following holes were drilled: 1” diameter press fit, ½” inch diameter press fit, and a total of 4 1/4:” diameter clearance holes. Figure 55 depicts milling of the stock aluminum.

Figure 55: Team member KC Balfour milling stock aluminum to create the frame-to-shaft attachment piece for the back wheels

The 1” diameter frame tubing was press fit into the attachment piece. This tubing was carefully clamped and the holes for the bolts were drilled into the frame tubing with the drill press and using the attachment piece as a guide.

Next, the ½” inch shaft was press fit into the attachment piece. Similar to previously, the tubing, shaft, and part were carefully clamped and the bolt holes were drilled into the shaft using the holes in the attachment piece as a guide.

After the tubing and shaft were bolted into the attachment piece, the spacer and ball bearings of the wheel were press fit onto the shaft. A collar was added onto the far end of the shaft as a safety measure in case the press fit between the ball bearings and shaft were to fail. The final back wheel assembly can be seen in Figure 56.

Figure 56: Final back wheel subassembly

Front and Back Wheels:

All components of the front and back wheels were purchased. The wheels are 10 inch pneumatic wheels purchased from KneeRover as a replacement part for the company's KneeRover Jr. child's all-terrain rollator.

Arms:

Both arm components are attached to the frame in two locations. The arm component consists of vertical aluminum tubing clamped to an additional vertical tubing that is welded to the frame. These clamps allow the arms of the walker to be adjusted vertically for Azelia's growth. The parallel clamps were purchased from McMaster-Carr and specifications for the clamps are available in Appendix D. The vertical bars of the arm components were welded to horizontal support bars. The horizontal bars were welded to 2.5" vertical aluminum tubing with an inner diameter of 1.245" and a wall thickness of 0.065" to allow the arms to telescope (Appendix C: Arm, Part, Inside Telescoping). Nylon tubing was cut to size to fit in between the larger diameter vertical bar and frame tubing to allow the arm bars to slide easily vertically, as seen in figure 57. The nylon tubing was turned down using a lathe to fit into the larger aluminum tubing before finally being epoxied on the inside of this larger tubing.

Figure 57: Telescoping arm connection

To attach the armrest components to the walker, an arm connector adapter piece (Appendix C) was manufactured. A round 2" diameter stock of aluminum was turned down in the lathe on both sides. The part was placed in a rotary vise and a mill was used to center the part. A ¼ inch hole was drilled in the part before increasing the diameter of the hole to 1 inch. The vise was rotate 90 degrees and smaller holts in the side of the part were drilled for bolts to fasten the part onto the horizontal tubing of the arm component. This part was then inserted in a hole on one end of the arm connector piece which allows the armrests to pivot. The arm connector piece, seen in Appendix C, was water jet cut and then two holes were drilled in the side of the part using a mill. The final manufactured part can be seen in figure 58. These holes allow machine screws to tighten the slot cut into the middle of the part and clamp the parts fitted in the piece. A design flaw that occurred was the arm connector piece was cut so precisely by the water jet that the slot was too small; the part did not have enough clamping force to completely allow the armrests to not move when moderate force was applied. The armrests were able to be moved when the connector piece was clamped the tightest. Unfortunately, due to how small the slot in the part was, a file was not able to be used and the slot could not be widened.

Figure 58: Arm connector in final assembly

As Azelia needs a specific forearm support and hand grip, the team needed to specifically purchase or obtain these aspects of the walker. The U-shaped forearm support was donated from a company called R82 that designs pediatric walkers as well as the additional plastic bottom attachments were purchased. The ball handgrips were donated from URise Products and the handgrips are used on their StandUp Walker. Further information on these products is listed in Appendix D. To attach the arm connector to the forearm supports, the cylindrical end of the forearm support attachment needed to be filed and edges rounded as seen in figures 59 and 60. Forearm support component also included a smaller aluminum tubing with a hand grip what was cut to size with a vertical bandsaw. The ball hand grips were attached using epoxy putty and additional epoxy once dry as seen in Figure 61.

Figure 59: Forearm support from manufacturer, Figure 60: Filed part to fit into the arm connector

Figure 61: Arm component of final assembly

Seat:

The team discussed and planned the fabrication of a custom seat for Azelia's Walker with the company SLO Sail and Canvas. However, due to time constraints and the realization that the walker was not safe for the user, the team decided to not complete the seat fabrication. The bottom and back bars of the seat were already cut to size, the spacers on the back bars were welded, and the seat bars were mechanically fastened to the frame. For Senior Design Expo, a cloth seat was sewn to demonstrate how the seat would be folded up as seen in figure 62 and down in figure 63.

Figure 62: Full walker final assembly with seat folded up

Figure 63: Seat folded down for use

Communication Device Holder:

The communication device holder/mount did not require a lot of manufacturing on the team's part. However, the team worked closely with Joel Hitchen from Mob Armor in order to provide the necessary information. While the frame attachment, rotational joint, and tablet mount are current Mob Armor products, a custom plate needed to be designed so that the table mount could be mounted to Azelia's unique tablet. Figure 64 shows the dimensions necessary to create a custom plate that utilizes the bolt pattern on already on Azelia's tablet. With these dimensions, Joel was able to produce a small plate that bolts into Azelia's device as well as the existing Mob Armor mount. It is important to note that this plate is small enough to not interfere with any other use of the tablet so that Azelia does not need to remove this plate regardless of using the Mob Armor mount.

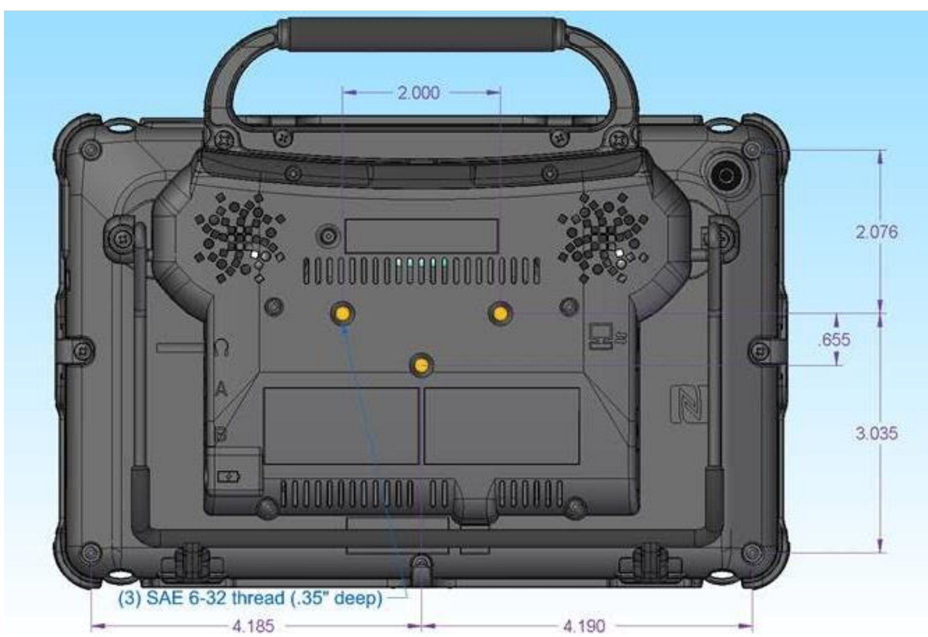


Figure 64: Dimensions of Azelia's communication device required to complete communication device holder/mount

Joel provided the team with a frame attachment that was meant for a ⅞" diameter. This was too small and was unable to fit on the frame appropriately. To fix this, we took the frame attachment piece and used a drill press to ream out the center hole. This created a nice press fit of the hard plastic to the 1” frame tubing. The entire communication device holder/mount can be seen in figure 65 below.

Figure 65: Custom Communication Device Holder/Mount, from left to right Mob Armor tablet mount, rotational piece, and frame attachment.

6.2 Divergence Between Final Design and Prototype

Frame:

The frame was one of the components that did not diverge significantly from the final design. The only difference was due to error on the team’s part. The tubes used to support the arms were cut to a length longer than specified on the CAD, which ultimately led to the height of the arms being too tall for Azelia’s dimensions. This is an easy fix, as the tubes can be cut to specified length with a hacksaw or power saw and clamps to secure the frame in place. Also, the team had specified that the final walker would be powder coated pink per the client's wishes. A company called PowderCoating USA in Paso Robles, CA had agreed to donate the services of powder coating the walker. Once it was realized that the walker would not be given to the client due to safety reasons, the team did not pursue finalizing the powder coating of the walker.

Collapsible Back:

The back was relatively unchanged from the CAD model. The only change was that the back brackets do not have curved edges since they were not made on a mill. The tolerances were also all too tight so all the holes with bolts in them were reamed or filed out.

Back Legs:

The back legs of the final product do not differ greatly from the CAD model. However, there were components of the back legs that did not make it to the final design for various reasons but were highly desired and considered.

During the design process, the team wanted to use a small bar with a wheel in order to prevent the walker from tipping over backwards. One of these was purchased from a walker company and only needed to be bolted into the frame of the walker. The issue that arose with this was that the frame that the part would need to be bolted into needed to be completely vertical. However, the final design of the frame has the back legs at an angle. This issue was not resolved due to lack of time and resources, as well as the walker being heavy enough that the likelihood of tipping backwards was extremely low. The second issue that differed from prototypes was a brake. The brake was seen as a necessary safety feature and is common among almost all current walkers on the market. Issues with designing for the brakes were that Azelia would be unable to use them herself and that the team was concerned with the extra weight and complexity of the walker as is. Thus, our prototypes and CAD models included using a simple anti-reverse lock as a means of a brake. The part that was purchased can be seen in Figure 66. This part was purchased because it had a clamp that was expected to fit onto our frame. However, upon receiving this part and testing it with the assembly, it was clear that this part would fail quickly. Because the wheels are much thicker than the R82 Crocodile (the walker that this part belongs on), the anti-reverse piece itself was not thick enough to match the width of the wheels and provide enough friction force to keep the wheels from turning. Additionally, because of the larger width of the wheels and the frame-shaft attachment piece, the anti-reverse piece would need to be on a cantilever in order to be placed on the center of the wheel. Lastly, the clamp that originally came with the part would not be able to be used because it is plastic and the team feared that attempting to modify the original clamp would permanently damage and/or shatter it.

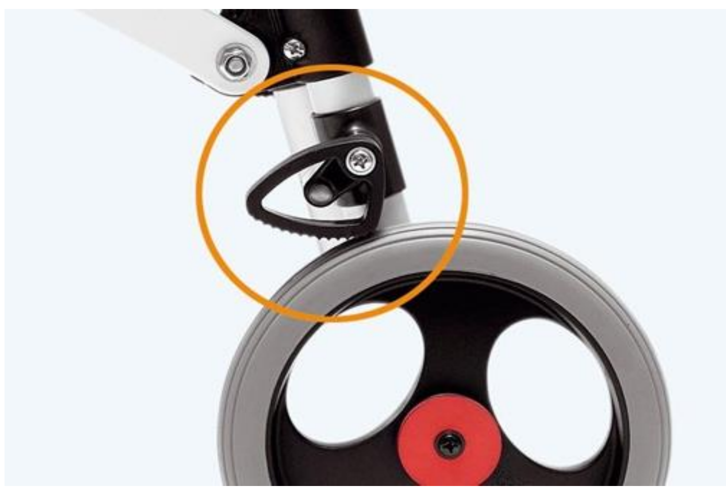


Figure 66: R82 - Crocodile Walker, Anti-Reverse Wheel Stops

Arms:

Due to taking dimensions specifically from the CAD and not double checking the measurements of the previously welded frame piece, the parallel vertical arm bars (Figure 67) were not the correct distance between each other. Originally, one clamp would be used on the top and bottom of the bars to clamp a bar to the bar directly next to it. To adjust for this spacing, additional clamps, which were extras the team had received, were used to attach a small spacer tubing to be clamped between the parallel bars. The clamps were meant to be an easy way for Azelia's family to adjust the height of the walker as Azelia grows. Due to the extra clamps needed and tube spacers, adjusting the height is more difficult.

Figure 67: Parallel arm bars

Seat:

Due to safety reasons of the final prototype, the team chose to not finish having the seat sewn onto the walker so as not to use additional funds for a part of the walker that would not be usable. The seat material was not sewn onto the seat bars nor the drop hooks fastened as the hooks arrived too late for Senior Design Expo.

Communication Device Holder:

There were no large design changes in this aspect of the assembly. This is due mainly because this part was outsourced to Mob Armor.

7.0 Design Verification

7.1 Specification Verification:

To ensure that the walker meets all specifications, testing that adheres to the ISO standards will be performed. This is further outlined along with an example of ISO load testing diagrams below in figure 68.

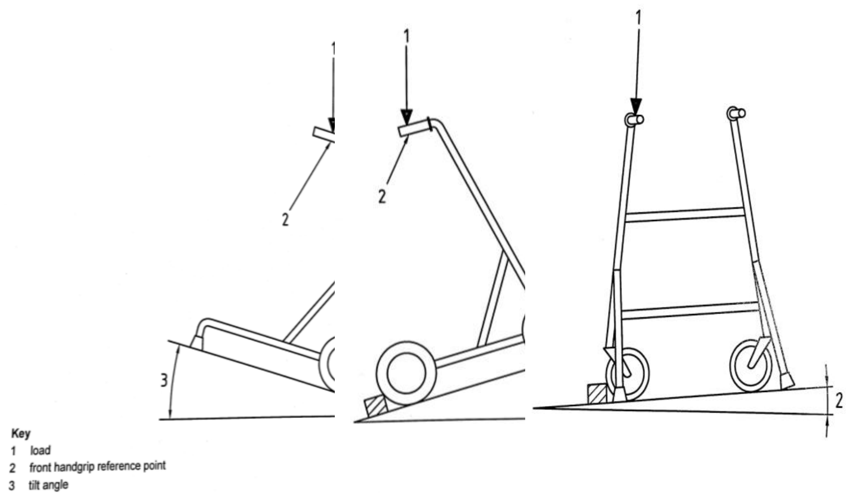


Figure 68: ISO load testing of a walker

ISO 11199-1:1999(E), 11199-2:2005(E) - Walking aids manipulated by both arms - Part 1: Walking Frames, Part 2: Rollators

- Stability
  - Test Performed: Each member of the team put their full body weight on the stationary walker.
  - Result: Did not move/wobble - PASS
- Materials and Finishing
  - Test Performed: No skin discoloring, burrs, sharp edges (PASS/FAIL)
  - Result: PASS
- Marking and Labeling
  - Test Performed: Maximum weight, maximum length of bars
  - Result: N/A - As the final product is not being given to any user, no labels were added.
- Load testing
  - Test Performed: Each member of the team put their full body weight on the walker at rest and while in motion.
  - Result: Walker did not fail - PASS
- Force required to move walker
  - Test Performed: Members of the team subjectively quantified whether it was easy or

difficult to move the walker from rest to motion.
- Result: Team members agreed it was easy, however this was subjective - UNABLE TO DETERMINE

Additional Tests

- Sitting load
  - Test Performed: Put weights on the seat for 30min and test for displacement, cracks, and any failure in seat or walker frame
  - Result: UNDETERMINED. As the final seat was never implemented onto the final design this test was unable to be completed.
- ADA Compliance - 32 inches wide
  - Test Performed: Take the walker through doorways, accessibility ramps
  - Result: The walker was capable of clearing standard doorways and traveling down the slope of accessibility ramps (Figure 69). Although clearing standard doorways, the back wheels often hit the door unless walking through the doorway perfectly straight. This is due to the larger width of the walker than planned. This can be seen in figure 70 below. - PASS BUT COULD BE IMPROVED


Figure 69: Testing Walker on ADA ramp, Figure 70: Walker through a doorway

- Test for all-terrain
  - Test Performed: Team members used the walker around the Cal Poly SLO Campus.
  - Result: Pavement and grass were easy terrain for the walker to travel over but switching from one terrain to another proved more challenging (Figure 71) - PASS BUT COULD BE IMPROVED SIGNIFICANTLY
  - Test Performed: Sand ski attachments for wheels were fitted and tested with Azelia’s old walker on the beach. The testing team member placed their full weight on the walker when pushing the walker through the sand. The walker and skis performed well on the sand as seen in figure 72. - PASS
  - Result: Sand skis proved a sufficient wheel attachment to make the walker beach-accessible.

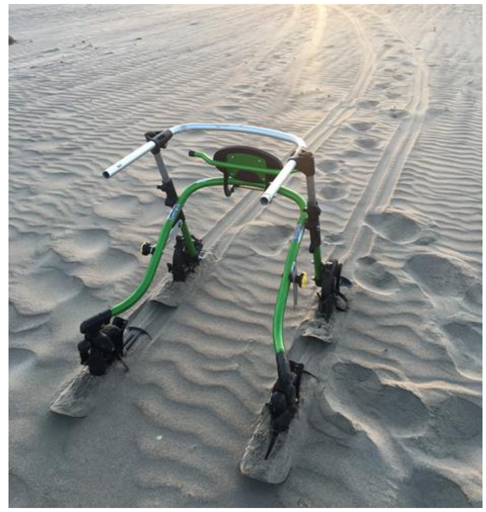


Figure 71: Testing walker on multiple terrains, Figure 72: Testing skis on the beach

- Ergonomic/comfort test with Azelia
    - UNABLE TO DETERMINE - As the final product is not being given to any user, the team was unable to test this with Azelia
- Ease & User-Friendliness of Collapsibility
    - Test Performed: Varying amount of team members collapse the walker to its minimal size and quantify the ease in terms of persons required
    - Result: The final design required four separate hinges to be folded, one for each leg joint. This proved to be cumbersome for folding, taking a minimum of 5 minutes to collapse and open up again as seen in figure 73. - DOES NOT PROVIDE EASY USE
- Collapsibility/Prius test
    - Test Performed: The walker was collapsed and fit into the back of a Prius as seen in figure 74.
    - Result: PASS
- Arms range of motion
    - Test Performed: Confirm the arms have an 8-inch vertical range of motion
    - Result: FAIL. The arms were measured and determined to be capable of adjusting two inches. In part, this was due to error in fabrication that resulted in arm support bars 3 inches longer than required. With those arm bars shortened, the arms could adjust 5 inches in height. This is still three inches short of the design requirement.

Figure 73: Collapsing the walker

Figure 74: Collapsed walker in the back of the Prius

8.0 Conclusion and Recommendations

8.1 Recommendations

Ultimately this walker prototype is not one that, in good conscious, the team can pass on to Azelia and her family. In the future, should this project be tackled again there are a few recommendations the team has.

When designing for a predicted growth, measure the walker user multiple times and err on the side of caution when estimating growth. With an individual who is already below average physical size due to genetic mutation, growth will also be below average. The team ultimately chose dimensions that were too large for Azelia's small stature, an outcome that could have been avoided with increased caution in measurement and growth prediction given physical conditions.

Designing custom hinges are challenging. The hinge in Azelia's walker has served both as a method for collapsing as well as hold the walker open during use, two contradictory functions. Calculate degrees of freedom and prototype any hinges before final design. Building a wood prototype of the back hinge mechanism helped the team realize the importance of preloaded fasteners to keep the hinge assembly from buckling.

Double and triple check safety features! A walker for an individual with limited mobility must be able to withstand jerky movement. After fabrication and assembly, it was discovered that the back hinge mechanism on Azelia's walker would start to close should the walker user lean left or right. A safety latch across the top of the hinge center bar and connecting horizontal bars would prevent this movement from occurring during use.

Spend more time brainstorming and researching existing designs. Often times, if a design does not exist on the market this is because it either does not work or is challenging to make successfully. One of the points of failure in the final design was that the assembly designed to keep the walker together was also designed to fold. All-terrain vehicles are often bulky and heavy, features that do not combine well with portability, which is why there is a limited to non-existent selection of all terrain walkers for children on the market.

Finally, manufacture with several weeks built in for modifications. The chances of unforeseen issues coming up after assembly, especially with a group of young engineers, is high. Giving a grace period to make modifications and improvements to solve design errors is key to a successful final design.

8.2 Conclusion

Azelia's Walker utilizes a customized collapsing mechanism, large wheels not standard to market walkers, and parallel clamping bars to offer a final design that meets the customer's wishes and provides opportunity for a higher quality of life. The final design is meant to be functional, with capabilities to traverse over multiple types of terrain, grow with the client, and collapse to a portable size for transportation. After completion of fabrication it is recommended by the team to not allow Azelia to use the walker.

The walker functions as it was designed to with the exception of some overlooked design flaws mentioned earlier. In the exploration of a potential for an off-roading walker, the walker had several successes. The mechanism used for the back was capable of reducing the width of the walker by half. In addition it can go over two of the primary off-roading goals. The wheel systems allow for smooth movement, despite the fact that it has a large turning radius. The ergonomics for the hand grips are also far better suited to Azelia's resting hand grip than her current walker.

In the end, the walker could not be delivered to the family because of key safety concerns. The primary concern is that when the walker turns the mechanism that allows the walker to collapse will fold when the user leans left or right. Other minor concerns include no brake system to prevent the walker from rolling backwards when at rest, feasibility of Azelia getting into or out of the walker due to the armrests narrowing the walker opening, and splaying of the legs under loading.

As a team we learned a great deal about working within a team and with a customer. This experience has allowed us to learn and experience the need to design for manufacturability, how to fit customer requirements, and to avoid scope creep at all costs. We recommend that this project undergo a second iteration by another Senior Project group in order to provide Azelia with the walker she deserves. All in all, Azelia's walker has enjoyed working with Azelia and her family in our attempts to build an all-terrain walker.

9.0 Acknowledgement

Azelia's Walker would like to sincerely thank many members of the Cal Poly and San Luis Obispo community and companies willing to donate their time, expertise, and products so that our team was able to create the best prototype possible. We would like to thank the Cal Poly Student Shop Techs, Cleisha Stancil of R82, CPConnect - Boeing, Foothill Cyclery, Hannah-Forbes Project Fund, Ian Goodyear of Central Coast Creative Cutting, our project advisor Jim Widmann, Joel Hitchen of Mob Armor, Karl Deardorff of SLO Sail and Canvas, Kevin Williams of Cal Poly's IME department, Mimi Sardou of URise Products, PremierSki, and PowderCoating USA. Thank you for all for your help.

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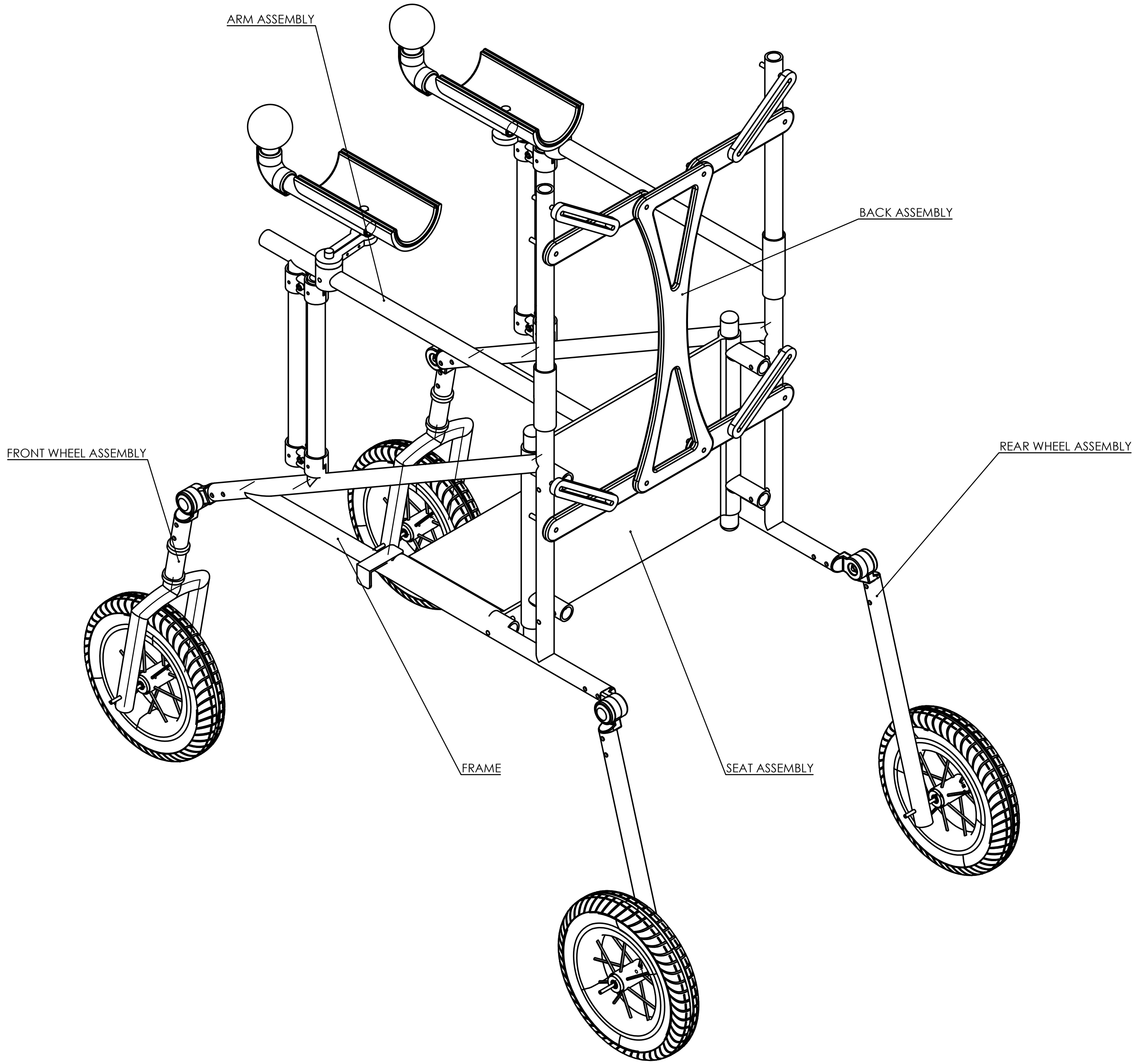
16. "Drive Nitro 4 Wheel Rollator" Drive Nitro 4 Wheel Rollator. Just Walkers, n.d. Web. 09 Dec. 2016.
17. Cargo, United World. "Revisiting..... Load Locks." Revisiting..... Load Locks. N.p., n.d. Web. 06 Dec. 2016.

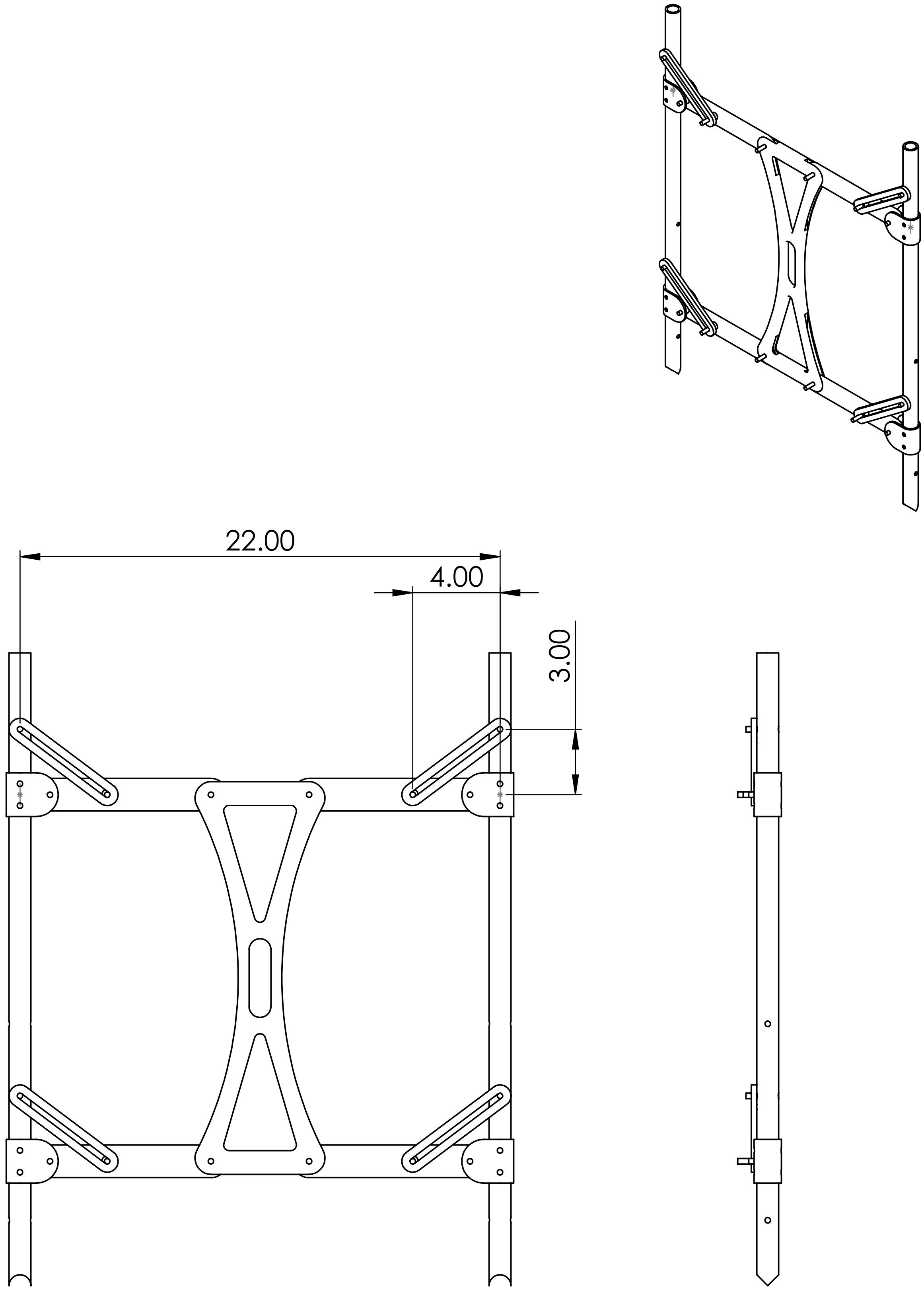
Appendix B: QFD

Quality Function Design (QFD)			Weighting (1 to 5)	Engineering Requirements (HOWS)									
				Collapsible	Adjustable	Lifespan	Weight	Height	Width	Clearance of lowest bar	Center of Gravity	Color	Length
Customer Requirements Defined		Portable	4	**9**	**1**		**9**	**9**	**9**		**1**		**9**
		Grows with her	4		**9**	**9**		**9**			**3**		
		Durable	4	**1**		**9**							
		Forearm support	5	**1**	**3**								**1**
		All-terrain	5		**1**		**3**	**9**		**9**			
		Comfortable seat	2										
		Communication Device Storage	1	**1**									
		Stability	5						**3**		**9**		**1**
		Aesthetics	2									**9**	
		Safety	4		**3**	**3**				**9**	**9**		
9	Strong Correlation	**Units**		in	in	years	lbs	in	in	in	in	N/A	in
3	Medium Correlation	**Targets**		20x32x20	10	7	25	25	20	1		Y	32
1	Small Correlation	**Benchmark #1**			4	2	13.5	22.36	22	N/A		Y	70
	No Correlation	**Benchmark #2**											
		Importance Scoring		46	72	84	51	117	51	81	97	18	46
		Importance Rating (%)		6.94	10.86	**12.67**	7.69	**17.65**	7.69	**12.22**	**14.63**	2.71	6.94

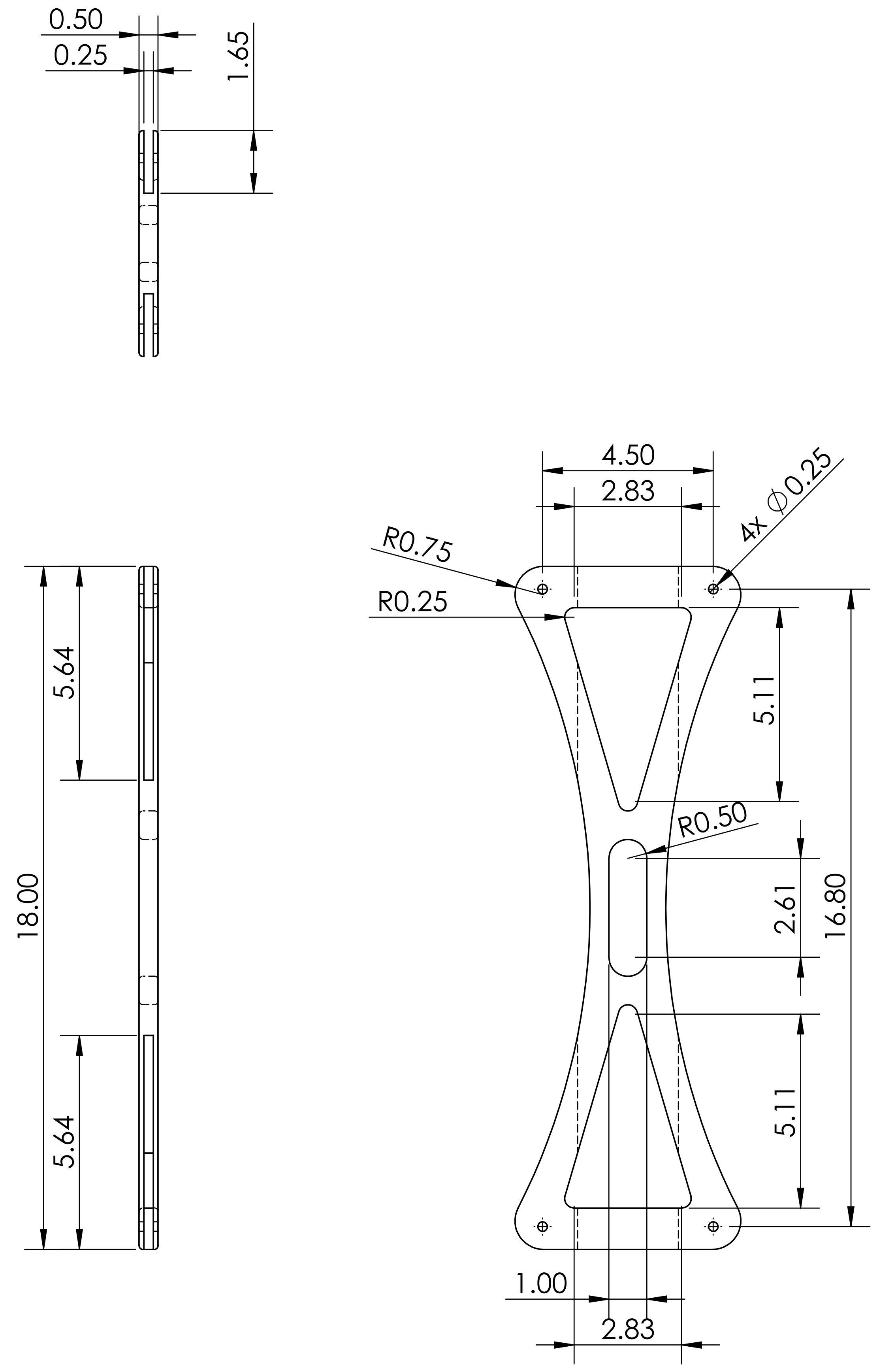
Appendix C: CAD Drawings


Y
X
Z

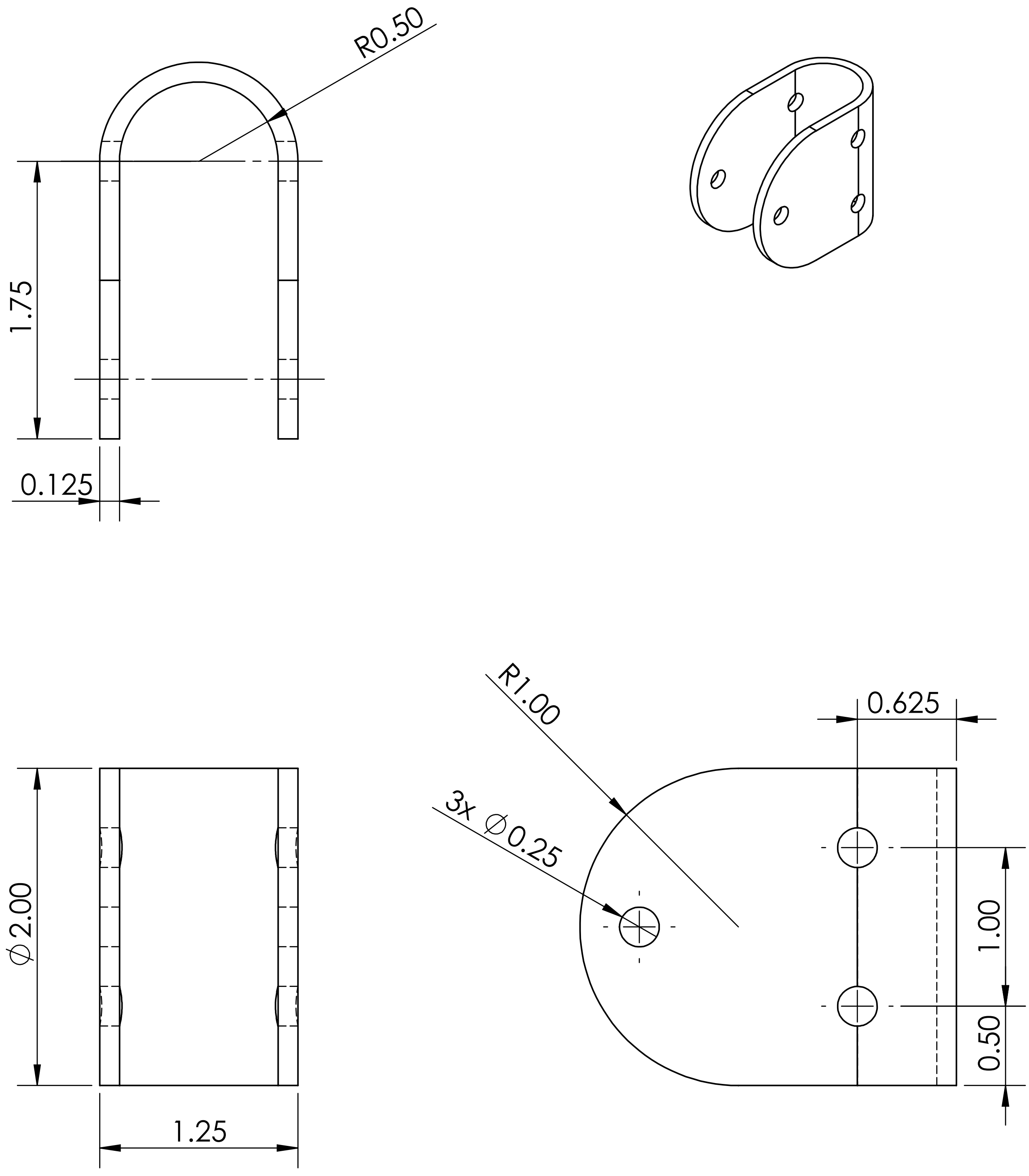

ARM ASSEMBLY
BACK ASSEMBLY
FRONT WHEEL ASSEMBLY
REAR WHEEL ASSEMBLY
FRAME
SEAT ASSEMBLY



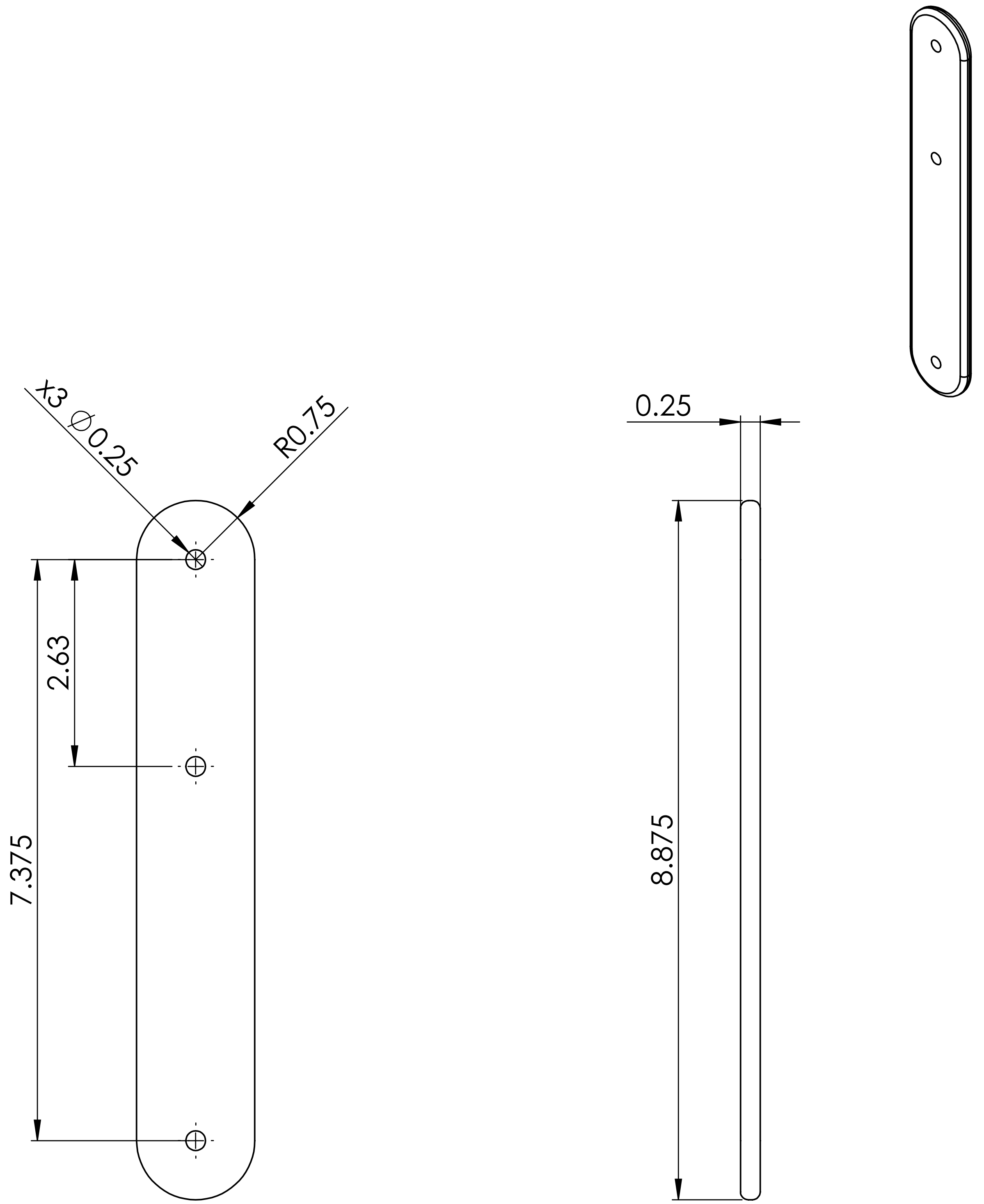
Azelia's Walker Cal Poly Mechanical Engineering	Asm: Back	Part: Back Assembly	Scale: 1:7
	Dwg #: 00	Drawn By: Jayne Benedict	Date: 5/23/2017



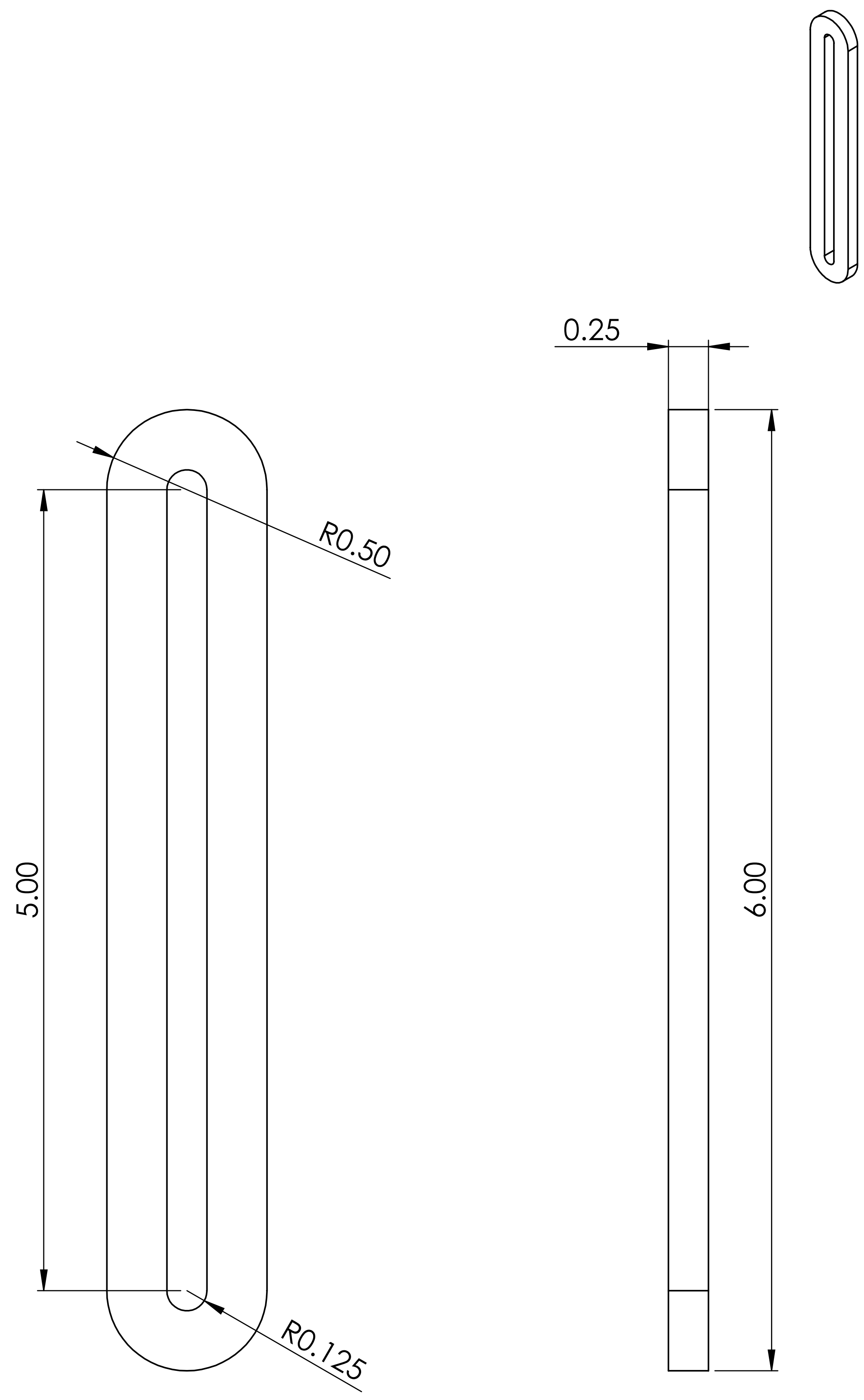
Azelia's Walker	Asm: Back	Part: Center Bar	Scale: 1:4
Cal Poly Mechanical Engineering	Dwg #: 01	Drawn By: Jayne Benedict	Date: 5/12/17



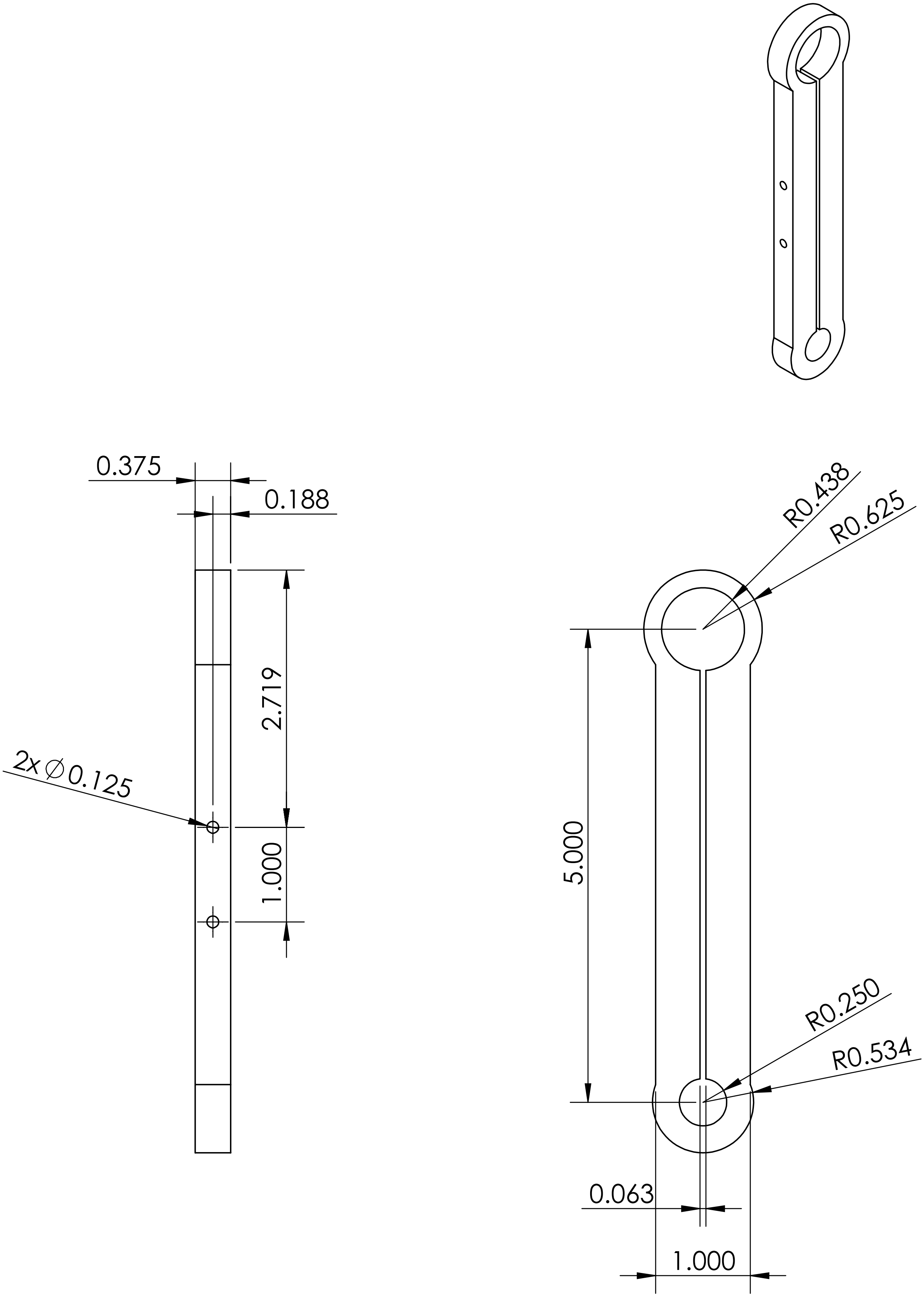
Azelia's Walker	Asm: Back	Part: Back Bar Mount	Scale: 1:1
Cal Poly Mechanical Engineering	Dwg #: 02	Drawn By: Jayne Benedict	Date: 5/12/17



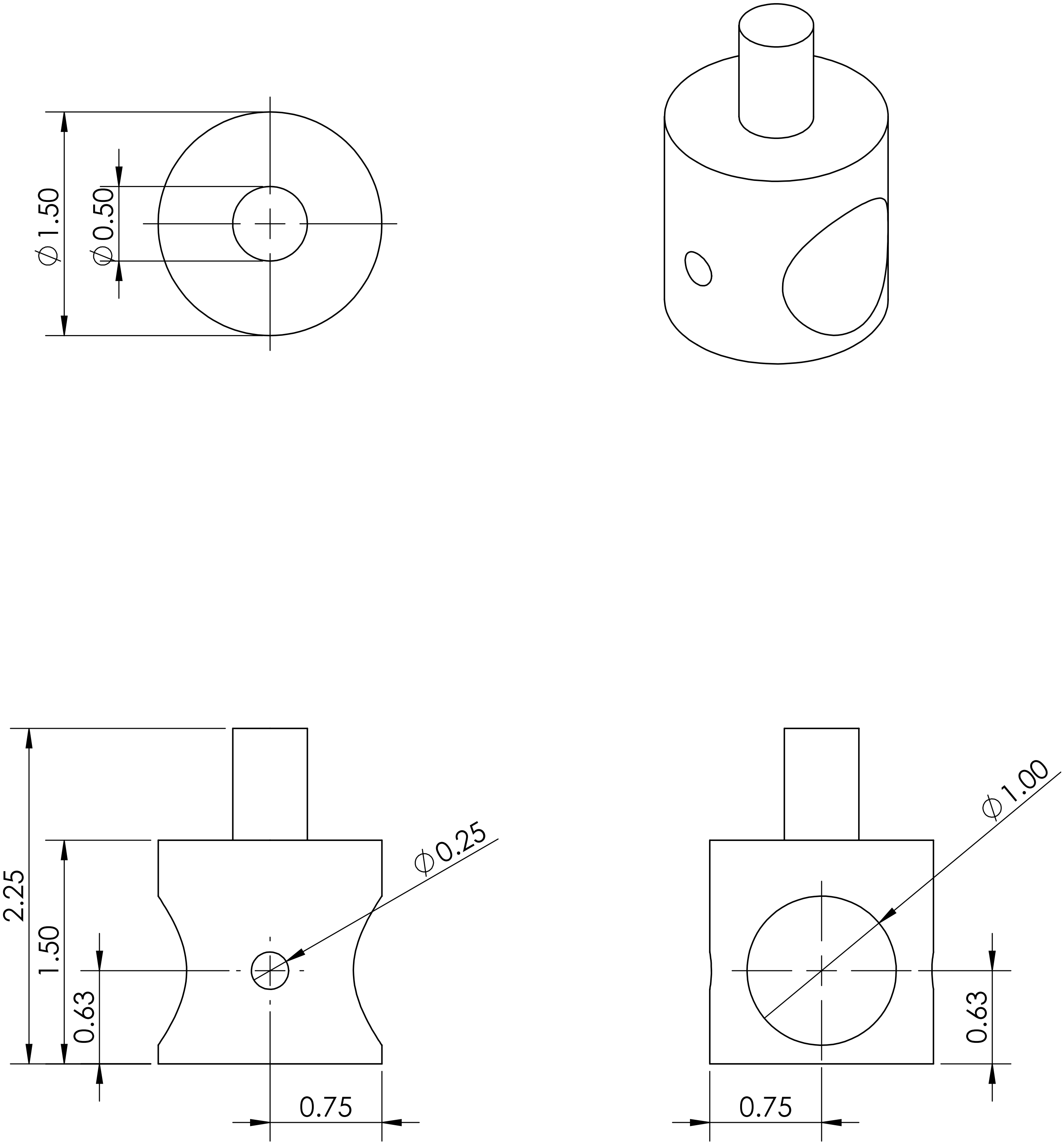
Azelia's Walker Cal Poly Mechanical Engineering	Asm: Back	Part: Horizontal Back Bar	Scale: 1:2
	Dwg #: 03	Drawn By: Jayne Benedict	Date: 5/2017



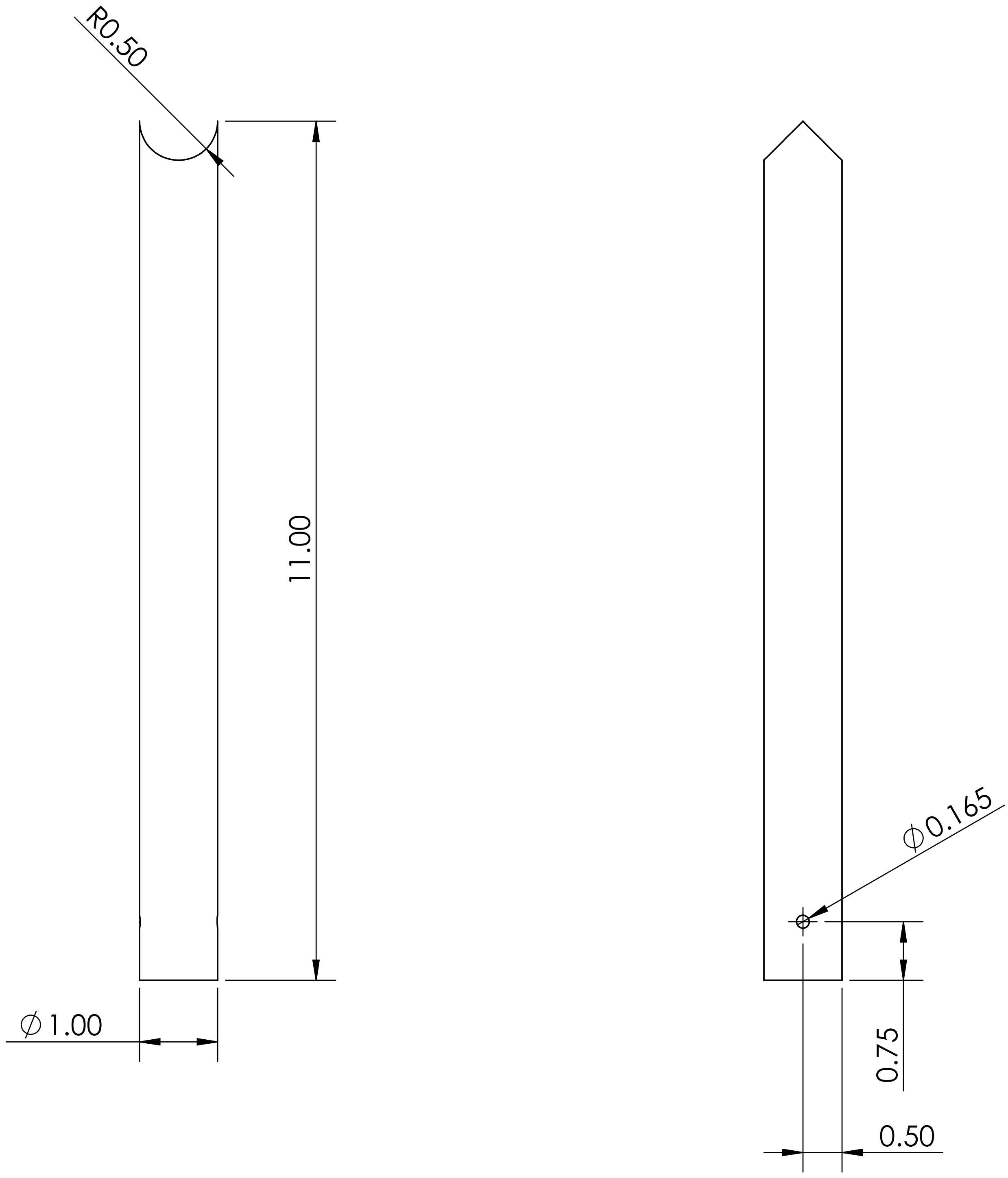
Azelia's Walker	Asm: Back	Part: Slotted Hard Stop	Scale: 1:1
Cal Poly Mechanical Engineering	Dwg #: 04	Drawn By: Jayne Benedict	Date: 5/23/2017



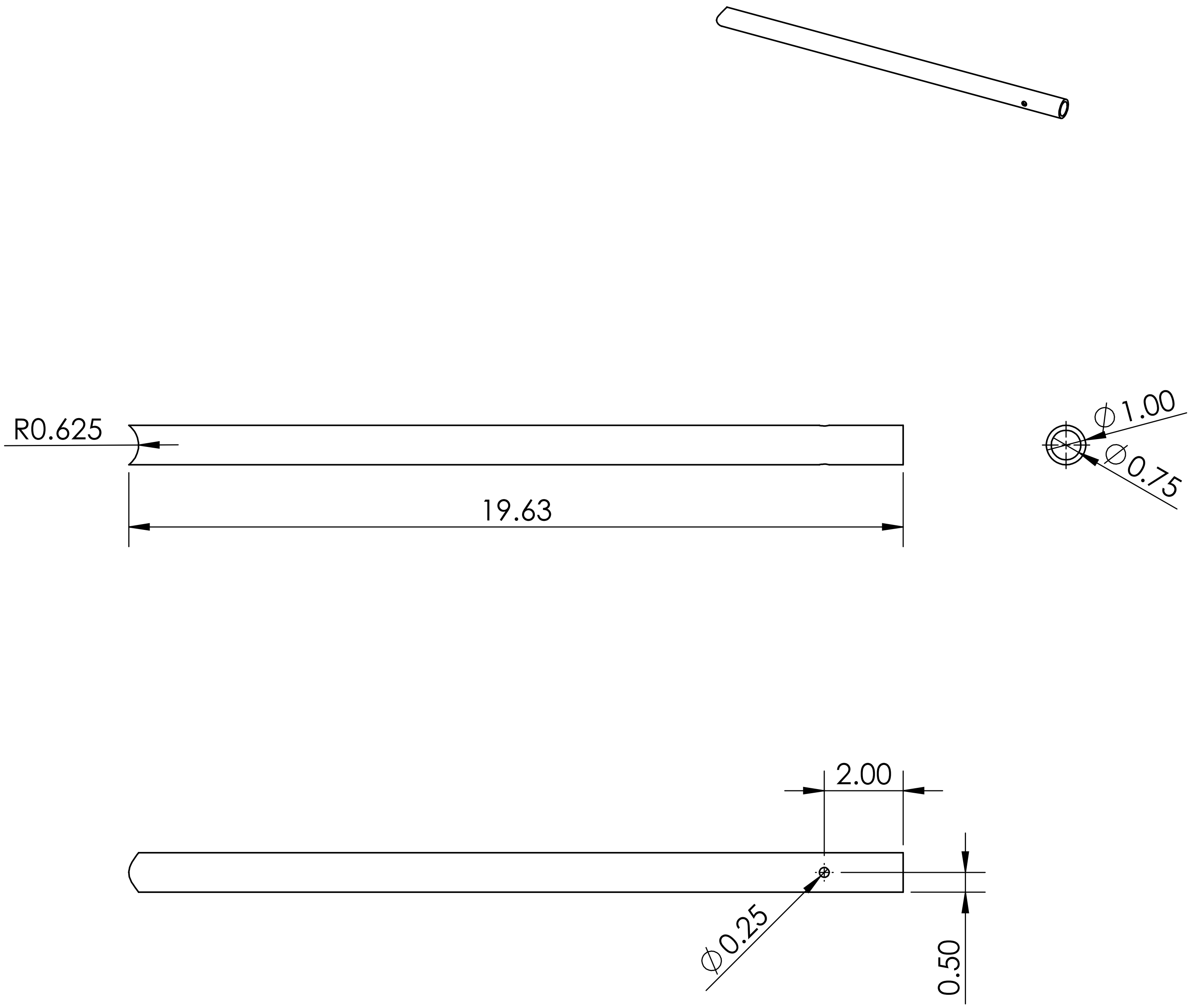
Azelia's Walker	Asm: Arm	Part: Arm Connector	Scale: 2:3
Cal Poly Mechanical Engineering	Dwg #: 01	Drawn By: Jayne Benedict	Date: 5/11/17



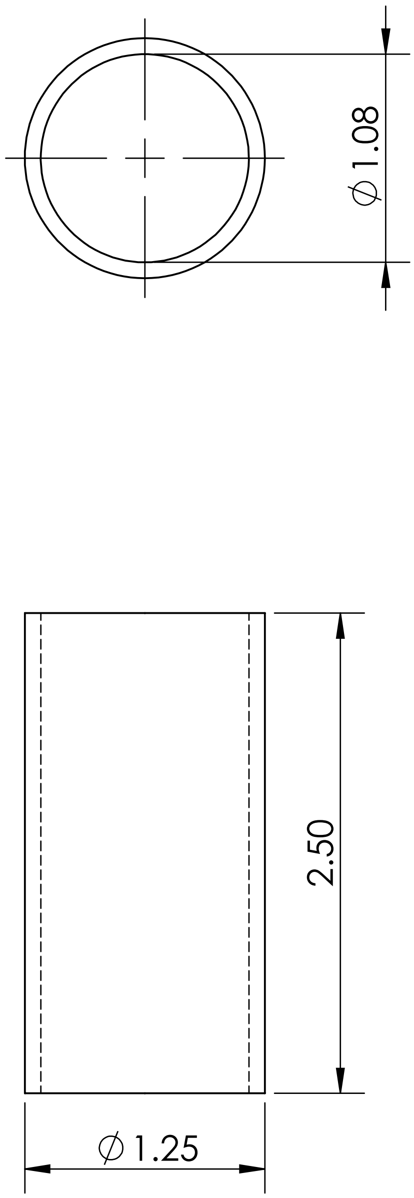
Azelia's Walker Cal Poly Mechanical Engineering	Asm: Arm	Part: Arm Connector Adaptor	Scale: 1:1
	Dwg #: 02	Drawn By: Jayne Benedict	Date: 5/12/17



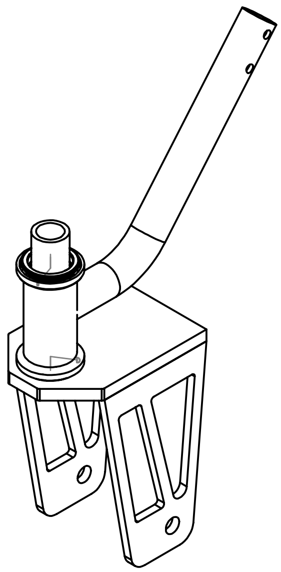
Azelia's Walker	Asm: Arm	Part: Sliding Arm Support	Scale: 1:2
Cal Poly Mechanical Engineering	Dwg #: 03	Drawn By: Jayne Benedict	Date: 5/12/17

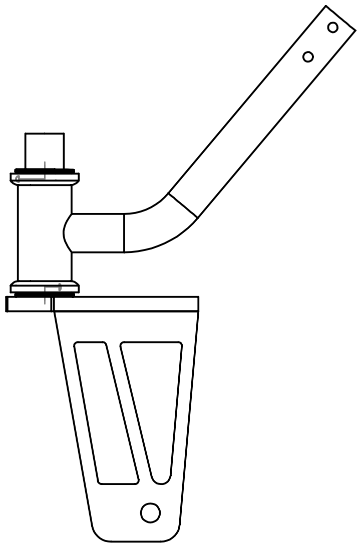


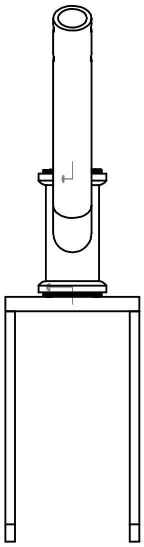
Azelia's Walker	Asm: Arms	Part: Horizontal Arm Bar	Scale: 1:3
Cal Poly Mechanical Engineering	Dwg #: 02	Drawn By: Jayne Benedict	Date: 5/12/2017



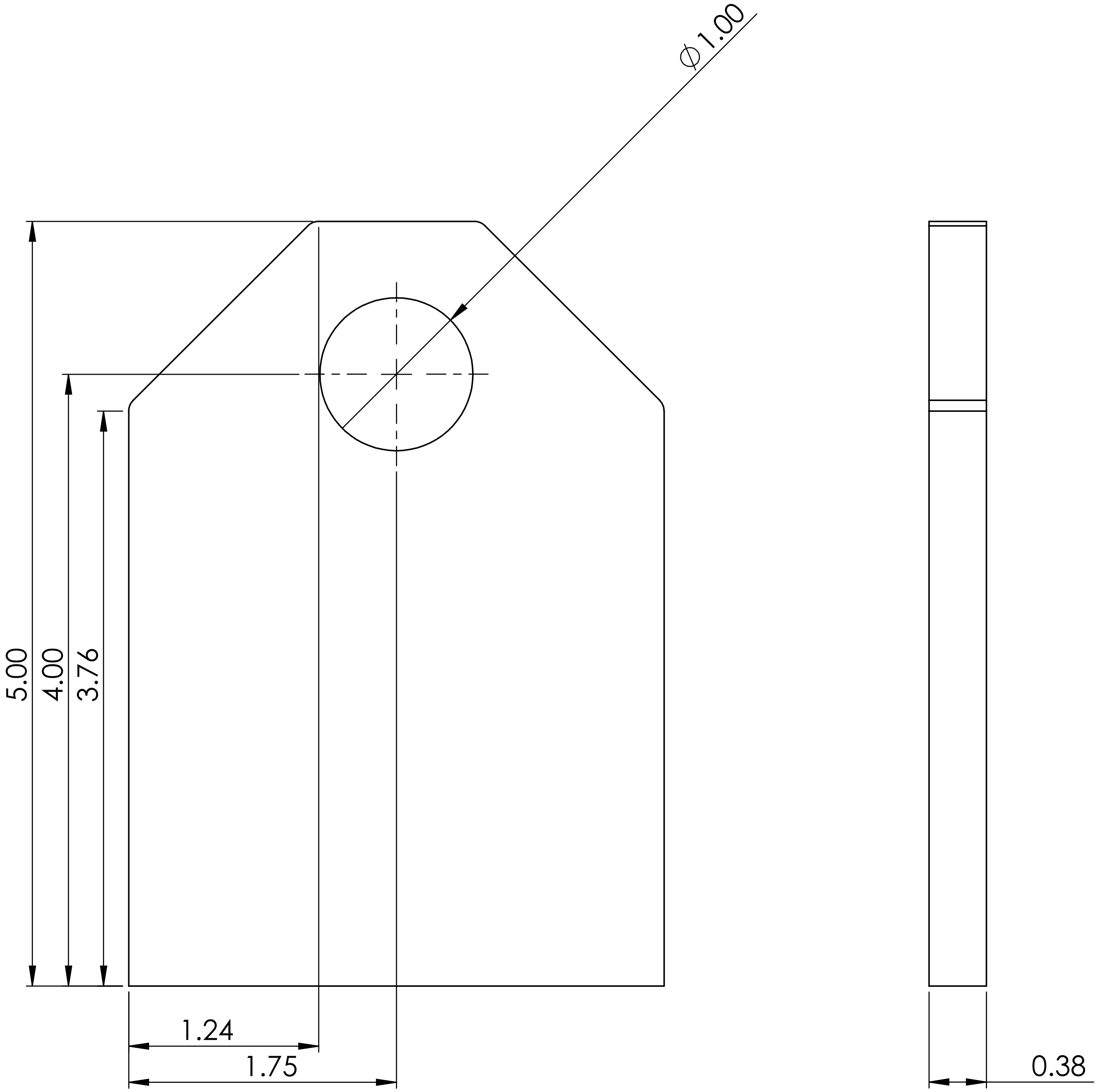
Azelia's Walker Cal Poly Mechanical Engineering	Asm: Arm	Part: Telescoping Tube	Scale: 1:1
	Dwg #: 04	Drawn By: Jayne Benedict	Date: 5/12/17



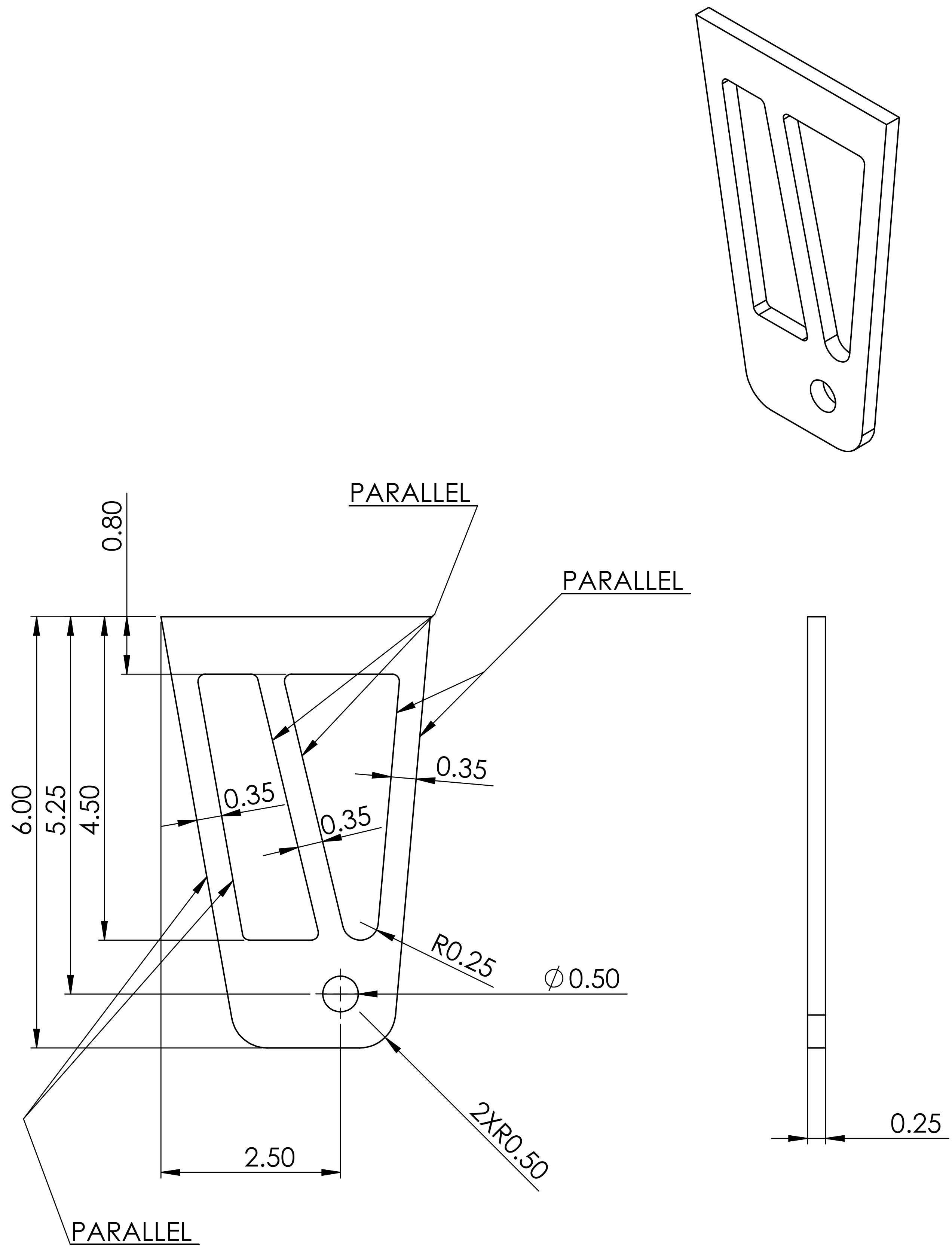




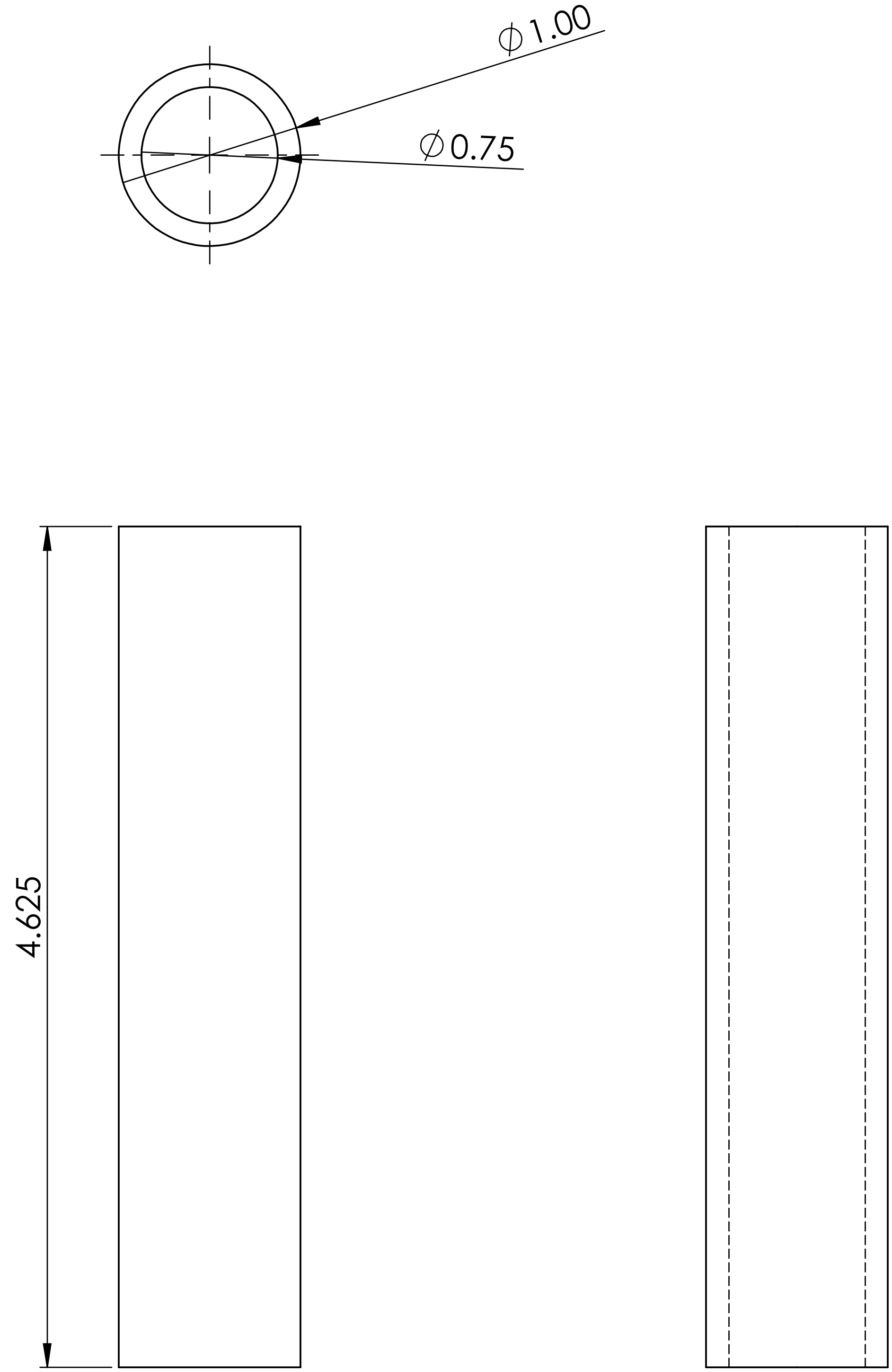
Azelia's Walker	Asm: FRONG LEG	Part: OVERALL ASSEMBLY	Scale: 1:5
Cal Poly Mechanical Engineering	Dwg #: 5	Drawn By: GABRIELLE MERKIN	Date: 6/1/17



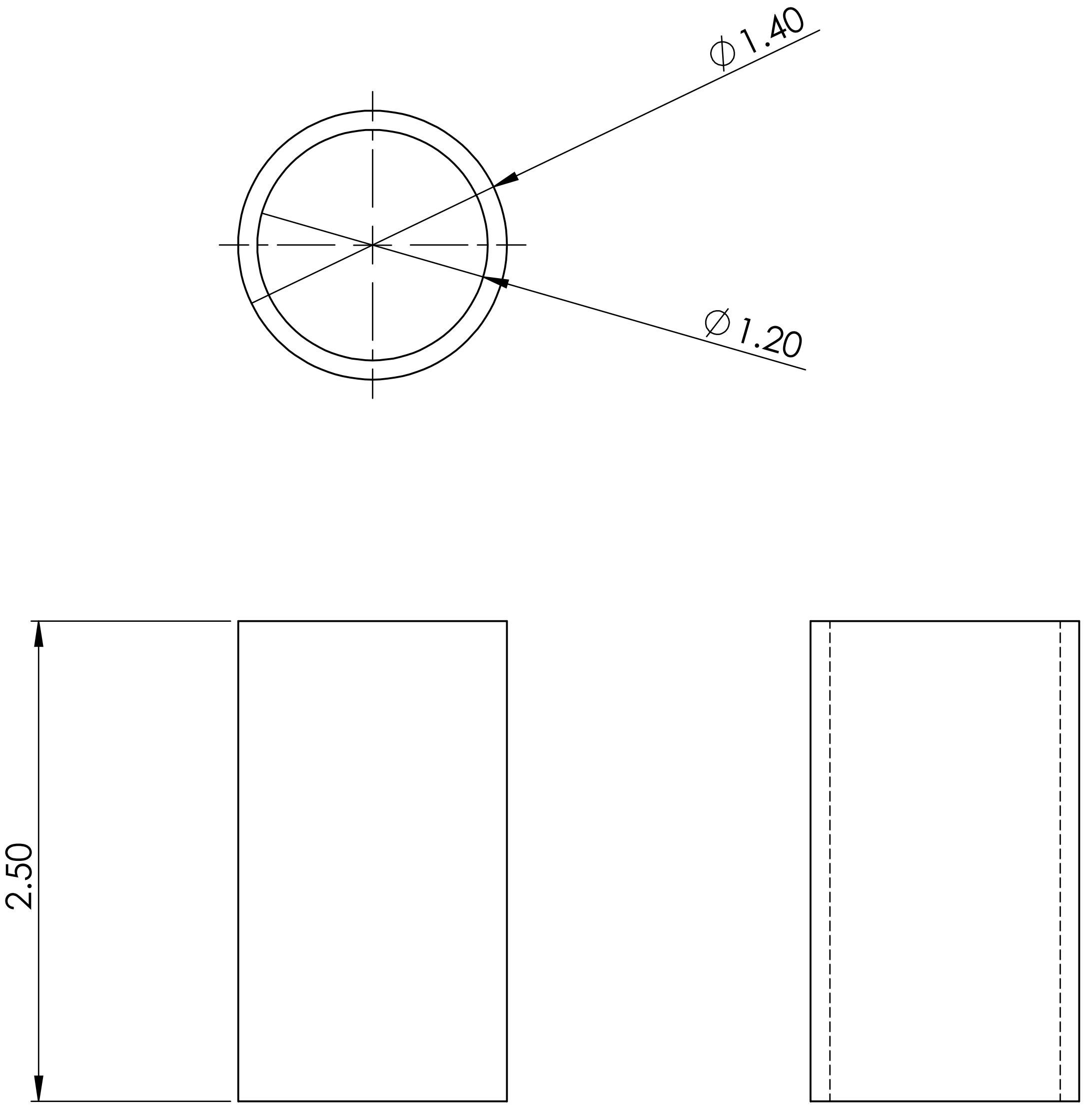
Azelia's Walker	Asm: FRONT LEG	Part: CASTER TOP PLATE	Scale: 1:1
Cal Poly Mechanical Engineering	Dwg #: 1	Drawn By: GABRIELLE MERKIN	Date: 5/31/17



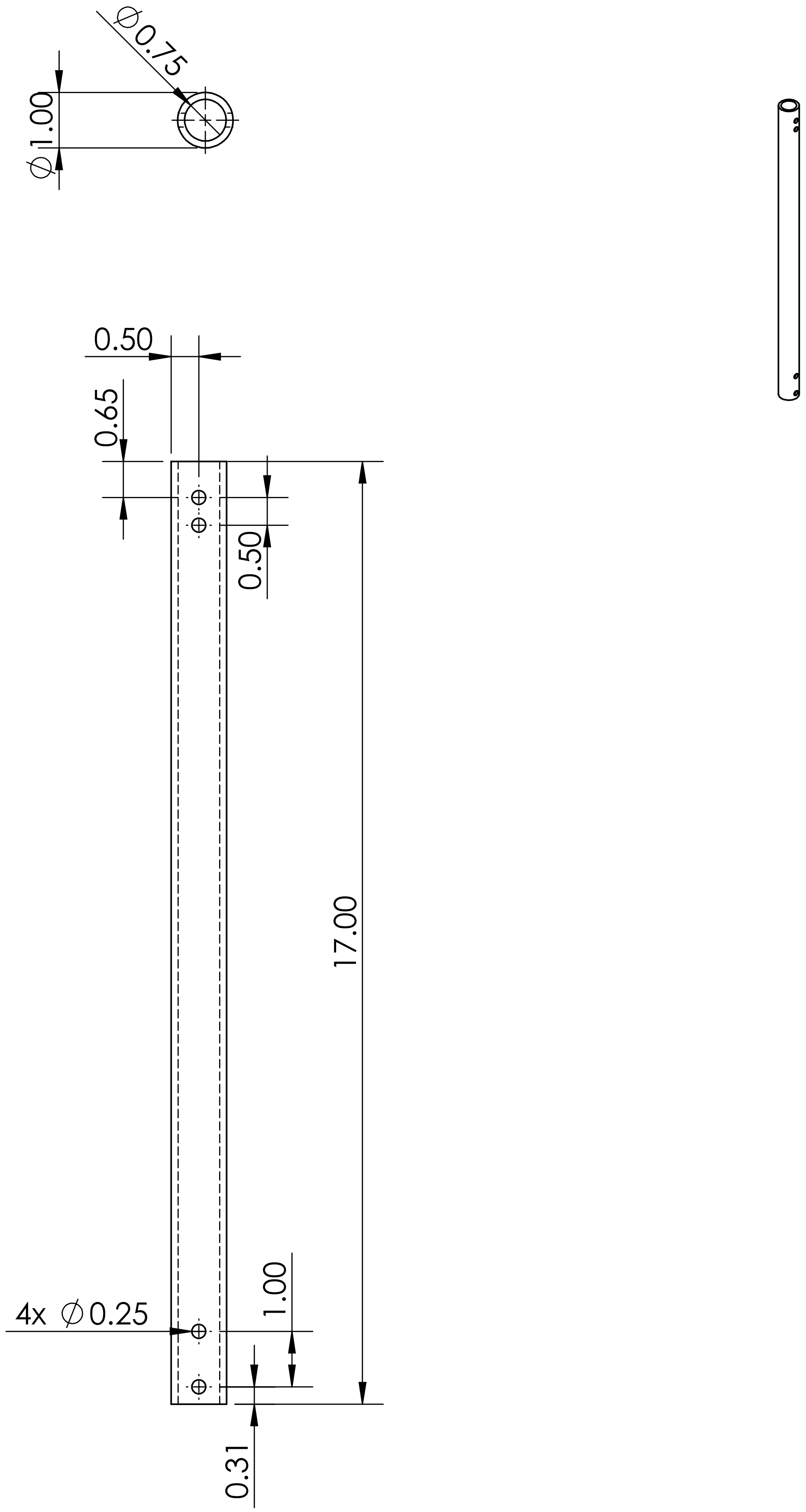
Azelia's Walker Cal Poly Mechanical Engineering	Asm: FRONT LEG	Part: CASTER SIDE PLATE	Scale: 1:2
	Dwg #: 2	Drawn By: GABRIELLE MERKIN	Date: 5/31/17



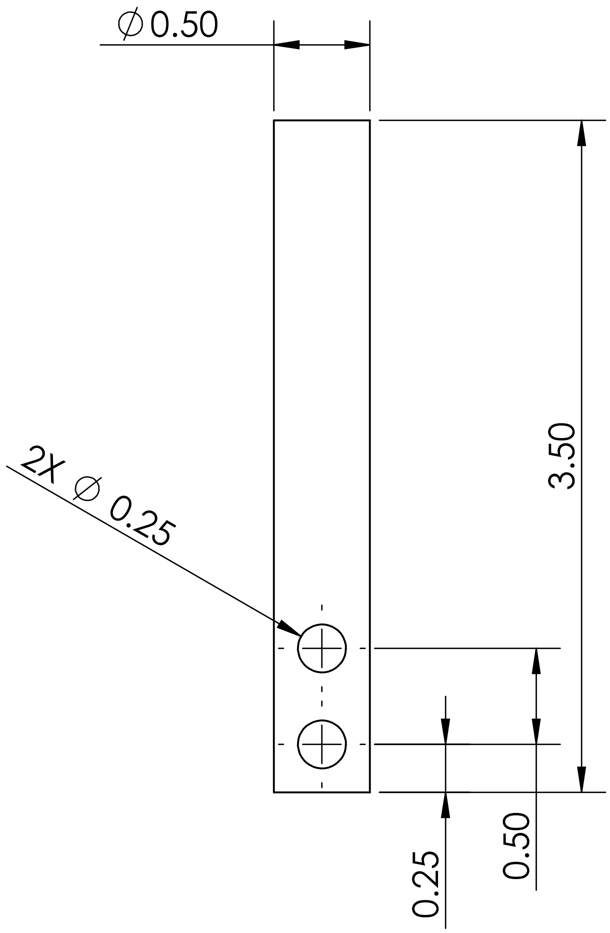
Azelia's Walker	Asm: FRONT LEG	Part: CASTER TUBE	Scale: 1:1
Cal Poly Mechanical Engineering	Dwg #: 3	Drawn By: GABRIELLE MERKIN	Date: 5/31/17



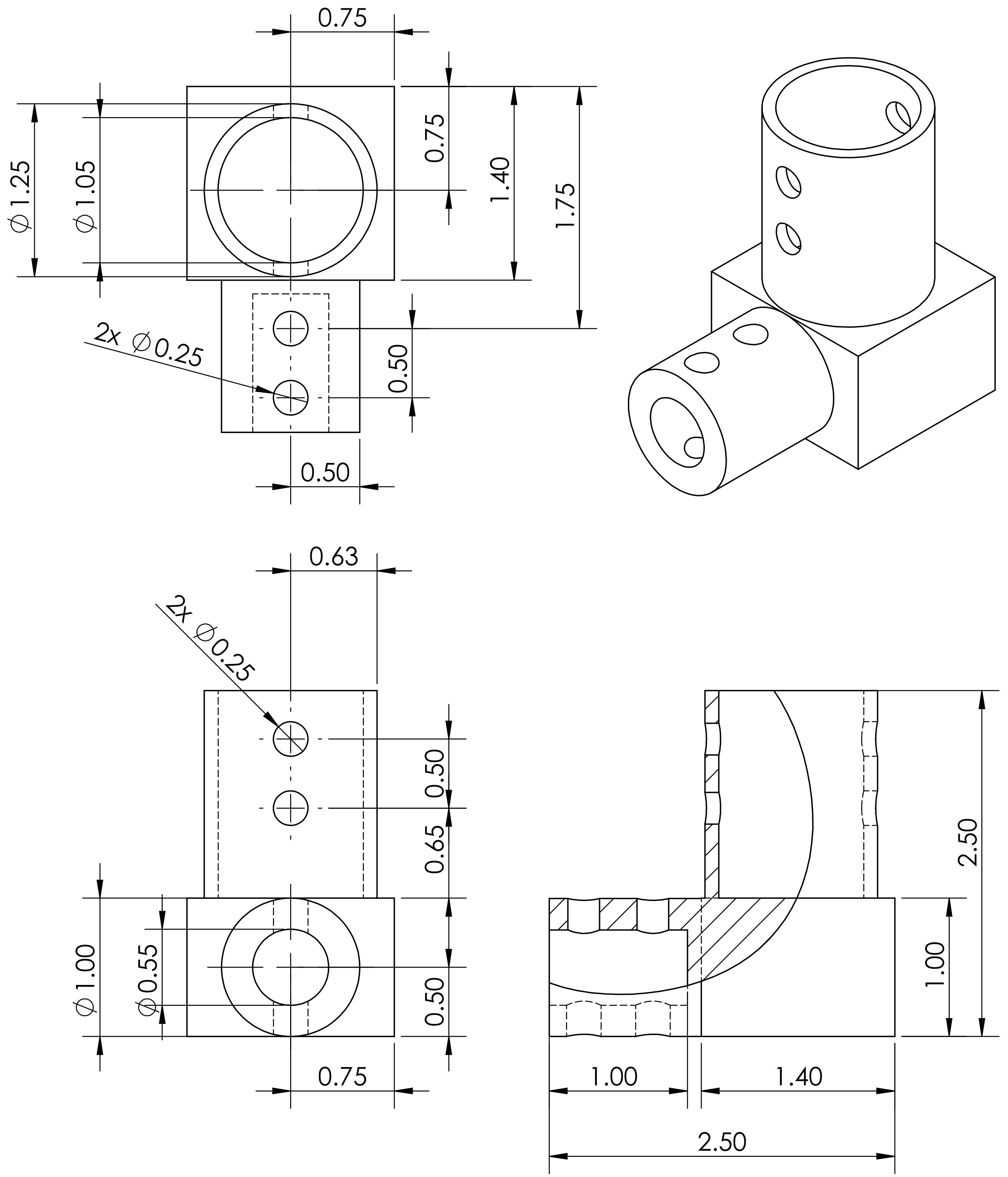
Azelia's Walker	Asm: FRONT LEG	Part: CASTER TUBE	Scale: 1:1
Cal Poly Mechanical Engineering	Dwg #: 4	Drawn By: GABRIELLE MERKIN	Date: 5/31/17



Azelia's Walker	Asm: Back Leg	Part: Back Leg	Scale: 1:3
Cal Poly Mechanical Engineering	Dwg #: 01	Drawn By: Jayne Benedict	Date: 5/12/17



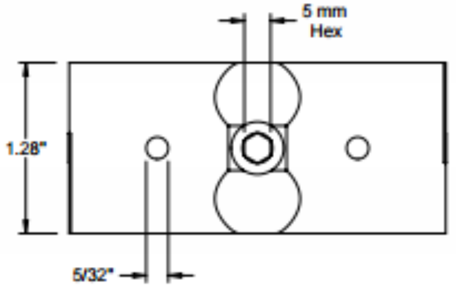
Azelia's Walker	Asm: xxx	Part: Back Wheels, Wheel Shaft	Scale: 1:1
Cal Poly Mechanical Engineering	Dwg #: xxx	Drawn By: xxx	Date: xxx

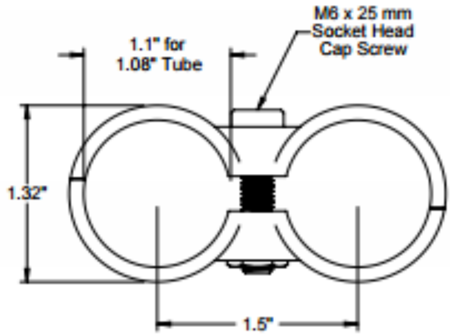


Azelia's Walker Cal Poly Mechanical Engineering	Asm: xxx	Part: xxx	Scale: xxx
	Dwg #: xxx	Drawn By: xxx	Date: xxx

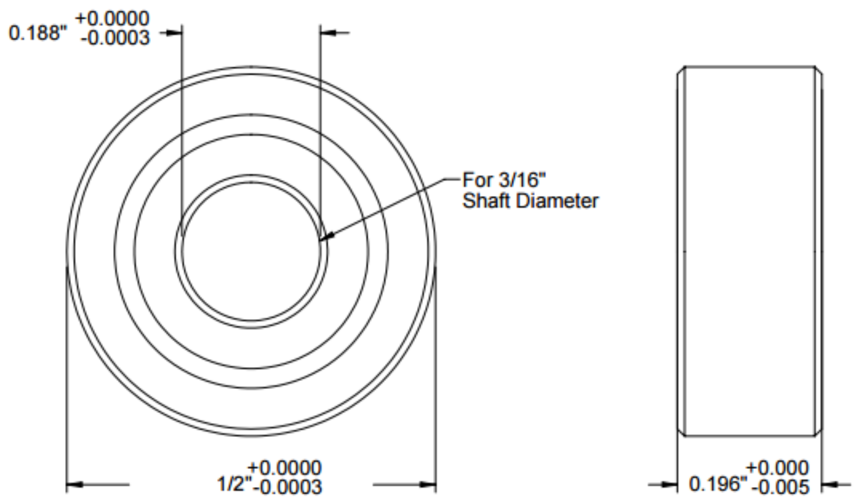
Appendix D: Vendor Information, Specifications, and Data Sheets

1. McMaster Carr
2. Wheeleez, Inc
3. Premier Ski
4. BikeBoards, LLC
5. Adjustable Locking Technologies
6. Crocodile
7. Tab Grabber

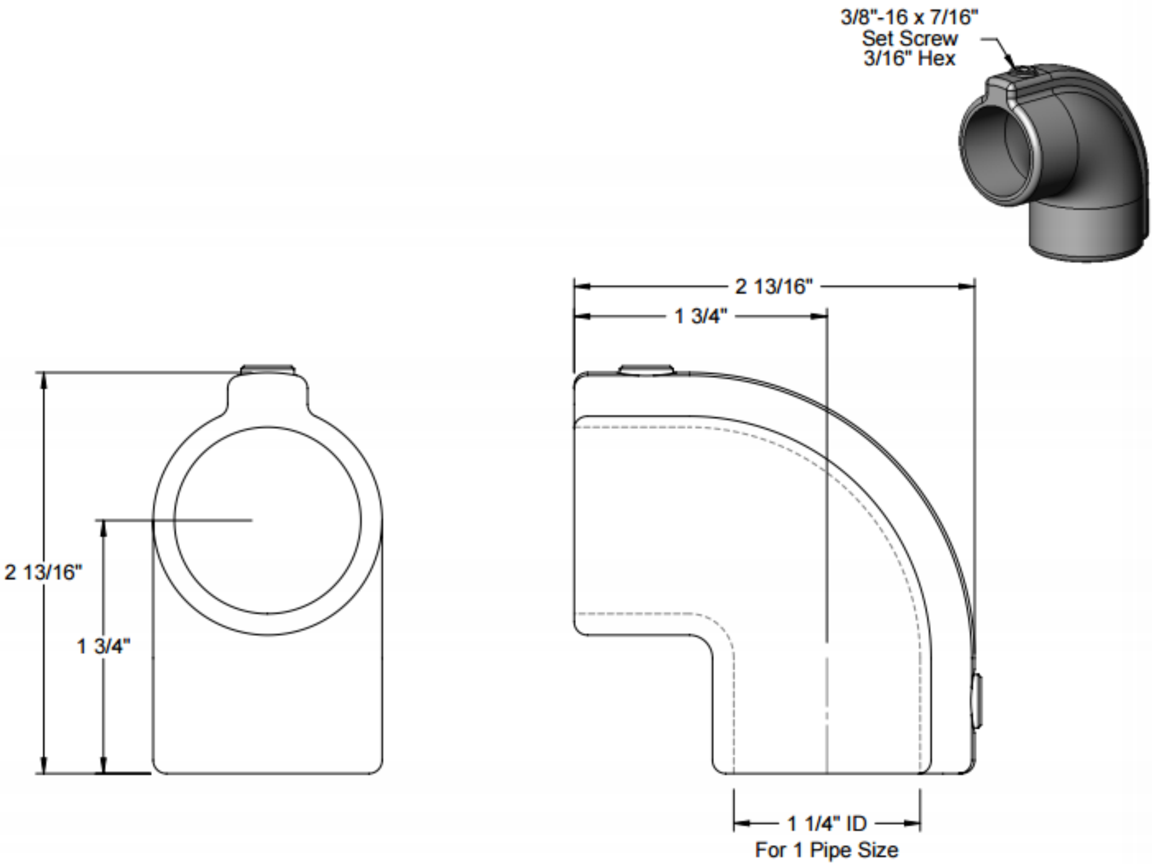




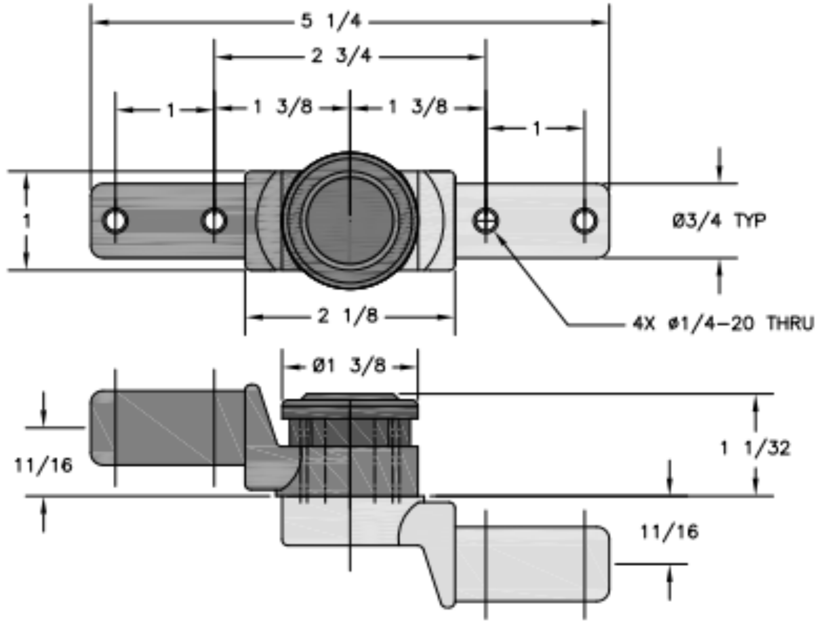
McMASTER-CARR® CAD	PART NUMBER	2534T31
http://www.mcmaster.com Information in this drawing is provided for reference only.		Steel Clamp-On Parallel



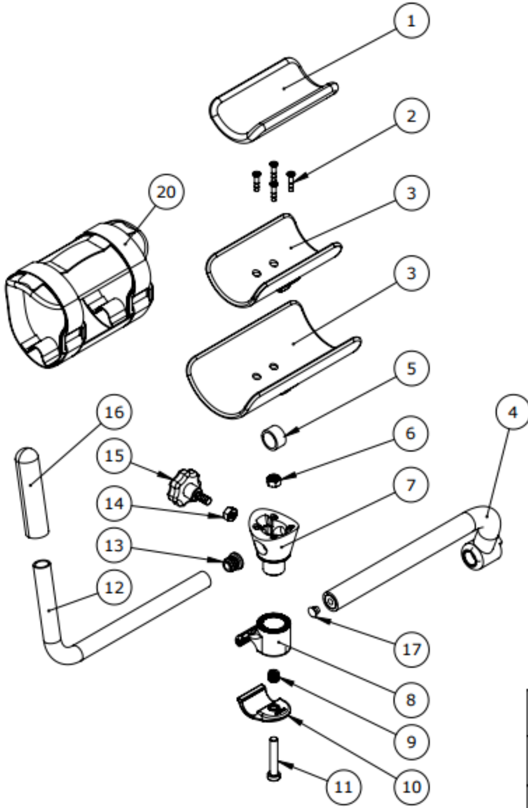
McMASTER-CARR® CAD	PART NUMBER 60355K861
http://www.mcmaster.com © 2016 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Ball Bearing



McMASTER-CARR® CAD	PART NUMBER	4698T32
http://www.mcmaster.com © 2015 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Aluminum Slip-On 90° Elbow	



HEAVY DUTY 4140 ALLOY STEEL TWO ROUND ENDS OFFSET (360 ROTATION)				
PART NO.	TOTAL ADJUSTMENT RAINGE	ADJUSTMENT INCREMENTS	ALLOWABLE TORQUE(INCH-LBS)	
VXS10360PB	360	10°	1200	5 TO 1 SAFETY FACTOR
VXS10360CR	360	10°	1200	5 TO 1 SAFETY FACTOR



Tolerance	Project	R82 nothing compares to a smile!		
Surface	Tool 100351	Created by PN Created date 13-09-04	Revision 1	Revision by fja Revision date 24-06-2013
Material		Scale 1:5	Weight 841g	
Title Armrest Crocodile size 1-2		Format A4	Item no 107813	

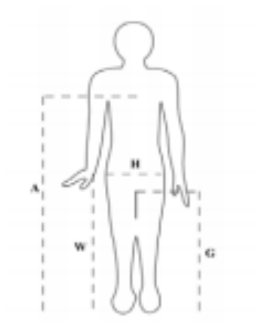
Request Quote | Send Purchase Order

crocodile™ | R82

U.S. Suggested Retail Price List	HCPCS E8000 & E8001	September 2016

844 US MOBILITY Fax: 704-882-0751 www.R82.com PO Box 1739 Matthews, NC 28106

Account No.	Drop Ship:
Date:	Name
P.O. Number:	Address
Buyer:	City
Marked For:	State Zip
E Mail:	Tel. Fax



A (Axilla to Floor Height)
W (Wrist to Floor)
G (Groin to Floor)
H (Hip Width)

Features included in standard price

Sizes 1 and 2

Size 3

- Width and height adjustable rotational handles - for children from 18 months to teenage
- Directional lockout
- On/off anti-reverse wheel stops
- Light-weight durable aluminum frame - sizes 1 & 2
- Durable steel & aluminum frame - size 3
- Easy to fold
- Friction adjustable rear drag wheels
- Swivel front casters
- Padded rear stabilizer bar with tool kit

Crocodile	Description	Size	Part No.	Price	
	HCPS E8000				
	Crocodile gait trainer, yellow	size 1	86801	740	☐
	Crocodile gait trainer, orange	size 2	86802	740	☐
	Crocodile gait trainer, black	size 2	86852	740	☐
	Crocodile gait trainer, metallic grey	size 3	86803	1,220	☐

844 US MOBILITY | Fax: 704-882-0751 | www.R82.com | PO Box 1739 Matthews, NC 28106

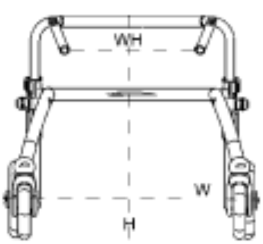
Crocodile	Description	Size	Part No.	Price	
Accessories					
	Forearm support w/handgrip, set (R82)	size 1	86858	370	☐
	Forearm support w/handgrip, set (R82)	size 2	86859	370	☐
	Forearm support w/handgrip, set (R82)	size 3	86860	370	☐
	Min/Max Height = 31"- 45"				
	Padded forearm positioner, EACH	one size	869370	68	☐
	Pelvic Support, R82	Size 1 & 2	86816	130	☐
	7"w x 4½"h				
	Pelvic pad w/ lateral, small	Size 1 & 2	86808	262	☐
	3 1/2"h x 4-3/4 to 9"w				
	Pelvic pad w/ lateral, large	Size 1 & 2	86809	262	☐
	3 1/2"h x 7 to 11-1/2"w				
	Lateral strap (Attaches to lateral pads)	one size	905011	51	☐
	Hip supports, set	Size 1 & 2	86819	235	☐
	Back support, angle and width adjustable	size 3	86886	505	☐
	Crossbar required				
	Back support strap - 11½" W x 3" H		85490-1	87	☐
	Back support strap - 13½" W x 4" H		85490-2	87	☐
	Crossbar required to back support	size 3	86880	97	☐
	Knobs for handles	all sizes	86861	51	☐

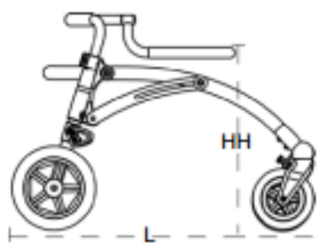
Crocodile
September 2016 Price List

844 US MOBILITY | Fax: 704-882-0751 | www.R82.com | PO Box 1739 Matthews, NC 28106

Crocodile	Description	Size	Part No.	Price	
	Solid Seat, Yellow	size 1	86820	170	☐
	Solid Seat, Orange	size 2	86821	170	☐
	Solid Seat, Black	size 2	86823	170	☐
	Solid Seat, Metallic Grey	size 3	86863	170	☐
	Sling seat	size 1	86824	135	☐
	Sling seat	size 2	86825	135	☐
	Anti-tip device, swing-away, set	size 1 & 2	86815	160	☐
	Anti-tip device, fixed, set	size 1 & 2	86815-F	77	☐
	Anti-tip device, swing-away, set	size 3	86815-3S	160	☐
	Anti-tip device, fixed, set	size 3	86815-3F	82	☐
	Storage Bag - *11" w x 7" h*	size 1 & 2	86839	71	☐
	Storage Bag - *14" w x 11" h*	size 3	86843	210	☐
	Hand Brake	size 1 & 2	86834	240	☐
	Hand Brake	size 3	86873	240	☐
	Attendant handle	size 1 & 2	36-4050	120	☐

Measurements





	Size 1 cm (inch)	Size 2 cm (inch)	Size 3 cm (inch)
Height - floor to top frame (H)	49-66 (19 - 25¾")	65-82 (25½ - 32")	77 (30¼")
Width, max (W)	62 (24")	69 (27")	69 (27")
Lenght (L)	72 (28")	84 (32¾")	87 (34¼")
Width between handles (WH)	27-55 (10½ - 21½")	32-60 (12½ - 23½")	35-69 (13¾ - 27¼")
Height - floor to handles (HH)	39-70 (15¼ - 27½")	55-88 (21½ - 34½")	70-100 (27½ - 39½")
Length, folded	72 (28")	86 (33½")	100 (39½")
Height, folded	31 (12")	27 (10½")	29 (11½")
Weight, standard	5,5 kg (12 lb)	6,5 kg (14 lb)	12 kg (25 lb)
User height, maximum	115 (44¾")	150 (58½")	180 (71")
User weight, maximum	30 kg (66lb)	45 kg (99 lb)	80 kg (172 lb)
Turning radius	100 (39")	114 (44½")	90 (35½")
Solid seat to floor height	12"	18"	22"

Tablet Computer and eReader Holder For Wheelchairs

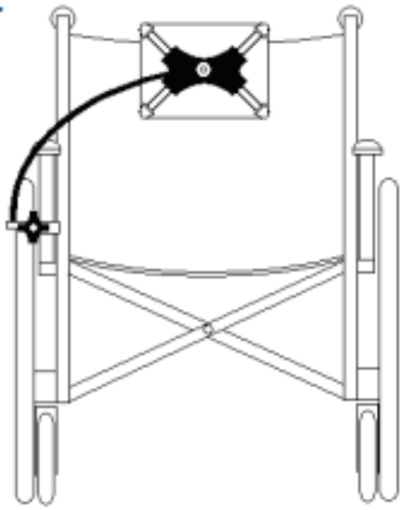
Product Information and Mounting Tips

Mounting Tab Grabber

The clamp on the Tab Grabber is specifically designed to fit round tubing up to 1 1/8" diameter. This will fit all wheelchairs, round bed rails or other tubing and poles.

The best attachment point for a wheelchair application will most likely be the arm rest frame as shown.

A supplemental clamp is available for attaching the Tab Grabber to tables or other flat surfaces.
Order Part No. TG-TC



Tips

With the clamp firmly tightened onto the wheelchair frame, the flexible gooseneck and swiveling head allow for perfect positioning.

When leaving the Tab Grabber mounted to a wheelchair for a prolonged period, simply swing it out of the way to enter or exit the wheelchair.

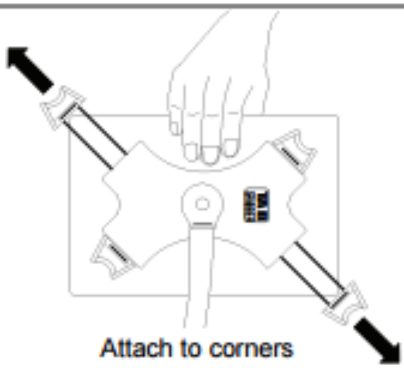
Clean all components of the Tab Grabber with a soft cloth and mild cleaning solution. Remove before power washing wheelchair.

Attaching Tablet

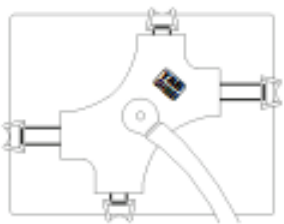
Hold tablet firmly when mounting or removing from Tab Grabber head.

The typical clip location for most tablets will be at the corners. However, if this interferes with controls, the clips can be located anywhere along the edge of the tablet as shown.

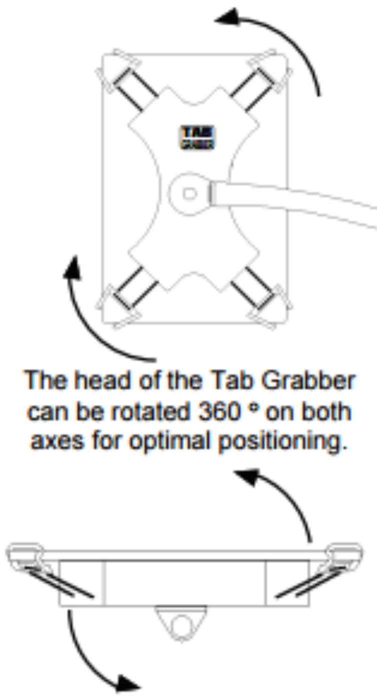
Extend retractable clips and place over opposite corners or edges first.
Extend and attach two remaining clips.



Attach to corners



Attach to edges



The head of the Tab Grabber can be rotated 360 ° on both axes for optimal positioning.

WARRANTY The Tab Grabber is warranted to be free from defects in material and workmanship under normal use for a period of one year. 210 Innovations sole obligation under this warranty is limited to repair or replacement of defective parts. This warranty does not cover failure due to abuse, misuse, alteration or improper installation.

Manufactured by 210 Innovations, LLC
210 Leonard Drive
Groton, CT 06340

800.210.2298
www.safetmate.com
Made in the USA · Patent Pending

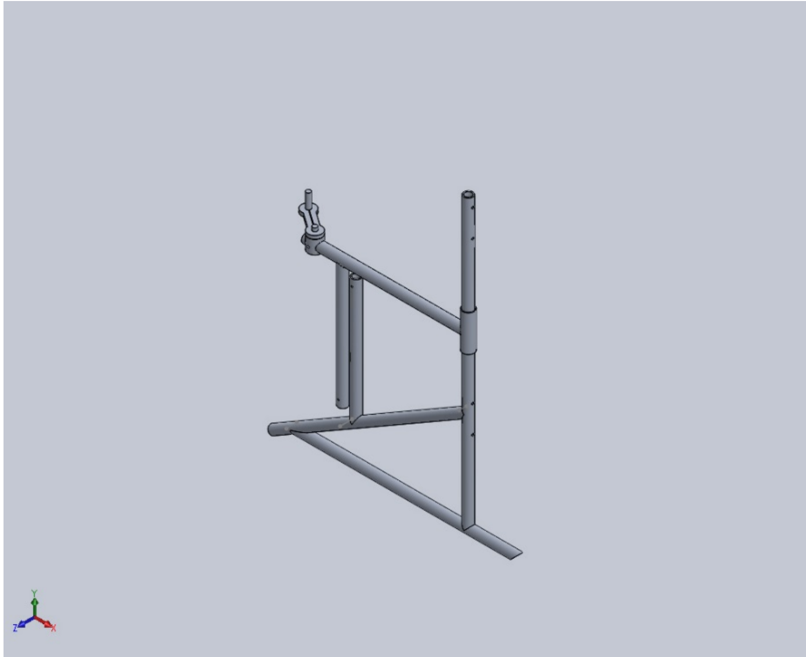
Safe•t mate

Product use and specification sheet

Model Number	**TG-1**
Brand Name	Tab Grabber ®
Description	Tablet Computer / eReader Holder for Wheelchairs
Manufacturer	210 Innovations, LLC 210 Leonard Drive Groton, CT 06340 860-445-0210
Recommended Use	For wheelchair users desiring to have a tablet computer holder that attaches directly to their wheelchair frame.
Not recommended for	Wheelchair users who may tend to move unpredictably increasing the chance of injury by coming in contact with the unit. Wheelchair users who may tend to treat such attachments very roughly whereby breaking one or more components on the device.
Operation	To achieve greatest stability, the Tab Grabber mounting clamp is best attached to a vertical frame member on the wheelchair such as and armrest support. Once secured, the flexible gooseneck arm allows the unit to be swung to the side for ease of wheelchair entry and exit. At the same time, the arm is stiff enough to provide a firm position for touchscreen applications. The "head" of the Tab Grabber will swivel on multiple axis to provide optimal positioning. The tablet is mounted to the head by means of four retractable clips attached to elasticized cord that can be mounted to the corners or anywhere along the edge. Thin cases will work with the unit but thicker protective cases may prevent mounting clips from properly grabbing the tablet.
Specifications	Materials: Injection molded ABS plastic, Foam rubber, PVC plastic, steel, nylon covered shock cord. Fits: Round tubing from 5/8" diameter to 1 1/8" diameter. Weight capacity: 4 lbs. Tablet size capacity: Smallest- 3.5" X 5.5" Largest -8.5" X 11" Tablet thickness up to ½" at edges. Flexible arm length: 18" Minimum bend radius of flexible arm: 3.5"
Care	Wipe unit with cloth and mild spray cleaner such as glass cleaner. Do not submerge.

Utility Wheels	 zoom
Product Name & Number	25.4 cm (10") EVA Solid Foam Wheels WZ1-25EVA
Dimensions	25.4 x 6 cm (10 x 2.4")
Width at Bushing/Bearing	5.7 cm (2.25")
Max. Payload per Wheel	34.9 kg (77 lbs)
Weight	0.27 kg (9.5 oz)
Materials	**Tire:** Durable EVA Foam **Hub:** High strength plastic **Bushing:** Nylon
Pressure Range	Solid Foam
Works on	Hobie Standard Plug In
Price	**$18.00** (per pair)
Add to Cart By Selecting Bushing Size	1/2" Bushing

Appendix E: Analysis



Simulation of Frame, Assembly

Date: Thursday, February 09, 2017
Designer: Solidworks
Study name: Static 3
Analysis type: Static

Table of Contents

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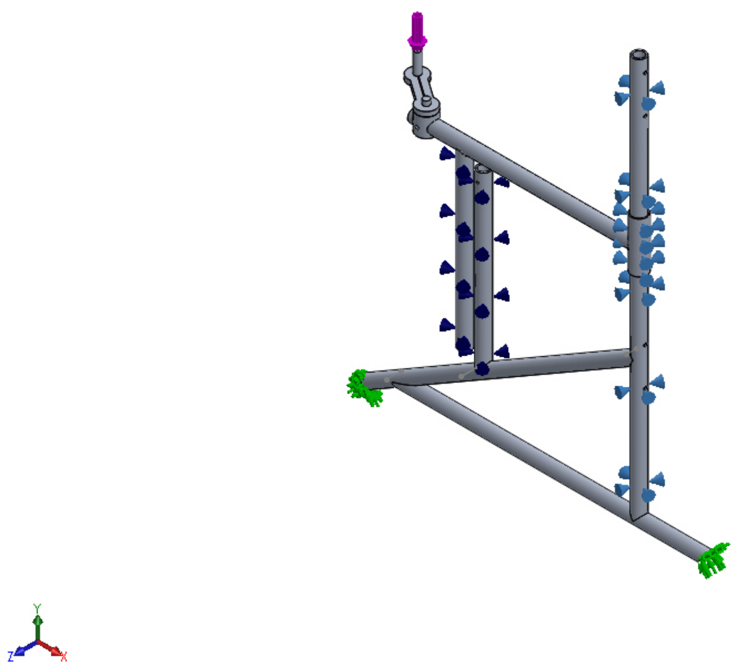
Description

No Data

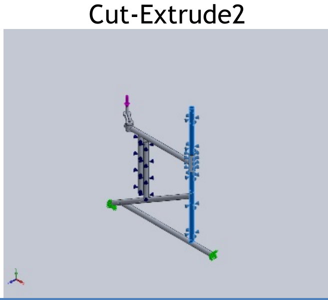
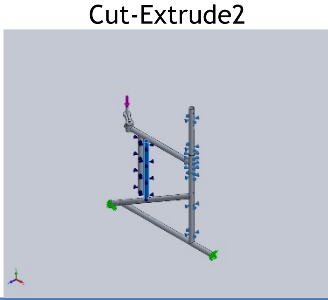
Assumptions

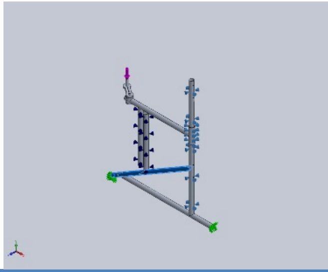
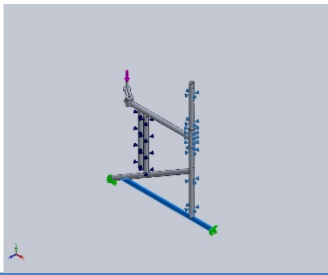
Model Information



Model name: Frame, Assembly
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Boss-Extrude1	Solid Body	**Mass:0.0538547 kg** **Volume:1.99462e-005 m^3** **Density:2700 kg/m^3** **Weight:0.527776 N**	**E:\Azelia's Walker\CAD\FEA frame\Arm Supports\Arm, Part, Back Outside Telescope.SLDPRT** Feb 09 00:43:16 2017

Cut-Extrude2	Solid Body	Mass:0.264952 kg Volume:9.81305e-005 m^3 Density:2700 kg/m^3 Weight:2.59653 N	E:\Azelia's Walker\CAD\FEA frame\Arm Supports\Arm, Part, Horizontal Support.SLDPRT Feb 09 00:43:16 2017
Cut-Extrude2	Solid Body	Mass:0.206886 kg Volume:7.66245e-005 m^3 Density:2700 kg/m^3 Weight:2.02748 N	E:\Azelia's Walker\CAD\FEA frame\Arm Supports\Arm, Part, Inside Telescope.SLDPRT Feb 09 00:43:14 2017
Boss-Extrude2	Solid Body	Mass:0.0736663 kg Volume:2.72838e-005 m^3 Density:2700 kg/m^3 Weight:0.721929 N	E:\Azelia's Walker\CAD\FEA frame\Arm Supports\Arm, Part, Swing Arm Connector.SLDPRT Feb 09 00:43:16 2017
Cut-Extrude1	Solid Body	Mass:0.0753926 kg Volume:2.79232e-005 m^3 Density:2700 kg/m^3 Weight:0.738848 N	E:\Azelia's Walker\CAD\FEA frame\Arm Supports\Arm, Part, Swing Arm.SLDPRT Feb 09 00:43:16 2017
Boss-Extrude1	Solid Body	Mass:0.017375 kg Volume:6.43518e-006 m^3 Density:2700 kg/m^3 Weight:0.170275 N	E:\Azelia's Walker\CAD\FEA frame\Arm Supports\Arm, Part, Swivle Rod.SLDPRT Feb 09 00:43:16 2017
Cut-Extrude2 	Solid Body	Mass:0.478576 kg Volume:0.00017725 m^3 Density:2700 kg/m^3 Weight:4.69005 N	E:\Azelia's Walker\CAD\FEA frame\Back, Part, Frame Verticle Tubes.SLDPRT Feb 08 23:54:22 2017
Cut-Extrude2 	Solid Body	Mass:0.206003 kg Volume:7.62974e-005 m^3 Density:2700 kg/m^3 Weight:2.01883 N	E:\Azelia's Walker\CAD\FEA frame\Frame, Part, Arm Outside Telescope.SLDPRT Feb 08 23:54:22 2017

Cut-Extrude2 	Solid Body	**Mass:0.373452 kg** **Volume:0.000138316 m^3** **Density:2700 kg/m^3** **Weight:3.65983 N**	**E:\Azelia's Walker\CAD\FEA frame\Frame, Tube, Diagonal.SLDPRT** Feb 08 23:54:22 2017
Cut-Extrude3 	Solid Body	**Mass:0.363124 kg** **Volume:0.00013449 m^3** **Density:2700 kg/m^3** **Weight:3.55861 N**	**E:\Azelia's Walker\CAD\FEA frame\Frame, Tube, Horizontal 31in.SLDPRT** Feb 08 23:54:22 2017

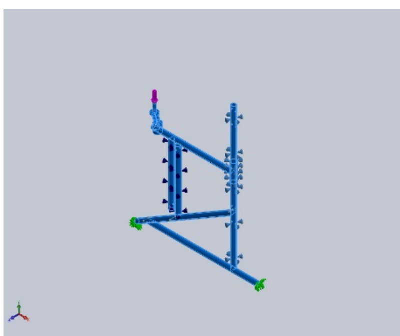
Study Properties

Study name	Static 3
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (E:\Azelia's Walker\CAD\FEA frame)

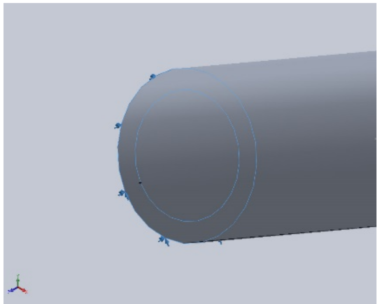
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

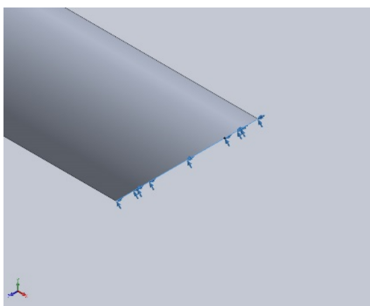
Model Reference	Properties	Components
	**Name:** 6061 Alloy **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 5.51485e+007 N/m^2 **Tensile strength:** 1.24084e+008 N/m^2 **Elastic modulus:** 6.9e+010 N/m^2 **Poisson's ratio:** 0.33 **Mass density:** 2700 kg/m^3 **Shear modulus:** 2.6e+010 N/m^2 **Thermal expansion coefficient:** 2.4e-005 /Kelvin	SolidBody 1(Boss-Extrude1)(Arm, Assem-1/Arm, Part, Back Outside Telescope-1), SolidBody 1(Cut-Extrude2)(Arm, Assem-1/Arm, Part, Horizontal Support-1), SolidBody 1(Cut-Extrude2)(Arm, Assem-1/Arm, Part, Inside Telescope-1), SolidBody 1(Boss-Extrude2)(Arm, Assem-1/Arm, Part, Swing Arm Connector-1), SolidBody 1(Cut-Extrude1)(Arm, Assem-1/Arm, Part, Swing Arm-1), SolidBody 1(Boss-Extrude1)(Arm, Assem-1/Arm, Part, Swivle Rod-1), SolidBody 1(Cut-Extrude2)(Back, Part, Frame Verticle Tubes-1), SolidBody 1(Cut-Extrude2)(Frame, Part, Arm Outside Telescope-1), SolidBody 1(Cut-Extrude2)(Frame, Tube, Diagonal-1), SolidBody 1(Cut-Extrude3)(Frame, Tube, Horizontal 31in-1)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
On Flat Faces-1		**Entities:** 1 face(s) **Type:** On Flat Faces **Translation:** 0, 0, 0 **Units:** in

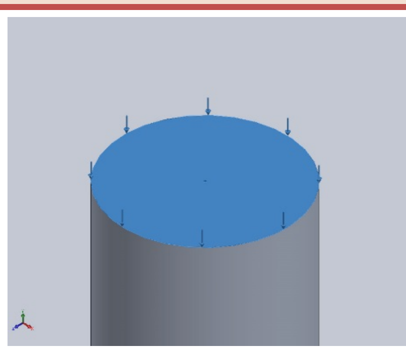
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	402.545	284.313	-0.765198	492.825
Reaction Moment(N.m)	0	0	0	0

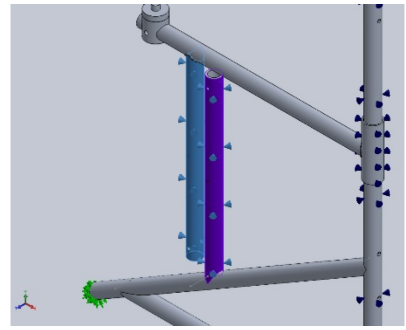
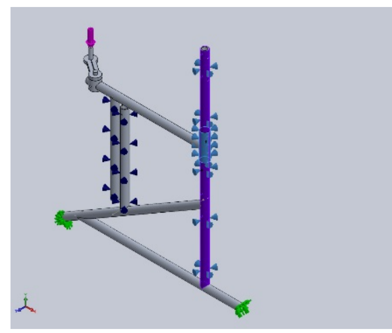
Fixture name	Fixture Image	Fixture Details
On Flat Faces-2		**Entities:** 1 face(s) **Type:** On Flat Faces **Translation:** 0, 0, 0 **Units:** in

Resultant Forces

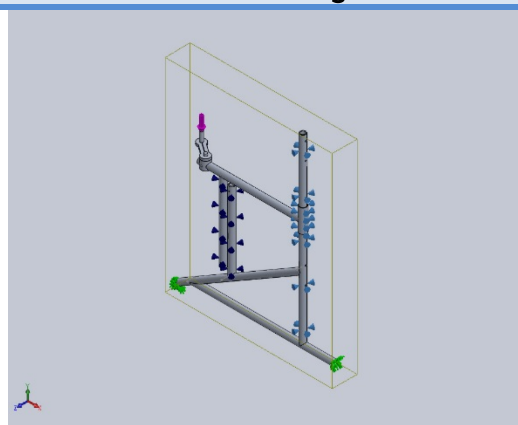
Components	X	Y	Z	Resultant
Reaction force(N)	-402.545	-17.4193	0.765269	402.923
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		**Entities:** 1 face(s) **Type:** Apply normal force **Value:** 60 lbf

Connector Definitions

Connector Name	Connector Details	Connector Image
Rigid Connector-1	**Entities:** 2 face(s) **Type:** Rigid	 Rigid Connector-1
Rigid Connector-2	**Entities:** 2 face(s) **Type:** Rigid	 Rigid Connector-2

Contact Information

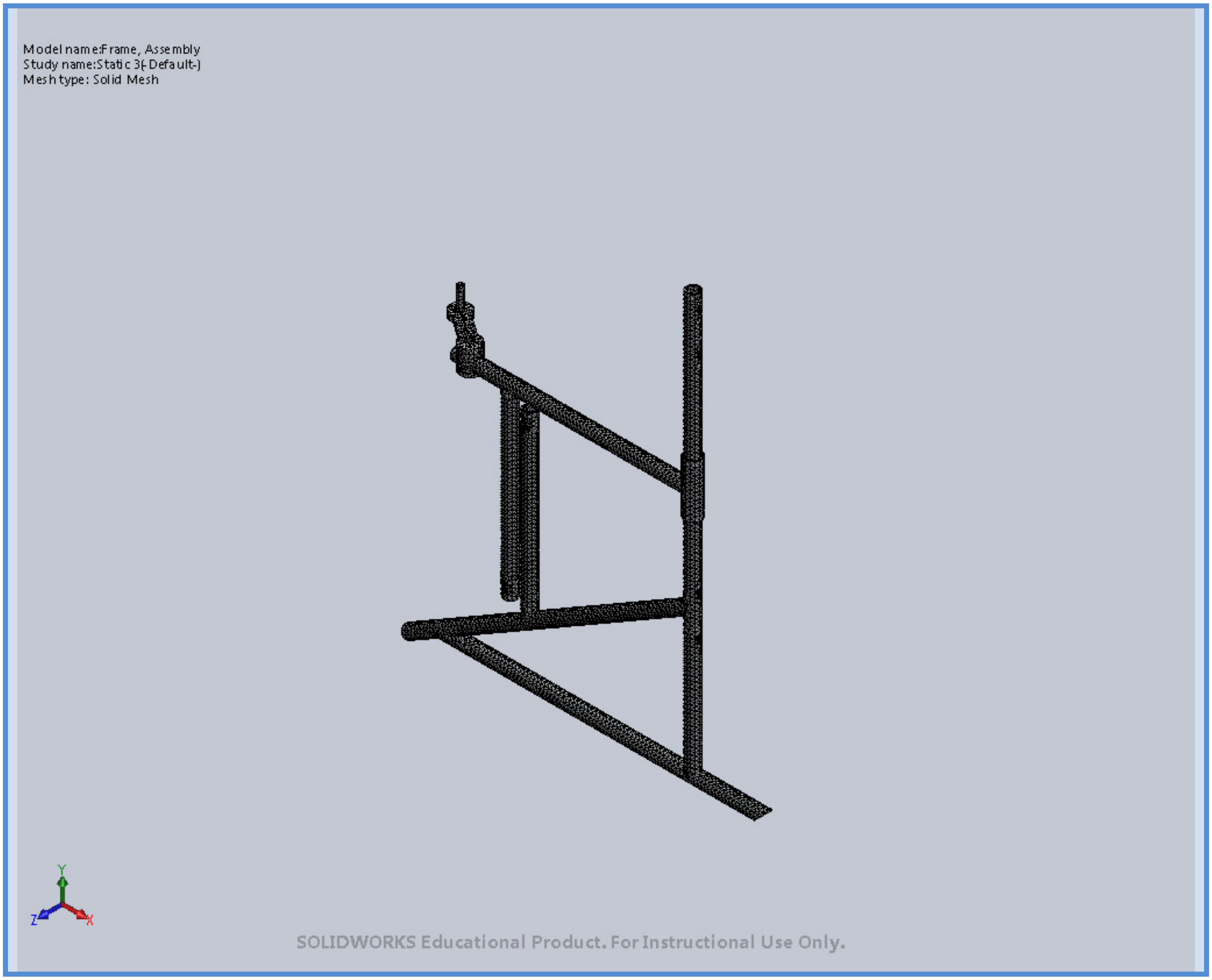
Contact	Contact Image	Contact Properties
Global Contact		**Type:** Bonded **Components:** 1 component(s) **Options:** Compatible mesh

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.275116 in
Tolerance	0.0137558 in
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off

Mesh information - Details

Total Nodes	67737
Total Elements	34172
Maximum Aspect Ratio	13.719
% of elements with Aspect Ratio < 3	93.7
% of elements with Aspect Ratio > 10	0.0468
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:13
Computer name:	ME-192-132-09



Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.000133514	266.893	7.15256e-005	266.893

Reaction Moments

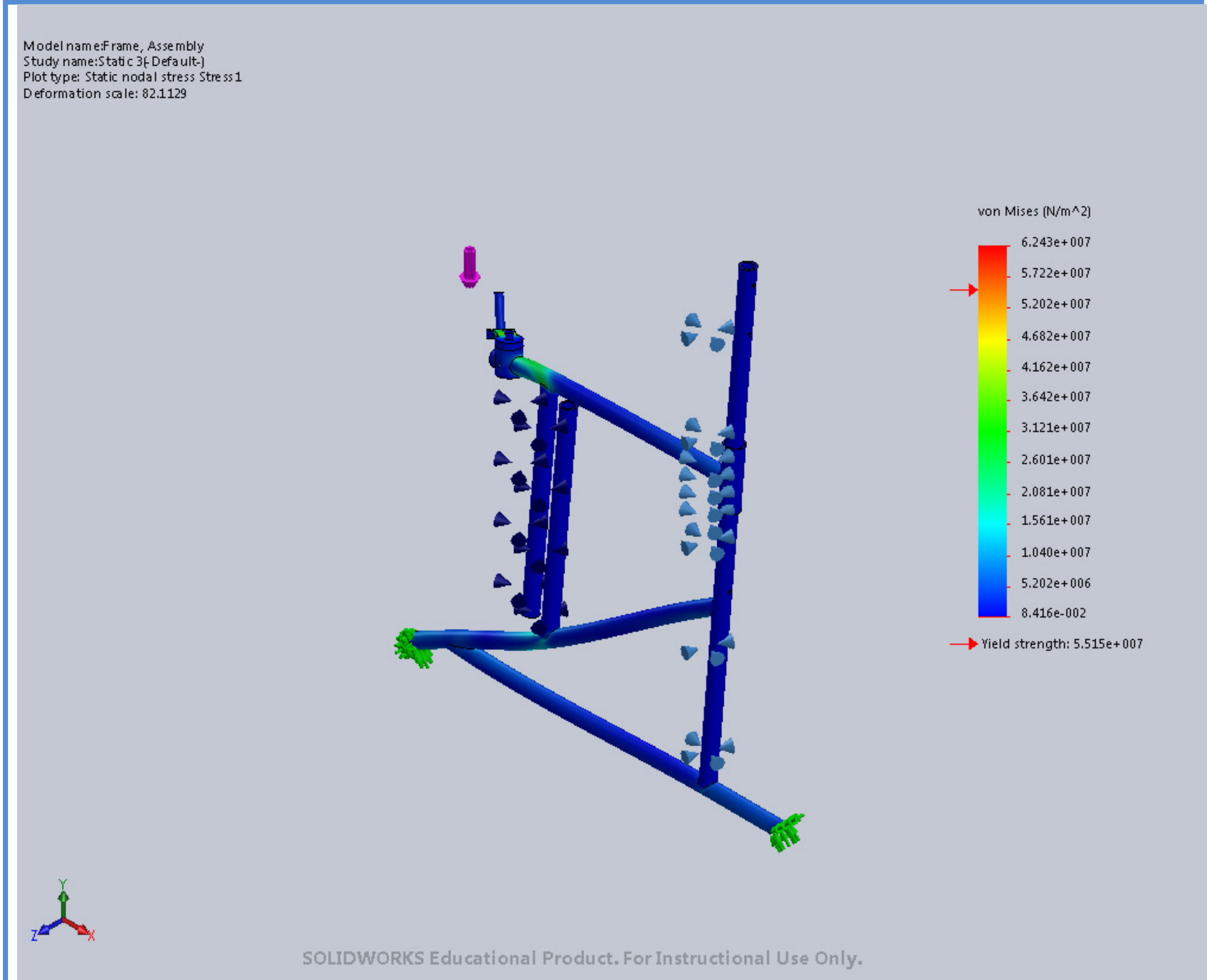
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

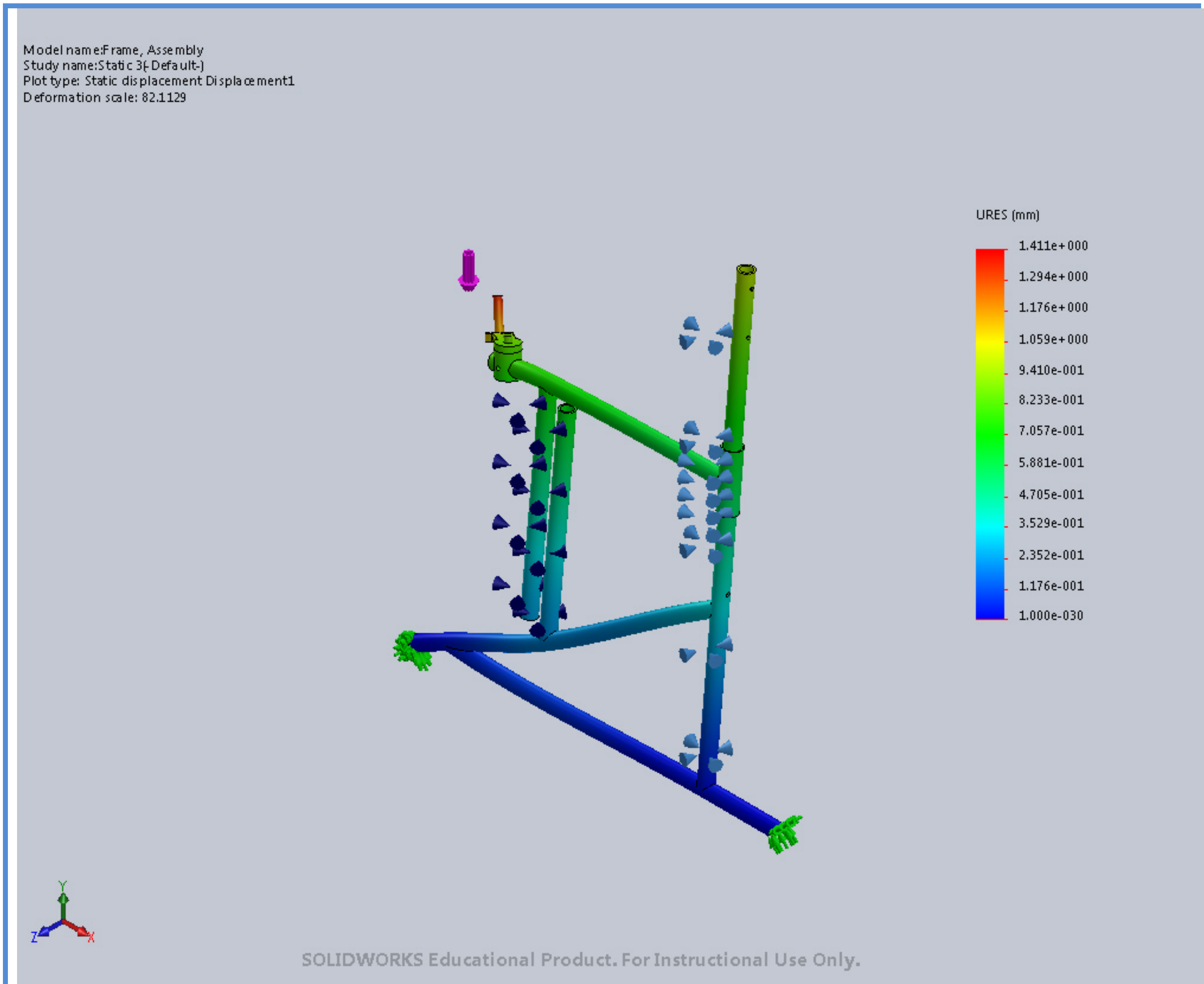
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.0841601 N/m^2 Node: 33023	6.24266e+007 N/m^2 Node: 10897



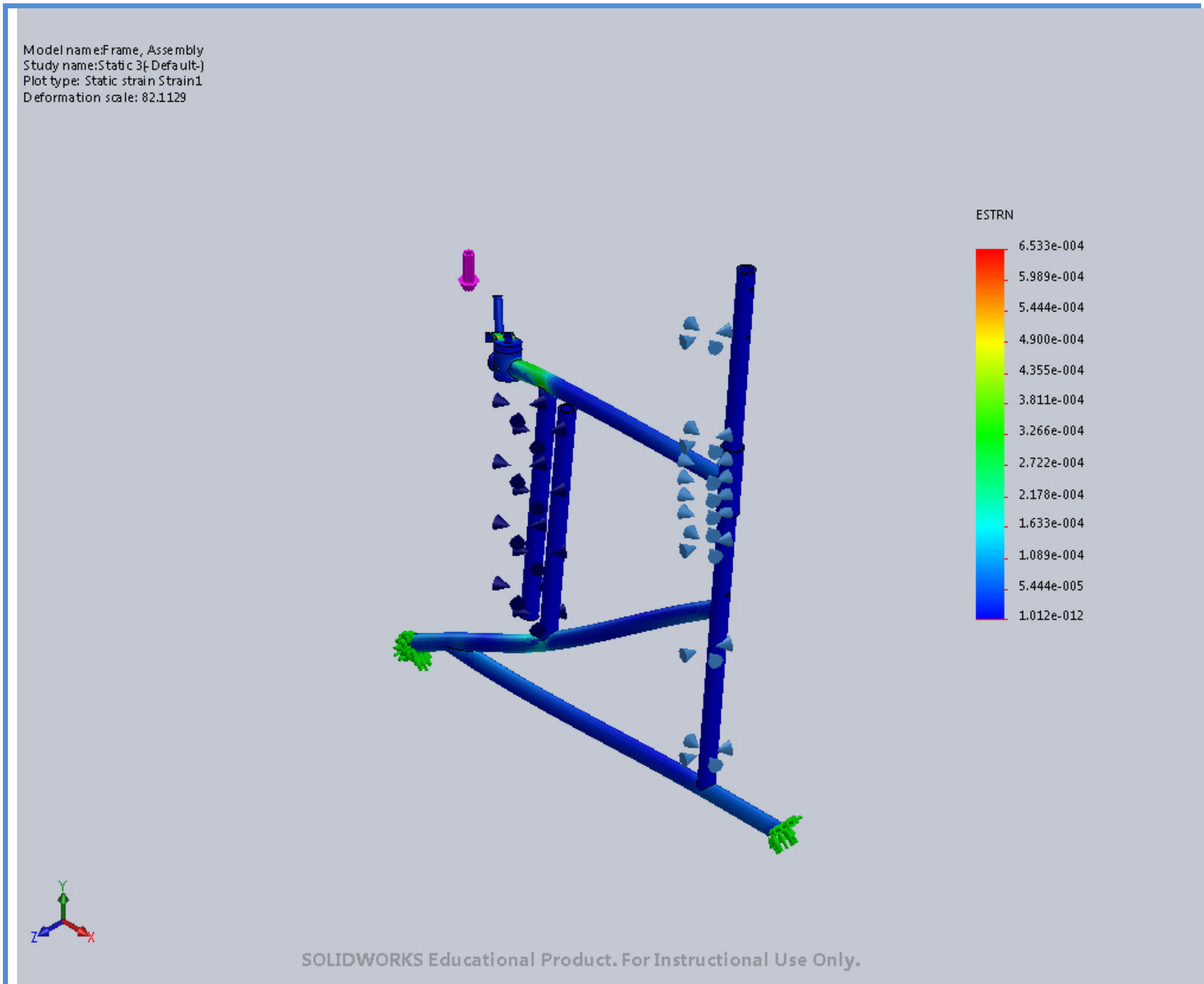
Frame, Assembly-Static 3-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 45595	1.41145 mm Node: 22712



Frame, Assembly-Static 3-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.01247e-012 Element: 18870	0.000653292 Element: 3147

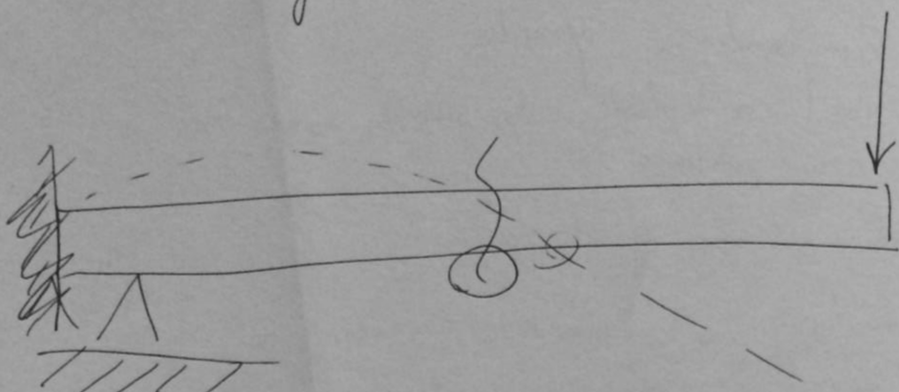


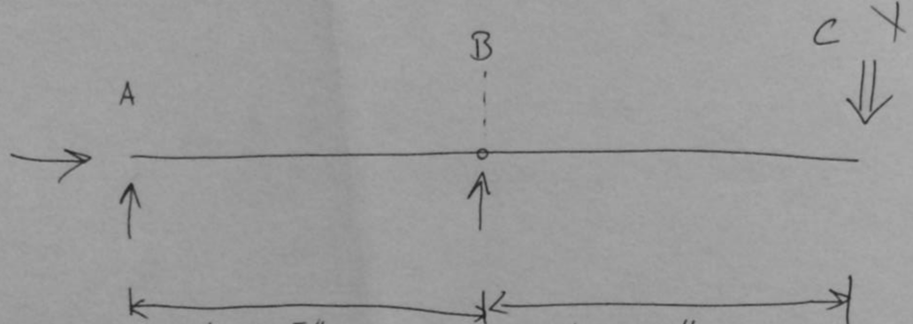
Frame, Assembly-Static 3-Strain-Strain1

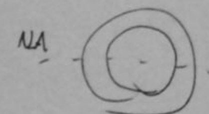
Conclusion

2/16 Beam analysis For Seat

60 lbs







$$\theta_B = \frac{ML_1}{3EI}$$

$M = 300$ lb in

$M = 60(5)$

$= 300$ lb in

$E = 10{,}000$ ksi $= 10^6 \frac{lb}{in^2}$

$$I_x = \frac{\pi(OD^4 - ID^4)}{64}$$

$= 0.02\ in^4$

$$\theta_B = \frac{300\ [lb \cdot in]\ [in]\ 5}{3\left(10^6\ [\frac{lb}{in^2}]\right)(0.02\ in^4)}$$

Worst case Scenario

$= 0.025$

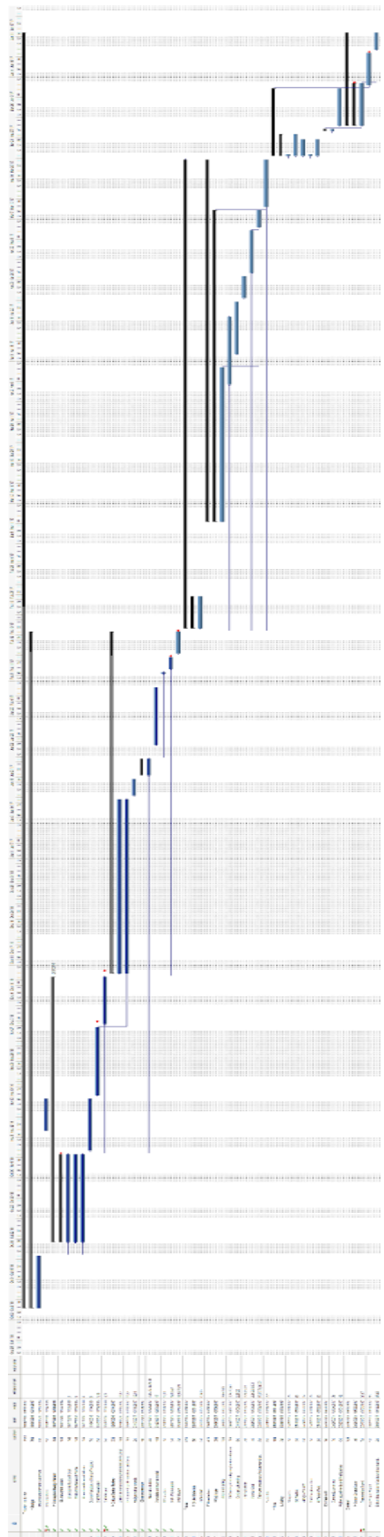
$\delta_c = \theta_B L_2$

$\delta_c = 0.125$ in

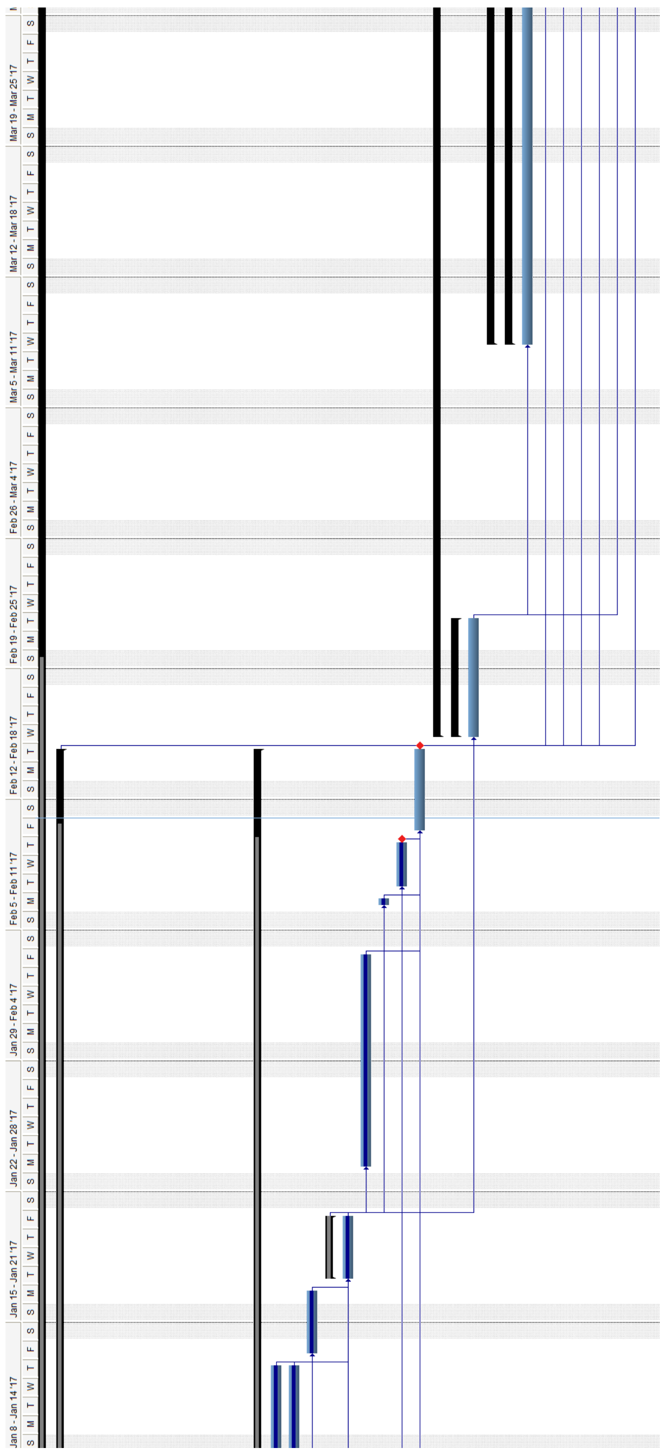
Appendix F.1: Gantt Chart

	ⓘ	Name	Duration	Start	Finish	Predecessors
1		**Walker for Azelia**	**155d**	**10/04/2016**	**06/12/2017**	
2		**Design**	**76d**	**10/04/2016**	**02/14/2017**	
3	✔	Project Requirements Document	9d	10/04/2016	10/14/2016	
4	✔	Decision Matrix	5d	11/08/2016	11/14/2016	
5	✔	**Conceptual Design Review**	**34d**	**10/17/2016**	**12/08/2016**	
6	✔	**Conceptual Model**	**14d**	**10/17/2016**	**11/03/2016**	
7	✔	Brainstorm/Research Seat	14d	10/17/2016	11/03/2016	3
8	✔	Brainstorm/Research Frame	14d	10/17/2016	11/03/2016	3
9	✔	Brainstorm/Research Wheels	14d	10/17/2016	11/03/2016	3
10	✔	Design Variations of Walker/Prototype	7d	11/04/2016	11/14/2016	6
11	✔	CoDR Presentation	5d	11/15/2016	11/28/2016	6,10
12	✔	CoDR Report	8d	11/29/2016	12/08/2016	6,11
13		**Critical Design Review**	**33d**	**12/09/2016**	**02/14/2017**	
14	✔	Gather all necessary measurements from Azelia	10d	12/09/2016	01/12/2017	11,12
15	✔	Test armrest handle prototypes with Azelia	10d	12/09/2016	01/12/2017	11,12
16	✔	Analyze walker wheels	2d	01/13/2017	01/16/2017	12,14
17	✔	**Bill of Materials**	**4d**	**01/17/2017**	**01/20/2017**	
18	✔	Material selection	4d	01/17/2017	01/20/2017	7,8,9,12,14,15,16
19	✔	Complete solidworks model	10d	01/23/2017	02/03/2017	17
20	✔	FEA analysis	1d	02/06/2017	02/06/2017	17,19
21	✔	CrDR Presentation	3d	02/07/2017	02/09/2017	12,19,20
22		CrDR Report	3d	02/10/2017	02/14/2017	12,19,20,21
23		**Build**	**62d**	**02/15/2017**	**05/18/2017**	
24		**Order Materials**	**5d**	**02/15/2017**	**02/21/2017**	
25		Place Order	5d	02/15/2017	02/21/2017	2,18,22
26		**Manufacture**	**47d**	**03/08/2017**	**05/18/2017**	
27		**Fabricate**	**39d**	**03/08/2017**	**05/08/2017**	
28		Initial tube cutting	18d	03/08/2017	04/07/2017	25FS 10d
29		CNC/water jet cut collapsing back mechanism	10d	04/04/2017	04/17/2017	2,25FS 24d
30		Contract out welding	9d	04/10/2017	04/20/2017	2,25,28
31		Test Assembly	3d	04/21/2017	04/25/2017	2,28,29,30
32		Powder Coat	7d	04/26/2017	05/04/2017	2,25,28,30,31
33		Fabricate remainder of subassemblies	2d	05/05/2017	05/08/2017	25,28,29,30,32
34		Assemble	8d	05/09/2017	05/18/2017	2,27
35		**Test**	**10d**	**05/19/2017**	**06/01/2017**	
36		**Safety**	**3d**	**05/19/2017**	**05/23/2017**	
37		Sharpness	1d	05/19/2017	05/19/2017	23
38		ISO Testing	3d	05/19/2017	05/23/2017	23
39		Sitting Load Test	2d	05/19/2017	05/22/2017	23
40		ADA Compliance Test	1d	05/19/2017	05/19/2017	23
41		All Terrain Test	2d	05/19/2017	05/22/2017	23
42		**Azelia Test**	**1d**	**05/24/2017**	**05/24/2017**	
43		Comfort/Ergonomics	1d	05/24/2017	05/24/2017	36
44		Walker adjustments and final touches	6d	05/25/2017	06/01/2017	42
45		**Deliver**	**13d**	**05/25/2017**	**06/12/2017**	
46		**Senior Design Expo**	**7d**	**05/25/2017**	**06/02/2017**	
47		Presentation Board	7d	05/25/2017	06/02/2017	36,42
48		Final Project Report	5d	06/02/2017	06/08/2017	35
49		Deliver final walker to Azelia and her parents	2d	06/09/2017	06/12/2017	47,48

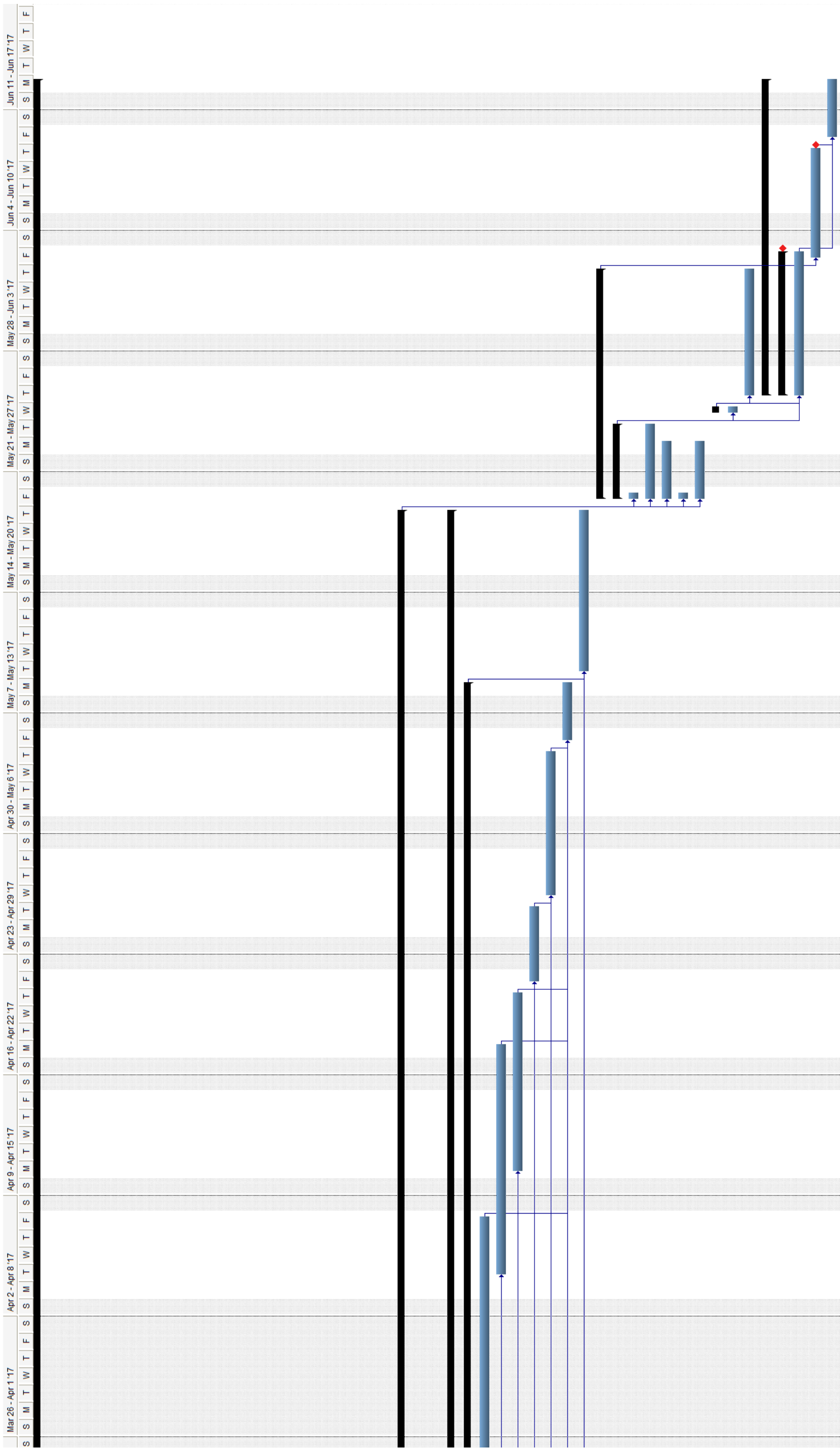
Appendix F.2: Gantt Chart Fall Quarter



Appendix F.3: Gantt Chart Winter



Appendix F.4: Gantt Chart Spring Quarter



Appendix G: Safety Checklist

SENIOR PROJECT CRITICAL DESIGN REVIEW HAZARD IDENTIFICATION CHECKLIST

Y	N	
☒	☐	Do any parts 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 adequately guarded?
☐	☒	Does any part of the design undergo high accelerations/decelerations that are exposed to the user?
☐	☒	Does the system have any large moving masses or large forces that can contact the user?
☐	☒	Does the system produce a projectile? c c Can the system to fall under gravity creating injury?
☒	☐	Is the user exposed to overhanging weights as part of the design?
☐	☒	Does the system have any sharp edges exposed?
☐	☒	Are there any ungrounded electrical systems in the design?
☐	☒	Are there any large capacity batteries or electrical voltage in the system above 40 V either AC or DC? **N/A**
☐	☒	c Is there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids when the system is either on or off?
☐	☒	Is there any explosive or flammable liquids, gases, dust, or fuel part of the system?
☐	☒	Is there any explosive or flammable liquids, gases, dust, or fuel part of the system?
☐	☒	Is the user of the design required to exert any abnormal effort and/or assume an abnormal physical posture during the use of the design?
☐	☒	Is there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
☐	☒	Will the system generate high levels of noise?
☒	☐	Will the product be subjected to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc. that could create an unsafe condition?
☐	☒	Is it easy to use the system unsafely?
☐	☒	Is there be any other potential hazards not listed above? If yes, please explain on the back of this checklist?