Doggone It

Final Design Review: Service Dog Ramp

Sponsor: Quality of Life Plus, Vanessa Salas

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Abstract

This document is intended to illustrate the design direction chosen, explain our design process, give justification for each decision, and provide instructions for the future of the project. This Final Design Report builds on the content from the Critical Design Review document with updated sections and new sections for finishing the project in the future. Before the team can continue with the decided direction, approval from the sponsor must be obtained. The project involves designing a device to help a service dog easily get into and out of a truck.

1.0 Introduction

Quality of Life Plus (QL+) is a nonprofit that partners with universities in the creation of innovative solutions to aid injured veterans. This nonprofit has given us the opportunity to design and manufacture a device to help a retired military veteran's service dog enter and exit his truck. Rory, the service dog, frequently jumps in and out of the truck causing his hips and elbows to endure much stress. Some mechanism is needed to minimize stress on Rory's body as he enters and exits the truck. The retired military veteran, Peter Way, has tried other devices currently on the market which are mentioned in the Background section. All the tried solutions have produced non-satisfactory results due to their heavy weight and big size. Another issue with the other solutions was that Rory would not find the device approachable and would jump over the device into the cab, making the device purposeless. Specific research into the current devices available on the market in addition to other background research can be found in the Background section of the document. To improve upon the solutions already created, we have established a list of customer needs and specifications that need to be fulfilled. These items can be found in the Objectives section. Information about the leading concept design as well as a detailed description of the selection process can be found in the Concept Design section. The Manufacturing section contains information on items that were fabricated, and detailed instructions on how a future engineering team could finish the rest of manufacturing and assembly. The Project Management section describes what the team achieved and what they were not able to finish.

2.0 Background

This Background section involves research conducted early in the process from customers, existing products, patents, and technical literature. This provides a baseline of knowledge to move forward.

2.1 Summaries of Customer Observations, Meetings, and Interviews

To better understand the scope of our project, a phone interview was conducted with Peter on October 10, 2019. The full team and QL+ representative, Vanessa Salas, were present during the interview with the goal of fully understanding Peter's needs and wants for this project. Our interview gave us a better understanding of why this project is so important to him. Rory performs a lot of mobility tasks for Peter, and because there is a long waiting period and high price to get a new service dog, Peter would like to prolong Rory's service as much as he can. However, because Rory enters his truck 6-8 times a day, Peter fears the repeated wear and tear of entering and exiting the truck may begin to take a toll physically on Rory. Peter has tried various products, but none have been satisfactory, as the current products he has tried are either too large or heavy for him or are not easily usable for Rory.

2.2 Existing Products

As a part of the background research, existing products were examined, and each design was evaluated and compared to one another. These evaluations can be seen in Table 1 and pictures of each product can be found in Appendix A. Most of the existing products had a folding and carrying mechanism for easy portability and storage and were all relatively lightweight. However, the sturdiness of each product is questionable, as multiple online reviews for each product cited stability as an issue. With our own design we hope to incorporate the positive aspects of these different products, while also mitigating or even removing their drawbacks.

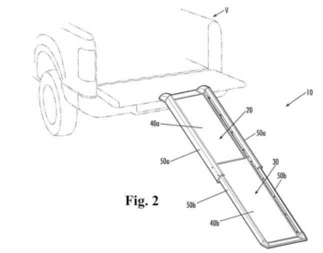
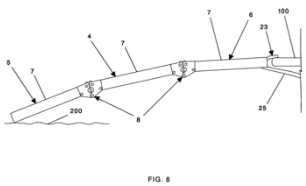
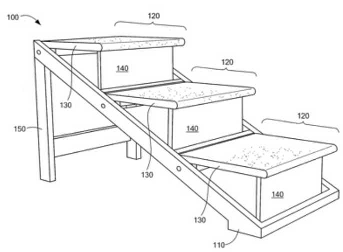
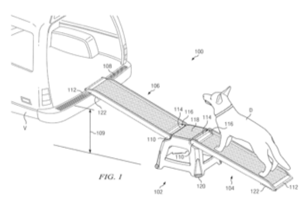
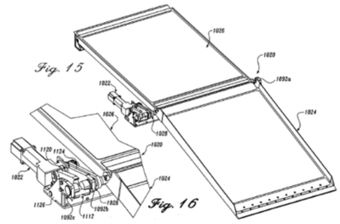
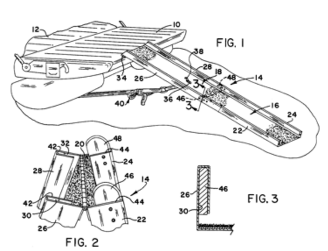
Table 1. Pros and Cons of Current Products

Product	Pros	Cons
Pet Gear Travel Lite Bi-Fold Ramp [1]	- Foldable for compact storage - SuperTrax Mat adds traction for pet paws - Has a handle for portability - Rubber grip on bottom keep ramp steady when deployed	- Sides of ramp are not covered with traction mat, easy for dog to slip and fall off - Plastic material; may not be sturdy enough - May be too steep for Peter's truck
Petstep Gray Folding 2 Step Assist [2]	- Lightweight (5.75 lbs) - Collapsible and can be opened with one hand - Weight capacity: 300 lbs - No-slip rubber grips on steps	- Steps may be difficult to use - Plastic material may not be sturdy enough despite 300 lb weight limit - Not high enough to reach truck
Upgraded Nonslip Pet Steps [3]	- Foldable for compact storage - Plastic boards in steps prevent sagging and provide added traction - Can decrease the angle of the steps to lower the incline - Carrying handle	- Design may be too flimsy for Rory's size (150 lb weight limit) - Steps may be difficult for Rory to use - Designed for the trunk or bed of a truck
PetSafe Solvit Telescoping Ramp [4]	- Telescoping function makes it easy to store as well as adjustable - Metal frame but only 13 lbs - Weight limit: 400 lbs - Carrying handle - Easy to clean	- Traction surface may hurt paws; surface still may be too slippery - Design is not as sturdy despite metal frame - Has some sharp edges
Auto Dog Ramp [5]	- Foldable - Optional grip tape for additional traction - Ramp hinges lock into place when in use - Carrying handle for portability	- Weight limit is only 120 lbs - Durability of grip tape is questionable - Designed for trunk or truck bed

2.3 Patent Research

Another important step in conducting background research was searching for existing patents on other devices used for transporting pets to and from vehicles. In addition to fully assembled devices, we also searched for patents on individual mechanisms that we might incorporate into our design. The reason for doing a patent search in addition to a product search is that patents include much more detail on the technical aspects of the products. This is beneficial to the team because it gives us ideas on how to solve potential problems. It is also beneficial from a design perspective because it allows us to pick and choose which components we may want to incorporate into our design. Table 2 shows some of the patents found during our research.

Table 2. Product Patents

Patent Name	Picture	Description
Telescoping Pet Ramp [6]		A telescoping pet ramp having first and second ramp segments telescopically extendable from a compact state to an extended state. Side rails of the panels include end caps with abutment members for preventing the first-floor panel and second floor panel from being separated when the pet ramp is fully extended, and including interlocking angled contact faces that frictionally engage one another when the ramp is fully extended.
Tri-Folding Ramp [7]		The tri-folding ramp is a portable, collapsible device that includes three sections. The arc-shaped profile of the ramp can reduce the loading angle between the distal end of the ramp and an upper loading surface, thereby inhibiting contact between the vehicle's undercarriage and the ramp's upper surface.
Folding Pet Ramp and Steps [8]		The apparatus includes a frame supporting an upper platform member and a lower platform member. The lower platform member has a lower riser and a lower runner. The upper platform member has an upper riser and an upper runner which are movable between a ramp mode and a step mode. The upper riser fixedly supports the upper runner against the frame when in the step mode, and is moveable from the fixed supported position to permit the upper runner to move to the ramp mode.
Pet Ramp System [9]		A pet ramp system comprised of a platform and two ramp sections. The angle for each ramp can be adjusted due to the axle connection on the platform which allows for various climbing angles as well as accommodation for various ground heights.
Fold-out Ramp Having a Load Dampener [10]		The ramp assembly includes a ramp platform coupled to a frame, a reciprocating mechanism coupled to the ramp platform for reciprocating movement of the ramp platform between a stowed position and a deployed position, and a dampener coupled to the reciprocating mechanism to dampen loads associated with operation of the ramp platform.
Portable Dog Ramp [11]		The ramp comprises two relatively narrow alignable ramp sections which are centrally hinged and designed to cause their edges adjacent the hinging to firmly abut and be interlocked. The hinge and locking interconnection are relatively closely toleranced so as to provide a stable linearly-extending ramp capable of supporting heavy pets. Carpeting is provided on the walking surface for traction, and a strap may be used to tie the ramp to a vehicle and further stabilize it, thereby overcoming any fear an animal may have in traversing the ramp.

2.4 Technical Information

Technical literature offered some great insight before fully diving into the problem solution. It's important to understand why a dog would need help getting into and out of a truck. Labrador retrievers are commonly affected by both elbow and hip dysplasia, especially as they age. These lesions weaken their legs, and definitely make it hard to jump into a truck [12]. Another common issue in Labradors is myopathy, a surprisingly common muscle disease that doesn't let muscle fibers function properly [13]. Also, as labs age their immune systems gradually weaken and make it harder to fight things like dysplasia or myopathy [14]. Rory is at risk for all of these issues, and we need to be aware of this and limit the stresses on his legs. A successful project will keep him working and healthy for a long time.

Technical literature was important for making an actual product as well. Metal will definitely be part of the project due its strength and durability, and welding might be a process we use at some point. Welds need to be inspected for cracks and porosity which can cause failure over time [15]. Failure that could cause injury to the dog is absolutely unacceptable, and we must be certain that any welds are professionally inspected. Tolerances for any metal parts must also be thoroughly designed, especially if there are moving parts. It gets quite hot inside a car sitting in the sun, which causes metals to expand and weaken [16]. Everything needs to work perfectly and safely, even if the product has been sitting in the hot car for a few hours.

3.0 Objectives

3.1 Problem Statement

Peter is a retired military veteran who had his right leg amputated above the knee. He uses a wheelchair to get around and needs a way to get his service dog in and out of his truck safely and easily, that he can use independently. This product will assist with prolonging the dog's life and mobility.

3.2 Boundary Diagram

The boundary diagram in Figure 1 shows aspects that we don't have control over. We cannot change the dog, the wheelchair, or the truck itself. There may be some flexibility with the backseat, but that will depend heavily upon our collaboration with the wheelchair lift team. That team is building a wheelchair storage device for the same user, Peter, that will be stored in the back seat of his truck. Ultimately, we can work with the open space in the backseat represented by dotted lines and our product itself.

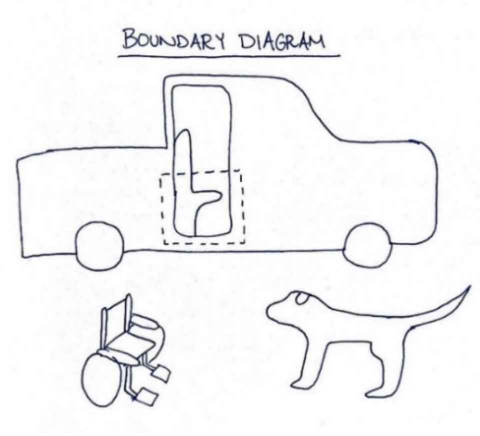


Figure 1. Boundary Diagram

3.3 Summary of Customer Wants & Needs

We want to deliver a product that makes Peter and Rory happy and comfortable. We must meet or exceed these basic needs in Table 3.

Table 3. Customer Wants and Needs

Wants	Needs
Lightweight	Comfortable climbing angle
Usable in other vehicles	Safe/strong
Fits compactly in Tacoma cab	Durable and long-lasting
Easy to assemble	Independently operated
Easy to clean	Does not interfere with wheelchair lift
Inexpensive	Comfortable/grippy on paws

3.4 Brief Description of the QFD Process

Part of project planning involves Quality Function Deployment (QFD). Using this process and a "house of quality" allows us to make sure all needs are met and can be tested. Customer needs are compared with engineering specifications, and competing products are analyzed for competition. Different criteria are given weights based on overall importance; this allows a visualization of what benchmarks our product must meet or exceed. The full QFD house of quality is in Appendix B attached to this report.

3.5 Engineering Specifications Table

Table 4, generated from the house of quality, displays our primary engineering requirements.

Table 4. Engineering Specifications

Spec No.	Description	Requirement/Target	Tolerance	Risk	Compliance
1	Weight	25 lbs	±15 lbs	H	T
2	Vehicle Compatibility	4 vehicle types	Min	H	T
3	Rust	No rust	Max	L	T
4	Deflection	10% of length under 150 lbs	Max	L	A,T
5	Dimensions	2 inches thick	±1 inch	H	A,I,T
6	Cleaning Time	5 minutes	Max	L	T
7	Assembly Time	2 minutes	Max	H	T
8	Dog Willingness to Use	3 fearless dogs	Min	H	T
9	Cost	$1,000	Max	L	A

The risk of meeting a goal is set to high, medium or low, and compliance is assessed either by testing, analyzing, or inspecting. Each specification will be measured as follows:

1. We will put the final product on a scale to test the weight.
2. We will try to use the product in a truck, car, van, and SUV.
3. We will conduct a salt-spray test and observe any oxidation effects.
4. We will analyze the product using finite element analysis, and then test the real product with a 150 load and measure the deflection.
5. We will design and analyze the product in SolidWorks before building and measuring it.
6. We will clean the product and time it.
7. We will assemble the product and time it.
8. We will get 3 dogs and make sure they're comfortable using the product instead of jumping over it or being scared.
9. We will maintain a detailed bill of materials and ensure we don't exceed the target budget.

Weight, vehicle compatibility, compact dimensions, assembly time, and dog willingness are all the high-risk areas to meet. Weight and dimensions will need to be thoroughly designed for so that it's easy to use and store. Since we're designing primarily for Peter's Tacoma, it may be hard to get the product to work in four different types of vehicles. Whatever mechanism is employed must be simple so that assembly time is not long. And finally, the angle of the product must be gradual enough for dogs to feel comfortable using it.

4.0 Concept Design

4.1 Process for Design Selection

The process of the final design selection consisted of an ideation stage and the creation of Pugh matrices and a weighted decision matrix. The ideation stage involved techniques such as brainstorming, functional decomposition, and brainwriting. Brainstorming consisted of the traditional technique where a team member wrote down ideas of all team members on a whiteboard as they were voiced. The next technique used to brainstorm was functional decomposition, which broke down the main function of the device into subfunctions that could be brainstormed. The final technique used was brainwriting that required each team member to individually draw their ideas and present them to the team. This technique allowed each member to have a voice in the design.

After the ideation stage, concept models were constructed from each team member's ideas. These concept models were constructed using foam core and toothpicks. Appendix C compiles all the designs the team came up with. From these models, Pugh matrices were constructed to rank each design on its ability to carry out each desired function of the ramp; to get Rory in the truck, to be compact, to be easily stored, and to attach to the vehicle. Pugh matrices break the main function of the device into subfunctions and evaluates how well different solutions work against a specific subfunction. Based off the rankings of the Pugh matrices, a morphological matrix was created to assess the best combination of solutions for each subfunction. In order to factor in the desires of the customer, a weighted decision matrix was used to evaluate which design would be the best according to the customer's needs. The Pugh matrices, morphological matrix, and weighted decision matrix can be seen in Appendices D, E, and F, respectively.

4.2 Top Concepts

Our top 5 concepts are shown in the sketches of Figure 2. The most basic idea is a simple flat ramp that stays rigid. A bi-fold ramp would fold in half and could lead to more portability and be easier to store. A rolling ramp offers even more portability and has many more hinges than a bi-fold ramp. A scissor lift would have to be powered by hand or motor and would remove the dog's need to actually climb an incline. A telescoping ramp offers a great combination of being compact and rigid at the same time since it can telescope into itself.

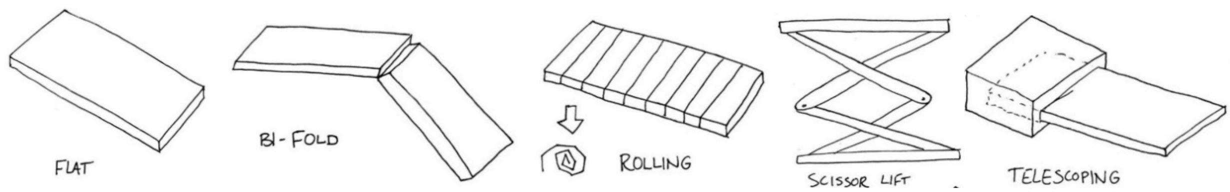


Figure 2. Top 5 Concept Sketches

4.3 Weighted Decision Matrix

To factor in the needs of the customer, a weighted decision matrix was used to evaluate the combinations deemed best by the Pugh matrices. The weighted decision matrix is presented in Table 5 and Appendix F. From the weighted decision matrix, the telescoping ramp that hooks onto the side of the truck bed was found to be the best option.

Table 5. Weighted Decision Matrix

Criteria	Weighting	Options					
		Telescoping Ramp Hooked onto Side of Bed		Folding Stairs Strapped to Truck Bed		Roll-Up Lift Clamped to Ceiling	
		Score	Total	Score	Total	Score	Total
Lightweight	3	3	9	3	9	5	15
Safe/Strong	5	5	25	4	20	3	15
Use in other Cars	5	4	20	5	25	5	25
Climbing Angle	2	5	10	3	6	3	6
Dog Comfort	5	5	25	1	5	2	10
Wheelchair Lift Interference	4	5	20	5	20	5	20
Customers Preference	3	5	15	3	9	3	9
	Total		**124**		**94**		**100**

4.4 Concept Description

Figure 3 shows our selected concept CAD model, while Figure 4 shows the 3D printed version. After going through different stages of feedback, the final design looks different from this model, but the overall functionality is similar.

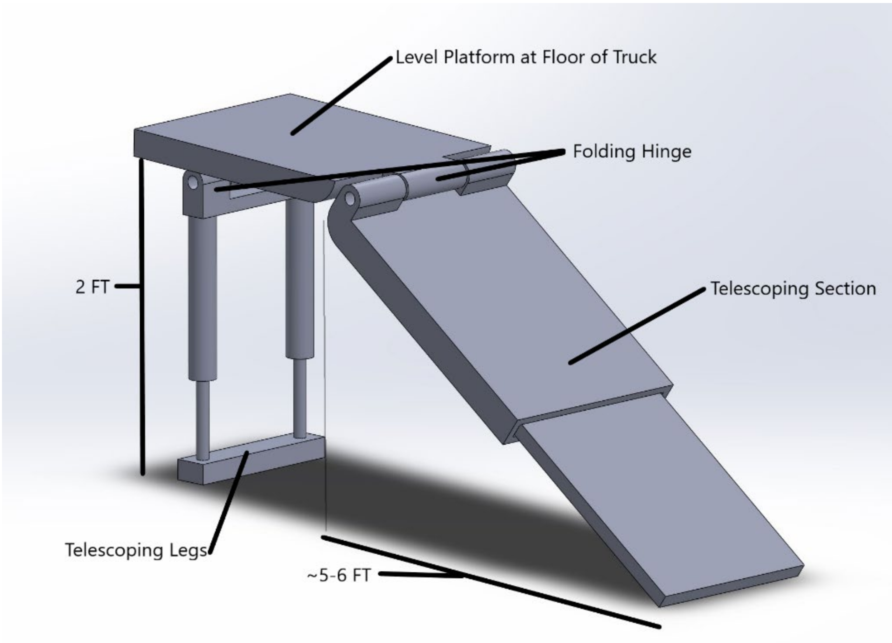


Figure 3. Labeled Isometric CAD Model

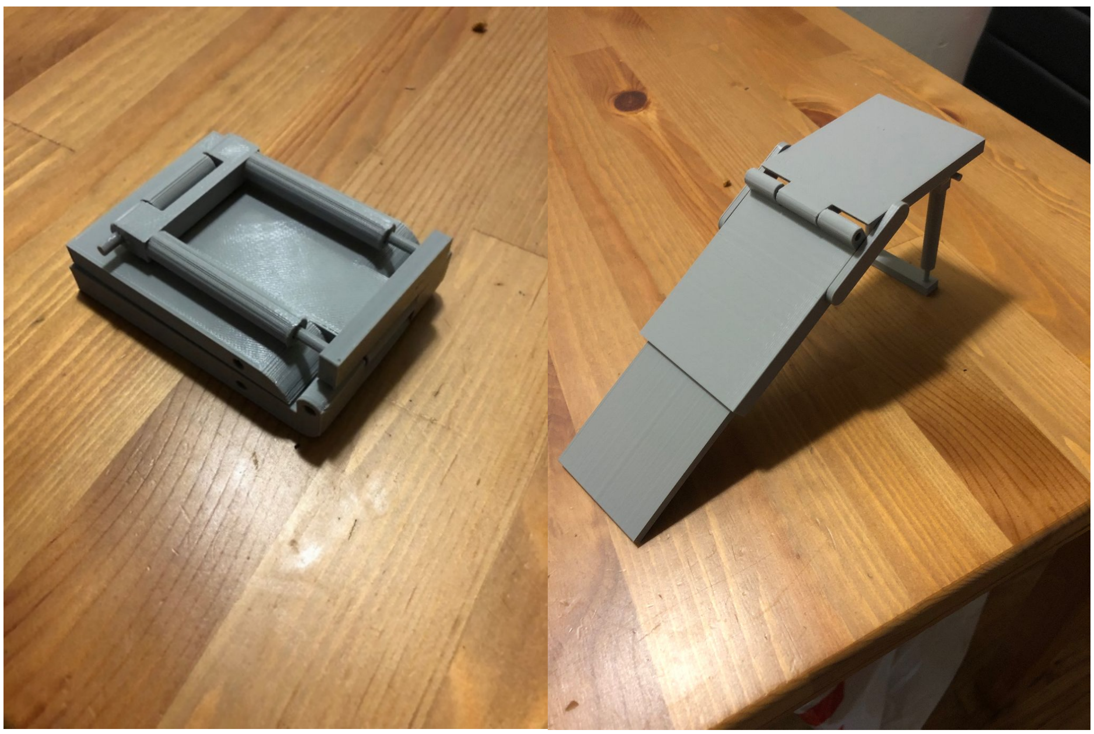


Figure 4. Folded and Extended 3D Printed Concept Prototype

The four major design components that are planned to be kept throughout the design process are the level platform, folding hinge, telescoping ramp, and adjustable legs. The level platform is necessary since the ramp will not lead directly into the cab of the truck like most products on the market. Instead the ramp will run parallel to the truck tucking closely alongside the bed and end at the cab. With this configuration Rory will need space to complete a 90° turn into the cab, hence the level platform. The reason the ramp will run parallel instead of perpendicular into the truck is because Peter has specified a climbing angle of around 20°. With that constraint along with the height of the truck floor, the ramp needs to be roughly five feet long. A ramp of that length sticking out perpendicularly from the cab is impractical and would not be able to operate in a handicap parking space.

The folding hinge was a design choice that specifically targeted the compactness of the system. The telescoping ramp and legs were chosen not only for their compactness, but also for their ability to be deployed on varying ground and vehicle heights which fulfills the requirement for the system to be used in other vehicles. Upon deployment, Peter would first extend the legs, unfold the telescoping ramp, then extend the ramp to the desired length.

The ramp is intended to be constructed out of aluminum because of its high specific strength and weather resistant properties. As for manufacturing, some welding and standard machining will be necessary, both of which can be done in Cal Poly's machine shops. Store-bought components will be implemented as much as possible to hasten the manufacturing process and to allow easy part replacement. Specific dimensions have not been finalized yet, but based on other products on the market, the ramp width is estimated to be about 18 inches. The way the ramp will be attached to the truck and how it will be stored has not been determined yet. These determinations depend on the final dimensions of the product as well as coordination with the Wheelchair Team.

Based off preliminary analysis, the device will be safe for Rory. Bending analysis was conducted to find an optimal size for a ramp made of aluminum. This analysis can be seen in Appendix G. If the ramp is 18 inches wide and 6.33 feet long, it would have to be almost 4 inches thick to accommodate for the dog's weight with a bending safety factor of 2.00. This safety factor ensures the ramp will bend less than an inch at the least supported section under 100 pounds. It comes nowhere close to making the metal yield. A thickness of 4 inches exceeds the desires of the customer, so the analysis was conducted again but with the assumption that the ramp will be supported in the center and at both ends. With this assumption, the thickness of the ramp was calculated to be 2 inches, which is much more reasonable.

Analysis on the usage of bolts was also conducted in the case that hinges would be utilized. With a safety factor of 2.00 and a worst-case scenario of a 100-pound shear load on one bolt, ¼" steel bolts were found to have plenty of strength to hold this load safely. Additionally, this standard size makes it easy to purchase and to drill mating holes. ½" bolts were looked into but were concluded to be overkill for this purpose.

4.5 Current Risks, Challenges, and Unknowns

To determine the current risks and challenges, a Design Hazard Checklist was filled out. This checklist can be seen in Appendix H. With this checklist, potential hazards the design may encounter as well as how to correct those hazards were evaluated. A table of our findings can be seen in

Table 6.

Table 6. Design Hazards and Planned Corrective Action

Description of Hazard	Planned Corrective Action
System could fall due to gravity	Attach the system to either the side of the truck bed or onto the seat inside the cab
The system could have pinch points and sharp edges	Cover the sharp edges with a protective sheet to prevent injury. We will add a guard to cover pinch points.
Exposure to harsh environments	Make the system out of material that can withstand large temperature changes as well as confirm our tolerances to account for expansion
Could be used in an unsafe manner	Provide a procedure manual as well as warning labels

5.0 Final Design

The following section describes our final design along with justifications for every component and changes that came after the Critical Design Review. Additionally, a summary of our safety, maintenance, and repair considerations are provided along with our cost analysis.

5.1 Description and Explanation of Final Design

The subassemblies of our final design include a flat platform, a telescoping ramp, and an X-stand. Our plan is to custom fabricate the flat platform out of aluminum square tubing. This subassembly will be supported by the X-stand and will function as the interface between the ramp and the cab floor. It will ensure that Rory has enough room to turn into the cab with even footing. The telescoping ramp subassembly will be purchased from Petco. The manufacturer, Solvit, has designed its product to support 300 pounds, which ensures the safety of Rory. With the telescoping mechanism, we can accomplish our goal of keeping our product compact and provide the length needed to reduce the incline angle of the ramp. While providing a support for the flat platform, the X-stand will also provide Peter with height adjustability. We purchased a heavy-duty piano bench from Guitar Center and removed the padded seat portion so we can mount our flat platform directly to the X-stand portion of the bench. This bench has predetermined heights that Peter can use to adjust to whatever vehicle he plans to use. Figure 5 provides a visual of the final design.

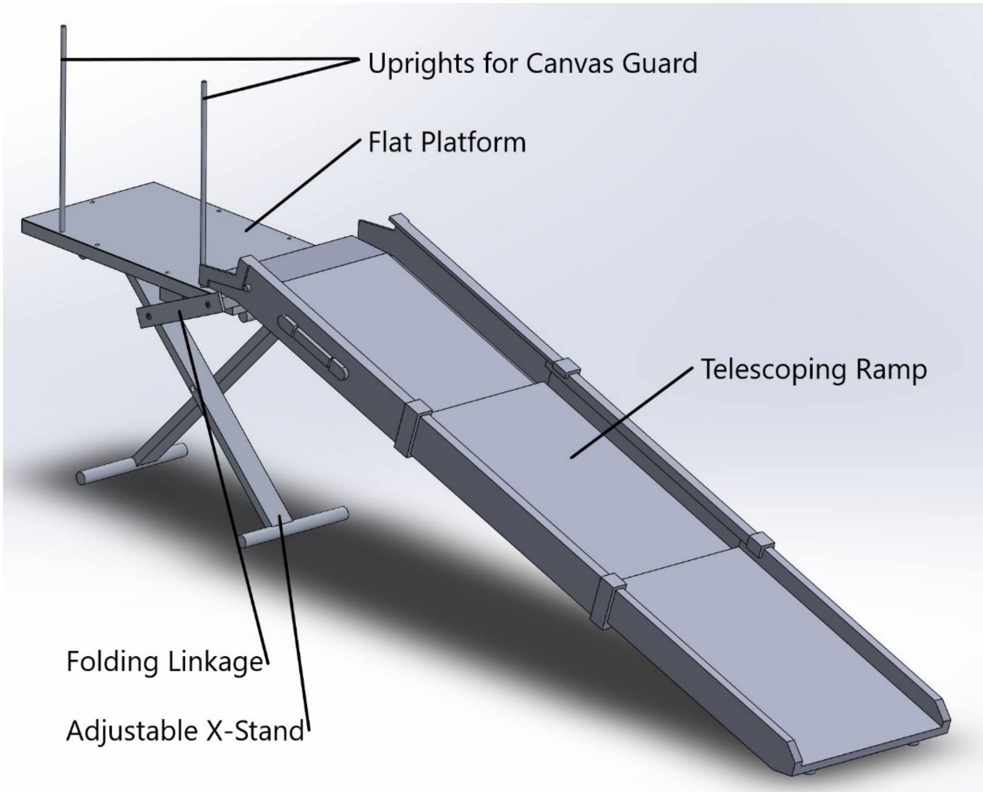


Figure 5. Final Design of Service Dog Ramp with Components Labeled

With all parts put together, the final product will fit the specifications of being compact, accessible to wheelchair users, and, most importantly, will reduce the stress on Rory's hips and elbows. The telescoping ramp portion will reduce the storage space and give Rory a way to climb up to the level of the truck cab. Rather than jumping from the ground into the cab, the ramp provides a gradual climb that is less impactful on his hips and elbows. Additionally, the X-stand and telescoping ramp gives Peter a way to assemble the ramp easily from his wheelchair. The assembly on Peter's part requires deploying the X-stand by spreading its legs and pulling out the telescoping ramp.

5.2 Evidence of Meeting Specifications

It is important to prove that this design will function properly and be safe before moving onto manufacturing and testing. As mentioned previously, the purchased telescoping ramp is rated from the factory to support 300 pounds, so that is not an area of worry. The purchased X-stand is also rated for 400 pounds, so the strength of that isn't a concern either. The main areas that must be analyzed are the strength of the custom fabricated flat platform, the strength of the folding linkage, and the potential for the X-stand tipping over.

Before using numerical analysis methods on a computer, hand calculations were performed to get a general estimate of how strong each part should be. These hand calculations for strength and stability can be found in Appendix I. Finite element analyses were then conducted to confirm the hand calculations on the center member of the flat platform and the folding linkage are correct. These analyses can be found in Figure 6 and Figure 7 respectively.

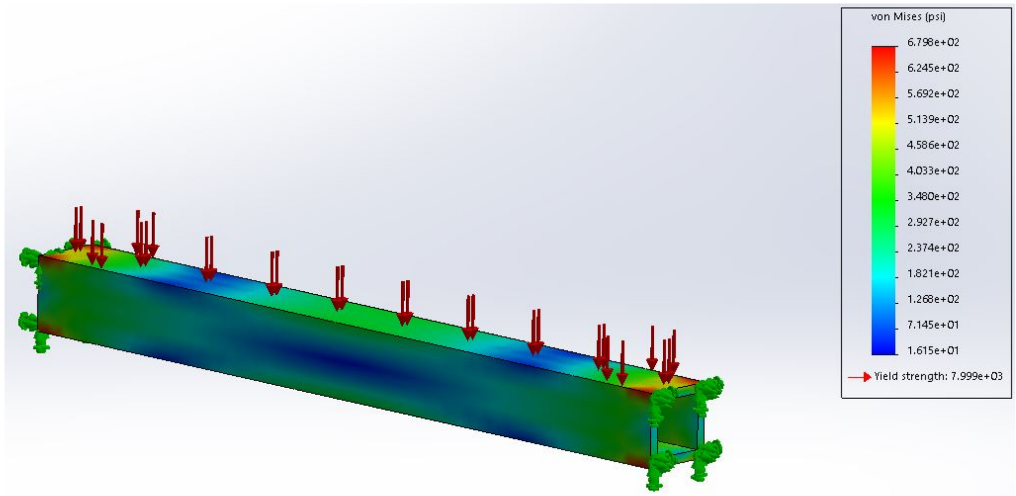


Figure 6. Flat Platform FEA

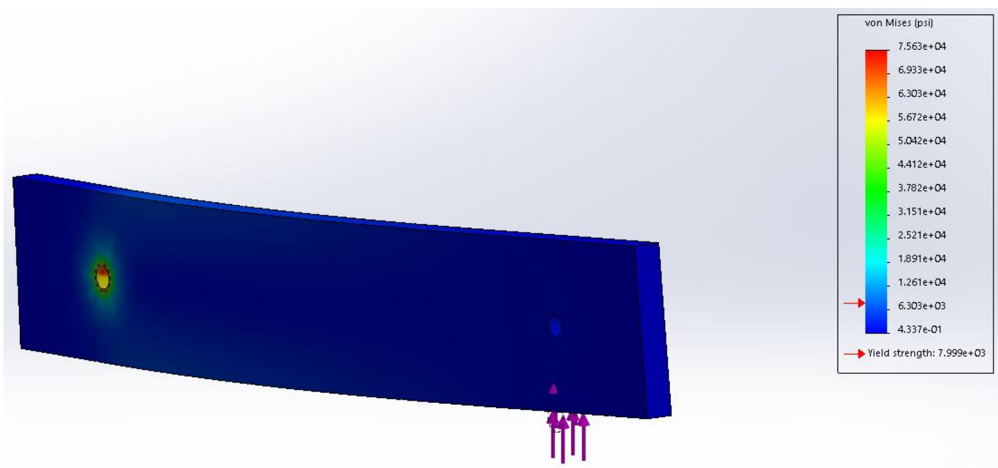


Figure 7. Linkage FEA

The hand calculations and finite element analysis both inspire confidence that the most critical parts of this design will function as intended. Each individual linkage can support 96 pounds before yielding, providing an overall linkage safety factor of 2.4. This may seem a little bit low for Rory, but through practical testing we have found that the linkage takes practically no load during operation. The center member of the flat platform ended up coming nowhere close to yielding, with a safety factor around 50. This is very high, and a smaller geometry could possibly be used, but that would make the folding mechanism much more difficult to operate so we are sticking with 1-inch square tubing.

To analyze X-stand stability, group members trusted the hand calculations and put the ramp on a team member's current keyboard stand. They risked X-stand collapse and put considerable weight on the ramp, going both up and down it. This test proved that the stand would stay firmly planted in the ground under loads much heavier than Rory can produce.

5.3 Safety, Maintenance, and Repair Considerations

A lot of thought and consideration went into the safety aspect of the design. Safety concerns have shaped and altered the design in order to make it safer for both Rory and Peter. An example of this is the implementation of the X-stand for the support of the flat platform. Originally the team wanted to use telescoping legs that could also fold and tuck under the flat platform which can be seen in Figure 4. After assessing the tipping risk of such a design, the team decided to select a sturdier form of support. Another source of concern came from the possibility of the ramp tipping away from the truck. The solution to that problem would be to anchor the ramp to the truck somehow. The team decided that the best and safest way to do that would be to utilize the unused seat belt buckle and a strap that would hold the ramp system tightly to the truck. Another safety concern was possible pinch points for Rory while he walks up the ramp, and for Peter as he assembles it. The only possible pinch point that Rory would have encountered would have been at the connection of the ramp and the flat platform. If those two components met flush with each other, then there likely would have been a pinch point. In order to avoid this, the connection has been designed so that when the ramp is folded out and deployed it rests on top of the flat platforms edge which can be seen in Figure 5. As far as pinch points during assembly and disassembly of the system, the only area of concern would be the two linkages. Since the linkage range of motion is very minimal and there are no scissor-like sections where a finger could get trapped between two objects sliding past each other, the team is confident in the linkage system's safety. The linkage system was also tested for safety when the structural prototype was made and was deemed safe. The last area of concern was the possibility of Rory wanting to jump straight off the flat platform when exiting the vehicle. In order to prevent this, a canvas guard was designed to keep him on the ramp.

This ramp system requires virtually no maintenance in order to work properly. One main reason for this is because the design does not use any small delicate parts, or intricate mechanical systems. It does however have several moving parts, but those parts only move when setting up and taking down the ramp system. Otherwise, the system is static. The moving elements involve the telescoping ramp section, the linkage system, and the collapsing x-stand. Out of these components, the only one in risk of being jammed would be the telescoping ramp. This would most likely be the result of dirt and debris getting into the sliding mechanism. The only maintenance required to avoid or fix such a problem would be to rinse down the ramp when dirty and apply lubricant such as WD-40 to any moving parts. Since the entire assembly is made out of Aluminum, there is no concern of rusting.

There are only two components (linkages and flat platform) of the ramp system that are custom made, everything else is store bought which means replacements can be found online. If for some reason the linkage piece breaks or is bent to where it can no longer be used, it can easily be unbolted and replaced with another link. The team planned to send two spare linkages, but this will need to be accomplished by whoever takes over the project. The flat platform will be made from aluminum and is very robust. It is extremely unlikely that it will be compromised in a way that would make it unusable. However, there is a protective layer of rubber that will be applied around the perimeter of the flat platform which will protect the truck from being scratched. If this protective layer of rubber gets scratched off, all Peter would need to do is apply more Flex Seal liquid rubber to the exposed metal.

5.4 Summary of Cost Analysis

A bill of materials was compiled to lay out the full system assembly with all components as well as the accompanying costs. This bill of materials can be seen in Appendix L. Below is a table containing the different costs of each subassembly.

Table 7. Cost per Subassembly

Subsystem	Cost
Flat Platform	$123.79
Ramp	$240.26
Legs	$39.99
Total	**$434.04**

As seen from the table, the ramp subassembly of the system is the most expensive. This is because the telescoping ramp was purchased as is and will only be altered. The legs are also made from an alteration from a current keyboard seat product. The team decided to purchase existing products that could be modified to fit the design rather than fabricate them completely, as some components were deemed too difficult to manufacture given the teams current experience level and availability of shop tools. The flat platform must be fabricated completely from raw materials.

5.5 Changes After the Critical Design Review

For the most part, the final design direction remained unchanged after the Critical Design Review. The biggest thing was having Peter specify which kind of canvas guard he would like. It took a while to find the right pattern, but we found a New Camo print to use. After seeing the final implementation of the wheelchair storage system from another design team, we have decided to let Peter decide if he wants his wheels behind the driver or passenger seat. The ramp will fit behind the open seat. This will depend on him finding out which configuration is more comfortable.

We considered changing our design from aluminum square tubing to T-slot framing rails to avoid welding, but they are magnitudes more expensive than aluminum tubing and they would involve more redesign than we had time to complete. No more analysis was necessary for our design.

6.0 Manufacturing

This section describes the manufacturing process used in order to fabricate our system.

6.1 Procurement of Materials

Table 8 contains all materials needed for the project with their costs. All items were ordered online from their respective source websites. The materials were purchased through QL+, and these sources can be used for future ordering needs.

Table 8. Material Costs

Material	QTY	Unit Cost	QTY Cost	Source	More Info
Sheet Metal	1	$33.38	$33.38	Online Metals	Part #1238
Square Tubing	10	$5.11	$24.41	Online Metals	Part #18014
Grip Surface	1	$15.00	$15.00	Amazon	FlexSeal
Aluminum Round Rod	2	$2.00	$4.00	Online Metals	-
Canvas Sheet	1	$10.00	$10.00	Beverly's	New Camo Print
Hole Plugs	2	N/A	N/A	QL+ 3D Print	-
Hole Pins	2	N/A	N/A	QL+ 3D Print	-
Pet Safety Belt	1	$8.00	$8.00	Vastar	-
End Caps	2	$22.85	$45.70	Custom	Machined aluminum
3/16 Rivets	6	$0.69	$4.14	McMaster Carr	-
1/4-20 Bolts 1"	4	$2.29	$9.16	McMaster Carr	-
Telescoping Ramp	1	$130.00	$130.00	PetSafe	TriScope
Pivot-Linkage Connection	2	$22.85	$45.70	Custom	Machined aluminum
End Caps	2	$22.85	$45.70	Custom	Machined aluminum
1/4-20 Screws 1.5"	2	$2.43	$4.86	McMaster Carr	-
Button Strap	2	$7.00	$14.00	Amazon	Sumind
X Stand	1	$39.99	$39.99	Guitar Center	Item #1377810373366
TOTAL PARTS	**42**	TOTAL	**$434.04**		

6.2 Manufacturing and Assembly

For the design, we decided to purchase and modify an existing product for both the ramp portion and leg portion of the design. The flat portion is the only sub-assembly of the system that needs to be fabricated. The dimensions and specifications can be found in the drawing package in Appendix K. All machining processes was done using the available resources found in the Cal Poly Machine Shops.

6.3 Completed Manufacturing

The COVID-19 pandemic came around right in the middle of our manufacturing stage of the project. We are disappointed that we could not finish the entirety of the project, but here is what we did complete that a future team can use as-is:

Aluminum End Caps:

Figure 8. Completed End Caps

Guard Rail:

Figure 9. Completed Canvas Guard Rail

Linkages:

Figure 10. Completed Linkages

Frame Members:

Figure 11. Completed Frame Members

6.4 Leftover Manufacturing and Assembly

We hope that another team can take over and complete this project for Peter, either through Dr. Self's rehabilitation engineering course or through another QL+ project. It helps to have the drawing package handy when reading through this section. We want to make project completion as easy as possible, so here are detailed instructions on manufacturing and assembling the remaining parts:

Frame:

1. Refer primarily to Drawings 110-112 in the drawing packet.
2. Members were cut previously, but they may need to be re-cut by the new team since we practiced one weld and it did not come out too cleanly. The pre-cut parts would be great for welding practice if you do not choose to outsource welding. Lengths are needed according to the drawings for the long members, short members, cross member, and spacers. See Table 9.

Table 9. Frame Member Dimensions

Member	Quantity x Dimensions
Long	2x24" long
Cross	1x8.25" long
Short	2x10.25" long
Spacer	4x3.875" Long

3. The short and long members are then bevel cut at 45^o angles using the chop saw. Ask a shop tech about setting the chop saw clamp at 45^o. We recommend using Mustang 60 since the clamp in the Hangar does not clamp as needed. The 45^o angles can also be created slowly on a grinding wheel. This will take a lot of time and will require you to occasionally dunk the part in water since the grinding creates excessive heat.
4. The member from Drawing 112-1 must also be cut to its specified length. Drill and tap the holes as shown. After that, you must insert 2 end caps into the ends of the member and weld them in place. You may need to use a heat gun on the end cap before welding since they are so thick. You may also need helicoils for the threads if they become warped.
5. The sheet metal top must be cut down to 24" x 10.25" using the press brake. We have cut 2 pieces already, but you can make more if desired.
6. Once the frame pieces are all cut, they are to be TIG welded together in the orientation laid out in Drawing 110-3. Use a 90^o clamp to ensure that the 45^o bevels on the long and short members meet flush. If not, use a grinding wheel to hone the angles. Weld the 4 main corners of the frame first. After that, weld the cross member in the middle of the rectangular frame. The spacers are welded after this according the drawing dimensions, and 2 end caps should be placed into the outside of the spacers and welded in place. Refer to welding instructions from step 4.
7. Once the frame has been welded, the sheet metal will be riveted on top of the frame using 3/16" rivets. Follow Drawing 111 for rivet locations. The holes may need to be slightly larger for the rivets. Make sure you read the rivet packaging as they often show the needed pilot hole size.
8. Finally, the 3/8" holes for the net uprights must be drilled on a drill press according to Drawing 111. Make sure the canvas guard fits in these holes. If not, widen them.

Linkages:

1. Linkages were already completed, but you should make at least 2 spares.
2. The linkages must be cut to 10” in length out of ¼” x 1 ½” bar stock as shown in Drawing 132.
3. If you don’t have the DXF file for the linkage outline, you can save the drawing as one and use this on the waterjet cutter at Mustang 60. Shop techs are necessary for setting up the correct cutting files. We recommend cutting only the holes and outside radii since the height of the linkages is already set by the stock.
4. You can tap the two holes in the linkages to fit the bolts as specified in the drawing. If this makes assembly or deployment difficult, make them through-holes at a slightly larger diameter.

Assembly:

1. First take the member from Drawing 112-1 and line it up with the holes underneath the top of the telescoping ramp. You may need to remove the ramp’s rubber stoppers. Drill the ramp holes to be slightly larger than they already are, but no bigger than ¼”. Use a ¼-20 bolt to go through the top of the ramp through the aluminum member. You may need to use a nut to secure it in place if the threads are not enough.
2. This next step may take trial and error since we had to leave campus before fully defining this step with the parts in hand. The metal pieces from the piano bench assembly must be installed in the bottom of the flat platform. The pipe clamp portion must be attached to the side of the frame where it will meet the telescoping ramp with its part of the X-stand in place. They need to be centered on the long members, so you will likely have to drill a new hole in the clamps, as well as holes in the frame.
   The height adjustable portion will need to be placed so that the highest height setting makes the ramp come up to 24” off the ground. Stability is important, so don’t let the lowest height setting only support half or less of the flat platform. Drill new holes in the frame so this portion is centered on the long members. You can likely use the bolts that came with the parts, but test them to make sure they’ll work with the frame.
3. The final step involves attaching the ramp to the flat platform. End caps should already be tapped and welded in place. Set up the X-stand and rest the ramp on the flat platform as seen in Drawing 100-1. Use a ¼-20 bolt to attach the end caps to the flat platform spacers first. Ensure the linkages can swing freely at this point. If not, you may need to drill out the linkage holes. Once ready, align the linkage holes with the end caps attached to the ramp. Use ¼-20 bolts to finish this attachment.

The ramp is assembled! You can put the canvas guard in its holes and remove it as necessary. You still need to use the Flex Seal Liquid rubber to coat the top of the flat platform, as well as the linkage and side of the ramp that will be near the vehicle to prevent scratches. Follow the directions on the can of Flex Seal for application. Also, feel free to coat more parts of the ramp as you see necessary.

7.0 Design Verification Plan

For the project, the team determined certain specifications the design needed to meet. These specifications are listed in *Table 10*. The tests that will be used to verify the specifications are the following:

1. Weight Test – How much does the ramp weigh?
2. Fit Test – Does the ramp fit into Peter's truck?
3. Deflection Test – How much does the ramp deflect under a given load?
4. Deployment Test – Can the ramp be easily deployed by wheelchair users?
5. Dog Test – Can dogs use the ramp comfortably?
6. Destructive Weld Test – Are the welds in then flat platform strong enough?

The testing the team will conduct to verify each specification can be seen in Table 10. Each of these tests will be conducted in facilities located on Cal Poly's campus. Specifically, the deflection test will require numerical data collection from the human biomechanics lab, which will be used to conduct data analysis. Using the data, uncertainty propagation calculations will be performed.

This table is a portion of the Design Verification Plan (DVP) which can be found in Appendix M.

Table 10. Specification Testing

Spec. #	Test Description	Criteria	# of Samples Tested	Type
1	Use a scale to weigh our full system prototype	Doesn't exceed 30 lbs	1	Full System
2	Place whole system into different cars to determine how well it fits given space constraints	System sits in space behind driver seat	1	Full System
3	Apply load on ramp and flat portions and measure displacement	Displacement doesn't exceed 10% of length	1	Sub System
4	Time how fast it takes to deploy system and to store it	Process doesn't take more than 5 minutes to complete	1	Full System
5	Have different dogs use the system and see how comfortable they are walking on it	Dogs are willing to use system without difficulty	1	System
6	Apply a load to the welded flat platform members and see if they break	Welds do not break	1	Component

For testing, the team was only able to complete the deflection test. The team went to the biomechanics lab and placed several sensors along the ramp and determined deflection at different loads. The data was then extrapolated out to determine the trendline equation which would help predict the deflection at any load. A graph of the results can be seen in Figure 12. The given weight restriction for the ramp is 300 lbs, and after conducting the test, it was determined that Rory, who weighs about 80 lbs, would not cause significant deflection to the ramp while in use.

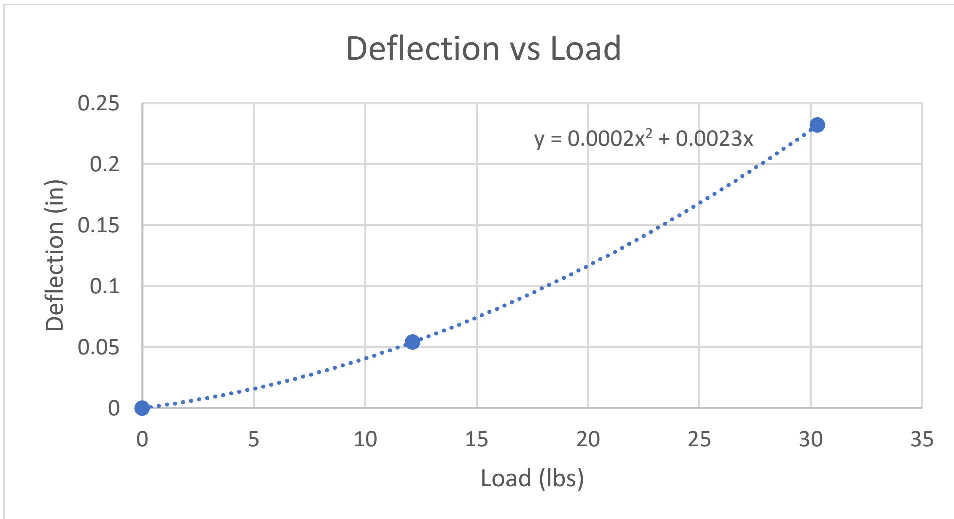


Figure 12. Extrapolated deflection test results

For the remaining tests that need to be completed, the data recording sheets and procedures for the tests can be found in Appendix Q. All of these tests can be completed on using resources provided on campus or with the help of our sponsors and local businesses. The testing procedure for each remaining test are as follows:

- Weight Test
    1. Place a scale on a level surface
    2. Place entire device onto scale
    3. Read off measurement
- Fit Test
    1. Adjust driver's seat to how Peter has his seat set in his truck
    2. Place device into the open space behind the seat
    3. Measure space, either extra space or the space needed for the device to fit cleanly behind the driver's seat
- Deployment Test
    1. Have person testing sit in a wheelchair to simulate what Peter's experience would be like deploying the device
    2. Begin timing
    3. Have tester set up device
    4. Stop timer once the device has been fully deployed and record the time
- Dog Test
    1. Deploy ramp along a truck or wooden mock assembly (whichever is more accessible)
    2. Guide dog up ramp (use treats if necessary)

3. Record observations
- Destructive Weld Test
    1. Weld 2 pieces of aluminum tubing together
    2. Place one leg of welded piece in bench vise
    3. Use vise grips to bend apart the welded pieces

8.0 Project Management

The project management section of this report has been updated to reflect what has been completed and what still needs to be done.

Unfortunately, the unforeseen circumstances of shelter-in-place orders due to COVID-19 has caused our team to have unaccomplished manufacturing and testing tasks. For the manufacturing, we finished making the linkages, end caps, canvas guard uprights, and canvas guard. The main component that needs to be finished is the flat platform. The steps that need to be completed to finish the flat platform can be seen in the *Leftover Manufacturing and Assembly Section*. Once the flat platform is completed, all that is left is the final assembly. The directions for the final assembly can also be seen in the *Leftover Manufacturing and Assembly Section*.

In terms of testing, not much was completed. A trial deflection test was completed at the human biomechanics lab but accurate weights were not used. It would be best to conduct the test again. Therefore, the remaining tests that need to be completed are the Weight Test, Fit Test, Deflection Test, Deployment Test, Dog Test, and Destructive Weld Test. The procedure for each test can be found in the *Design Verification Section*.

Next Steps

The next steps that will be taken to move forward with this project is to pass this project onto students of a technical elective class, such as the Rehabilitation Engineering class. We have provided a manufacturing plan that can be followed to complete the remaining manufacturing.

9.0 Conclusions & Recommendations

This Final Design Report is intended to provide a comprehensive view of the overall process we executed to take a concept sprung from brainstorming, to a marketable product. Unfortunately, due to the current circumstances, we were not able to complete the manufacturing of the final product which also means we were unable to conduct full scale testing of any kind. Hopefully another team down the line will be able to pick up where we left off so that Peter and Rory can benefit from our year long journey.

One of the most beneficial exercises we did came in the beginning of the project and that was the collaborative prototype brainstorming. Being able to pick and choose the best parts of each of our concepts is what allowed us to create the design of our final product. Having QL+ as our sponsor was also tremendously beneficial for several reasons. One, we had access to the QL+ lab where we could work 24/7 and safely store our materials. Second, we had access to industry engineers that gave us advice and approval during the design process. All of these factors combined made the entire project more enjoyable and far less stressful.

Had we been able to complete the manufacturing, we would have met all of our main goals which is something we are very proud of. Throughout the project, the goal of storing the product in the cab of the truck was up in the air and for a while we accepted the idea that it would be stored in the bed of the truck. We even started to come up with ideas on how we would secure the ramp in the bed so that it would not slide around and thought of different ways we could protect it from the elements. However, we worked with the Wheelchair group towards the end of the second quarter and managed to find a solution that allowed us to store the ramp in the cab. Completing that last goal was very satisfying because we knew how much better it would make Peter's experience.

Looking back, if we were to do this project over again there is little we would change. Often times in hypotheticals like these a common answer is to start things earlier, and that could of course apply in our situation, but throughout the project we never ran into a major time crunch. We completed our design on time, our verification prototype went smoothly and on pace, and we were on track to finish the manufacturing early. There is one aspect of our that we could have gone about another way. The flat platform we designed was made from aluminum square tubing which needed to be cut and welded. Custom endcaps needed to be manufactured as well. Because of this design choice, the required manufacturing time and skill level is fairly high, especially since TIG welding is necessary, as opposed to creating the flat platform from an easier to work with material such as aluminum T-slot framing. If we were to do this project over again it would be interesting to explore the use of T-slot instead of the aluminum square tubing.

The team is immensely proud of how the project progressed and each and every one of us can honestly say that we are better for the experience. The amount of practical and real-world knowledge gained from working on a design-build senior project like this one has only bolstered our engineering prowess and helped to prepare us for our future careers.

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Appendices

A. Existing Products
B. QFD House of Quality
C. Compilation of Brainstorm Ideas
D. Pugh Matrices
E. Morphological Matrix
F. Weighted Decision Matrix
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Appendix A. Existing Products

Pet Gear Travel Lite Bi-Fold Ramp, $63.63

Petstep Gray Folding 2 Step Assist

Upgraded Nonslip Pet Steps

PetSafe Solvit Telescoping Ramp

Portable Outdoor Folding 60" Step Ladder

Appendix B: QFD House of Quality

Correlations	
Positive	+
Negative	−
No Correlation	

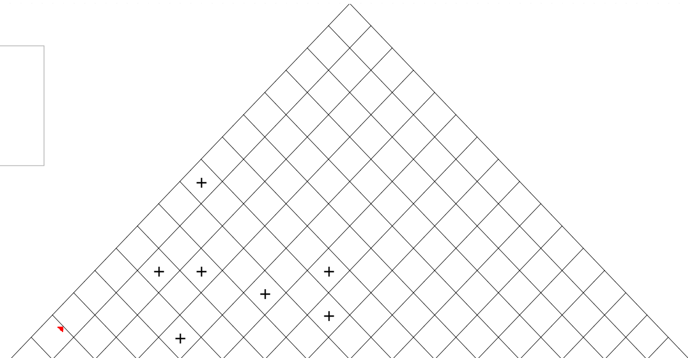
Relationships	
Strong	●
Moderate	○
Weak	

Direction of Improvement	
Maximize	▲
Target	
Minimize	▼

QFD House of Quality

Project: Service Dog Ramp

Revision Date: 10/13/19

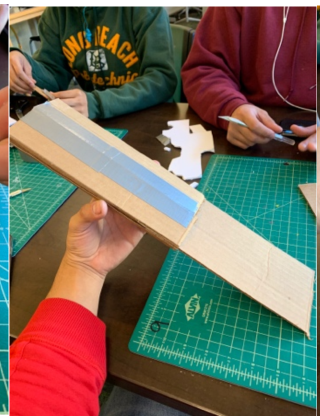


								Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16						
	WHO: Customers							Direction of Improvement	▼	▲		▼	▼		▼		▼	▼							NOW: Curr. Products					
Row #	Weight Chart	Relative Weight	Peter Way	Rory the Dog	QL+	Manufacturers	Maximum Relationship	HOW: Engineering Specifications (Tests) / WHAT: Customer Requirements (Needs/Wants)	Weigh It	Try in Other Vehicles	Neutral Salt Spray Test	Cost Analysis	Deflection/Bending Test	Measuring Dimensions	Test Surface Material Clean Tim	Dog Test	Independent Assembly Time	Cost Analysis							Our Current Product	Folding Suitcase Ramp	PetSafe Telescoping Ramp	Solvit PupSTEP Stairs	Pet Gear Tri-Fold Ramp	Row #
1	II	6%	10	1	1	3	9	Lightweight	●																	1	4	5	3	1
2	II	5%	6	1	3	1	9	Usable in Other Cars		●				●												1	3	3	3	2
3	II	4%	10	1	1	1	9	Independently Operated	○								●									1	5	4	5	3
4	III	8%	1	10	1	1	9	Comfortable/Grippy on Paws								●										5	5	1	5	4
5	II	4%	10	1	1	1	9	Fits in Tacoma Cab						●												1	2	1	2	5
6	I	4%	8	1	1	1	9	Easy to Clean							●											5	1	5	1	6
7	IIIII	11%	7	10	1	3	9	Easy Climbing Angle		○				●		●										1	4	1	2	7
8	II	6%	5	1	1	5	9	Weatherproof			●															5	4	2	5	8
9	IIIIIIII	19%	9	10	10	6	9	Safe/Strong					●			○										5	5	1	5	9
10	II	4%	10	1	1	1	9	Not Interfere w/ Wheelchair Lift						●												1	3	1	1	10
11	IIII	10%	10	1	1	10	9	Easy to Assemble	●								●									1	5	5	3	11
12	IIII	9%	9	1	8	1	9	Durable/Lasting					●			○										5	4	4	4	12
13	IIIII	11%	1	1	10	7	9	Inexpensive				●						●								2	2	4	2	13
14		0%																												14
15		0%																												15
16		0%																												16

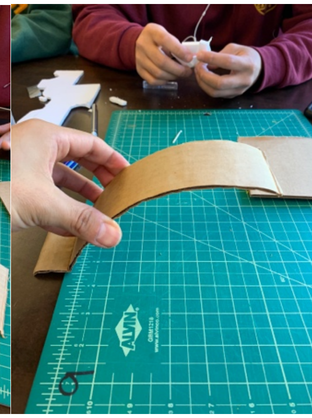
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	HOW MUCH: Target Values	25 lbs	Truck, car, van, SUV	Rust-free	$1,000	Less than 1 inch under 150 lbs	Less than 2 inches thick	5 Minutes	Dog willingness	Less than 2 minutes	$1,000						
	Max Relationship	9	9	9	9	9	9	9	9	9	9						
	Technical Importance Rating	154.1	78.1	54.35	102.6	243.7	217.1	45.55	245.7	129.7	102.6	0	0	0	0	0	0
	Relative Weight	11%	6%	4%	7%	18%	16%	3%	18%	9%	7%	0%	0%	0%	0%	0%	0%
Curr. Products	Our Current Product																
	Folding Suitcase Ramp	1	1	3	5	5	1	5	5	5	5						
	PetSafe Telescoping Ramp	2	4	2	4	3	1	2	4	5	5						
	Solvit PupSTEP Stairs	5	3	5	1	1	1	5	1	5	5						
	Pet Gear Tri-Fold Ramp	2	4	2	5	3	1	3	4	5	5						
	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Appendix C. Compilation of Brainstormed Ideas

Single-Fold Ramp



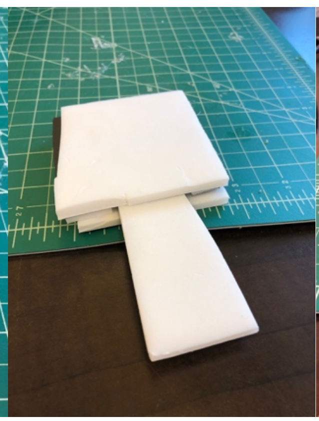
Telescoping (Wide)



Arch Ramp

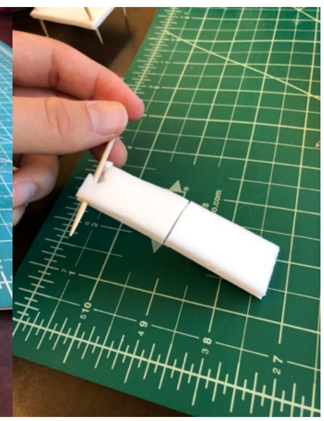
Roll-Up (Vertical)

Roll-up (Horizontal)



Telescoping (Thin)

Kick Stand Ramp



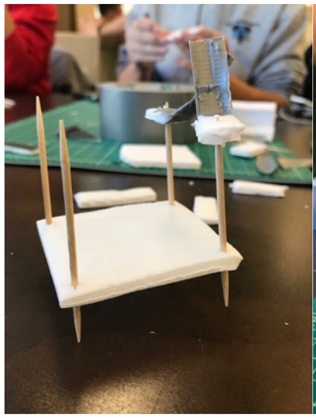
Single-Fold with Pivot

Two-Fold with Pivot

Steps

Support Rails & Canvas

Swinging Ramp



Lifting Platform

Harness & Pulley

Appendix D. Pugh Matrices

Function: Getting Dog In	Options					
Criteria	Jumps	Ramp	Pulley	Sling	Stairs	Lift
Climbing angle	S	+	S	S	+	S
Grip	S	+	-	-	+	S
Safe	S	+	+	+	+	+
Dog Comfort	S	+	-	-	-	S
Total	**0**	**4**	**-1**	**-1**	**2**	**1**

Function: Compactibility	Options				
Criteria	Flat Ramp	Fold	Telescope	Roll-Up	Scissor Lift
Size	S	+	+	+	S
Manufacturability	S	+	-	-	-
Potential Hazards	S	S	-	S	-
Total	**0**	**2**	**-1**	**0**	**-2**

Function: Storage Area	Options						
Criteria	Floorboard	On Door	Side of Bed	Ceiling	Bed	Under Truck	Against Seat
Space	S	-	+	+	+	+	S
Accessibility	S	+	+	-	+	-	S
Impact on Car	S	-	-	+	+	S	S
Total	**0**	**-1**	**1**	**1**	**3**	**0**	**0**

Function: Attachment to Vehicle	**Options**						
Criteria	Resting	Bolts	Hooks	Velcro	Magnets	Straps	Clamps
Independent Use	S	S	S	S	S	S	S
Car Modifications	S	-	+	S	-	+	+
Transferability	S	-	S	+	+	+	+
Stability	S	+	+	S	S	-	S
Total	**0**	**-1**	**2**	**1**	**0**	**1**	**2**

Appendix E. Morphological Matrix

Number	Sub-Function	Concepts			
		Option 1	Option 2	Option 3	Option 4
1	Getting Dog in	Ramp	Stairs	Lift	Pulley
2	Compactibility	Fold	Roll-up	Telescoping	Scissor Lift
3	Storage Area	Truck Bed	Side of Bed	Ceiling	Lean against seat
4	Attaching to Vehicle	Clamps	Hooks	Velcro	Straps

(yellow)	1st Choice
(green)	2nd Choice
(red)	3rd Choice

Appendix F. Weighted Decision Matrix

Criteria	Weighting	Options					
		Telescoping Ramp Hooked onto Side of Bed		Folding Stairs Strapped to Truck Bed		Roll-Up Lift Clamped to Ceiling	
		Score	Total	Score	Total	Score	Total
Lightweight	3	3	9	3	9	5	15
Safe/Strong	5	5	25	4	20	3	15
Use in other Cars	5	4	20	5	25	5	25
Climbing Angle	2	5	10	3	6	3	6
Dog Comfort	5	5	25	1	5	2	10
Wheelchair Lift Interference	4	5	20	5	20	5	20
Customers Preference	3	5	15	3	9	3	9
	Total		**124**		**94**		**100**

Appendix G: Preliminary Analysis

PRELIMINARY CALCULATIONS

ALUMINUM
$S_u = 42$ ksi
$S_y = 35$ ksi
$E = 10$ ksi

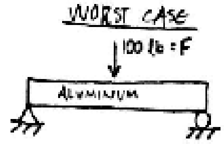
STEEL
$S_u = 63.8$ ksi
$S_y = 53.7$ ksi
$E = 29.7$ ksi

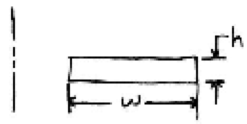
ASSUME:
- SOLID RAMP (ALUMINUM)
- BOLTED HINGES (STEEL)

DESIRE: LESS THAN 1" DEFLECTION

LOAD = 80 lb
SF = 1.25 → DESIGN FOR 100 lb

WORST CASE





$$MAX\ \delta = \frac{FL^3}{48EI} = \frac{100\text{lb}\,(75.96\text{in})^3}{48(10000\ \text{lb/in}^2)\,I}$$

$$I = \frac{1}{12} w h^3$$

TRY FOR DOG, ($w = 18"$) $h =$

$$1\text{in} = \frac{4.383\times10^7\ \text{lb in}^3}{4.8\times10^5\ \text{lb/in}^2\ I}$$

$$I = 91.3125\ \text{in}^4$$

$$\sqrt[3]{h^3} = \sqrt[3]{12\left(\tfrac{1}{18}\right)(91.3125)\ \text{in}^3}$$

$h = 3.93$ in TOO THICK, CONSIDER CENTER SUPPORT TO CUT L IN HALF

$L = 3.165' = 37.98$ in
↳ $I = 11.41$

$$h = \left(12\left(\tfrac{1}{18}\right)(11.41)\ \text{in}^3\right)^{1/3}$$

($h = 1.96$ in) THIS WORKS FOR ANALYSIS

BOLT SELECTION

SHEAR LOAD = 100 lb

$$A = \frac{\pi}{4}(D)^2$$

(1/4" BOLT $A = .0491\ \text{in}^2$)

1/2" BOLT $A = .1963\ \text{in}^2$

$$\tau = \frac{V}{A}$$

($\tau_{1/4} = 2036$ psi)

$\tau_{1/2} = 509$ psi

BOTH ARE WELL WITHIN BOLT STRENGTH LIMITS. SELECT 1/4" FOR NOW DUE TO STANDARD SIZE AND SAFETY.

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Appendix H. Design Hazard Checklist

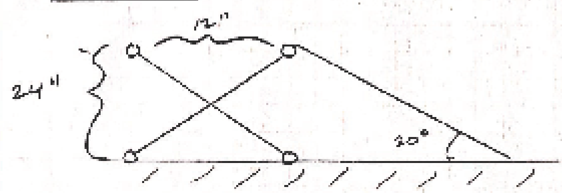
Y	N	
☐	☒	1. Will the system include hazardous revolving, running, rolling, or mixing actions?
☐	☒	2. Will the system include hazardous reciprocating, shearing, punching, pressing, squeezing, drawing, or cutting actions?
☐	☒	3. Will any part of the design undergo high accelerations/decelerations?
☐	☒	4. Will the system have any large (>5 kg) moving masses or large (>250 N) forces?
☐	☒	5. Could the system produce a projectile?
☒	☐	6. Could the system fall (due to gravity), creating injury?
☐	☒	7. Will a user be exposed to overhanging weights as part of the design?
☒	☐	8. Will the system have any burrs, sharp edges, shear points, or pinch points?
☐	☒	9. Will any part of the electrical systems not be grounded?
☐	☒	10. Will there be any large batteries (over 30 V)?
☐	☒	11. Will there be any exposed electrical connections in the system (over 40 V)?
☐	☒	12. Will there be any stored energy in the system such as flywheels, hanging weights or pressurized fluids/gases?
☐	☒	13. Will there be any explosive or flammable liquids, gases, or small particle fuel as part of the system?
☐	☒	14. Will the user be required to exert any abnormal effort or experience any abnormal physical posture during the use of the design?
☐	☒	15. Will there be any materials known to be hazardous to humans involved in either the design or its manufacturing?
☐	☒	16. Could the system generate high levels (>90 dBA) of noise?
☒	☐	17. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, or cold/high temperatures, during normal use?
☒	☐	18. Is it possible for the system to be used in an unsafe manner?
☐	☒	19. For powered systems, is there an emergency stop button?
☐	☒	20. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

Appendix I. Hand Calculations

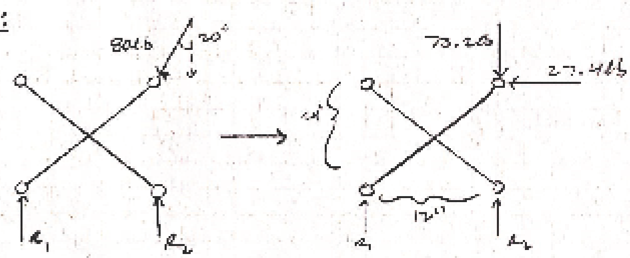
X-STAND

CHECKING TO SEE IF THE X-STAND WILL TIP

DIAGRAM:



FBD:



ANALYSIS

FIND R_1 & R_2

$\Sigma M_{R_2} = 0$

$27.4\,lb \cdot 24\,in - (R_1 \cdot 12\,in) = 0$

$\boxed{R_1 = 54.8\,lb}$

$R_1 + R_2 = 75.2\,lb$

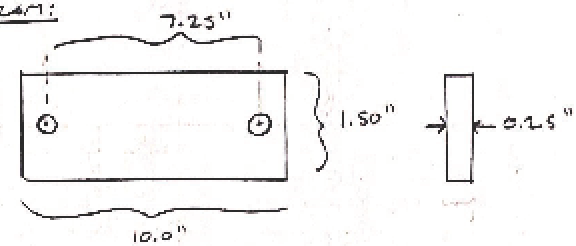
$54.8\,lb + R_2 = 75.2\,lb$

$\boxed{R_2 = 20.4\,lb}$

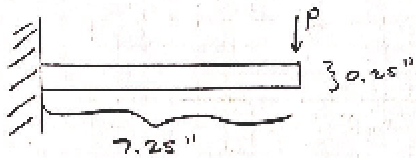
IN ORDER FOR THE STAND TO TIP ONE OF THE VALUES (R_1 OR R_2) WOULD NEED TO BE ZERO WHICH MEANS THE STAND WONT TIP UNDER THE DOGS WEIGHT.

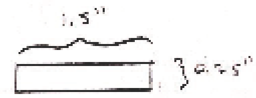
LINKAGE

DIAGRAM:



TREAT LINKAGE AS CANTILEVER BEAM





$I = \frac{1}{12} \cdot 1.5 \cdot .25^3$

$I = 0.00195 \ in^4$

ANALYSIS:

$M_{max} = P \cdot 7.25 in$

WE ARE CONCERNED WITH THE LINKAGES BENDING & NOT WITH THEM SHEARING ∴ WE'RE ONLY CONCERNED WITH YIELDING

$\sigma_{max} = \frac{-My}{I}$

$\sigma_{max} = \frac{P(7.25 in)(0.125 in)}{0.00195 \ in^4}$

$\sigma_{max} = P(464.7) \ 1/in^2$

$\sigma_y = 45,000 \ lb/in^2$

SOLVE FOR P

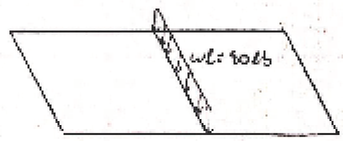
$P = \frac{45,000 \ lb/in^2}{464.7 \ 1/in^2}$

$P = 96.83 \ lb$

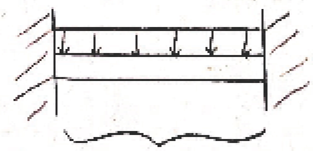
EACH MEMBER CAN SUPPORT A LOAD OF ABOUT 97 lb's & THERE ARE 2 LINKS ∴ AT THEIR WORST CASE SCENARIO ORIENTATION, THE LINKS CAN SUPPORT A FORCE OF 194 lb's BEFORE YIELDING.

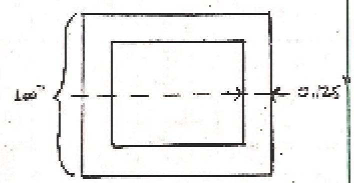
FLAT PLATFORM

DIAGRAM:



SOLVE FOR WORST CASE SCENARIO: ALL OF THE DOGS WEIGHT ON A SINGLE MEMBER





$$I = \frac{(1in)^4 - (.75in)^4}{12}$$

$I = 0.057 \, in^4$
$Q = 0.072 \, in^3$

ANALYSIS

$$M_{max} = \frac{wl^2}{12}$$

$$= \frac{80lbs \cdot 10.875in}{12}$$

$M_{max} = 72.5 \, lb \cdot in$

$$\sigma_{max} = \frac{-M_{max} \, y}{I}$$

$$= \frac{(-72.5 \, lb \cdot in)(0.5in)}{.057in^4}$$

$\sigma_{max} = -636 \, lb/in^2$	$<<< 45{,}000 \, lb/in^2$

$$\tau = \frac{VQ}{It}$$

$$= \frac{(40lb)(0.0723 \, in^3)}{(0.057in^4)(0.125in)2}$$

$\tau = 202.95 \, lb/in^2$	$<<< 30{,}000$ psi

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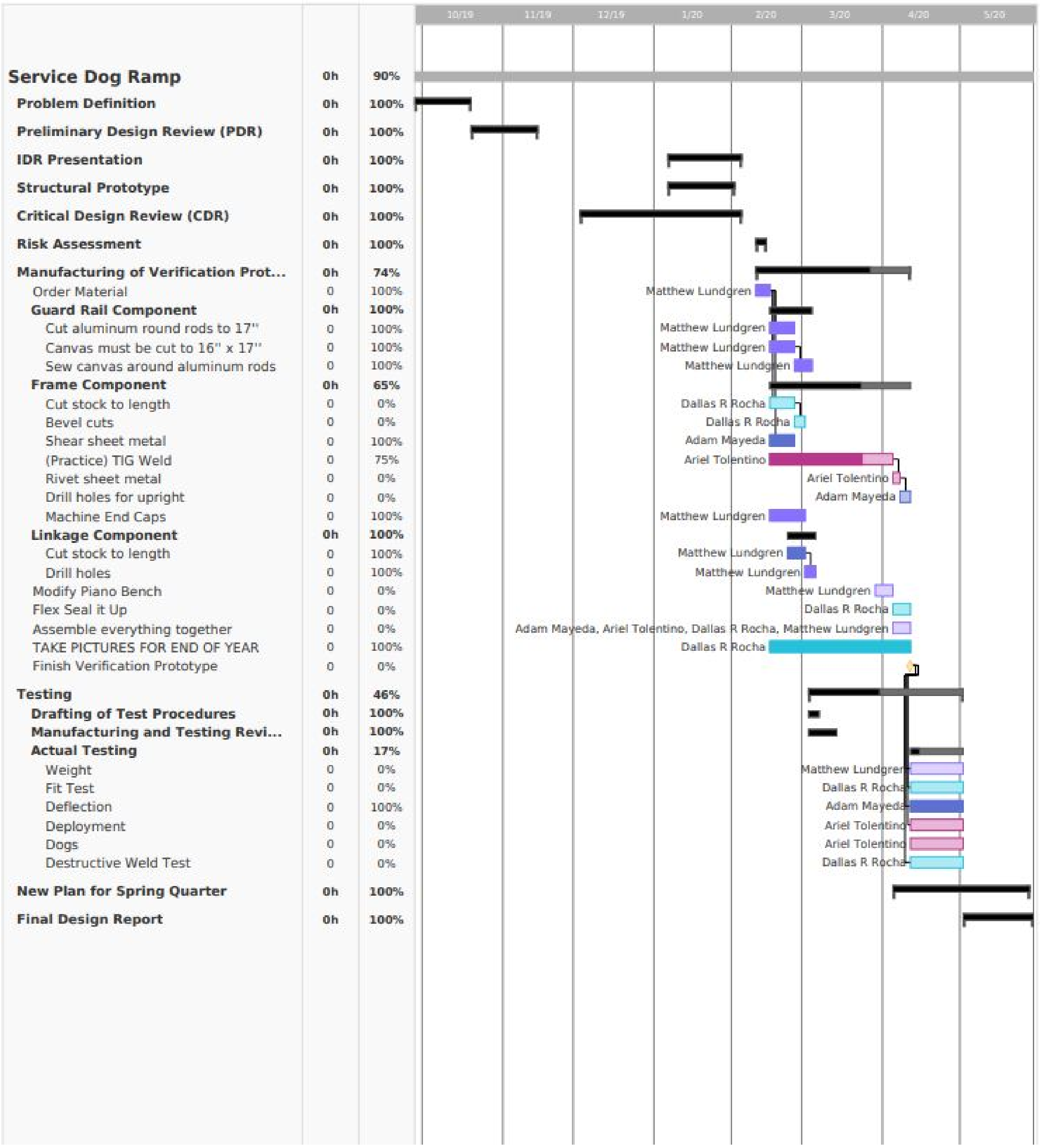
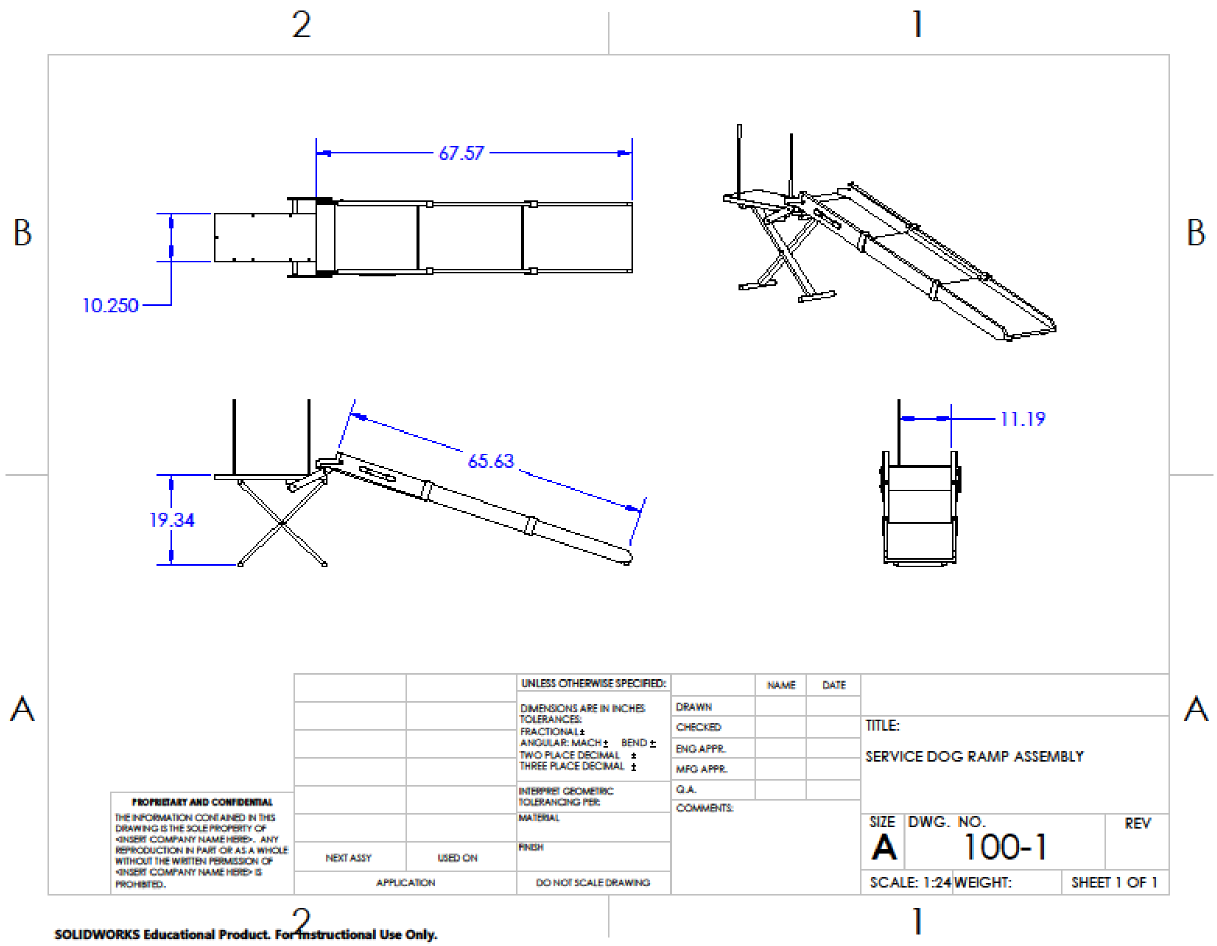
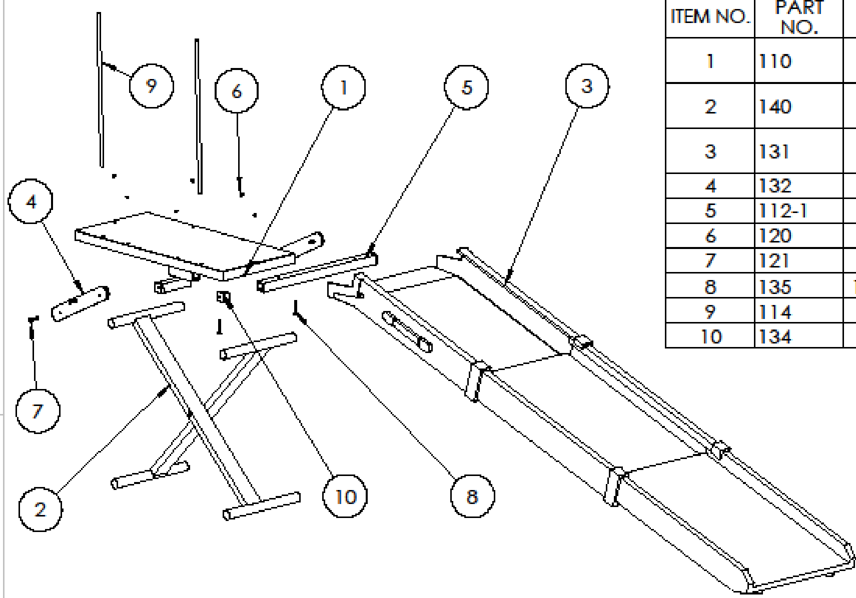
Appendix J: Project Gantt Chart



Appendix K. SolidWorks Drawing Package





ITEM NO.	PART NO.	DESCRIPTION	
1	110	FLAT PLATFORM SUBASSEMBLY	1
2	140	LEG/X-STAND SUBASSEMBLY	2
3	131	RAMP SUBASSEMBLY	1
4	132	PIVOT LINKAGE	2
5	112-1	TUBING LINK	1
6	120	RIVETS	6
7	121	1/4-20 1" BOLT	4
8	135	1/4-20 1.5" SCREW	2
9	114	NET UPRIGHT	2
10	134	END CAP	2

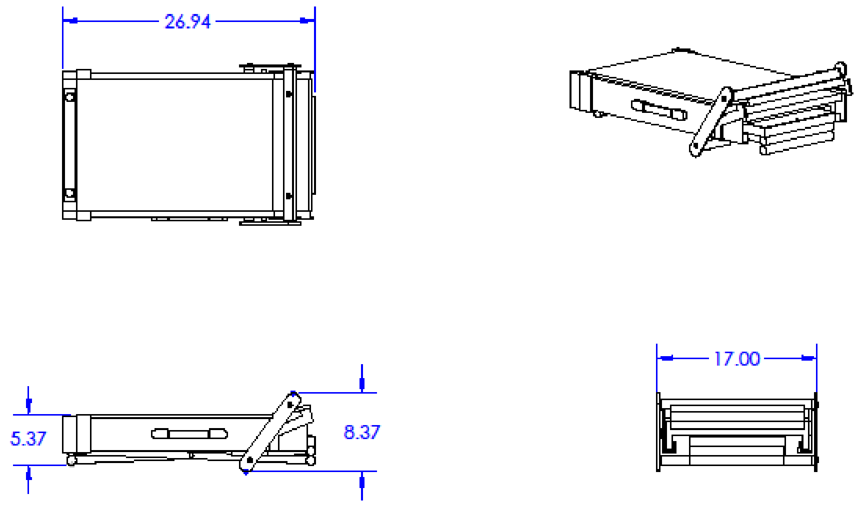
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY | USED ON
APPLICATION
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	ML	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
SERVICE DOG RAMP ASSEMBLY (EXPLODED)

SIZE A | DWG. NO. 100-2 | REV
SCALE: 1:32 | WEIGHT: | SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	ML	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

NEXT ASSY	USED ON
APPLICATION	

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TITLE:

SERVICE DOG RAMP ASSEMBLY (COLLAPSED)

SIZE	DWG. NO.	REV
A	100-3	

SCALE: 1:12 WEIGHT: SHEET 1 OF 1

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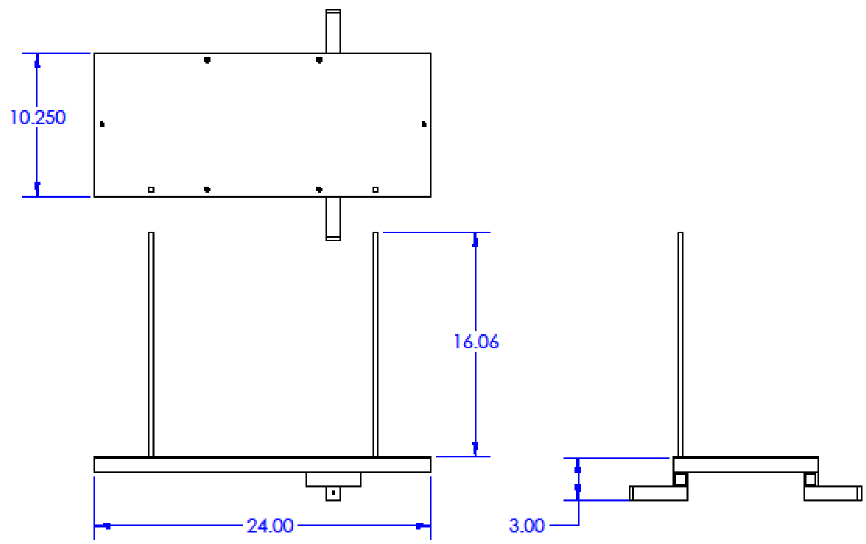

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DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	ML	
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL	COMMENTS: 112-2 THROUGH 112-6 WITH 111, 114, AND 119 ASSEMBLED WITH ROUGH DIMENSIONS SHOWN		
FINISH			
DO NOT SCALE DRAWING			

NEXT ASSY	USED ON
APPLICATION	

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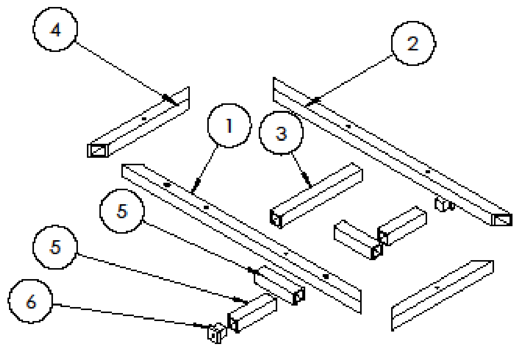
TITLE:

FLAT ASSEMBLY

SIZE	DWG. NO.	REV
A	110-1	
SCALE: 1:8	WEIGHT:	SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	112-2	LONG MEMBER FOR NET	1
2	112-3	LONG MEMBER	1
3	112-4	CROSS MEMBER	1
4	112-5	SHORT MEMBER	2
5	112-6	SPACER	4
6	119	END CAP	2



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

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	ML	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
FLAT ASSEMBLY (EXPLODED)

SIZE **A** DWG. NO. 110-2 REV

SCALE: 1=8 WEIGHT: SHEET 1 OF 1

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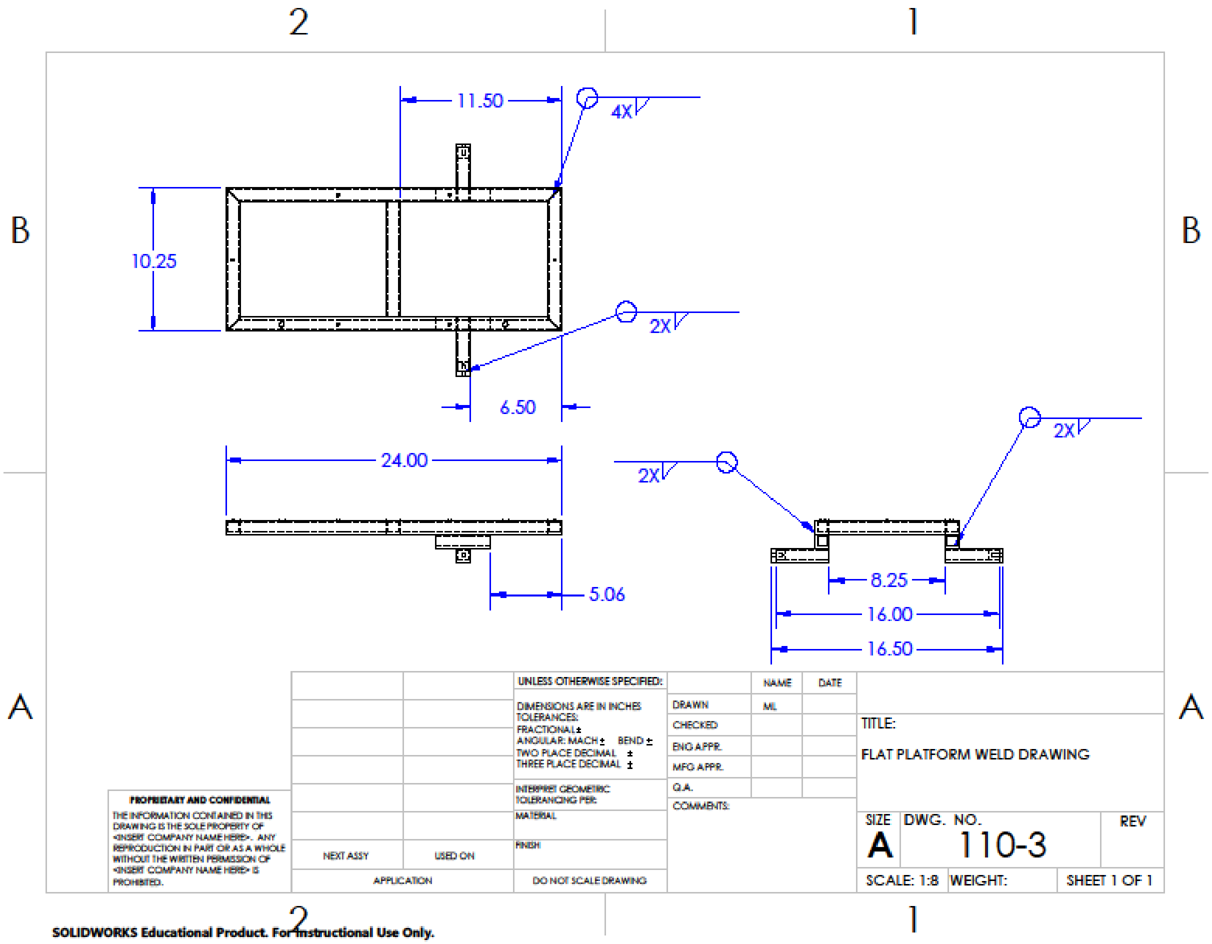

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5.06
2X
2X
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
ML
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
FLAT PLATFORM WELD DRAWING
SIZE
A
DWG. NO.
110-3
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
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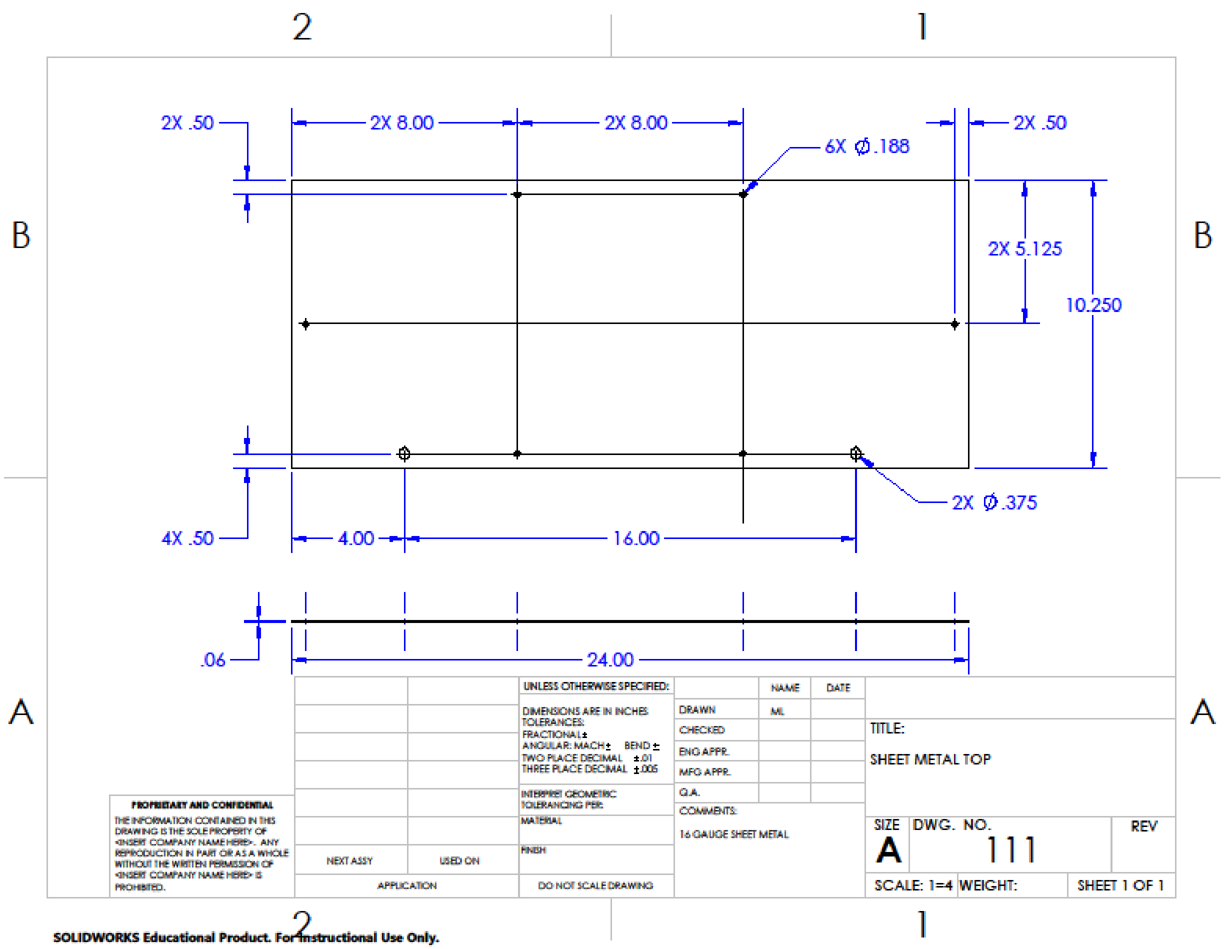
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10.250
2X ⌀.375
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
ML
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
16 GAUGE SHEET METAL
TITLE:
SHEET METAL TOP
SIZE
A
DWG. NO.
111
REV
SCALE: 1=4
WEIGHT:
SHEET 1 OF 1
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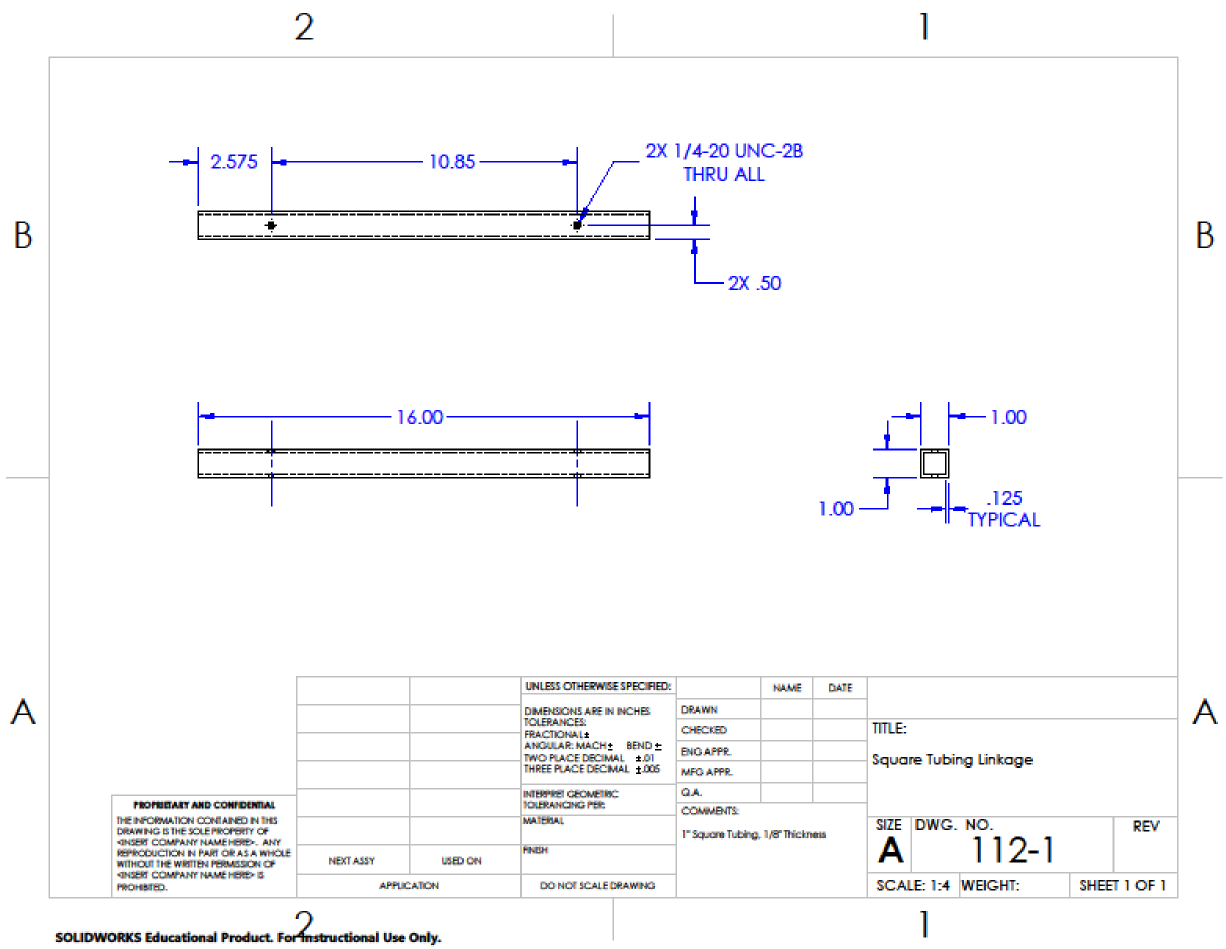
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1.00
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TYPICAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1" Square Tubing, 1/8" Thickness
TITLE:
Square Tubing Linkage
SIZE
A
DWG. NO.
112-1
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
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APPLICATION
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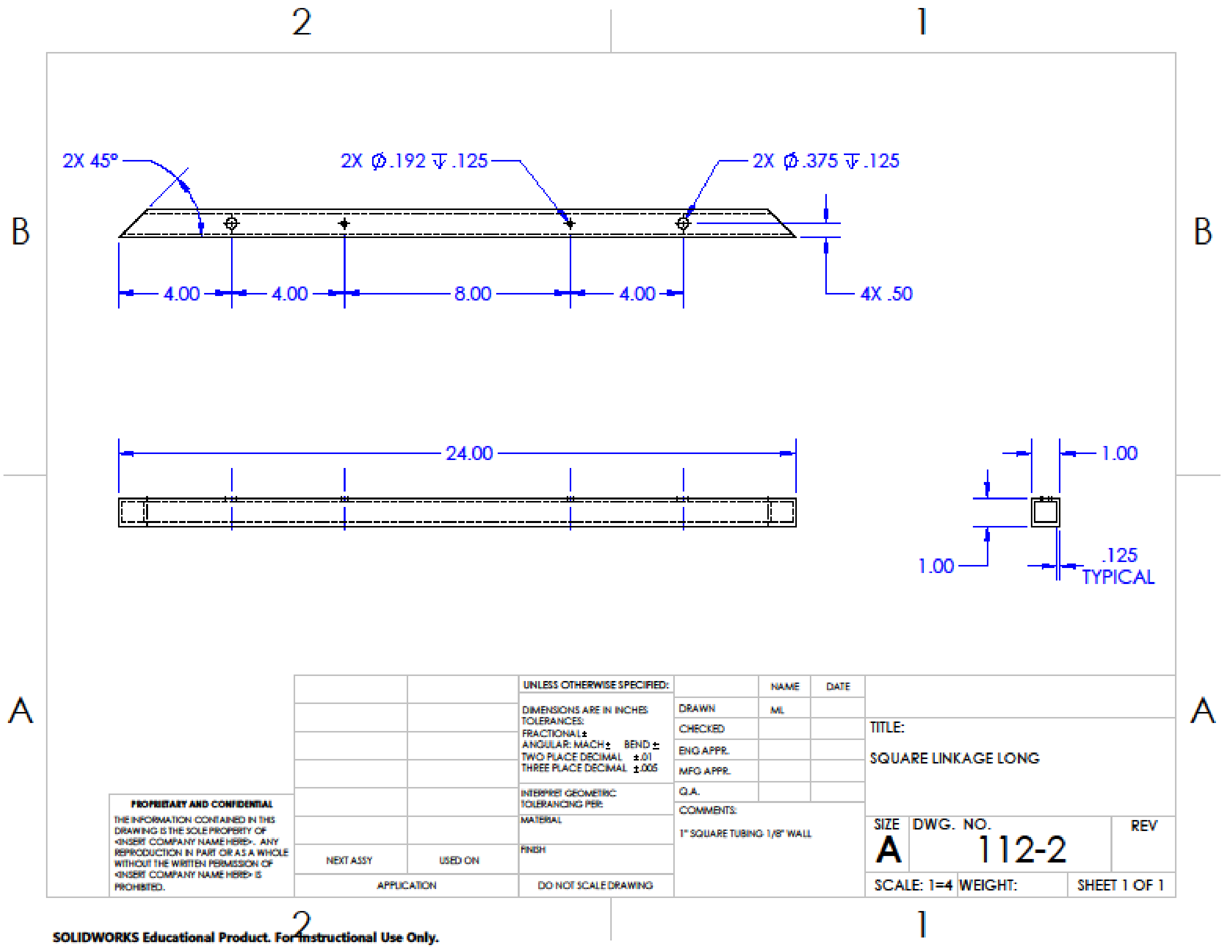

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	ML	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
1" SQUARE TUBING 1/8" WALL

TITLE:
SQUARE LINKAGE LONG

SIZE A | DWG. NO. 112-2 | REV

SCALE: 1=4 | WEIGHT: | SHEET 1 OF 1

NEXT ASSY | USED ON
APPLICATION

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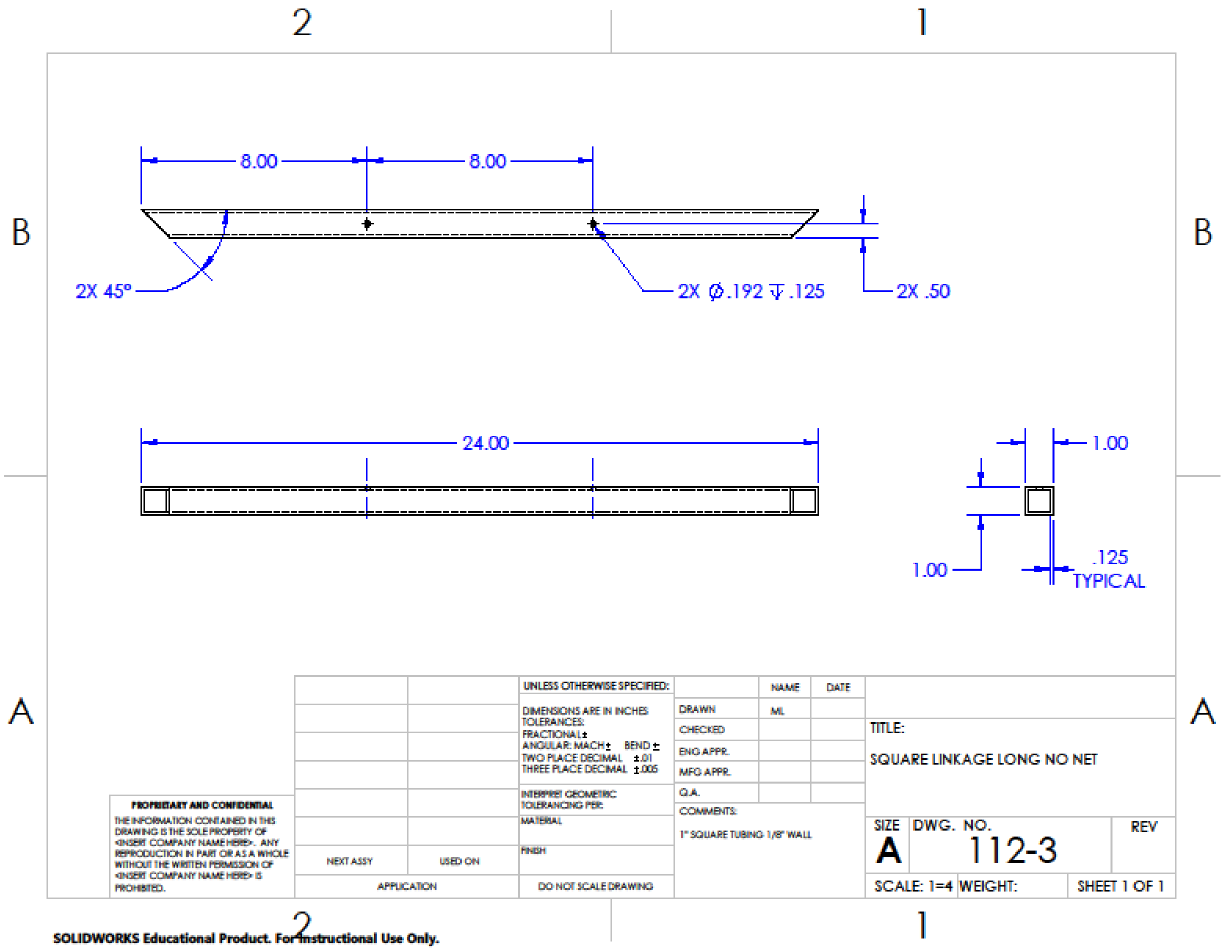
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2X ⌀.192 ↧ .125
2X .50
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1.00
1.00
.125
TYPICAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
ML
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1" SQUARE TUBING 1/8" WALL
TITLE:
SQUARE LINKAGE LONG NO NET
SIZE
A
DWG. NO.
112-3
REV
SCALE: 1=4
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
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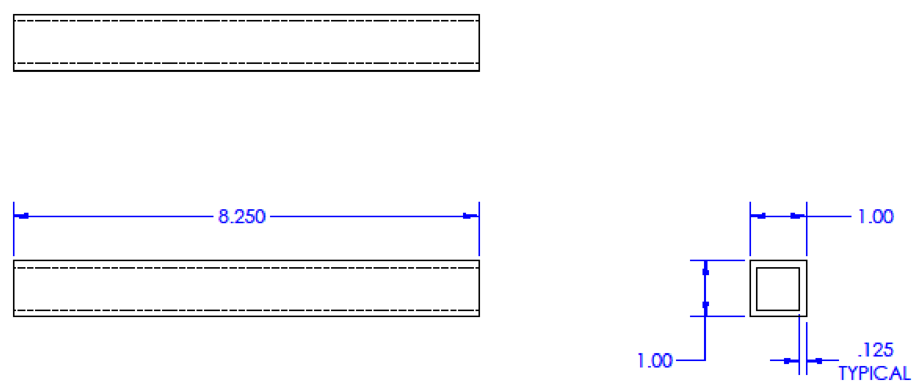
2 1

B B



A A

UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DRAWN	ML	
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

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

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

COMMENTS:
1" SQUARE TUBING, 1/8" WALL

NEXT ASSY | USED ON
APPLICATION

DO NOT SCALE DRAWING

TITLE:
SQUARE LINKAGE CENTER

SIZE A | DWG. NO. 112-4 | REV

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

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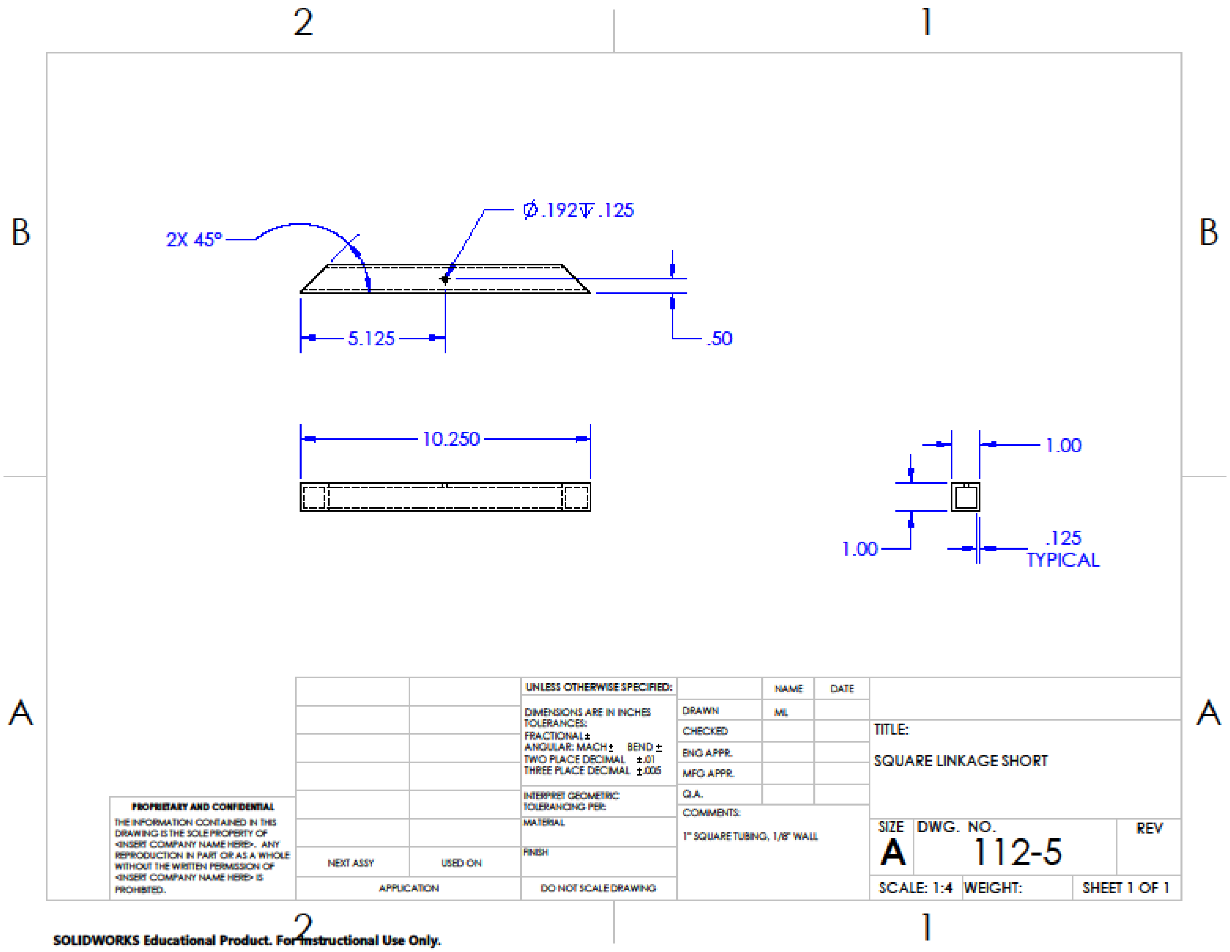
2 1



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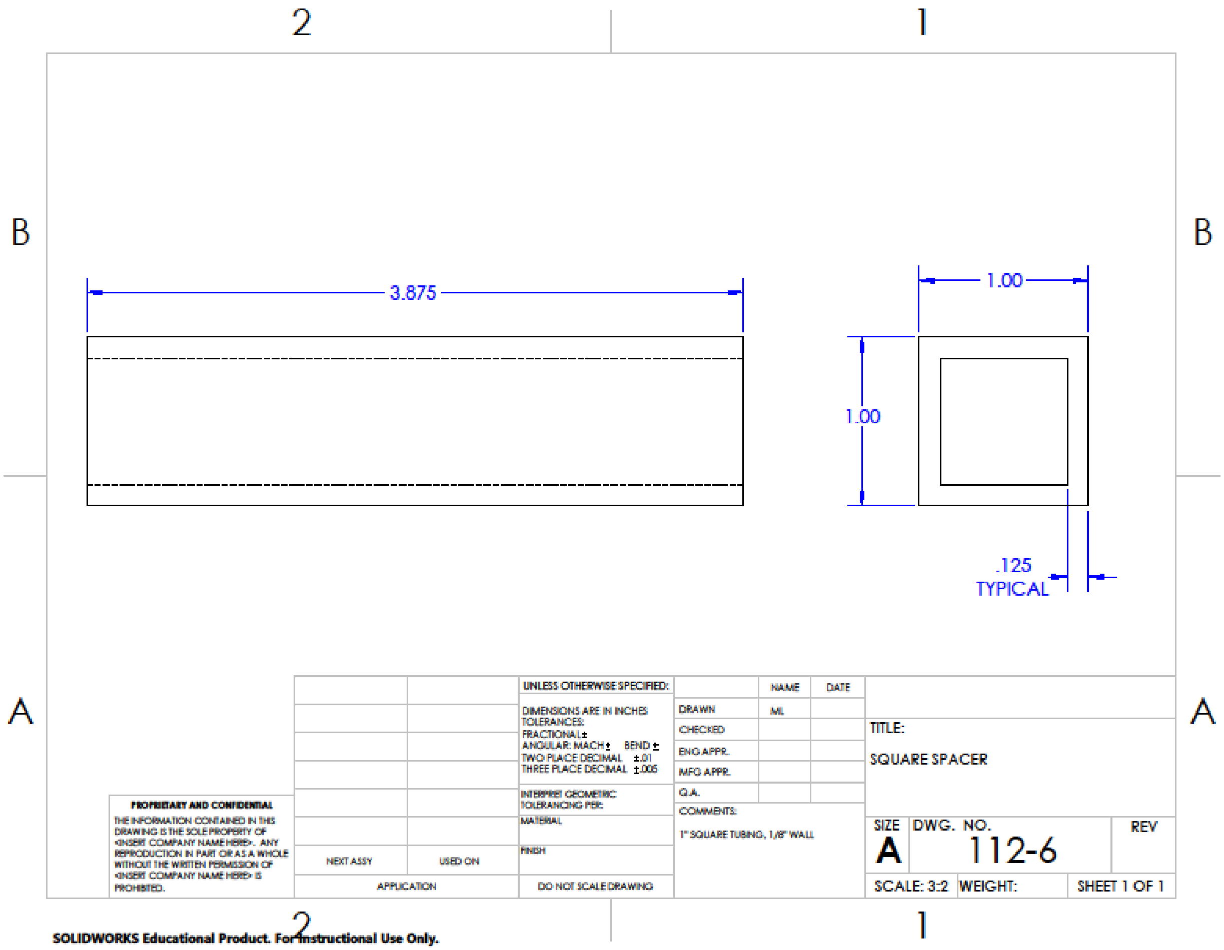

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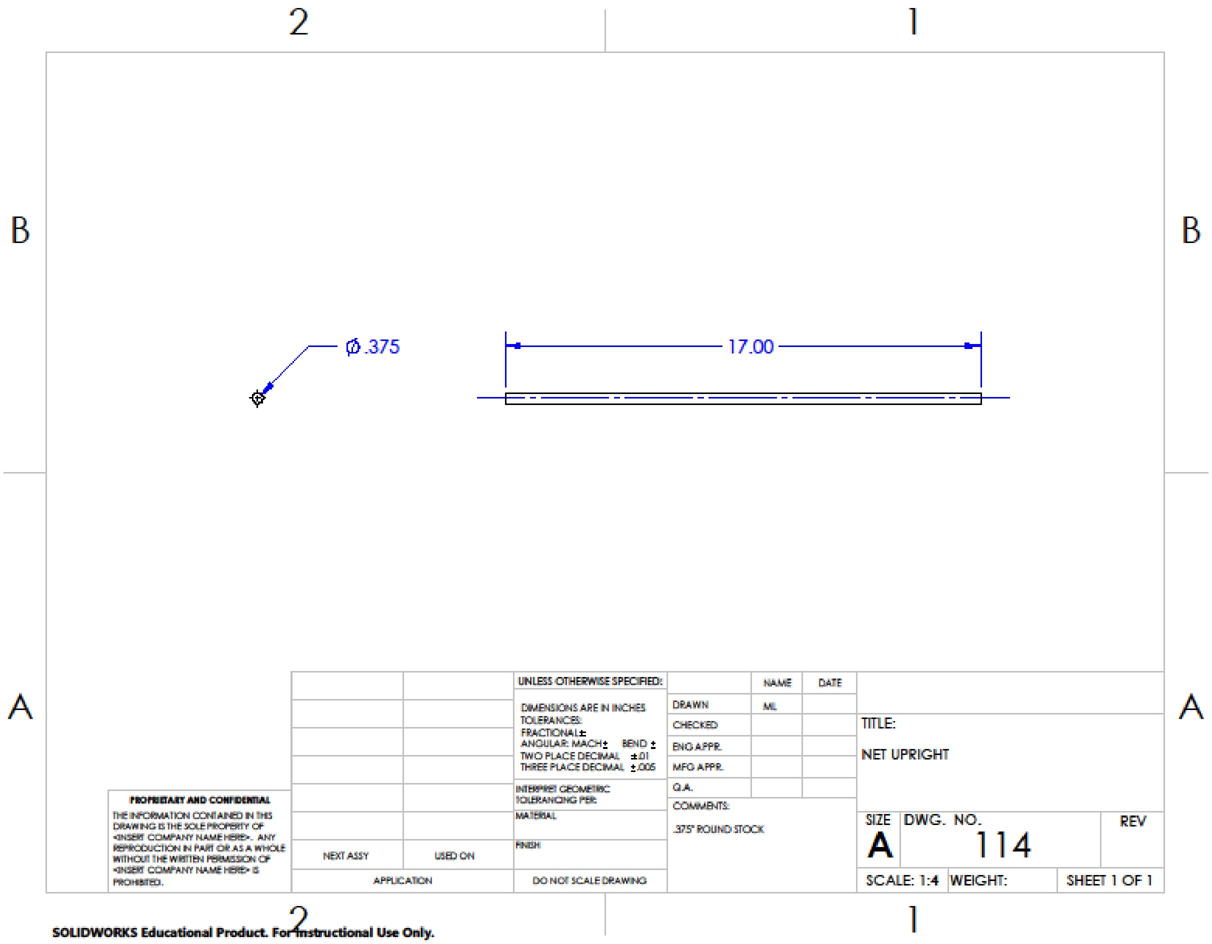
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ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
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MATERIAL
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DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
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DRAWN
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CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
.375" ROUND STOCK
TITLE:
NET UPRIGHT
SIZE
A
DWG. NO.
114
REV
SCALE: 1:4
WEIGHT:
SHEET 1 OF 1
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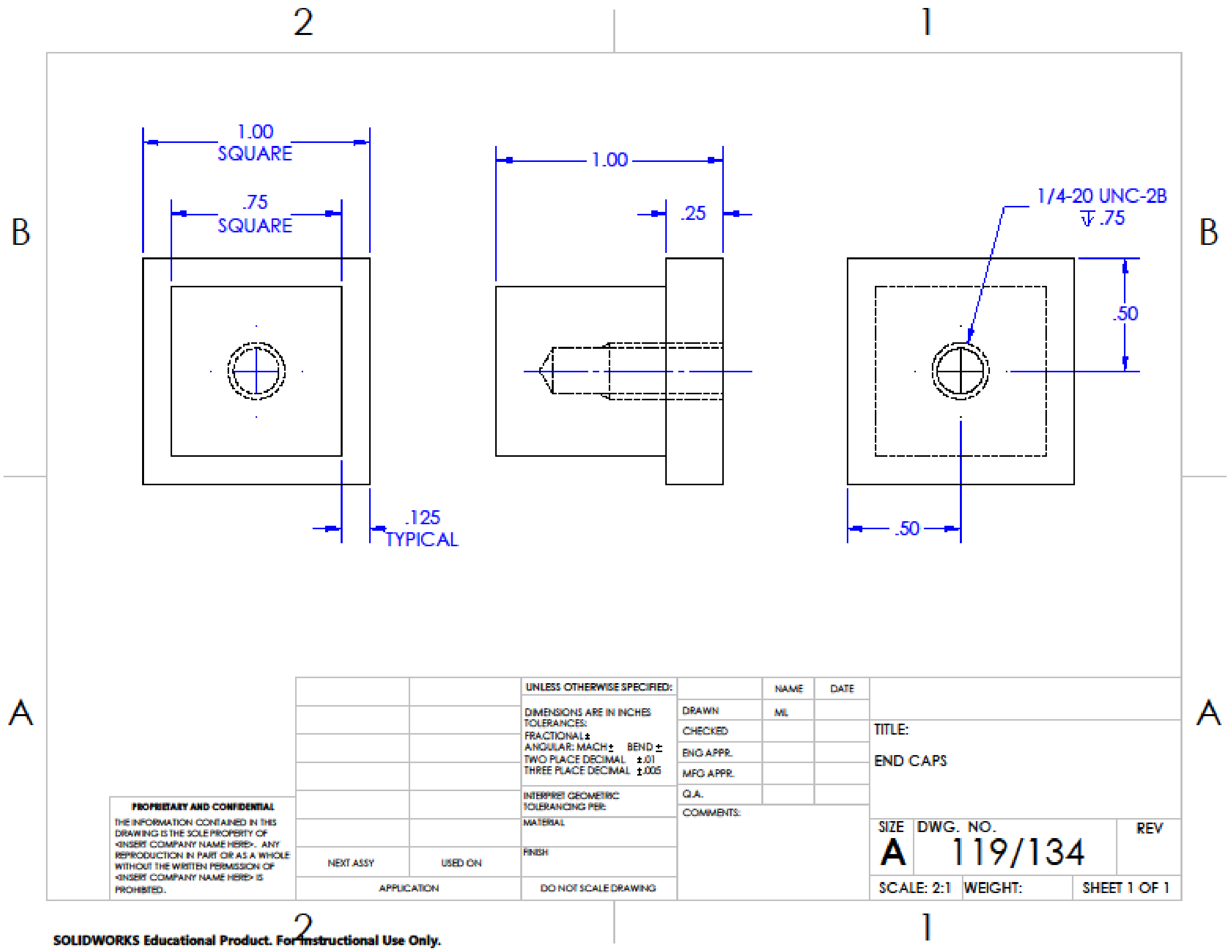
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SQUARE
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TYPICAL
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
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ENG APPR.
MFG APPR.
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COMMENTS:
TITLE:
END CAPS
SIZE
A
DWG. NO.
119/134
REV
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1
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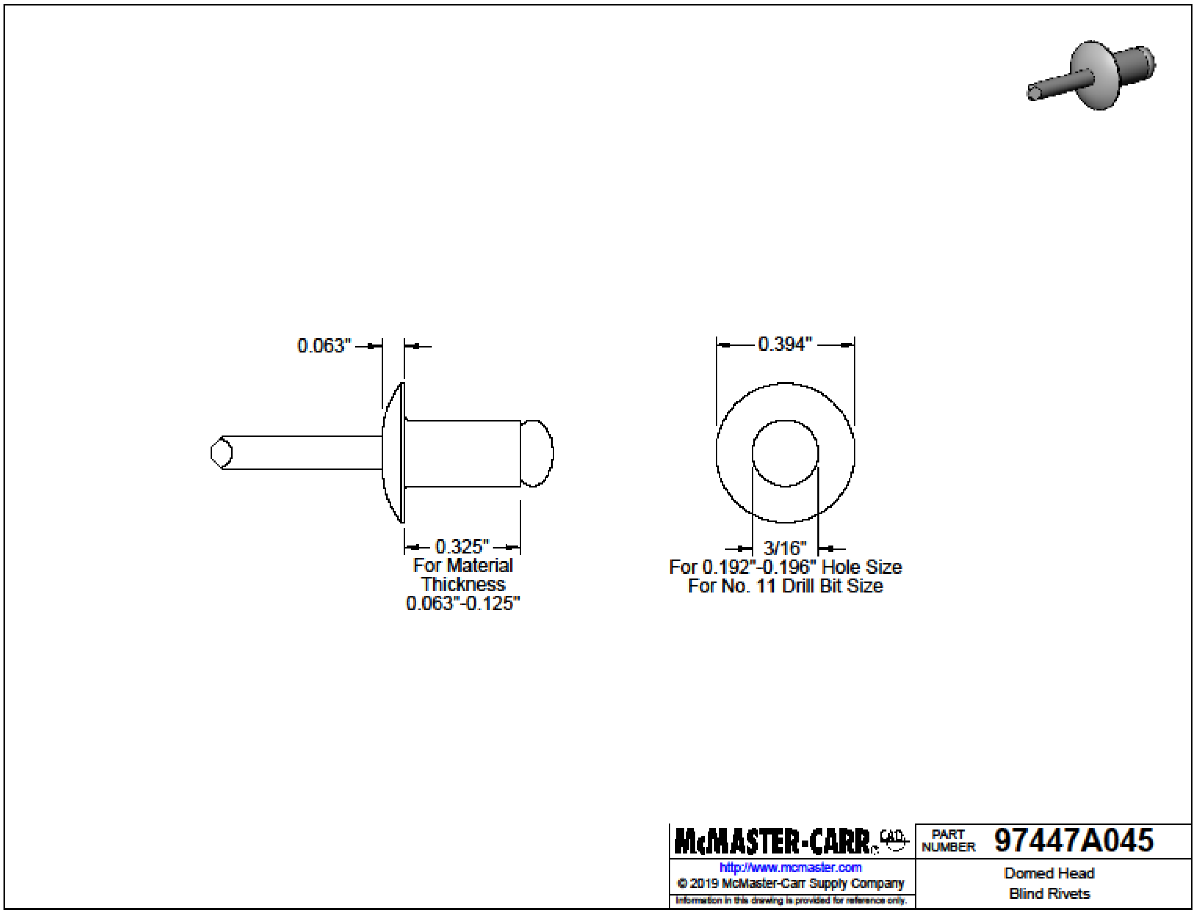
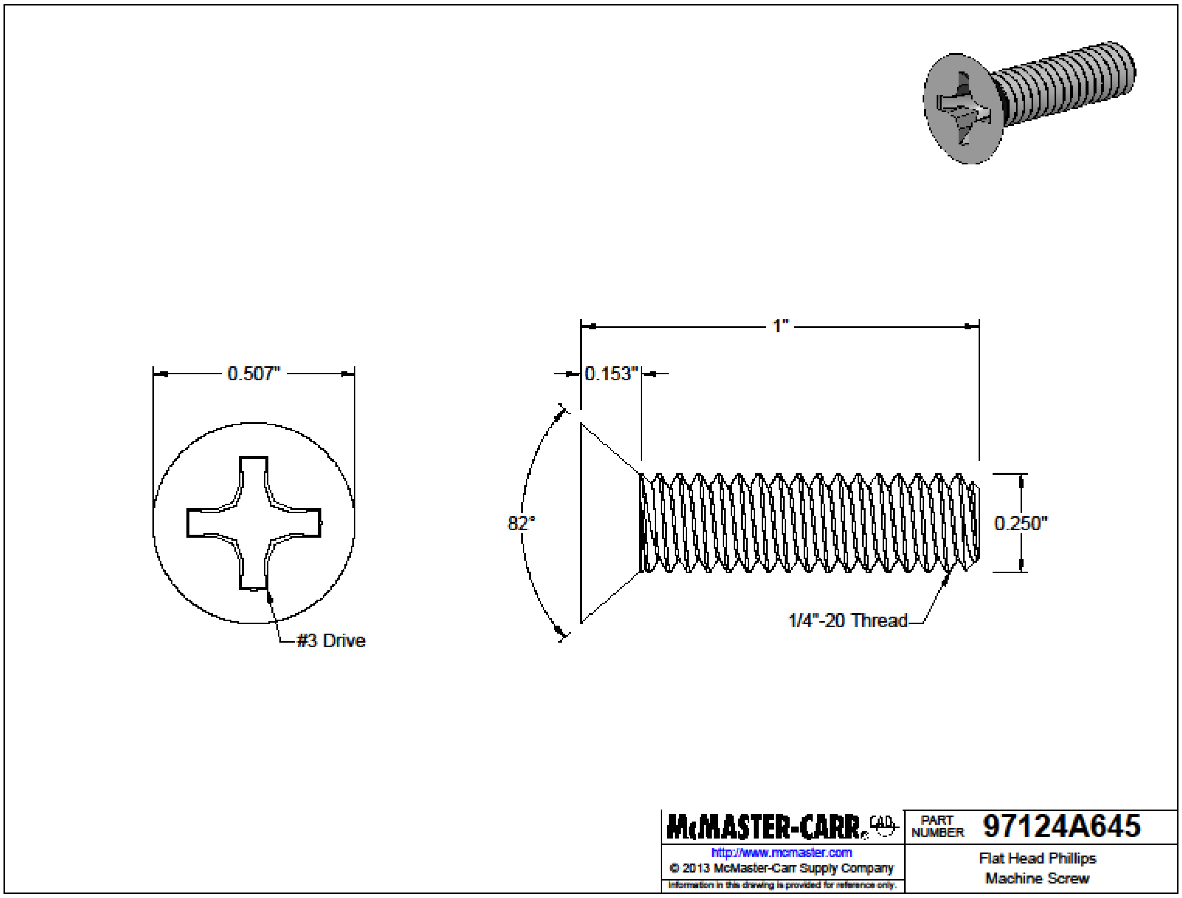

0.063"
0.325"
For Material
Thickness
0.063"-0.125"
0.394"
3/16"
For 0.192"-0.196" Hole Size
For No. 11 Drill Bit Size
McMASTER-CARR
CAD
http://www.mcmaster.com
© 2019 McMaster-Carr Supply Company
Information in this drawing is provided for reference only.
PART
NUMBER
97447A045
Domed Head
Blind Rivets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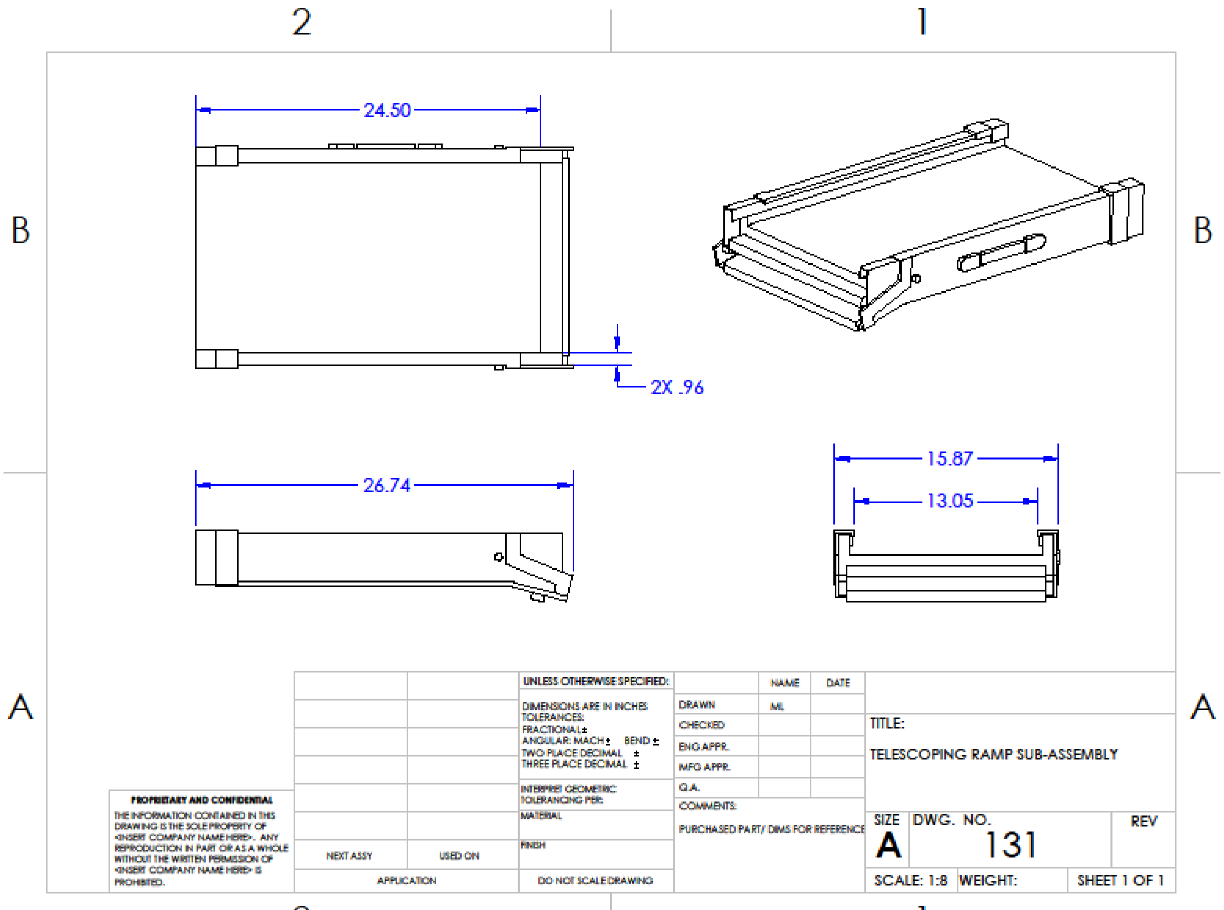
0.507"
0.153"
82°
0.250"
#3 Drive
1/4"-20 Thread
McMASTER-CARR
PART NUMBER
97124A645
http://www.mcmaster.com
© 2013 McMaster-Carr Supply Company
Information in this drawing is provided for reference only.
Flat Head Phillips
Machine Screw



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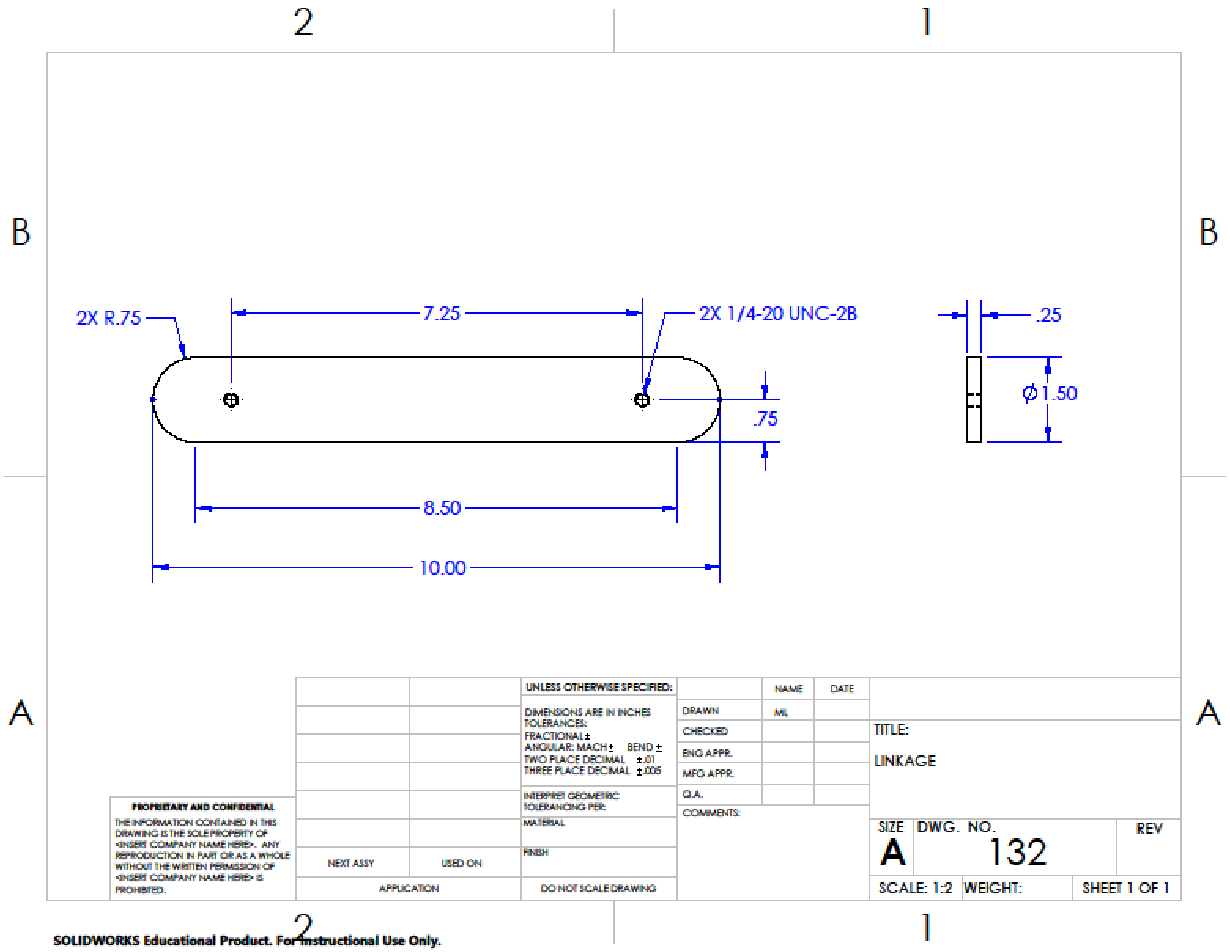
2
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B
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Ø1.50
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±.01
THREE PLACE DECIMAL ±.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NAME
DATE
DRAWN
ML
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
LINKAGE
SIZE
A
DWG. NO.
132
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
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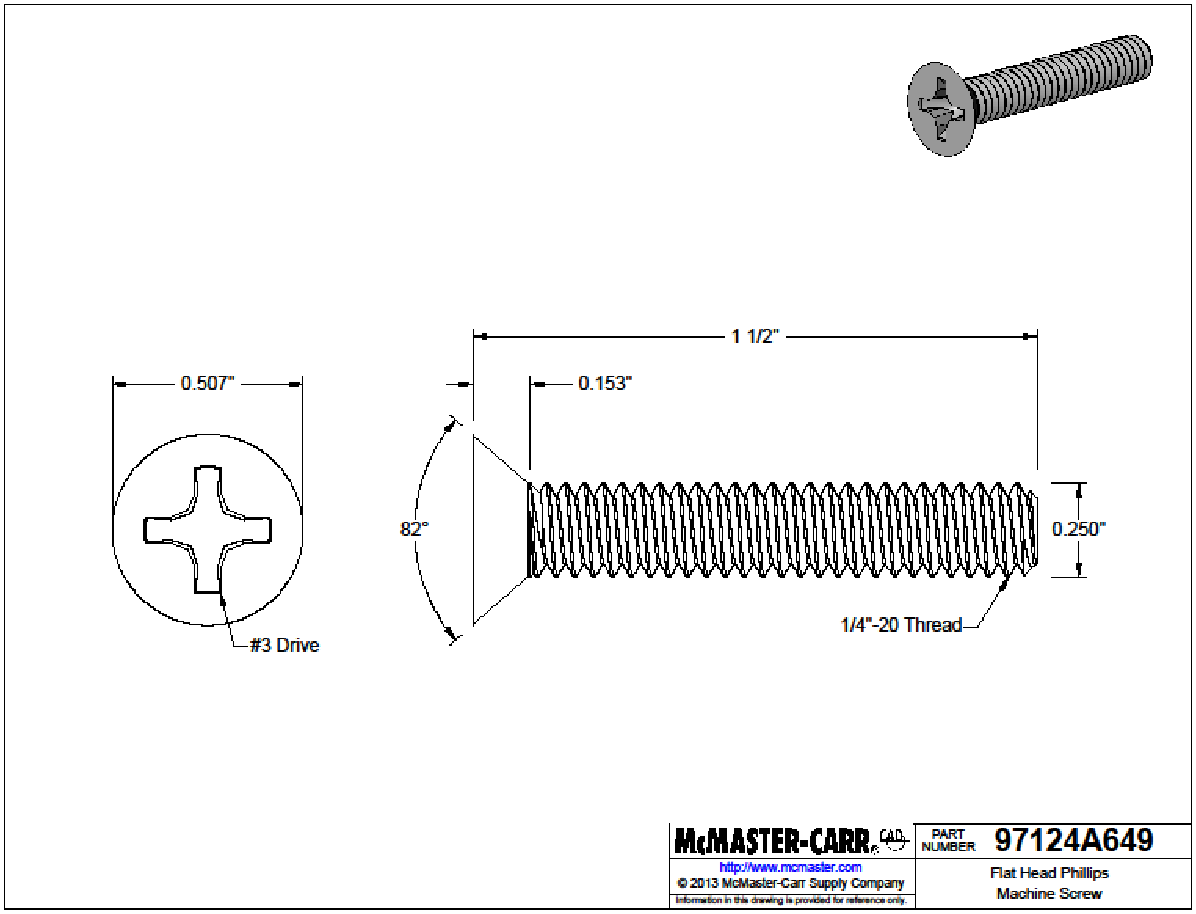
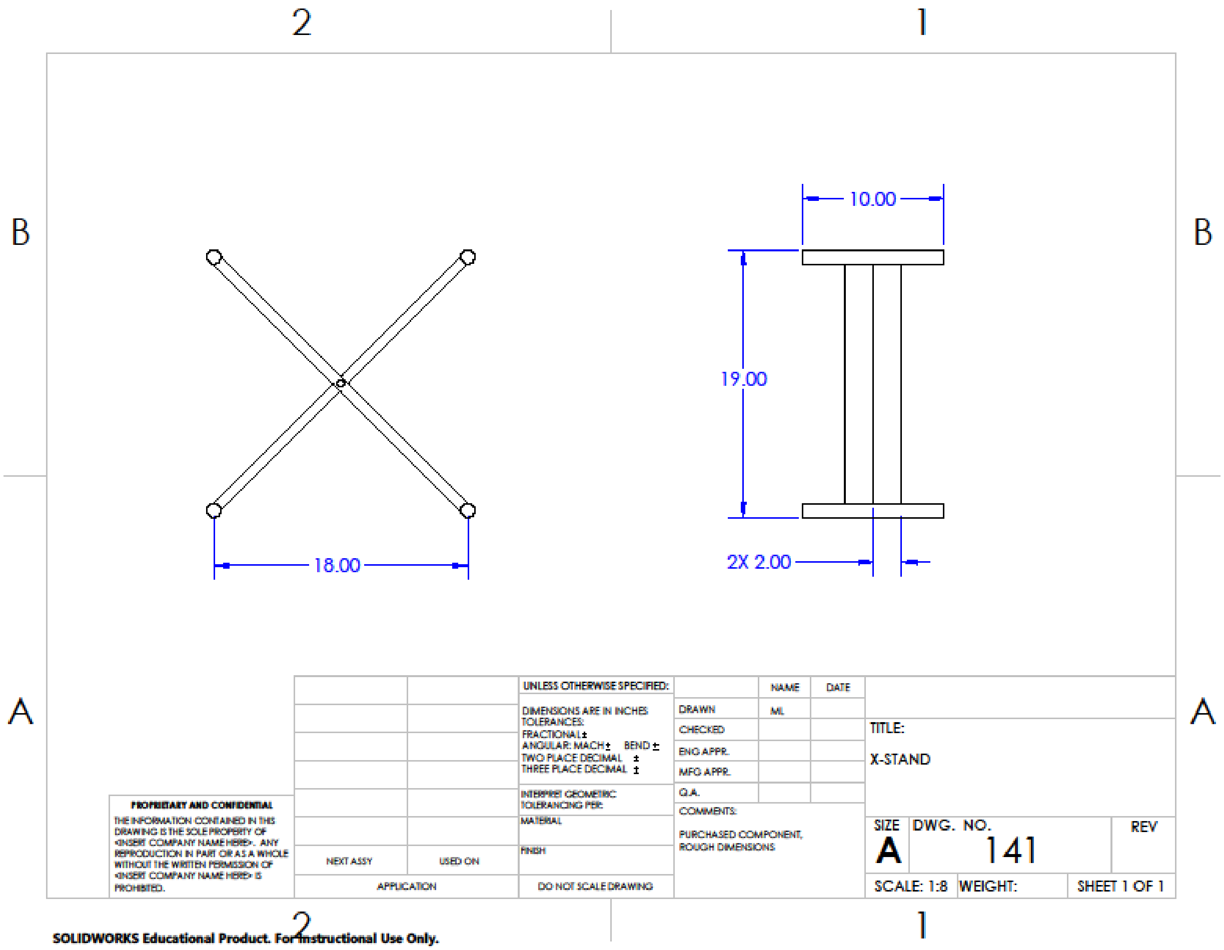

0.507"
#3 Drive
1 1/2"
0.153"
82°
0.250"
1/4"-20 Thread
McMASTER-CARR CAD
http://www.mcmaster.com
© 2013 McMaster-Carr Supply Company
Information in this drawing is provided for reference only.
PART NUMBER 97124A649
Flat Head Phillips Machine Screw


10.00
19.00
18.00
2X 2.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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NAME
DATE
DRAWN
ML
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PURCHASED COMPONENT, ROUGH DIMENSIONS
TITLE:
X-STAND
SIZE
A
DWG. NO.
141
REV
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
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Appendix L. Intended Bill of Materials

Assembly Level	Part Number	Description					Qty	Cost	Ttl Cost	Source	More Info
		Lvl0	*Lvl1*	*Lvl2*	*Lvl3*	*Lvl4*					
0	100	Final Assembly								------	
1	110		Flat Platform							------	
2	111			Sheet Metal			1	$ 33.38	$ 33.38	Online Metals	Part #1238
2	112			Square Tubing			10	$ 5.11	$ 24.41	Online Metals	Part #18014
2	113			Grip Surface			1	$ 15.00	$ 15.00	Amazon	FlexSeal
2	114			Aluminum Round Rod			2	$ 2.00	$ 4.00	Online Metals	
2	115			Canvas Sheet			1	$ 10.00	$ 10.00	Beverly's	
2	116			Hole Plugs			2	$ -	$ -	QL+ 3D Print	
2	117			Hole Pins			2	$ -	$ -	QL+ 3D Print	
2	118			Pet Safety Belt			1	$ 8.00	$ 8.00	Vastar	
2	119			End Caps			2	$ 22.85	$ 45.70	custom	machined aluminum
2	120			3/16 Rivets			6	$ 0.69	$ 4.14	McMaster Carr	
2	121			1/4-20 Bolts 1"			4	$ 2.29	$ 9.16	McMaster Carr	
1	130		Ramp								
2	131			Telescoping Ramp			1	$ 130.00	$ 130.00	PetSafe	
3	132				Pivot Linkage Connection		2	$ 22.85	$ 45.70	custom	machined aluminum
3	134				End Caps		2	$ 22.85	$ 45.70	custom	machined aluminum
3	135				1/4-20 Screws 1.5"		2	$ 2.43	$ 4.86	McMaster Carr	
3	136				Button Strap		2	$ 7.00	$ 14.00	Amazon	Sumind
1	140		Legs								
2	141			X Stand			1	$ 39.99	$ 39.99	Guitar Center	item #1377810373366
						Total Parts	**42**		**$ 434.04**		

Appendix M. Design Verification Plan

TEST PLAN

Item No	Specification #	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES		TIMING	
						Quantity	Type	Start date	Finish date
1	1	Use a scale to weigh our prototype	Doesn't exceed 30 lbs	Matt	FP	1	Sys	2/25/2020	N/A
2	2	Place whole system into different cars to determine how well it fits given space constraints	System sits in space behind drivers seat	Adam	SP,FP	1	Sys	2/4/2020	N/A
3	3	Use a salt spray on exposed metal parts of our system	No visible corrosion after 24 hours	Matt	FP	1	C	2/18/2020	N/A
4	4	Apply load and measure displacement	Displacement doesn't exceed 1 in	Dallas	SP,FP	1	Sub	2/25/2020	N/A
5	7	Time how fast it takes to deploy system and stores it	Process doesn't take more than 5 minutes to complete	Ariel	SP,FP	1	Sys	2/25/2020	N/A
6	8	Have different dogs use the system and see how comfortable they are	Dogs are willing to use system without difficulty	Adam	FP	1	Sys	2/27/2020	N/A

Appendix N. Failure Modes & Effects Analysis

System / Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Causes of the Failure Mode	Current Preventative Activities	Occurence	Current Detection Activities	Detection	Priority	Recommended Action(s)	Responsibility & Target Completion Date
Ramp / provide climbing surface for dog	Dog slips on surface	user can't climb comfortably	4	1) not enough traction 2) too steep	a) installing traction material b) ensuring comfortable climbing angle	2	testing with yellow lab from Don	1	8		
	Ramp material yields under dog weight	dog startled and jumps off, system won't operate anymore	9	1) material too thin 2) material too weak 3) lack of support	a) deflection analysis b) yielding analysis c) material selection d) fastener shear analysis	1	material strength testing, dog testing	5	45	a) measure deflection under varying loads b) full FEA analysis on telecoping components	January & February
	Dog walks off the edge	a) dog's hips and elbows take stress b) dog is injured	9	1) no guide rail 2) ramp not wide enough	a) install guide rail b) train with treats	5	dog test	1	45	a) test guide rail with dog	Spring Quarter
	Surface is too hot	dog can't comfortably walk on surface	4	1) thermal conductivity of material too high	a) material selection for non conductive stuff b) ramp cover for storage	4	take temperature of surface	1			
Flat Platform / Transition dog from ramp to car	Bare/open platform	Dog jumps off and strains joints	9	1) no guide rail	a) guide rail	5	dog test	1	45	a) test guide rail with dog	Spring Quarter
	Not at height of truck floor	dog has to jump or take a large step	5	1) legs don't fully deploy 2) height adjustment not refined	a) measure twice at Toyota, build once	1	testing truck compatibility	1	5		
Legs / Provide stability and height adjustment	*Legs buckle*	*Whole system falls, injuring dog*	*9*	*1) material too thin 2) material too weak*	*a) buckling analysis b) material selection*	*1*	*material buckling tests*	*4*	*36*	*a) full analysis and FEA b) testing materials under load*	*January & February*
	Legs tip over	*Whole system falls, injuring dog*	*9*	*1) legs not perpendicular with level platform 2) not enough grip/surface area to interface with ground*	*a) multiple anchor points b) grip on feet c) deployment lock*	*2*	*deployment tests*	*1*	*18*		
	Telescope slips	*Whole system falls, injuring dog*	*9*	*1) material too thin 2) material too weak 3) lack of support*	*a) component selection b) deployment lock*	*2*	*deployment tests*	*1*	*18*		
Flat Platform connection to Ramp	Tip over	Whole system falls, injuring dog	9	Incorrect dimensions for connection of ramp to flat platform	a) Add a stabilizing component to interface the platform with the truck	2	deployment tests	1	18	a) full analysis and FEA b) testing materials under load	January & February
	Tip over	Whole system falls, injuring dog	9	Uneven terrain	a) Add a stabilizing component to interface the platform with the truck	6	deployment tests	1	54		

Appendix O. Purchased Product Information

Petsafe Telescoping Pet Ramp: https://www.petsafe.net/support/travel/happy-ride-compact-telescoping-dog-ramp

X-stand: https://www.guitarcenter.com/Musicians-Gear/KS-515-MG-Deluxe-Keyboard-Bench-1274228076903.gc?source=4WWRWXGP&gclid=Cj0KCQiApt_xBRDxARIsAAMUMu8Xz06-XMEBcfs6trpcB4quB_vuXU7nbZpycSeOits0-3orFGqGaD8aAnvPEALw_wcB

Appendix P. Purchase List

Purchase List			
Item	Qty	Part #	Vendor
Sheet Metal	1	111	Online Metals
Square Tubing	10	112	Online Metals
Grip Surface	1	113	Amazon
Aluminum Round Rod	2	114	Online Metals
Canvas Sheet	1	115	Beverly's
Pet Safety Belt	1	118	Vastar
3/16 Rivets	6	120	McMaster Carr
1/4-20 Bolts 1"	4	121	McMaster Carr
1/4-20 Screws 1.5"	2	135	McMaster Carr
Button Strap	2	136	Amazon
X Stand	1	141	Guitar Center
Telescoping Ramp	1	131	PetSafe

Appendix Q. Testing Procedures

Test Procedure

Test #1: Weight

Description of Test:

Weigh the device to determine total weight

Acceptance Criteria:

Does not exceed 30 lbs

Location: Hanger

Required Materials:

- Scale

Testing Protocol:

1. Put scale on level surface
2. Place device on scale
3. Read off measurement

Data:

Weight	

Passed or Failed

Test Procedure

Test #2: Fit

Description of Test:

Determine if the device will fit in the allotted space within the vehicle

Acceptance Criteria:

System fits behind driver's seat

Location: Toyota Dealership

Required Materials:

- Truck
- Ruler

Testing Protocol:

1. Adjust seat to roughly where Peter has his set in his truck
2. Place device into open space behind seat
3. Measure space – either extra space or the space needed to place device into vehicle

Data:

Space	

Passed or Failed

Test Procedure

Test #3: Deflection

Description of Test:

This test will determine if our product will flex an acceptable amount under normal load conditions.

Acceptance Criteria:

The ramp bends less than 10% of its length at an equivalent load of 150 lbs.

Location: Biomechanics Lab, Building 52 Room D17

Required Materials:

- Scale
- Ramp
- Keyboard Bench (For incline)
- Deflection Test Equipment & Software

Testing Protocol:

1. Extend ramp fully and position top of ramp at 24 inches in height.
2. Attach 5 markers to edge of ramp.
3. Add known-weight objects to center of ramp in 3 increments. Interpolate deflection data for equivalent load required.

Data:

Load Condition	**Interpolated Deflection Over Length**
80 lbs (Dog)	1.82%
150 lbs (Worst Case)	5.98%

Passed or Failed

Test Procedure

Test #4: Deployment

Description of Test:

This test will determine if our product can be used by wheelchair users.

Acceptance Criteria:

The ramp can be deployed by a wheelchair user under 5 minutes.

Location: Along a car that fits the designated heights.

Required Materials:

- Wheelchair (Ideally a regular wheelchair user too)
- Timer
- Ramp

Testing Protocol:

1. Get a participant/group member to use a wheelchair.
2. Start timer.
3. Have participant in wheelchair deploy the ramp in the car.
4. Stop timer once the task has been completed and record the time and any notes.
5. Repeat steps 1-4 with at least three different wheelchair users.

Data:

Trial	Time (minutes)	Notes
1		
2		
3		

Passed or Failed

Test Procedure

Test #5: Dogs

Description of Test:

This test will determine if dogs are willing to use our product.

Acceptance Criteria:

Three or more dogs use the ramp without any problems.

Location: Near a Toyota Tacoma or a Mock-up Model

Required Materials:

- Dogs
- Ramp

Testing Protocol:

1. Deploy ramp along Toyota Tacoma or Mock-Up Assembly
2. Guide dog up ramp (use treats if necessary)
3. Record Observations

Data:

Dog	Breed Description	Observations (Willing/Not willing)
1		
2		
3		

Passed or Failed

Test Procedure

Test #6: Destructive Weld Test

Description of Test:

This test will asses the quality of the different welds used in joining the 1" square aluminum tubing together by using sample welds and trying to break them under different conditions.

Acceptance Criteria:

The weld will pass if it stays in tact while the workpieces fail.

Location: Hangar

Required Materials:

- 4 Pieces of scrap aluminum
- Bench vise
- Vise grip pliers

Testing Protocol:

1. Weld 2 pieces of scrap aluminum together
2. Place one leg of welded piece in bench vise
3. Use vise grips to bend apart two legs of welded test piece

Data:

Weld Type	Pass	Fail
Horizontal at 45°		
Vertical Fillet		
Vertical Edge		

Passed or Failed

Appendix R. Operator Manual

Deploying the Dog Ramp

Buckle the safety strap into the unused seat belt buckle. This will be attached to the ramp after it has been deployed. Use the handle located on the side of the ramp to lift it out of the car. Place the ramp on the ground adjacent and parallel to the vehicle. The pivot links should be pointed towards the back of the vehicle so that the ramp will deploy towards the back of the vehicle. Unbutton the latch holding the assembly together. Do not unfold the ramp until the x-stand has been securely deployed. Lift the flat platform/ramp section upwards so that the flat platform is as flush as possible with the floor of the cab. Secure the x-stand by placing the free crossbar underneath the flat platform and into one of the slots. Once the x-stand is secure, unbutton the latch on the bottom of the telescoping ramp. Unfold the ramp and allow it to telescope out and reach the ground. Some adjustment may be necessary to increase or decrease the slope of the ramp. Fasten the safety strap to the side of the ramp closest to the vehicle. It is strongly recommended that you install the canvas guard rail when getting your pet adjusted to using the ramp especially during egress. To do so, place the two uprights into the holes located along the outside edge of the flat platform.

Collapsing and Storing the Dog Ramp

Once your dog is safely inside the vehicle, it is time to put the ramp away and go to your destination.

Collapsing the Ramp

If you are still using it, the first thing you must do is take out the canvas guard rail from the top of the ramp. This is very compact and can be put into the pouch in the back of a seat, a pocket inside of the door, or simply on the floor. With that out of the way, pick up the bottom part of the telescoping ramp and slide it back into its place. After the telescoping section has been collapsed, fold it over onto the flat portion of the ramp so that they sit flush against each other. Now you can simply take the x-stand leg out of whichever height setting you have chosen and either slowly let the ramp sit flat on the ground or pick it up from the bottom and flatten it by hand. Make sure you keep the telescoping and flat portions level with the ground while doing this!

Putting the Ramp Away

If you plan on using this ramp and nothing else in your vehicle, you can simply set it down on the floor behind the driver's seat of your vehicle. For Peter Way specifically, things may need to get more creative due to the wheelchair storage system. If possible, it is best to store both the wheelchair wheels and the ramp behind the driver's seat. If this does not work, it is advisable to store the wheels behind the passenger seat and the ramp behind the driver's seat, or vice versa. It depends on personal comfort and preference.

Training your Dog to Use the Dog Ramp

Training your dog to use the dog ramp is going to require a lot of patience and a lot of your dog's favorite treats!

Get your Dog Exposed to the Dog Ramp

When first starting out the training, it is best to expose the dog to the ramp when it is at its lowest setting. Make sure the ramp leads onto a stable surface/platform. Without a leash, encourage your dog to approach the ramp. Anytime your dog approaches or interacts with the ramp in any way, praise and award your dog with a treat. These approaches and interactions include your dog sniffing, touching, or looking at the ramp.

Get your Dog's Paws on the Ramp

Once it seems your dog is comfortable with the ramp. Encourage your dog to get its paws onto the ramp. When one paw is on the ramp, award them with a treat. Keep on encouraging your dog to get another paw onto the ramp. When there are two paws on the ramp, award your dog with another treat. Keep on continuing this process until all their paws are on the ramp.

Get your Dog to Climb the Ramp

Using a treat, lure your dog to walk on the ramp. Once your dog has reached the top of the ramp, award them with a treat. When your dog seems used to climbing up the ramp, raise the ramp to its next highest setting. Keep on continuing this procedure until your dog is able to climb your highest desirable setting of the ramp.

Get your Dog to Climb the Ramp while it Leads into the Car

Once your dog can climb up all settings of the ramp, set up the ramp as indicated in the *Deploying the Dog Ramp* Section of the Operator Manual. This is where the detachable guard rail will be a huge help for the initial uses. With the ramp set up, guide your dog up as usual awarding with treats when the task is completed. When you feel comfortable and feel like the guard rail is no longer needed, feel free to remove it.

Performing Maintenance on the Dog Ramp

No active maintenance is required to keep the Dog Ramp working correctly. The ramp can be used indoors or outdoors and on any terrain. The system is made of mostly metal and has rubber coating in some areas, so it is water resistant. It can be cleaned by any common method such as rinsing with a hose, using a wipe, etc. However, it shouldn't be left outside or exposed to wet conditions for extended periods of time. It also shouldn't be exposed to high temperatures for prolonged periods of time either.

Appendix S. Risk Assessment

designsafe Report

Application:	Service Dog Ramp	Analyst Name(s):	Matt Lundgren
Description:	Analysis for senior project at Cal Poly	Company:	Doggone It
Product Identifier:		Facility Location:	Cal Poly
Assessment Type:	Detailed		
Limits:			
Sources:			
Risk Scoring System:	ANSI B11.0 (TR3) Two Factor		

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1	All Users <None>	<None>						
2-1-1	passer by / non-user walk / work near machinery	electrical / electronic : shorts / arcing / sparking welding sparks	Minor Unlikely	Negligible	fixed enclosures / barriers, special clothing	Minor Remote	Negligible	In-process Ariel
2-1-2	passer by / non-user walk / work near machinery	heat / temperature : burns / scalds touching welded part	Moderate Likely	Medium	warning sign(s)	Moderate Unlikely	Low	In-process Ariel
2-1-3	passer by / non-user walk / work near machinery	noise / vibration : noise / sound levels > 80 dBA loud machining	Minor Very Likely	Medium	hearing protection	Minor Unlikely	Negligible	In-process All
3-1-1	Peter set up / take down ramp	mechanical : pinch point fingers in hinge mechanism	Serious Unlikely	Medium	instruction manuals, warning label(s)	Serious Remote	Low	In-process Matt
3-2-1	Peter move ramp into / out of truck	ergonomics / human factors : lifting / bending / twisting improper lifting technique	Moderate Remote	Negligible	standard procedures	Moderate Remote	Negligible	In-process Matt
4-1-1	Rory climb up / down ramp	slips / trips / falls : fall hazard from elevated work not walking up ramp straight	Minor Unlikely	Negligible	standard procedures	Minor Remote	Negligible	In-process Peter

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
5-1-1	Doggone It cut and drill metal	mechanical : cutting / severing improper hand placement	Catastrophic Unlikely	Medium	E-stop control, special tools or fixtures	Catastrophic Remote	Low	In-process All
5-2-1	Doggone It weld	heat / temperature : burns / scalds not letting metal cool off	Serious Unlikely	Medium	gloves	Serious Remote	Low	In-process Ariel
5-3-1	Doggone It clean up	ergonomics / human factors : lifting / bending / twisting improper broom usage	Minor Remote	Negligible	standard procedures	Minor Remote	Negligible	In-process Adam
5-4-1	Doggone It mill	mechanical : drawing-in / trapping / entanglement not tying loose hair/clothing/jewelry etc.	Catastrophic Remote	Low	E-stop control	Catastrophic Remote	Low	In-process All
5-4-2	Doggone It mill	mechanical : unexpected start inattentiveness near machine	Moderate Unlikely	Low	E-stop control	Moderate Unlikely	Low	In-process All
5-5-1	Doggone It transport materials	material handling : excessive weight carrying too much at once	Minor Likely	Low	supervision	Minor Remote	Negligible	In-process Dallas
5-6-1	Doggone It normal operation	mechanical : pinch point putting fingers in hinge mechanism	Moderate Unlikely	Low	standard procedures	Moderate Remote	Negligible	In-process All