FAMU & FSU COLLEGE OF ENGINEERING
Department of Mechanical Engineering

EML 4552C – Senior Design II – Spring 2013

Final Design

Mobility Lift for European Insider Applications

Group # 19

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Project Sponsor: Harmar Mobility Inc.

Project Advisor: Dr. Carl A. Moore, Ph.D.

ABSTRACT

Harmar is an innovation and design leader that is dedicated to helping individuals enhance their mobility, independence, and quality of life. Their wide range of accessibility and mobility solutions are all built to offer the highest quality, reliability, and value. Currently, there is a need to provide a solution for individuals in Europe who transport themselves in smaller vehicles. The task is to design a lightweight inside lift to compete in the European Market.

Initially, three concepts were proposed and presented to Harmar. These initial concepts differed highly from one another and had their own associated advantages and disadvantages. Ultimately, one of these concept was chosen and expanded upon at the end of the fall semester. The beginning of the spring semester was spent further altering this design to suit the needs of Harmar and their management at their newly created European branch in the Netherlands. A full stress analysis was simulated before an entire CAD package was presented to Harmar. Machining too place at the Harmar facility in Sarasota, FL, however, the unit was assembled by the team at the FAMU-FSU College of Engineering. Finally, the prototype was tested and analyzed before being presented to a panel of industry experts for evaluation.

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BACKGROUND

Harmar Mobility currently provides mobility lift solutions for a wide range of vehicles in the United States. However, the majority of vehicles driven in Europe are much smaller and more compact than those in the United States. This prevents the company's current lifts from achieving optimal performance when installed into European vehicles. The goal is to provide a solution for the individuals who transport themselves in more compact vehicles and require a mobility lift. The task is to design a lightweight interior lift to compete in the European market.

Although a universal fit is ultimately the goal of this design, to achieve a suitable prototype, all design aspects were initially based on the Volkswagen Golf VI – the bestselling vehicle in Europe for the past three years [6]. All relevant dimensions for this vehicle are provided in Appendix A1. Special consideration was paid to the dimensions of the vehicle trunk—considering that the final design will ultimately be installed in that subdivision of the car.

PRODUCT SPECIFICATION REVISITED

Since this will be a product marketed towards consumers, the final mobility lift that is developed must be tested for safety and reliability. Since safety is a number one concern, the design must meet industry, as well as Harmar, standards for safety. The structure for the design must withstand a maximum load of roughly 180 kg—or three times the normal operating condition. Additionally, the unit must perform a 10,000 cycle test with a load rate of 130 lbs as a means for ensuring an adequate lifespan that should be expect.

CONSTRAINTS

Since the target consumer for our device will be marketed more towards the disabled and senior citizens, the design must be user-friendly and easy to use. This will be achieved by the selection of a simple and user intuitive device. Simplicity will be based on a design with a limited number of complex components such as actuators and other electro-mechanic devices. On the same note, since these users are physically limited in their day to day operations, the design must also be lightweight for manual operation. This includes lifting and positioning of the different components. At the same time, however, structural strength and rigidity should not be compromised since strict consumer safety standards are to be expected. Lastly, European products are generally known for their distinction with respect to quality and style. The intended customer will then be expecting a product that meets a certain level of sophistication. Therefore, as requested from our sponsor, the overall design must be aesthetically pleasing in these regards.

INITIAL DESIGN CONCEPTS

DESIGN CONCEPT 1

Overview of Design Concept

The motivation behind this design concept comes from a fork lift. In the cargo area of the vehicle a track is installed, this allows for smooth movement of the lift platform in and out of the cargo area. A sample CAD drawing of this design is presented in Figure 1, below.

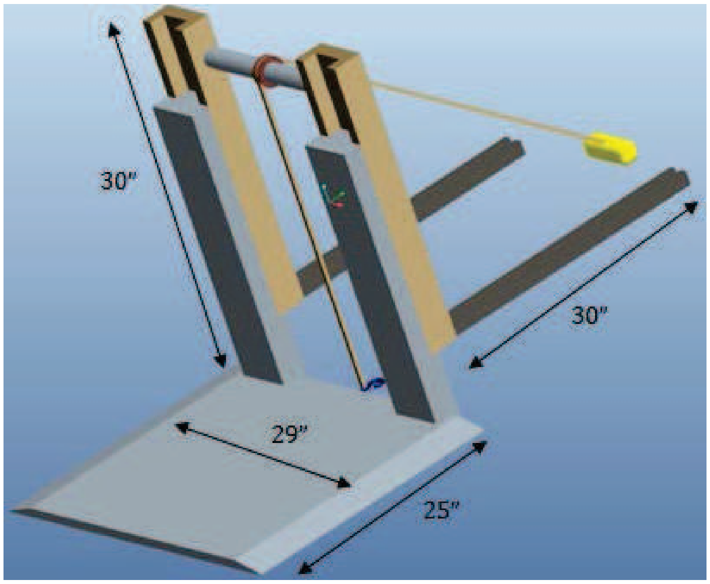


Figure 1 – Concept 1: Front Angle View

Attached to the track, by way of rollers in a c-channel, are the upright gear tracks. These gear tracks are responsible for keeping the lift platform level while raising and lowering the lift platform. The motor is attached to a strap that goes up over the roller bar, which is fixed between the upright gear tracks, and down to a hook at the base of the lift platform. This allows the employment of a single motor for lifting the platform vertically as well as moving it horizontally; therefore the design is fully automated.

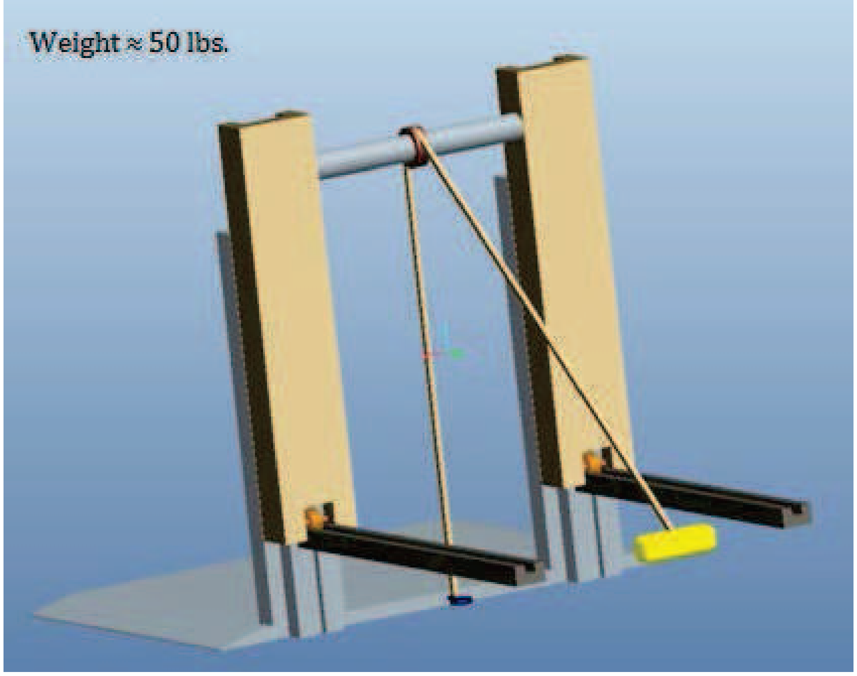


Figure 2 – Concept 1: Rear Angle View

Components and Function

Affixed to the floor in the cargo area, the track system will be the foundation of the design. The method of affixation has not yet been fully examined; however upon doing some rudimentary calculations for a single fixture, the fixture needs to be able to support a bending moment of approximately 6,230 N-m, or 1,400 lbf-ft. For this design, multiple fixtures will be employed, allowing for overcompensation of forces, as well as the safety of the component. The tracks will have a channel cut into them. This channel is where the roller that is attached to the upright gear track will move horizontally.

The upright gear tracks will have c-channels cut into them, which the lift platform uprights can slide in and out. Although this component has not yet been fully designed, the idea is to have at minimum one set of gears on each side of the channel, which will help to reduce the chance of abrupt sliding and allow for smooth movement vertically of the lift platform. Also, we would like to include some locking mechanism such that once the lift platform is lifted to some height it cannot go back down without unlocking the mechanism. Between the upright gear tracks is the roller bar, and in the middle of the roller bar is a pulley wheel. This pulley wheel allows the strap to be run up over the bar and out past the bumper, so as to not damage the vehicle.

The lift platform consists of two components, the uprights and the platform. The platform is the component that the mobility device will be maneuvered onto and will convey the mobility device into the vehicle. In order to allow the mobility device to drive onto it, the platform needs to be thin, yet it must be thick enough to withstand the weight of the mobility device plus a factor of safety of three. An alternative to the solid platform is to have a reinforced grate; this would cut down on the weight of the platform. The uprights will be T shaped and will have gear teeth along the T to mesh with the upright gear tracks, enabling the smooth motion previously described. A motorized wench and strap runs the entire assembly. The strap remains connected to the base of the lift platform, between the uprights. It is then run up over the pulley and roller bar, and down onto the motorized wench system.

DESIGN CONCEPT 2

Overview of Design Concept

This design concept is a product between classic and modern design. It resembles a typical insider mobility lift that is tailor fit to the European market. Since the 6th Generation Volkswagen Golf will be used as the test base to aid in the development of this product, the mobility lift dimensions are limited to 30 inches in height and 29 inches in width. This concept offers the best versatility and user-friendliness. The design has several advantages at achieving the requirements set by Harmar Mobility, Inc. For instance, it is able to fold to save space, can be rotated and swung about its center line, and the boom arm length can be extended and contracted depending on the customers need.

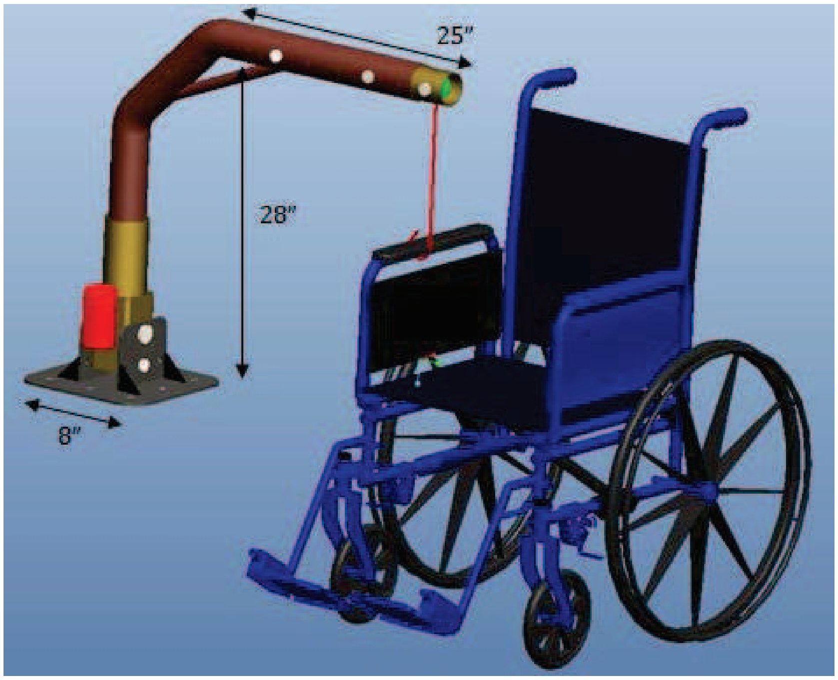


Figure 3 – Concept 2: Lift Assembly and Wheelchair (not to scale)

Components and Functions

At the foundation of the mobility lift is its base. It is mounted directly into the customer's vehicle or testing platform. Four gusset plates are welded to the base plate to provide additional strength and assist with the welding process by creating a 90 degree angle. In addition, the user can rotate or swing the device arm from 0 degree to approximately 180 degrees about the upright center line. This design concept provides two folding options—flat at 0° and approximately 20° depending on the user's desire. The user can select any folding option by removing the lower pin and inserting it into one of the three pre-drilled holes at the base side.

The arm has a built-in extending and contracting mechanism, which can manually lengthen by an additional 10 inches for easier reach of larger objects. The extending arm is fit nicely into the main arm and secured to the main arm by two screws. The user can extend or contract the arm by placing the two screws at desired locations. The motor is placed inside a secure housing that is mounted directly to the lower arm. The control for this design will be accomplished with by a remote control system provided by Harmar Mobility. There will be precautionary safety switches built-in to limit the travel distance of the cable and hook system. Also, all cables, electrical wires, and pulley can be housed internally inside the arm, with a screw cap to keep it securely away from weather, dirt, and debris.

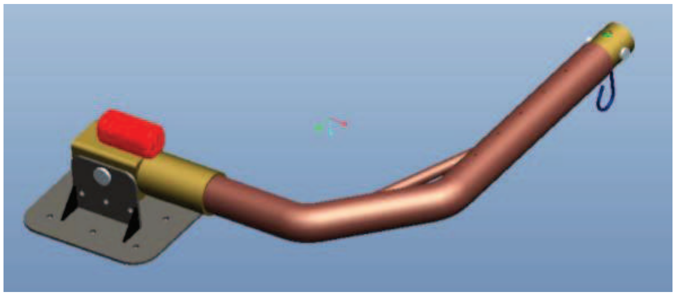


Figure 4 – Concept 2: Mobility lift at 0° Folding Position

The round pipe with a correct wall thickness was chosen over a square or t-slotted material for several reasons. One reason being to utilize the round pipe bender available at the College of Engineering machine shop in order to simplify the manufacturing process. Also, it provides a free rotation when pivoted about the center line. In addition, it is more sensible in price when compared to a t-slot structure channel. More likely than not, high grade aircraft aluminum will be used to save weight, but at this design stage no decision has been made. Since this design is based on a typical mobility lift, it is user friendly to the physical impaired and seniors. Based on initial market analysis, older citizens prefer traditional design with modern accessories. This design concept provides the user-friendliness, ease in manufacturing and cost effectiveness. Also of importance, it satisfies all requirements out forth by Harmar Mobility.

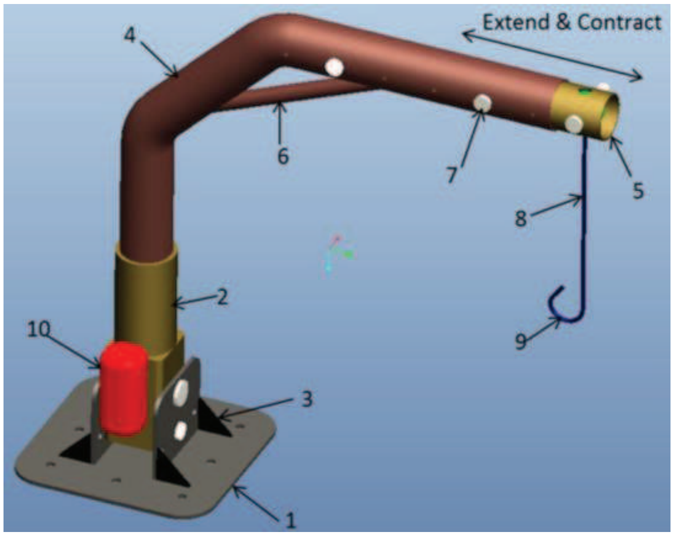


Figure 5 – Concept 2: Fully Assembly View (10 components)

DESIGN CONCEPT 3

Overview of Design Concept

In essence, this project requires the development of a specialized type of crane, or lifting mechanism. To accomplish this, a design featuring multiple advantageous aspects of various crane types was developed. First and foremost, this design concept is based primarily off of an overhead type crane system. This particular type of crane features certain properties that may be more beneficial than other types of traditional mobility lifts in the market today. For example, in industry, overhead cranes are used for their reliability and ability to lift heavy loads. Additionally, this design calls for the implementation of an extending and contracting boom similar to that of a telescoping crane. The relative compactness of a telescoping boom makes them adaptable for many mobile applications [13].

Components and Functions

For this application, all designs presented are to be based on the Volkswagen Golf VI. At its core, this design features a u-shaped structure. The u-shape allows the apparatus to lift the wheelchair and then secure it within itself. Due to the light weight constraint set for the design, an aluminum alloy will most likely be used such as AL6061. However, if a more economical alternative presents itself, the material selection may be changed. This component will be drawn out from a single tube of material and will, therefore, add to the overall strength of the design. Furthermore, the simplicity in design will not only make it easier to manufacture, but also add to its user-friendliness.

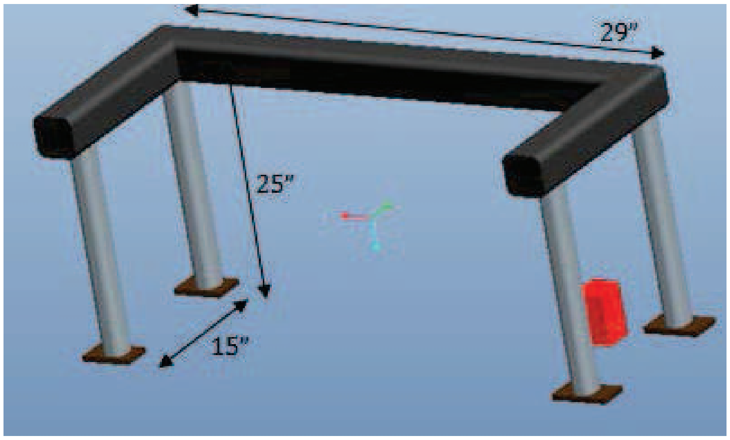


Figure 6 – Concept 3 Lift Assembly: Fully Retracted Arms

Attached are four legs that will be bolted to the floor of the automobile. Therefore, these legs are to be attached to the floor of the hatchback. The increased number of fixations to ground will ultimately help in distributing the weight of the load to be lifted. Currently, this design calls for the bolting of the legs to the floor of the automobile. This will be accomplished by a total of 16 bolts, 4 per foot. Structural analysis is to be performed to verify the required number of bolts needed for the 390 lb maximum load to be upheld. While a permanent, solid fixture adds to the overall strength of the design, some consumers may shy away from such a tradeoff. Further research into a more compromising alternative is to be explored.

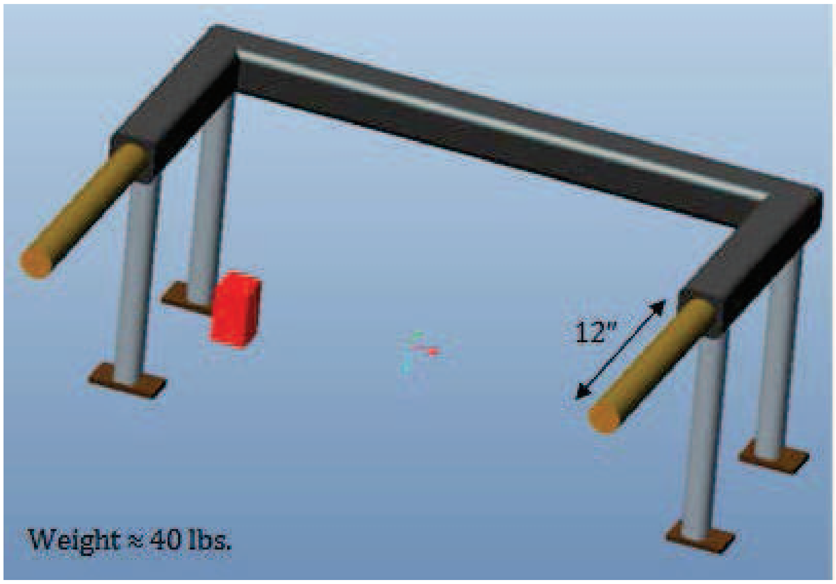


Figure 7 – Concept 3 Lift Assembly: Fully Retracted Arms

Within the structure, telescoping arms will be housed on each side. These arms will be constrained to only move forward (i.e. out of its housing) and backwards (i.e. into its housing). To achieve this, a bearing slide device will be used. Though not yet decided upon, this design may incorporate any of the following types: linear ball-bearing slides, roller bearing slides, progressive action slide. A sample drawing of a three member ball bearing slider rated at 400 – 600 lbs is shown in [4].

Within each tracks, a braided cable will run the length of the arm to be connected to the motor. The motor is to be supplied by Harmar Mobility. Therefore, proper attention will be paid to the selection of an in stock motor that will meet the demand of the design. Communication with Harmar personnel and engineers for input and advice on motor selection will be taken. Sample motor data from Harmar is shown in the Appendix. An accompanying strap and various hooks will be supplied to the consumer for attaching to the cables for lifting their load.

Lastly, an electronic mean for operating the lift will be developed in the form of a small hand control. Through discussion, Harmar has expressed their interest in using the new two-button control currently being used for their AL600 model. Harmar currently uses a PC board with a 2-button pendant (hand control) which could be used. The connection is to be wired to ensure possession with lift (i.e. will not get lost).

Overall, the design explained above is a far deviation from what is currently available in the US and Europe. This may be an advantage for Harmar as a means of distinguishing themselves from other competitors. Though different, this design is not without its advantages. Its basis from an overhead type crane directly adds to its ability to lift larger load if needed—also adding to a higher factor of safety for this particular application. Furthermore, the required custom fitting of the design for cars other than the Volkswagen Golf VI may be seen as both an advantage and a disadvantage. This includes the length of the lift to ensure the telescoping boom extends to a length suitable for lifting, as well as the height to ensure the driver's visibility is not impede for operating the vehicle.

DESIGN SELECTION

Based on the design concepts presented above a decision on which selection to continue developing must be made. To accomplish this, a decision matrix was employed. Each design was rated from 1 to 10. Here, a value of 1 corresponded to the lowest score possible, while 10 was the maximum. Table 1, presented below, gives the weighted criteria along with a description of each factor. As described by Harmar, cost and functionality were explained to be of great importance. Because of this, these two factors are weighted the highest—25% and 20%, respectively.

Table 1 – Decision Matrix Criteria

Criteria	*Weight*	Description
Functionality	*20%*	"Does this product meet the specifications required by Harmar?" Some of these requirements are that it does not take up much cargo room, is lightweight, and can lift the required 60 kg (times a factor of safety of 3).
Durability	*15%*	"Does this product stand up to normal or greater use over a term longer than 7 years?" Harmar has a 3 year transferrable warranty on all the mobility lift models, during which the mobility lift should remain in excellent working condition. Doubling the time of warranty as the test period should enable this.
User Friendliness	*15%*	"Will someone who requires a mobility device be able to operate the product?" This aspect touches on the amount of labor a person must put into making the lift operate. Since the majority of persons using mobility devices are limited in their mobility, the labor involved should be at a minimum.
Manufacturability	*10%*	"Will the product need many specially made parts, or can it use pre-fabricated parts?" This can also affect the cost of the product.
Appearance	*15%*	"Is the product aesthetically pleasing?" The reasoning behind this being that, in Europe, consumers tend to value appearance more highly.
Cost	*25%*	"How much will the product cost to manufacture and is it a competitive price?" One of the most important aspects of the design. However, a low cost design that does not work is worthless. Goes hand in hand with functionality.

The decision matrix was then completed based of the aforementioned criteria explained in Table 1. The results of this selection can be seen in Table 2. From here, it is evident that Design 2 will be the selected concept to move forward with. This concept proved to be the best choice given the inputs required of the design and will be expanded upon for further improvements and analysis.

Table 2 – Decision Matrix

Criteria	*Weight*	Design 1	Design 2	Design 3
Functionality	*0.20*	7	9	8
Durability	*0.15*	7	7	6
User Friendliness	*0.15*	9	9	8
Manufacturability	*0.10*	6	8	7
Appearance	*0.15*	3	5	5
Cost	*0.25*	2	6	5
Total	***1.00***	**5.35**	**7.25**	**6.40**

In the end, Design 1 proved to be too bulky for the application at hand. Additionally, after speaking with our sponsor, all parties felt that this design was impractical for small applications. That is to say, Design 1 would lend itself more to the lifting of very heavy 200+ lb power wheelchairs found in the market today. Of course, this goes beyond the scope of this project and was therefore rejected. Lastly, the size of Design 1 would also limit the available choice of vehicles for installment. As noted in Figure 1 and Figure 2, Design 1 proved to be the largest in terms of overall dimensions and weight (≈ 50 lbs).

On that same note, Design 3 was relatively close to becoming the design of choice (6.60 design evaluation). However, it was ultimately concluded that this design proved to be more complex than what was needed for small scale applications. Although, most design criteria fell within range of the constraints, Design 3 was ultimately abandoned in favor of Design 2. The following text will describe the finalization, improvement, and analysis of Design 2.

FALL FINAL DESIGN

IMPROVEMENTS FROM INITIAL DESIGN

The final design is based on the original concept of Design 2 with the addition of more degrees of freedom. Additionally, the development of a universal base that can be mounted in many type of vehicle—including one with a spare tire—was added. Alterations to the round tubing found throughout the initial design were replaced with square tubing. This change was made in order to utilize the standard stock material that is already available at Harmar Mobility production facilities. Furthermore, the change to square tubing was made to eliminate the need of a tube bending machine; a change that will ultimately lower the manufacturing cost. The rigid neck was replaced by an adjustable neck that is able to give users a greater range of motion when lifting larger and differing sizes of wheelchairs. Lastly, the motor was relocated to the side of the base and is mounted securely inside a plastic molding housing. An initial assembly of the new design is given in Figure 8, below.

Figure 8 – Final Design (Assembled)

DETAIL OF DESIGN

The final design of this mobility lift concept includes many unique features, such as a telescoping arm. Figure 9 shows a more detailed assembly of the final design, as well as significant dimensions. To position the telescoping arm, the user must remove and place the two arm-pins in their desired location in the pre-drilled holes along the length of the outer arm. Another added feature is the adjustable height of the upright, or boom, that will allow users to lift any taller or larger objects within its operating weight. The height is adjusted through the use of a collar, help in place by a set screw. The set screw must be unscrews and the collar may be reset to any position along the length of the boom. Additionally, the neck pith is also adjustable via the adjustable pins placed at a desired orientation on the angle plate (blue). Two angle plates are mounted on both side of the hoisting arm, from which, the screws will enter on one side and exit through the other.

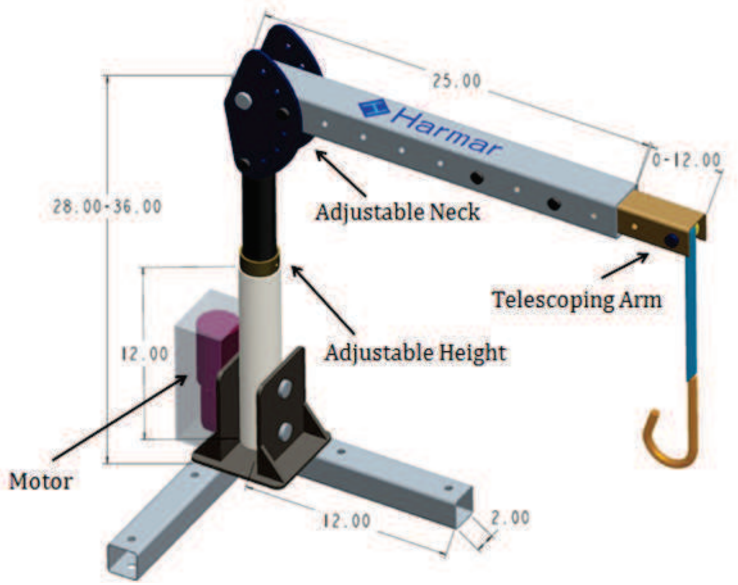


Figure 9 – Detail Assembly with Dimensions

One of the factors considered competitive in the European mobility lift market — also listed as a constraint for our design— is the ability for a design to be compact and have a folding option since European cars are smaller than American cars. In order to maximize cargo space and not obstruct the rear viewing space for divers, a full fold-down option was also expanded on from the initial design. Figure 10 below shows the implementation of this feature on our final design.

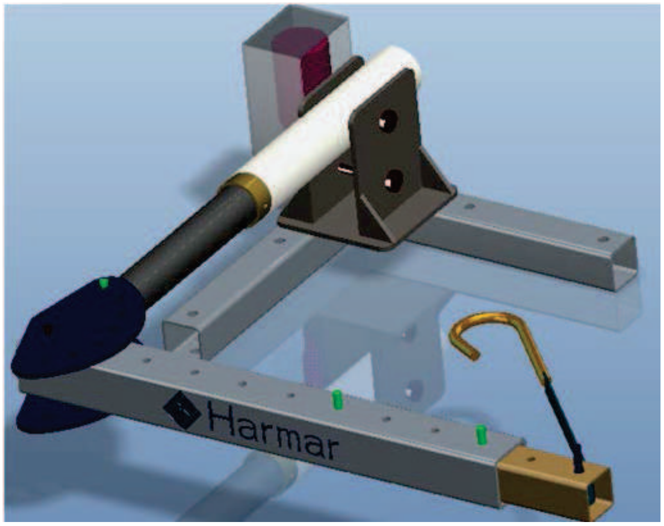


Figure 10 – Full Fold-Down Option

Lastly, since Harmar Mobility is providing customers with a limited warranty, our design must operate smoothly and trouble free in any reasonable weather and under any condition. Therefore, the pulley and roller system is protected internally inside of the extending arm. Although not shown in Figure 11, a plastic cap will be installed on the front-face opening of the extending arm to hide and protect these components from consumers and users.

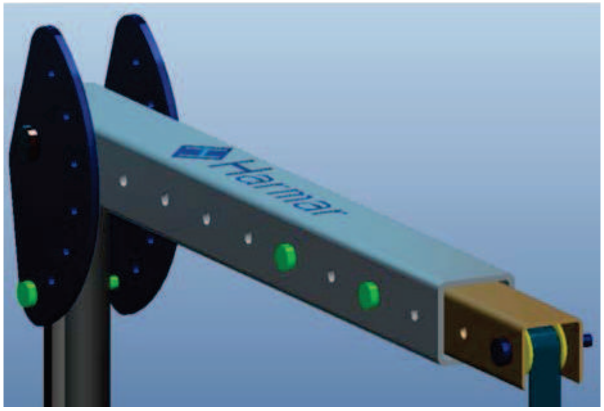


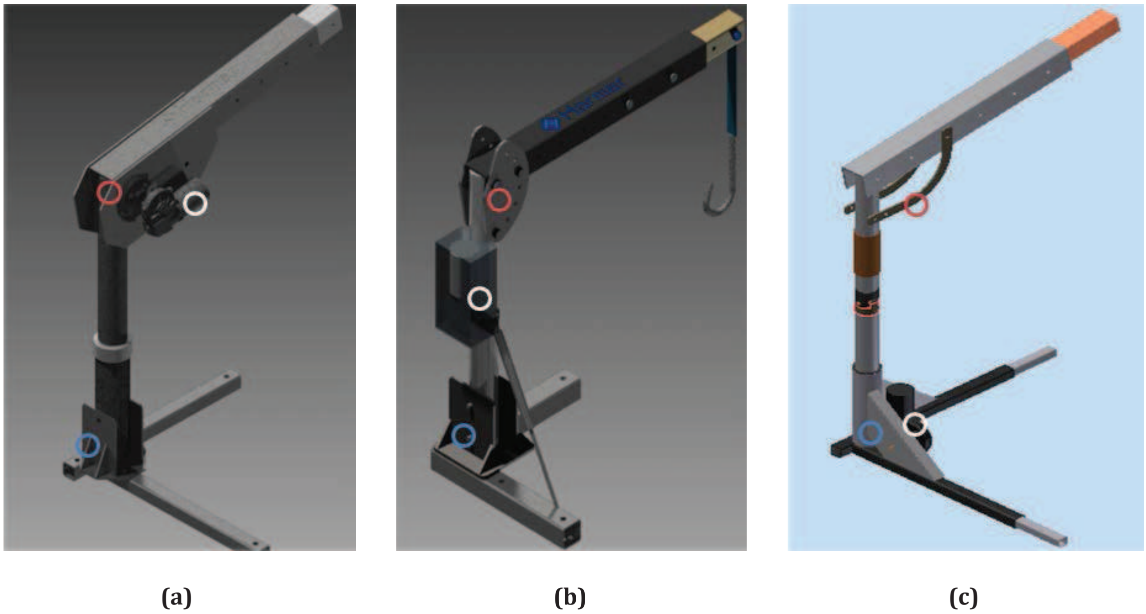
Figure 11 – Hoisting Pulley-Roller System

SPRING FINAL DESIGN

At the beginning of the Spring 2013 semester, a comprehensive CAD package was completed to begin the manufacturing process. However, over the winter vacations, Harmar had implemented a European branch of the company in the Netherlands. Due to the installation of this newly created facility, the team was introduced to representatives via electronic correspondence. Richard Koopmans, managing director for Harmar Europe, reviewed the documentation for the final propped design and suggested certain changes to better the design. In particular, Mr. Koopmans felt the final proposed design was a bit too bulky and emphasized a sleeker design. Additionally, added versatility was recommended for placement into automobiles with trunk spaces of different shapes and sizes. It was at this same time that the project sponsor, Mike Savinsky, recommended the use of a stock base already on hand.

DESIGN ITERATIONS

Several designs were then submitted to Harmar for approval. With each design submission, more gradual changes to certain components were realized. Figure 12a-c shows three such concepts that illustrate this point.



(a) (b) (c)

Figure 12 – Design Iterations

Shown on each concept in Figure 12 are three colored reference points—red, white and blue. These points are used to draw attention to three different components. The red circle corresponds to the changes in the angle brackets. As the designs progress, a change to a sleeker bracket—that is to say, one with less material—is seen. The white circle shows changes to the placement of the motor. While initially mounted at the base in the fall final design, the use of a spool and strap to ultimately lift a wheelchair required a certain amount of space and clearances not found in the base. Therefore, Figure 12a shows the motor mounted to the arm of the unit. However, as these designs progress, the placement of the motor finds its way mounted high to low once again. Lastly, the blue circle shows the implementation of the stock base assembly into the design.

FINAL DESIGN

A final design was eventually submitted and approved by Harmar. This design is shown below in Figure 13. After the continued design iterations, it is this team's view that this design incorporates the most, if not all, design features requested by Harmar.

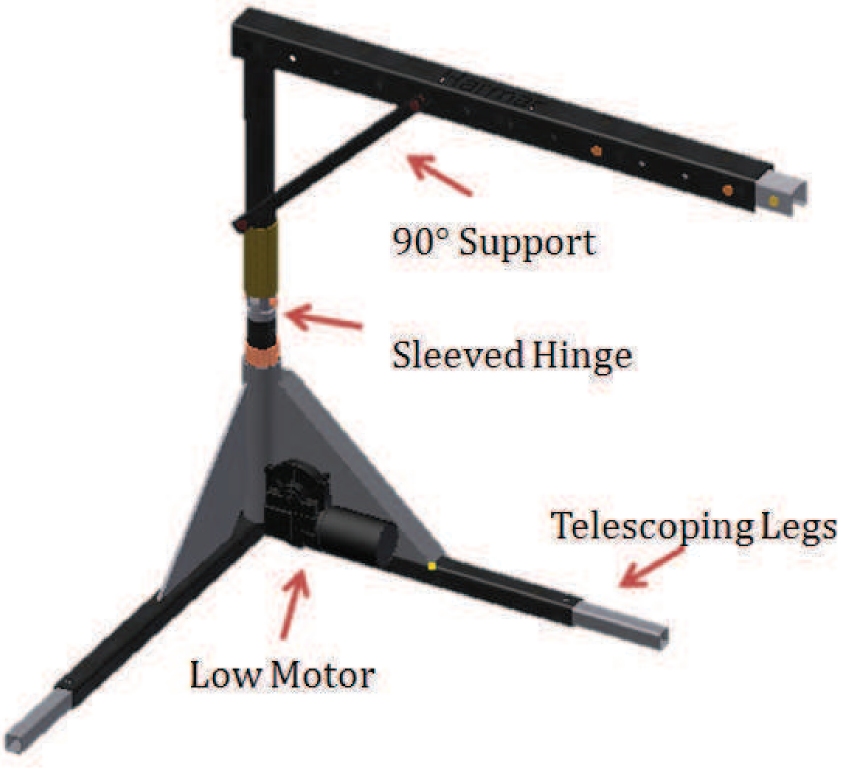


Figure 13 – Spring Final Design: Assembly

Figure 13 shows several significant features inherent with this new design concept. Aside from the motor being mounted at its lowest possible position, this design is shown with the integration of the stock base currently being used by Harmar for various other projects. Also, through testing, the chain-drive system was eliminated for the spool to be connected directly to the motor shaft. The base is paired with a set of telescoping legs that extend out and provide added flexability for installing the unit in trunks or hatches of differing configurations. Addtionally, the angled bracket has been done away with and replaced by a rigid support on only one side of the unit. Lastly, a sleeved hinge has been implimented to allow for a standard fold-down option—shown in Figure 14.

Figure 14 – Spring Final Design: Fold-Down Configuration

Design Features

As mentioned previously, a recommendation was requested to use a stock base currently on hand at the Harmar facilities. Much time was spent on the development of the actual lifting system. Traditionally, Harmar uses their trademark blue strap in their lifting mechanism. However, because of the placement of the motor, little room was available to implement this strap. Instead, a Kevlar wrapped cable was decided upon for lifting. This cable provided a lifting capability of 900 lbs [15]. The spool-cable system is attached directly to the motor shaft and is housed internally between the gusset plate support brackets on the base. This feature is shown below in Figure 15.

Figure 15 – Stock Base (from AL055)

Also, and probably the most significant design feature, is the addition of a sleeved hinge to allow for a fold-down option. When not in use, the sleeve is weighted down by its own accord. If the user wishes for the unit to remain in its upright position for an extended period of time, two set screw may be used to keep a secure and locked sleeve. However, when the user wishes to fold the upper half of the unit down, the raising of this sleeve will expose the hinge and allow for the folding. From Figure 16, it is also shown that the cable will run the entirety of the hinge system through a series of drilled holes.

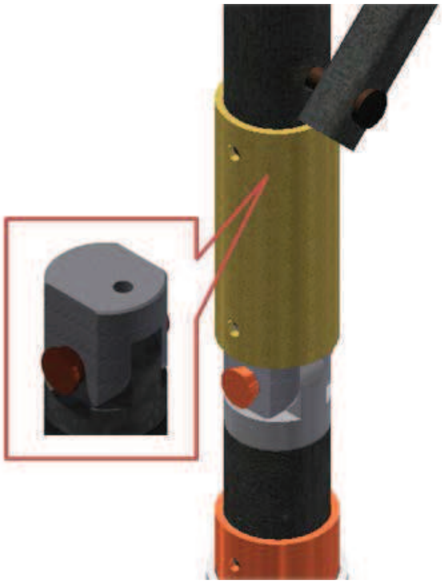


Figure 16 – Sleeved Hinge

COMPONENTS

Motor and Electrical System

In order to standardize the manufacturing process and minimize the research and development cost for this project, Harmar Mobility is provided a DC motor that connects directly to the standard 12 volt car batteries found worldwide. Conveniently, this motor already comes coupled with a gearbox. An example of this motor can be seen below in Figure 17. (Please refer to Appendix B1 for more technical specifications provided by Harmar Mobility, Inc.).

Figure 17 – Driver Motor

As seen from Table 3, the selected motor is available with three gear ratio options. The motor that was ultimately supplied for this design contained a gear ratio of 1:37.5. Further analysis was conducted to ensure that the supplied motor was in proper working condition and will be explained in more detail in the subsequent sections.

Table 3 – Motor Parameters

Motor Model – KSV 4030

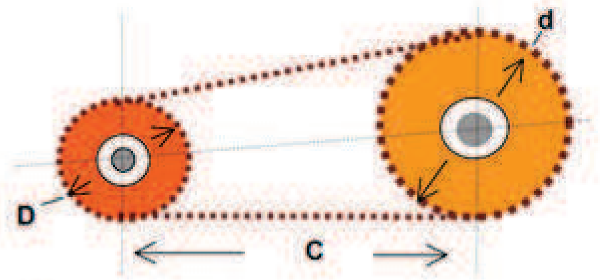
Gear Box	Aluminum
Speed (RPM)	15 – 260
Torque (N·m) [Max]	5
Starting Torque (N·m) [Max]	45
Gear Ratio	1:37.5

Similar to the motor selection, Harmar Mobility is also providing the control system and all the necessary wiring harnesses. Previously, no decision had been made as to whether or not a wired or wireless control was to be used. After communication Harmar, both involved parties felt a wireless control was beyond the scope of this design. In order to maintain an economical advantage over any possible competitors, a wired control was chosen. An example of the supplied motor can be seen in Figure 18. Keeping simplicity in mind, this motor only offers two options: up or down.

Figure 18 – Motor Controller

Chain-Drive System

Although the prototype achieve our initial goals, but the manufacture have sent the wrong motor with less torque, so we will need to increase the torque by using the chain drive and sprocket system. We calculated that the motor sprocket and spool sprocket size and number of teeth. The center distance is calculating using equation below; please refer to figure for additional information.



$$C = \frac{1}{8}\left[(2L - d - D) + \sqrt{(2L - d - D)^2 - \frac{8}{9.86}(D - d)^2}\right]$$

Figure 19 – Chain-Drive System Schematic

From the result we found that we the sprocket ratio is 4:1 to allow additional torque needed to lift up to 280 pounds. This table below shows results of critical component dimensions needed to implement a sprocket - chain drive system into the existing prototype motor mount. The most significant value found in Table 4 is that of the center distance, C. From this value, a minimum clearance of roughly 4.2 in. is needed to implement such a system. Therefore, after much deliberation and input from the team sponsor, an alternate drive system was deemed necessary.

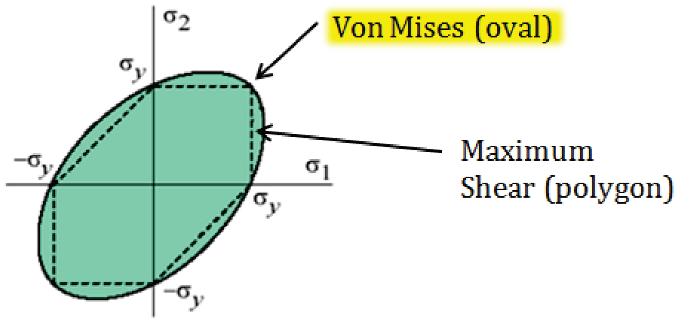
Table 4 – Chain-Drive Critical Dimensions

Chain Pitch	0.375 in
Links in Chain (L)	50
Drive Sprocket Teeth (d)	8
Driven Sprocket Teeth (D)	42
Center Distance (C)	4.197 in
Reduction Ratio	5.25
Motor Torque	35.4 in·lb

FEM ANALYSIS

After a proper design was selected, the structure was imported into a computer software program to begin finite element analysis. Because if its ease of use and relatively fast computing time, this analysis was limited only to COMSOL Multiphysics®. This software program is available for use at all computer stations throughout the FAMU-FSU College of Engineering.

In performing the FEM analysis, the design was subjected to the maximum static load set forth by Harmar, roughly 390 lbs. This value corresponded to a safety factor of roughly 3x the expected operating conditions. Additionally, stress analysis was tested against the Von Mises yield criterion. A visual explanation of this theory can be seen in Figure 20, below. Simply put, this theory states that yielding occurs when a stress value is encountered that equals or exceeds the von Mises boundary.



$$\frac{1}{2}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2] \leq \sigma_y^2$$

Figure 20 – von Mises Yield Theory

General Assembly

A general assembly was constructed in COMSOL with the hope of finding any potential stress concentrations that would lead to yielding or failure. A mesh of the assembly is given in Figure 21. This mesh consisted of 28,204 number of elements. A fair compromise between the memory and processing limitations of the hardware was met, while providing sufficient resolution for the analysis.

Figure 21 – Assembly Mesh

The output from the processed analysis is given in Figure 22. Again, it is important to reiterate that this analysis was conducted for a maximum static load of 390 lbs, or a factor of safety of 3. However, after continued study, computer simulation found that this safety factor was not possible. After some analysis, the computer model found that a maximum load capable for this design to be roughly 250 lb, or a safety factor of roughly 2. These findings were presented to Harmar and proved to be adequate for the prototype and the team was given permission to continue with the analysis. As future work, further investigation and alterations will be required to meet the initial safety factor of 3.

From Figure 22, two significant stress concentrations are seen. These include a stress of 502.73 MPa—the highest stress experienced—occurring at the connection of the base with the boom. Additionally, as Figure 22 shows, some deflection is to be expected to the subjection of this load. Through COMSOL, a maximum deflection of 0.52 in. was found to occur to this corresponding 250 lb static load.

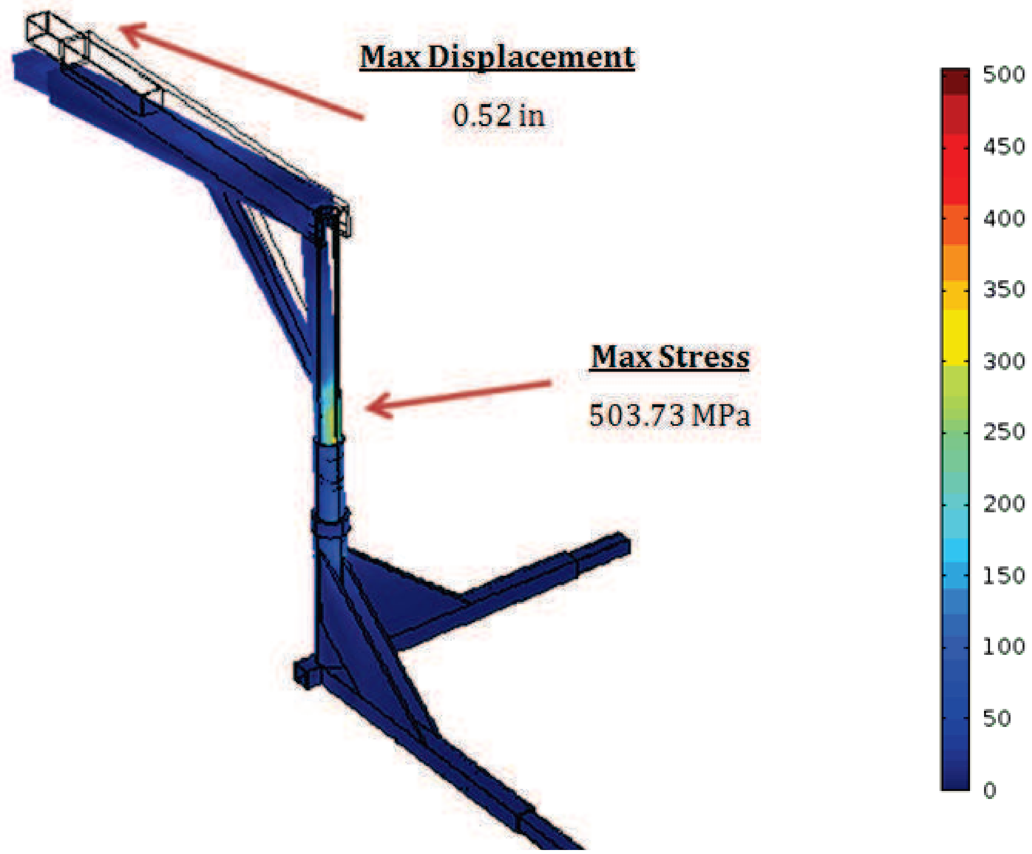


Figure 22 – COMSOL FEM Output

Material Selection Revisited

After finalizing the design process as well as the FEM analysis, examination then had to be made to determine if the proposed concept was viable in terms of strength and robustness of design. To make this analysis, the material selection had to be re-evaluated to account for these newly found stresses. After discussion with our sponsor, the catalog from which Harmar orders all their raw materials was obtained [16]. Form this catalog, and recalling a maximum incurred stress of 502.73 MPa in the post tubing, a specific steel composition was determined that accounted for this stress. This steel was then found to be an ASTM A513 Type 5 subjected to a drawn-over-mandrel manufacturing process. From this steel, five different compositions with respect to carbon content were available. However, the 1026 composition was said to exhibit a yield stress of 517.1 MPa. Table 5 shows these compositions with their corresponding yield stress.

Table 5 – Available Steel Compositions

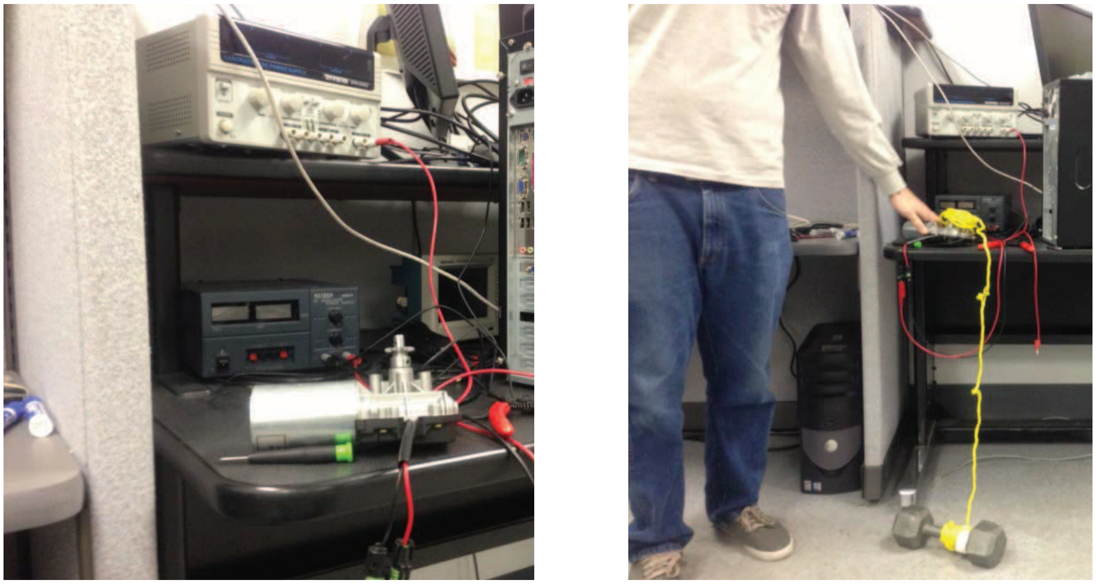
Carbon Content	Yield Stress
1010	**413.7 MPa**
1015	**448.2 MPa**
1018	**482.6 MPa**
1020	**448.2 MPa**
1026	**517.1 MPa**

PROTOTYPING AND TESTING

After all analysis had been complete, work was focused on developing and completing a full CAD package. The CAD package was developed entirely on Autodesk Inventor and submitted to Harmar to being the manufacturing process. As seen on the Spring 2013 Gantt chart, nearly two months were allotted for the building and testing of the prototype unit. However, with the development of the new design form the Fall Final Design to the Spring Final Design, half of this time was already used. However, with assurance from our sponsor and the material fully selected, ordering of the raw materials was begun.

Motor Testing

From the Spring Semester trip to the Harmar facility in Sarasota, Fl, the team was supplied with a few test components to continue with analysis. After being supplied with a mock motor, initial analysis was conducted to ensure a fully functioning unit. As seen in Figure 23a, the mock motor was connected to a power supply and corroborated against its performance map (Appendix B-2). Additional characteristics were also investigated further to ensure a proper design. For example, the RPM of the motor with a substantial load was sought out to determine the lifting time required by the user. Because the lift is intended for the elderly as well as handicapped, the safest and minimal amount of time would be ideal—especially in cases where the weather would impact the user's time to wait. Lastly, an attempt was made for analyzing if the lack of a chain-drive system would be sufficient for design purposes. After some investigation, and while not absolute, the analysis seemed promising (Figure 23b).



(a) **(b)**

Figure 23 – Testing of Motor

Prototype Assembly and Testing

While simultaneously testing various components on hand, small design revisions to the CAD package were being implemented almost daily to Harmar's machine shop. These minor revisions included changing of tolerances, addition of left out dimensions, and the fixing of title blocks on drawings. With the machining process being completed, a time and place for assembly was discussed. It was ultimately decided upon that the assembly process would enrich the learning process and would therefore be completed by the team. The project sponsor, Mike Savinsky, traveled from Sarasota to Tallahassee, FL to deliver the final machined parts. The assembly process was the carried out in the Senior Design Lab and Solid Mechanics Lab of the FAMU-FSU College of Engineering (Figure 24).

Figure 24 – Initial Assembly

While assembling the prototype unit, certain errors were detected. For example, in one such case, a hole for a set screw in the motor-spool housing was not drilled out. Additionally, it was found that certain threading did not match up well with their corresponding screw or bolt. This was particularly true for the set screws used for the sleeve component on the post. With the help of the college machine shops, these problems were corrected and the assembly continued. A view of the final assembly is shown in Figure 25 with a lifting hook and battery pack attached for testing.

Figure 25 – Final Assembly

Once the final assembly was completed, the lift was subjected to various loads. From Figure 26a, the unit can be seen lifting a bucket of approximately 40 lbs to a height of 3 ft. Also, in Figure 26b, the unit is being prepared to lift a traditional manual wheelchair of roughly 60 lbs to the same height. Both tested proved successful, with a total time of lift of less than 15 sec. Video recording of these preliminary tests can be found on the Team 19 design webpage as well.

(a) (b)

Figure 26 – Testing of Various Loads

MANUFACTURING

While most other Senior Design projects were competition based or research oriented, this particular design project proved to be more manufacturing oriented. Because our sponsor was an actual company with the intent of commercializing a product to make a profit, the manufacturing aspect of the project was significant. Therefore, a detailed and comprehensive CAD package was developed to aid in the manufacturing and machining of our design. Through the use of Autodesk Inventor, welding analysis and other manufacturing based analysis were determined.

PROCEDURE

When completed, the final design consisted of a total of 33 parts. A complete Bill of Materials can be found in Appendix C-1. This included main components as well as nuts, bolts, and screws. Moving pieces should be ran through their full range of motion ensure that tolerances and clearances are adequate to continue the assembly process.

(a) **(b)**

Figure 27 – Exploded View Rendering

SUBSYSTEMS

When assembling, the design can be broken up into three distinct subassemblies: the base, post, and arm. Each subsystem can be built independent of the other to further expedite the manufacturing process. In fact, it is recommended to do so as a means of test fitting each component before being sent to powder coating.

Arm

The arm subassembly consists of 8 distinct components. An exploded view if this subassembly can be seen in Figure 28 below. Additionally, the parts list for this subassembly is provided below in Table 6. The use of washers or spacers is recommended when connecting parts 9 and 25. The pulley used at the end of the arm assembly must not be over tightened or will be restricted from rotating freely.

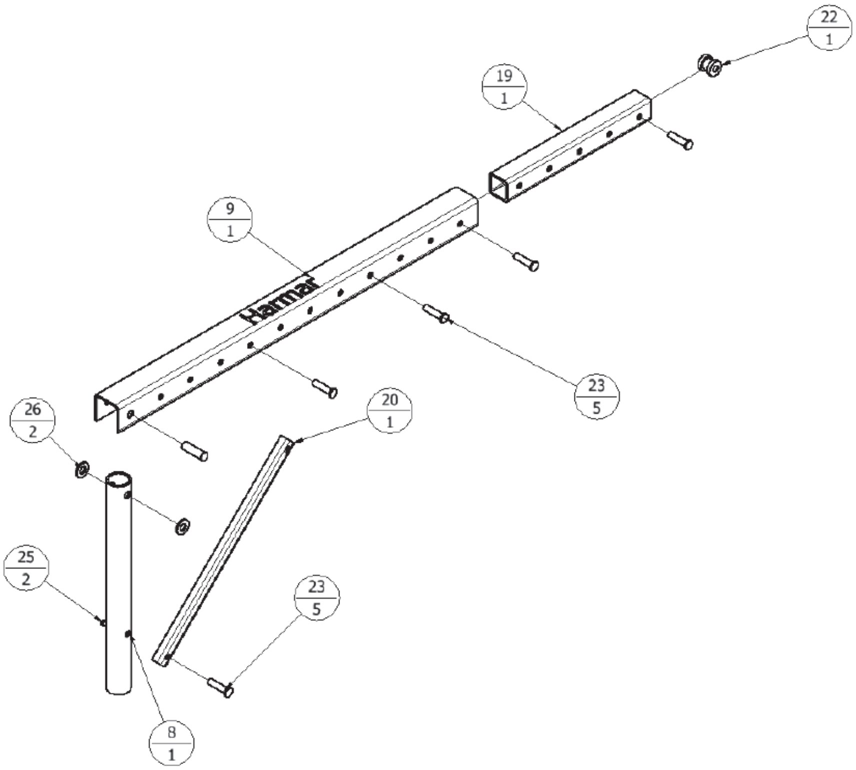


Figure 28 – Arm Subassembly

Table 6 – Arm Subassembly Parts List

Item	QTY	Item No	Description
8	1	EU-AL060-108	Tube Inner Upper
9	1	EU-AL060-109	Arm
19	1	EU-AL060-110	Arm Inner
20	1	EU-AL060-112	Braces
22	1	EU-AL060-119	Roller
23	5	Bolt 0.375	Arm Bolts
25	2	M-6 Screw	M-6 Screw
26	2	Washer	Steel Spacer/Washer

Post

The post subassembly consists of 9 distinct components. An exploded view if this subassembly can be seen in Figure 29 below. Additionally, the parts list for this subassembly is provided below in Table 7.

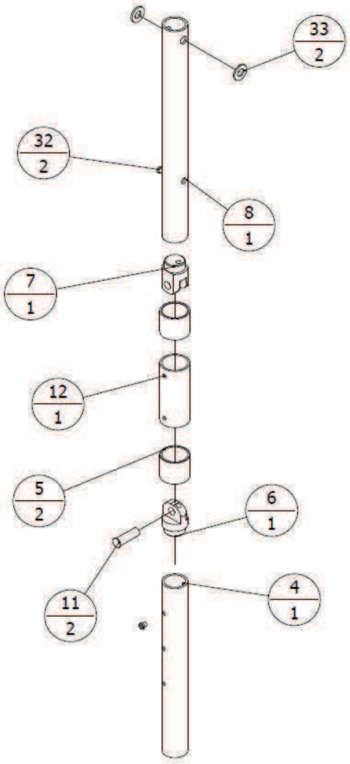


Figure 29 – Post Subassembly

Table 7 – Post Subassembly Parts List

ITEM	QTY	ITEM NO	DESCRIPTION
4	1	EU-AL060-107	TUBE INNER LOWER
5	2	MSI-2428-24	SLEEVE BEARING
6	1	EU-AL060-116	HINGE MALE
7	1	EU-AL060-117	HINGE FEMALE
8	1	EU-AL060-108	TUBE INNER UPPER
11	2	BOLT 0.50D	POST BOLTS
12	1	EU-AL060-111	SLEEVE UPPER
32	2	M-6 SCREW	M-6 SCREW
33	2	WASHER	STEEL SPACER/WASHER

Folding Mechanism

As seen in Figure 30 below, the Kevlar cable is ran through the hinge via a series of drilled holes. The hinge is designed in such a way that the cable circumvents the press-fit pin. When placed in the fold-down position, the user is encouraged to check the cable periodically to ensure no fraying or failure has occurred.


(a) **(b)**

Figure 30 – Folding Mechanism

Base

The base subassembly consists of 11 distinct components. An exploded view if this subassembly can be seen in Figure 30 below. Additionally, the parts list for this subassembly is provided below in Table 8.

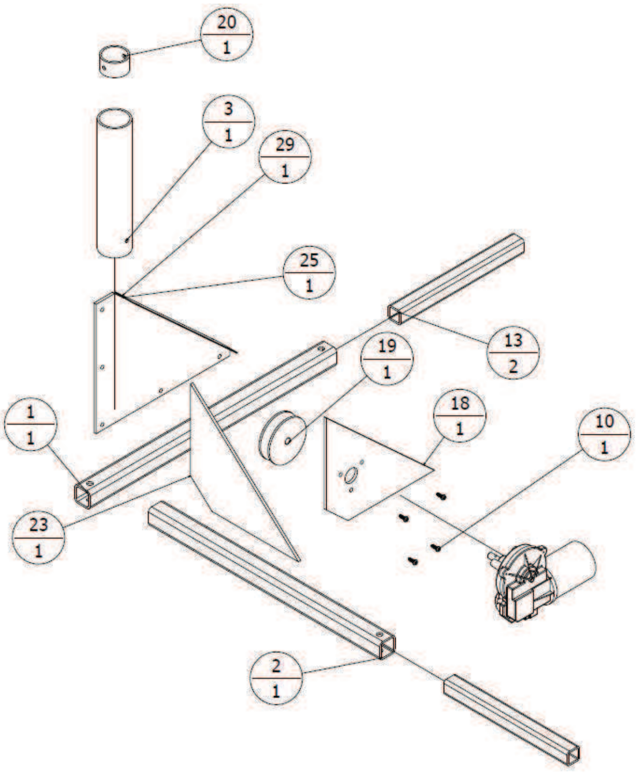


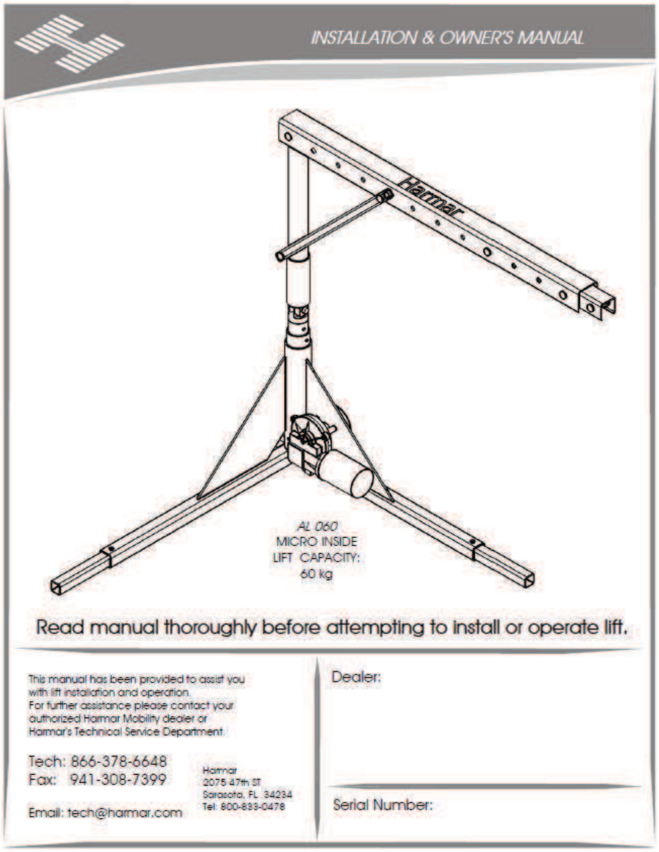
Figure 31 – Base Subassembly

Table 8 – Base Subassembly Parts List

ITEM	QTY	ITEM NO	DESCRIPTION
1	1	EU-AL060-101	BASE LEG LONG
2	1	EU-AL060-102	BASE LEG SHORT
3	1	EU-AL060-103	TUBE LOWER OUTER
10	1	700-ZB01-AA	MOTOR
13	2	EU-AL060-114	LEG EXTENDER
18	1	EU-AL060-105	HOUSING PLATE INSIDE
19	1	EU-AL060-118	SPOOL
20	1	EU-AL060-113	SLEEVE SUPPORT
23	1	EU-AL060-104	HOUSING PLATE
25	1	EU-AL060-106	HOUSING PLATE OUTSIDE
29	1	EU-AL060-115	HOUSING TOP COVER

OPERATION MANUAL

In addition to a complete CAD package, an in-depth operation manual was completed to assist users after the purchasing of their lift. This manual begins with the proper preparation that must be taken in the vehicle such as test fitting, vehicle wiring, etc. Next, the installation process and daily operation of the lift is described. The operation includes the methods for loading and unloading of the user's wheelchair along with the manner in which to adjust the lift to predetermined setting in the arm, post, and base. Additionally, safety protocols and maintenance routines are also described. Lastly, a section pertaining to the technical information associated with the lift is given. In this section a simple troubleshooting guide is given along with diagrams of each subassembly. The cover page for the aforementioned operation manual is shown in Figure 32 below. The actual operation manual can be found on the Team 19 design webpage as well.



INSTALLATION & OWNER'S MANUAL

AL 060
MICRO INSIDE
LIFT CAPACITY:
60 kg

Read manual thoroughly before attempting to install or operate lift.

This manual has been provided to assist you with lift installation and operation.
For further assistance please contact your authorized Harmar Mobility dealer or Harmar's Technical Service Department.

Tech: 866-378-6648
Fax: 941-308-7399

Email: tech@harmar.com

Harmar
2075 47th ST
Sarasota, FL 34234
Tel: 800-833-0478

Dealer:

Serial Number:

Figure 32 – Operation Manual (Cover Page)

ENVIRONMENTAL AND SAFETY ASPECTS

Since this will be a product marketed towards consumers, the final mobility lift that is developed must be tested for safety and reliability. Since safety is the number one factor, our design must include a safety which can cut off power to the device. Our design musts also pass a factor of safety of 3, which is set by Harmar, and corresponds to a static load test of 390 pounds. Additionally, the unit must perform 10,000 cycles with a load rate of 130 pounds.

Since the motor and control system is being supplied by Harmar Mobility, the safety power shut off being used is the one currently being utilized on all the lifts currently offered by Harmar mobility. Upon speaking with our sponsor, he informed us that they have not yet had any safety issues with the current motor and controls.

As for testing the testing the loading of the unit, prior to building, computer based Finite Element Analysis will be done on the entire assembly. When it passes the Finite Element Analysis, and has been build, the plan it to test it much like Harmar Mobility's manufacturing plant does. The first will be to lift the static test load of 390 pounds. Once that has been completed, we will connect the controls to a computer which will run a program, supplied by Harmar Mobility, that will make the mobility lift operate every three minutes. This will be done a total of 10,000 times to ensure it will not fail due to fatigue.

The environmental impact of our design is no more than any other mobility lift device. It is comprised mainly of steel parts, which is a large contributor of CO2 emissions into our atmosphere, mostly due to the coal being used to heat the blast furnaces (Iron and Steel Emissions). Initially the design was to be comprised of aluminum, however our budget did not allow for such high priced materials. One other environmental concern would be the use of the automobile battery as the power source for the lift. This may cause the battery to drain quicker, causing the need to replace the battery sooner. This would have been a problem about 15 years ago, before the disposal of lead-acid batteries was prohibited, however lead battery recycling has reached approximately 97% in the United States (Lead-Acid Battery Recycling).

COST ANALYSIS

Table 9 below provides a detailed cost estimation based on McMaster Carr supplier for components. The materials, motor, and miscellaneous components such as nuts and bolts are based on current market prices and shipping costs. From the table, we see that the motor is the most expensive item next to the overall cost of materials. For the machining cost, an online cost estimation calculator was used based on the machinability of our design. Currently, labor cost is assumed to be zero for this estimation. This is because, the team feels, the designing and building of the initial prototype is expected to be significant and would otherwise skew the overall cost estimation.

The total for the design and prototype for this product is approximate at about $425.00. This fits well into our $500.00 assigned budget. In addition Harmar Mobility provided any materials and necessary hardware to build a working prototype for this mobility lift that cannot be found or made by ourselves. As a comparison, a similar product was found to sell for roughly $720.00 [17].

Table 9 – Detailed Cost Estimation

Square and Round Tubing	$83.42
Sleeve Bearings	$8.95
Hardware	$25.60
Heavy Duty Nylon Pulley	$8.90
Motor and Housing	$146.95
Steel Plates	$35.37
Nuts and Bolts	$30.00
Machining Cost	$85.50
Labor	$00.00
TOTAL PROTOTYPE COST	**$424.69**

CHALLENGES AND DIFFICULTIES

As with any project there will be challenges to overcome and eventually learn from. In our case, the challenges we had to overcome as a team in the fall semester included learning new software, becoming familiar with our sponsors manufacturing process, and trying to please the client with our design concepts. Initially we had decided to use ProEngineer to draw the concepts and attempt to allow that program to run structural analysis. This proved difficult and we had to seek an alternative program, COMSOL Multiphysics, which none of us had ever used before. Although the program was similar to others we had used, it still required extra time to learn the ins and outs of the program. Then the fall semester came to an end, we had a 'final design' and were on track to complete our prototype and test the prototype.

In the spring semester our challenges grew exceptionally from the previous semester. The placement of the motor caused an issue with the strap used to hoist the wheelchair. When the arm rotated the strap would twist and created a weak-point in the material of the strap. This caused a minor redesign, which was taken care of within a week or two. At this point everything seemed to be going smoothly. The CAD drawings were being created, materials were being researched, and components were being acquired. We even visited the facility and spoke with the sponsor, Mike Savinsky, about the design changes and he was on-board with our new 'final design'.

In the second week of February our sponsor sent the team an email, with tidings from the European managing director, Richard Koopmans, and how he didn't like the design, said it was too bulky, and wanted a redesign. The team was completely caught off-guard by this new development and additional person making decisions on our project. But none the less, we got together and came up with a few more design iterations in order to please the sponsor. At this point, we had nearly finished drawing all the parts for previous 'final design', and came up with a completely new design and had to start from scratch with the CAD drawings. The sponsor also requested that we might make use of some of the existing parts that were kept in stock in the warehouse, in order to keep manufacturing simple. The most paramount was the use of a base from another lift, specifically the lift that our design project might take the place of because of similarities, yet enhancements like the folding. We did implement the base into our design, but made some modifications. In the end, the base worked out well because it forced us to reduce the diameter of the upright, and made the assembly look slimmer. As for the time we lost, that was never made up, and little testing was done on the final assembly.

Once all the CAD drawings were complete, and minor touch-ups and dimensioning were all that was left to be done, one of the team member's computer's hard drive perished, along with most of our CAD drawings. Thankfully CMS recovered about 80% of the drawings, but the remainder had to be redone and time was beginning to run short, it was already late March, and our Gantt chart said we were supposed to be assembling and testing the prototype.

The new design took a bit of time to get approval on, due to the multiple parties involved as well as their locations across the globe. The sponsors manufacturing facility is located in Sarasota, Florida, which is about 275 miles from Tallahassee. The machining and welding of most of our parts was done at they're facility, as well as the powder coating of the parts. Initially we had felt relieved that the client wanted to make all the parts for us, but when it came down to building the assembly we found that the tolerances were all off, the mating surfaces had been powder coated, there was missing and ill sized hardware, and the improper motor had been mounted. Then to top it all off, the sponsor forgot to send us a critical part, the outer extension arm. The extension arm was overnighted, and assembly of the lift system was completed a few days before final presentations. To get some of the parts to fit, we had to have the powder coat machined off in some areas.

FUTURE RECOMMENDATIONS

First, the modification of the cable anchor system would be recommended we would recommend. Currently we a single M3 coupled with a flat aluminum piece with a slot to hold the cable in place is being used. In order to secure the cable in place more tightly, another piece is needed to sandwich the cable in between the two plates. The M3 screw is to be replaced by one of M5, as it is larger and is able to provide more clamping force.

With respect to the folding mechanism, the internal holes in the folding hinge need to be enlarged from 0.25 to 0.50 in. A change from a chamfer edge to round edge is also recommended. This way, friction between the cable and that of the contacting surface will be minimized when in operation. This enlargement of the hole and rounded edge will also reduce the rubbing between the two which may added increased cable life.

An edited set of drawings for powder coating and painting should also be created. With these drawings, the specific amount of powder coat on particular surfaces can be indicated.

Currently, a stock cable roller from Harmar is being used. This roller, while made to fit in the prototype, was designed for the traditional Harmar strap. Therefore, a custom roller will need to be design for this particular application. The new roller design must have a smaller track width which will allow the cable to run through and safely keep it in place.

Lastly and most importantly, although the prototype achieved the initial goals, during the manufacturing process the wrong motor—with less torque—was permanently mounted to the base. Therefore, an increase in torque will be needed for the current prototype and will be created by using the chain drive and sprocket system. Calculations were made for the motor sprocket and spool sprocket size and number of teeth in Table 4. From the results, a sprocket ratio of 4:1 is required to allow for the additional torque needed to lift up to 280 pounds.

CONCLUSION

Although there are some improvements that could and should be made to the final design project, the overall experience was exactly what it was tailored to be. This project was designed to help students develop team work skills, apply the knowledge gained from all engineering courses and gain real world experience. Complications and communication issues happen every day in industry. Each member of the team now has firsthand experience dealing with these conflicts them, learning from personal mistakes and also learning from mistakes made by others. Being on a consumer-driven project gave the team an advantage over some of the competition based projects, with regards to gaining this practical experience and knowledge. Overall, the prototype functioned as planned. The sponsor was great to work for, while the design project was also interesting and challenging to work on—an overall enriching experience.

ACKNOWLEDGMENTS

Our genuine and sincere thanks go out to Mr. Mike Savinsky and the Harmar Mobility team. The guidance, patience, and assistance afforded to us (Team 19) allowed for a great amount of learning and education. While stressful at times, the thought of possibly disappointing our sponsor kept the team moving in a positive direction. Hopefully, the work presented to Harmar is of the same quality exemplified by the company itself.

Additionally, we would like to thank the FAMU-FSU College of Engineering for providing us with the opportunity to integrate our knowledge learned these past years with the creation of a design project for start to finish.

In particular, we would like to thank our professors: Dr. Kamal Amin, Dr. Chiang Shih, and Dr. Carl A. Moore; without which, this project would not be where it is today. Gratitude must be given to our TA's, Peter Rivera and Richard Carter, for providing helpful feedback. Last, but not least, a thank you is extended to Dr. Peter N. Kalu for allowing us space for completing our project in his laboratory, as well as Jeremy Phillips and Dana Edmunds of the machine shop for providing quick and helpful assistance.

MEMBER BIOGRAPHY

LAUREN HULETT

Lauren Hulett is a senior studying mechanical engineering with specific focus on thermal fluid sciences. She is a member of the student section of American Society of Mechanical Engineers, as well as the secretary for the student section of American Institute of Aeronautics and Astronautics. After graduating in spring 2013, she plans to pursue a Masters degree in thermal fluid sciences at either Texas A&M or Southern Methodist University. From there she would like to work in the aeronautics field for either military or civilian applications. In her free time she enjoys cooking, specifically baking, as well as hosting tailgates on home football weekends

PHONG TRAN

Phong Tran is a senior in mechanical engineering at the Florida State University. He was born in Vietnam and grew up in the beautiful Emerald Coast. Before going back to college, he spent several years in the defense and aerospace sectors. He worked as a machinist, jet turbine assembler, engineer supporter, and CAD designer & drafter. Phong earned an A.S. degree in mechanical design & drafting, as well as an Autodesk AutoCAD foundation certificate. In 2010, he decided to go back to college and pursue his dream of becoming mechanical engineer. His short term goal is to graduate and get a job in a defense or aerospace industry. In his free time, he enjoys working on cars, playing soccer, and watching Seminole football.

RICHARD VALLE

Richard Valle is currently a senior studying mechanical engineering at Florida State University. In his final year as an undergrad, he has focused on classes in dynamic systems and is set to receive a certificate of specialization in that area on his University transcript. For his extracurricular activities, he is a member of both Tau Beta Pi (the Engineering Honor Society) and Pi Tau Sigma (the Mechanical Engineering Honor Society). Additionally, he has been a Laboratory and Teaching Assistant for Mechanics and Materials II, currently being taught by Dr. Peter N. Kalu, since the fall of 2011. After receiving his Bachelor's degree in the spring of 2013, he will pursue his Master's under the BS-MS program here at the FAMU-FSU College of Engineering in Tallahassee, FL

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14. Wheelchair CAD Drawing

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15. McMaster-Carr: Kevlar Strap

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16. Alro Metals Guide Catalog

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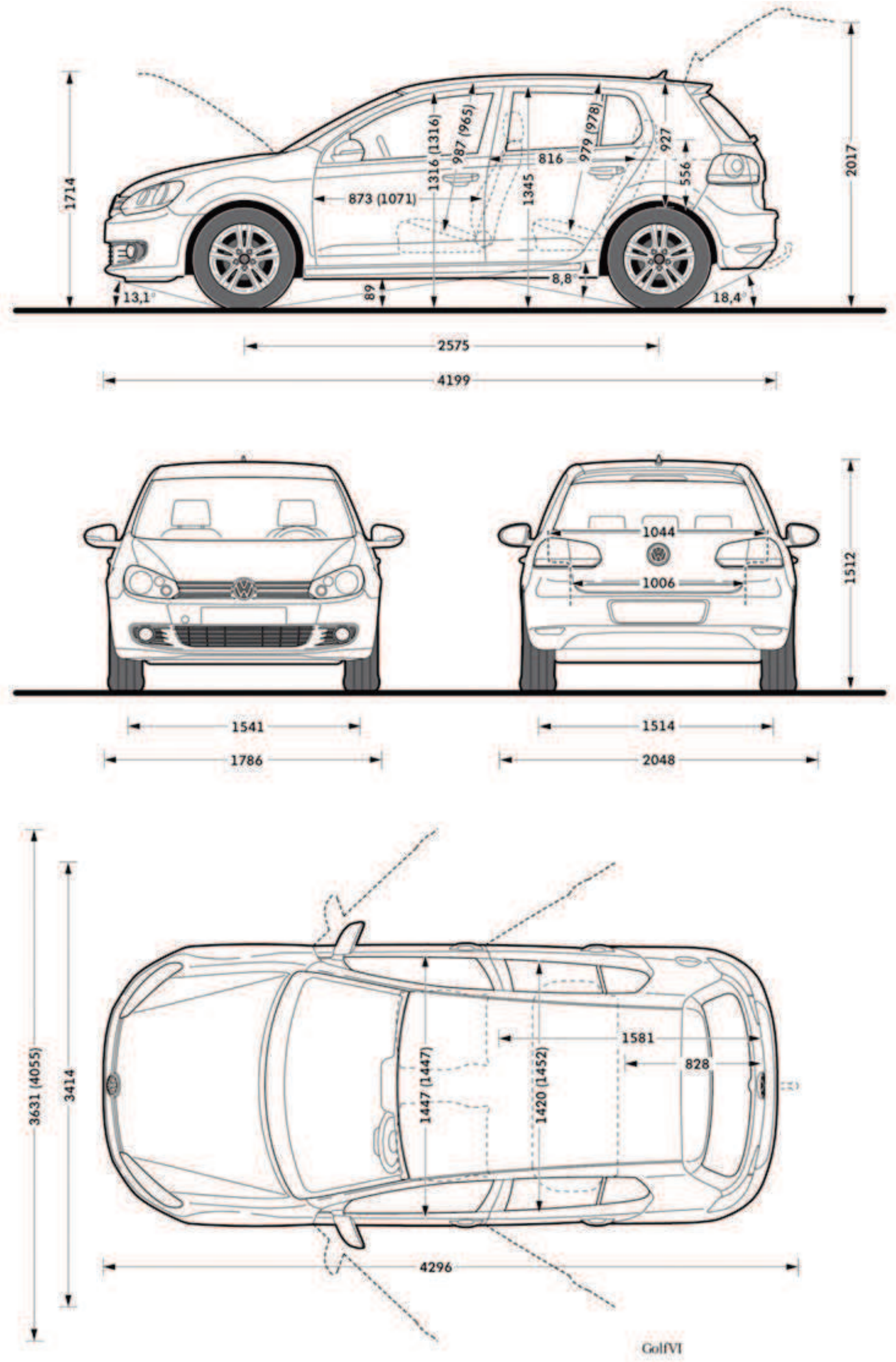
17. Retail Inside Lift Comparison

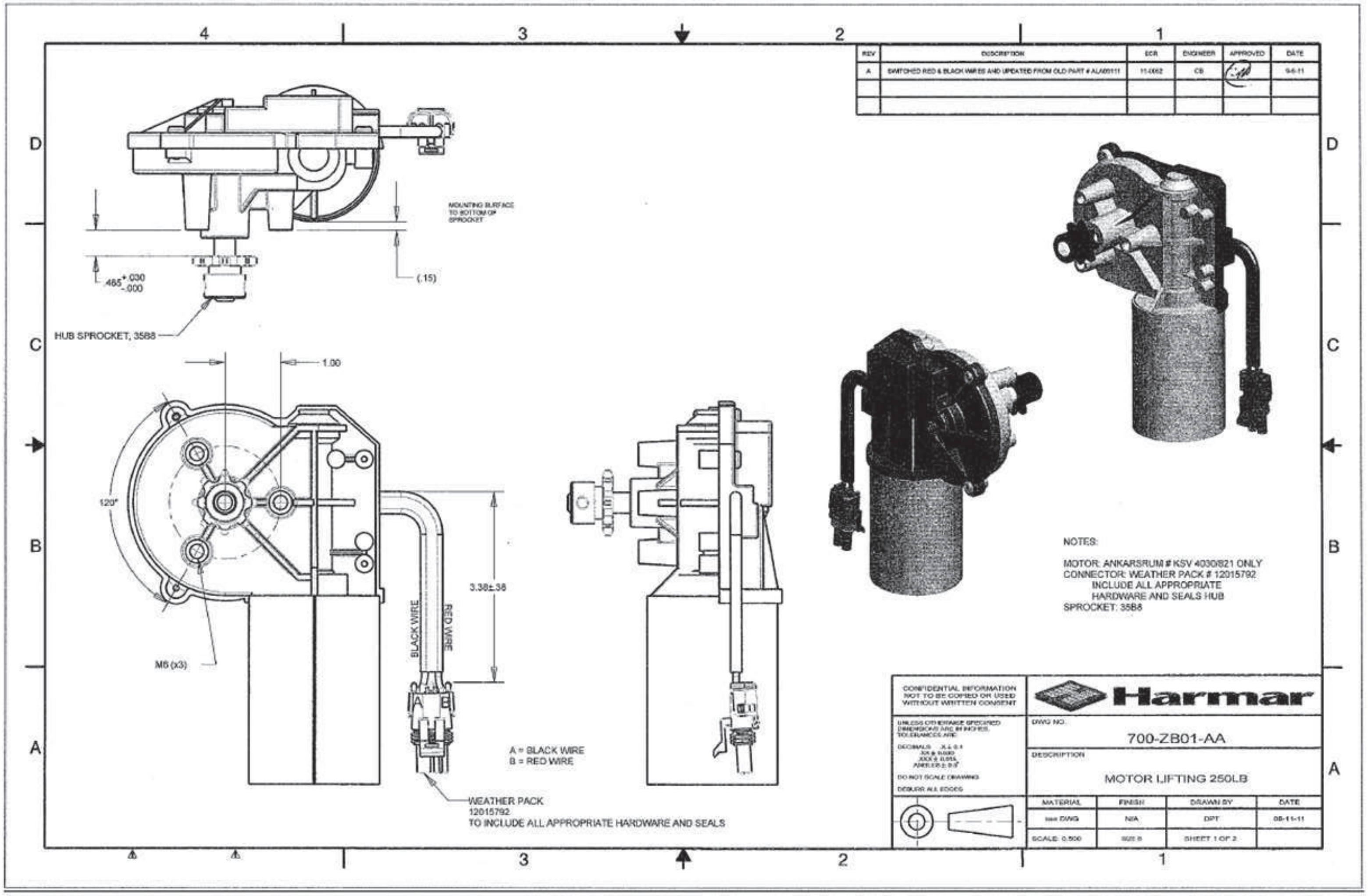
    http://www.gomobilityscooters.com

APPENDIX

A1 - Volkswagen Golf VI Dimensions



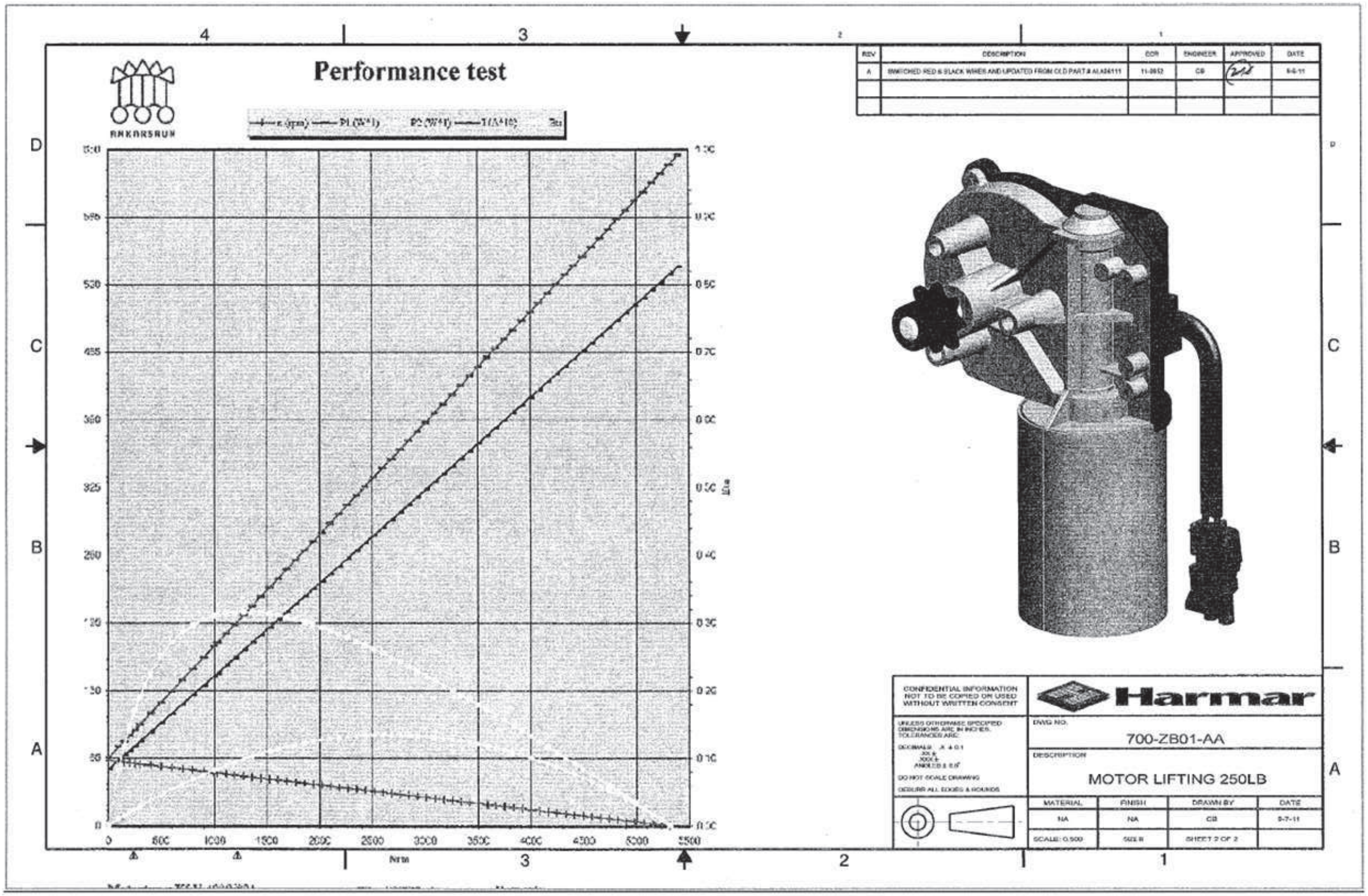
B1 - Motor Specifications



REV	DESCRIPTION	ECR	ENGINEER	APPROVED	DATE
A	SWITCHED RED & BLACK WIRES AND UPDATED FROM OLD PART # ALA00111	11-0062	CB		9-6-11

NOTES:

MOTOR: ANKARSRUM # KSV 4030/821 ONLY
CONNECTOR: WEATHER PACK # 12015792
INCLUDE ALL APPROPRIATE
HARDWARE AND SEALS HUB
SPROCKET: 3588



REV	DESCRIPTION	ECR	ENGINEER	APPROVED	DATE
A	SWITCHED RED & BLACK WIRES AND UPDATED FROM OLD PART # AL406111	11-0652	CB		9-6-11

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UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ARE:

DECIMALS .X ± 0.1
.XX ±
.XXX ±
ANGLES ± 0.5°

DO NOT SCALE DRAWING

DEBURR ALL EDGES & ROUNDS

Harmar

DWG NO.
700-ZB01-AA

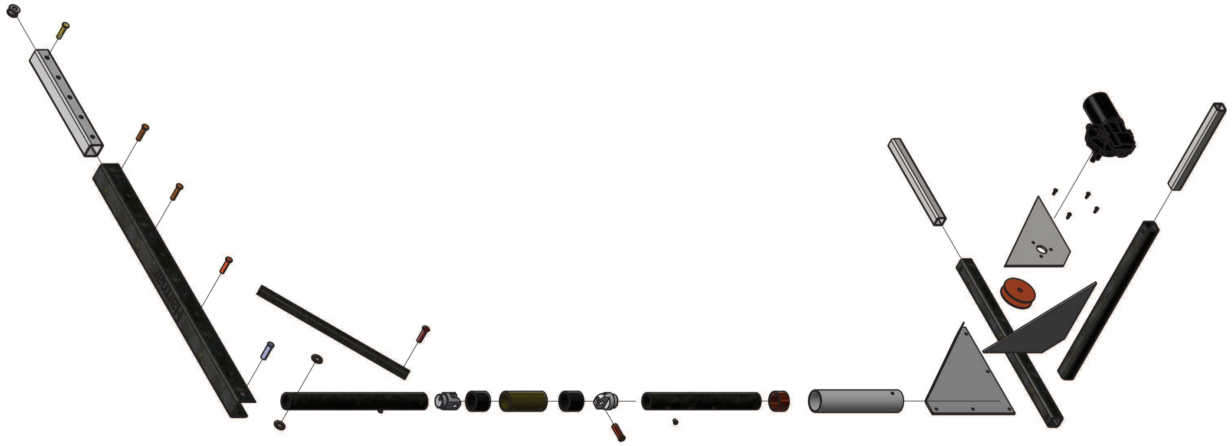
DESCRIPTION
MOTOR LIFTING 250LB

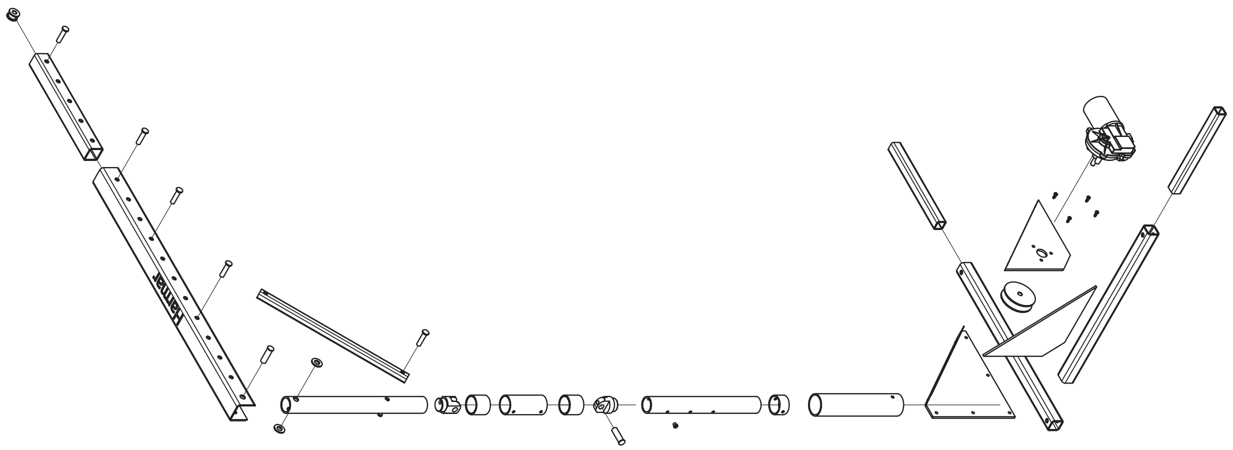
MATERIAL	FINISH	DRAWN BY	DATE
NA	NA	CB	9-7-11
SCALE: 0.500	SIZE B	SHEET 2 OF 2	

C1 – Bill of Materials

QTY	ITEM NO	DESCRIPTION
1	EU-AL060-101	BASE LEG LONG
1	EU-AL060-102	BASE LEG SHORT
1	EU-AL060-103	TUBE LOWER OUTER
1	EU-AL060-104	HOUSING PLATE
1	EU-AL060-105	HOUSING PLATE INSIDE
1	EU-AL060-106	HOUSING PLATE OUTSIDE
1	EU-AL060-107	TUBE INNER LOWER
1	EU-AL060-108	TUBE INNER UPPER
1	EU-AL060-109	ARM
1	EU-AL060-110	ARM INNER
1	EU-AL060-111	SLEEVE UPPER
1	EU-AL060-112	BRACES
1	EU-AL060-113	SLEEVE SUPPORT
2	EU-AL060-114	LEG EXTENDER
1	EU-AL060-115	HOUSING TOP COVER
1	EU-AL060-116	HINGE MALE
1	EU-AL060-117	HINGE FEMALE
1	EU-AL060-118	SPOOL
1	EU-AL060-119	ROLLER
5	BOLT 0.375	ARM BOLTS
2	M-6 SCREW	M-6 SCREW
2	WASHER	STEEL SPACER/WASHER
2	MSI-2428-24	SLEEVE BEARING
2	BOLT 0.50D	POST BOLTS
1	700-ZB01-AA	MOTOR


Hamar




Hamar

REV	DESCRIPTION	ECR	ENGINEER	APPROVED	DATE

CONFIDENTIAL INFORMATION
NOT TO BE COPIED OR USED
WITHOUT WRITTEN CONSENT

Harmar MOBILITY

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE

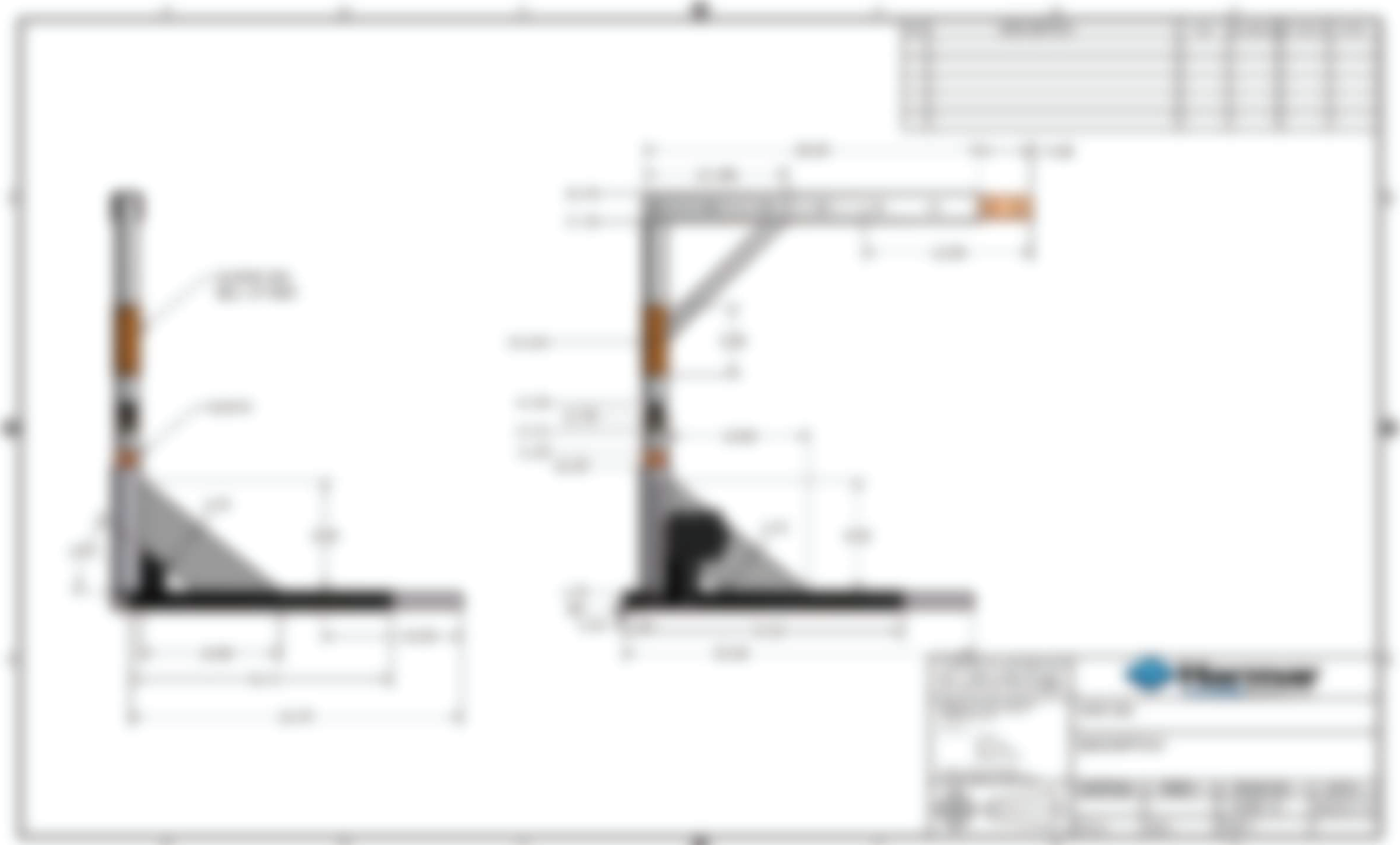
DECIMALS
X ± 0.1
XX ± 0.02
XXX ± 0.010
ANGLES ± 0.5°

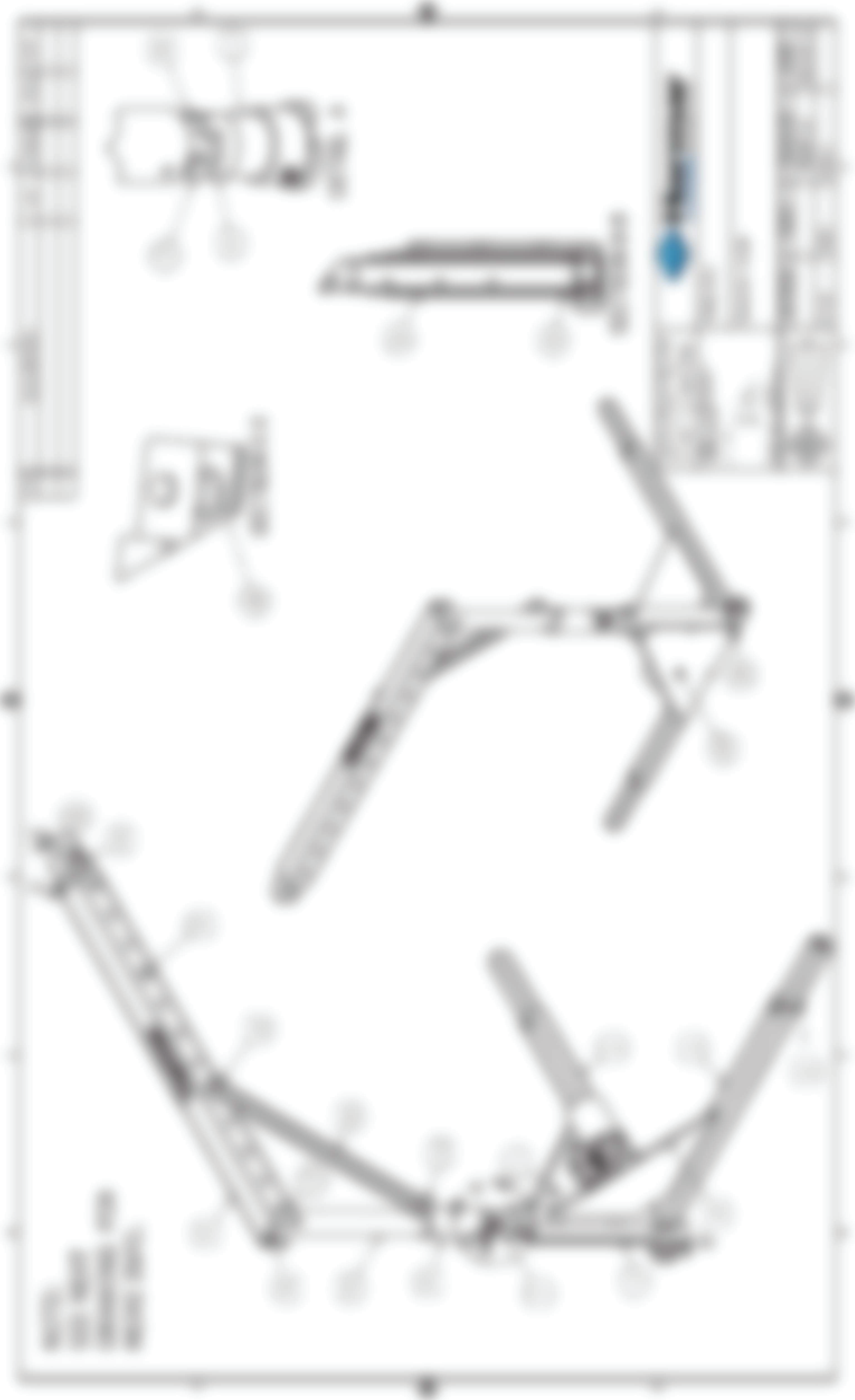
DO NOT SCALE DRAWING
DEBURR ALL EDGES & ROUNDS

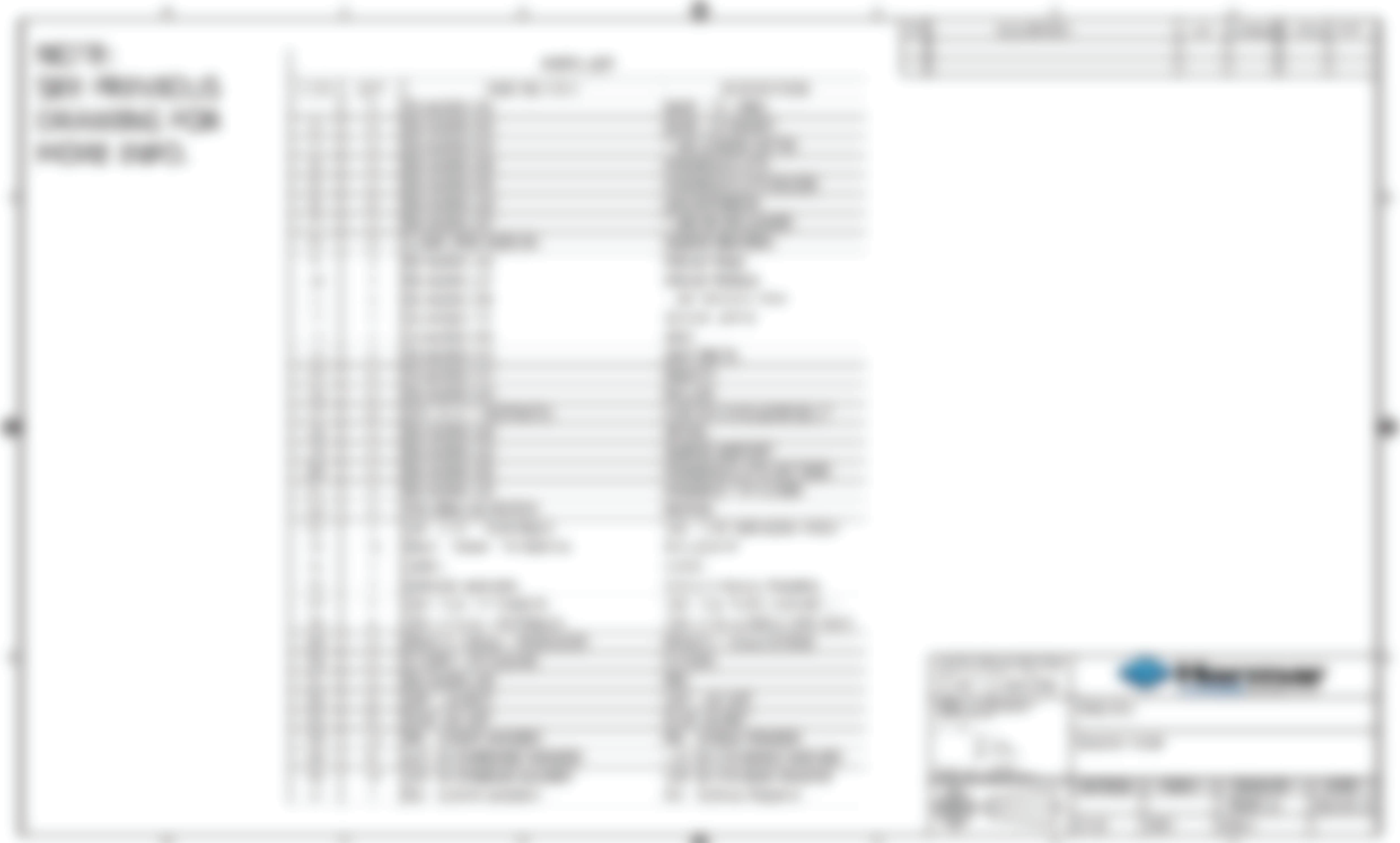
DWG NO.

DESCRIPTION

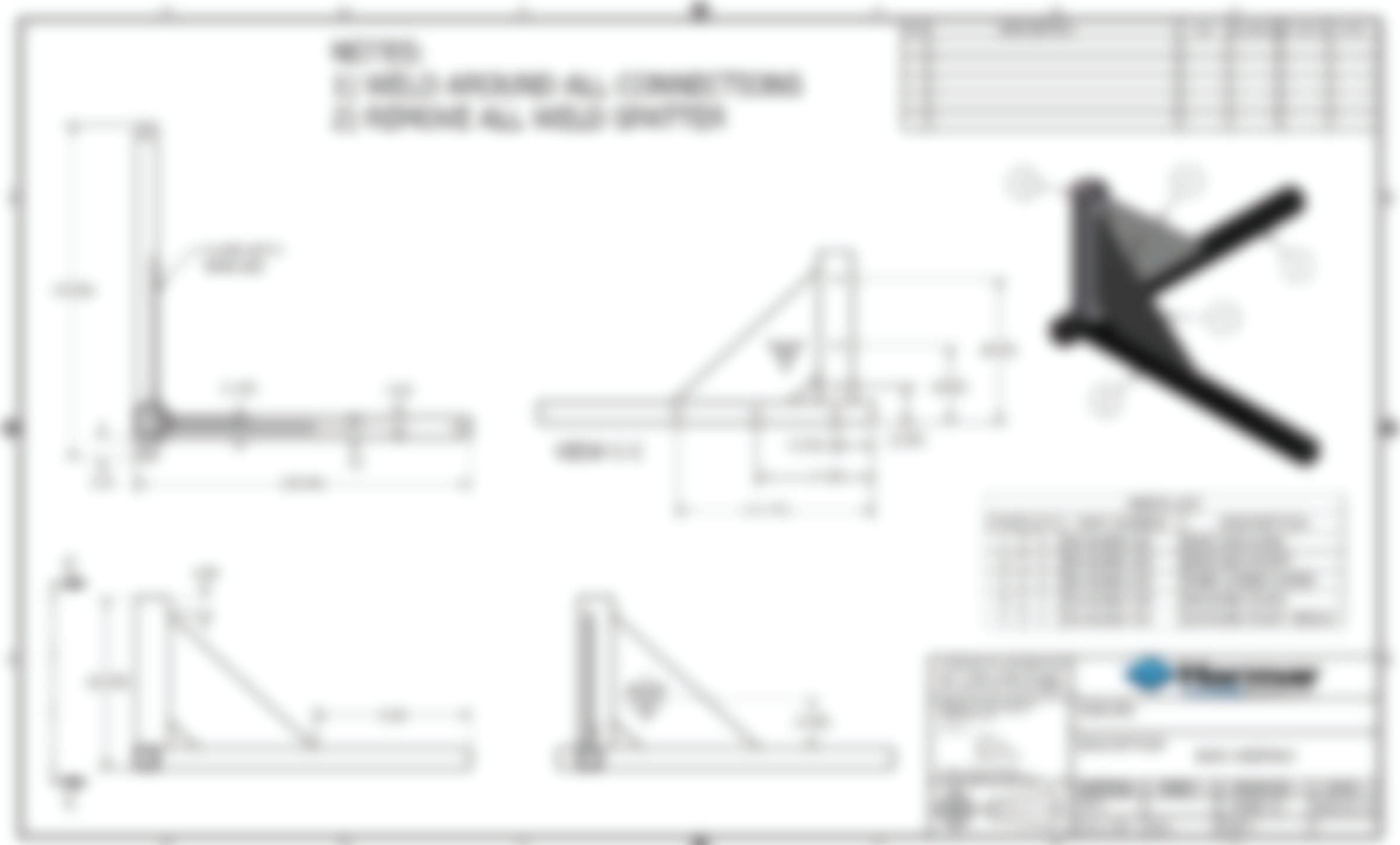
MATERIAL	FINISH	DRAWN BY	DATE
		TEAM 19	03/07/13
SCALE	SIZE	SHEET	



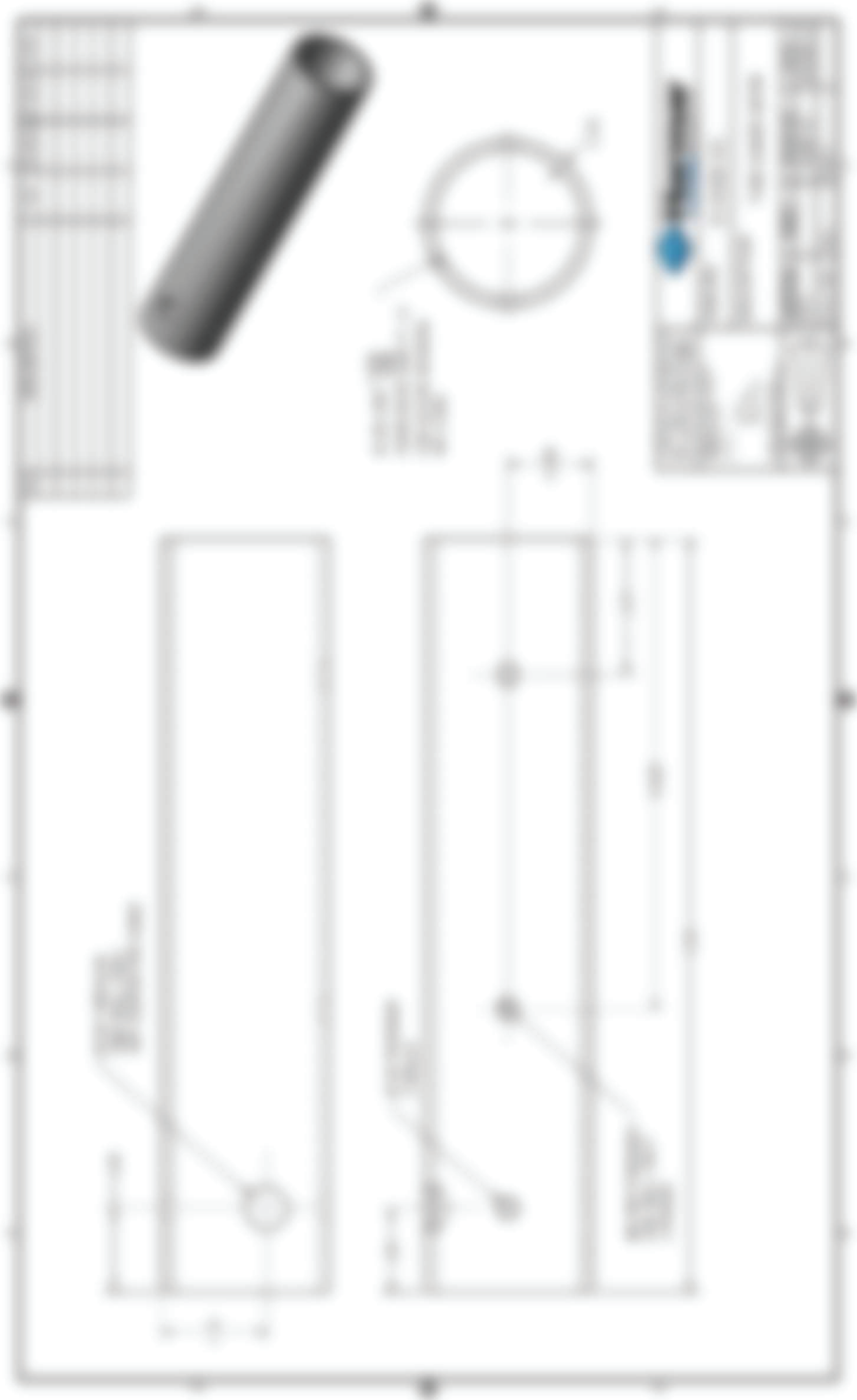


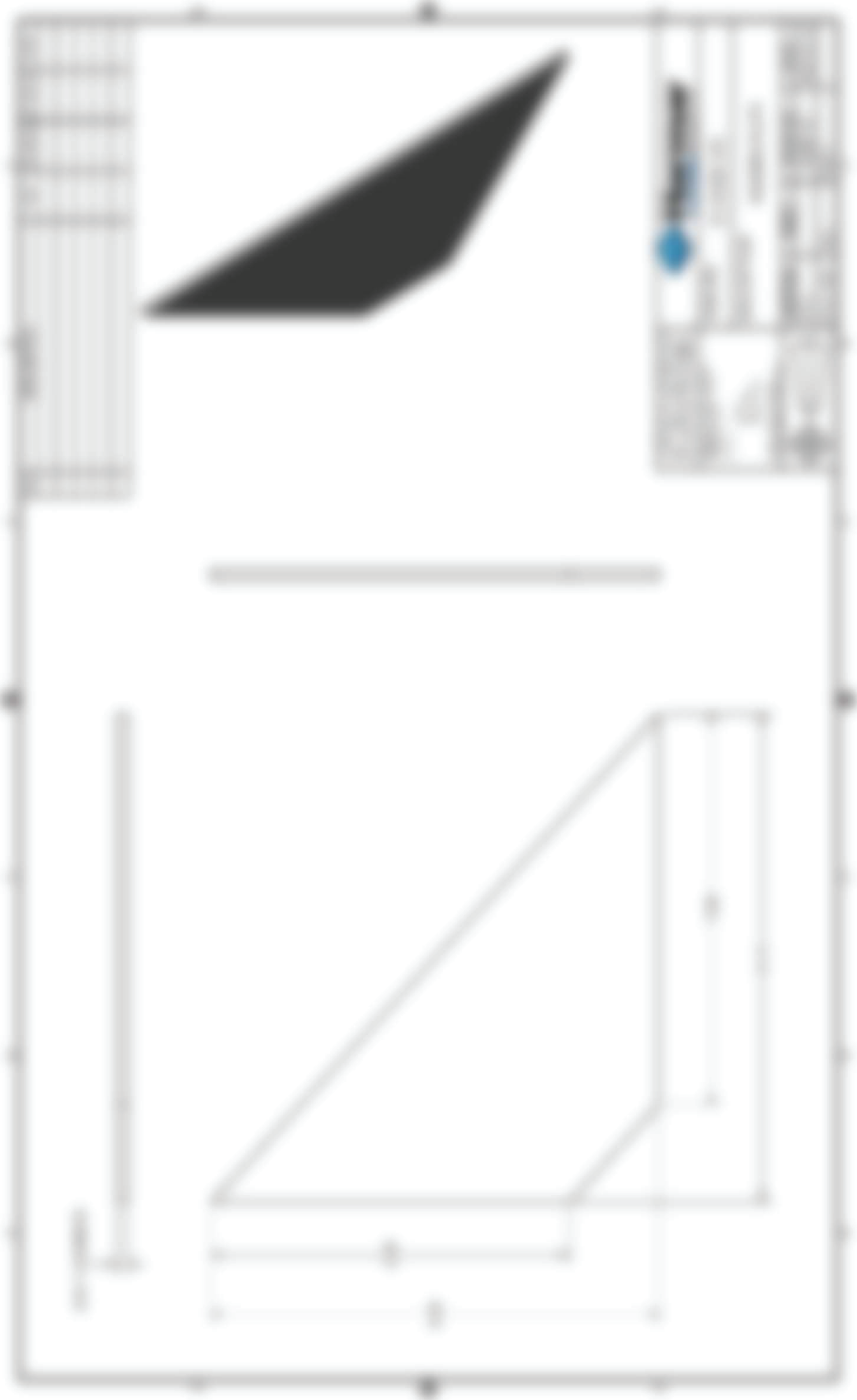


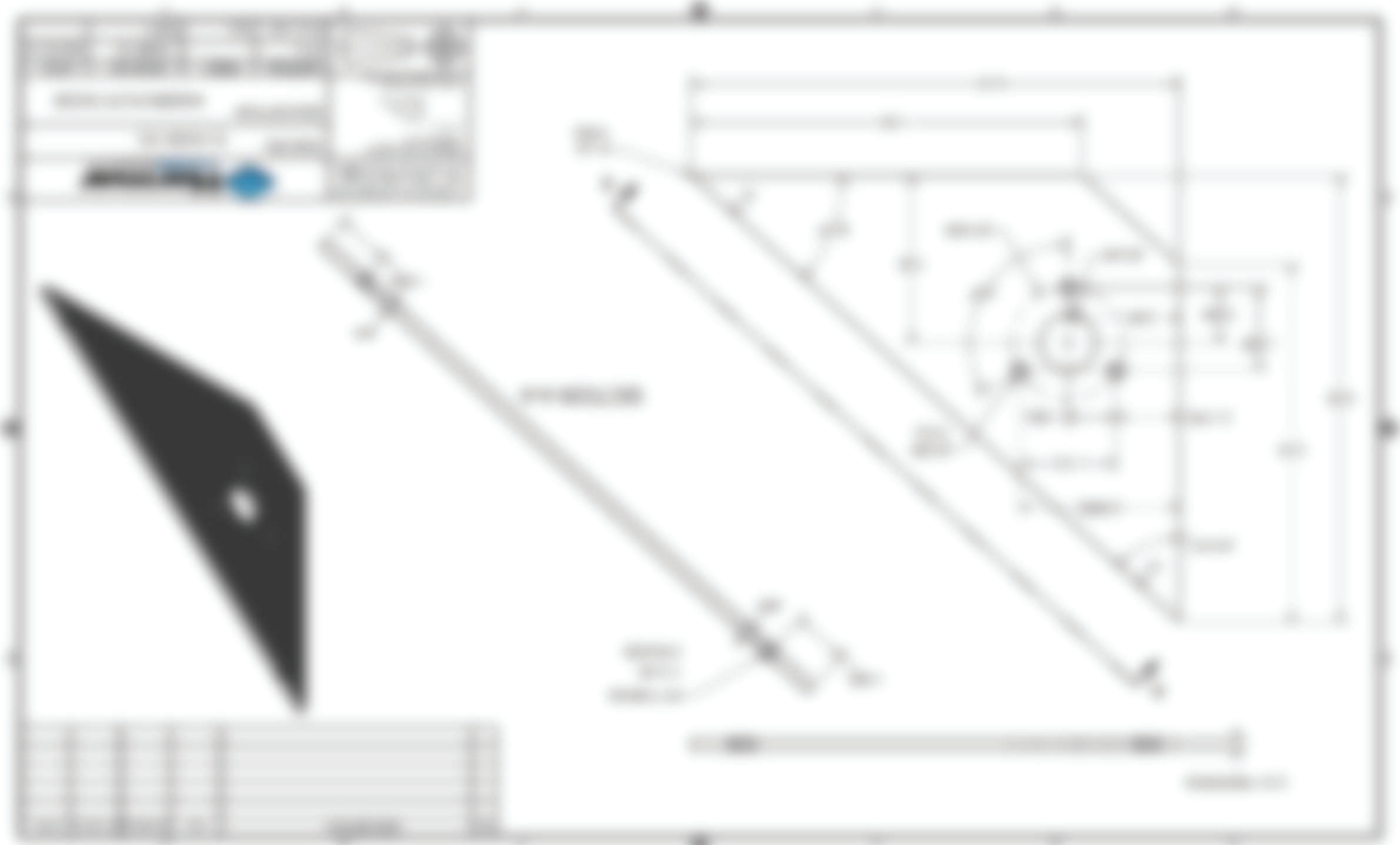
[illegible]

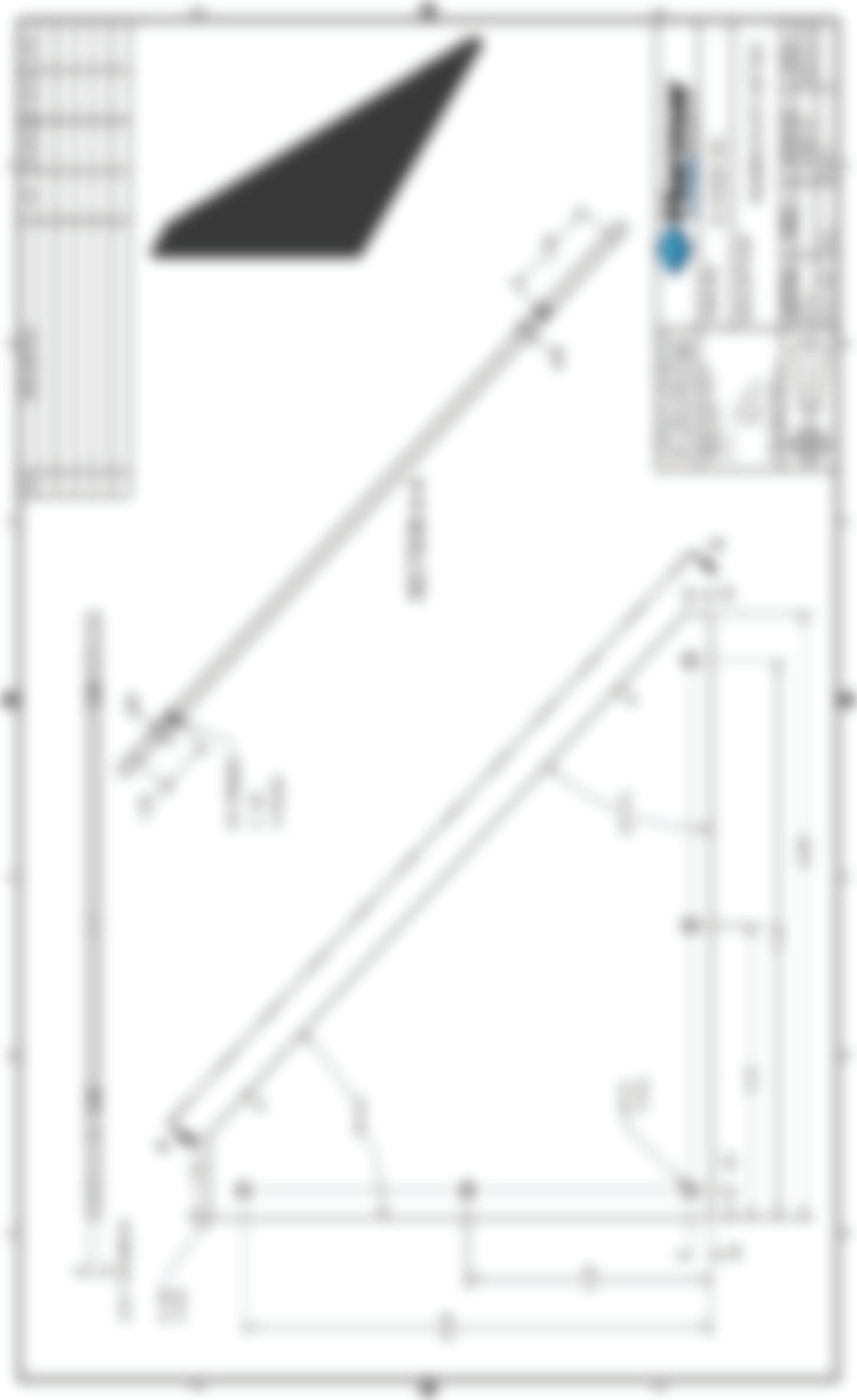


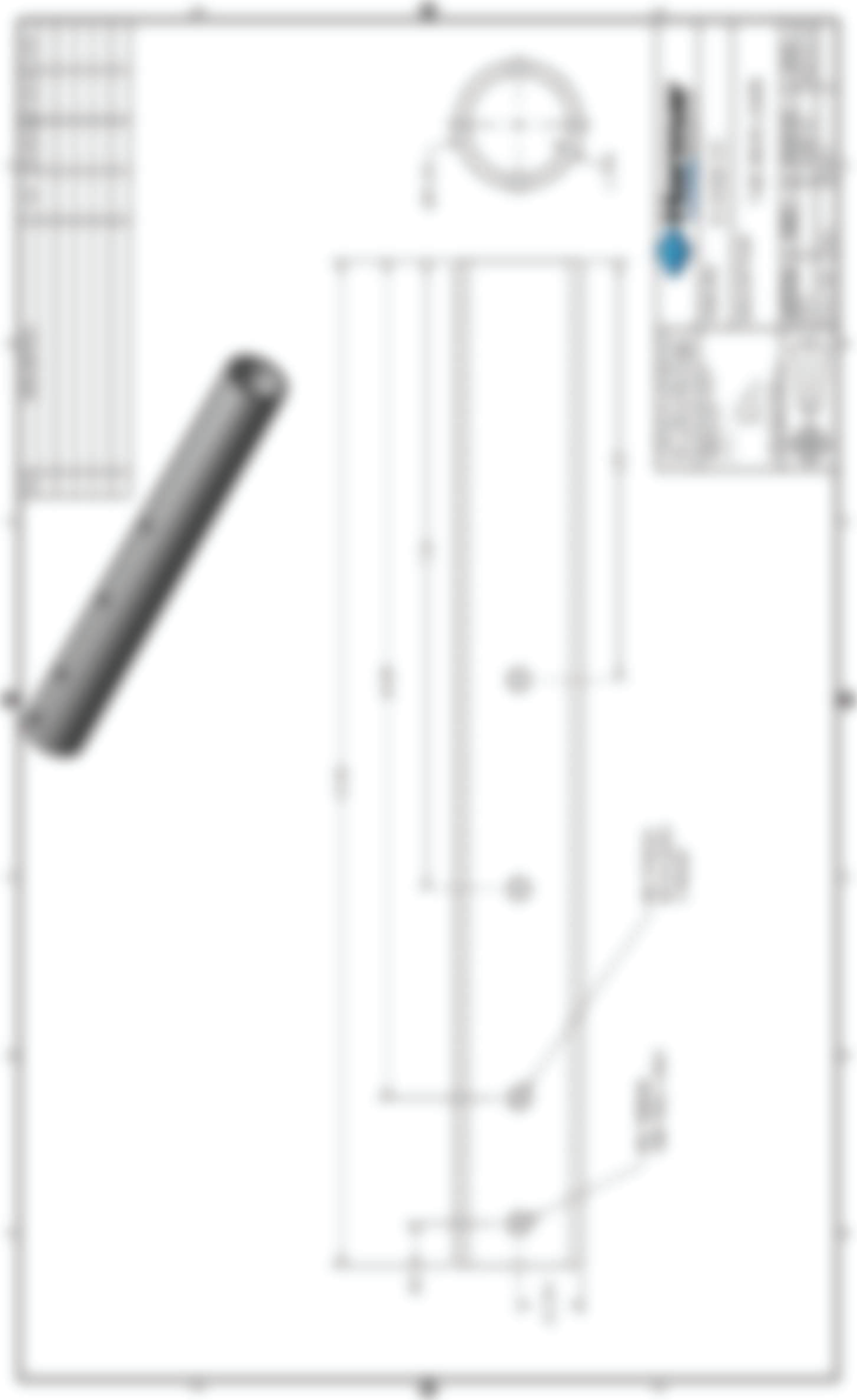
NOTES:
1) WELD AROUND ALL CONNECTIONS
2) REMOVE ALL WELD SPATTER

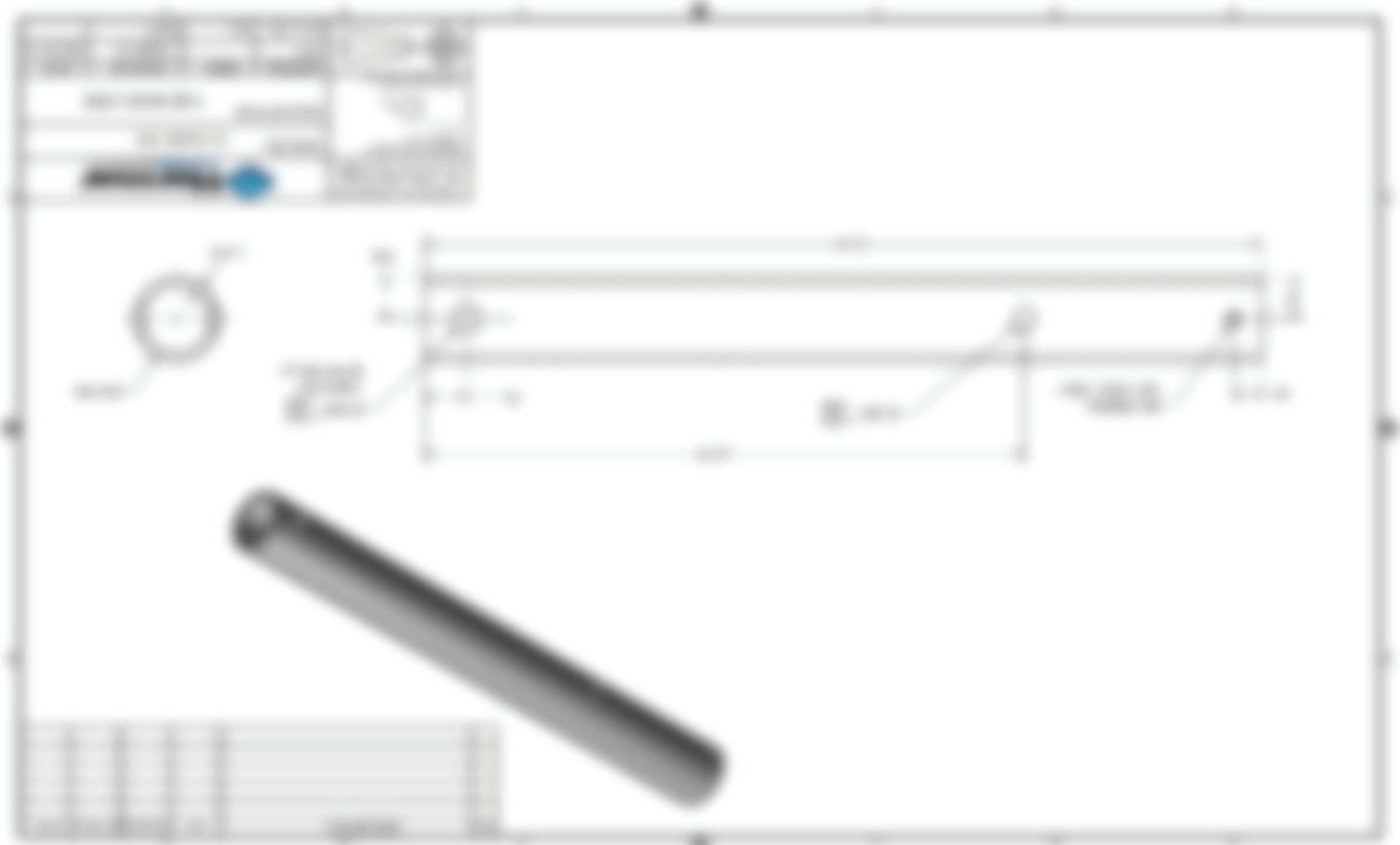


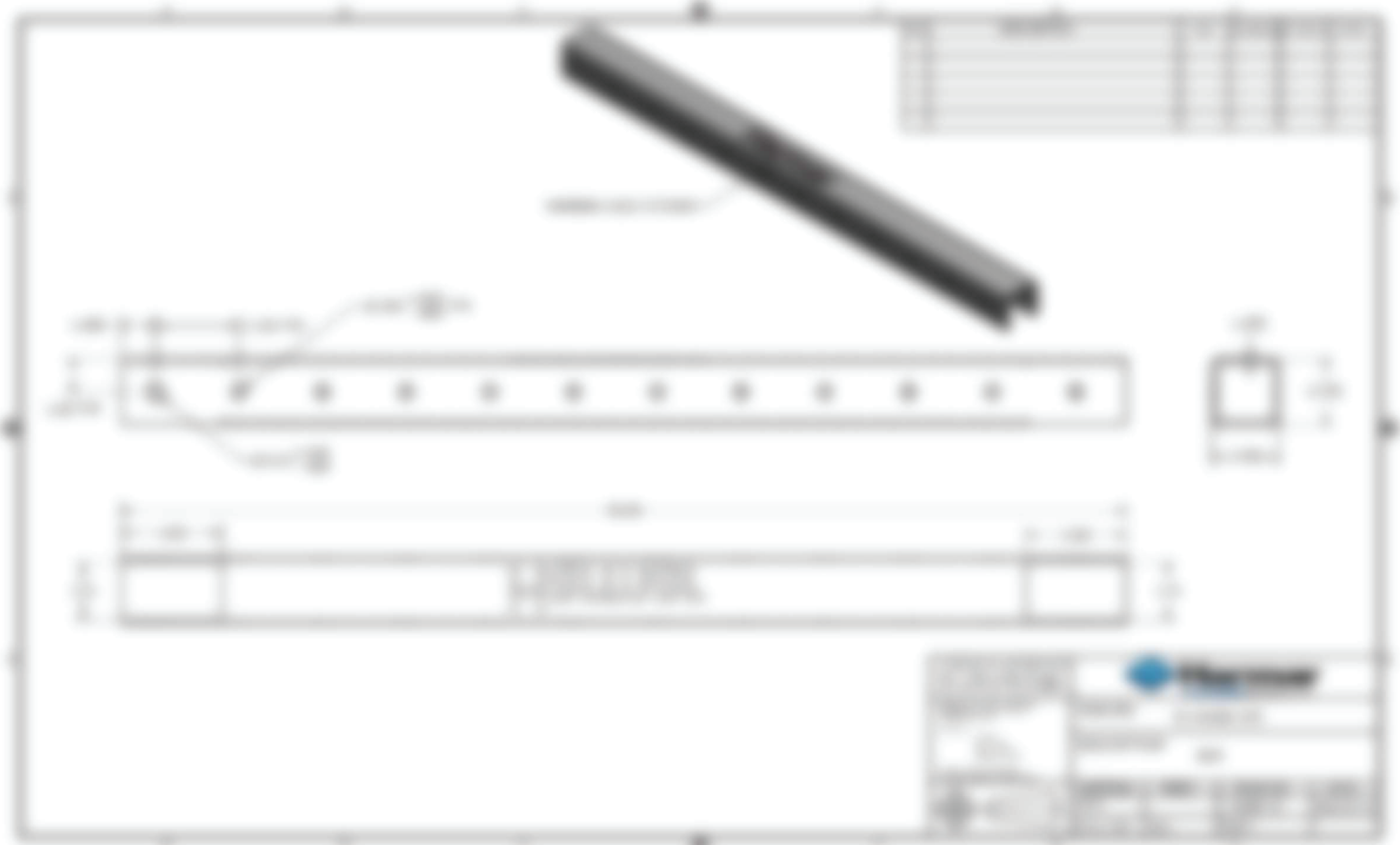


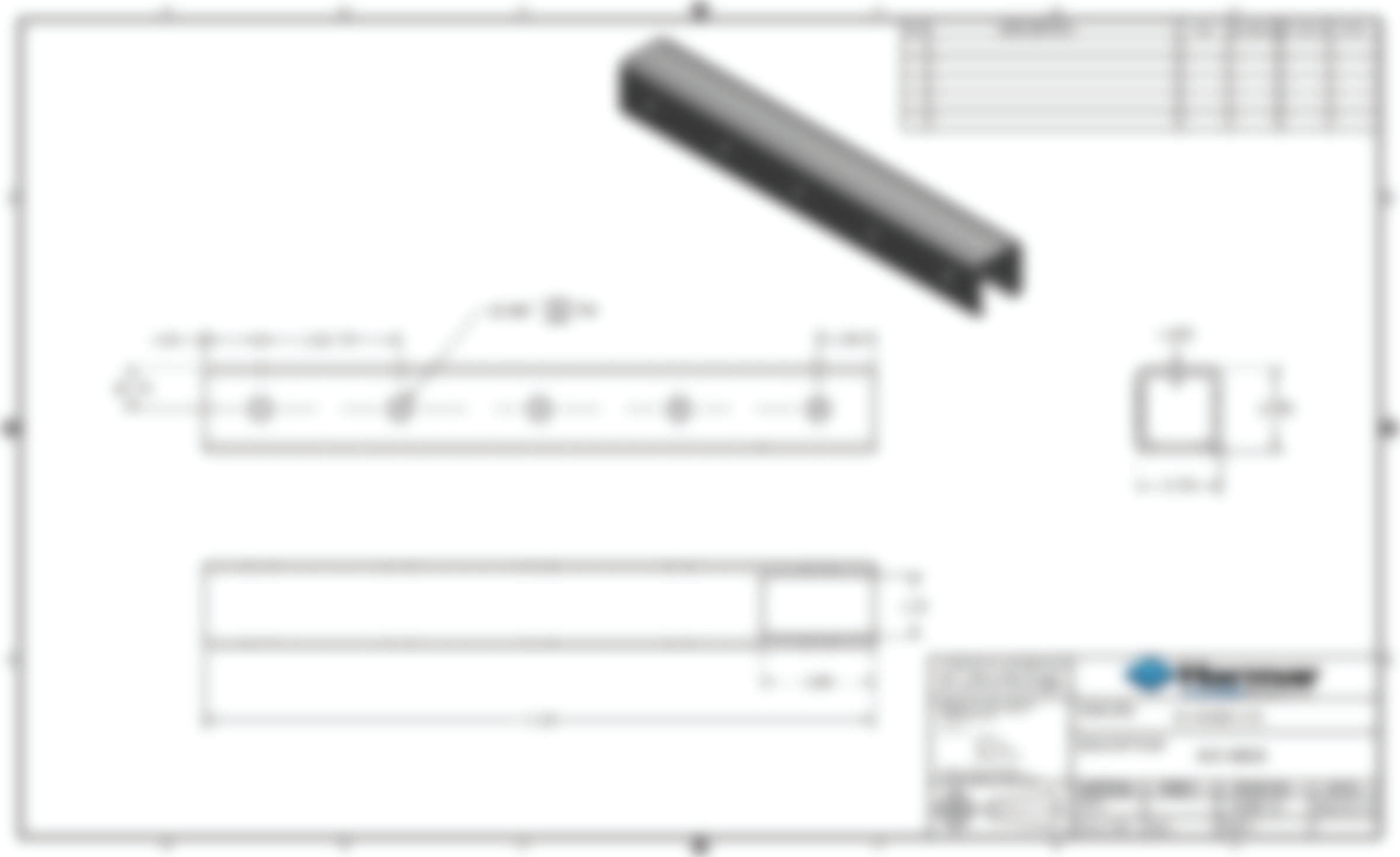


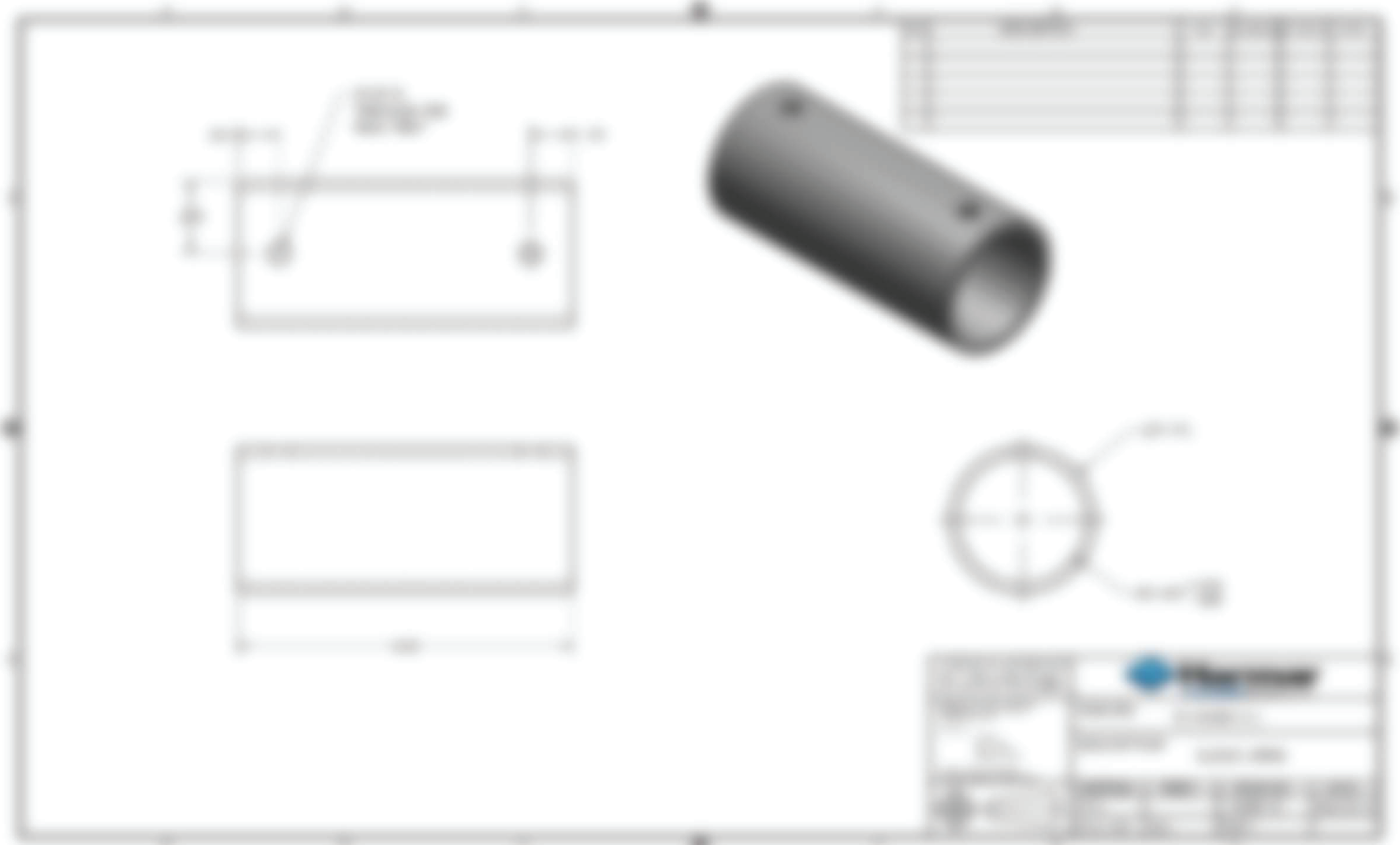


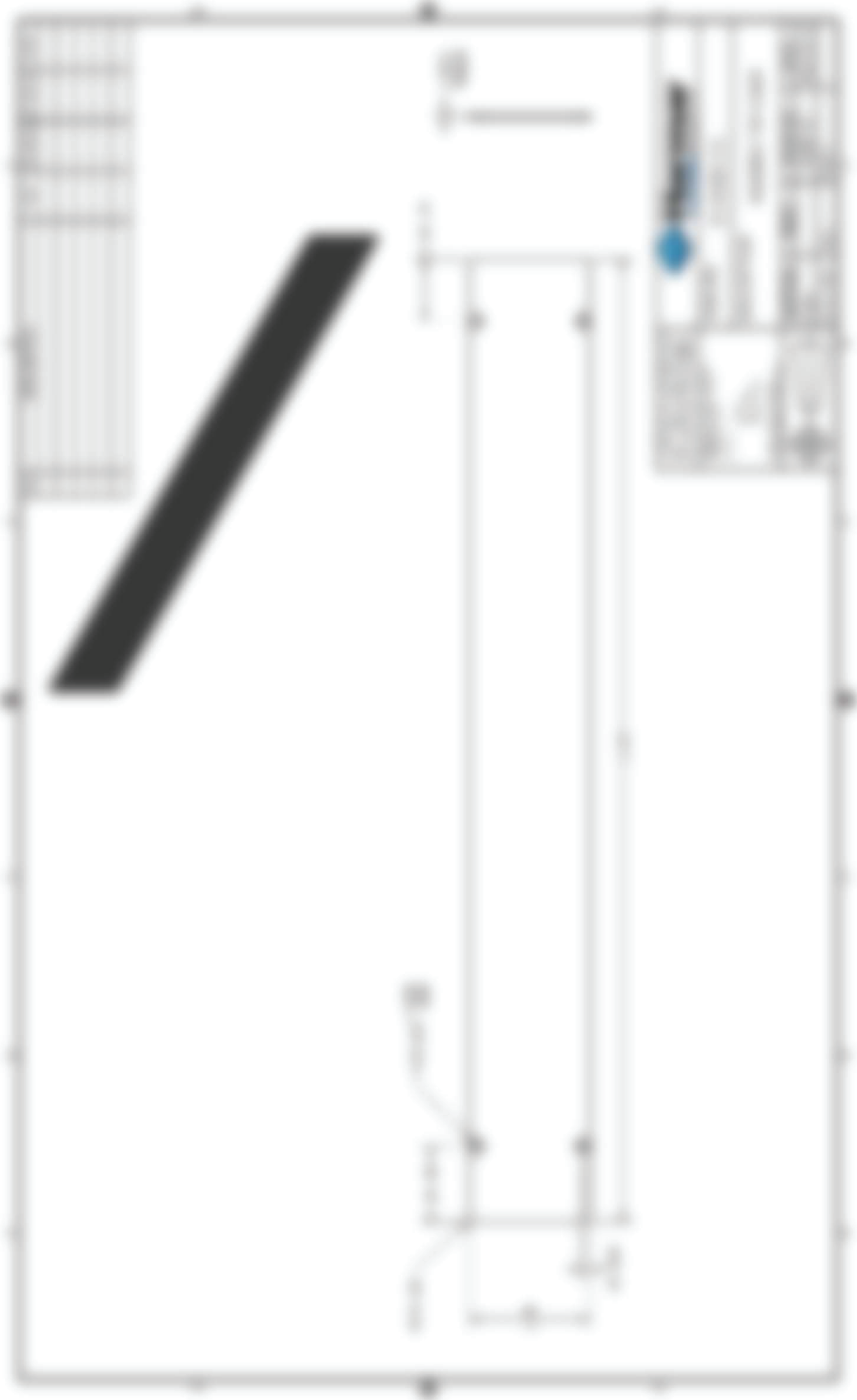


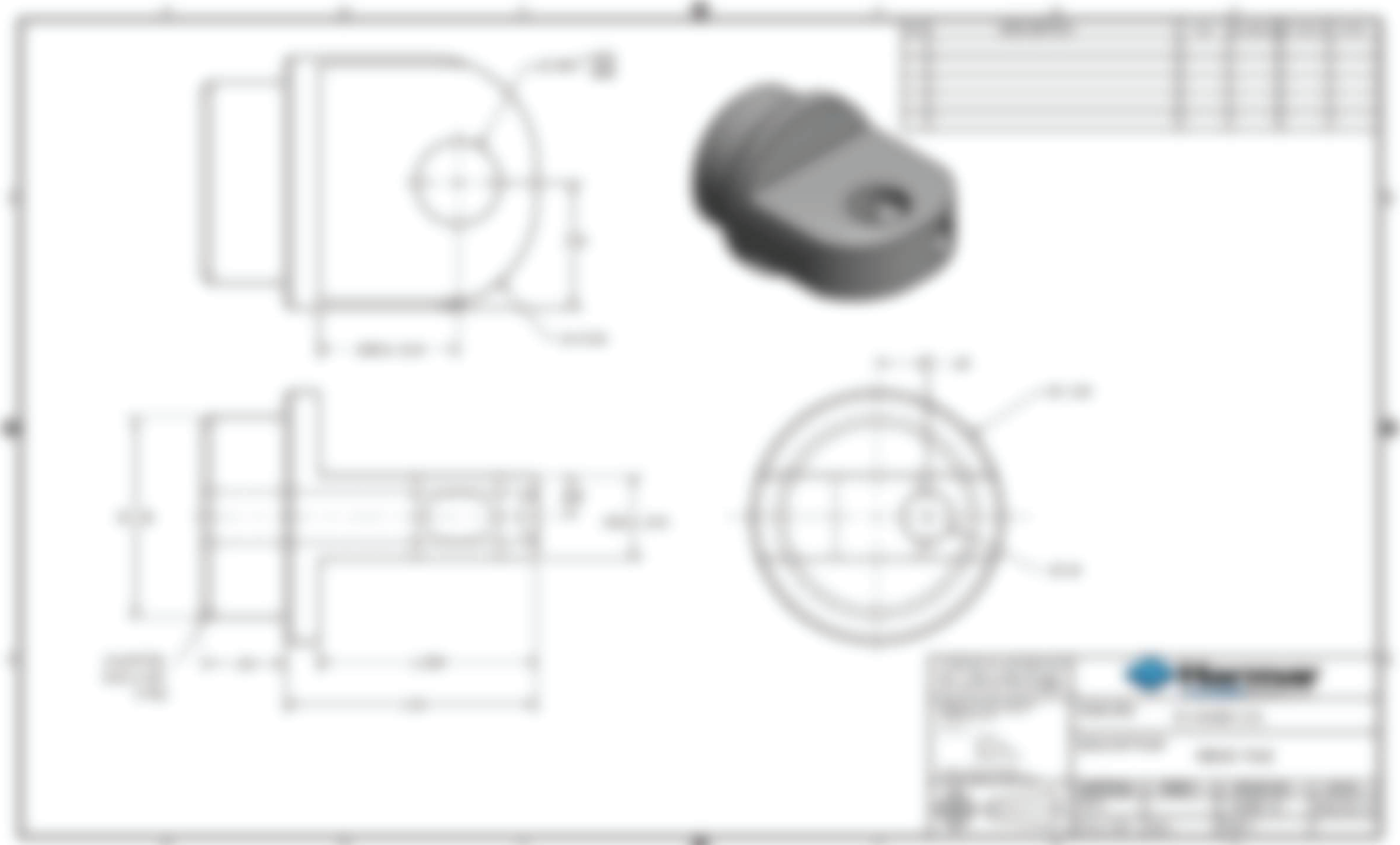


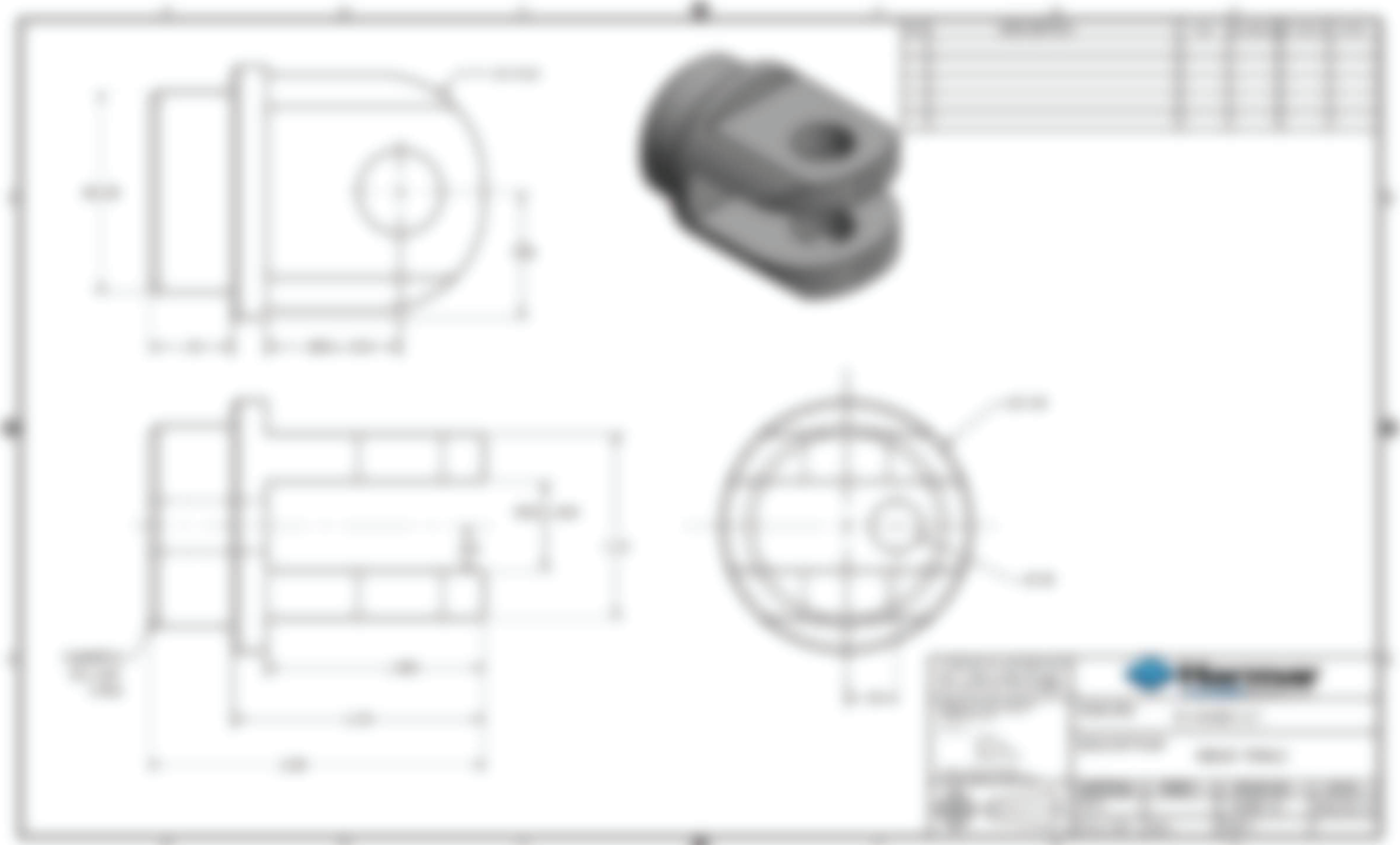


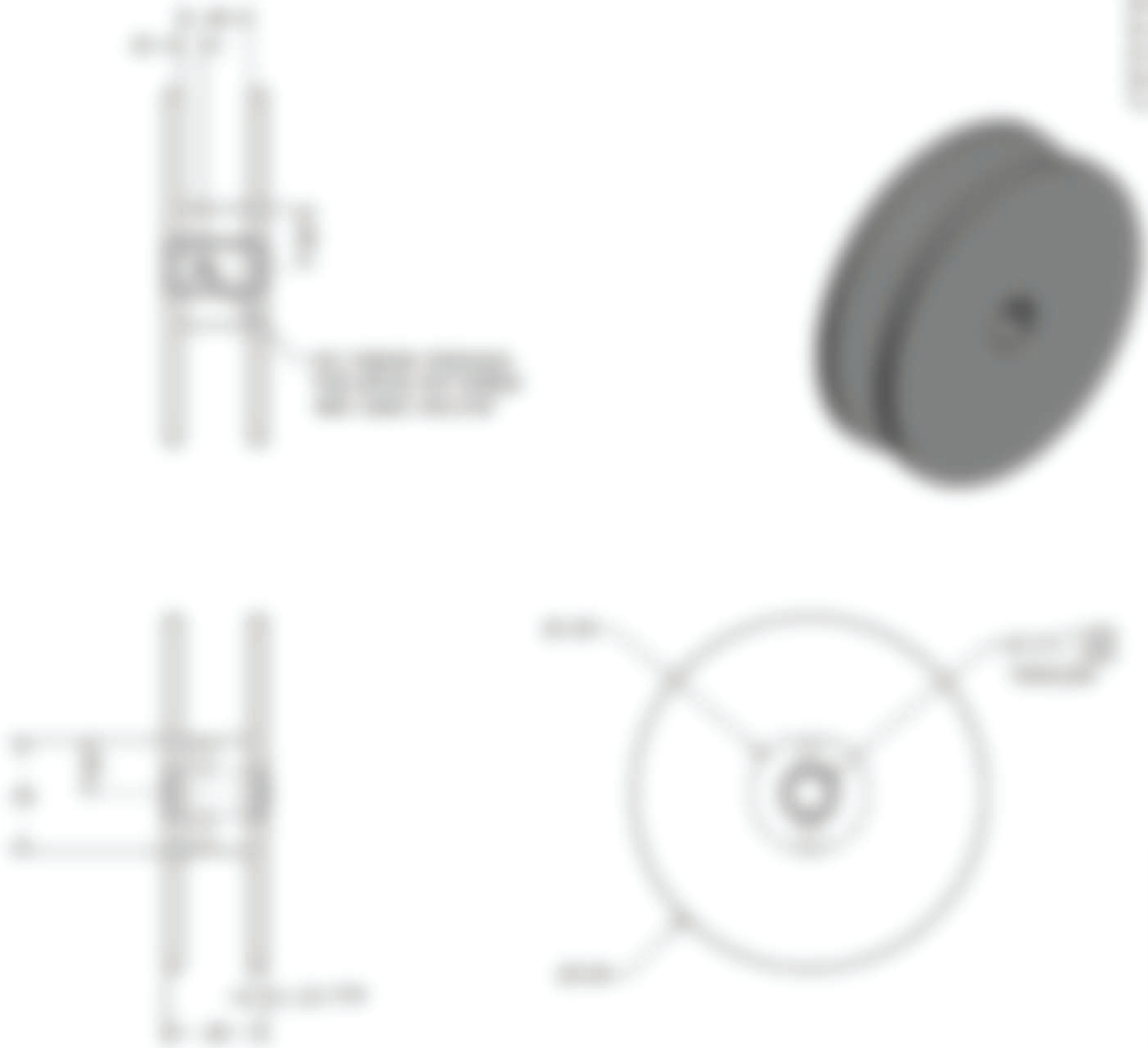


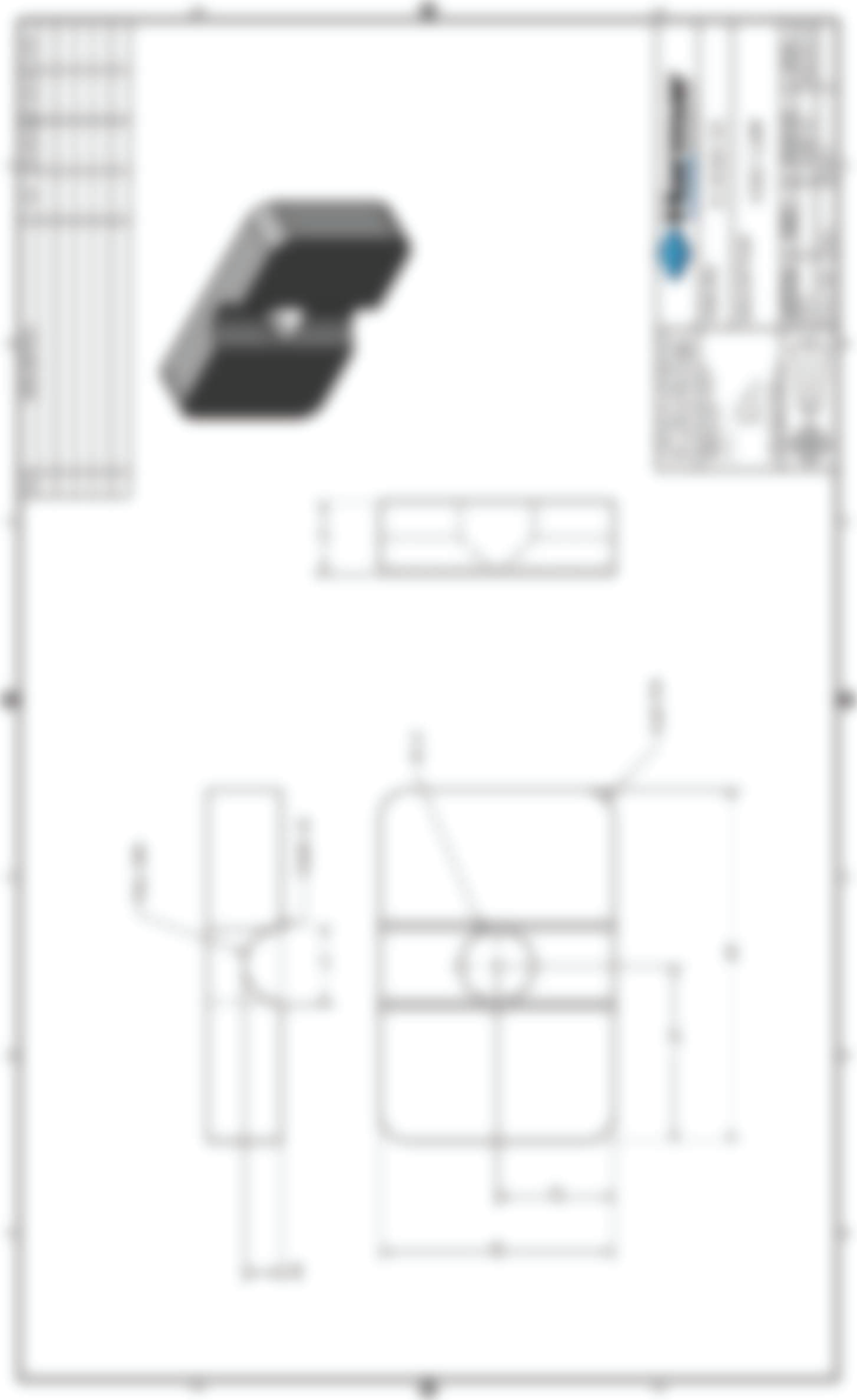




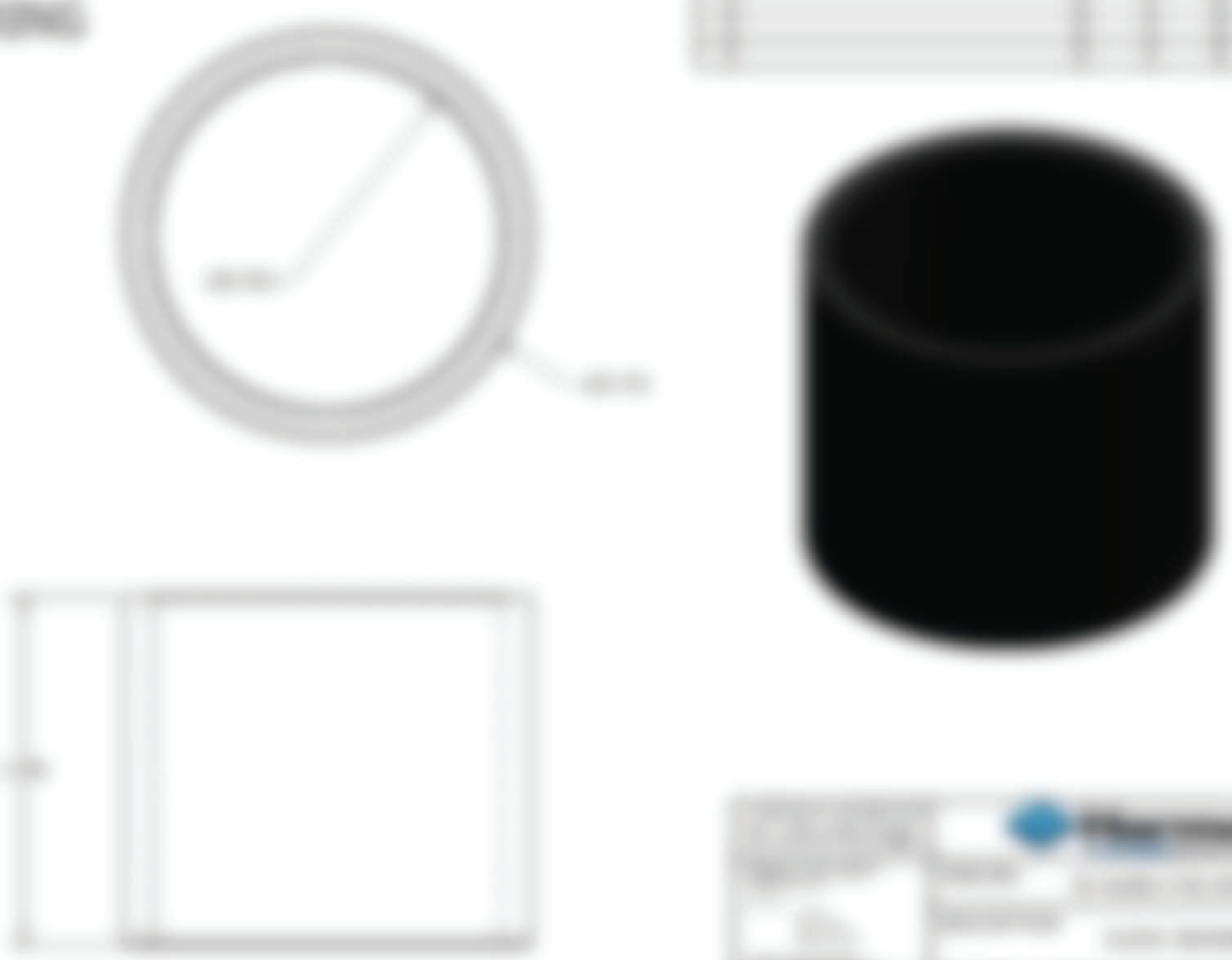








M250 - SLEEVE BEARING
MSI-2426-24
FROM IGUS.COM



Released in Groove

Note: Clearance diameter is the diameter of a housing that can pass freely over the ring.

McMASTER-CARR

97431A340

Black-Finish Steel Side-Mount External Retaining Ring

THANK YOU FOR MAKING HARMAR AMERICA'S LEADER IN LIFTS AND RAMPS