UNIVERSITY OF MANITOBA

Project Name: The Design of a Composite Motorcycle Cargo Trailer

Client Name: Cormer Group Industries

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Date of Submission: _December 1, 2014__

December 1, 2014

[redacted]

[redacted]

I am pleased to announce that my team, *Smaller Hauler*, and I have designed a composite motorcycle trailer, detailed in our report 'The Design of a Composite Motorcycle Cargo Trailer', on behalf of the University of Manitoba.

Detailed in the report is a thorough explanation of the design process that was used to develop the final design, in addition to the design specifications, manufacturing process, cost analysis and recommendations for the design. Throughout the design process, as many analytical and computational analyses as possible were performed to ensure that our design is feasible and safe for highway use, prior to physical testing of the prototype. This work was distributed between each team member, and verified by the group to ensure that the best possible design could be developed.

We hope that this report satisfies Cormer Group's needs, but if any questions arise from this report, please do not hesitate to contact myself or my team members to clear your concerns.

Sincerely,

[redacted]

Team Smaller Hauler

December 1, 2014

[redacted]

[redacted]

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[redacted]

Team Smaller Hauler

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EXECUTIVE SUMMARY

The primary objective of this project, provided to us by our client, Cormer Group Industries, was to design a high-end cargo trailer for towing behind a motorcycle. For this trailer, the use of composite material was to be maximized in the design, with a minimum of having a carbon fiber outer shell. The team was required to provide Cormer with full, detailed drawings of all trailer components, along with a complete manufacturing plan for the prototype. The finished product will be priced for the higher end customer, and therefore a high level of quality needs was pursued throughout all aspects of the design process.

We began our design process with brainstorming, and developed the body design using a multi-tiered concept selection process using weighted needs from both the client and our own internal research. We refined our final design by integrating the most desirable features from our 3 highest ranked concepts.

In order to reduce the complexity and cost of manufacturing, we have outsourced components for the trailer whenever in-house fabrication would be impractical or too complex. In addition, we performed extensive research to make selections of all outsourced components and materials used in our design. This ensured that the final design fully met all of the customer needs.

Our final design has a dry weight of 153.9 lbs. This makes on average one of the lighter trailers of this type available, but features the best in-class interior cargo volume of 28.4 ft^3. This easily meets the client's requirement that the trailer be capable of carrying 2 golf bags or two large suitcases. The final cost for a single trailer, including materials, manufacturing and assembly, was determined to be $5,600 with a sales price of $6,750.

With regards to the manufacturing and assembly, we have created full engineering drawings for all parts and assemblies in our design, as requested by Cormer. This serves as a detailed record of our design, as well as instructions for manufacturing our design. These drawings are detailed down to the component level for the parts made in house. The assembly drawings make reference their respective part numbers in the bill of materials for each set of drawings.

In completing this project, we have designed a motorcycle cargo trailer that meets all of our initial requirements, constraints, and objectives. In addition to designing the trailer, we have created a complete set of engineering drawings, a manufacturing plan and assembly plan for the trailer. Having satisfied all our customer's needs with our design, the only recommendations we have are with regards to prototype testing in order to perform a more accurate fatigue analysis, as well as small features which could be added to improve the use of the trailer but are outside the scope of this project.

1. Introduction and Background

Cormer Group Industries is a Winnipeg based manufacturing company serving the global aerospace industry since 2001, and the defense industry since 1989, by providing high quality integration of all sub-contracting processes [1]. With 200 full-time employees and over 150,000 square feet of manufacturing, warehousing, and processing facilities, Cormer is capable of handling large contracts for major clients such as Boeing, Goodrich and GKN. Cormer Group Industries takes pride in its expertise in precision high speed machining and integration, lean manufacturing, and high quality capabilities, to serve its clients [1].

Cormer has recently been venturing into the design and manufacturing of composite components and assemblies. In order to increase Cormer's involvement in this market, the company has decided to design and manufacture a consumer motorcycle luggage trailer made primarily of carbon fiber. The trailer was designed to be towed behind a standard cruiser or touring motorcycle. The trailer must be designed with high quality standards, and geared towards an older demographic. Cormer's intentions are to market and sell this trailer in North America, with an initial production of approximately 2000 units per year. Their new composites facility allows for much of the manufacturing process to be done in-house, making this a feasible and economic project. Cormer's goal at the end of the project is to have a detailed final design and manufacturing plan that will allow them to go straight into building a prototype [1].

1.1. Project Objectives and Expectations

The primary objective of this project was to design a high-end cargo trailer for towing behind a motorcycle. The use of composites is to be maximized in the design, having a minimum of a carbon fiber appearance. The team must provide the client with full, detailed drawings of all of the trailer components along with a complete manufacturing plan for the prototype with an end goal production capacity of 2000 units per year. The finished product was priced for the higher end customer, and therefore a high level of quality needs to be pursued throughout all aspects of the design process.

Extensive research has been performed on many available materials, and appropriate selections have been made with consideration to the client's needs and their manufacturing capabilities. Parts have been outsourced when possible to reduce the manufacturing complexity, and limit additional tooling required in the manufacturing process outside of Cormer's capabilities. Through the use of carbon fiber, we have created a light weight design. We have considered all applicable standards and regulations regarding motorcycle trailers to ensure that the final product can be sold within North America.

1.2. Customer Needs

After meeting with one of our Cormer representatives, Jordan Bisharat, our team determined a list of customer needs taken from our interactive project discussion. The customer needs are identified below.

- The interior must be lined with a carpet or other lining material; carbon fiber should not be seen in the interior of the trailer.
- The carbon fiber must be aligned with the direction of trailer travel.
- The trailer must be able to hold two large golf bags.
- The trailer must have appropriate lighting and reflectors following the applicable regulations.
- The outer shell finish must have a minimum of a clear coat gel.
- The tongue of the trailer must comply with standard motorcycle hitches.
- The compartment door must have a locking mechanism.
- The motorcycle trailer must be designed to travel at fast highway speeds.
- The suspension must provide a soft ride to protect trailer contents.

Using the needs gathered from the customer, the team produced a list of target specifications. Additionally, limitations and constraints were identified for the project.

1.2.1. Target Specifications

The target specifications were developed by the team from the meeting with the client, to assist with the process of design. TABLE I below lists each of the target specifications of the motorcycle trailer design.

TABLE I: TARGET SPECIFICATIONS [2]

Variable	Target Specification
Carbon Fiber Alignment	0-90 degrees**
Trailer Capacity	150 lbs
Minimum Volume	16 ft3*
Minimum Interior Height	16 inches*
Minimum Interior Width	32 inches*
Minimum Interior Length	54 inches*
Number of Axles	1 or 2
Maximum Budget	$5,600
Speed Range	0-100 mph

**The carbon fiber should follow an aesthetic [0,90] appearance
*Dimensions are derived from assuming space for two large golf bags (16"x16"x54")

1.2.2. Limitations and Constraints

Due to the initial open-ended nature of the design, our team needed to define the constraints and limitations of the project in regards to the overall design. The team has spoken in detail with the Cormer representatives to determine a list of detailed constraints for the project. In addition to this meeting, the team researched federal trailer requirements and regulations, which further added to the list of constraints. TABLE II provides a list of the gathered constraints for the motorcycle trailer design.

TABLE II: LIST OF CONSTRAINTS FOR MOTORCYCLE TRAILER DESIGN

Feature	Description of Constraints
Wiring	Must be able to withstand all weather conditions: rain, snow, sleet, hail
Lights	Type and placement must meet requirements in federal regulations (Section 3.1.1)
Reflectors	Type and placement must meet requirements in federal regulations (Section 3.1.1)
Suspension	Designed for low vibrations on smooth roads at high speeds
Frame	Designed for adequate strength on smooth roads at high speeds
Wheels	Designed for smooth roads at high speeds
Body	Must be completely enclosed and weatherproof with a single door access
Frame	Must not be exposed outside of the body
Body Size	Must be able to fit inside Cormer's on-site curing oven, approximately 4 feet wide, 7 feet high and 8 feet deep
Frame Materials	Must be steel or aluminum; cannot be made from magnesium or titanium

Considering the target specifications (TABLE I) and the constraints (TABLE II), the scope of the project was narrowed down, giving the team a basic framework to begin researching and brainstorming possible trailer designs. Before beginning the research and design phase, the team completed a detailed risk analysis of the project to help us understand each of the risks associated with the project and the level of severity of each of these.

2. Final Design Development

The procedure and methodology used to develop and finalize the final design was a long and thorough undertaking. The team started by developing preliminary and secondary conceptual designs, and ran through a thorough selection process to choose the best kind of design. Specific design analyses were also developed to assist with the design process. These additional analyses included a frame design selection, a suspension system selection, and composite structure design.

Once the analyses were completed, the final design for the trailer could be developed. The team was then able to design a mold casing for the development of the body and lid. These parts were selected to be made from carbon fiber pre-preg. With the use of thorough selection processes, general analysis and design, a new generation trailer was developed for further design and analysis.

2.1. Conceptual Design Selection

The final design was developed through a process of brainstorming, screening, scoring, and combining the best concepts into an optimized final concept. The whole process explained in this section, is detailed further in Appendix A. After we had completed a significant amount of research into customer needs, competitor's motorcycle trailers, applicable laws and regulations, suspension possibilities and composite design, we each developed several trailer concepts with approximate dimensions and features. Each of these concepts were analyzed, and the top eight concepts to move forward with were chosen.

The team created a screening matrix to assist in the selection of the top eight preliminary designs, to evaluate each design based on an intuitive estimation of weight, volume, aerodynamics, durability, ease of access, manufacturability, stability and cost. Due to the concepts being rough sketches at this point, these parameters were not evaluated numerically, but were simply based on a theoretical analysis of each concept.

The screening results indicated the top three trailer designs to move forward with were the Teardrop, the Bullet, and the Stealth Jet concepts. From these concepts, we were able to begin the final design selection process. To do this, a customer needs matrix was completed by the group to assign weightings to each design parameter. In addition, this customer needs matrix was sent to the Cormer representatives in order to get their perspective on the parameter weightings.

With the weightings developed for each design parameter, the team could move on to the weighted selection process. Using both sets of weightings and a less subjective method of scoring each design, we determined whether one concept is clearly better than the rest. This process is less subjective due to the fact that physical models were developed with relatively realistic dimensions. Assumptions were also used because several important components in the designs were missing, such as the interior framing.

It was clear from the selection process that the Bullet concept scored higher than the Teardrop and Stealth Jet concepts. However, since the other two concepts ranked closely to one another, the top features from each concept were incorporated into the final design of the body. Some of these features include a spare tire compartment in the floor of the trailer and a lid, which opens from the side. Before finalizing the body of the design, a finalized frame design along with a suspension system needed to be established.

2.2. Frame Design

The type of material to be used for the frame along with cross-sectional geometry and the overall layout of the frame needed to be determined in order to move forward the design. Numerous frame materials were considered and screened in a systematic process to determine an optimum material for our application.

2.2.1. Frame Materials

One of the initial constraints given by Cormer was that the frame of the trailer had to be made from either steel or aluminum. Following this constraint, the most common structural frame materials were determined to be 7075 Aluminum, 6061-T6 Aluminum, 4130 Chromoly Steel, AISI 1020 Carbon Steel, and AISI 304 Stainless Steel. Properties and information relevant to our application was then found for each of these materials and is summarized in the following table.

TABLE III: INITIAL FRAME MATERIALS [3][4][5][6][7]

	7075 Aluminum	6061-T6 Aluminum	4130 Chromoly Steel (annealed)	AISI 1020 Carbon Steel (annealed)	AISI 304 Stainless Steel
Density	2.8 g/cm3	2.70 g/cm3	7.85 g/cm3	7.87 g/cm3	8.0 g/cm3
Elastic Modulus	72 GPa	69 GPa	205 GPa	200 GPa	193 GPa
Ultimate Strength	572 MPa	310 Mpa	560 MPa	395 GPa	505 MPa
Yield Strength	503 MPa	276 Mpa	360 MPa	295 MPa	215 MPa
Manfacturablility	Capable of machining while in its annealed state, and low weldablility (Can only use resistance welding)	High weldability and machinablility	This alloy is readily machined by conventional methods (good forming and welding properties)	High machinability and weldablility	High machinablility and weldablility
Corrosion Resistance	3	2	3	4	1
Cost	3	2	5	1	4
Strength-to-weight Ratio	204	115	71	50	63

The corrosion resistance for each alloy was ranked from 1 to 4, with 1 being the highest and 4 being the lowest. Alloys with 1 and 2 ratings can be used in industrial and seacoast atmospheres without protection [6]. With regards to the cost ranking, a rank of 1 relates to the cheapest alloy, while a ranking of 5 relates to the most expensive alloy. The cost analysis involved comparing the costs of each alloy for the same geometry.

The best alloy for the trailer frame was determined using a screening matrix that compares the alloys in terms of strength-to-weight ratio, manufacturability, cost, and corrosion resistance. The reference alloy was chosen to be the AISI 304 Stainless Steel because it is a common steel alloy and is used in various applications. The screening matrix is shown in the table below.

TABLE IV: INITIAL FRAME MATERIAL SCREENING MATRIX

	AISI 304 Stainless Steel	7075 Aluminum	6061-T6 Aluminum	4130 Chromoly Steel (annealed)	AISI 1020 Carbon Steel (annealed)
Strength-to-weight Ratio	0	+	+	+	-
Manufacturability	0	-	0	0	0
Cost	0	+	+	-	+
Corrosion Resistance	0	-	-	-	-
Total	0	0	**1**	-1	-1

The outcome of this screening matrix was that 6061-T6 Aluminum scored the highest, and is therefore the best choice for the frame material. 6061-T6 Aluminum is a very common alloy and is known for its high strength-to-weight ratio and toughness. It also offers good finishing characteristics and it reacts well to clear coat, color dye, and hard coat anodizing [7]. In terms of weldability, it responds the best to arc (TIG) welding, but gas, MIG, and resistance welding can also be used [8]. The best filler alloys that can be used when welding 6061-T6 Aluminum are 5556, 5356, and 5183 Aluminum alloy [9]. These alloys are compared in terms of ease of weld, strength, ductility, corrosion resistance, and colour match in the following table. Note that these top three filler alloys came from a list of eight that were ranked from A to D in decreasing order of merit. Therefore, any one of these filler alloys would be an acceptable choice.

TABLE V: 6061-T6 ALUMINUM FILLER ALLOY COMPARISON TABLE

Filler Alloy	Ease of Weld	Strength	Ductility	Corrosion Resistance	Colour Match
5556	B	A	B	B	B
5356	B	B	A	B	A
5183	B	A	B	B	B

2.2.2. FRAME CONFIGURATION

During the brainstorming process, numerous frame configurations were considered. Many of these designs were based on existing trailer frames with modifications or combining several ideas into one. These frame concepts ranged in strength, durability, manufacturability, weight, and their compatibility to various frame concepts. Figure 1 illustrates these potential frame designs.

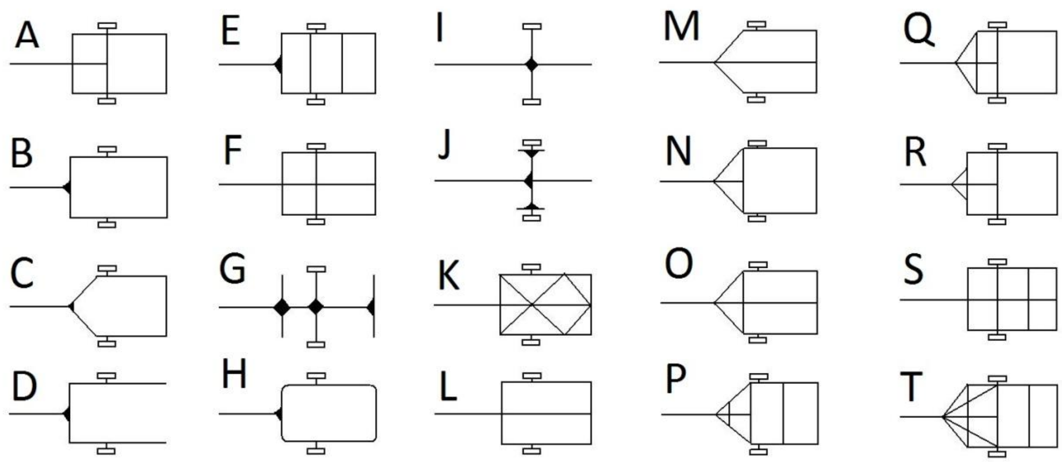

Figure 1: Frame concepts considered during brainstorm process of concept generation

Because the team has decided to place a spare tire compartment in the floor of the trailer, a large number of these concepts were eliminated where a frame support went through the central rear region of the frame (the location of the spare tire compartment). Eliminating these, the trailer frames was narrowed down to eight and are shown below in Figure 2.

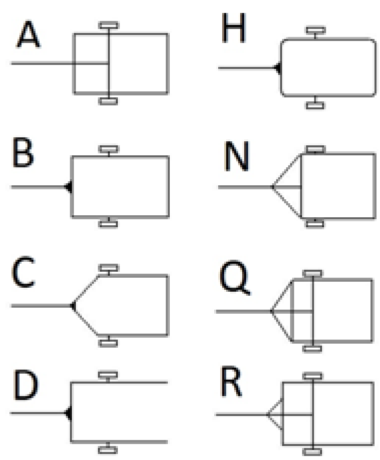

Figure 2: Possible frame configurations for desired spare tire placement

From these final eight compatible designs the team completed a screening matrix to determine which frames to move forward with for further analysis. The screening matrix is shown in TABLE VI, with concept A as the reference frame.

TABLE VI: SCREENING MATRIX FOR FRAME CONFIGURATIONS

	A	B	C	D	H	N	Q	R
Manufacturability	0	1	-1	1	-1	-1	-1	-1
Durability	0	-1	-1	-1	-1	0	1	1
Light Weight	0	1	1	1	1	1	-1	-1
TOTAL:	0	1	-1	1	-1	0	-1	-1

The results from the screening matrix showed the top four frame types highlighted in yellow. Each of these frames were modeled on SolidWorks, and then analyzed for stresses assuming a static load of 250 lbs on the frame (in areas where the body sits), fixed at the hitch and axles. Additionally, concept D and concept A were combined to form a fifth possible frame configuration called concept X. The results from these FEA stress simulations are shown from Figure 3 to Figure 7. For each of these models, 1.5 inch square tubing was used with a 0.25 inch wall thickness. Additionally, the width of the frame for this preliminary analysis was 29 inches while the length was 86.75 inches.

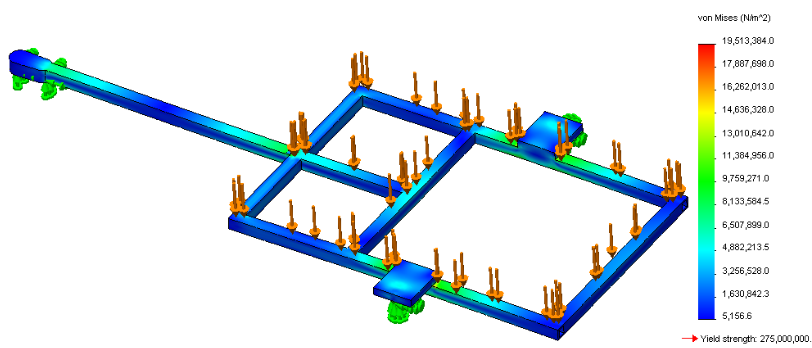

Figure 3: Stress analysis results of frame concept a showing a max stress of 19.5 MPa

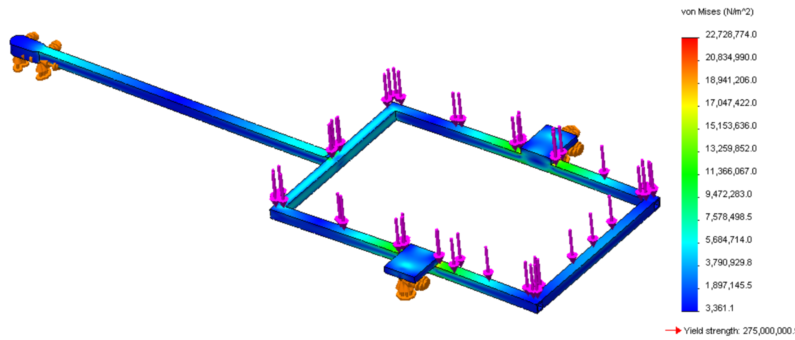

Figure 4: Stress analysis of frame concept B max stress of 22.7 MPa

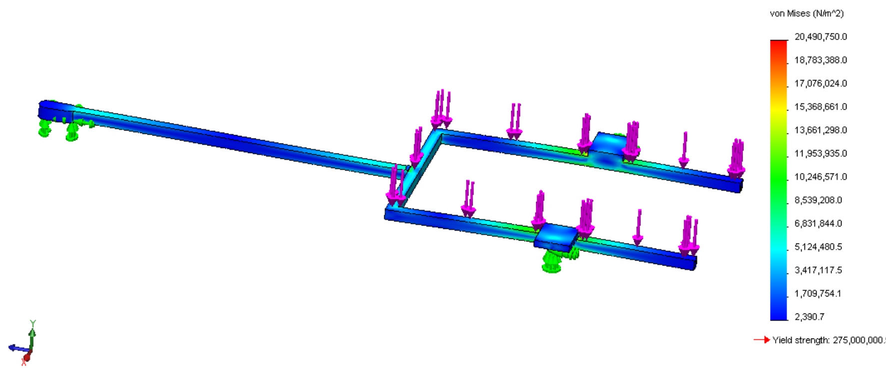

Figure 5: Stress analysis of frame concept D max stress of 20.5 MPa

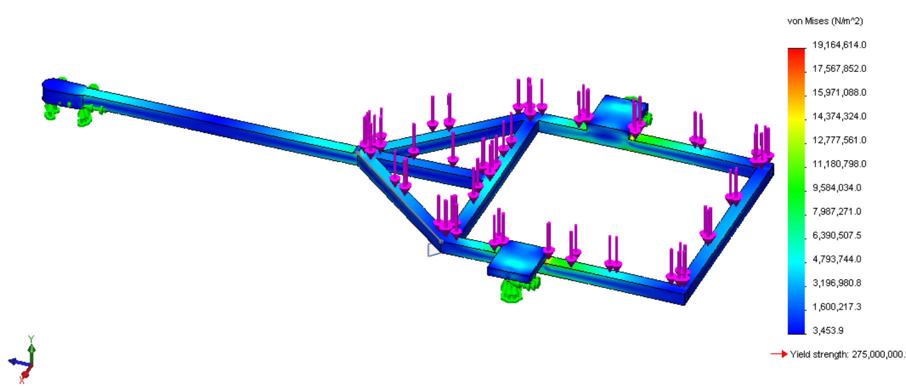

Figure 6: Stress analysis of frame concept N max stress of 19.2 MPa

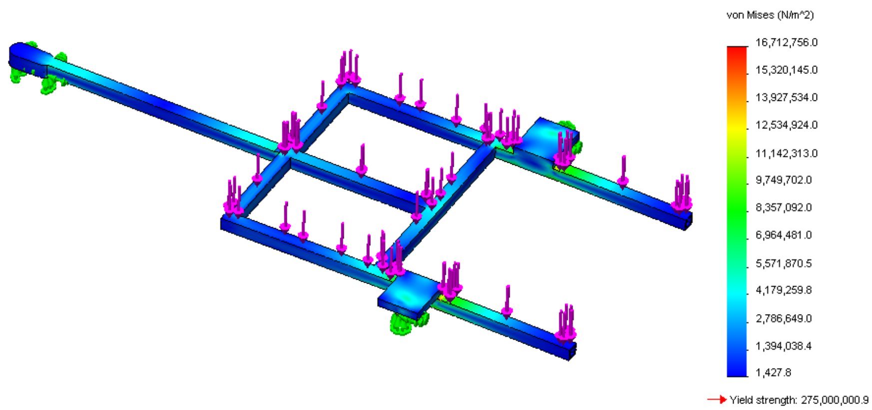

Figure 7: Stress analysis of frame concept X max stress of 16.7 MPa

TABLE VII: SUMMARY OF STRESS ANALYSIS FOR TOP FIVE FRAMES

	Weight [lbs]	Max Stress (Mpa)	Maximum Stress to Weight Ratio
Frame A	32.6	19.5	0.6
Frame B	29.7	22.7	0.76
Frame D	26.7	20.5	0.77
Frame N	30.7	19.2	0.63
Frame X	29.6	16.7	0.56

Based on the results from comparing the maximum stress to weight ratio, frame X scored the best with the lowest maximum stress to weight ratio. From this analysis, the team decided to move forward with the frame X design and implement it into the final motorcycle trailer model. In addition to this, the cross-section of the frame bars was selected to be square tubing.

2.3. Suspension System Selection

In order to reduce unnecessary design and manufacturing, we decided to try to find a prebuilt suspension solution to source as one component. Based on simplicity, range of motion, compatibility and packaging in the body of the trailer we decided on a trailing arm style suspension system for our trailer. The research quickly showed that a torsion half-axle suspension system offered high performance in a small and easily mountable package, and that they are a common choice for motorcycle cargo trailers. Using this we looked specifically for a quality torsion style suspension, which was rated for the same weight as our expected loaded trailer weight.

The first system we found for the trailer was the FeatherRide suspension system, shown in Figure 8, featuring airbag shocks mounted to a swing arm articulated solid axle[8]. This system was ill suited to our design due to the heavy weight and the spring rate which is far too stiff for our trailer mass.

Figure 8: FEATHERRIDE Suspension system [8].

The second option we explored was the TIMBREN 400lbs axle-less suspension, shown in Figure 9 designed primarily for off-road applications**Invalid source specified.**. This was initially considered due to the rated capacity and soft rubber springs, however it was ruled out due to incompatible packaging with our design.

Figure 9: Timbren axle-less suspension Invalid source specified.**.**

The Flexiride FR-425 torsion axle suspension system is rated for 425lb per pair, and features a compact, simple design. This product is commonly used on similar trailers and comes highly reviewed. Figure 10 shows a rendering of the FR-425-S torsion axle assembly with a 4-4” hub.

Figure 10: Render of FR-425-S axle with 4-4" hub installed [9]

Based on the positive results of research performed, and the time constraints on this project we decided that we would source the FR-425-S from Southwest Wheel at a bulk rate of $247.46 USD [8].

2.4. COMPOSITE MATERIAL SELECTION AND STRUCTURAL DESIGN

The selection of the composites for the final design was deemed as a priority, as a prior to the design of the body of the trailer. This structure must be thoroughly analyzed due to the fact that the interfacing, weight and rigidity of the bulk of the trailer are based on this selection. This selection process went through several phases to assist with further development of the design. These phases include determining the manufacturing involvement in the composite development process, structural selection of the composite and desired coating for the final product. An analysis for the tooling (mold) used during the layup and curing process will be discussed, followed by a summary of the composite structure that will be used in the trailer design.

2.4.1. MANUFACTURING INVOLVEMENT SELECTION

The client requested that the minimum for composite usage in the trailer is of a 0-90° carbon fiber alignment and appearance. We deemed it necessary to make a selection of whether or not the design would require that the composite be made completely in house, use pre-impregnated carbon fiber sheets, or outsource composite panels [2]. This analysis does not deal with the actual cost of labour, but an estimation of the time for the labour in manufacturing. The amount of involvement in the composite manufacturing process is dependent on the level of processing that the composite has undergone prior to manufacturing.

Several parameters were developed for determining whether a pre-form, pre-preg or outsourced panels would be better for the development of a commercial trailer to be put out in the market. The strength for the in-house pre-forms would in most cases be weaker than pre-pregs, due to how the matrix flows while curing [2]. As the cure results of in-house composites are unpredictable due to warpage or other unnoticed defects, outsourced panels and pre-pregs would be stronger as their strength is pre-defined by the outsourced company. Other parameters would be based on the manufacturability and cost of the composite material.

The selection matrix for determining the level of manufacturing that Cormer group should invest is indicated by TABLE VIII. Using general knowledge about composites, the group was able to select pre-preg usage as the starting level of manufacturing for Cormer. The primary reasons for this include the fact that the Cormer facilities have the capabilities of composite development, and using pre-pregs allows for the trailer body design to be developed to its full complexity. Manufacturing the trailer this way would also give Cormer some control in the manufacturing process of the composite structure, and reduce the overall cost by using the in-house composite material.

TABLE VIII: SELECTION MATRIX FOR COMPOSITE MANUFACTURING

	In House Pre-Form	Pre-Preg	Outsourcing Composite Panels (Reference)
Strength	-	-	0
Time of Manufacture	-	-	0
Void Formation	-	0	0
Part Formability	+	+	0
Consistency of Thickness	-	0	0
Degradation Composite Prior to Manufacture	+	-	0
Ability to Reinforce Part Prior to Cure	+	+	0
Complexity of Composite Design	+	+	0
Complexity of Design Analysis	-	0	0
Cost	+	+	0
Total	0	1	0
Rank	2	**1**	2

2.4.2. Composite Material and Structure Research

The use of pre-pregs decreases the amount of time required for manufacturing compared to the development of the composite material in-house, but it also allows for a greater amount of control for the development process of the material. This section will compare the feasibility between using a simple laminate carbon fiber structure and the use of a sandwich structure. This section gives detail for the core material for various types of sandwich structures, based on a carbon fiber skin.

Our client, Jordan Bisharat stated that the cost of the carbon fiber pre-preg sheet was approximately 2 $/sqft [10]. This price corresponds to the CYCOM 5320-1 pre-preg sheets they use, with properties depending on the fiber alignment. In this analysis, the team has considered the specifications for the 0-90° alignment (as shown in TABLE IX) using the specifications provided by the Cormer representatives. These specifications also provide both the tensile and compressive properties for holes that will be fastened for bolts, in addition to impact strength and curing properties. Other carbon fiber sheeting have been considered, but prices have ranged from 1.8 $/sqft for a lower quality and strength, to several hundred dollars for excessively manufactured plates [11][12]. Cormer's in-house supply was thus selected, as it is already purchased in bulk, reaping the discounts provided.

TABLE IX: CYCOM 5320-1 SPECIFICATIONS [13]

Property	Magnitude
0-90° Compressive Strength	167 ksi
0-90° Compressive Modulus	7,600 ksi
0-90° Tensile Strength	190 ksi
0-90° Tensile Modulus	11,900 ksi

2.4.2.1. LAYERED CARBON FIBER STRUCTURE

The group considered a simple carbon fiber laminate over the course of the design process to assist with the development of ideas for the outer shell. This design would consist of several layers of the 0-90 sheets arranged on top of the other, each layer arranged at a different angle (45 degrees apart), essentially with a quasi-isotropic structure. The 0-90 sheets pre-preg have most of their strength in two directions (parallel to the fiber), which is due to the anisotropy of the fiber material [14]. By stacking each layer at different angles, the overall strength and stiffness improve by the reduction of this anisotropy (in other words, the fibers will be aligned in more directions) [15].

As requested by Cormer, the outermost layer will consist of the 0-90° arrangement for the aesthetic appearance. As the strength requirements depend a lot on the loading on the trailer, the number of plies of the composite is important. Research from various websites and textbooks on composite panels useful for this application seem to vary from 5-20 layers which can range anywhere in thickness from 1/16” to 1/2" (depending on the thickness of each ply) [14][15]. Calculations to determine a sufficient thickness will be provided further in the report. The alignment considered would follow the pattern of [0, 90], [45,-45], [0, 90], and so on, as illustrated by Figure 11 to follow the quasi-isotropic structure (which in turn reduces the anisotropy).

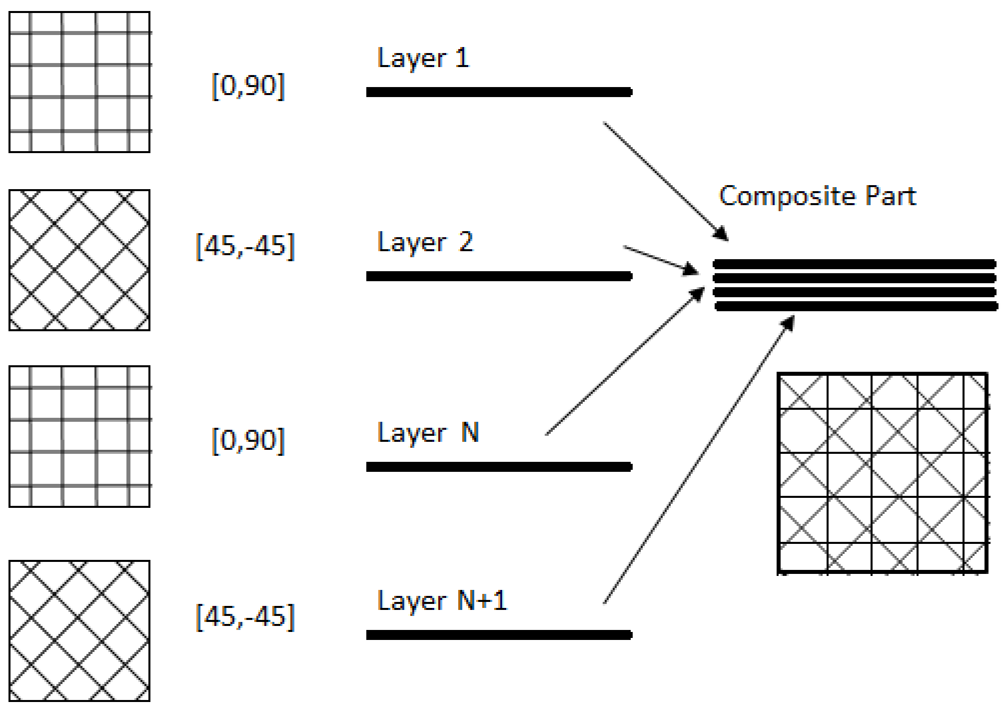

Figure 11: Carbon fiber pre-preg layup for composite component

2.4.2.2. Sandwich Composite Structure

A sandwiched composite structure for this application will consider a layered carbon fiber sheets over a core material, to reduce the overall weight and improve the rigidity. These cores can range from wood, foam, metal and honeycomb which can be sandwiched between the carbon fiber sheets. This can further decrease the weight of the trailer, as these materials are usually of lower densities because of the material properties or arrangements [14].

As previously mentioned, due to the anisotropic properties of the carbon fiber pre-preg, the strength is direction dependant. Using a core material could significantly improve the strength in the weakest direction for a carbon fiber panel, in the direction perpendicular to the sheet, essentially increasing the rigidity of the structure [16].

The sandwiched structures to be considered will consist of the alternating layers of the [0, 90] and [45,-45] carbon fiber sheets as the skin. These core thicknesses were recommended by Dr. Paul Labossiere to be approximately 1/2" [17]. To better illustrate this, the conceptual structure may be seen in Figure 12. Further discussion will include the different possible core materials considered for the design including wood and foam, as they are widely and conventionally used in industry for various composite structures [14]. Honeycomb core was decided not to be included in the analysis due to the Cormer representatives' hesitance to use the material because of the high cost [2].

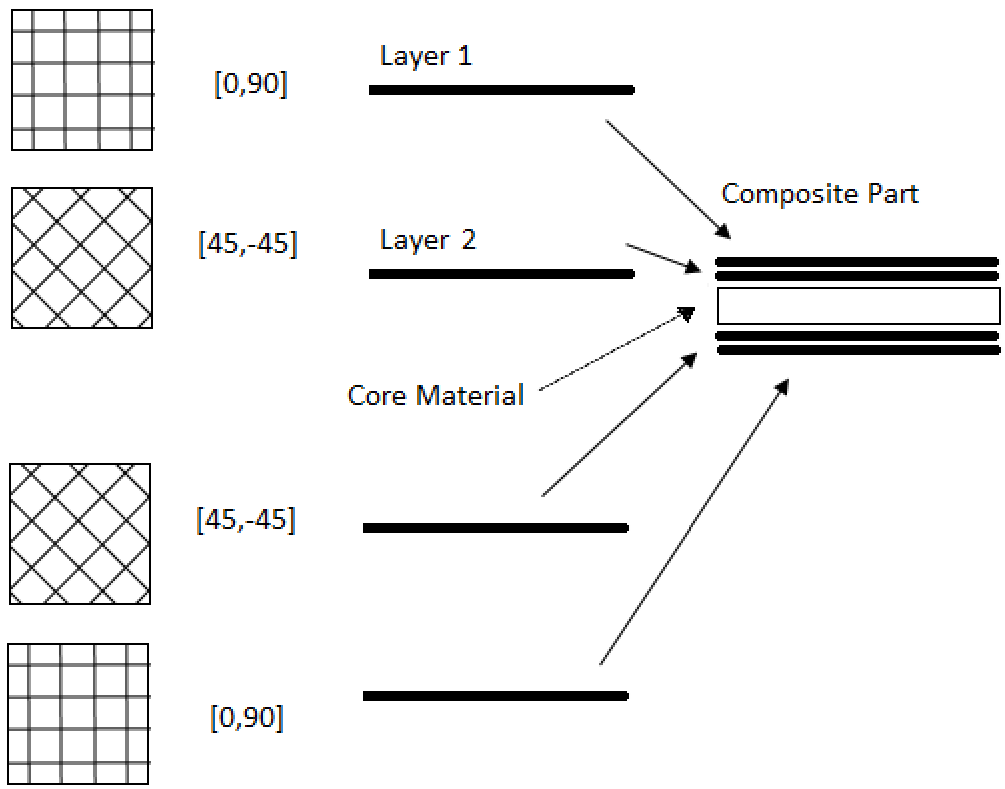

Figure 12: Carbon fiber layup considered with a sandwich structure

Using wood as a core material has numerous benefits and disadvantages. Wood varies in density depending on the region in which it is grown, ranging from 0.16 kg/m^3 for Balsa to 1.3 kg/m^3 for ebony [18]. This variation of density can be a benefit or drawback for use in the trailer, as the density of wood is always different. The strength and stiffness of the wood on the other hand can vary from 790 psi for cottonwood to 2660 psi for oak [19], based on the moisture content and temperature of the material. In woodworking, warpage of wood has been known to occur due to those factors, which could significantly reduce the quality of the overall structure if not properly treated.

Wood has a limitation with its manufacturability, as the grains grow in one direction, taking advantage of the strength can be difficult at times. Like the carbon fiber, wood is also anisotropic, with properties varying depending on the direction of the grain. In this case, the direction of the wood grains should be on a parallel plane to the direction of the fibers [20]. In addition to this, attempting to make a curved trailer design with wood is not as feasible compared to other methods due to the lower formability of wood and the difficulty with grain direction manipulation. Three wood cores with high strength to weight ratios include Balsa, Gray Birch and Douglas Fir. As shown in TABLE X, these would be suitable for their use as a composite sandwich because of this ratio. As the structure desired is to be lightweight and strong, the woods with the greatest strength to weight ratio of the three are Balsa and Douglas Fir, which will be considered in the selection matrix to come.

TABLE X: PROPERTIES OF VARIOUS WOOD AS POTENTIAL CORES [21][22][23]

Wood Type	Density (lb/ft^3)	Compressive Strength (lab/ft^2)	Modulus of Rupture (lab/ft^2)	Modulus of Elasticity ($/ft^2$)
Balsa	9	1,690	2,840	538,000
Gray Birch	35	4,870	9,800	1,150,000
Douglas Fir	32	6,950	12,500	1,765,000

Although foam is not known for its stiffness, the material is significantly easier to form compared to wood. In addition to this, depending on the density and strength of the foam, the impact strength and insulative properties could be improved. Some of these foams used with composites in industry include polyurethane, polystyrene, depron and airex [14][24]. These foams are much easier to work with depending on how they are purchased, they can be molded into the desired shape with ease, while in other cases they might be as complicated to deal with as wood. The properties of these foams may be found in TABLE XI. With the limited data, the foam types to be further analyzed in the selection matrix include polystyrene and Airex foams.

TABLE XI: PROPERTIES OF VARIOUS FOAM CORES

Foam Type	Density (lb/ft^3)	Compressive Strength ($/ft^2$)	Modulus of Elasticity ($/ft^2$)	Source
Polyurethane	1.8-4.4	-	523,000-1,254,000	[10]
Polystyrene	1.8-2.8	20,900	418,000-627,000	[10]
Airex	2.5	9,360	580,000-770,000	[20]
Depron	2.5	-	-	[20]

The use of adhesives is necessary to bond composite components for a sandwich structure. The adhesives bonding the core and skin material should have a low and consistent thickness overall during application on a cleaned surface, ranging from 0.025-0.2 mm in order to minimize the overall weight of the structure [14]. If a sandwich structure is selected, the core material in most cases would not be able to be cured with the carbon fiber due to the high curing temperatures. In this case, the adhesive selected would be required to cure and harden at room temperature. A low cost adhesive is desirable in order to reduce the overall cost of manufacturing. Finally, the strength of the bond is necessary to select the best adhesive, although this would depend more on the surface roughness of the bonding material as well as interfacial reactions [25].

A suitable adhesive material that would be able to cure at room temperature would be a two part epoxy. This epoxy consists of the resin and a hardener, where the chemical reactions causing the hardening allow this curing process to happen at room temperature [16]. The time for cure depends on the type of epoxy, and could take a few days to completely cure. A rough surface to work with provides a better bond, reducing the likelihood of peeling because of its lower peel strength [16].

Urethane adhesives require a similar process of application as epoxy, where the two and one part urethanes can be cured at room temperature [16]. This material requires a minimum of room temperature to cure. The temperature must be kept at that level to prevent poor and/or incomplete bonding. Polyurethane has great adhesion strength with materials such as wood and some plastics, which is desirable for the finished product, in addition to its superior impact properties relative to epoxy [16]. With a lower cost, polyurethane seems to be a better overall choice for this application.

Many other adhesives were considered, but these two are used more frequently in industry, and provide the most desirable properties compared to other varieties, especially when it comes to the curing temperature. Various other mechanical properties of the epoxy and urethane adhesives can be seen in TABLE XII. Regardless of the mechanical properties, if the adhesive does not have a rough and clean surface to bond to, it will not function up to the desired standard.

TABLE XII: EPOXY AND URETHANE PROPERTIES [26]

	Epoxy	Urethane
Strength (psi)	5000	3000
Elongation (%)	3	75

To assist in the selection process between the two adhesives analyzed, a selection matrix was formed to select the better material for the trailer design, as can be seen in

TABLE XIII. We decided that the best adhesive for the purpose of the trailer design was urethane. Although it is weaker, many other general properties of this material have been found to be better and more suitable for the application of an adhesive for the sandwich material.

TABLE XIII: ADHESIVE SELECTION MATRIX [16]

	Epoxy (Reference)	Urethane
Shear Strength	0	-
Peel Strength	0	+
Elongation	0	+
Cost	0	+
Cure Time	0	+
Impact Strength	0	+
Cost	0	+
Total	0	5
Rank	2	**1**

2.4.3. COMPOSITE STRUCTURE SELECTION

The final stage in the composite structure selection process is of a screening matrix to determine the best composite structure for the body of the trailer. Using the properties discussed before, the best combinations of the composite structure were used in the analysis. The selection matrix in

TABLE XIVTABLE XIV displays the final result is that the best composite structure that could be used in the design is a carbon fiber sandwich with a polystyrene core.

TABLE XIV: COMPOSITE STRUCTURE SELECTION MATRIX

	Carbon Fiber Plate	Carbon Fiber Sandwich with Balsa Core (Reference)	Carbon Fiber Sandwich with Douglas Fir Core	Carbon Fiber Sandwich with Polystyrene Core	Carbon Fiber Sandwich with Airex Core
Strength	+	0	+	+	-
Rigidity	+	0	+	0	0
Density	-	0	-	+	+
Time of Manufacture	+	0	0	+	+
Manufacturability	+	0	0	+	+
Cost	+	0	+	+	0
Total	4	0	2	5	2
Rank	**2**	5	3	**1**	3

With a close result, the team decided to go further into analysis with a weighted matrix to assist with the selection process. Using a customer needs matrix, weightings were assigned with each parameter, as can be seen in TABLE XV. With these new weightings, each composite structure was ranked 1-5, 1 being the worst and 5 being the best, as can be seen in the weighted matrix in TABLE XVI. These rankings were multiplied by the weightings and summed to develop a final score, to select the final structure.

TABLE XV: CUSTOMER NEEDS MATRIX FOR COMPOSITE SELECTION PARAMETERS

		Strength	Rigidity	Weight	Manufacturing Time	Manufacturability	Cost
	ID	A	B	C	D	E	F
Strength	A		A	A	A	E	F
Rigidity	B			B	D	E	B
Weight	C				C	C	F
Manufacturing Time	D					D	D
Manufacturability	E						E
Cost	F						
	Customer Need ID	A	B	C	D	E	F
	Occurrence	3	2	2	3	3	2
	Calculated Weight [%]	20.00	13.33	13.33	20.00	20.00	13.33

TABLE XVI: COMPOSITE STRUCTURE WEIGHTED MATRIX

Weighted Selection Matrix	Group Weighting	Carbon Fiber Plate	Weighted Score	Carbon Fiber Sandwich with Balsa Core	Weighted Score	Carbon Fiber Sandwich with Douglas Fir Core	Weighted Score	Carbon Fiber Sandwich with Polystyrene Core	Weighted Score	Carbon Fiber Sandwich with Airex Core	Weighted Score
Strength	0.200	5	1.000	2	0.400	1	0.200	4	0.800	3	0.600
Rigidity	0.133	1	0.133	4	0.533	5	0.667	3	0.400	2	0.267
Weight	0.133	5	0.667	2	0.267	1	0.133	3	0.400	4	0.533
Manufacturing Time	0.200	5	1.000	2	0.400	1	0.200	4	0.800	3	0.600
Manufacturability	0.200	5	1.000	2	0.400	1	0.200	3	0.600	4	0.800
Cost	0.133	5	0.667	1	0.133	3	0.400	4	0.533	2	0.267
TOTAL			4.467		2.133		1.800		3.533		3.067

The best structure selected was deemed to be a simple carbon fiber plate, which is used for further analysis. The group agreed with this, as the complex contours with sandwiched structure tends to get complicated, and would end up weighing more than necessary with an addition of the adhesive to bond the sandwich.

2.4.4. Composite Coatings

The Cormer Group representatives requested that on top of the carbon fiber, a clear gel coating should be applied so as to reduce the probability of damage to the hardened fibers [2]. Minor damage could happen while the trailer is in motion, from impact of small pebbles to accidental scrapes with cars, trucks, animals, and more. As the primary requirement for the coating is to protect the fibers, the other parameters deemed as most important for the selection were a low cost, smooth finish, scratch/abrasion resistance, clear finish, simple application to the body, and waterproofing capabilities.

After filtering through numerous coatings using the previously stated parameters, the best coating found and recommended was determined to be an isophthalic spray-on gel coat used for composites [27]. Other coatings considered were polyurethane, paint, and polyester, but were rejected because of the method of application, lack of waterproofing, and weight. An acrylic spray-on clear coating used for cars was also considered, but rejected due to the fact that small pebbles may still damage the surface because of how thin the coating would be [28]. By applying several layers of a coating, waterproofing becomes possible for the carbon fiber body.

2.4.5. Composite Design for Structural Components

As a simple carbon fiber plate was selected for the structure of the body, the final structure for the walls and body could be determined. The first step taken for completing the general structure of the body was determining the thickness of the carbon fiber plating. From a bending stress analysis, a safety factor of 8 was used to assist with compensation for the anisotropic properties of the carbon fiber, compensate for the holes that weaken the structure, and provides a thickness suitable for a high rigidity.

The wall thickness determined most suitable for the body was 1/10", equivalent to approximately 7 layers of the [0,90] carbon fiber sheets. The lid on the other hand would use 5 layers in the same arrangement, as the structure does not undergo as much loading compared to the body. In addition to the verification with calculations (Refer to Appendix A), use of the recommended 5-7 sheets was decided upon due to recommendations for strength [14].

The final structure follows a quasi-isotropic arrangement of the seven layers of carbon fiber ([0,90], [45,-45], and so on) to be layered onto the aluminum mold. Once arranged on the mold, the structure is to be cured in Cormer's composite oven. After curing and cooling, the spray-on clear gel coating can be applied to the structure on the exterior once removed from the mold and processed. The final product for the body design, similar to the outcome of the lid, is illustrated in Figure 13.

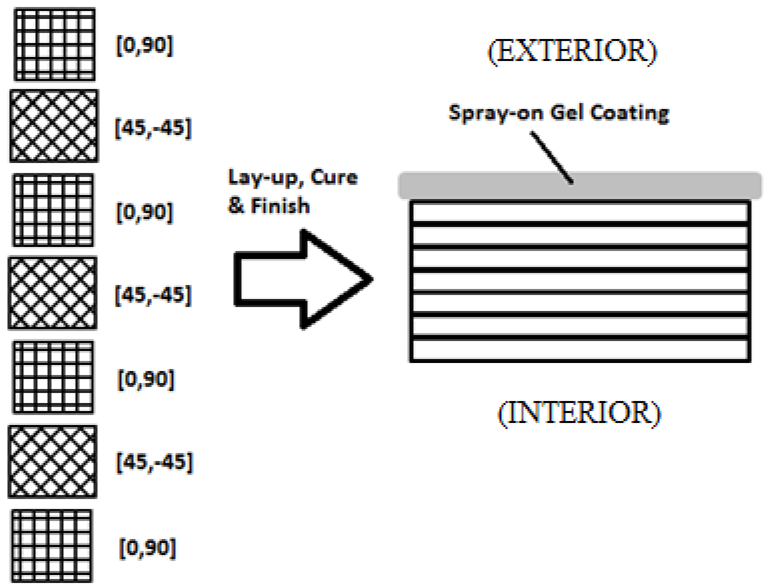

Figure 13: Composite structure for the body post-processing

2.5. Completion of the Body

Since the Bullet scored highest in durability and stability, its general shape was used as the starting point towards the final design. Its low center of gravity made it the most stable design while its solid connection to the frame gave the design its durability. In the Bullet design the carbon fiber body wrapped around the frame. This method provided a solid way to fix the body to the frame. This concept is illustrated below in Figure 14.

Figure 14: Illustration showing carbon fiber wrapping around square tubing on frame

Using this low center of gravity and mounting methods from the Bullet design, the team had an additional brainstorming session where we tried incorporating the best aspects of each body shape into a final design. Following numerous iterations of sketches, the team came to an agreement on a final design which incorporated some of the angles and edges from the Stealth Jet design with a tear drop shape rear end, shown in Figure 15 and Figure 16. The other sketches drawn-up during this brainstorming design session can be found in Appendix A.

Figure 15: Front and back view of final design based on integrating the best aspects of the Stealth Jet, the Bullet, and the Tear drop design

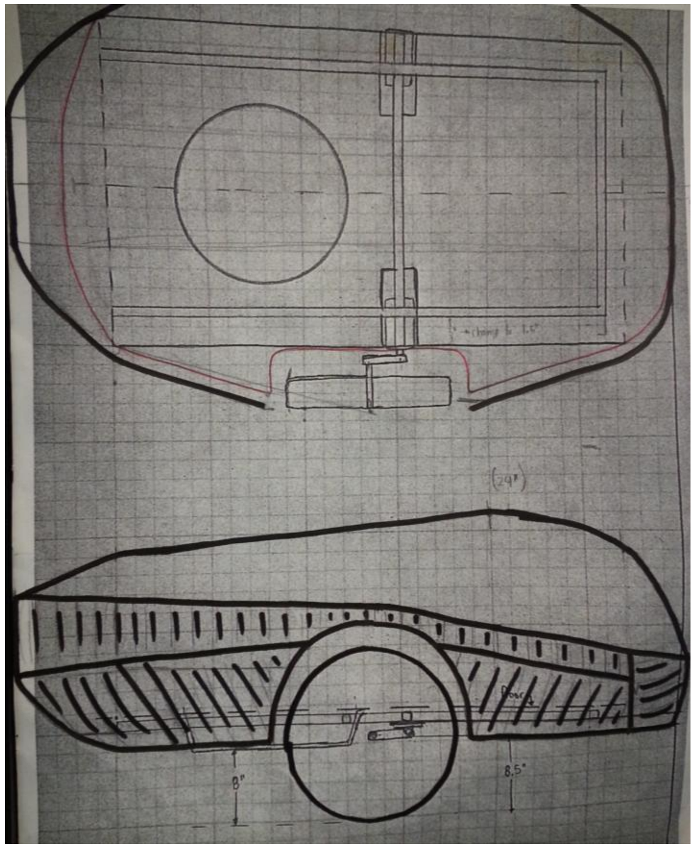

Figure 16: Top and side view of final design based on integrating the best aspects of the Stealth Jet, the Bullet, and the Tear drop design

Due to the complexity of all the different angles on the body, translating this final design into a three dimensional digital CAD model was proving itself difficult since it is challenging to visualize the final product. In light of this, a team member used plasticine to make a proportional 3D design of the trailer reflecting the final design sketches, accurate to about 5% of the overall dimensions. Pictures of the final plasticine model are illustrated in Figure 17.

Figure 17: Plasticine model of final body design.

This method gave the team a better visual of the design, prior to translating it into a 3D CAD model. Using the plasticine as a model also allowed for further refinement of the initial drawings, especially on the lid where little detail was placed originally. Following team approval, the model was designed in SolidWorks based off of the plasticine 3D model and combined with the chosen frame and suspension system. The final SolidWorks model of the final design is shown below.

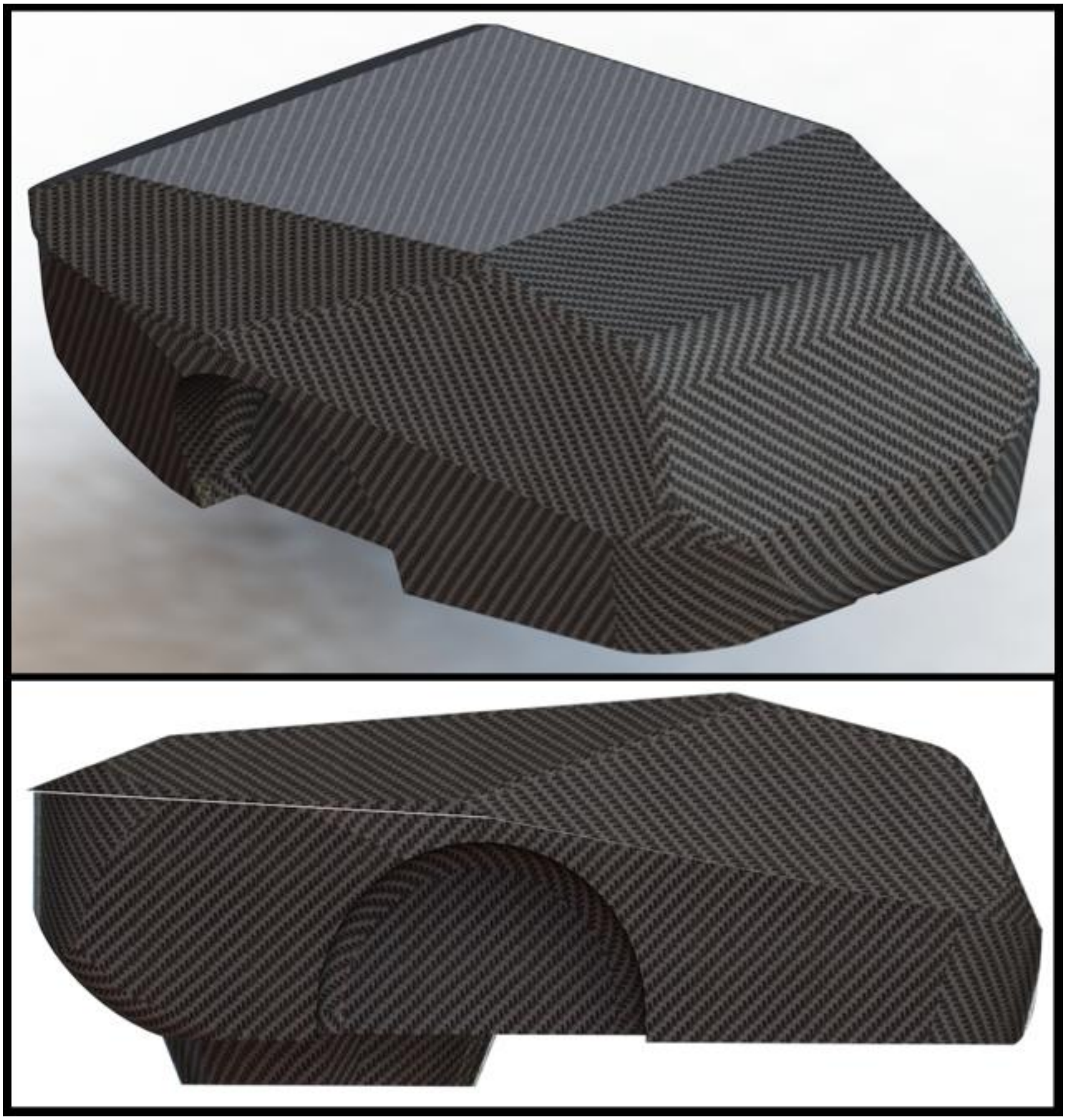

Figure 18: Renders of final body design.

As seen in figure 22, the final design of the trailer body closely reflects the plasticine molds. The major difference is the drop-down storage compartment for the spare tire, which wasn't shown in the molds. With this final design, we are confident that we have effectively combined the preferred features from the top three body concepts.

2.6. Mold Design

Prior to receiving a specified tooling material, several materials were recommended by Gethin James, a UMSAE Formula member, including multi-density fiberboard, uniform density fiberboard, fiberglass and aluminum [28]. Cormer's final decision following further communications on this material discussed was Aluminum 6061-T6 [29].

To reduce the overall cost and weight of the mold, the initial strategy of the team was to take advantage of the relatively flat surfaces used in the body design. This strategy became too complex due to the splines and curves joining these planes together, resulting in a design that the group deemed unfeasible for manufacture.

Further analysis deemed that the most feasible way to reduce manufacturing time and complexity of the design was to use Aluminum billets, using a CNC to produce the desired shape [29]. This would require the use of a 4 Axis CNC at minimum to develop, which is available at Cormer's facilities. Although this method is more expensive, this would ensure a smooth finish with high accuracy for multiple uses in its lifetime. With the reduction of pieces for the mold design, fewer inconsistencies in the carbon fiber layup where the billets connect would be evident once cured and hardened for the client.

To coat this mold, Frekote was also selected to provide a smooth finish to the composite part, especially at the seams where the mold blocks are placed together [30]. This smoothness is desired to improve the overall quality of the part. This coating also assists in the part removal, which would reduce the overall manufacturing time.

The current design for both molds consists of several machined aluminum billets, bolted together by the use of large brackets, and coated in Frekote on the interior. The mold for the base sits on a series of aluminum bars welded together, where this framework is bolted onto the main body mold. The total weight estimate is 3,000 ± 300 lbs for the body mold and 1600 ± 100 lbs for the lid mold, meaning that the pieces are not to be moved manually. It is recommended that these are transferred by forklift, or placed on a rolling platform for usage and storage.

The mold, requires minor assembly prior to layup. Once the coating is applied with the required films to remove the part, the carbon fiber could be laid up, as seen in Figure

19. Upon completion of curing, the part can be removed from the mold by slowly taking the mold apart, illustrated by Figure 20.

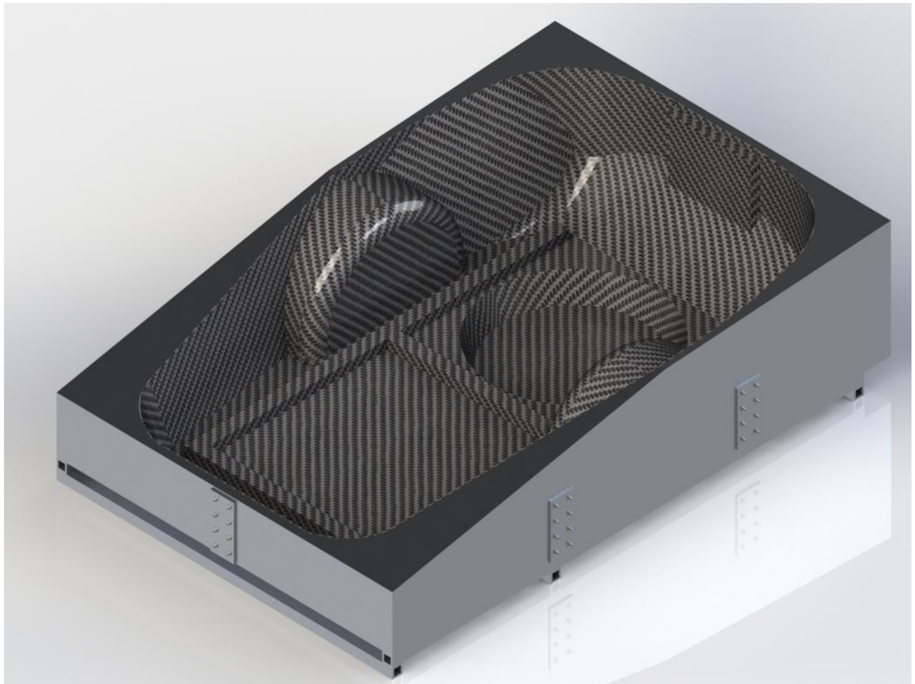

Figure 19: Part lay-up in assembled mold

Figure 20: Part removal upon completion of curing

In addition to the mold for the body section, a mold was developed for the lid. The designs are discussed further in the mold manufacturing process within section 6.1.1, where the procedure to develop these molds will be explained.

3. Final Design Analysis

Two significant sets of analyses were performed on the trailer to ensure that a stable design was developed. A computational fluid dynamics (CFD) analysis was performed on the bare trailer design, followed by a stress analysis on the structure of the frame.

3.1. Computational Fluid Dynamics Analysis

In order to ensure that the trailer design is aerodynamically stable, several flow simulations were performed for verification. Three different programs, including Solidworks' own *FloXpress* and *Flow Simulation*, in addition to *Star-CCM*, were used for verification of the aerodynamic stability. The group defined aerodynamic stability in this project as the symmetry of the pressure distribution across the body of the design for the straight forward motion in air, as well as down force present to ensure that the trailer is not bouncing around while in motion. Our main intentions with computational fluid dynamics (CFD) were to determine the drag force acting on the trailer, verify that lift is non-existent on the design, and to analyze the streamlines flowing around the body for symmetry. These were performed without a motorcycle in front to analyze the full force of air acting on the body.

The first CFD analysis used was with *FloXpress*, which though not intended for numerical data, was used to analyze the streamlines passing around the body. To analyze this, the body was placed on its own inside a box with air flowing from the front end of the box to the rear end at 40 mph. The results of this analysis have shown that greater velocities (indicated with the red colours) were existent along the top of the trailer than the bottom as seen in Figure 21 and Figure 22, which may indicate that lift exists in the design. As only a single trial was performed with *FloXpress*, this data on its own is not reliable, which is why the other flow simulation programs were used to assist in this analysis.

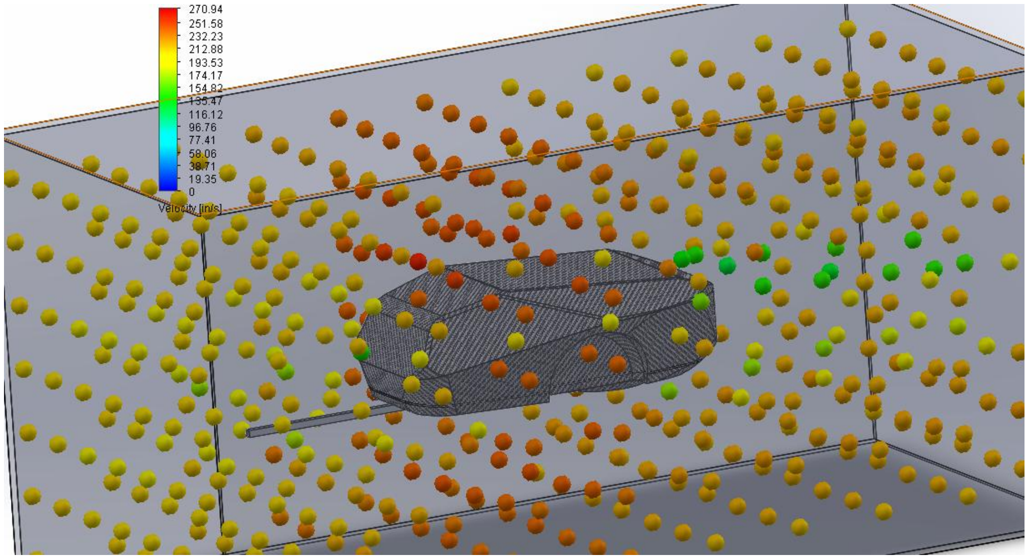

Figure 21: FloXpress CFD analysis illustrating flow with particles

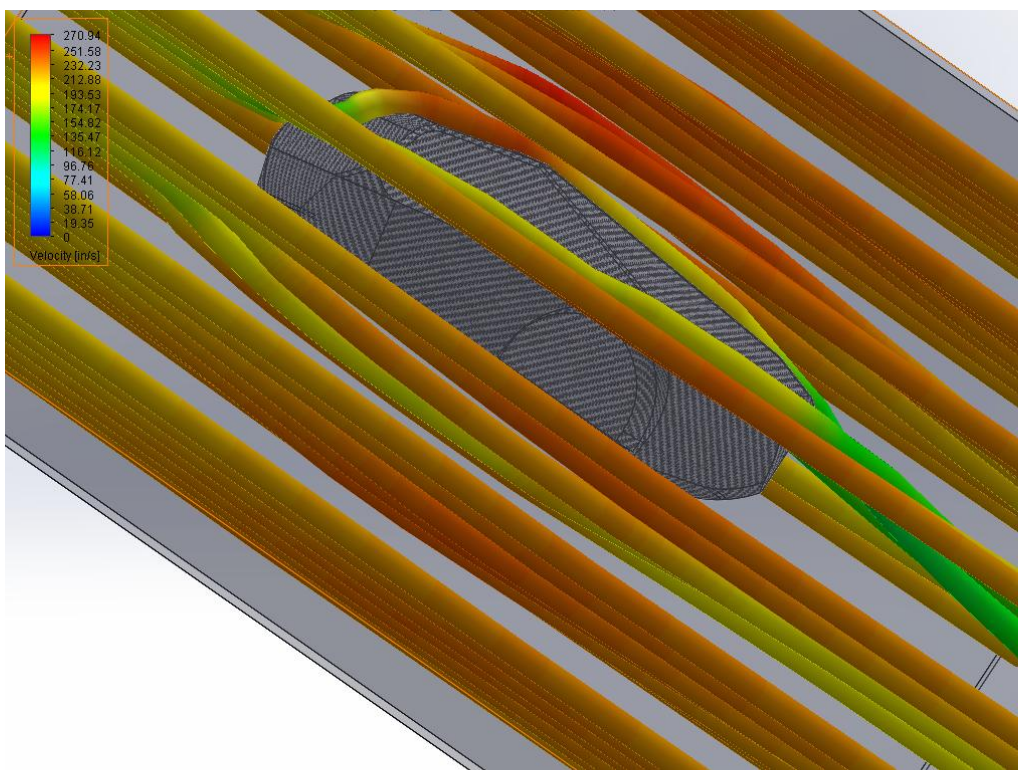

Figure 22: FloXpress CFD analysis illustrating flow with streamlines

Using the *Flow Simulator* package in SolidWorks, another CFD was performed to assist in further analysis. Using the same body, with the trailer this time travelling at 75 mph into static air, the flow analysis proved to be ineffective. As may be seen in Figure 23, similar paths for the streamlines can be seen when compared to the flow simulator. A low pressure area may also be seen following the trailer, illustrating the separation of air flow at the rear like in the previous CFD. Although this software is known to provide better results than *FloXpress*, the data still did not seem reasonable, since the pressures around the body did not vary.

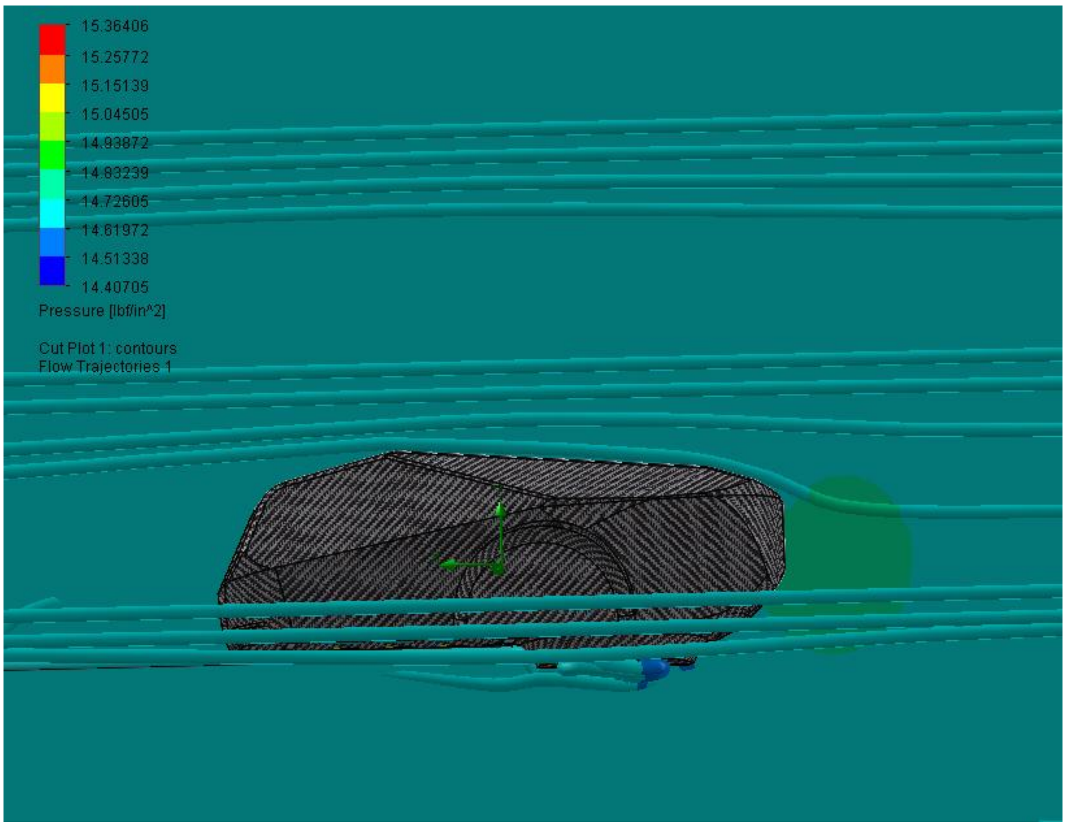

Figure 23: Solidwork's flow simulator CFD with pressure plane and streamlines

With assistance in analysis for the final CFD, the final trial was run using *Star-CCM* [31]. Using a fine meshing of 1 mm elements, the model was converted into a format useful for analysis as seen in Figure 24. An obvious change in this analysis would be the incorporation of wheels in the model. In this case, the flow parameters were for a trailer travelling at 75 mph into a headwind of 40 mph. The wheels were also simulated at a rotational speed of 630 rpm, for analysis of the turbulence formed in the wheel wells.

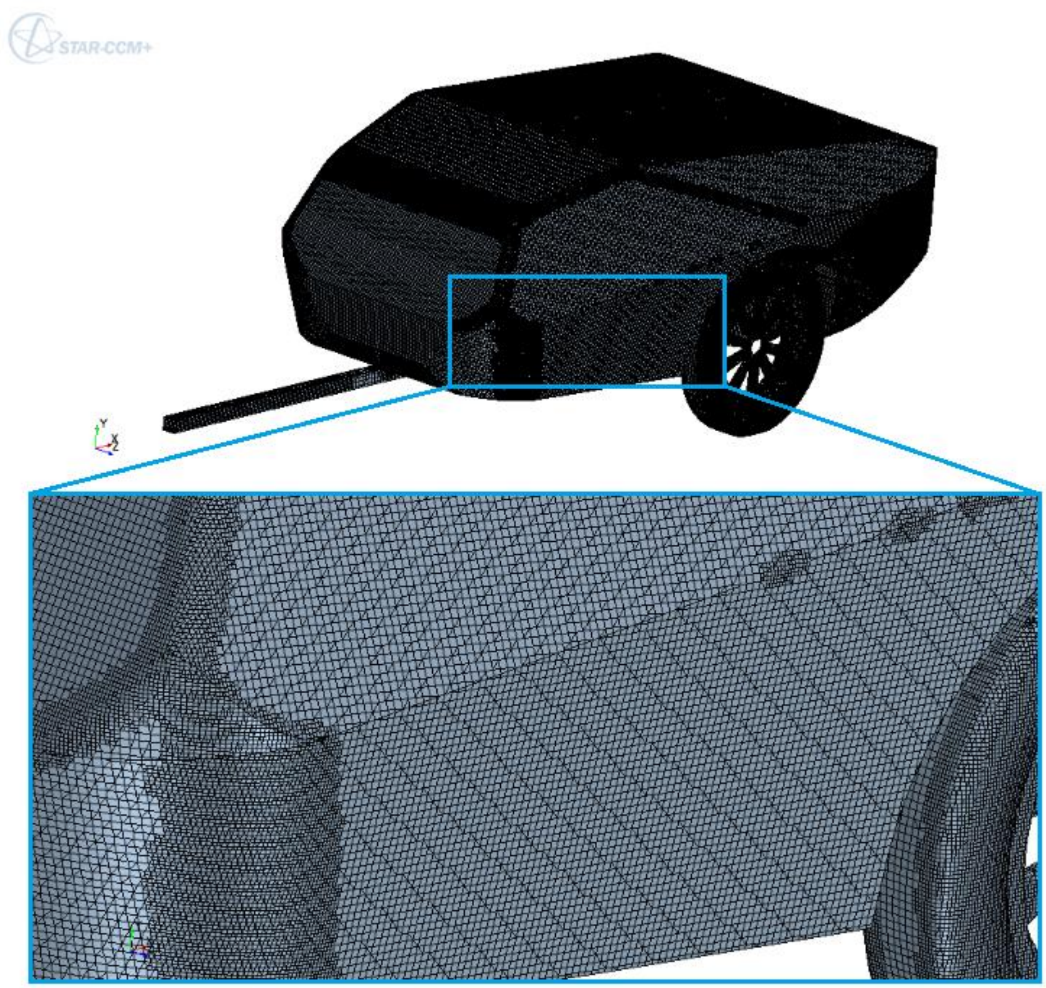

Figure 24: Star-CCM's model meshing for CFD

Running 295 iterations, the *Star-CCM* was able to converge its data to provide meaningful results. The streamlines seen in Figure 25 are illustrated more evidently with greater accuracy compared to the other two simulations run. As can be seen in this image, the front of the trailer seems to be pushing down the rest of the trailer, seen by the red high pressure lines. This pressure is more evident in the following picture, Figure 26, where the red surface indicates that the pressure is keeping the trailer down. The static pressure seems to decrease further as the flow underneath the trailer passes under the spare tire addition. These results seem to illustrate that a down-force is evident in the design, contrary to the first simulation.

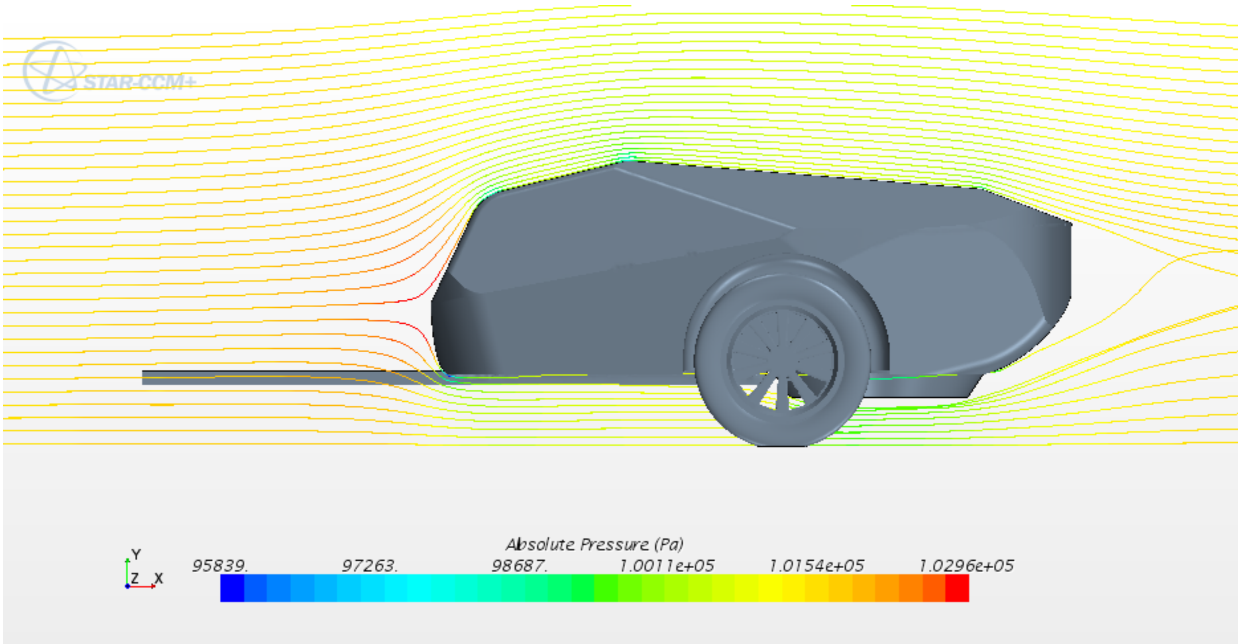

Figure 25: Star-CCM side view pressure distribution with streamlines

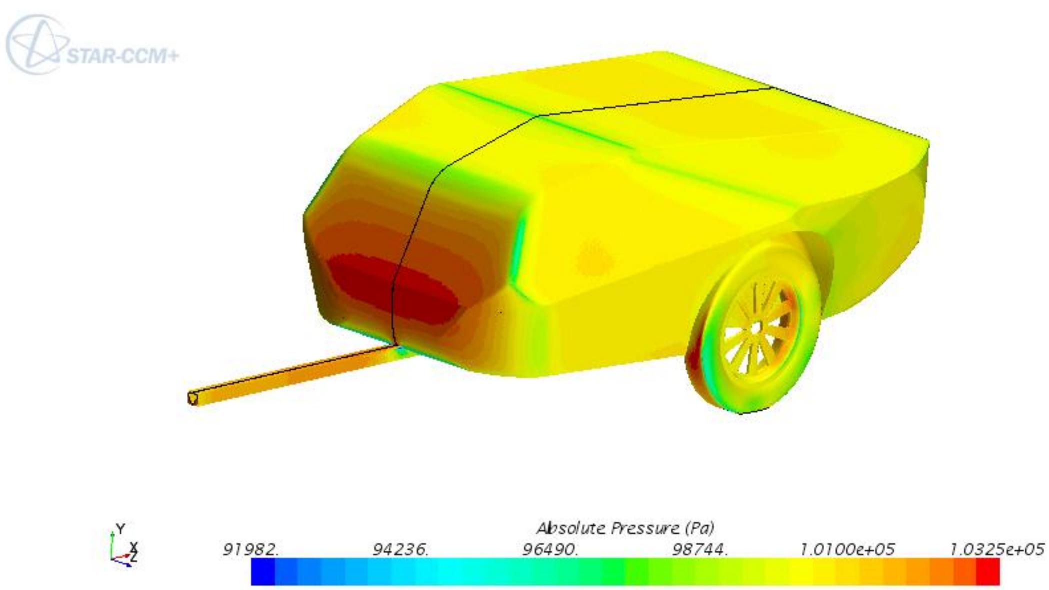

Figure 26: Star-CCM's surface pressure plot

Although the trailer was designed in the shape of an airfoil, the simulation shows that the design does not provide any lift. The total drag and lift that the data converged to was 117.8 and -18.8 lbf respectively, as can be seen in Figure 27. As illustrated in this graph, an approximation method was used by *Star-CCM* to approximate the final results. This information provided the group with the first objective of attaining the total drag force, and verifies that the second objective of an absence of lift was achieved, leading the group closer to an aerodynamically stable design.

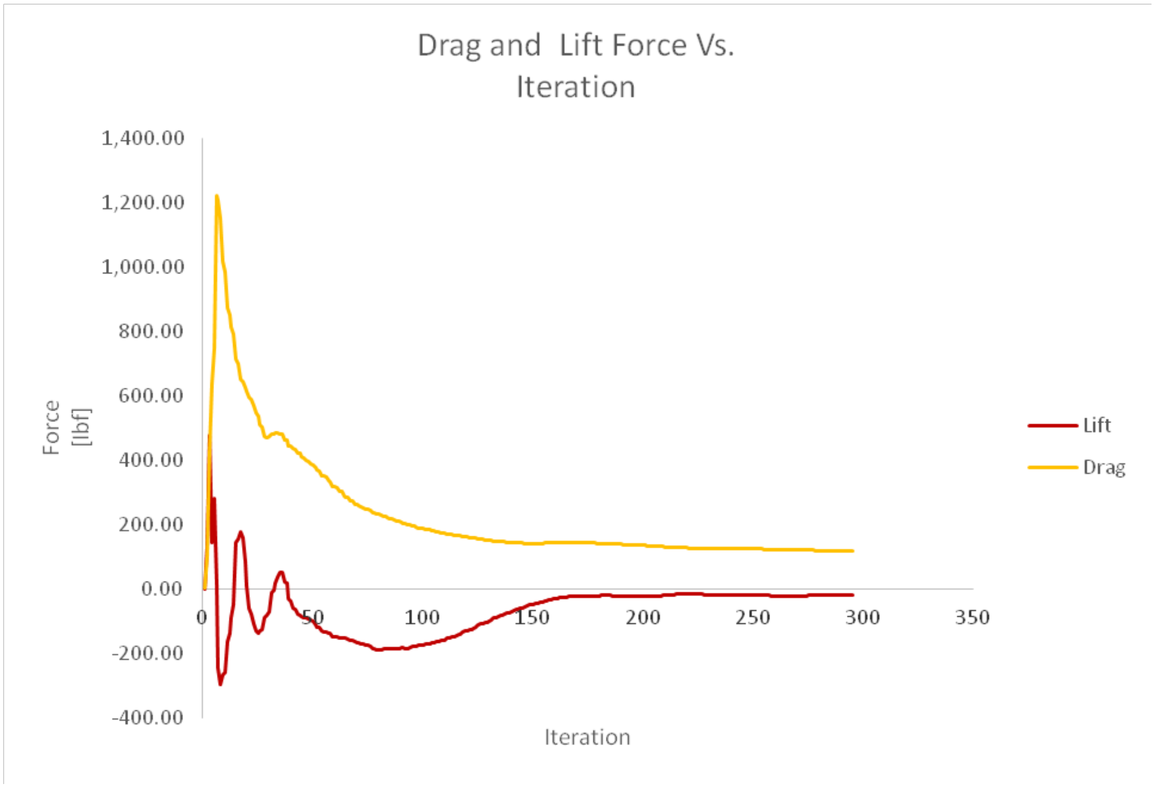

Figure 27: Convergence plot of drag and lift forces relative to the iteration

The third objective was to verify the symmetry about the trailer to ensure stability is kept while in motion, which can be seen in Figure 28 and Figure 29. With relatively constant and symmetric pressure distribution across the body, these figures assist with the verification of the trailer being an aerodynamically stable structure according to our previous definition.

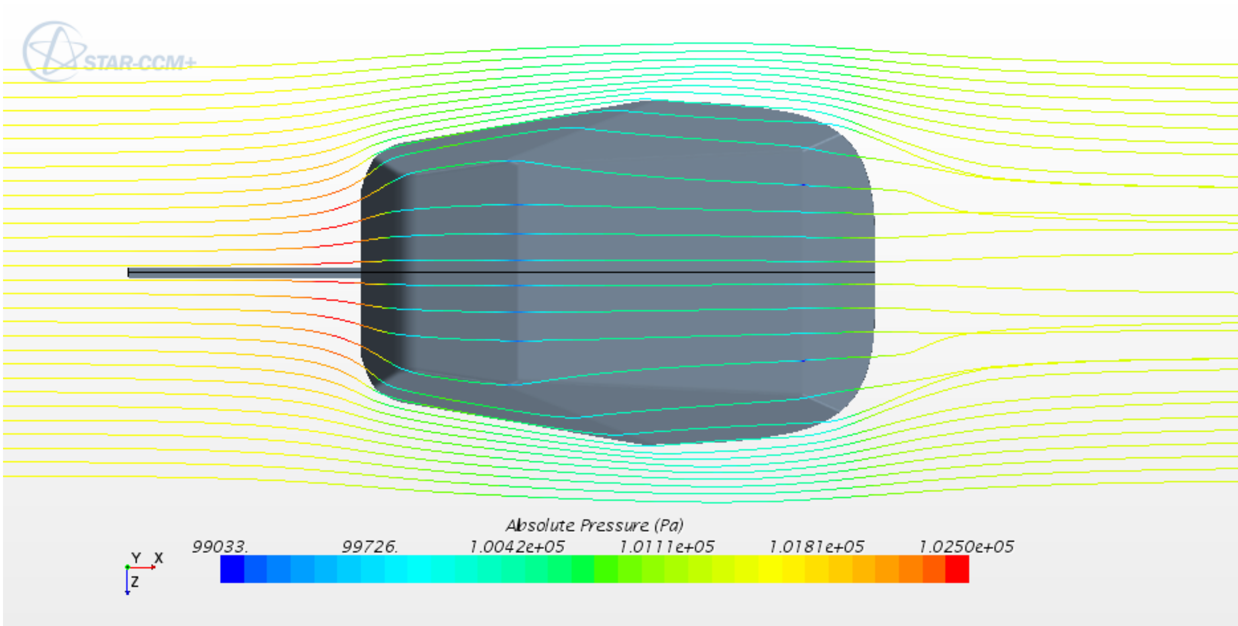

Figure 28: Star CCM's pressure distribution across the top of the trailer

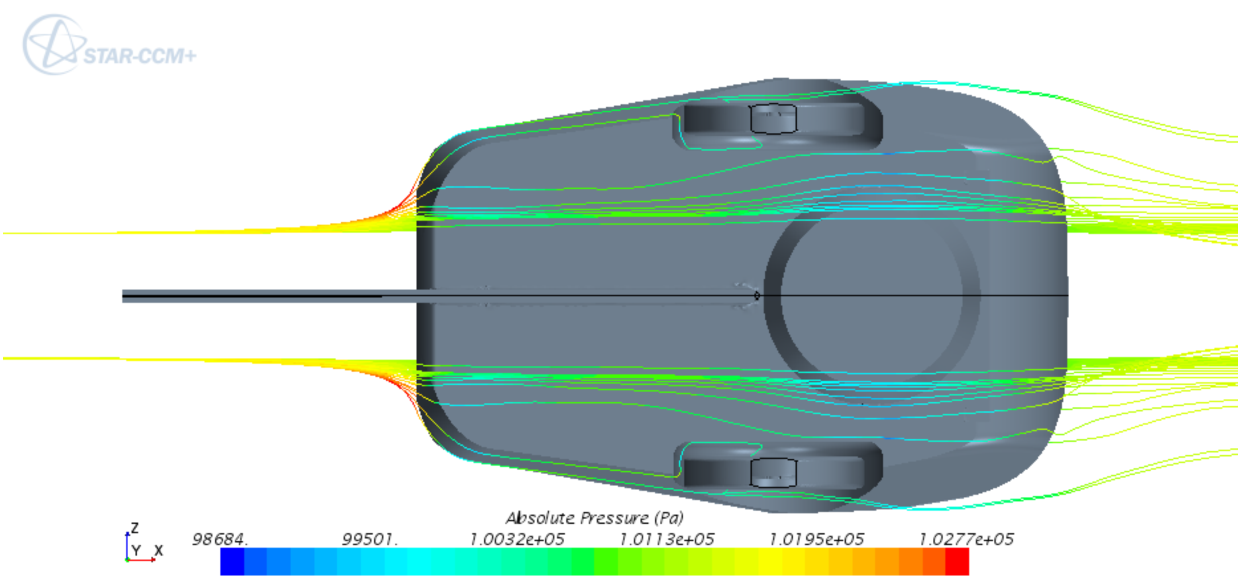

Figure 29: Star CCM's pressure distribution across the bottom of the trailer

Finally, the CFD was analyzed around the rotating wheels. The group originally designed the wheel wells to extend lower than the axle of the wheels to reduce the turbulence and air flow around the top half of the wheel, which can be seen in Figure 30.

As predicted, the flow around the top half of the rotating wheel was turbulent, with higher pressures located near the front of the wheel. With this result, the group decided that the wheel wells are located at an optimal height, and any additional changes (if desired) should use a cover around the wheels, or just a lower wheel-well.

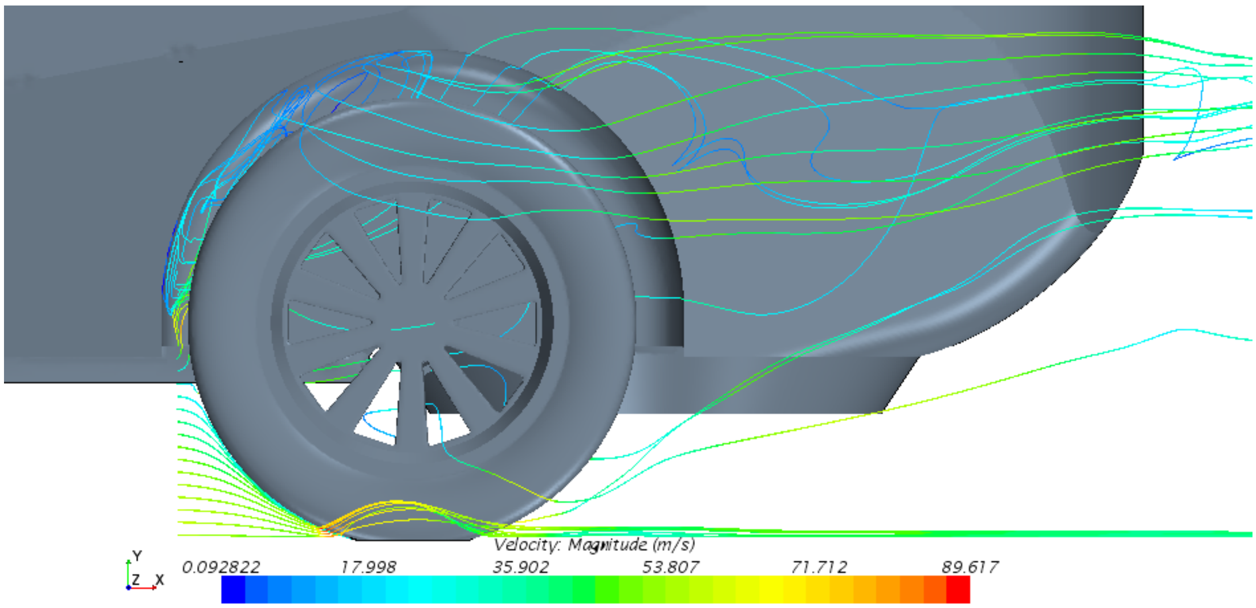

Figure 30: Star-CCM's simulation of flow distribution across the rotating wheel

3.2. Stress Analysis

A stress analysis was performed on the frame to ensure a lasting and durable design as well as to confirm an optimal square tube cross section and thickness. High stresses could cause failure, especially when subject to cyclic loading of a bumpy road. The team recommends doing a complete fatigue analysis following the production of the first prototype. This could be done by mounting an accelerometer on to the frame of the trailer and test out what additional accelerations are added due to the road roughness and bumps. Because this data was unavailable to us, a simple stress analysis was performed on the frame model to see how high or low the stresses are compared to the yield stress and endurance limit of aluminum 6061-T6.

Using a maximum trailer capacity of 350 lbs, a simple FEA was performed in SolidWorks to get an idea of the stresses throughout the frame structure. The results from the FEA stress simulation are shown in Figure 31, where the frame is fixed at the hitch and the two axles, and the load is distributed along the areas where the body should be.

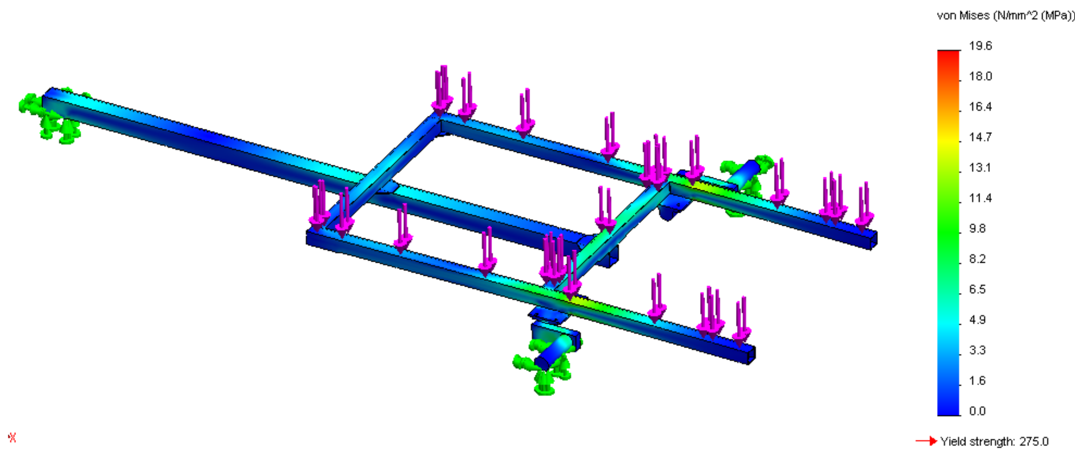

Figure 31: Static stress analysis of the proposed frame with 1650 N (350 lbs) of force spread out evenly across the frame

This first result shows the cargo spread out over whole trailer body. The maximum stress shown using this loading condition is 19.6 MPa. Additionally, a worst case scenario loading was also done where all the cargo is place in the center of the trailer. The stress plot of this loading condition is shown below.

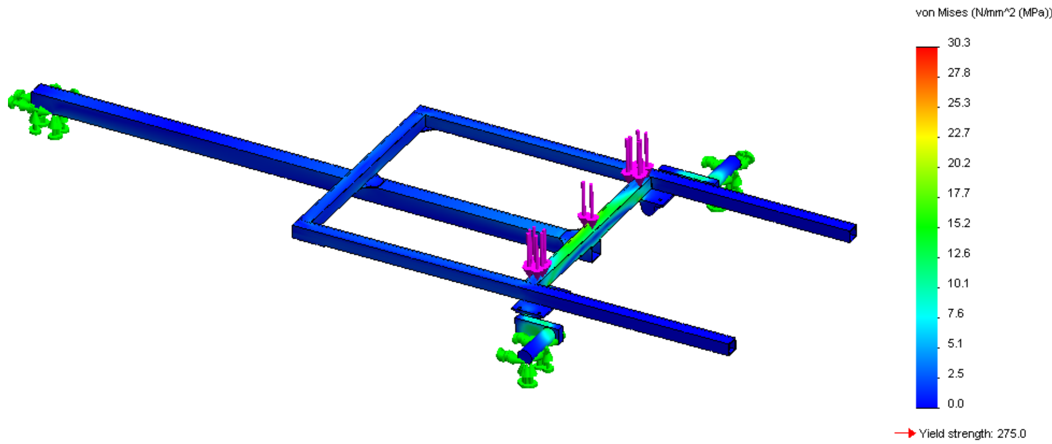

Figure 32: Static stress analysis of 1560 N of force on the center support beam of the trailer

The maximum stress in the frame using the worst case scenario loading condition is 30.3 MPa. The endurance strength of 6061-T6 is 97 MPa [32]. Using the worst case scenario, the frame is has a safety factor of over 3 on the endurance limit and a safety factor of 8 for the yield strength of the material. Based on these results, we have chosen to move forward with this frame design, but still recommend further fatigue testing to be performed on the prototype before moving into mass production.

4. Final Component Selection and Outsourcing

Following the finalization of the body, frame, and suspension system, the remainder of all parts needed to complete the trailer were researched and outsourced. The outsourced parts fall into several categories, namely the wheels, hatch components, lighting, wiring, interior design, aluminum frame, and composite materials. The section concludes with a summary of each of the outsourced parts, their sources and associated costs.

4.1. Wheels

Many tire and wheel combinations were evaluated for our trailer as it is important that the trailer ride smoothly, and be aesthetically pleasing. The most important factors to be considered for ride quality are the outer diameter of the tire, the stiffness, and the mass of the wheel. The outer diameter should be large so that bumps and small cracks in the road are comparatively small, minimizing their effect. The stiffness of a tire is largely controlled by the inflation pressure, however, the tire side wall impacts the stiffness since it acts a spring as well, generally increasing the side wall depth, or the aspect ratio of the tire reduces stiffness.

Finally it is important to reduce unsprung mass in order to improve the ride. This is important because the wheel is in contact with the road causing it to follow the bumps in the road. Since the vertical motion of the tire is dictated by the road, we can think of it as being one mass in a 2 mass spring system in which a bump would be a step input deflection on the wheel mass. By minimizing the wheel mass, we also minimize the resulting forces in the system. Since the air filled tire is lighter than the metal rim, the mass of the wheel assembly can be reduced by using smaller rims with a larger tire section. This also reduces the stiffness of the tire while allowing us to maintain a large tire outer diameter.

Other requirements of the wheel assembly included the tire section width and appearance of the wheel assembly. We wanted a small tire section width to reduce the overall width of the trailer while maintaining our interior capacity, as well as reducing our rolling resistance. We considered many options in sourcing this wheel, including motorcycle wheels, drag racing wheels, and temporary tires.

The first option we considered for wheels was the basic motorcycle wheel, because the most common wheels used on similar products, such as the Bushtec brand trailers, are motorcycle tires on a modified motorcycle rim. This option was ruled out due to the incompatibility of our design with off the shelf products, which meant that anything we sourced would have to be made custom, at an estimated cost of $1600 a pair[33].

Drag racing style front tires (non-driven) also looked promising as they were available in sizes that were compatible with the spindles on the suspension we sourced; however, upon further research we discovered that these tires were not legal for use on public roads, and were only meant for private race tracks.

Temporary compact tires, or “donut” tires were considered for their narrow section width and smaller overall diameter however, this type of tire is not rated for permanent use. With these more specialized products ruled out, we looked at more standard rims made for trailers which are largely of steel construction for their strength and low cost however, this means that trailer rims are often heavy, and overbuilt for our application. After extensive searching for an appropriately sized wheel for our trailer, an aluminum rim with a Kenda light-trailer tire assembly was found that met our needs at a reasonable price.

The final wheel assembly we sourced is a Kenda 4.80-12 Bias Ply trailer tire mounted to an Americana 5-Star 12”x4” aluminum trailer rim with a 4 on 4” bolt pattern. The assembly is sourced from etrailer.com and has a retail price of $139.95 [34].

4.2. Hatch Components

Several components needed to be sourced to open the lid of the trailer, seal the compartment from the elements, and latch the lid closed. These components include the hinges, gas springs, weather stripping and the latch.

4.2.1. Hinges

Many hinge solutions were considered for our trailer opening mechanism, including the option of custom designed parts. We decided that the main requirements for the hinge would include the capability to support the weight of the trailer lid and cross wind forces. Additionally, a range of motion allowing the lid to open without interferences between lid and lower body shell was desired. In order to reduce complexity of manufacturing, we decided to try to source a hinge assembly before attempting to design a custom solution. In order to meet our loading requirement, full size door hinges were considered as they are designed to carry substantial loads however, in order achieve the range of motion desired to maintain clearance between the edges of the trailer body and the lid we found that a concealed type hinge would be the best fit. Upon further research we narrowed the results down to three primary options including the SOSS invisible hinge, the PINET concealed hinge, Roton geared hinge, as well as the SPEP continuous hinge.

The SOSS invisible hinge is made to be concealed in the gap of the door jam and features a 180 degree range of motion; Figure 33 below shows the hinge fully open.

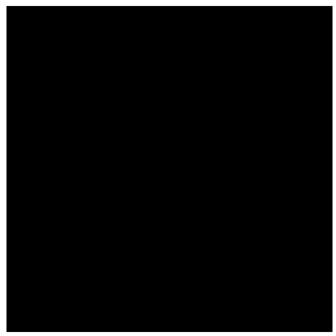

Figure 33 SOSS invisible hinge model #218FR [35]

The next hinge we considered is better suited to our application allowing for a better range of motion for the lid as shown in Figure 34. The problem with this hinge is that the supplier doesnt have any distributors in North America. There is one European distributor which will ship to Canada, however shipping costs ruled this product out.

Figure 34: PINET concealed hinge [36]

We found a problem mounting both of these concealed hinges to the trailer, in a way that they would sufficiently spread the loads into the carbon fiber shells. This led us to look at continuous style hinges which would run along the entire length of the edges where they are mounted. This concept would simplify the design, eliminating the need for a complex mounting bracket. In order to preserve the range of motion in the hinge, we considered a Roton® continuous geared hinge, shown in Figure 35, which consists of extruded gears which roll against each other to provide the hinge motion.

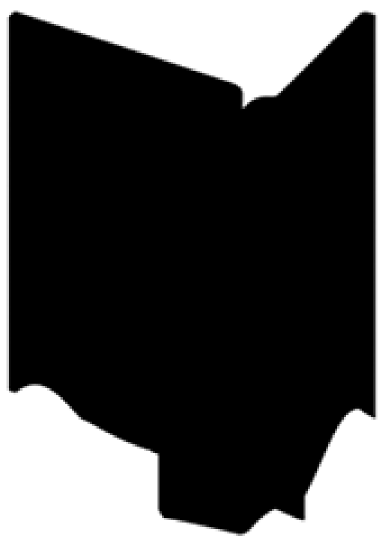

Figure 35: Roton® continuous geared hinge [37]

However this hinge is relatively expensive, and posed problems in the form of an awkward gap at the hinge joint. In the process of trying to solve the problems with this geared hinge we found a solution which would work with a standard butt-joint continuous-hinge, both requiring only minor modifications to the assembly of the hinge. A rendering of the hinges, before and after the modification are shown in Figure 36.

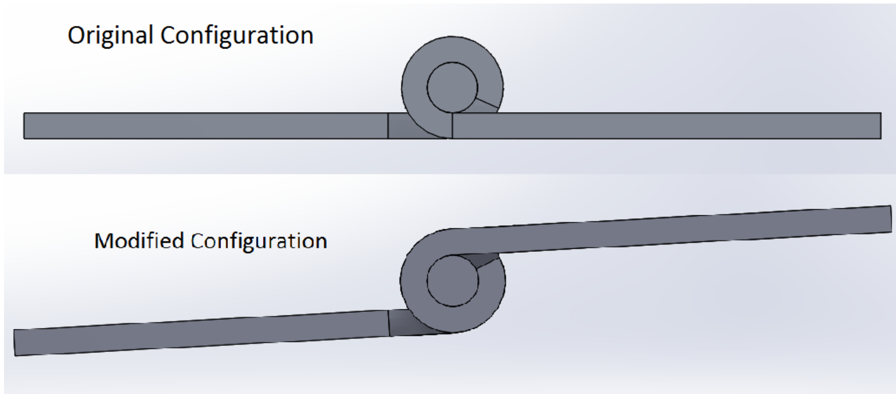

Figure 36: Hinge modification

This part was found through the SolidWorks content central site and is sourced from the same supplier used for the latch assembly, which simplifies part ordering. The final hinge assembly is from Sierra Pacific Engineering and Products, product code A15032, with a slight modification made to the arrangement, which is detailed above in Figure 36. Dimensioned drawings of this hinge from the manufacturer in Figure 37 below, show that the hinge measures 5” wide when opened flat. This spreads the contact with the carbon fiber shell.

Figure 37: SPEP continuous hinge model A15032 [38]

4.2.2. HATCH LIFT PISTONS

In order to aid with lifting the lid, as well as keeping it fully open during loading/unloading we decided that a gas spring piston assembly would be required. The Stabilus 1436EI was chosen based on the lifting force capacity, the stroke and sizing and options for distributors and the availability of models for use in our assembly. The spring consists of a pressurized cylinder which applies force to the piston assembly, and also features hydraulic oil damping to regulate the speed with which the lid will can be opened or closed. A rendering of the cylinder is shown in Figure 38 below.

Figure 38: Stabilus gas spring model 1436EI [39]

This piston has a stroke of 250 mm, an extended length of 585 mm and applies a force of 300N. With 2 springs mounted near the hinge, they are capable of resisting reasonable wind forces on the lid, while requiring less than 90N force at top edge to close. These springs are mounted to 10mm ball studs sourced from the same distributor as the springs themselves. They provide a larger surface area to attach the springs to the carbon fiber shell. This ball-stud assembly is shown in Figure 39 below.

Figure 39: TCH 10mm ball stud model 530-103800[40]

These brackets can be attached to the carbon fiber body panels via a 2 part epoxy adhesive.

4.2.3. Weather Stripping

We decided that a rubber weather stripping product would be used along the edge of the shells where the lid meets the trailer body in order to seal the trailer compartment from the elements. In order to seal this opening we created an offset in between the lid and the body for the weather-strip to be pressed into contact and form a seal.

The TRIM-LOK trim seal product was chosen for its durability, and compatibility with our design[41]. For edge of the lower body shell we chose the “top-bulb” style product, shown in Figure 40; it features a foam rubber “bulb” on the leading edge to make contact with the interior edge of the lid.

Figure 40: TRIM LOK trim seal with top-bulb profile [41]

The stripping for the lid is another TRIM LOK product, however since the lid will overlap the edge of the lower body we have chosen a side-bulb style product shown in Figure 41[42]. This arrangement creates a more seamless appearance while creating a seal between the two edges.

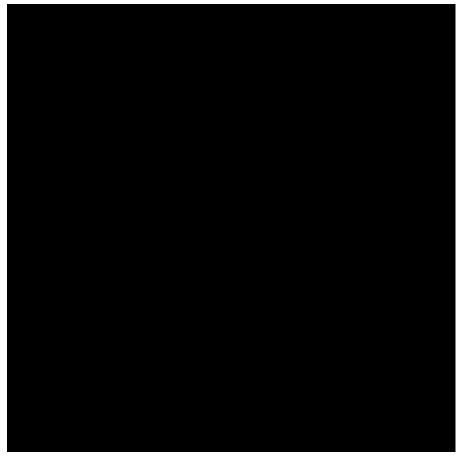

Figure 41: TRIM LOK trim seal side-bulb profile [42]

Both upper and lower strips are sourced from Grainger, having product codes, 10D053 and 10D059, respectively.

4.2.4. LATCH

We determined several requirements for the latching mechanism for the trailer. It must not protrude more than 2 inches inside the trailer to keep it out of the way, and it must not protrude more than ¼ inches from the outside of the trailer to reduce aerodynamic drag. The latch should also be lockable, and should latch automatically when the lid is slammed shut.

In the case of latches, there is a significant library of products available on the SolidWorks online supplier content portal. A wide variety of latches were considered from this selection. From these, we selected this latch from sierra pacific for its low profile, simple design, and the compatibility with our trailer lid design. The latch is sourced from the same manufacturer as the hinge which simplifies sourcing. Our final latch is shown in Figure 42

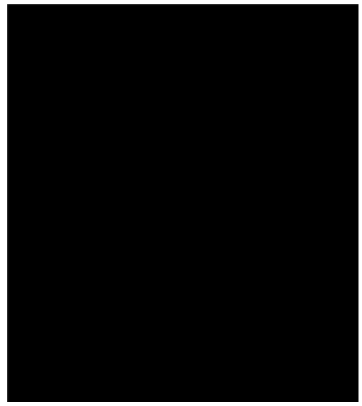

Figure 42 Locking slam latch with handle SPEP model # 6-10BKCH751 [38]

This latch can be installed easily into the carbon fiber, with its round design which eliminates the need for complex cutting.

4.3. Lighting

The brake and turning lights for this trailer consist of four Optronics GLOLight LED lights, which combine the stop and turn tail functions. This light, which is shown in the figure below, also meets DOT FMVSS 108/SAE requirements [43].

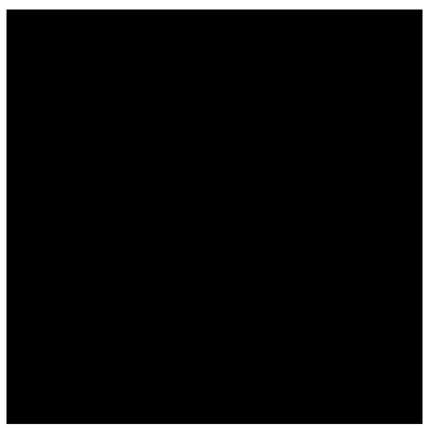

Figure 43: Optronics GLOLight LED tail light [43]

These taillights feature LED lights housed behind a durable polycarbonate lens that is engineered for maximum clearness. The outer band of red LEDs functions as a tail light and brightens when the brakes are applied. The center red LEDs illuminate for turning and braking. These lights are rated for 12.8V, and are sourced from eTrailer.com for $22.95

each. This type of light requires a 4'' (inner diameter) rubber grommet for installation, which is also sourced from eTrailer for $0.95**[43]**.

The side marker lights for this trailer consist of rectangular Optronic LED Miro-Flex® lights with the dimensions 2-1/2" L x 1-3/16" W x 1" D. Following the federal lighting location requirements, the trailer features a red light on each side behind the wheels of the trailer (near the rear) and a yellow light on each side in front of the wheels of the trailer[44]. These marker lights are designed to increase visibility of the trailer and are always on whenever the trailer is in use. These lights meet all DOT and SAE requirements and are shown in Figure 44.

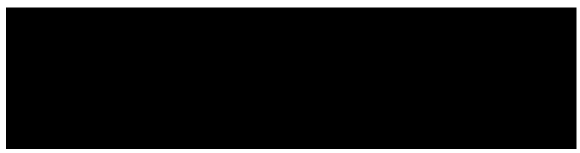

Figure 44: Optronics Trailer LED Marker Lights [43]

These marker lights feature three LEDs per light with built-in reflectors that spread the light for maximum visibility. The LEDs and reflectors are housed behind a durable polycarbonate lens. The lights were sourced from eTrailer.com for $6.25 each [43].

In order to meet the federal lighting requirements for the license plate [2], the trailer features a TecNiq DOT compliant license plate lamp. This white LED light (shown in the Figure 45) consists of a single piece waterproof lens and a black polymer housing. The light is designed to be mounted directly above the license plate.

Figure 45: TecNiq license plate lamp [45]

This LED light operates on 12 VDC (0.03 Amps), and has a lifespan of 50,000 hours. This light was sourced from TruckNTow.com for $12.99 per light [45].

The interior compartment lighting for this trailer consists of a Slimlite LED Courtesy Lamp with dimension 13.75" L x 1.17" W x 0.938" D. This light features white LED lights that uses 12 VDC (0.23 Amps), and are housed behind a sturdy polycarbonate lens. This light comes with the option of a built-in power switch, which can be seen as the top light in Figure 46.

Figure 46: Slimlite LED courtesy lamp [46]

This interior light (with the power-switch) was sourced from TruckNTow.com for $48.99 each [46].

4.4. WIRING & WIRING HARNESS

The wiring for the trailer consists of Deka jacketed 4-wire. This wiring package features four 16-gauge general-purpose primary wires in a PVC jacket. The wire is sourced from eTrailer at $0.57 per foot [47]. With regards to a wiring harness, a Wesbar 4-Pole Flat Connector was sourced from eTrailer for $11.99 [48]. This wiring harness is shown in the Figure 47. The combination of these two provides an optimal electrical output for the trailer design.

Figure 47: 4-Pole wiring harness [43]

4.5. INTERIOR DESIGN

The interior components for the trailer design include the interior lining and flooring. Within the trailer, a 12 V outlet is located along the front corner for accessory power.

4.5.1. INTERIOR LINING MATERIAL

The entire trailer was designed to be lined in a standard non-woven vehicle trunk lining. This fabric is made of Polypropylene, which is stain, rot, and mildew resistant. Shear Perfection Upholstery out of Winnipeg will source the fabric from their supplier and the price will be included in their total upholstery cost.

4.5.2. FLOORING MATERIAL

The floor of the trailer consists of a 0.25’’ thick sheet of Acrylonitrile Butadiene Styrene (ABS) plastic. This type of plastic has high rigidity, toughness, impact strength, creep resistance and chemical resistance. It is easily thermoformed resulting with excellent mold detail. It is easily machined, die cut, routed, sanded, buffed and polished. Typical applications for this material include vehicle instrument panels, motorcycle fairings, and luggage shells. This part was sourced from Johnston Industrial Plastics facility located here in Winnipeg. This facility does not provide custom cutting and machining, therefore Cormer will be required to cut the material to the proper dimensions [49].

4.5.3. 12-VOLT OUTLET

A 12-Volt power supply socket will be fastened to the floor in the front corner of the trailer. This product features a plastic cap to keep dust, dirt, and debris from entering the socket. This outlet was sourced from Enns Brothers Winnipeg for $2.99 and is shown in the figure below [50].

Figure 48: 12-Volt power outlet [50]

4.6. ALUMINUM FRAME

The assembled frame consists of 6061-T6 Aluminum square tubing, gussets, tongue mounting plates, and two steel mounting plates for the suspension. The amount of material used per trailer frame is summarized in TABLE XVII.

TABLE XVII: ALUMINUM FRAME CUT LIST

Component	Quantity	Dimensions	Thickness
Side Tube	2	1.5"W x 1.5"H x 54.5"L	0.125"
Cross Tube	2	1.5"W x 1.5"H x 25"L	0.125"
Tongue Tube	1	2" W x 2" H x 62" L	0.125"
Front Corner Gusset	2	Refer to figure X1	0.125"
Front Center Mounting Plate	1	Refer to figure X2	0.125"
Rear Center Mounting Plate	1	Refer to figure X3	0.125"
Suspension Mounting Plate	2	6" W x 4" H	0.1875"

The following figures give the dimensions for the corner gussets, and front and rear center mounting plates for the tongue.

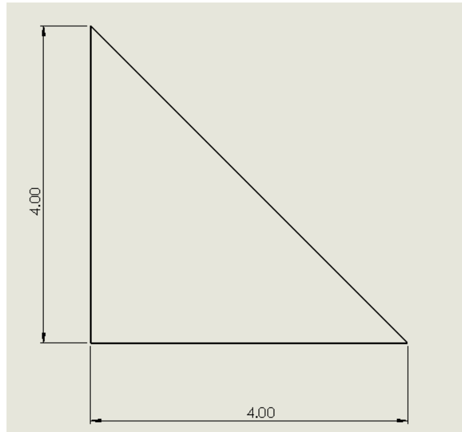

Figure 49: Front corner gusset dimensions.

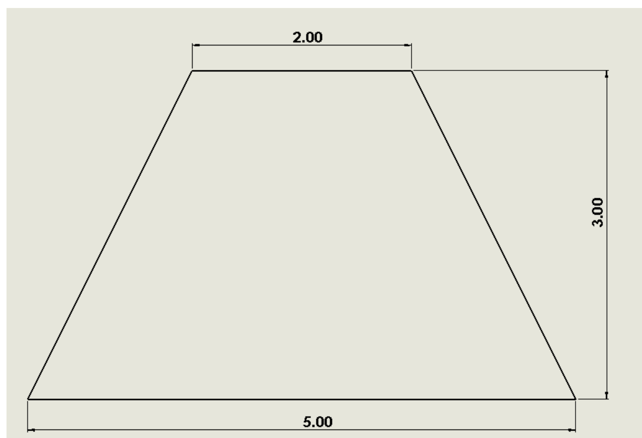

Figure 50: Front center mounting plate dimensions

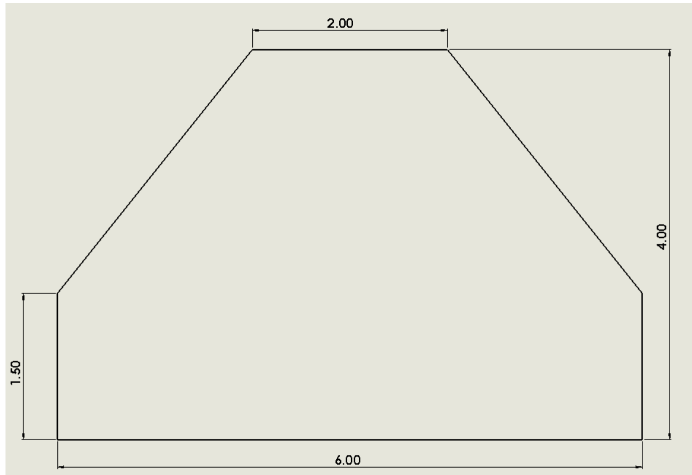

Figure 51: Rear center mounting plate dimensions

The total amount of material for the different frame geometries along with the cost for one trailer is given in the following table. These materials are sourced from Russell Metals.

TABLE XVIII: FRAME MATERIAL REQUIRED PER TRAILER [51]

Material	Total Amount	Cost
1.5" Square Tubing	159 in.	$25.44
2" Square Tubing	70 in.	$18.99
0.125" Thick Aluminum Plating	37.5 in.^{2}	$2.50

4.7. Summary of Outsourced Components

The extensive list of sourced parts for the trailer along with the cost of each is given in the following table.

TABLE XIX: OUTSOURCED COMPONENT COSTS

Trailer Components	Cost	Source
For Frame		
6061 Aluminum 1.5"x1.5" x 1/8" square tubing	$26.88	[51]
6061 Aluminum 2" x 2" x 1/8" square tubing	$18.00	[51]
6061 Aluminum 4' x 8' x 3/16" plates	$1.55	[51]
6061 Aluminum 4' x 8' x 1/8" plates	$2.50	[51]
Sponge seating plates	$22.73	[52]
For Trailer Body		
Clear Gel Coat	$167.47	
1/8" 6061Aluminum seating plates	$13.00	[51]
Latch	$8.94	[32]
Hinge[30]	$5.65	[30]
Gas Piston [31]	$32.54	[31]
Ball Stud [32]	$2.85	[32]
Weather Stripping Top [33]	$45.72	[33]
Weather Stripping Bottom [33]	$39.18	[33]
Lid Hinge Mounting Plate	$2.50	[51]
Base Hinge Mounting Plate	$1.93	[51]
1/4" 48" x 96" ABS Sheet for Floor	$107.80	[49]
Interior Upholstering	$372.90	[53]
For Lighting and Electrical		
Taillight with grommet [26]	$95.60	[26]
Side Marker Light with mounting bracket [26]	$34.58	[26]
License Plate Light	$29.36	[45]
Interior Light	$110.72	[46]
4-pole wiring harness [26]	$16.94	[26]
Bonded 4-wire (0.57$/foot) [26]	$9.70	[26]
3-wire Pigtail [26]	$5.20	[26]
Quick Splice Wire Connectors [26]	$8.70	[26]
Fasteners		
5/16-24 x 1 " HEX bolts	$1.36	[54]
5/16-24 HEX lock nuts	$0.45	[54]
0.25" x .67' Length' rivets	$1.76	[55]
#10-32 HEX nut	$0.36	[54]
#10-32 x 0.75 Torx Security Bolts for	$3.16	[56]

hinge		
1/4-20 x 2.75 " HEX bolts	$0.57	[54]
1/4-20 HEX nuts	$0.11	[54]
1/4 " washer	$0.27	[57]
#8-32x1/2" machine screws	$0.90	[58]
#8-32 hex lock nuts	$0.68	[59]
#8 washers	$0.27	[60]
Miscellaneous		
Flexiride Torsion Suspension (both sides)	$279.63	[9]
Alloy Wheels (with Kenda tires)	$474.43	[34]
Swivel Hitch	$200.00	[61]
48” Safety Chain with 7/16” Hooks	$7.99	[62]
Total	$2,154.25	

As shown in the TABLE XIX, the total cost for sourced components is $2154.25. This relates to the cost required for each individual trailer. Two items that were also sourced include the Loctite H8000 adhesive and Model G100-6 Spray Gun Tip for $141.25 [63] and $183.84 [64], respectively. Since it is unclear how long these items will last before being replaced, they were not included in TABLE XIX.

5. FAILURE MODE AND EFFECTS ANALYSIS

An analysis was developed focus primarily on the design failure modes was developed, in order to discuss the risks associated and acknowledged with the composite trailer design. Each failure mode was provided with a severity, frequency and detection rating, each used to develop the risk priority number. The rating system used may be found in TABLE XX, where each rating range was assigned a definition to assist with the FMEA development.

TABLE XX: FMEA RATING SYSTEM

Rating	Severity of Failure Mode	Frequency of Failure Scale	Detection Scale
1-3	Minor	Rare	Controlled
4-7	Considerable	Often	Noticeable
8-10	Catastrophic	Unavoidable	Undetectable

With the assistance of the ratings to assign the severity, frequency and detection to each failure mode, a compiled list was developed to assess the primary risks associated to the design of the trailer. This list may be seen in TABLE XXI, organized by each trailer component. From this chart, the highest risk priority number developed was associated to the frameworks, specifically to the integrity of aluminum welds. These welds were considered a high risk, because of how weak aluminum welds are known to be compared to aluminum.

To assist in mitigating this risk, the frame is fastened to the body of the trailer with numerous bolts to assist in distributing the loading coming from the road. In addition, gussets were added to increase the surface area of the welded areas, so as to improve the strength at the joints. From this analysis, the high value risks seem to be associated to the framework and wheel assembly, which all depend on the quality of the associated materials and quality of assembly. These should be further assessed and improved prior to manufacturing.

TABLE XXI: FMEA CHART [65][66] [67]

Trailer Part	Potential Failure Mode	Potential Effect	Severity	Potential Causes	Frequency	Current Controls	Detection	RPN	Methods of Mitigation and Elimination of Failure Mode
Body	Rocks and small objects impact the trailer	Fibers break upon impact	4	Wind, passing vehicles, gravel roads	5	User can hear rocks hitting the trailer	3	60	Coat the body exterior with a protective coating
Body	Strong winds damage the trailer	The lid rips off from the strong forces	9	Strong wind storms	3	User can feel the strong wind while outdoors	1	27	Latch the lid down and secure firmly with pistons and lower the angle of the lid
Body	Trailer becomes unbalanced when lid is open causing it to tip on its side	Structure of the body is punctured or fractures	8	The lid is too heavy and opens in such a way that it tips	3	User controls the position of the lid	1	24	Reduce the maximum angle that the lid can open and use light material for design
Electrical Systems	Electrical systems failure	Lights do not function throughout the trailer	2	Wear or corrosion of wiring	2	User notices that interior lights do not function	5	20	Better insulation from elements, include circuit tester with repair kit
Electrical Systems	Lamp and signal failures	Vehicle behind the trailer crashes into trailer due to low visibility	10	Poor wiring connection, or wiring/lead corrosion	2	User notices that exterior lights do not function while motorcycle is operational	4	80	Use coated wiring & leads, and keep components sealed inside body, Use Reflectors
Frame	Aluminum frame fails	Frame structure fails, which breaks parts of the wheel assembly and body	9	Poor welding, aluminum's poor strength after welding	4	None	10	360	Use of Gussets for additional strength, Frequent use of bolts for distribution of stress to body
Frame	Bolts shear off the	Interface between	8	Fatigue, undesired	1	None	10	80	Add more bolts in the high

Trailer Part	Potential Failure Mode	Potential Effect	Severity	Potential Causes	Frequency	Current Controls	Detection	RPN	Methods of Mitigation and Elimination of Failure Mode
	assembly due to fatigue	body and frame breaks		shearing loads					stress regions
Frame	Hitch fails while driving	Trailer detaches from motorcycle potentially causing damage to other vehicles	10	Wear, rust, unpredicted impact, continuous damage to hitch	2	User notices that the hitch is damaged	7	140	Safety chains
Wheel Assembly	Wheels fall off	Trailer fails in motion leaving the drive stranded with a trailer	10	Fatigue in the axles, bolts shear off	1	None	10	100	Spare wheel kit
Wheel Assembly	Bearing/Axle Failures	Wheels fall off	10	Wear or fatigue	1	User notices that the trailer sways to one side while riding	8	80	Replacement of bearings and axles every so often and check regularly
Wheel Assembly	Flat tire	Trailer becomes difficult to move	6	Cold temperatures, punctures to the tire	5	User notices that tires are becoming flat	5	150	Spare tires
Wheel Assembly	Trailer sways in motion	Trailer sways to one direction causing rider to lose control	4	Poor wheel alignment	3	User notices that the trailer sways to one side while riding	6	72	Keep the weight of the trailer well distributed and concentrated around and in front of the axle and have a low center of gravity

6. MANUFACTURING PROCESS

The full process of manufacturing has been divided into two distinct sections. The first is the pre-manufacturing setup, which includes the one time investment of the mold for the composite lid and body, the second of which includes the development of the jig for welding purposes. Once this pre-manufacturing setup is complete, the actual manufacturing for the prototype and/or commercial product can take place. In this case, the body, lid, and frame can be made independent of one another, for further adjustments in the assembly.

6.1. PRE-MANUFACTURING SETUP

The first-time setup generally requires a greater amount of time and effort to use because of the manufacturing processes are new or unfamiliar to the company with the prototype. With regards to development of this trailer, two specific assemblies were designed. The first design is of the physical mold, made out of the planned aluminum billets, while the second is the frame jig made from the 2”x4” cutouts. Upon completion of both of these developments, manufacturing the motorcycle trailer is available.

6.1.1. MOLD DESIGN

The mold was designed with the intention of a reduction of stress throughout the process of part removal. The body mold comes two separate assemblies, one for the lid and another for the body of the trailer, which can be seen in Figure 52. Both designs are assembled from several billets, held together by various hardware, brackets, and framework to sit on. Complete details in engineering drawings may be found in Appendix B.

For the mold development, the group deemed that the best manufacturing method for this one-time manufacture would be to utilize one of Cormer’s many 4-Axis CNC machines. In addition to the two functional mold models, several drawings were developed to illustrate the positions of holes, types of hole taps, welds, etc., which can be referred to in Appendix A. In addition to the drawings provided in the report, the group will send an electronic file to be used for CNC processes.

TABLE XXII: LIST OF COMPONENTS FOR THE LID AND BODY MOLDS

Part No.	Description	Part No.	Description
A04	Body Mold Assembly	M14	Mold Bracket
A05	Lid Mold Assembly	M15	Support Frame Assembly
H09	Flat Washer Selected A Narrow FW 0.266	M16	Lid Mold Front Right Block
H10	Hex Bolt 1/4-20x.75x.75	M17	Lid Mold Front Left Block
M01	Base Mold Front Right Upper Block	M18	Lid Mold Center Right Block
M02	Base Mold Front Right Lower Block	M19	Lid Mold Center Left Block
M03	Base Mold Front Left Upper Block	M20	Lid Mold Rear Right Block
M04	Base Mold Front Left Lower Block	M21	Lid Mold Rear Top Right Block
M05	Base Mold Center Right Upper Block	M22	Lid Mold Rear Left Block
M06	Base Mold Center Right Lower Block	M23	Lid Mold Rear Top Left Block
M07	Base Mold Center Left Upper Block	M24	Short Mold Bracket
M08	Base Mold Center Left Lower Block	M25	Right Support Assembly
M09	Base Mold Rear Right Upper Block	M26	Left Support Assembly
M10	Base Mold Rear Right Lower Block	MSF01	Body Mold Base Bar
M11	Base Mold Rear Left Upper Block	MSF02	Body Mold Resting Bar
M12	Base Mold Rear Left Lower Block	MSF03	Lid Mold Resting Bar
M13	Base Mold Spare Wheel Block		

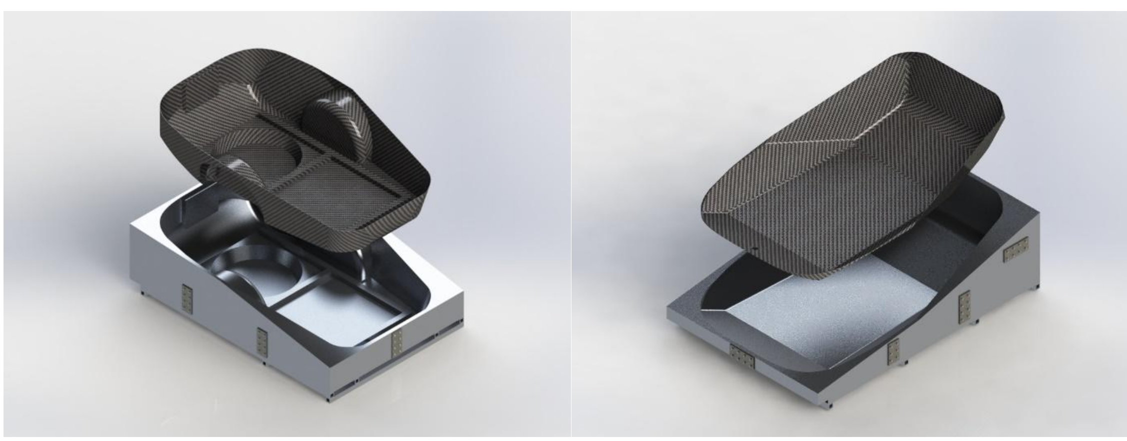

Figure 52: Body mold (left) and lid mold (right) with composite parts floating above

A list of components used in both molds as well as their respective subassemblies may be found in TABLE XXII, where it can be seen that each component was provided with a letter code prior to the name. These letter codes are used as references to the parts in the explanation of the manufacturing process. In addition to this, these parts names correspond to their drawings for convenient reference.

6.1.1.1. Body Mold

The process for the manufacturing of the body mold first requires the development of each component. Each of the mold components would need to be machined using Cormer's CNC, to cut the shape and tap the holes within the respective tolerances. As this process is moving forward, the support frame could be assembled according to its respective drawing.

1. Prepare each support frame member (4xMSF01 and 3xMSF02) by cutting the parts to their corresponding lengths.
2. Assemble the support frame to be used (M15), welding each frame member (MSF01 and MSF02) as indicated by the drawings. Figure 53 displays the completed assembly for the support frame.

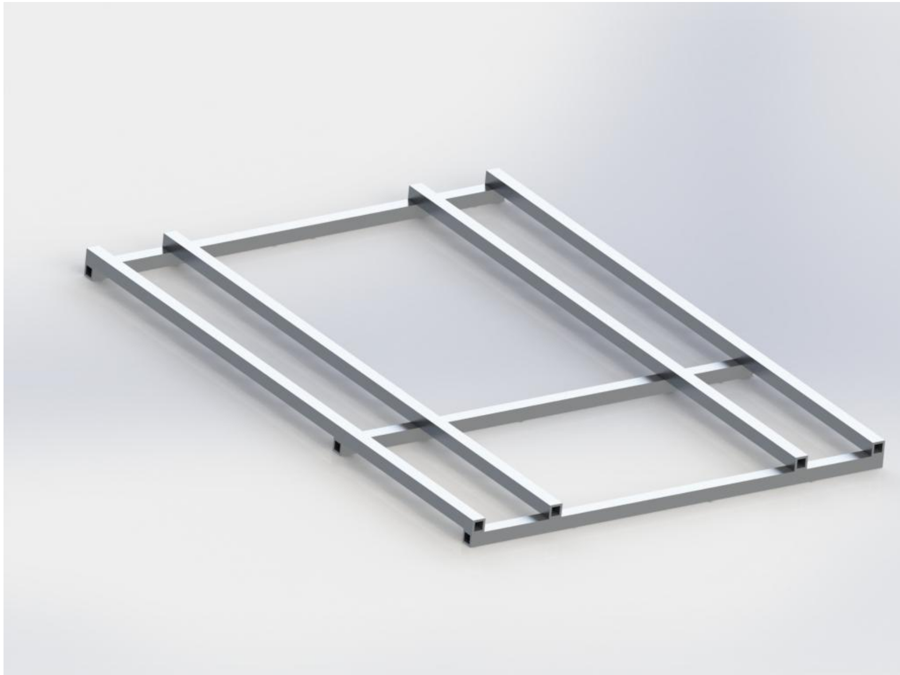

Figure 53: Body mold support frame

3. Cut and drill holes into six mold brackets (M14) according to the appropriate drawing. The bracket is to be made out of plain carbon steel, and used to align the molds together, which can be seen in Figure 54.

Figure 54: Mold bracket

4. Machine each mold component for assembly (M01-M13 seen in Figure 55). Ensure that forklifts are used to transfer the aluminum blocks used for the CNC, as the weight of each block may be too heavy to manually handle.

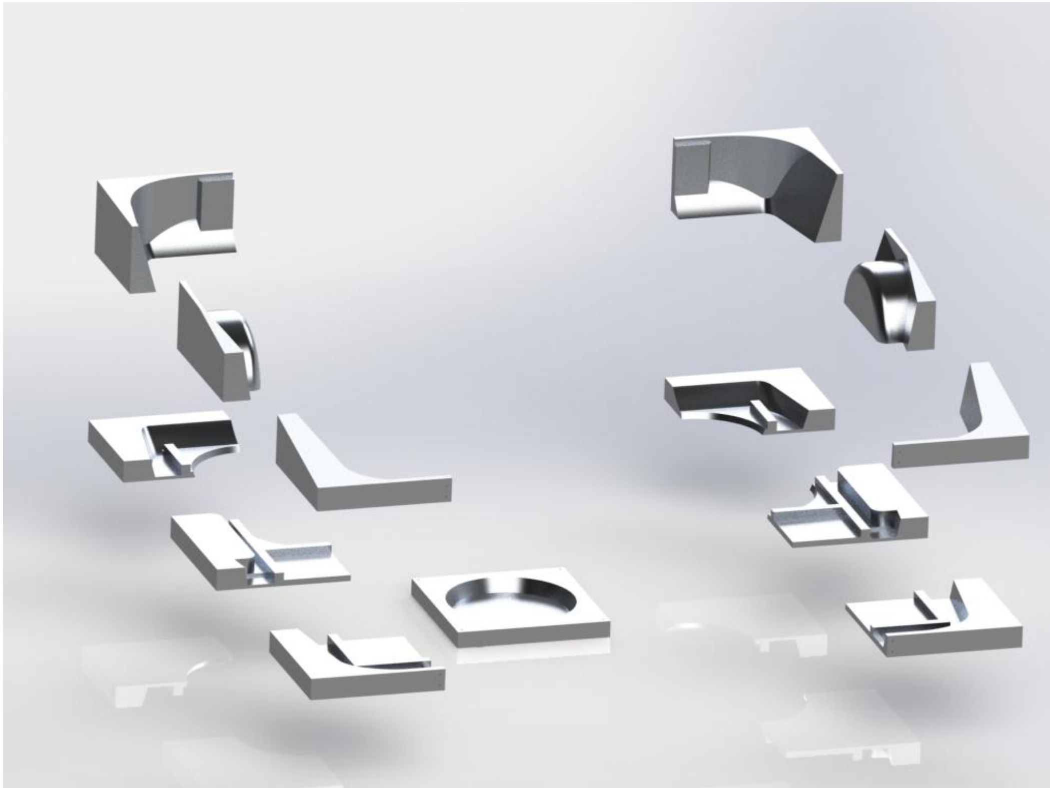

Figure 55: Exploded view of all mold components requiring CNC

5. Once the mold components are set up, the lower level molds are to be assembled onto the frame (M02, M04, M06, M08, M10, M12, and M13). Once set-up, these molds require enough alignment to ensure that the welding onto the frame is successfully within tolerance, which could be done by temporarily bolting the mold brackets (H09, H10, and M14) to develop the required shape. Post alignment, these brackets may be removed to assemble the upper molds. The setup displayed in Figure 56 is ready for its necessary welding (M15 weld).

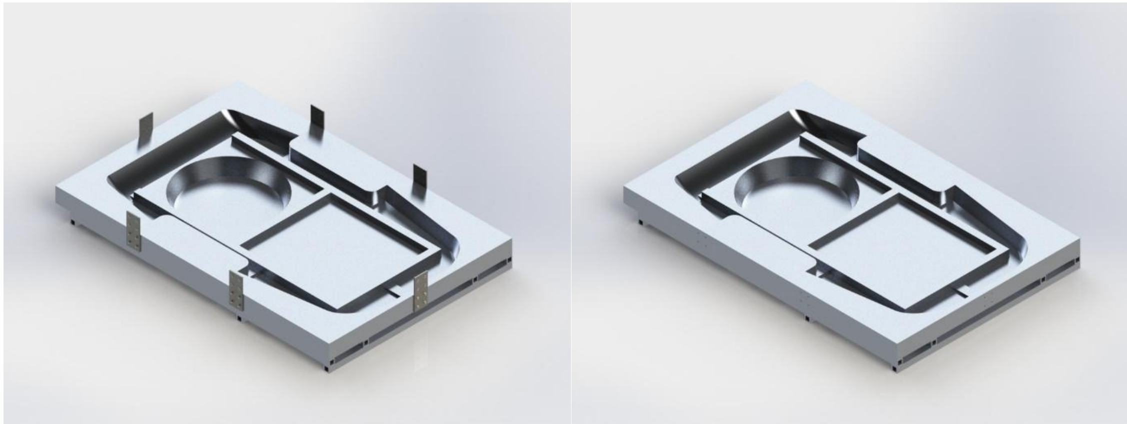

Figure 56: Aligned mold base on frame (left) and weld-ready mold base (right)

6. The final layer of the mold blocks could be set-up and aligned using the brackets (48xH09, 48xH10, M01, M03, M05, M07, M09, M11 and 6xM14), bolted in place with the appropriate torque (noted in the drawings). For later use in the composite layup, the Frekote coating can be applied in several coatings to ensure that the part can be removed without a problem. The completely manufactured assembly may be seen in Figure 57 (A04) and should set for half an hour prior to composite layup, to ensure that the coating is hardened.

Figure 57: Complete mold assembly

6.1.1.2. LID MOLD

The process of assembling the mold for the lid is very similar to the body mold, with the main difference being that the mold is assembled on two separate frame support systems.

7. Prepare the remaining support frame members (4xMSF01 and 8xMSF03) by cutting them into shape.
8. Assemble the frame members together (M25 and M26), welding the components together into two separate assemblies seen in Figure 58, for the left and right section.

Figure 58: Frame assemblies for lid mold

9. Like for the previous mold, cut and drill the shorter and longer mold brackets from ¼” steel sheeting (M14 and M24). The shorter brackets should have only 6 holes instead of the usual 8.
10. With the assistance of the CNC, the mold components for the lid require machining (M16-M20, and M22). These components may be seen with the separated framework in Figure 59.

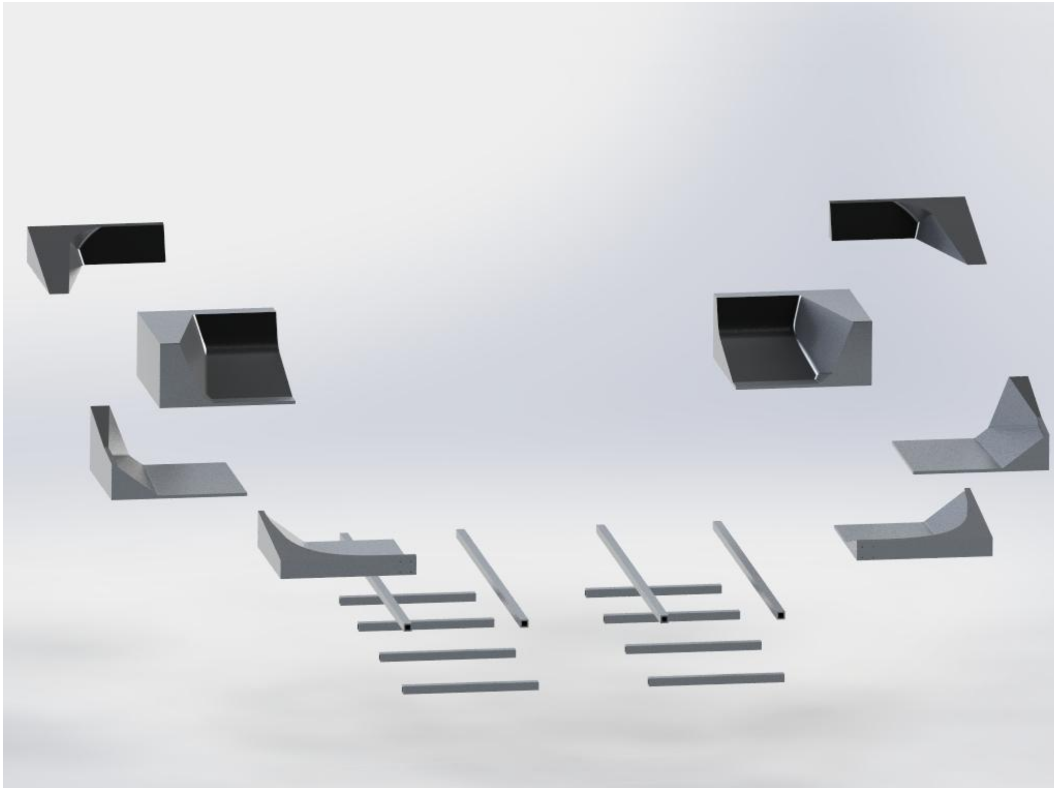

Figure 59: Machined mold components with cut frame pieces

11. Assemble the lower level molds onto the framework, and weld once properly aligned (following the previously mentioned method). These completed assemblies may be seen in Figure 60.

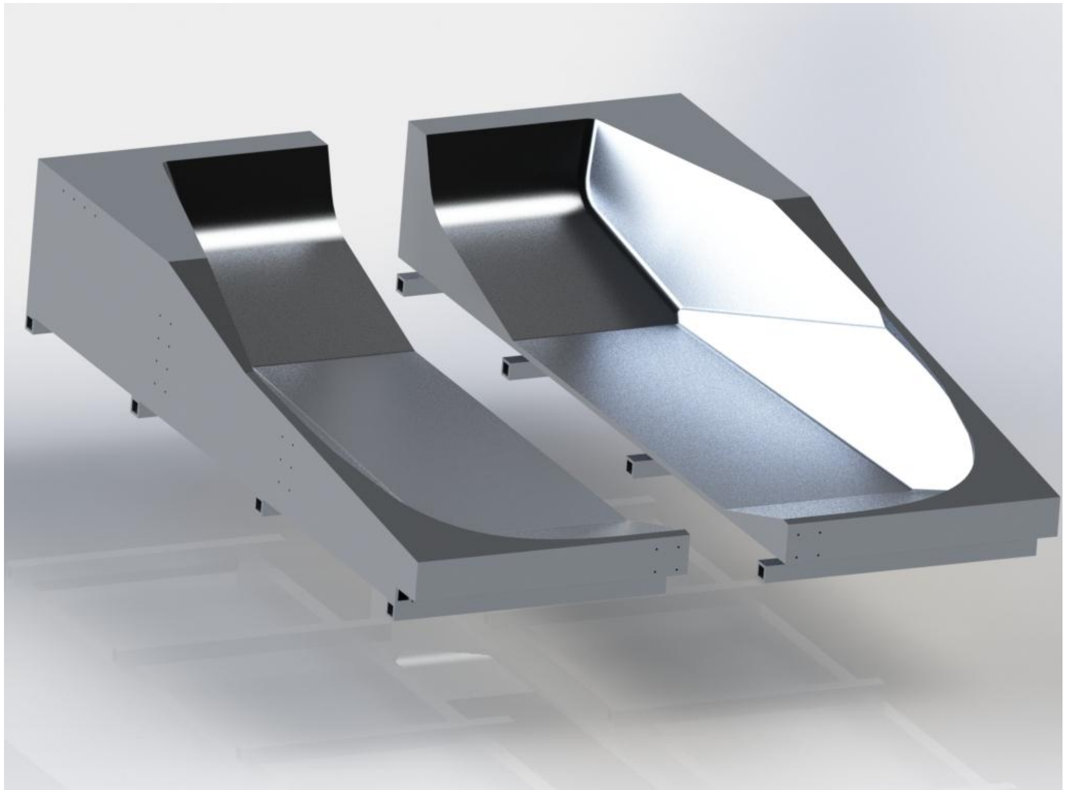

Figure 60: Lower level sections welded on corresponding support frames

12. Assemble the upper level molds onto the two assemblies (H09, H10, M14, M16-M26), aligning with the brackets and bolts to make the final lid mold assembly (A05), which can be seen in Figure 61. Once completed, as in the previous process apply the Frekote and allow it to settle for half an hour.

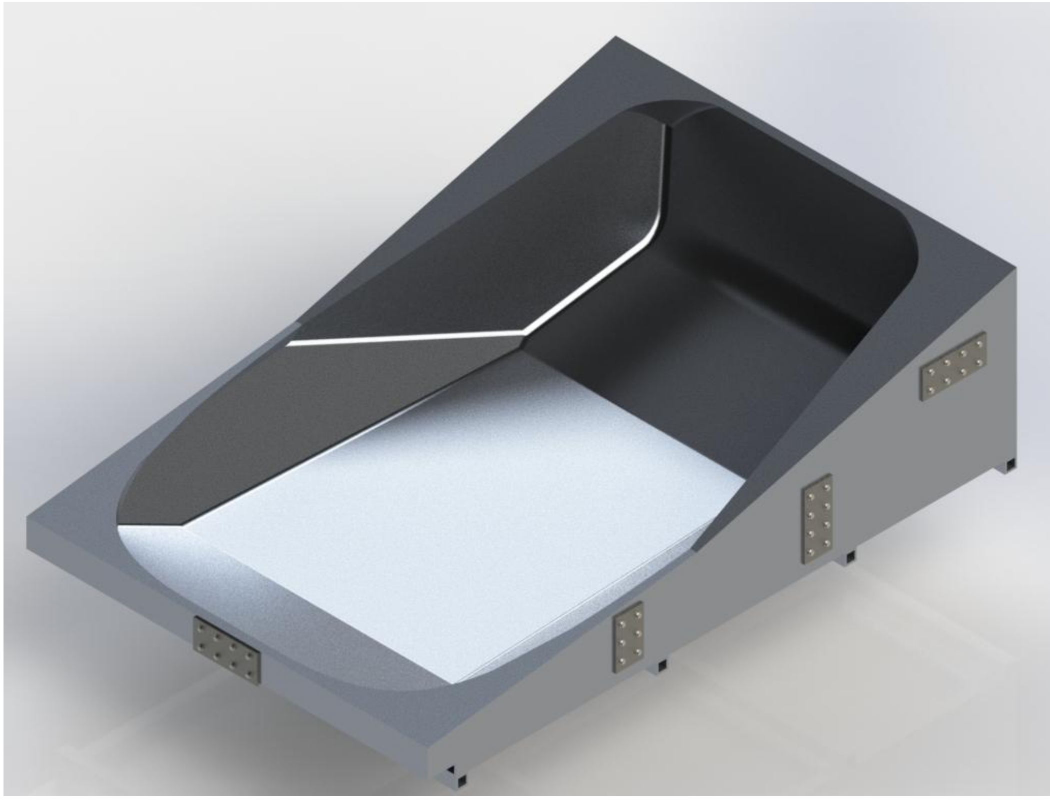

Figure 61: Final lid mold assembly

6.1.2. JIG FOR FRAME

The reason why the team decided to design a jig for the completion of the assembly was to ensure that accuracy is kept in the high quality part while manufacturing. This jig though, was kept simple and covers the general shape of the frame structure, to allow for the preliminary spot welds along the aluminum bars. The complete assembly of the frame jig may be seen in Figure 62 with the frame set up in place. Further details may be found in Appendix B. A bill of materials for the assembly is available following the figure, in TABLE XXIII.

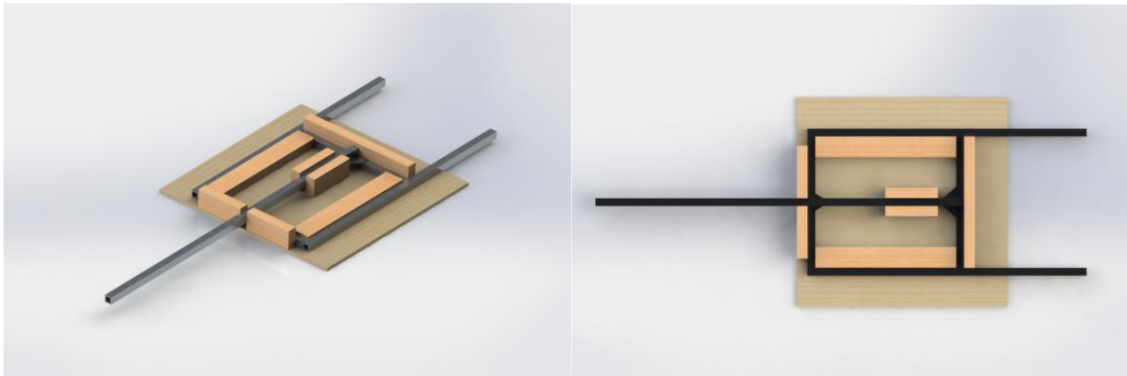

Figure 62: Isometric view (left) and top view of the frame jig holding the frame in place

TABLE XXIII: FRAME JIG BILL OF MATERIALS

Item No.	Component	Quantity	Dimensions	Material
1	Jig Base	1	40”x40”x3/4”	Plywood
2	Rear Frame Jig	1	2”x4”x25”	Wood
3	Side Frame Jig	2	2”x4”x26.75	Wood
4	Front Frame Jig	4	2”x4”x10”	Wood

The complete setup of the jig allows for the workers to attain the general 90° angles by a preliminary spot weld of the aluminum tubes, for further welding of the aluminum members as well as the other gussets and brackets. A drawing of this jig was developed to illustrate the required positions where each block is relative to the base of the jig, as seen in Figure 63.

As this entire assembly is made out of wood, the primary components required are 2”x4” standard wood beams, as well as a ¾” thick sheet of plywood. Although the type of wood screw is not stated in the drawing, the positions of where each screw is to be placed is illustrated by a point, and is recommended that 2” long nails are used for an improved rigidity of the product. A tolerance of ±0.01” was used across the drawing to ensure that the aluminum members could fit within the assembly, and also factors in the usual inconsistent thicknesses of wood.

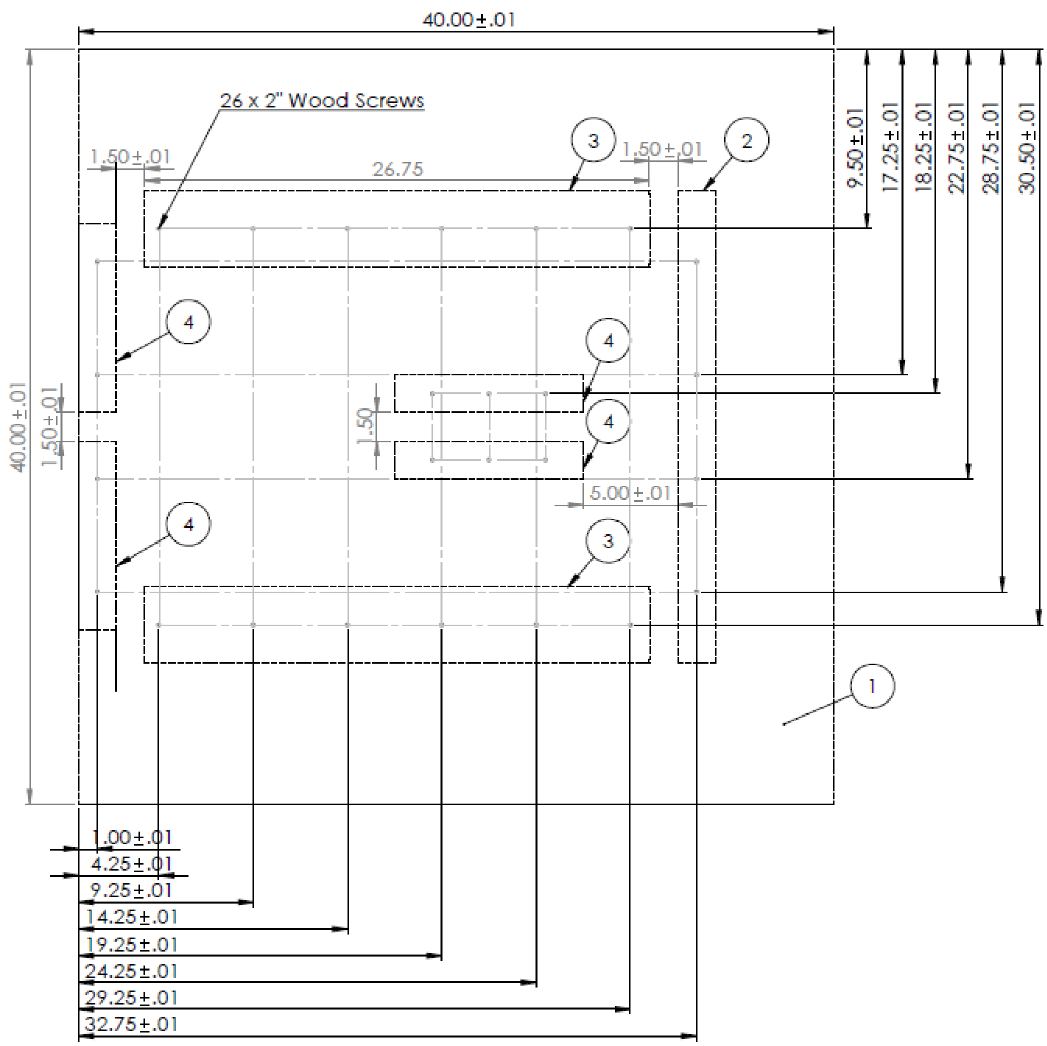

Figure 63: Drawing for the frame jig

The process of the jig development is relatively simple, and has been created for ease of manufacturing.

1. Cut the 2”x4”x8’ wood beams into several sections, according to the sizes indicated within the bill of materials.
    a. A single rear frame jig block is to be cut into a 25” section.
    b. Two side frame jig blocks are to be cut into 26.75” sections.
    c. Four front frame jig blocks are to be cut into 10” sections.
2. Cut the 4’x8’x3/8” plywood board into a single 40”x40” plate.

3. Mark out the positions of each 2”x4” block onto the jig baseboard, and then mark out the positions of each hole on the seven blocks.
4. Align each block into place, and screw in each block using the recommended 2” wood screws. Upon completion, ensure that the final assembly is square, and provides adequate distance for the 1.5” aluminum tubing to lie.

6.2. FRAME AND BODY MANUFACTURING

The following section provides detail into the manufacturing process of the aluminum frame, body shell and lid of the trailer.

6.2.1. ALUMINUM FRAME

The thickness of the aluminum materials we are using ranges from 1/8’’ to 3/16’’. According to TABLE XXIV, a weld size of 1/8’’ would be adequate. But since the minimum fillet weld size for cyclic loading must be at least 3/16’’, our fillet weld sizes for the frame will be adjusted to 3/16’’ [68].

TABLE XXIV: MINIMUM FILLET WELD SIZES [68]

Base metal thickness (T)	Minimum size of fillet weld
T ≤ ¼”	1/8”
¼” < T < ½”	3/16”
½” < T < ¾”	¼”
¾” < T	5/16”

6.2.2. BODY DESIGN

Using a completely set-up mold for the final design, the composite components of the trailer could be developed. The composite parts are specifically the body as well as the lid of the trailer, which are to be layed-up in their corresponding molds. After these molds are set-up and cured in the oven, they could be taken out to cool and be processed for further assembly.

6.2.2.1. Mold Set-Up

The first process is to set up the mold, prior to the lay-up process. This involves setting up both the body and lid molds, similar to the last few steps of the manufacturing procedure. With regards to the body mold, the upper blocks (M01, M03, M05, M07, M09, and M11), brackets (M14), bolts (H10) and washers (H09) would be removed from the previous process, as seen in Figure 64. The upper blocks may be aligned in place, and then bolted in at the 4 lbf-ft recommended torque, shown by Figure 65.

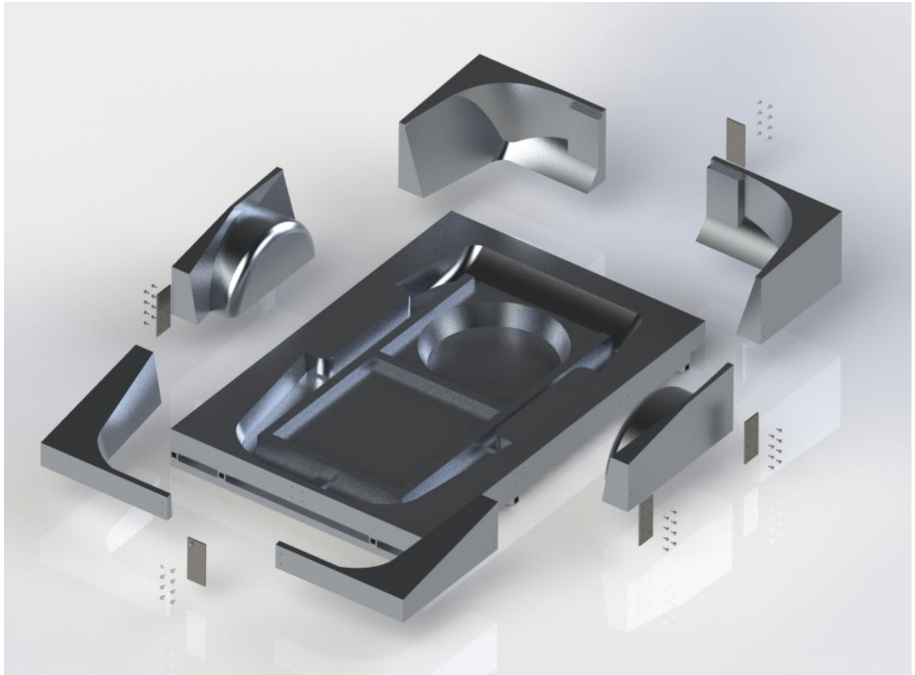

Figure 64: Unassembled body mold

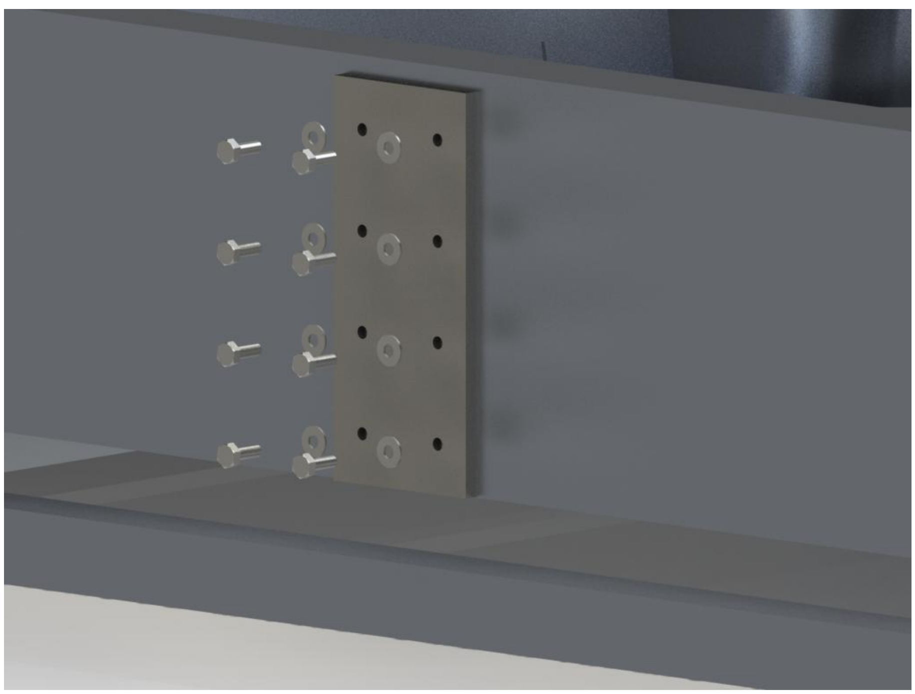

Figure 65: Attaching bolts through the mold bracket

The lid mold would be separated into four main pieces, the left half of the mold (on the subassembly M26), the right half of the mold (on the subassembly M25), and the upper blocks on the top (M21 and M23). A few of the brackets and bolts would also be removed from a previous process, illustrated in Figure 66.

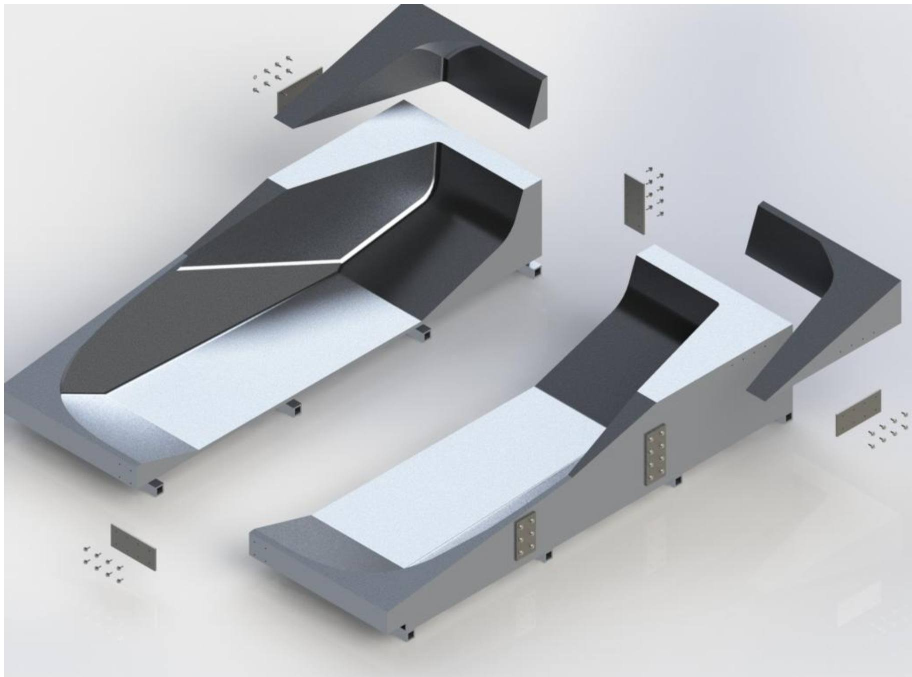

Figure 66: Unassembled lid mold

To assemble these, the upper blocks may first be mounted onto the two mold halves, and then bolted in place, as shown in Figure 67. Upon completion, the two halves of the mold may be assembled together.

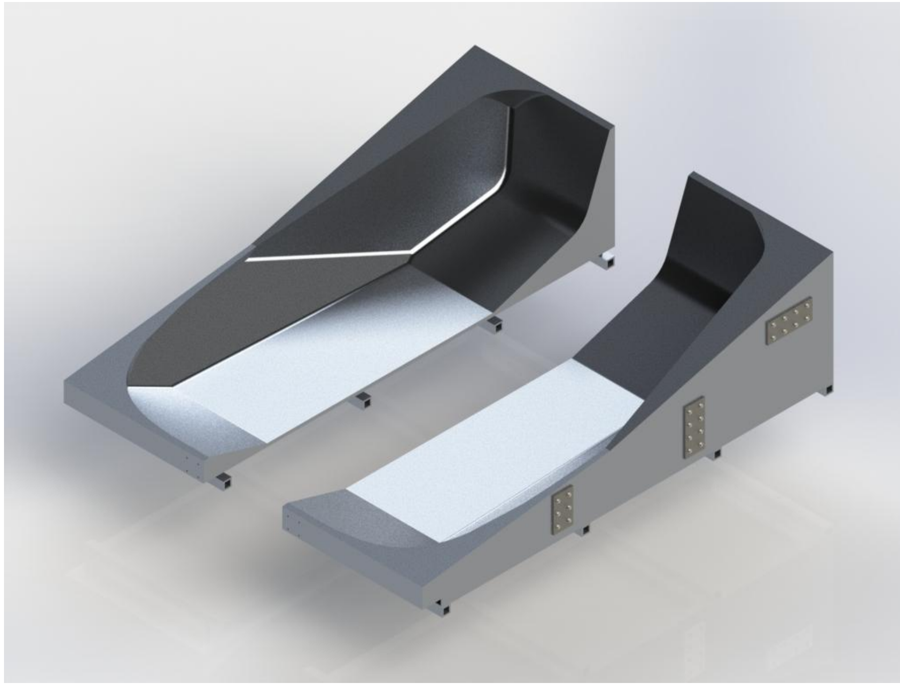

Figure 67: Mold halves setup in place

Once both molds are fully assembled, a layer of the mold removal gel (Frekote) may be applied (by spraying) to the inside of both molds to ensure a smooth surface is kept. The final result should look like Figure 68, with the gel in place, ready for the next step of the composite development.

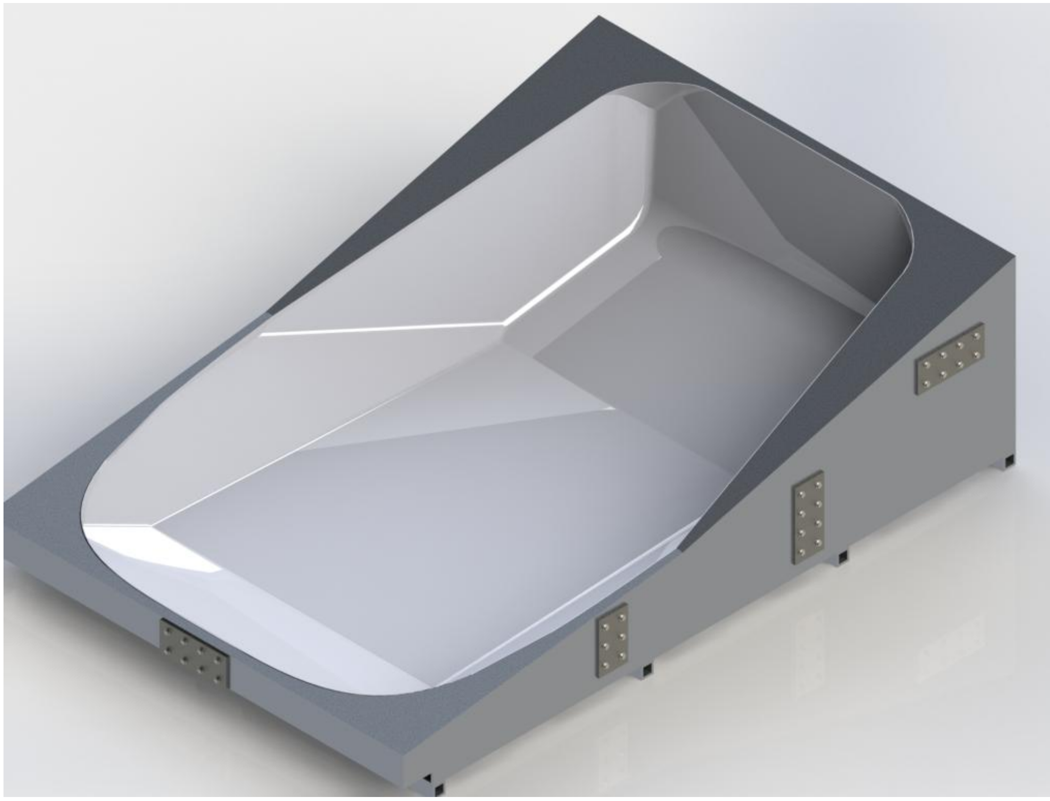

Figure 68: Gel coated mold

6.2.2.2. Sheeting Lay-Up

To begin the pre-preg lay-up process, the release film must first be set up onto the complete mold, which will ensure that the part could be removed easily with a smooth surface [69]. The manual sheeting procedure will follow a general vacuum bagging process, which requires the use of release film for both sides of the part, breather fabric on the open end, and the vacuum bagging sheet for the part. Upon completion, the pre-preg can be layed-up onto the mold piece.

Prior to laying the carbon fiber pre-preg, it is highly recommended that stencils are made to make proper cut-outs onto the pre-pregs. For the body mold, strips should be set onto the bottom of the mold where the frame is to be developed. Each strip should follow the same direction as the other so as to follow the [0,90] orientation. As each strip is being laid onto another, a slight ½" overlap should be made. Once the strips are made and added to the frame area, the rest of the strips can be layed-up onto the sides. The lid mold on the other hand, can be layed-up onto using fewer sheets, as less contours are evident.

Upon completion of the first layer, the next layer can be set up. The pieces for the next layer are to be oriented 45° from the first layer, to produce the [45,-45] layer. It is suggested that every 3-4 layers be vacuumed to produce a smoother and consistent surface, and sealed by a tacky tape. When vacuuming every 3 or so layers, the release film needs to be placed onto the part, breather fabric over the release film, and vacuum bag over the whole part. One section of the vacuum bag should be set for the vacuum valve, to compress the part onto the mold. Figure 69 illustrates this complete vacuum bagging process for a cross section of the lid.

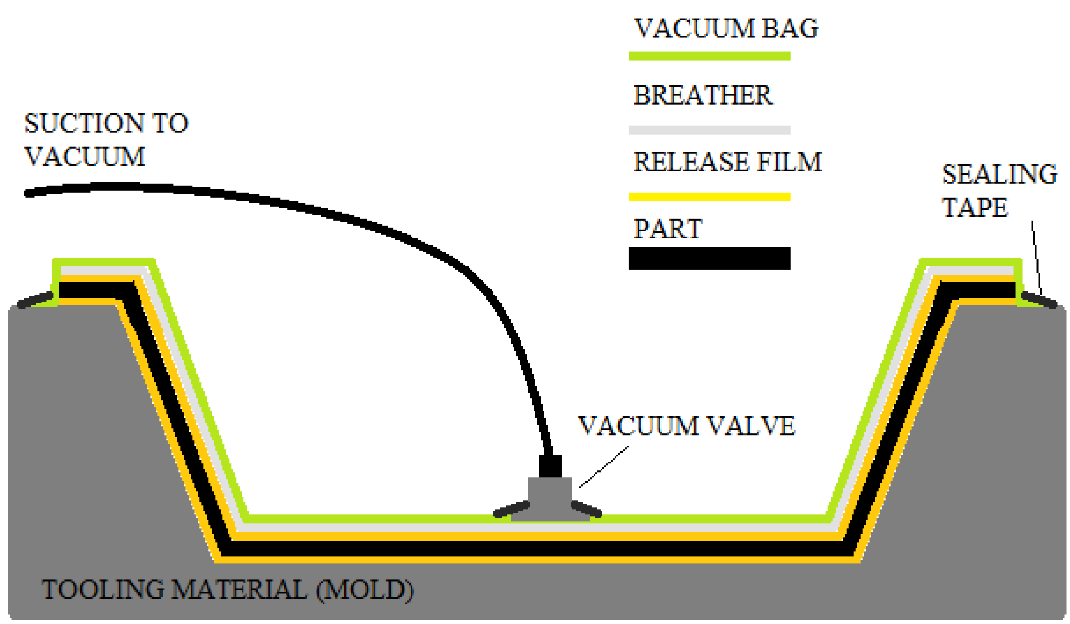

Figure 69: Lay-up of the composite part

As shown in the figure, some of the pre-preg hangs over the mold, which is necessary to ensure a smooth and flat surface after trimming. After all seven layers were layed-up, properly aligned, and vacuum bagged, the parts are ready to go into the oven (within the vacuum bag setup).

6.2.2.3. COMPOSITE CURE

The process of curing was discussed with the Cormer Group representatives that the procedure will be solely left to them, as they have standards of operation for their own oven [2]. With the dimensions of the oven provided (108"x51"x78" [29]), each mold would have to be put in separately as the only way to fit them in together is my stacking them, which is not feasible for such a heavy object. Once cured and taken from the oven, the vacuum bagging and the top of the release film may be taken out.

The part removal is relatively simple for the body mold, but should consider caution so as to not break the part. The first step for the body mold is to slowly remove the front and rear mold pieces. This should be done first by removing all of the mounting brackets from the mold itself. Once the front and back upper molds are fully removed, the upper side molds are free to remove from the sides. With care, the rest of the part can be removed from the base molds. This process is illustrated in Figure 70.

Figure 70: Front and rear upper molds removal (left), side molds removal (right), and complete part removal (bottom)

The lid mold was also designed for a part removal, but most of the blocks were meant to be held together upon removal. First, the upper rear mold sections can be removed away from the back of the lid. Upon completion, the two halves of the mold require removal. As the molds are too heavy to manually slide apart, it is recommended that each half be put on a separate sliding platform (on wheels). If that is done, each half can slide apart easily, revealing the cured composite part.

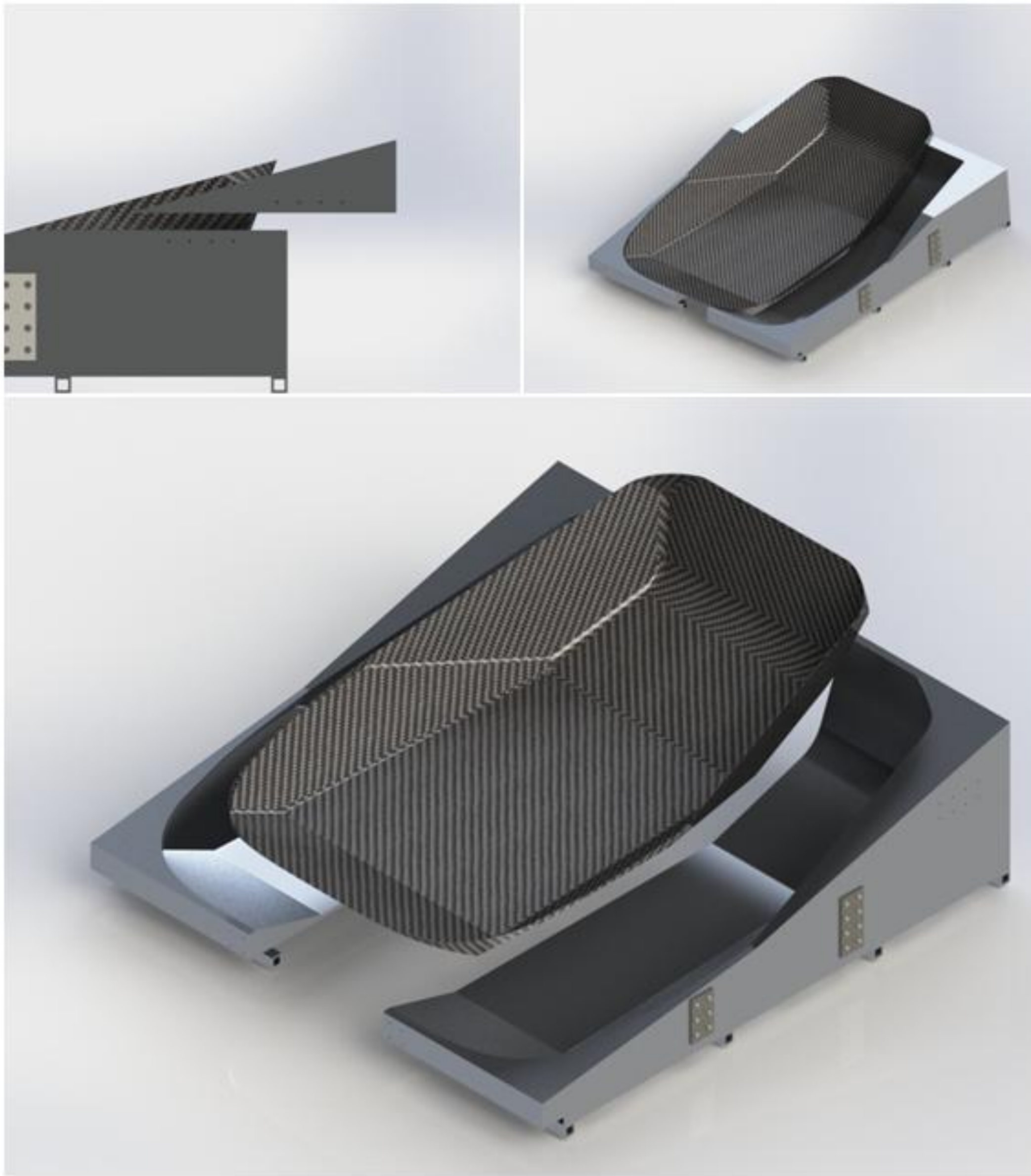

Figure 71: Upper mold removal (left), left mold half removal (right), and part removal (bottom)

6.2.2.4. Post-Cure Processing & Trimming

Shortly after removal from the mold, the body and lid require further processing prior to the application of the gel. First, the lip that was hanging over the mold area for each part could be cut off, and smoothed out using a sanding tool, resulting in a flat and smooth edge. Once the part is set up to the desired smoothness along the edges, the clear gel coating (which is specified in the cost analysis) can be applied. This coating can take approximately 30 minutes to cure and set for further use, and should utilize the additive MEKP to set off the curing process [70].

Holes for the trailer lid and body also need to be made for attachments including the lights, locks and bolts. For this process, stencils are recommended for use (but not necessary) to provide accuracy in the positioning of each component. If necessary, a CNC could be useful for this application. Holes for the reflectors and bolts are discussed in their individual manufacturing section, but the main holes to be made post-processing are the holes for the rear lamps, signals, and the hole for the locking mechanism.

The rear lamps require two 4.5” diameter holes to the left and right of the license plate area, as displayed in Figure 72. The holes for the light should be spaced 3” and 8.5” from the license plate indent, then smoothed out by sanding. These holes could be manually cut using a dremel, or by CNC. The 1” hole on the lid could then be drilled out, positioned 2” from the centre point of the rear lid area, as displayed in Figure 73. Upon completion, the body and lid are ready to be used for the rest of the assembly.

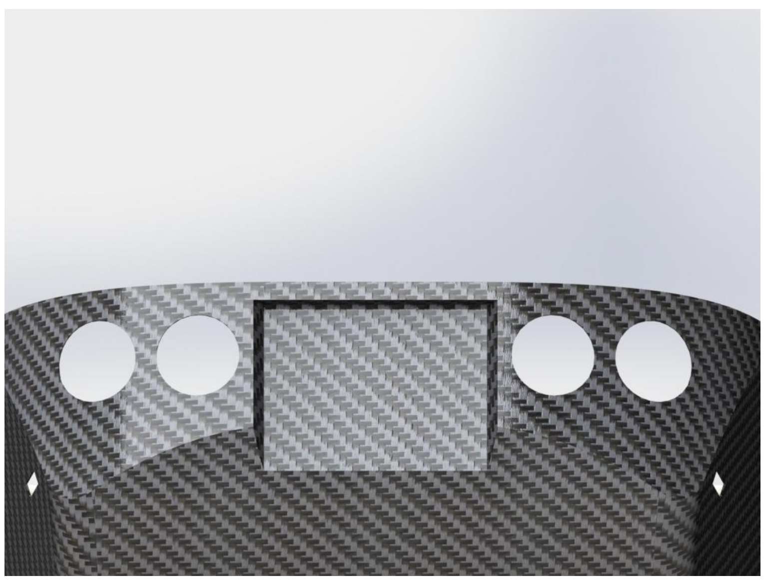

Figure 72: Hole cut-outs for lighting

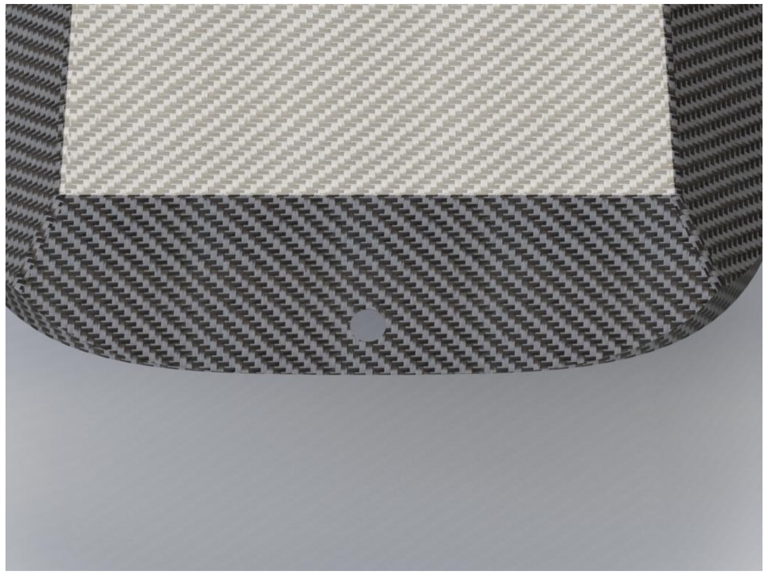

Figure 73: Hole positioned in the lid

7. Trailer Assembly Procedure

Each sourced and manufactured component was modeled and developed into an assembly. This assembly consists of numerous components that were specifically chosen to build the trailer. In addition to the design, Cormer Group requested that the team make a manufacturing process for the trailer [2]. This section covers the assembly of each component and section of the trailer, with a flow chart following, illustrating the brief procedure for the prototype development. Further details for the assemblies may be found in Appendix B.

7.1. Suspension, Wheels, and Frame

The first step of the assembly process is to put together each of the components on the main frame. The bill of materials needed for this section along with each parts corresponding reference number is shown in TABLE XXV. Following this is an exploded view of this stage of the assembly process in Figure 74.

TABLE XXV: BILL OF MATERIALS FOR FRAME ASSEMBLY

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Tongue Square Tube	WELDED ALUMINUM FRAME	1
2	FR-425-S Bracket	SUSPENSION MOUNTING BRACKET	2
3	FR-425-S Hub	SUSPENSION SWING ARM AND HUB	2
4	Rubber on Aluminum Frame	RUBBER VIBRATION DAMPENING STRIPS	1
5	HBOLT 0.3125-18x1x0.875-N	HEX BOLT 0.3125-18x1x0.875-N	8
6	HBOLT 0.2500-20x2.75x0.75-N	HEX BOLT 0.2500-20x2.75x0.75-N	2
7	HNUT 0.3125-18-D-N	HEX NUT 0.3125-18-D-N	10
8	Hitch	SWIVEL HITCH	1
9	Preferred Narrow FW 0.25	.25 INCH WASHER	4
10	AM30620 Wheel	Kenda 4.80-12 Bias Trailer Wheel	2
11	HHNUT 0.6250-18-D-N	LUG NUTS	8

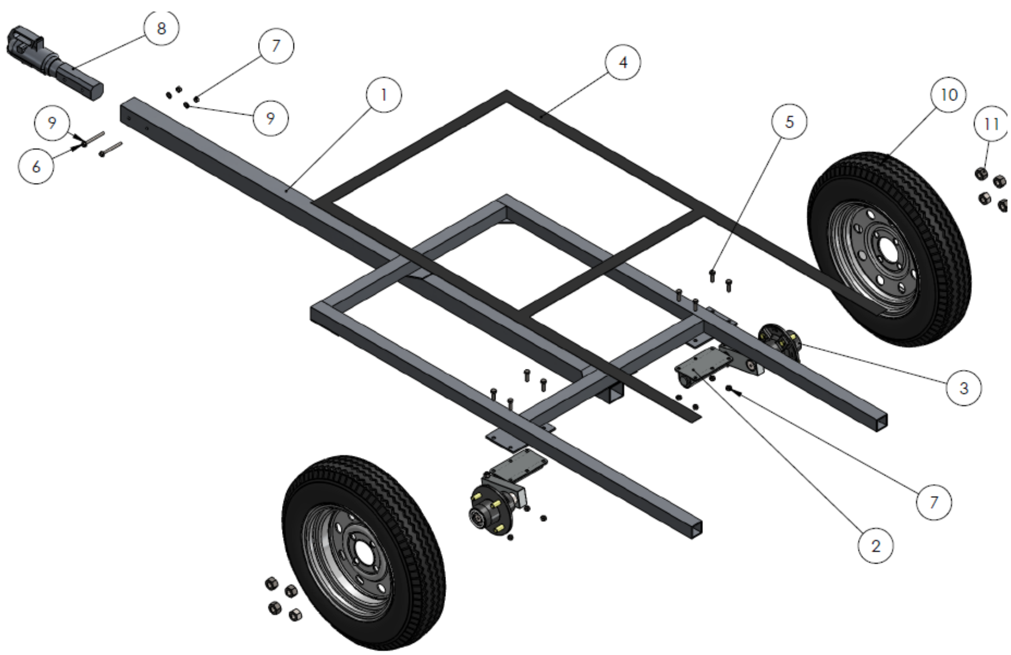

Figure 74: Exploded view of frame assembly

The first step of this process is to bolt the torsion suspension axles to the frame using the indicated bolts found in Figure 75.

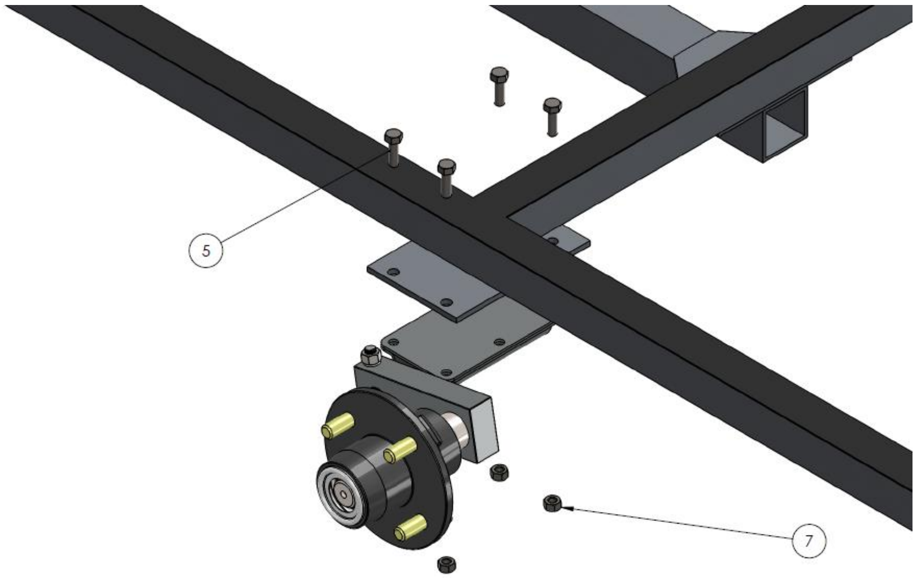

Figure 75: Assembly diagram of torsion suspensions axles mounting to frame

The trailing arm should extend backwards away from the front tongue of the frame as illustrated above. A torsion suspension axle is bolted on to each side of the trailer with the specified nuts and bolts. Following the attachment of the frame, the wheels can be mounted to the frame, as is done in Figure 76.

Figure 76: Assembly diagram of the wheel mounting to the hub of the axle

The swivel hitch must be assembled as per directions from the manufacturer. Following this complete assembly, the swivel hitch can mounted to the frame. During this process, a safety chain is also installed by placing one of the central links through the bolt, as shown in Figure 77.

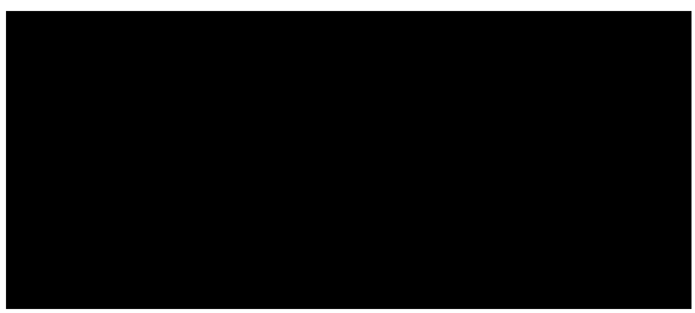

Figure 77: Safety chain installed during the assembly of the swivel hitch to the tongue [61]

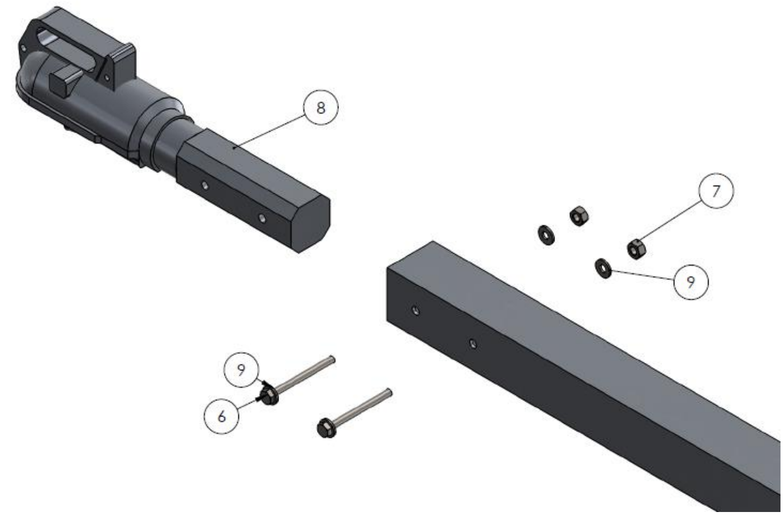

Figure 78: Assembly diagram of mounting the swivel hitch to the aluminum frame (safety chain not shown)

The body of the trailer consists of 2 main assemblies, the body base assembly which includes the wiring, lighting and the hardware associated with attaching the lid assembly which includes the latch, interior lights, as well as the hardware to attach it to the body base.

7.1.1. Body Base Assembly

Following the completion of the frame, the body base of the trailer is assembled. This includes installing the rear lights, side marker lights, license plate lights, hinge and the plate for the shock assembly. An exploded view of the overall assembly process is illustrated below.

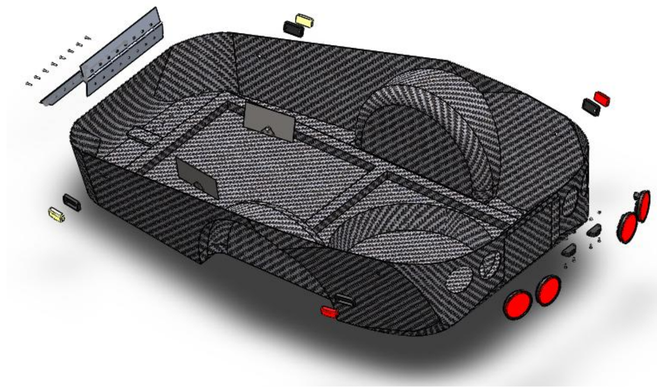

Figure 79: Exploded view of body with components to be installed

Details on how each of the components are installed along with their specific locations can be found in the assembly drawings in Appendix B. Details and wiring diagrams on the electrical components are explained in Section 7.3. Once all the components have been assembled on the body base, the assembly is combined with the frame. An exploded view showing this process is illustrated below.

TABLE XXVI: BILL OF MATERIALS FOR FRAME ASSEMBLY

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	A05	FRAME ASSEMBLY	1
2	A03	TRAILER BASE	1
3	B01	METAL WASHER STRIP LONG	2
4	B02	METAL WASHER STRIP FRONT	1
5	B03	METAL WASHER STRIP CENTER	1
6	1/4 INCH RIVETS	1/4 X .670 RIVETS	26
7	I05-NEW	FRONT FLOOR BOARD	1
8	I06-NEW	REAR FLOOR BOARD	1

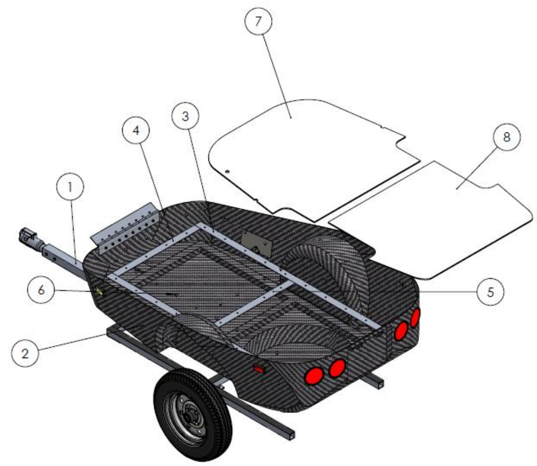

Figure 80: Body assembly diagram

Before placing the body on the frame, the metal washer strips are placed at their specified locations and are used as a template for drilling through the carbon fiber. Once all the holes have been drilled, the body base is lifted onto the frame and set in place. The body base is then fastened to the frame using 1/4 inch rivets. Once the body is secured to the frame, the floor boards can be placed in the trailer.

7.1.2. Trailer Lid Assembly

The trailer lid has few components that need to be assembled. An exploded view is shown below.

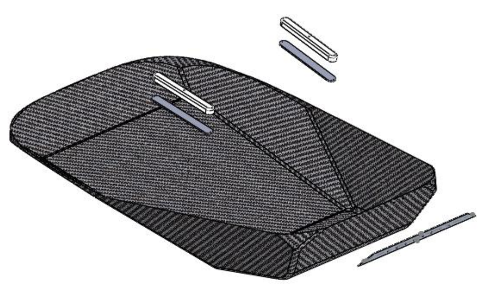

Figure 81: Lid component assembly diagram

A mounting plate is glued at a specified location on the ceiling of the trailer lid using Loctite H8000. The light strips are mounted to these plates using #8 screws. Additionally, an aluminum hinge plate is glued to the front of the trailer lid centered at the bottom edge using Loctite H8000 as illustrated in Figure 82. Once the adhesive as fully cured, the carbon fiber is drilled using the holes in the hinge plate as a template. These holes will be later used to connect to bolt onto the hinge.

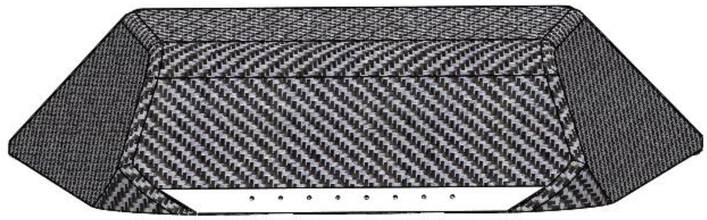

Figure 82: Assembled lid front view

Following this drilling procedure, the lid is ready to be mounted to the base. Using the specified screws and nuts, the lid is mounted to the hinge on the body. The shock assemblies are then installed at the specified locations following the detailed manufacturing drawings in Appendix AA.

7.1.3. WEATHER STRIPPING

The weather stripping is to be installed using the epoxy adhered to the edges along the lid and the body of the trailer. This epoxy should be left to cure for 24 hours and fixed on using duct tape or clamps while curing. While curing, other processes can be performed as long as the stripping is fixed in place.

7.2. ELECTRICAL COMPONENTS

The electrical system for the trailer is entirely concealed from the elements, as well as being hidden behind the liner on the interior to prevent damage or entanglement with the cargo. The electrical system runs on a standard 4 wire system from the motorcycle and auxiliary systems run on the tail lights circuit which is powered when the headlights are on.

7.2.1. TAIL LIGHTS

Before installing the 4 circular taillights, the rubber grommets must be inserted into the 4.5’’ circular holes. This simply requires pushing (from the outside) the grommets into the holes so that the carbon fiber shell is located between the inner and outer lip of the grommet. Once this is completed, the 4'' circular lights can be installed. This is done by simply pushing the light (from the outside) into the grommet until it seats into the grooves. The light can then be connected to the standard 3-prong plug at the back.

7.2.2. Side Marker Lights

The side marker lights consist of the mounting bracket at LED light clip-in light. The mounting bracket is connected to the side of the trailer with two small bolts placed through pre-drilled holes in the body. Once the bracket is fixed in place, the lights can be connected to the power source and then clipped into the bracket.

7.2.3. Interior Lights and License plate lamp

With regards to the two interior lights, they will be mounted to 15'' x 3'' x ¼'' plates of ABS plastic with the screws that are supplied with the lights. Since this plastic is bought in 48'' by 96'' sheets, these smaller pieces can be taken from the amount left over from the flooring. The plastic sheets will be adhered to their respective locations on the bottom of the lid with Loctite Speedbonder H8000 adhesive. The wiring will be held in place by the interior fabric of the trailer. The two license plate lamps will be bolted vertically into position using size 8-32 bolts that are 1/2'' long.

Wiring for the trailer will be run through the inside of the tongue and will exit at the center of the trailer through the opening in the 2'' square tube. From there, wiring will be ran to the edge of the trailer and then split into the required directions for each light fixture. The 4-pole wiring harness will exit the front of the tongue through the spaces at the swivel hitch connection point. A wiring diagram for the exterior lights on the trailer is shown the figure below (needs revised).

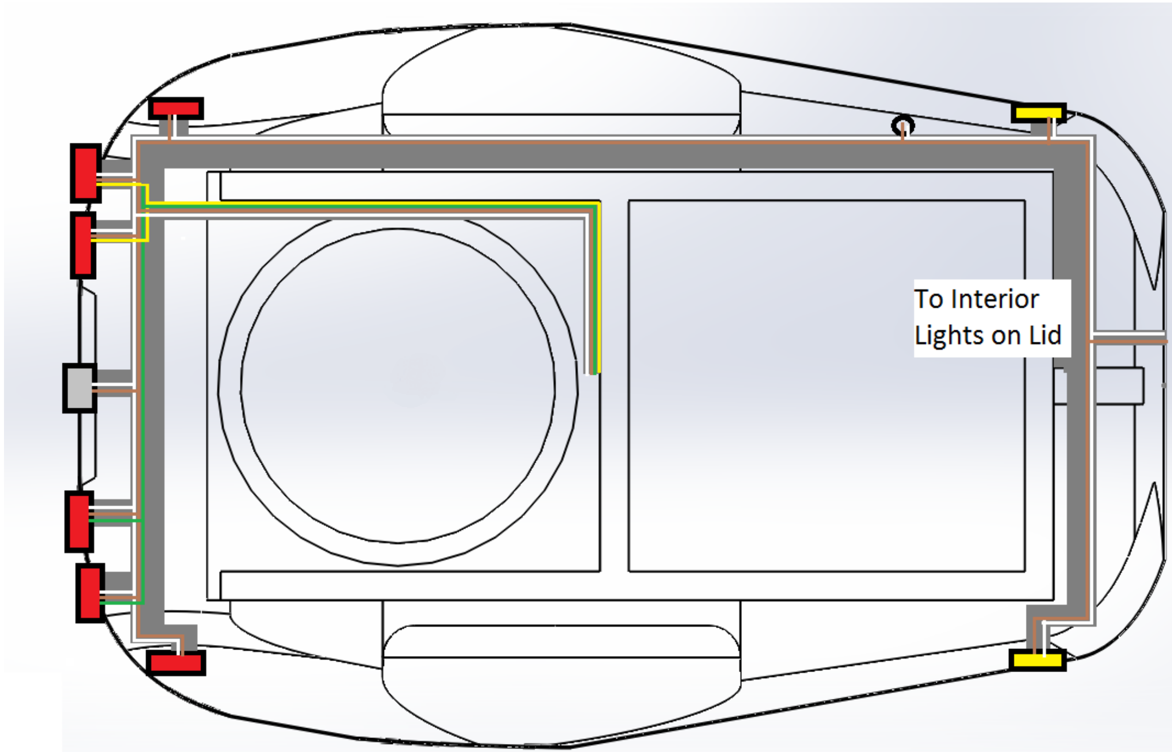

Figure 83: Trailer wiring diagram.

After the trailer has been wired, it should be connected to a power source to ensure all systems is functioning properly.

7.2.4. 12-Volt Outlet

The 12-Volt plug is installed by placing it in the pre-drilled hole, and then fastening it with screws drilled into the plastic flooring. The source website for the outlet does not specify the size of holes; therefore the size of screws will be determined after purchasing the part. This type of fixture does not need a specific type of screw.

7.3. Finalizing the Trailer

Once all the assembly process previously outlined is complete, the trailer can be sent to Shear Perfection Upholstery to have the carpet installed. Once the trailer has been returned, the trailer should be waxed, with all of the lights and plugs will be tested to ensure everything is working properly.

As the team was able to design a complete trailer, the steps for the manufacturing process were able to be condensed into several steps for simplification. As each detail for the manufacturing process were previously detailed, the flow chart following can visually display the complexity and detail of the manufacturing process designed for the manufacture of the prototype trailer, with mass production in mind.

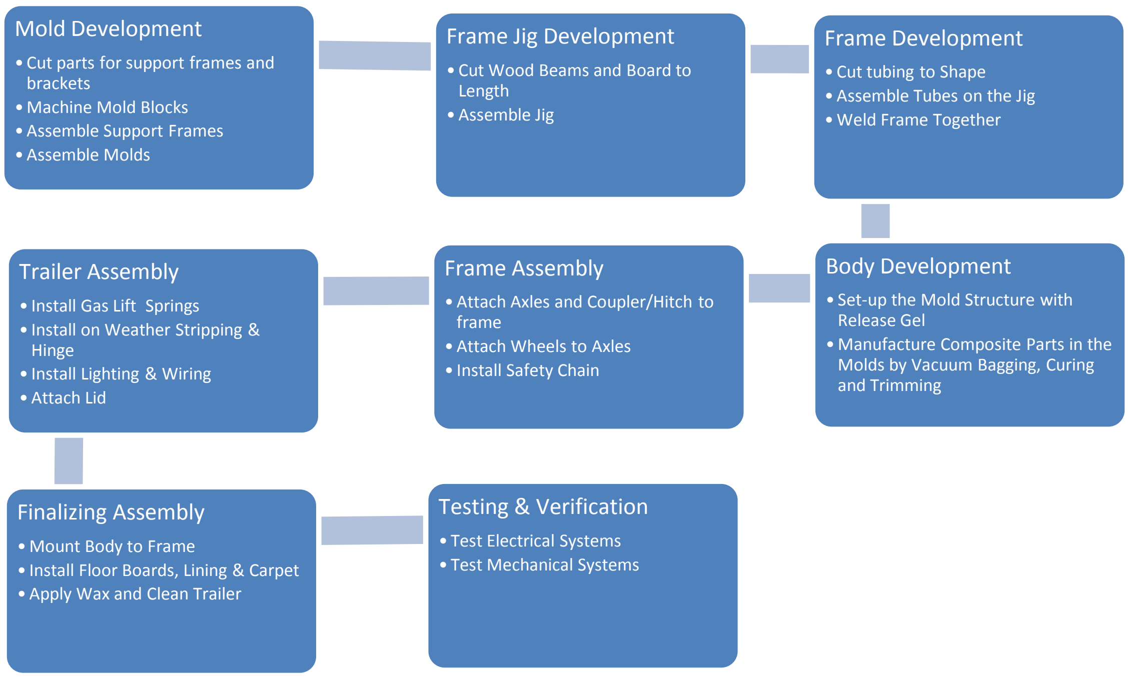

Figure 84: Flow chart illustrating the manufacturing process

8. Detailed Cost Analysis

8.1. Initial Set-up Costs

The initial set-up cost includes the cost of materials and labour required for manufacturing the molds for the body and the jig for the frame. These costs are shown in TABLE XXVII and TABLE XXVIII.

TABLE XXVII: PRE-MANUFACTURING MATERIALS COST

Item	No. Items	Cost/Item	Total	Source
Frame Jig				
Cedartone Classic PT Lumber 2 in x 4 in x 8 Feet	2	$4.79	$10.83	[71]
5/8 inch Sanded Pine Plywood 19/32" X 4' X 8'	1	$49.57	$56.01	[72]
Wood Screw 2" Coarse-50Ct	1	$3.99	$4.51	[73]
Mold				
FREKOTE 710 NC GALLON	1	$93.67	$105.85	[74]
1/4-20x.75 Bolts	120	$0.09	$12.42	[75]
#12 18-8 Stainless Steel Large OD Flat Washer	120	$0.06	$7.72	[76]
Low-Carbon Steel Bar (1/4" Thick, 8" Width, 1 ft)	1	$20.91	$23.63	[77]
Low-Carbon Steel Bar (1/4" Thick, 8" Width, 3 ft)	1	$83.64	$94.51	[78]
Low-Carbon Steel Rectangular Bar (1/4" Thick, 6" Width)	1	$26.94	$30.44	[79]
Total Cost for Aluminum Billets	n/a		$20,000.00	[80]
Total initial setup material cost			**$20,345.92**	

TABLE XXVIII: PRE-MANUFACTURING MOLD AND JIG DEVELOPMENT COSTS [10]

Part	Process	Time to Complete (hours)	Labour Cost/hr	Total Cost
Mold	Cutting Tubes for Support Frames	1	$85.00	$85.00
Mold	Machine Mold Blocks	80	$108.00	$8,640.00
Mold	Assemble Support Frames	3	$108.00	$324.00
Mold	Assemble Molds	5	$108.00	$540.00
Jig	Cut wooden beams and board to shape	1	$85.00	$85.00
Jig	Assemble Jig	0.5	$85.00	$42.50
Total labour cost for manufacturing molds and frame jig				**$9,716.50**

Total cost for the initial setup material cost comes to $40,345.92, while the labour cost required to do complete this is $9,7160. As the cost of each aluminum billet was unable to be determined in time, they were an estimate and could vary in either direction. This cost is a one-time expenditure that will pay itself off over time as trailers are sold.

8.2. Material and Component Costs

The cost details for all the materials and components that went into this trailer are summarized in the following table.

TABLE XXIX: COMPONENT AND MATERIAL COST FOR A SINGLE TRAILER

Item	No. Items	Amount of Material	Cost	Total	Source
Frame					
6061 1.5"x1.5" x 1/8"	1	14 ft	$1.92/ft	$26.88	[51]
6061 2" x 2" x 1/8"	1	6 ft	$3.00/ft	$18.00	[51]
6061 3/16" Plate (4' x 8' sheet)	1	37.5 in2	$5.94/ft2	$1.55	[51]
6061 1/8" Plate (4' x 8' sheet)	1	48 in2	$7.5/ft2	$2.50	[81]
Sponge Seating Cushion	1	13.25 ft	$1.72/ft	$22.73	[82]
Total cost for frame				$71.66	
Fasteners					
5/16-24 x 1 " HEX bolts	8	n/a	$0.15	$1.36	[54]
5/16-24 HEX lock nuts	8	n/a	$0.05	$0.45	[54]
0.25" x .67' Length' rivets	26	n/a	$0.06	$1.76	[55]
#10-32 HEX nut	8	n/a	$0.04	$0.36	[54]
#10-32 x 0.75 Torx Security Bolts for hinge	8	n/a	$0.35	$3.16	[56]
1/4-20 x 2.75 " HEX bolts	2	n/a	$0.25	$0.57	[54]
1/4-20 HEX nuts	2	n/a	$0.05	$0.11	[54]
1/4 " washer	4	n/a	$0.06	$0.27	[57]
#8-32x1/2" machine screws	4	n/a	$0.20	$0.90	[58]
#8-32 hex lock nuts	4	n/a	$0.15	$0.68	[59]
#8 washers	4	n/a	$0.06	$0.27	[60]
Total cost for fasteners				$9.90	
Body & Lid					
Gallon of Clear Gel Coat	2	1 gallon	$74.10	$167.47	[83]
Carbon Fiber (42" wide roll)	1	172 ft	$6.92/ft	$1,190.00	[10]
1/8" 6061 Seating Plates	1	1.63 ft2	$7.50/ft2	$13.00	[81]

Item	No. Items	Amount of Material	Cost	Total	Source
Total cost for body and lid				$1,370.47	
Lighting					
Taillight with grommet	4	n/a	$23.90	$95.60	[43]
Side Marker Light with mounting bracket	4	n/a	$7.65	$34.58	[43]
License Plate Light	2	n/a	$12.99	$29.36	[45]
Interior Light	2	n/a	$48.99	$110.72	[46]
Total cost for lighting				$270.25	
Electrical					
4-pole wiring harness	1	n/a	$14.99	$16.94	[47]
Bonded 4-wire (0.57$/foot)	1	17ft	$9.70	$9.70	[48]
3-wire Pigtail	4	n/a	$1.15	$5.20	[84]
Quick Splice Wire Connectors	22	n/a	$0.35	$8.70	[85]
Total cost for electrical components				$40.54	
Hatch Components					
Latch	1	n/a	$7.91	$8.94	[38]
Hinge	1	n/a	$5.00	$5.65	[38]
Gas Piston	2	n/a	$14.40	$32.54	[39]
Ball Stud	4	n/a	$0.63	$2.85	[39]
Weather Stripping Top	1	n/a	$40.46	$45.72	[41]
Weather Stripping Bottom	1	n/a	$34.67	$39.18	[41]
Lid Hinge Mounting Plate	1	48 sqin	$7.50/ft2	$2.50	[81]
Base Hinge Mounting Plate	1	37 sqin	$7.50/ft2	$1.93	[81]
8" x 4" x 1/16" gas piston mounting plate	1	32 sqin	2.00/ft2	$0.40	[81]
Total cost for hatch components				$139.31	
Flooring and Upholstery					
1/4" 48" x 96" ABS Sheet for Floor	1	1/4" 48" x 96"	$95.40	$107.80	[49]
Interior Upholstering	1	n/a	$330.00	$372.90	[53]

Item	No. Items	Amount of Material	Cost	Total	Source
Total cost for flooring and upholstery				$425.40	
Miscellaneous					
Flexiride Torsion Suspension (both sides)	1	n/a	$247.46	$279.63	[8]
Kenda tire and wheel	3	n/a	$139.95	$474.43	[34]
Swivel Hitch	1	n/a	$200.00	$226.00	[61]
Safety Chain and 2 Curt Hooks	1	n/a	$6.59	$7.36	[62]
Total cost for miscellaneous items				$987.42	
Repeated Use Miscellaneous					
Loctite Speed Bonder H8000	1	490 mL	$125.00	$141.25	[63]
Model G100-6 Spray Gun W FN-6 Tip	1	n/a	$162.69	$183.84	[64]
Total cost for repeated use miscellaneous				$325.09	
Total component and material cost for one trailer				**$3,640.03**	

The total cost of the components and materials required to manufacture and assemble one trailer came to $3,640. The expense for the trailer is a total of $5,600 including the total material and manufacturing cost.

8.3. Manufacturing and Assembly Costs

The labour costs were developed while in contact with the Cormer representatives. These labour rates provided were $85/hr for general work and $108/hr for loaded work [10]. The group developed the time to complete each process, and with this data, was able to develop a cost breakdown for each process within manufacturing. The labour costs for manufacturing and assembling the trailer are given in the following table.

TABLE XXX: MANUFACTURING AND ASSEMBLY COST BREAKDOWN

Part	Process	Time to Complete (hours)	Labour Cost/hr	Total Cost
Frame	Cutting Tubes for Frame	1	$85.00	$85.00
Frame	Assembling and Welding Frame Parts	1	$85.00	$85.00
Frame	Attach Axles & Coupler	0.5	$85.00	$42.50
Frame	Attach Wheels & Safety Chain	0.5	$85.00	$42.50
Body	Set-up Mold Structure	1	$108.00	$108.00
Body	Cut & Lay-up Pre-Preg	3.5	$85.00	$297.50
Body	Vacuum Bag & Cure Parts	3	$108.00	$324.00
Body	Trim and Process Finished Parts	1.75	$85.00	$148.75
Body	Attach Gas Lift Springs	0.5	$85.00	$42.50
Body	Install Weather Stripping and Hinge	1	$85.00	$85.00
Body	Install Lighting and Wiring	2	$85.00	$170.00
Body	Attach Lid	0.5	$85.00	$42.50
Trailer	Mount Body to Frame	1	$85.00	$85.00
Trailer	Install Floor Boards, Lining & Carpet	3	$85.00	$255.00
Trailer	Apply Wax and Clean Product	1.5	$85.00	$127.50
Total labour cost for assembling the trailer				**$1,940.75**

The total cost for assembling the trailer comes to approximately $1,940.00. Combined with the costs for trailer parts and materials, the total cost to manufacture and assemble one trailer is about $5,580, falling under our budget of $5,600.

9. SUMMARY OF THE DESIGN

Our final design features a sleek carbon fiber body, designed to carry and protect the cargo it transfers, and is mounted to a lightweight aluminum frame. The enclosed cargo bay of the trailer opens with a large hatch allowing easy access to the entire cargo area which is lit at night by interior lights powered by motorcycle. Figure 85 shows the trailer fully opened with the gas springs holding the lid in place.

Figure 85 Render of final trailer model showing hatch opening

We have selected stylish LED tail and side marker lights which contribute to the premium look of our trailer. The trailer rides on a torsion half-axle suspension system which is compact, durable, and lightweight while providing dampening through the natural hysteretic properties of the rubber. Figure 86 shows an exploded view of our final design assembly, illustrating the main components used in the design.

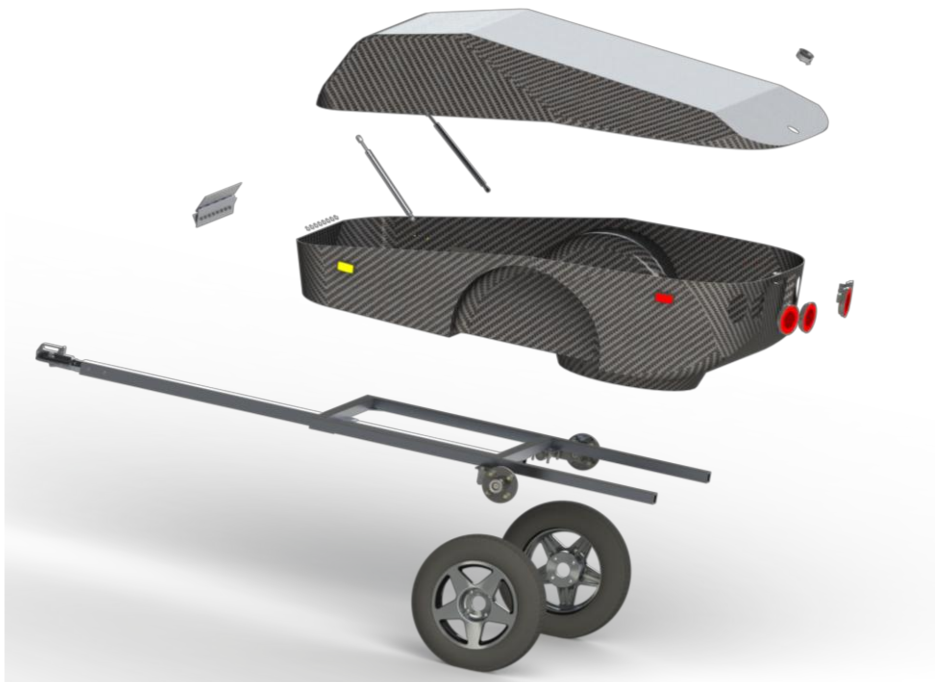

Figure 86: Exploded render of the final design assembly

The exploded view shows how the suspension is mounted to the aluminum frame which supports the carbon fiber body of the trailer. This reduces the mass of the trailer, while maintaining strength and manufacturability since the suspension system is outsourced. This frame can be made easily in-house, as is the carbon fiber body is layed-up using pre-cut pre-preg sheets. Figure 87 shows a detailed render of the rear of the trailer, showing the latch placement, the spare tire compartment, and the license plate mounting holes in the recessed panel designed to elegantly frame the license plate.

Figure 87: Rear view render of final design

The trailer uses a standard motorcycle hitch, and is equipped with reflectors on the sides to indicate its presence and width on the highways at night. Under the body is a compartment used to store a spare wheel, in case problems do occur on the road. The final design has a safety chain, which is not indicated in the final model. A side view of the design, displaying the previously stated devices can be seen in Figure 88.

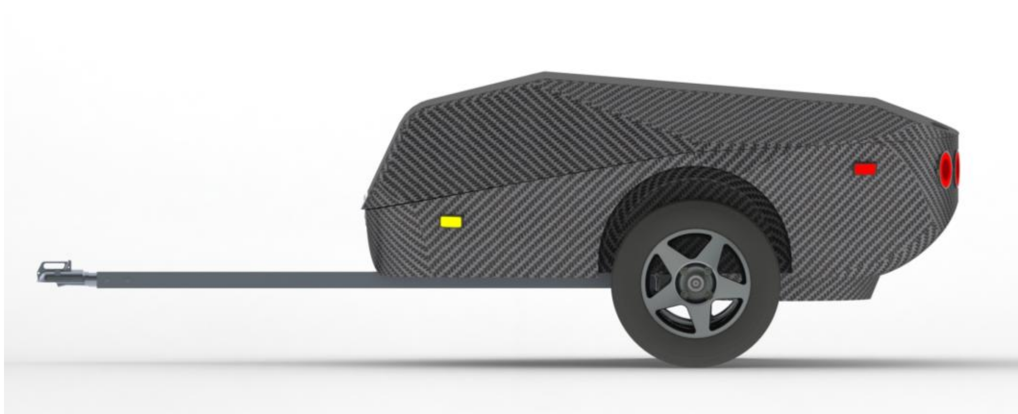

Figure 88: Side view render of final design

As a commercial product, the manufacturing expenses for the trailer including assembly and parts were determined to be approximately $5,600. Using the approximate

20% mark-up, the sales price of the trailer could be set at \$6,750. The total profit for the trailer is thus \$1,150 per unit, but can be increased further if the client decides to increase the mark-up.

10. Future Recommendations

The team developed several recommendations for Cormer Group to consider prior to manufacturing the prototype as well as for mass production. These recommendations were developed by the group primarily due to time constraints within the scope of the project. These recommendations were also developed to gain better performance for certain features of the trailer design or manufacturing methods.

TABLE XXXI: RECOMMENDATIONS FOR THE TRAILER DESIGN AND MANUFACTURING PROCESS

Feature	Recommendation
Prototype Mold	The current mold design is made of aluminum, and was designed for mass production of the composite parts. For prototyping the trailer specifically, it would be a significantly cheaper venture to purchase MDF (mixed density fiberboard), then to manufacture using the same mold. Any problems experienced with this mold could be redesigned prior to manufacturing one out of aluminum.
CNC Availability	For the mold designs, it was specifically recommended that a 4 axis CNC be used. Further research into Cormer's machining capabilities yielded that either the company's Mazak 630N or Toyoda FNH-80T horizontal machining centers be used. For a more accurate mold design, a 5 axis CNC could be used instead.
Stackable Mold	Both of the current molds were designed for curing in the oven separately. Having both molds for the lid and body able to fit into the oven would be significantly more economical, allowing for faster manufacturing times and reduced wasted time. This would require a set-up to stack the two molds on top of each other, either by a separate frame, or by manufacturing an attachment for the molds to stack onto each other, onto the heavier mold.
Stencils	To make cut-outs into the main body, the methods for manufacturing recommend stencils to accurately position holes and make cleaner cuts into the pre-preg. Although it is not completely necessary, these would assist the employees responsible for laying up the carbon fiber and processing the composite components of the trailer.
Prototype Testing	Although an obvious recommendation, it is suggested that full prototype testing for the trailer be performed. The team

Feature	Recommendation
	designed the trailer with safety and structural integrity in mind, but without physical testing, these analyses cannot be verified. This testing can range from (but are not limited to) vibrations, fluid flow, and stress analyses.
Lid Hinge Redesign	The hinge implemented into the current design was not intended for use with a weather strip. It is suggested that a hinge integrated with the strip is sourced, or that the weather strip in use is redesigned in a way that the hinge can be integrated within for better alignment when the lid is open.
Custom Rims	The current rims were not researched as thoroughly as possible due to time constraints. The team recommends that a set of rims be designed and machined in-house for a better aesthetic appearance and cheaper cost. Redesigning the rims would also allow for a narrower tire, as the current one slightly stick out from the body. Implementing the rims for the narrower tires would reduce the weight, rolling resistance, and drag of the wheels.
Custom Coupler	Even though the current coupler for a standard motorcycle hitch was researched thoroughly for cost and strength, it is recommended that Cormer Group design and manufactures their own custom coupler. The custom coupler would be desirable specifically for aesthetic purposes, and if possible a reduction in cost.
On-Board Battery	The motorcycle was intended for the design to power the trailer lighting, which may strain the battery of the vehicle. Using an onboard battery would allow for less power consumption, and a reliable light source
Optional Spare Tire	Implementation of the spare tire was a precaution in case the tire goes flat while riding. The spare tire should be considered optional, as the weight might be a considerable amount if the user tends to use the trailer for heavier loads. Although the trailer is capable of carrying the required 150 lbs, to reduce wear on the shaft and bearings over time, taking the tire out completely would be better for the trailer.
Tool Kit	By a thorough risk analysis, the team discovered many problems that could occur while the trailer is in motion from general wearing. If a problem arose that the spare tire be required, a tool kit within the trailer is recommended as a precaution to be able to replace the wheel with the optional wheel on the inside.
On-Board Air Compressor	For occasions where the tire runs flat during a long road trip, from deflation over the winter, or to assist drivers along the road, an on-board air compressor can be useful to pump up the tires to the required air pressure.

11. Conclusion

Our project was to design, and provide full engineering drawings for a carbon fiber enclosed motorcycle cargo trailer for our client, Cormer Group Industries. We were given initial needs for the design, which were used in conjunction with research into regulations, patents, and existing products to determine our target specs. We began our design process with brainstorming, and developed the body design using a multi-tiered concept selection process using weighted needs from both the client and our own internal research. We refined our final design by integrating the most desirable features from our 3 highest ranked concepts.

In order to reduce the complexity and cost of manufacturing we have outsourced components for the trailer whenever in-house fabrication would be impractical or prohibitively complex. We performed extensive research to make selections of all outsourced components, and materials used in our design to ensure that the final design fully met all of the customer needs, while reducing cost wherever possible without compromising quality.

Our final design has a dry weight of 154 lbs which makes it one of the lightest trailers of this type available, even while featuring best in class interior cargo volume of 28.4 ft^3 which easily meets the clients requirement that the trailer be capable of carrying 2 golf bags.

We have created full engineering drawings for all parts and assemblies in our design as requested by the client which serve as a detailed record of the design, as well as instructions for manufacturing our design. These drawings are detailed down to the component level for parts made in house and the assembly drawings make reference to vendors and their respective part numbers in the bill of materials for each set of drawings.

We have designed a motorcycle cargo trailer which meets all of our initial goals, and created a complete set of engineering drawings as well as manufacturing plans for the entire trailer. Having satisfied all our customer’s needs with our design, the only recommendations we have are with regards to prototype testing in order to perform a more accurate fatigue analysis, as well as small features which could be added to improve the use of the trailer but are outside the scope of this project.

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1. TEAM RESEARCH

As a group, the team is performing the rigorous task of developing ideas for the design. These ideas require extensive research prior to concept analysis, especially since much of the research applies to the development of various components. External research was performed to determine the applicable regulations, relevant patents, literature relating to trailers, and examine similar motorcycle trailers. Internal research on the other hand, was a thorough brainstorming method of idea generation, from the frame design to materials consideration. This research and brainstorming was then applied to the process of concept generation, necessary to developing the final design which is documented in section 2 of the main report.

1.1. EXTERNAL RESEARCH

The team performed several forms of research, each looking into various different sources for assistance. Some of the research was found useful and important for the design and analysis of the trailer design were the applicable regulations, patents, various magazines, and competitor trailers. This research was then incorporated into the initial stages of design, and will be further integrated into the final design to comply with laws, and be a competitive, high quality trailer in the market.

1.1.1. APPLICABLE LAWS AND REGULATIONS

One of the most important considerations is that the motorcycle trailer follows the road laws for the provinces and states that it would travel through. Since the trailer will designed for travel within Canada and the USA, numerous regulations were found to assist the team in designing for the general safety of the vessel. The highway regulations vary from state to state and province to province, meaning that all of the regulations discussed are a bare minimum required for both countries, regardless of state. In other words, the summary of the regulations to be discussed include the laws that deal with smaller trailers (like the one being designed), as most of the other regulations regarding trailer design deal with large trailers.

In general, different components used for trailer safety would be required depending on the type and size of trailer. The basic motorcycle trailer does not require many of these components due to the fact that its length and capacity are generally smaller than the regular truck-towed trailers. The required components are summarized in the following list:

- If the ratio of trailer weight (including cargo) to the combination of the motorcycle, trailer and cargo is less than 40%, the trailer is not required to use brakes. (US regulation) [1]
    - For a motorcycle with a trailer travelling straight on level ground at 30 km/h, brakes are not required as long the stopping distance at this speed is less than 9.15 m (or 30 ft) on smooth asphalt or concrete. (Canadian counterpart regulation) [1]
- A safety chain is the bare minimum with regards to preventing hitch failure in most states and provinces. [2]
- The trailer should at minimum be designed for driving conditions within the posted speeds of 0-75 mph (0-120 km/h), with a factor of safety for the vehicles that do not follow laws. [3]

The lighting and reflector requirements may vary from region to region, but have been summarized in Transport Canada's *Trailers: Federal Lighting Equipment Location Requirements*. The motorcycle trailer design is similar to one of the smaller trailers posted by Transport Canada, as seen in Figure 1. The regulations applicable to the trailer displayed are generally to indicate stopping, turning, the presence of the vehicle, and the size of the vehicle. The positions of the lights and reflectors are to be set up as the illustrations suggest, and must be a minimum of 15 inches from the ground [4]. The numbers indicated in Figure 1 can be referenced in TABLE I.

.

Figure 1: Transport Canada's applicable lighting and reflector requirements [4]

TABLE I: LIGHTING AND REFLECTOR REQUIREMENTS [4]

Designated Position	Lighting and Reflector Requirements
1	Tail, Stop, Rear Signal Lamps and Rear Reflectors
2	Licence Plate Lamp
3	Rear Side Lamps and Reflectors
4	Front Side Lamps and Reflectors
6	Rear Clearance Lamps
7	Rear Identification Lamps
8	Front Clearance Lamps

1.1.2. Patents and Other Trailer Designs

In order to better understand the designs currently on the market, our group researched patents applicable to motorcycle trailers. The results included patents related to hitch mechanisms for motorcycles, suspension geometries, shape of the hard shell body, and frame styles. The more comprehensive patents were helpful in highlighting the problems needing to be addressed with conventional trailers, such as body aerodynamics, and suspension geometry. US Patent 7121575 [5] describes a swing arm suspension geometry which places the swing arm above the axle in order to reduce the forces translated into the swing arm compared with geometries having the swing arm mounted bellow the line of the axle as shown in Figure 2.

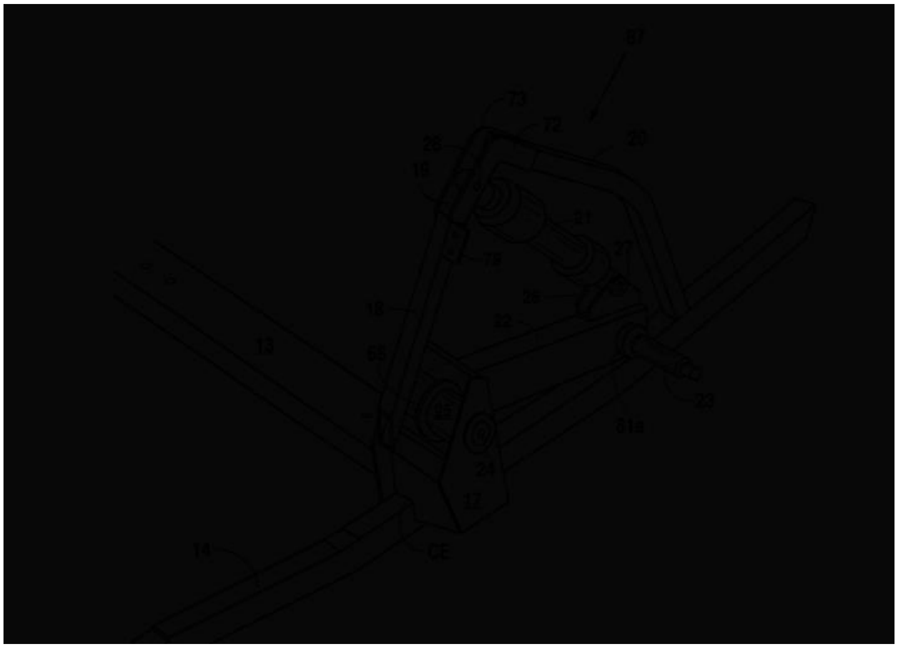


Figure 2: Trailing arm geometry [5]

This patent also describes a teardrop body shape, which reduces drag by facilitating the convergence of air around the back of the trailer; the proposed shape of the trailer is shown in Figure 3. While nothing specific to this patent will be used, it does serve to identify the common problems when designing a cargo trailer for a motorcycle.

Figure 3: Teardrop shaped body shell [5]

1.1.3. Relevant Literature

As part of the team research, we examined several articles on what customers are looking for in a motorcycle trailer along with reviews on trailers. Furthermore, literature on relevant engineering topics including fiber reinforced composites, aerodynamics, and manufacturing methods were researched. This information is discussed further in the following two sections.

1.1.3.1. Customer Considerations

When designing a motorcycle cargo trailer, one must keep in mind the satisfaction and safety of the rider. Since motorcycle cargo trailers are part of a limited market, it is important to appeal to as many motorcycle owners as possible [6]. According to *You Motorcycle,* consumers should consider some key factors when shopping for a motorcycle trailer [7]. These include trailer size and geometry, weight versus structural strength, and the interior compartment layout.

With respect to the size, the trailer should not be much wider than the widest part of the motorcycle (saddle bags included). If the trailer is too wide, the rider will experience considerable drag at highway speeds. A wide trailer will also force the rider to drive in the center of the road, which is where most dirt, oil, and debris will be encountered. The geometry of the trailer must also be considered in the design process. A sleek streamlined design will not only benefit the bike aesthetically, but also increases the trailer's stability at higher speeds. A streamlined design will also prevent the motorcycle's exhaust stream from getting caught in the turbulent vortex that forms around the windscreen [7]. With regards to the wheel size, *Rider* magazine recommends larger, narrower wheels. This makes the trailer more maneuverable, and is easier on wheel bearings because they make fewer rotations per kilometer and spin more slowly at a given speed than smaller wheels [8].

Another key design parameter is consideration towards the weight and strength of the trailer. It is important to design a trailer that is as light as possible while still providing adequate strength, along with having the durability to withstand rough roads and handling. Low weight is important because a lighter trailer allows the rider to tow more weight without it affecting the motorcycle's handling. The strength of the trailer will depend on the chosen materials for the trailer frame, wheel assembly, and body. Steel tubing is a common frame material used, but aluminum alloy would be a lighter but more expensive option. Carbon fiber provides an exceptional strength-to-weight ratio for the body.

The interior compartment of the trailer must be designed to store multiple items of various sizes and shapes. The best way to accommodate this is to have one large compartment rather than having numerous smaller ones. This allows the consumer to carry anything from everyday groceries to golf bags [7]. Other factors that may affect the volume of the compartment is the size of the wheel wells and the mounting system for the spare tire.

1.1.3.2. Engineering Considerations

In addition to the main literature researched, numerous automotive magazines were analyzed for concepts in industry that can apply to the structural integrity of the composite motorcycle trailer, specifically the *Momentum* magazines. These magazines are provided by SAE international to members living all around the world, to update them about the automotive and aerospace industries (for example civil, defense, and general research), specifically with regards to engineering design. Such design concepts deal with composites, aerodynamics, and other manufacturing methods, which are discussed below.

Fiber reinforced composites can vary in strength and appearance based on numerous factors. High-end vehicles, such as the Lamborghini Aventador, use various methods of arranging fibers within the cured resin for the purpose of strength or aesthetics. Techniques such as braiding and weaving using resin transfer molding can be used to develop the desired shape while keeping the desired strength relatively consistent throughout [9]. Depending on such arrangements, the strength in various directions can be improved. Some arrangements hold the fibers together more efficiently, preventing undesired separation.

While the directionality of the fiber is important, the quality of the matrix material is also important with regards to cost, strength, and quality. For example, the Milwaukee School of Engineering’s super mileage team determined that compared to epoxy, vinyl-ester works more efficiently because of its higher hardness, in turn reducing composite warpage, especially when travelling on hot days [10]. Preserving the overall shape of the trailer is important, as generally long distance travels occur during the summer time, where temperatures are well within a range to thermally induce strains.

The incorporation of fluid dynamics in the design of a fast moving vessel is important, especially when dealing with fuel economy. Reducing drag and gross weight can in turn improve the performance of a motorcycle and trailer combination to allow for greater distances to be covered. One such method to reduce drag is to design a trailer as short as possible, to reduce the friction between the air and the surface of the vessel, noted by the Laval University's super mileage team [11]. Incorporating a coating can improve the lifespan, especially by weather-proofing the vessel. One such method to improve this resistance to drag is by applying a polycarbonate film on the chassis [12].

Composite materials are well known to reduce the weight of a vehicle by combining high strength materials with low weight materials. This weight can further be optimized by improving the aerodynamics of the vehicle. Designing the form of the trailer to decrease the down force caused by aerodynamic forces, the overall lifespan of the bearings and tires can increase, which can be useful for the client when developing a warranty period [11].

Engineering design is limited in determining the performance of a vehicle in real world scenarios, but through testing and researching manufacturing methods, many overlooked flaws can be accounted for in the design. For example, the joints of metallic frames with weak welds can be improved in strength by using aircraft fabric (or cotton-polyester), as was noted by students on the South Dakota School of Mines & Technology super mileage team [13]. Composites, on the other hand, can use materials such as expanded polystyrene [14] or polyurethane [12], to be sandwiched between fiber panels to improve the rigidity and decrease the weight of the structure, as is used in high performance cars and aircraft components.

1.1.4. Competitor's Products and Specifications

Before designing a motorcycle trailer, our group researched the products that competitors were offering their customers with regards to features and the overall trailer design. A comparison between trailers from numerous motorcycle companies was performed and the results were summarized. TABLE III provides images and model names of twelve motorcycle trailers used in this comparison.

TABLE II: PICTURES OF COMPETITOR'S PRODUCTS

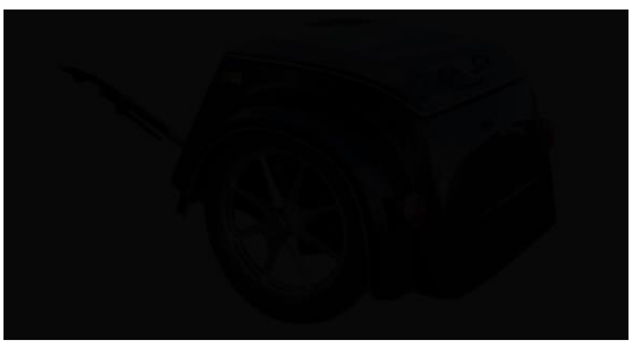
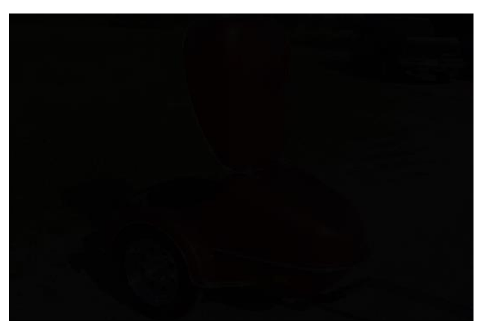
1. Bushtec Quantum GL New [15] 	5. Cycle Mate XL 1800 [16] 
2. Bushtec Quantum Sport [17] 	6. Kompact Kamp Clipper [18] 
3. Bushtec Sportstar [19] 	7. Escapade Excel [20] 
4. Bushtec Turbo+2 GT [21] 	8. Slingshot [22] 

TABLE III: PICTURES OF COMPETITOR'S PRODUCTS

9. Silhouette [23] 	11. ZZ [24] 
10. Tailwind [25] 	12. Trekker 185 SL [26] 

Each trailer was compared based on specifications such as volume capacity, weight capacity, dimensions, wheel size, ground clearance and price. The comparison is shown in TABLE IV. Each trailer number in the first row of the table corresponds with each motorcycle trailer shown above in TABLE III.

TABLE IV: COMPETITOR SPECIFICATIONS

Trailer No.	1 [27]	2 [28]	3 [29]	4 [30]	5 [31]	6 [32]	7 [33]	8 [34]	9 [35]	10 [36]	11 [37]	12 [38]	Avg
Capacity (ft3)	26	26	15	25	24	12	28	19	23	24	16.5	18.5	21
Net Weight [lbs]	140	140	110	125	210	110	253		185	205	200	150	166
GVWR [lbs]	350	350	375	350	500	500	600	550	435	400	400	500	443
Capacity Weight [lbs]	210	210	265	225	290	390	350		250	200	200	350	267
Total Length [in]	89	89	82	87	90			83	100	101	86	84	89
Body Length [in]					61		71	54	60		51	53	58
Height [in]	32	32	30	30	37			31	25	28	30	26	30
Width [in]	38	38	49	38	42		43.3	29	40	41	38	40	40
Ground Clearance [in]								8	5	8	8	10	8
Wheels [in]	16	16	16	16	12	8	12	12	14	12	12		13
MSRP [$]	4399	3999	2399	4399	2395	1795	2295	2380	2995		4295	3095	3131
Load Price [$]					4664	2225	4935	4405	6520				4550

Each of these twelve motorcycle trailers were researched to find the specifications listed above. Additionally, each of the compared specifications have been averaged to provide a general idea and benchmark of what is on the market in regard to dimensions, price, and capacity. When considering the averages provided, it is also important to look at the spread and range of data being considered. Finally, the blank cells in the table indicate unavailable data for the corresponding trailer.

Additionally, the team researched the features that were provided by these motorcycle trailers. A summary of the features found from all the combined results are listed below and categorized by genre of feature.

- Lights
  - Interior lights [39]
  - Spoiler lights [40] [41]

- Bumper running lights [39]
- Cargo Box
    - Locking cargo box [39]
    - Latch outside of storage area - total water and dust free compartment [42]
    - Fully carpeted interior [39] [41]
- Stone Protection
    - Bra (stone guard) [40]
    - Powder coated frame [42]
- Tires
    - Spare tire [39]
    - Spare tire mount [43]
    - Spare tire storage area [39]
    - 6-ply tires (instead of the standard 4 ply) [41]
- Extra Accessories
    - Storage cover [39] [43]
    - Gas-assisted lid props [39]
    - On-board battery (auto charge - does not draw from motorcycle battery) [40]
    - On-board air compressor [42]
    - Cooler on draw bar [43]
    - Cooler cover [43]
    - Roof luggage rack [39]
- Frame Accessories
    - Chrome tongue [39]
    - Trailer stand [39]
    - Swivel hitch [40]
    - Anti sway bar [41]
    - Swivel coupler [43]
- Suspension
    - Anti-roll suspension system [39]
    - Air shock suspension [39]
    - Air adjustable suspension [41]

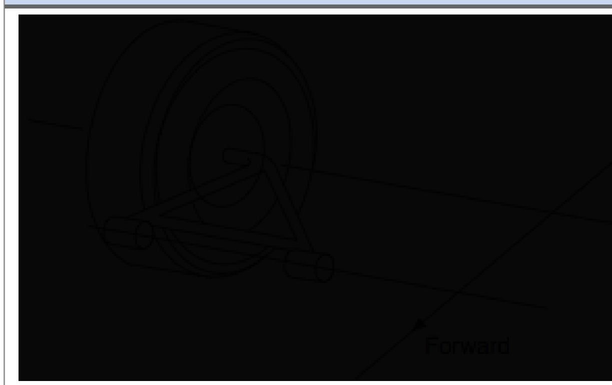
- Independent wheel suspension system [42]
- Shock on draw bar [42]
- Fully independent torsion suspension [43]

It is important to consider the features of current competitor's designs since the target customers for our design will want what other similar trailers have in addition to the carbon fiber design. Our design will be at the top of the market and therefore the team will consider as many features as possible and determine which features are the most important to our target buyers.

1.1.5. Suspension Systems

In addition to understanding competitor’s products, suspension systems have been researched to determine what systems could best be used in our motorcycle trailer design. TABLE V presents various suspension styles, which could be incorporated into our design, along with major benefits and drawbacks associated with each style.

TABLE V: SUSPENSION STYLES [44]

Diagram of Suspension Layout	Name of Style and Applicable Benefits/Drawbacks
	**Trailing Arm** Benefits: • Compact • Maintains camber and alignment • Simple

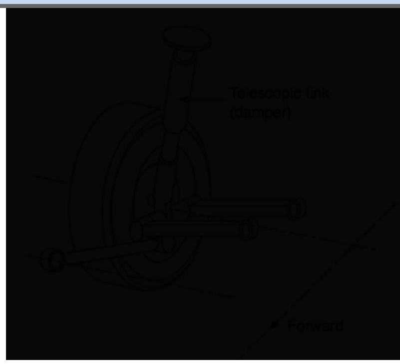
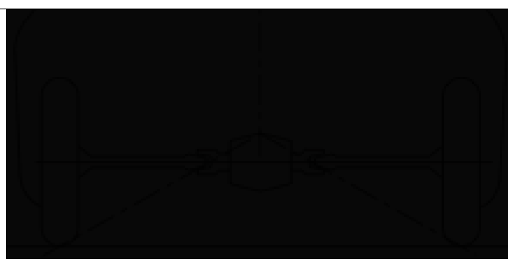
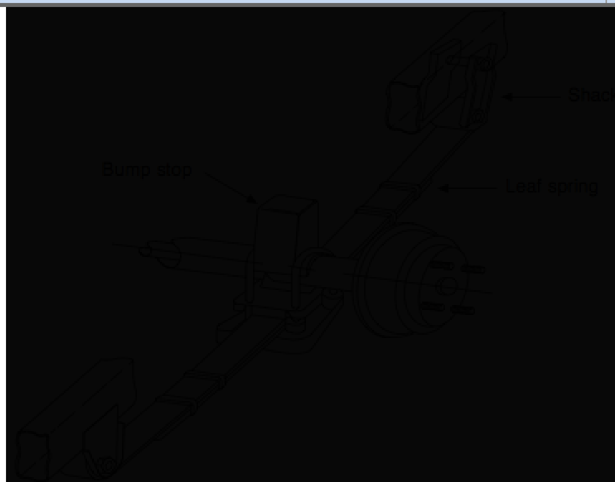
<table>
<tr><th>Diagram of Suspension Layout</th><th>Name of Style and Applicable Benefits/Drawbacks</th></tr>
<tr><td>
</td><td>Macpherson Strut
Benefits:
Maintains camber and alignment
Drawbacks:
Requires lateral stiffness in the strut (shock absorber)</td></tr>
<tr><td>
</td><td>Semi-Trailing Arm
Benefits:
Compact
Simple
Drawbacks:
Changes camber and toe</td></tr>
<tr><td></td><td>Swing Axle
Benefits:
Strong
Simple
Drawbacks:
Camber changes
Prone to suspension “jacking”</td></tr>
<tr><td></td><td>Double Wishbone
Benefits:
Compact
Allows for adjustments
Maintains camber and toe
Drawbacks:
Complex
Expensive</td></tr>
</table>

Diagram of Suspension Layout	Name of Style and Applicable Benefits/Drawbacks
	**Leaf Spring (Solid Axle)** Benefits: • Cheap • Simple • Strong Drawbacks: • Large • Heavy • Ugly • Stiff
	**Multi-Link** Benefits: • Compact • Allows for Adjustments • Maintains camber and toe Drawbacks: • Complex • Expensive

Selection of a specific geometry is dependent on its compatibility with the shape of the body and frame of the trailer. However, based on the preliminary designs, and the information provided in TABLE V, we would recommend the trailing arm style independent suspension. Both the trailing arm and semi-trailing arm suspension geometries are well suited to our application and meet our needs for simplicity and overall function.

1.2. Internal Research

The internal research for the composite motorcycle trailer design involved both individual and team brainstorming. The different methods used and the preliminary brainstorming results are discussed in the following sections.

1.2.1. Brainstorming Methods

At the start of the internal research phase, the team decided to break up the trailer into sections: body shape, frame design, and material selection. Each team member came up with as many concepts in each of these categories as possible.

Additionally, each team member came up with two complete designs with dimensions as an initial concept generation. Each body design were discussed and unique features were highlighted in each design. The designs were then compared using a screening matrix.

1.2.2. Initial Brainstorming Results

The following three sections contain the brainstorming results for the trailer body shape, frame design, and structural materials. The body shape results were intended to point our team in a more focused direction by narrowing down the options with the use of a screening matrix. The frame design results lay out the general options for the frame geometry, which will be analyzed further in the final design phase. Finally, the material selection results provide possible options and considerations for part materials.

1.2.2.1. Body Shape

In order to initiate the development of a body style for the trailer, we brainstormed various 3-dimensional shapes. These shapes represent a rough outline for the outer shell of the trailer and can be seen in Figure 4.

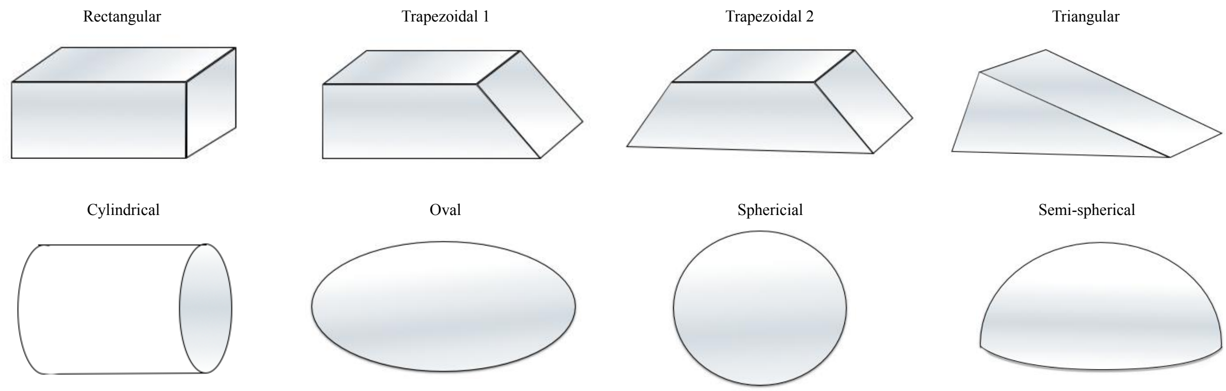


Figure 4: Initial body shapes consider for design

The team then determined the shapes with the best geometries by creating a screening matrix that ranks the aerodynamics, interior space, frame compatibility, and aesthetics for each shape. With regards to aerodynamics, shapes with sloped geometries scored highest. For the interior space, the relative interior capacity of the body was analyzed along with the shape (odd shapes limit the size of luggage). With regards to the frame compatibility, shapes with flat surfaces offer the best mounting points, and therefore scored higher than curved surfaces. The aesthetics were based on a combination of sleekness and how well the contours suit the design application. The shapes were ranked on a scale from -2 (worst) to +2 (best) and are totaled in the right column of the matrix, which is shown in TABLE VI.

TABLE VI: INITIAL BODY SHAPE SCREENING MATRIX

	Aerodynamics	Interior Space	Frame Compatibility	Aesthetics	Total
Rectangular	-2	2	2	-1	1
Trapezoidal 1	0	1	2	0	3
Trapezoidal 2	1	0	2	1	4
Triangular	1	-2	1	1	1
Cylindrical	-2	2	-1	-1	-2
Oval	2	1	-1	2	4
Spherical	-1	-1	-2	0	-4
Semi-Spherical	2	1	1	2	6

The results of the screening showed that the semi-spherical, oval, and trapezoidal shape scored the highest, while the spherical and cylindrical shape scored lowest. The highest scoring results were taken into account in the conceptual design analysis.

1.2.2.2. FRAME DESIGN

The team considered as many unique frame ideas as possible. These frame concepts range in strength, durability, manufacturability, weight, and their compatibility to various frame concepts. Figure 5 illustrates these potential frame designs.

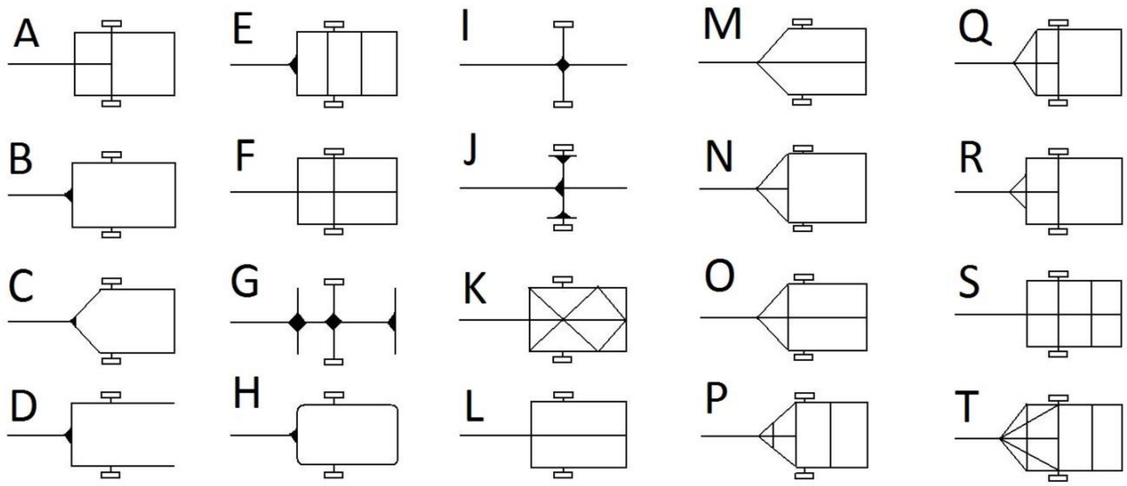


Figure 5: Frame concepts considered during brainstorm process of concept generation

Many of these designs may be altered or all together eliminated based on incompatibility, structural integrity, or other reasons not yet considered. Depending on the selected body style, only certain frames will be possible. Additionally, during the final design, a structural analysis of the frame will need to be performed to ensure the frame will not fail due to high stress or fatigue. These frames were further evaluated using FEA in the frame design section of the main report.

2. Conceptual Design Analysis

This stage of the project involved narrowing down the initial body designs, and then sketching preliminary trailer concepts from them. Once the preliminary designs were completed, we analyzed them with the use of a screening matrix. This gave us the top 3 trailer concepts, from which the top features will be taken and integrated into a final design.

2.1. Conceptual Design Development and Screening

This stage began with taking the four highest scoring body shapes and developing them into fundamental body concepts. This involved adjusting the geometry of the initial shapes to suit an actual trailer body design. The concepts are shown in

Figure **6**, where the right side of each concept represents the front of the trailer.

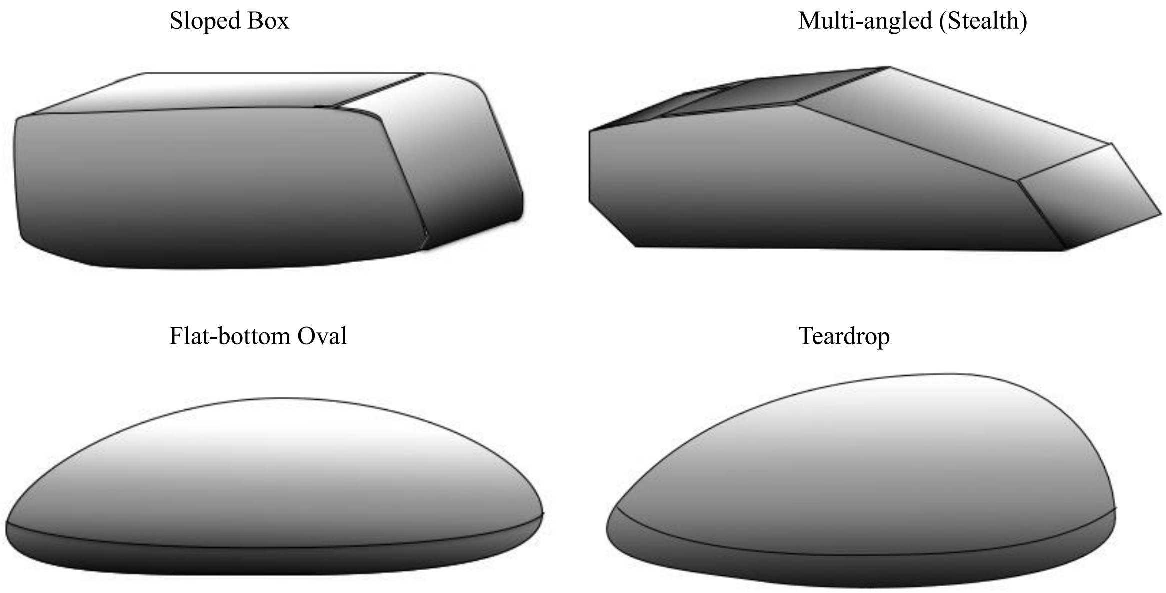


Figure 6: Fundamental Body Concepts

The ‘Sloped Box’ and the ‘Multi-angled’ concept were both derived from the trapezoidal shapes, with the latter being the more extreme version. In addition, the ‘Flat-bottom Oval’ and the ‘Teardrop’ concept were derived from the oval and semi-spherical shapes, respectively.

Once these four concepts were completed, the methods of how the trailer bodies would be opened were analyzed. The interior compartment of these concepts can be accessed in a number of ways. However, the most common method seen in industry consists of a top hatch, which hinges either at the front or the side of the trailer. This allows the user to easily access all areas of the interior from above and offers the most effective way of loading the trailer. For these reasons, our trailer concepts will have top hatch access.

The next step in the conceptual development was to create preliminary trailer concepts based on the four fundamental body concepts. To accomplish this, each group member came up with at least two preliminary concepts. These concepts included the specifics for the outer body style, frame, wheels, basic suspension type, and the general dimensions of the design. At this stage, it was decided that the development of the internal components and features such as the inner body support structure, inner lining, wiring, lighting, and sub compartments would not be developed. The reason for this decision was that the design of internal components and structures for each concept would be quite time consuming, along with the fact that these features will be developed further once the basic design is finalized. The preliminary trailer concepts are shown in Figure 7 through Figure 14 below.

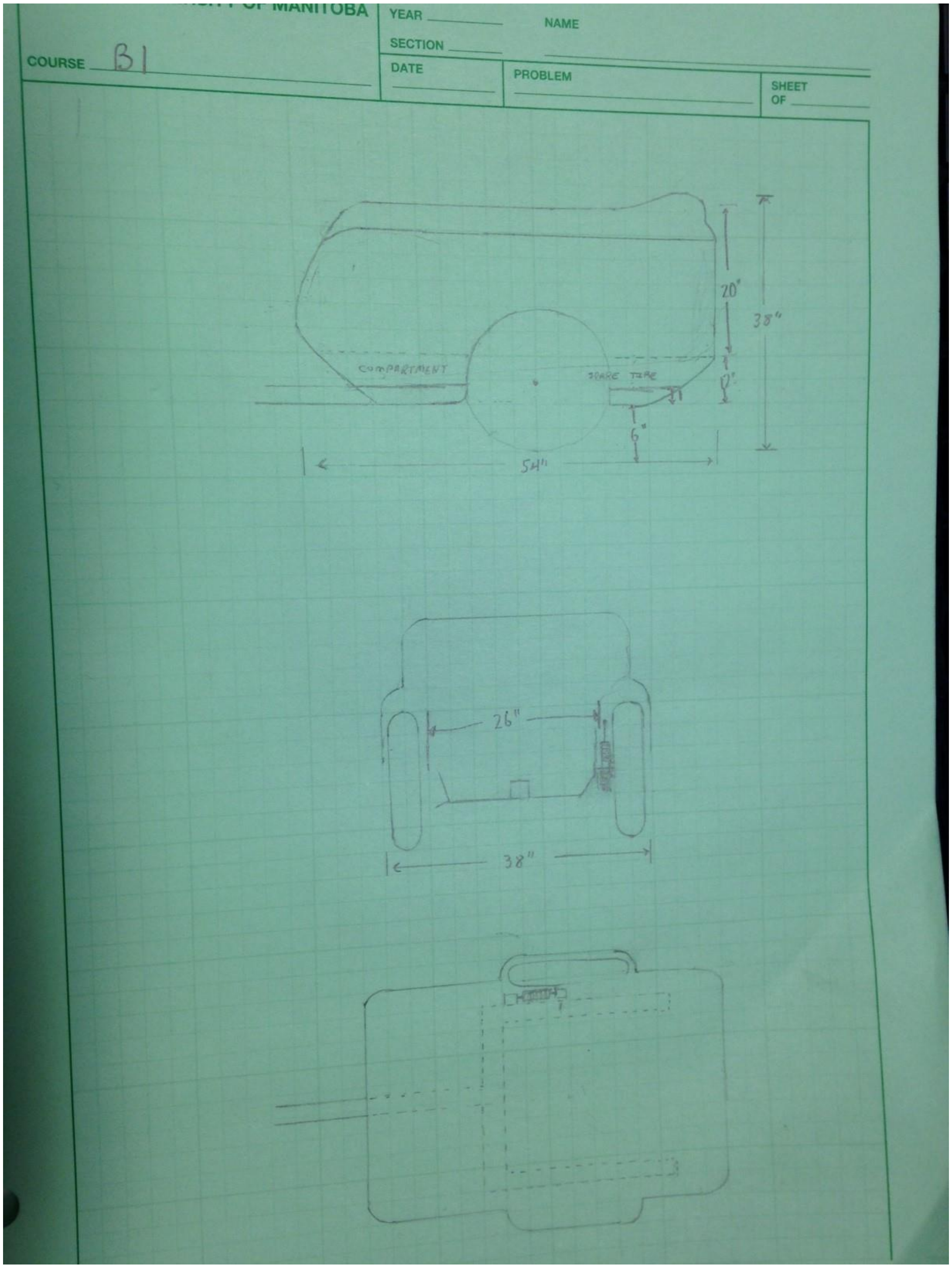


Figure 7: Box concept

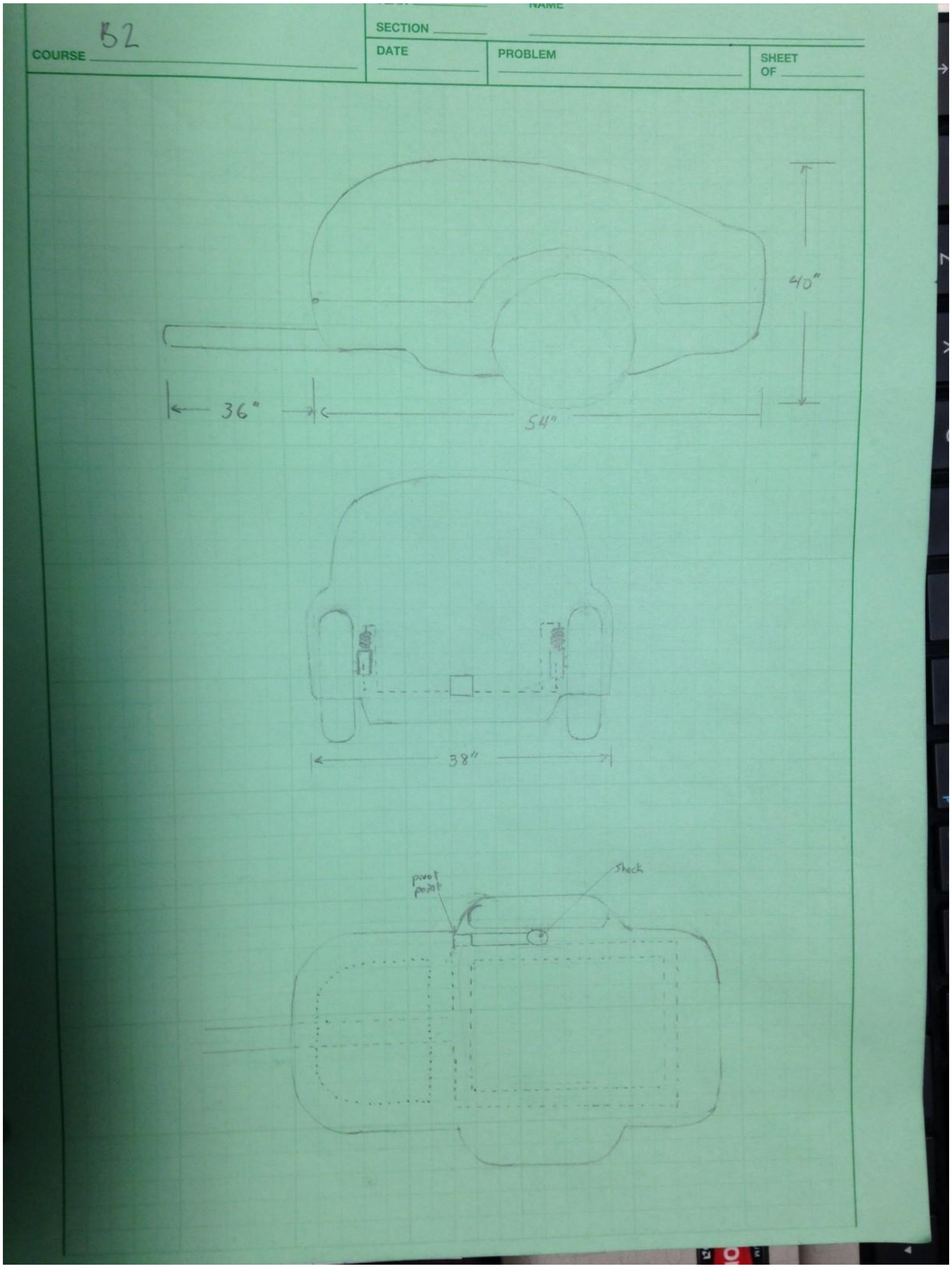


Figure 8: Teardrop concept

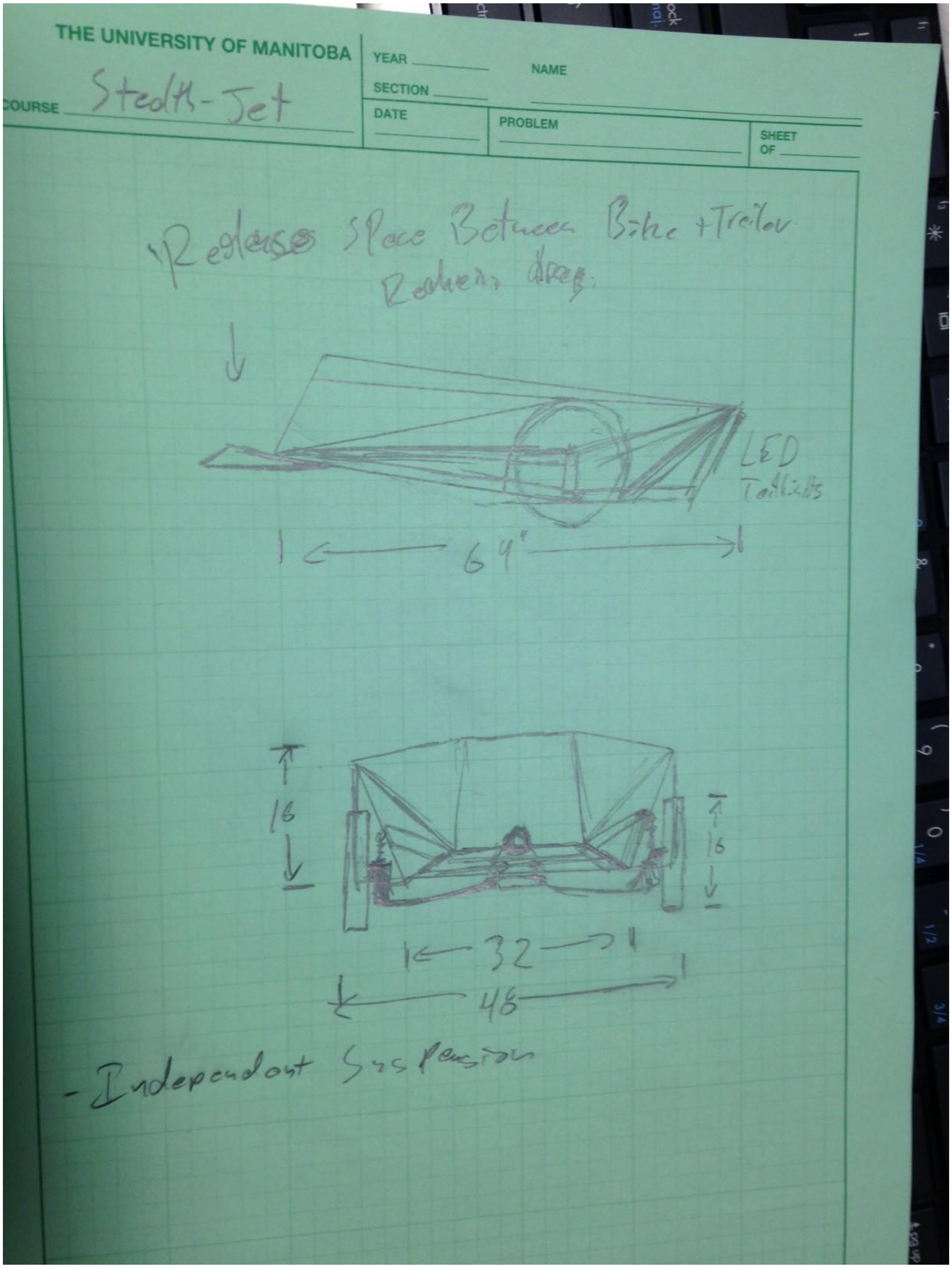


Figure 9: Stealth Jet concept

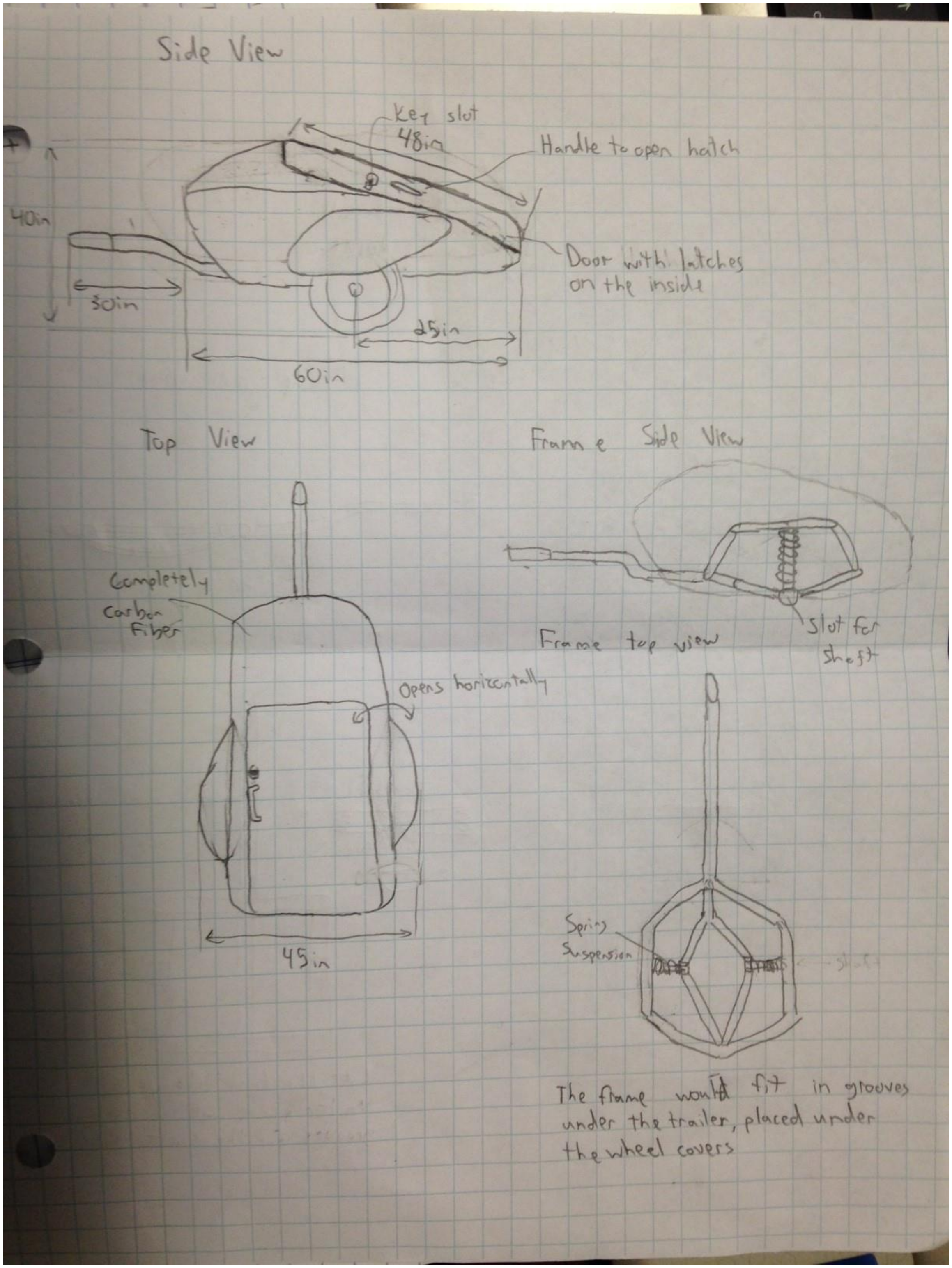


Figure 10: Old School Trailer concept

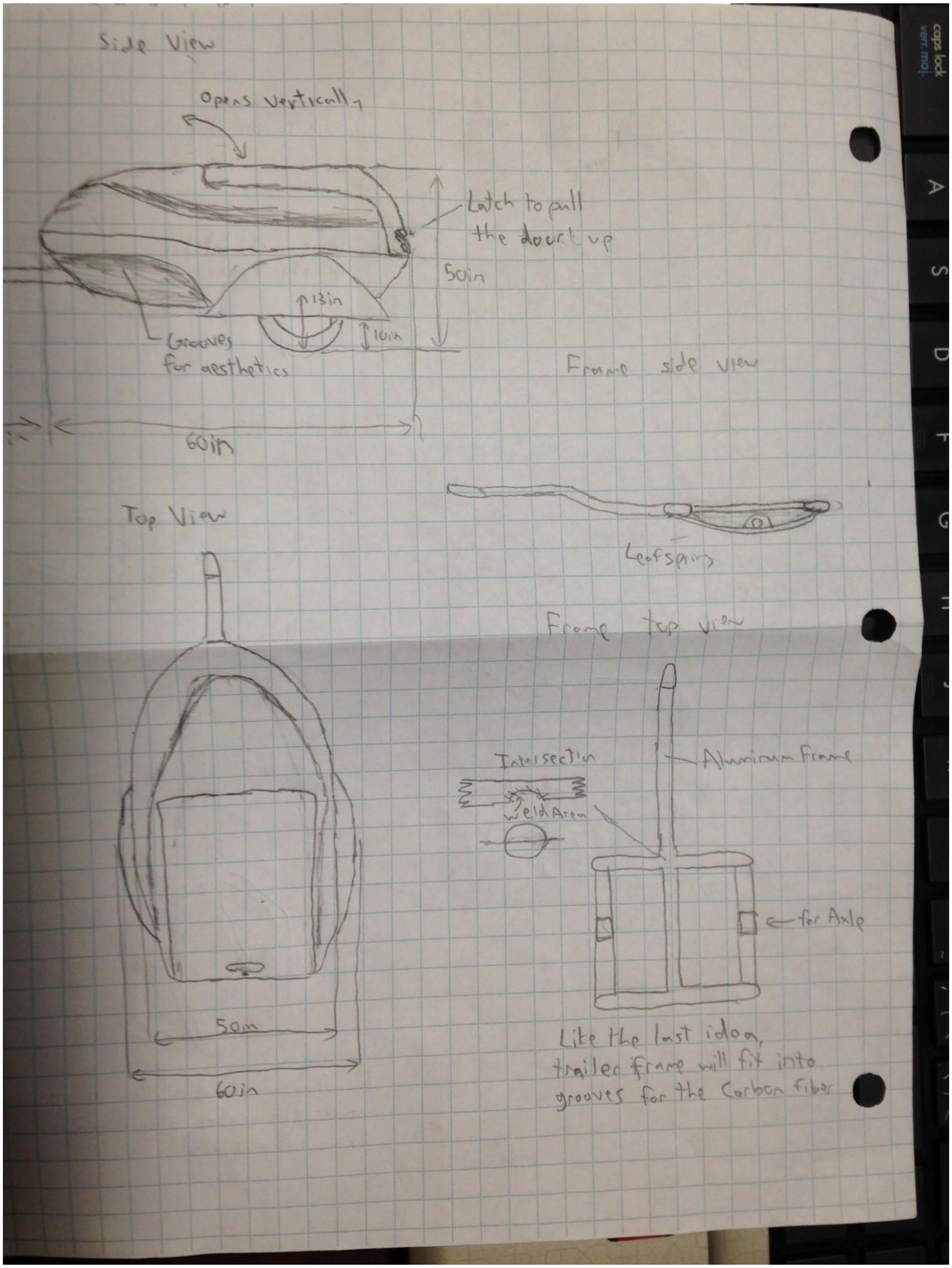


Figure 11: Streamlined Aero concept

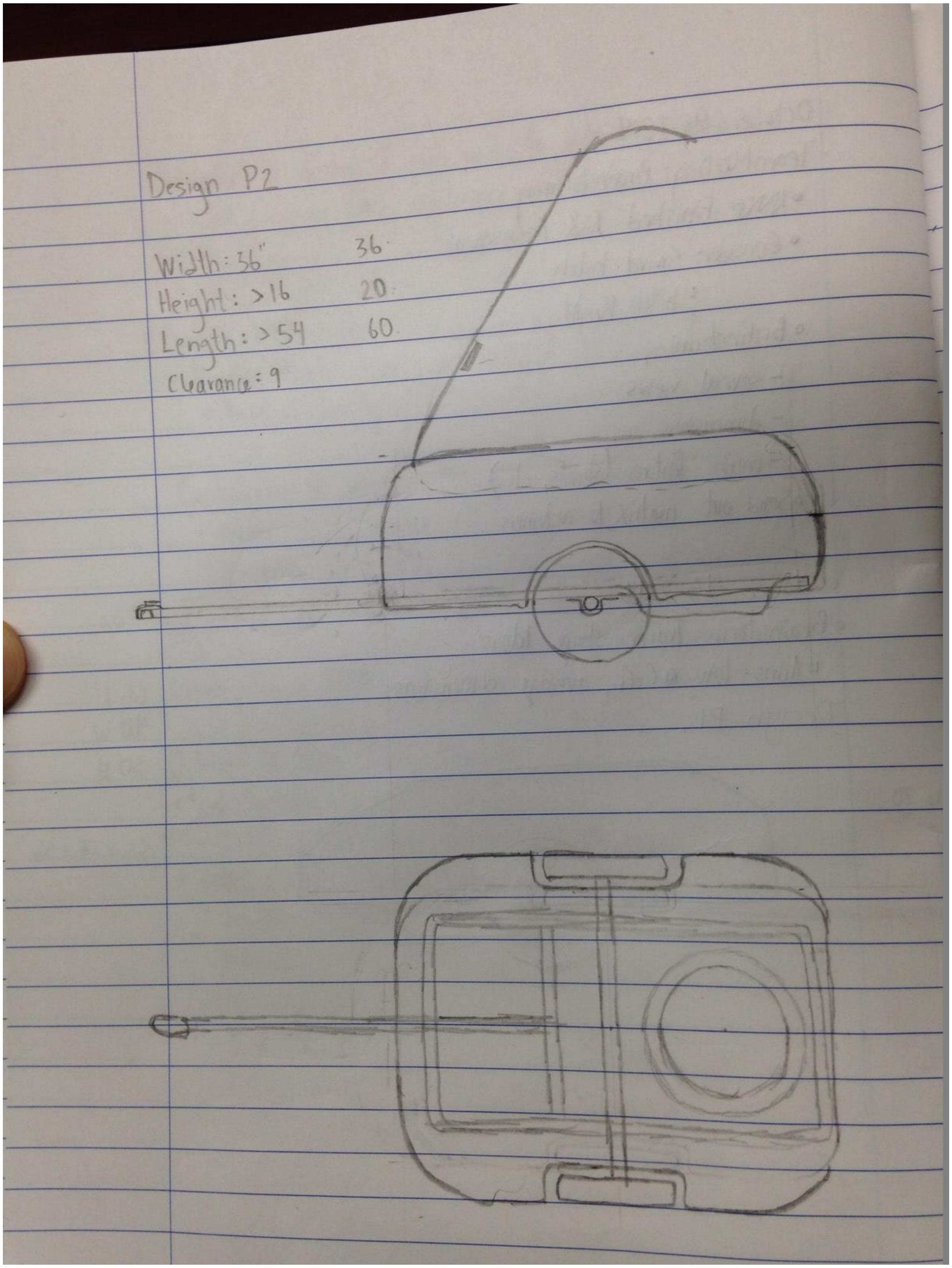


Figure 12: Car Trunk concept

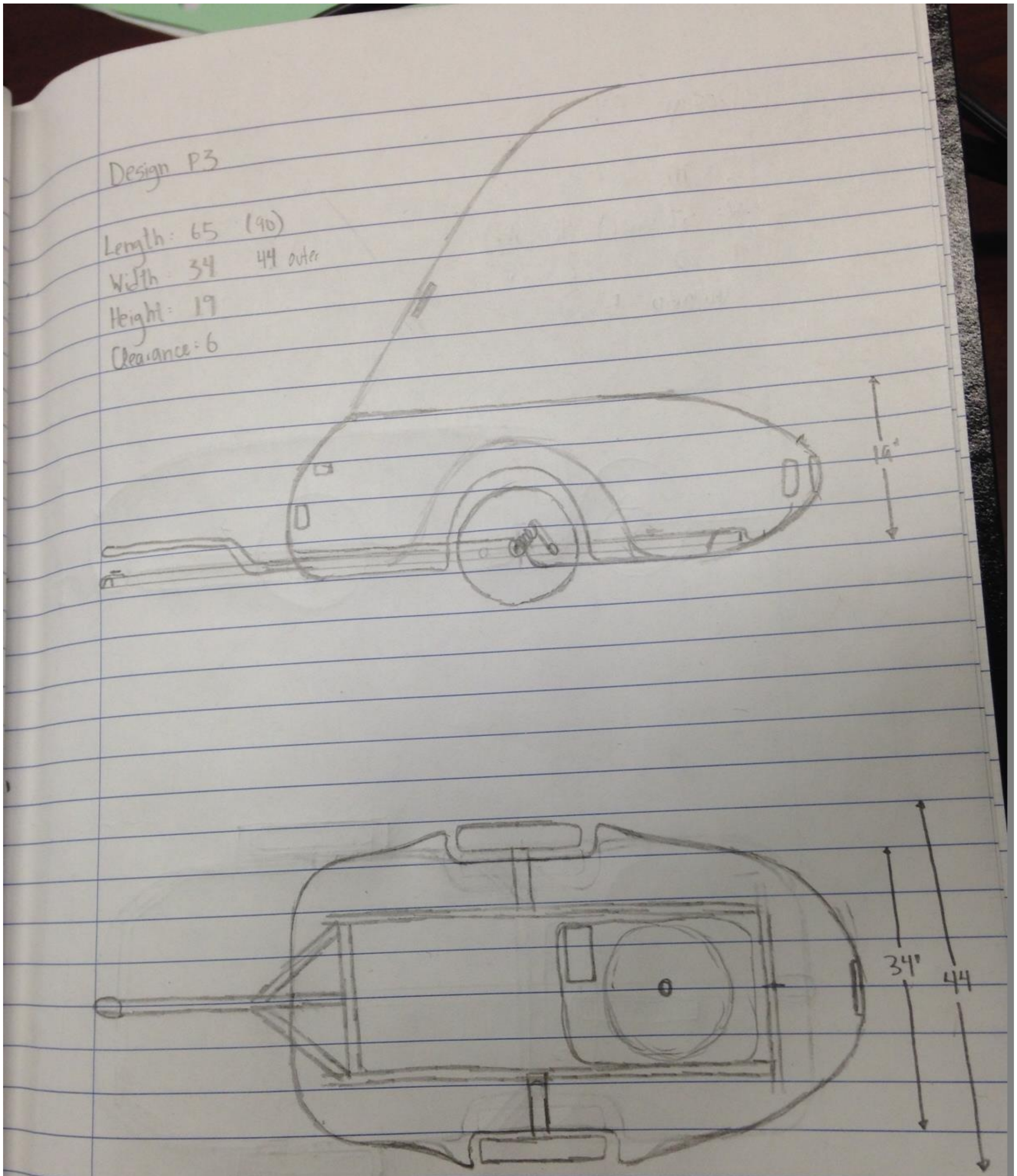


Figure 13: Bullet concept

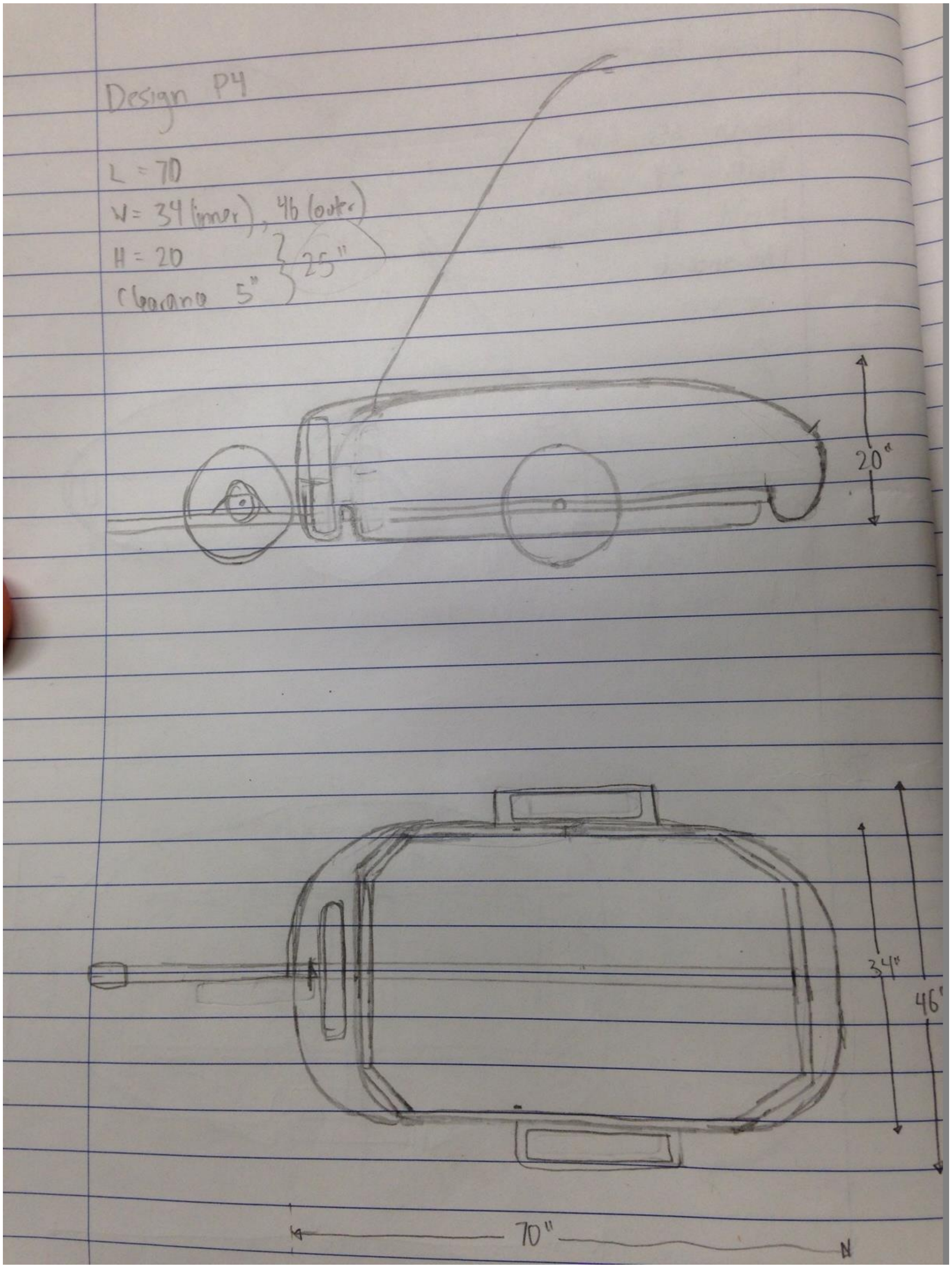


Figure 14: Low Rider concept

Once the preliminary concepts were developed, the team created a screening matrix to assist in the selection of designs to move forward with. They were each compared to a single reference design: the Box concept. The Box concept was used as a reference because it represents a common motorcycle trailer on the market, such as the Bushtec models. The concepts were then evaluated in terms of weight, volume, aerodynamics, durability, and ease of access. Due to the concepts being rough sketches at this point, these parameters were not evaluated numerically and were simply based on a theoretical analysis of each concept. The positive sign and negative sign relate to a parameter being better or worse, respectively, compared to the reference concept. This screening matrix can be viewed in TABLE VII

, which reveals that the top four designs are the Teardrop, Bullet, Old School and Stealth Jet concept. Since all four design concepts had features that would be beneficial to incorporate into the final design, components and features were made into a list shown in TABLE VIII.

TABLE VII: SCREENING MATRIX FOR SECONDARY DESIGN SELECTION

	Box (Reference)	Teardrop	Car Trunk	Bullet	Low Rider	Old School	Streamlined Aero	Stealth Jet
Weight	0	-	+	-	-	0	-	-
Volume	0	0	-	+	+	0	+	0
Aerodynamics	0	+	0	+	+	+	+	+
Durability	0	+	+	+	-	+	0	0
Ease of Access	0	+	0	+	0	-	-	+
Manufacturability	0	0	0	-	+	+	+	+
Stability	0	0	0	+	0	-	-	+
Cost	0	0	0	-	0	+	+	+
TOTAL	0	**2**	1	**2**	1	**2**	1	**4**

TABLE VIII: PREFERRED DESIGN FEATURES FROM THE PRELIMINARY DESIGNS

Concepts	Preferred Features
Box	Spare Tire Placement
Teardrop	Tear Drop Shape
Car Trunk	Light, Tire Storage Method
Bullet	Low Clearance
Low Rider	Body is easier to develop
Old School	Easy access for the key
Streamlined Aero	Clip on wheel covers
Stealth Jet	Area for the brake lights

Once the preliminary design selection process was completed, the team agreed that the concepts to move forward with were the Teardrop, Bullet, and Stealth Jet designs. The Old School concept was not included because it was very similar to the Teardrop design and the preferred features could be easily integrated into any concept. These three concepts were then modeled in Solidworks and can be seen in Figure 15 through Figure 20.

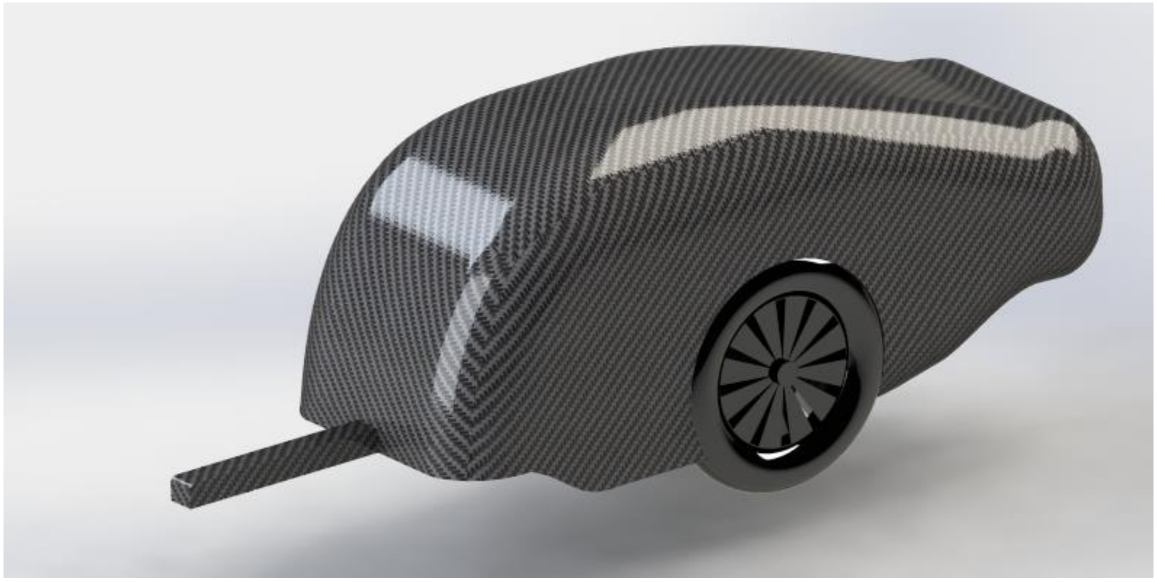


Figure 15: Teardrop concept.

Figure 16: Teardrop concept (side-view).

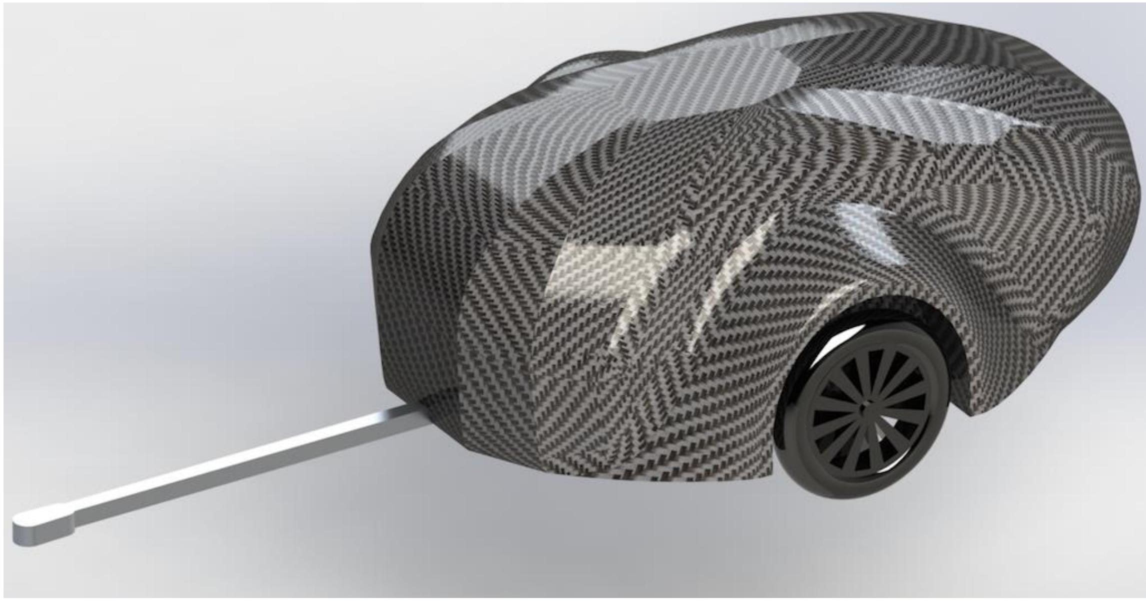


Figure 17: Bullet concept.

Figure 18: Bullet concept (side-view).

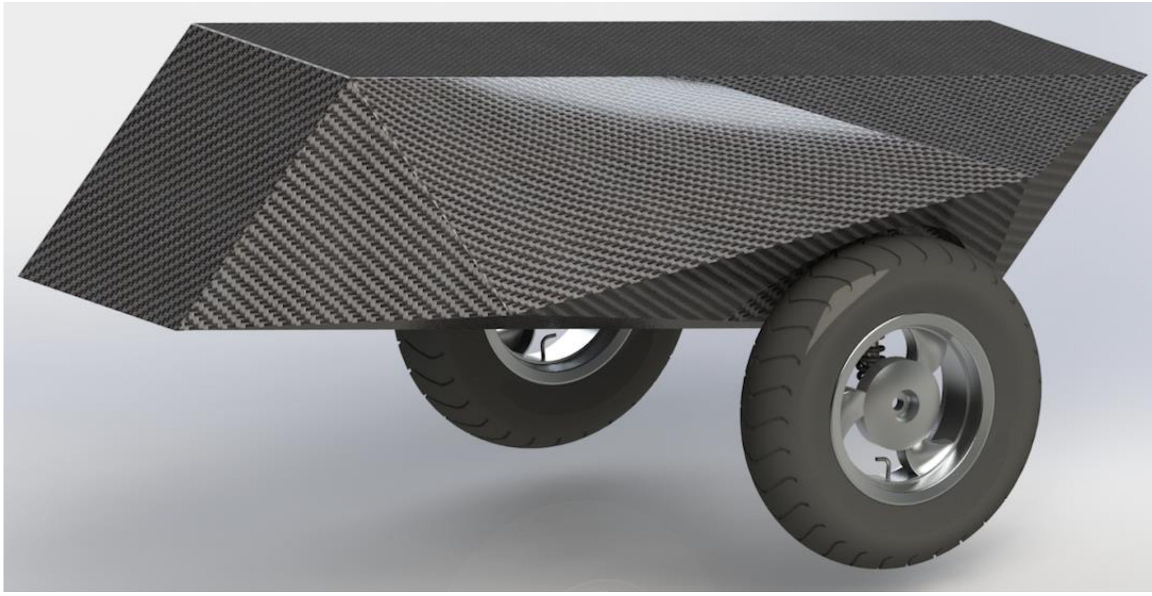


Figure 19: Stealth jet concept.

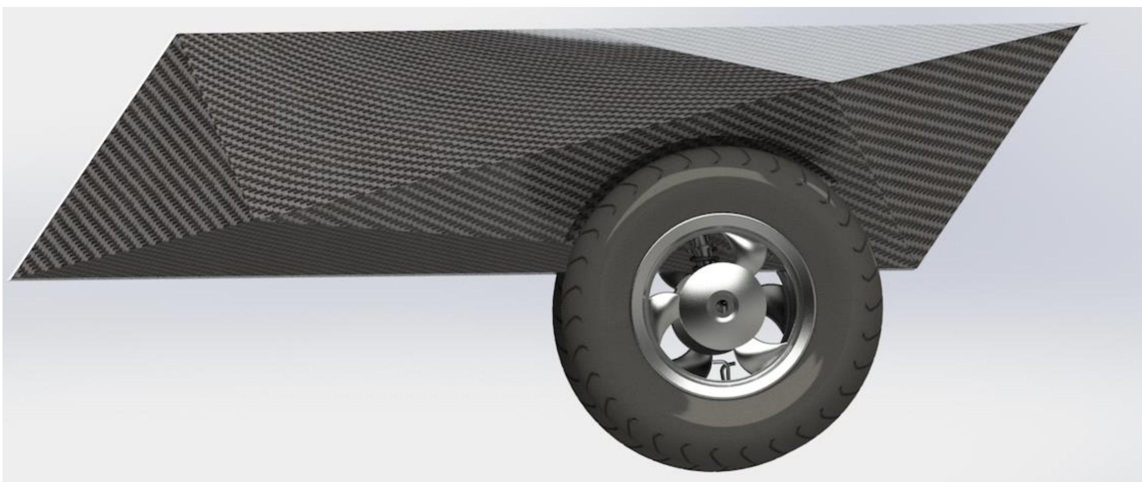


Figure 20: Stealth jet concept (side-view).

2.2. Final Design Selection Process

From these concepts, we were able to begin the final design selection process, allowing us to move into the final phase of the project. To do this, a customer needs matrix was completed by the group to assign weightings to each design parameter, as seen in TABLE IX. In addition, this customer needs matrix was sent to the Cormer representatives in order to get their perspective on the parameter weightings. As seen in TABLE X, Cormer's weightings were quite similar to ours.

TABLE IX: SMALLER HAULER SELECTION MATRIX

Customer Needs		Weight	Volume	Aerodynamics	Durability	Ease of Access	Manufacturability	Stability	Cost
	ID	A	B	C	D	E	F	G	H
Weight	A		B	A	D	E	F	G	A
Volume	B			C	D	E	F	G	B
Aerodynamics	C				D	E	F	G	H
Durability	D					D	D	G	D
Ease of Access	E						E	G	E
Manufacturability	F							G	F
Stability	G								G
Cost	H								
	Need ID	A	B	C	D	E	F	G	H
	Occurrence	2	2	1	6	5	4	7	1
	Calculated Weight [%]	7.14	7.14	3.57	21.43	17.86	14.29	25.00	3.57

TABLE X: CORMER GROUP SELECTION MATRIX

Customer Needs		Weight	Volume	Aerodynamics	Durability	Ease of Access	Manufacturability	Stability	Cost
	ID	A	B	C	D	E	F	G	H
Weight	A		A	C	D	E	F	G	A
Volume	B			C	D	E	F	G	H
Aerodynamics	C				D	E	C	G	H
Durability	D					D	D	G	H
Ease of Access	E						E	G	E
Manufacturability	F							G	F
Stability	G								G
Cost	H								
	Need ID	A	B	C	D	E	F	G	H
	Occurrence	2	0	3	5	5	3	7	3
	Calculated Weight [%]	7.14	0.00	10.71	17.86	17.86	10.71	25.00	10.71

With the weightings developed for each design parameter, the team could move on to the weighted selection process. Using both sets of weightings, as well as a less subjective method of scoring each design, we determined whether one concept is clearly better than the rest. This process is less subjective due to the fact that physical models were developed with relatively realistic dimensions. Assumptions were also used because several important components in the designs were missing, such as the interior framing.

For each parameter, the three concepts were scored from 1 to 3 using a comparison ranking method, where 1 is the worst, and 3 is the best. The group-generated weighted matrix can be seen in TABLE XI. In addition, Cormer's parameter weightings were put into the same matrix, as can be seen in TABLE XII.

TABLE XI: SMALLER HAULER WEIGHTED SELECTION MATRIX

Weighted Selection Matrix (Group)	Group Weighting	Teardrop	Weighted Score	Bullet	Weighted Score	Stealth Jet	Weighted Score
Weight	0.071	2	0.142857	2	0.142857	3	0.214286
Volume	0.071	2	0.142857	3	0.214286	1	0.071429
Aerodynamics	0.036	2	0.071429	2	0.071429	2	0.071429
Durability	0.214	2	0.428571	3	0.642857	1	0.214286
Ease of Access	0.179	2	0.357143	2	0.357143	3	0.535714
Manufacturability	0.143	2	0.285714	1	0.142857	3	0.428571
Stability	0.250	2	0.5	3	0.75	1	0.25
Cost	0.036	2	0.071429	1	0.035714	3	0.107143
TOTAL			2.00		**2.36**		1.89

TABLE XII: CORMER WEIGHTED SELECTION MATRIX

Weighted Selection Matrix (Cormer)	Cormer Weighting	Teardrop	Weighted Score	Bullet	Weighted Score	Stealth Jet	Weighted Score
Weight	0.071	2	0.142857	2	0.142857	3	0.214286
Volume	0.000	2	0	3	0	1	0
Aerodynamics	0.107	2	0.214286	2	0.214286	2	0.214286
Durability	0.179	2	0.357143	3	0.535714	1	0.178571
Ease of Access	0.179	2	0.357143	2	0.357143	3	0.535714
Manufacturability	0.107	2	0.214286	1	0.107143	3	0.321429
Stability	0.250	2	0.5	3	0.75	1	0.25
Cost	0.107	2	0.214286	1	0.107143	3	0.321429
TOTAL			2.00		**2.21**		2.04

3. Feature Consolidation Concepts

Once we determined which features from each of these concepts we wanted to keep we developed several designs combining them from which we would select our final design, these concepts are shown in

Figure 21 through Figure 27. Combination concept 3 was selected for further development as our final design; this development is documented in section 2.1 of the main report.

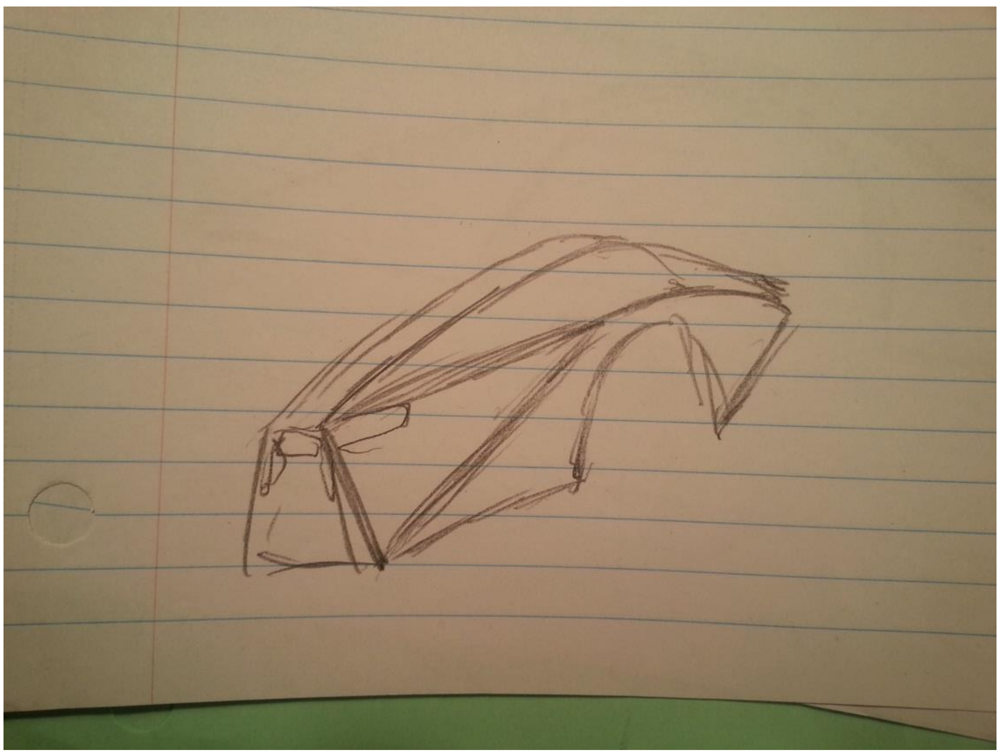


Figure 21: Perspective sketch of combination concept 1.

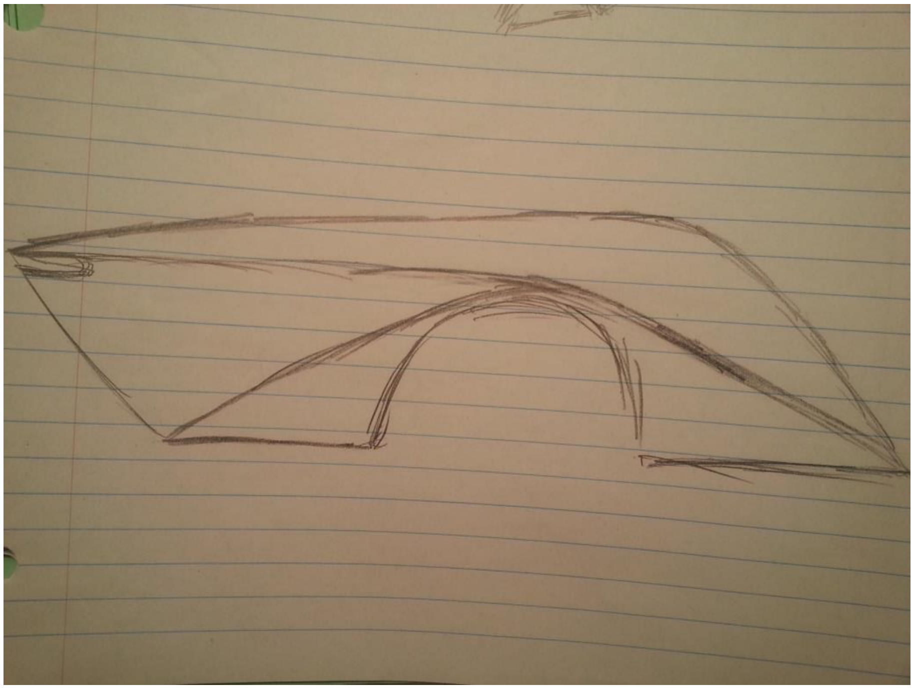


Figure 22: Side view sketch of combination concept 1.

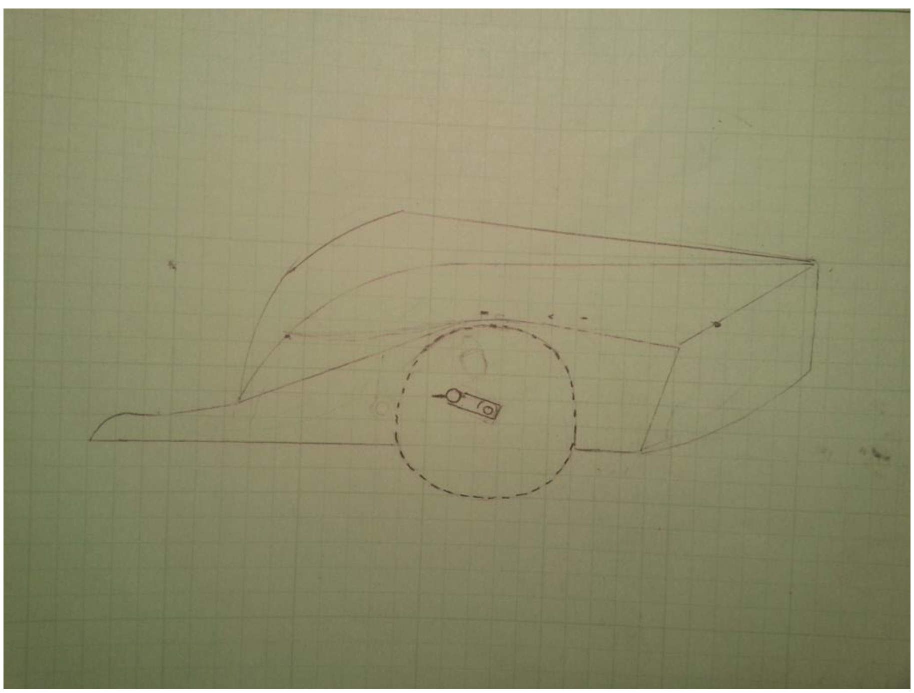


Figure 23: Sketch of combination concept 2

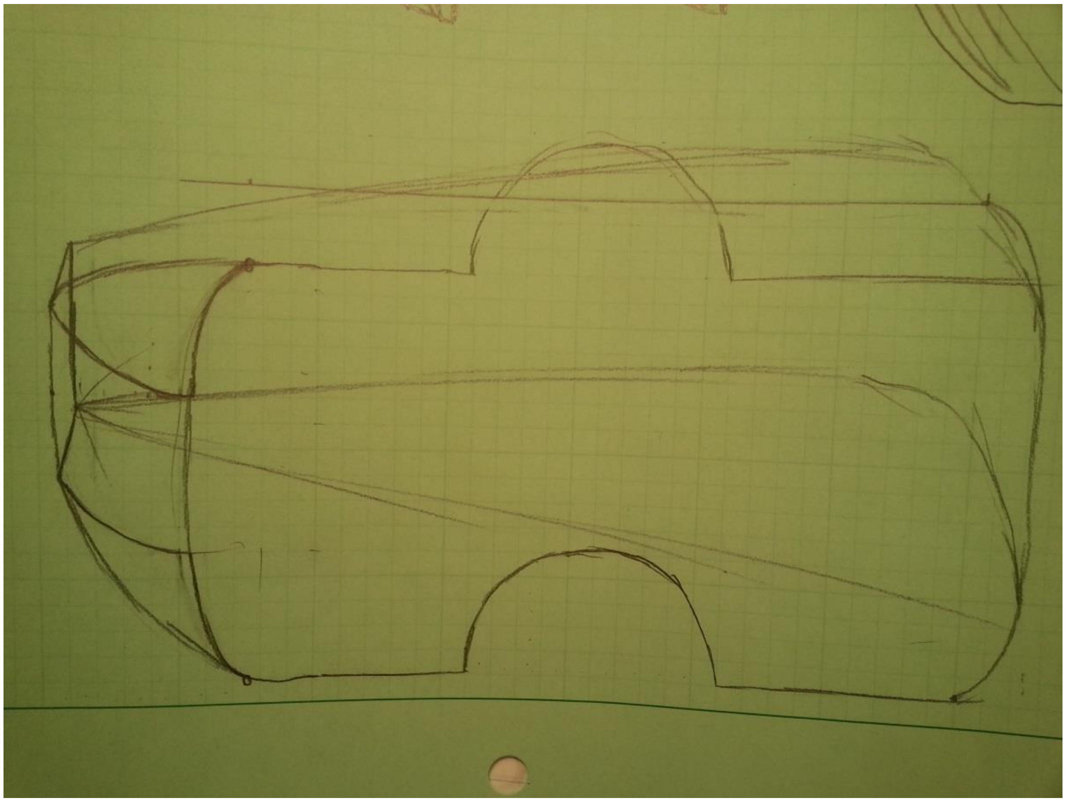


Figure 24: Sketch of combination concept 3.

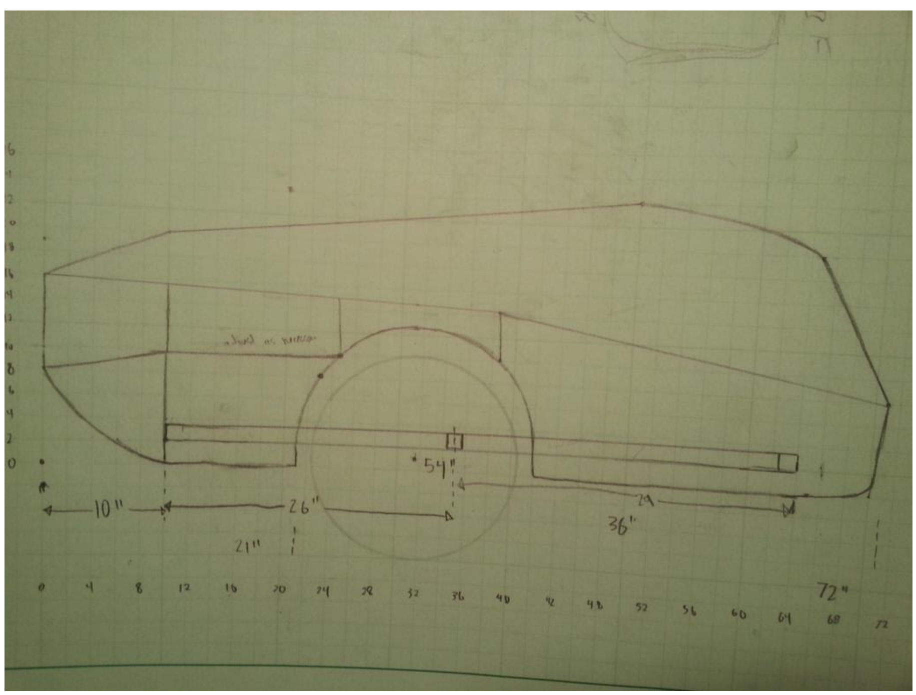


Figure 25: Detailed sketch of combination concept 3.

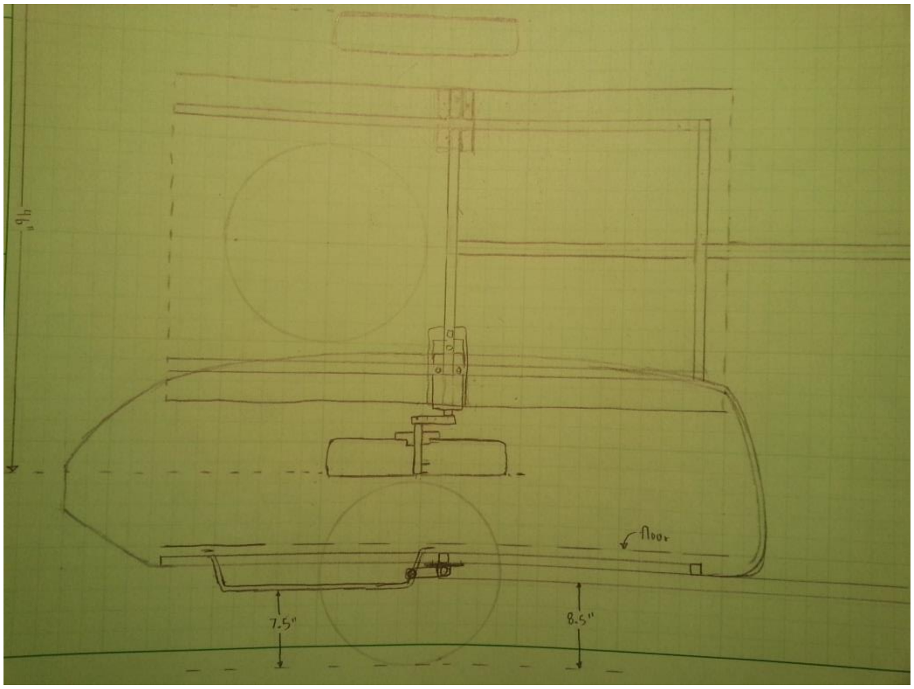


Figure 26: Cross sectional sketch of combination concept 3.

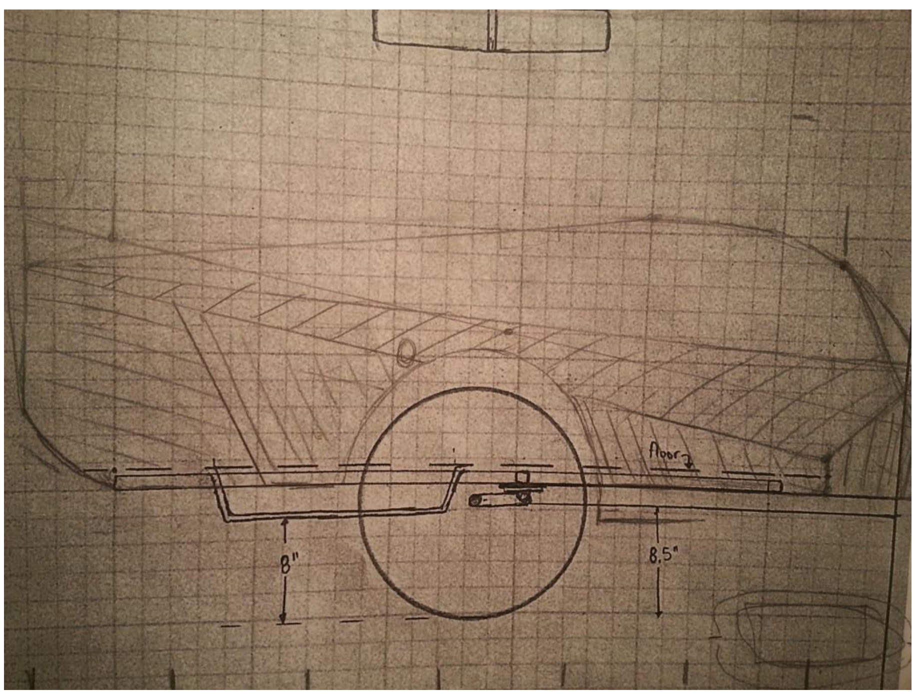


Figure 27: Stylized sketch of combination concept 3.

4. CARBON FIBER PLATE CALCULATIONS

Calculations were performed to determine the minimum thickness required for the carbon fiber structure, with regards to the lid and body designs. A rough estimate of the composite strength was performed, using a static bending analysis for simplicity. The carbon fiber was assumed to be isotropic for this scenario. For use in calculations, specifications for [0,90] carbon fiber in compression were used, the strength being 167 ksi [45]. As holes are evident in the body of the structure, the compressive strength for filled holes of a similar [45,90,-45,0] arrangement was specified to be 79.7 ksi, while for open holes a [45,0,-45,0,0,45,90,-45,0,0,45,0,-45,0] arrangement was specified to be 56.0 ksi [45]. The thickness of each [0,90] sheet was measured to be approximately 0.014” [46].

To analyze the designs, a factor of safety for both lid and body were specified as 4 for the lid and 8 for the body. These were used primarily to factor in the reduced compressive strength for the filled holes, fatigue strength, and other unintentional loads. The body uses an especially high safety factor because most of the loading is transmitted from the frame to the body, which contains numerous holes in the design, while the lid experiences minimal loading.

Two loading conditions were examined for the bending analysis, the first of which being a uniform loading condition concentrated on a 16 inch patch at the around the center (as seen in Figure 28). The second and more realistic loading condition was performed using an increasing linear loading condition, where the bulk of the load was placed around the center of the beam (seen in Figure 29). The load used for analysis was recommended to be 1.25 times the static load, resulting in 375 lbs from the 300 lb static load [47].

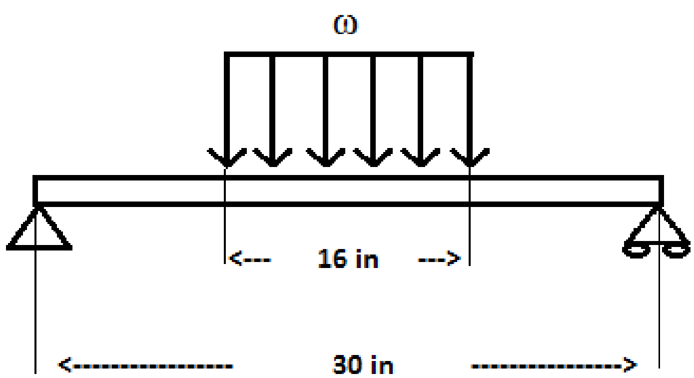


Figure 28: Bending analysis with uniform distribution loading condition.

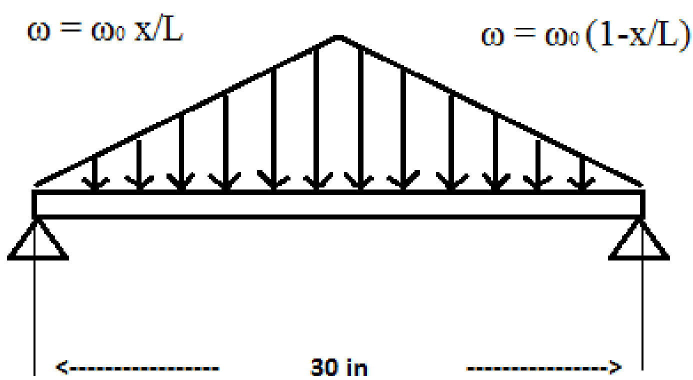


Figure 29: Loading condition with linear distribution loading condition.

For the loading condition illustrated in Figure 28, the maximum stress could be determined using Equation 1, where σ_{Max} refers to the maximum allowable stress [ksi], σ_Y refers to the yield strength [167 ksi] (which will use the compressive strength of the carbon fiber), S.F. represents the applied safety factor, M represents the maximum applied moment on the beam [1875 Ib*in], c refers to the distance between the top of the plate and the neutral axis [in] (or half of the thickness), and I refers to the second moment of inertia for the rectangular cross section [in^4]. The second moment of inertia could be determined using Equation 2, where b is the length of the plate [60 in] and t is the thickness [in].

Equation 1: Maximum Stress Equation for a Beam in Static Bending

$$\sigma_{Max} = \frac{\sigma_{Yld}}{S.F.} = \frac{Mc}{I}$$

Equation 2: Second Moment of Inertia Equation for Rectangular Cross Sections

$$I = \frac{1}{12} b t^3$$

Combining Equation 1 and Equation 2, the minimum required thickness could be calculated with the simplified to Equation 3. With this equation, the minimum thickness for the lid was determined to be 0.0670” while thickness of the body was 0.0948”.

Equation 3: Plate Thickness Equation for Static Bending

$$t = \sqrt{\frac{6 * M * S.F.}{b * \sigma_{Yld}}}$$

Using the second loading condition illustrated in Figure 29, Equation 3 could also be used to determine the minimum thickness, with a slightly altered maximum moment M [2063 Ib*in]. The results showed an increase in the thickness of the lid to 0.0703” and body to 0.0994”.

As each layer of the [0,90] carbon fiber was measured to be 0.014” [46], the slightly more realistic approach (with linear loading distribution) yielded slightly higher thicknesses than the uniform loaded approach. The minimum amount of layers determined with this is 5 (~1/16”) for the lid and 7 (~1/10”) for the body, which will be used in the design for the trailer.

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Appendix B

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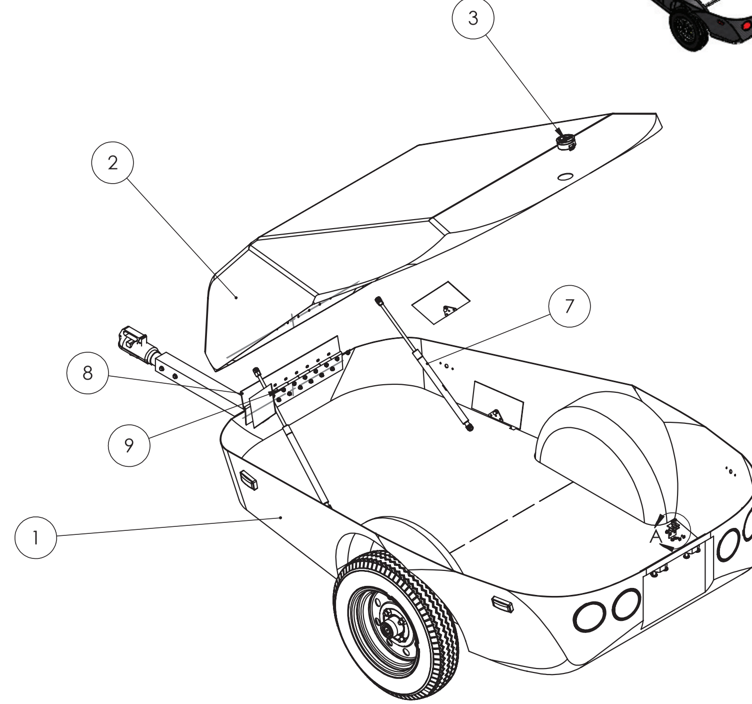
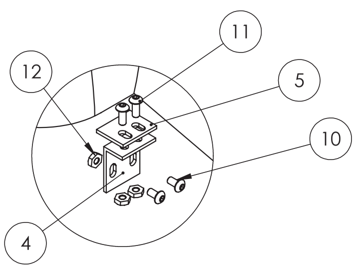
ITEM NO.	PART NUMBER	DESCRIPTION	VENDER	VENDER PART NUMBER	Default/ QTY.
1	A08		-		1
2	A07		-		1
3	E07				1
4	E07-S				1
5	E07-ADJUST				1
7	I13				2
8	SBHCSCREW 0.19-32x0.75-HX-N				8
9	HNUT 0.2500-20-D-N				8
10	SBHCSCREW 0.19-32x0.375-HX-N				2
11	SBHCSCREW 0.19-32x0.5-HX-N				2
12	MSHXNUT 0.190-32-S-N				4
13	A06				2





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SCALE 1 : 3

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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

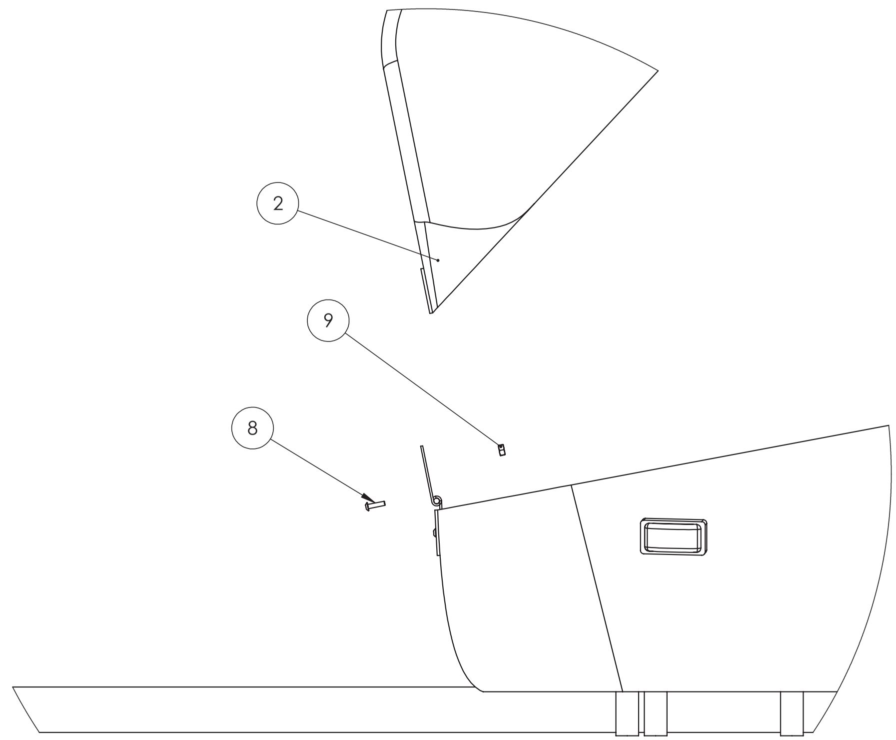
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE B | DWG. NO. Master Drawing 09 | REV

SCALE: 1:50 WEIGHT: | SHEET 1 OF 4



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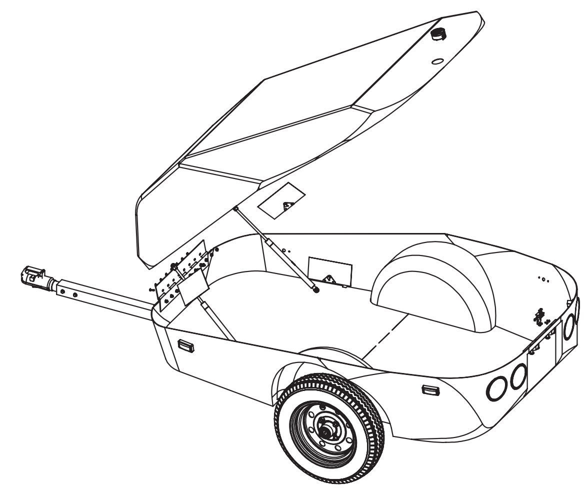

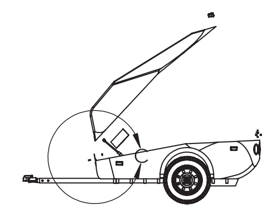

NOTE: LINE UP HOLES ON LIDE WITH HOLES ON HINGE AND BOLT TOGETHER WITH THE APPROPIATE BOLTS AND NUTS

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

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MFG APPR.		
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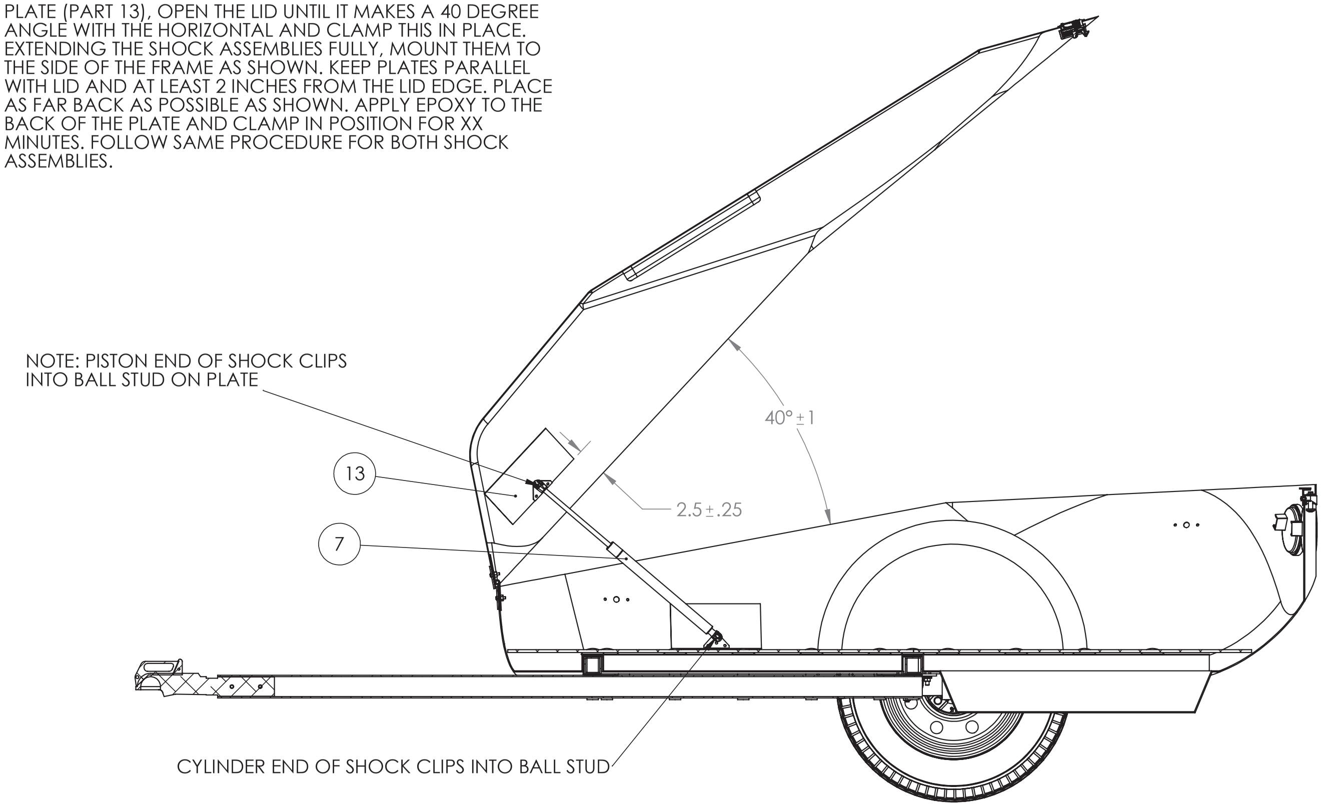
COMMENTS:

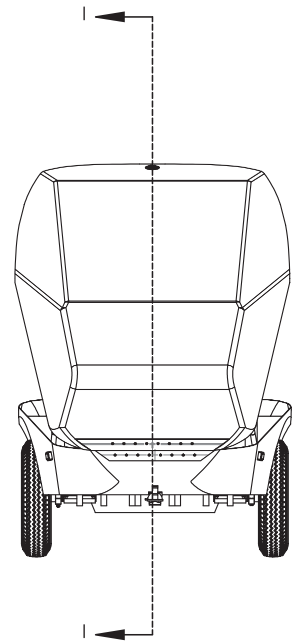
TITLE:

SIZE B DWG. NO. Master Drawing 09 REV

SCALE: 1:50 WEIGHT: SHEET 2 OF 4

ASSEMBLY INSTRUCTIONS: AFTER CLIPPING SHOCK ASSEMBLY TO THE BALL STUD ON THE BASE AND TO THE BALL STUD ON THE PLATE (PART 13), OPEN THE LID UNTIL IT MAKES A 40 DEGREE ANGLE WITH THE HORIZONTAL AND CLAMP THIS IN PLACE. EXTENDING THE SHOCK ASSEMBLIES FULLY, MOUNT THEM TO THE SIDE OF THE FRAME AS SHOWN. KEEP PLATES PARALLEL WITH LID AND AT LEAST 2 INCHES FROM THE LID EDGE. PLACE AS FAR BACK AS POSSIBLE AS SHOWN. APPLY EPOXY TO THE BACK OF THE PLATE AND CLAMP IN POSITION FOR XX MINUTES. FOLLOW SAME PROCEDURE FOR BOTH SHOCK ASSEMBLIES.





SECTION I-I
SCALE 1 : 10

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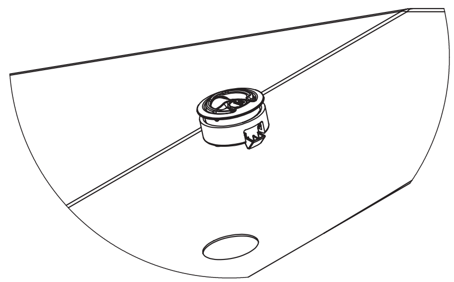
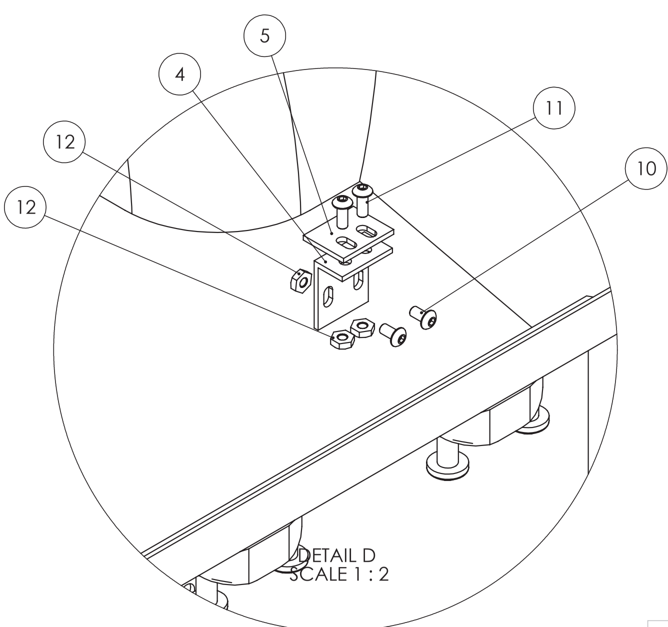
			CHECKED			TITLE:
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE B DWG. NO. Master Drawing 09 REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:50 WEIGHT: SHEET 3 OF 4

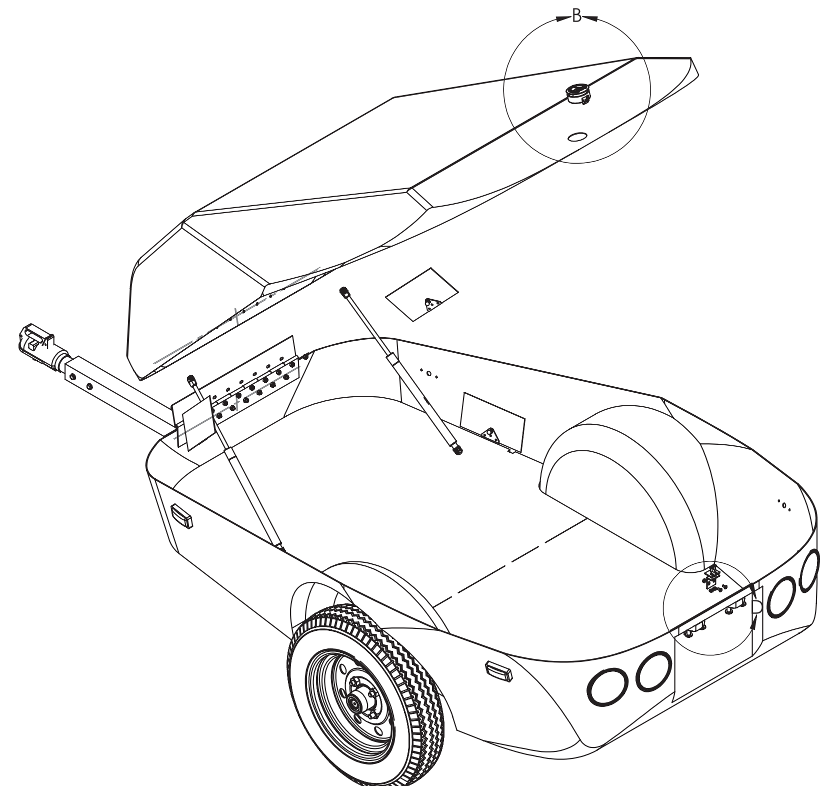


DETAIL B
SCALE 1 : 4

NOTE: INSTALL LATCH IN HOLE ON THE LID FOLLOWING MANUFACTURERS INSTRUCTIONS



DETAIL D
SCALE 1 : 2



NOTE: LOOSELY BOLT TOGETHER PARTS 4 AND 5, THEN BOLT ASSEMBLY ONTO TRAILER THROUGH SPECIFIED HOLES ON LICENSE PLATE INDENT USING SPECIFIED BOLTS (PART 11). THE HEIGHT OF PART 4 AND HOW FAR FORWARD PART 5 IS CAN BE ADJUSTED TO MATCH THE LATCH

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
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NEXT ASSY | USED ON
APPLICATION

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

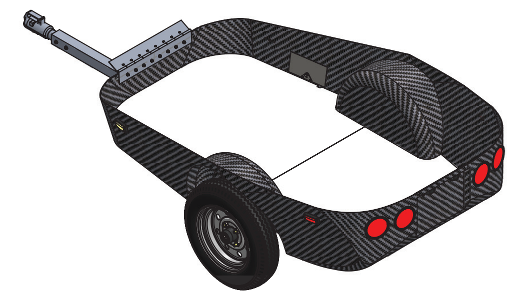
COMMENTS:

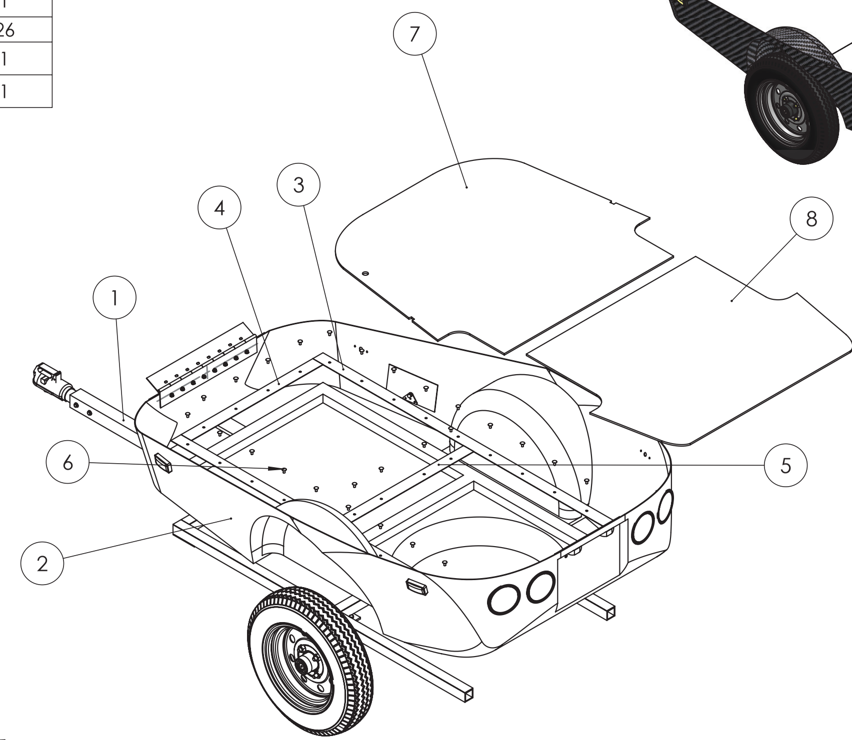
TITLE:

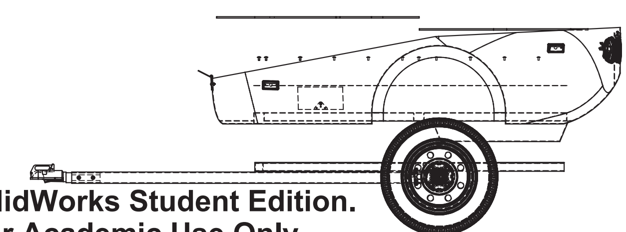
SIZE B DWG. NO. Master Drawing 09 REV

SCALE: 1:50 WEIGHT: SHEET 4 OF 4

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	A05	FRAME ASSEMBLY	1
2	A03	TRAILER BASE	1
3	B01	METAL WASHER STRIP LONG	2
4	B02	METAL WASHER STRIP FRONT	1
5	B03	METAL WASHER STRIP CENTER	1
6	1/4 INCH RIVETS	1/4 X .670 RIVETS	26
7	I05-NEW	FRONT FLOOR BOARD	1
8	I06-NEW	REAR FLOOR BOARD	1







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THREE PLACE DECIMAL ±
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MATERIAL
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	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

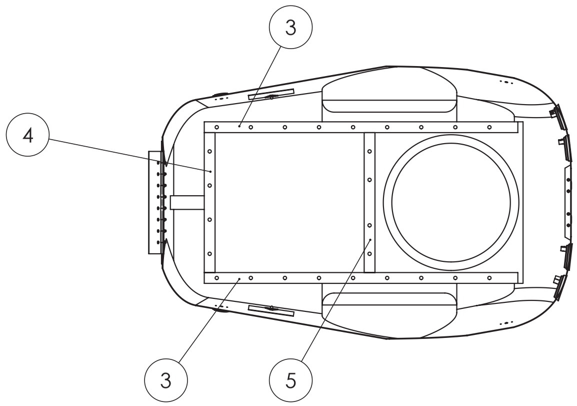
COMMENTS:

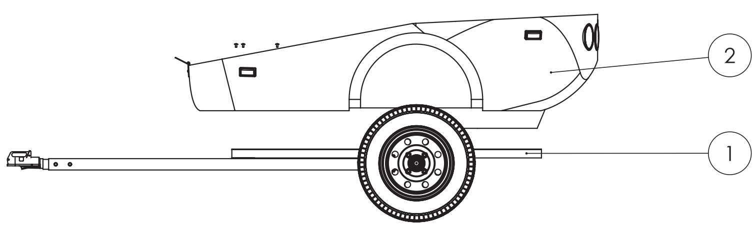
TITLE:

SIZE **B** | DWG. NO. A08 | REV

SCALE: 1:50 | WEIGHT: | SHEET 1 OF 2

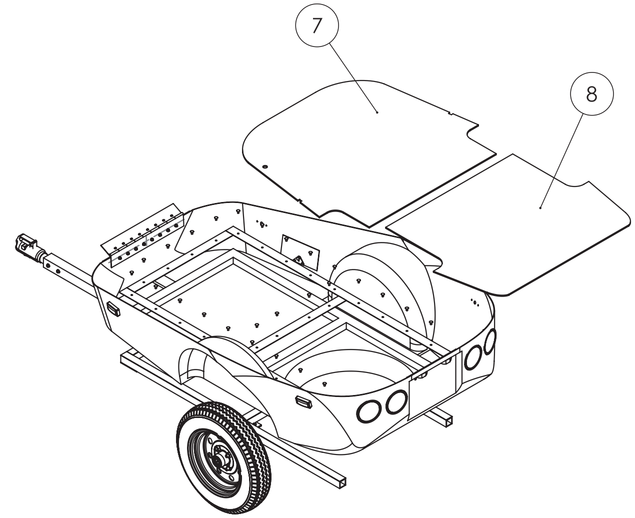
NOTE: USING THE METAL PLATES AS TEMPLATES, PLACE THEM AT THEIR SPECIFIED LOCATION AT DRILL THROUGH THE CARBON FIBER PRODUCING A .281 INCH HOLE





NOTE: PLACE BODY ON FRAME AND MATCH HOLES. ATTACH THE BODY TO THE FRAME USING xx RIVETS AND A RIVET GUN

PLACE FLOOR BOARDS AS SHOWN BELOW



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		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
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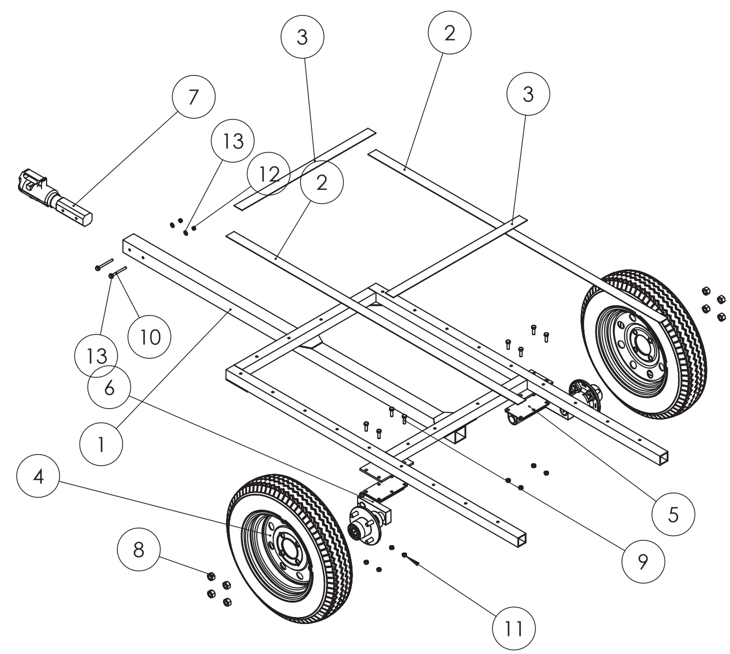
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

SIZE	DWG. NO.	REV
B	A08	
SCALE: 1:50	WEIGHT:	SHEET 2 OF 2

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	Vendor	VendorNo
1	A01	ALUMINU FRAME	1	-	-
2	B04	SPONGE STRIPPING LONG	2	ACKLANDS GRAINGER	6YHD8
3	B05	SPONGE STRIPPING SHORT	2	ACKLANDS GRAINDER	6YHD8
4	E01	ALUMINUM RIM AND TIRE	2	ETRAILER	AM30677
5	TORSION RIGHT	TORSION SUSPENSION AXLE	1	SOUTHWEST WHEEL	FR-425S
6	TORSION LEFT	TORSION SUSPENSION AXLE	1	SOUTHWEST WHEEL	FR-425S
7	E09	SWIVEL HITCH	1	OPEN ROAD OUTFITTERS	SMV-NOID
8	HHNUT 0.5000-20-D-N	LUG NUTS INCLUDE WITH WHEELS	8	ETRAILER	6YHD8
9	HBOLT 0.3125-24x1x0.875-N	HEX BOLT 5/16-24X1	8	-	-
10	HBOLT 0.2500-20x2.75x0.75-N	HEX BOLT 1/4-20X2.75	2	-	-
11	HNUT 0.3125-24-D-N	HEX NUT 5/16-24	8	-	-
12	HNUT 0.2500-20-D-N	HEX NUT 1/4-20	2	-	-
13	PREFERRED NARROW WASHER 0.25	1/4 INCH WASHER	4	-	-



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MATERIAL
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	NAME	DATE
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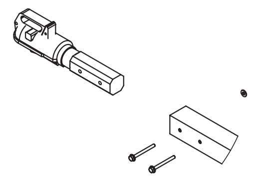
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

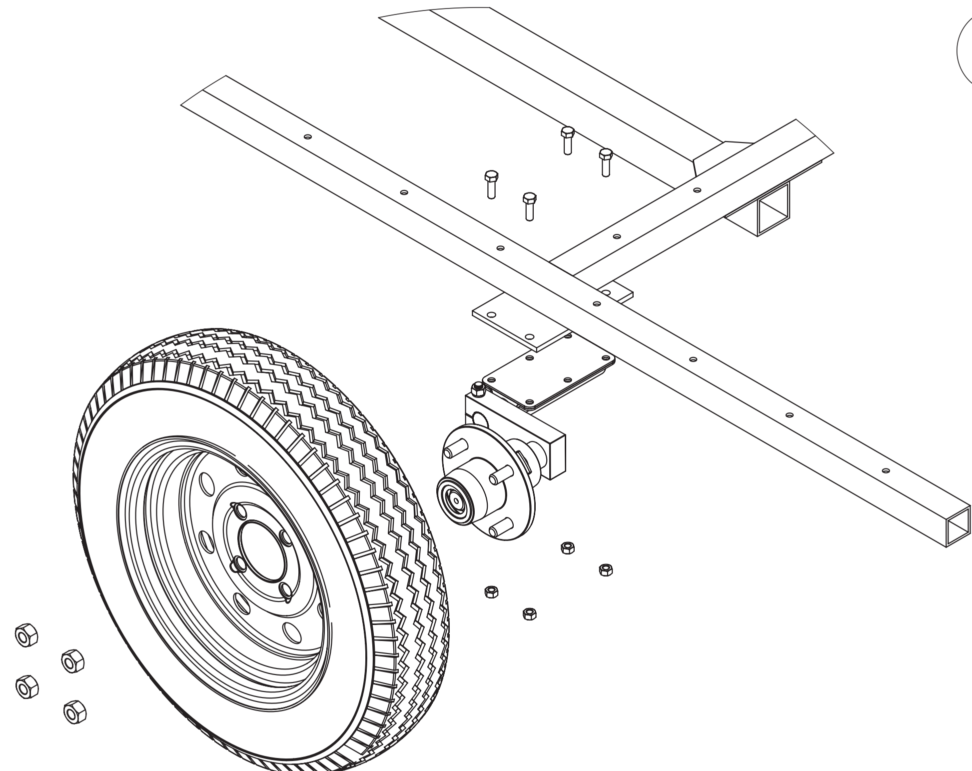
TITLE:

SIZE **B** DWG. NO. A05 REV

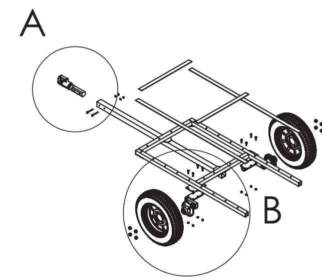
SCALE: 1:50 WEIGHT: SHEET 1 OF 3



DETAIL A
SCALE 1 : 10



DETAIL B
SCALE 1 : 5



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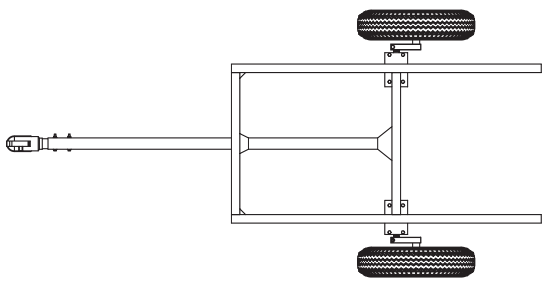
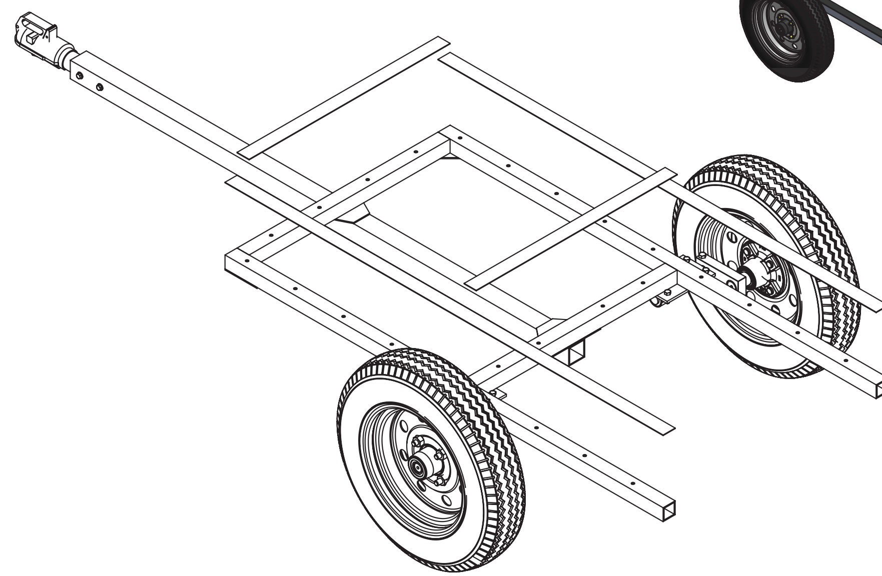
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:		
SIZE **B**	DWG. NO. A05	REV
SCALE: 1:50	WEIGHT:	SHEET 2 OF 3



NOTE: RUBBER STRIPS HAVE AN
ADHESIVE BACKING AND ARE
APPLIED DIRECTLY TO THE FRAME
SURFACE AS INDICATED



NEXT ASSY	USED ON
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	NAME	DATE
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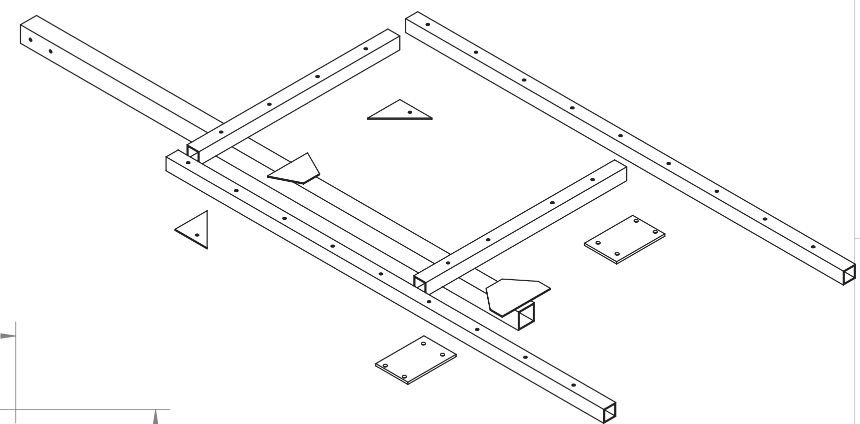
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

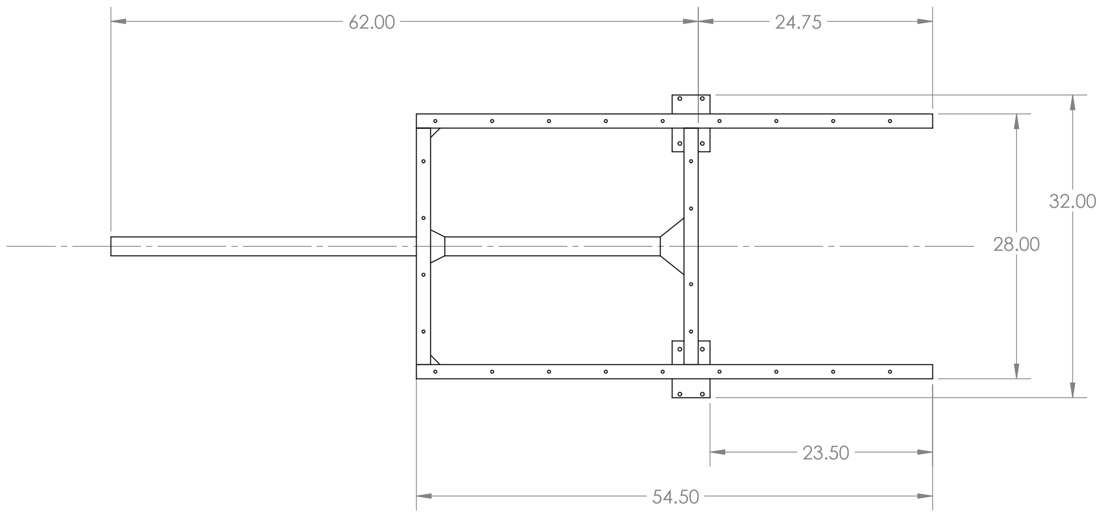
COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	A05	
SCALE: 1:50	WEIGHT:	SHEET 3 OF 3

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F02	CROSS BAR	2
2	F01	SIDE BAR	2
3	F03	TONGUE BAR	1
4	F04	MIDDLE CENTER GUSSET PLATE	1
5	F05	FRONT CENTER GUSSET PLATE	1
6	F06	FRONT CORNER GUSSET PLATE	2
7	F07	SUSPENSION MOUNTING PLATE	2





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DO NOT SCALE DRAWING

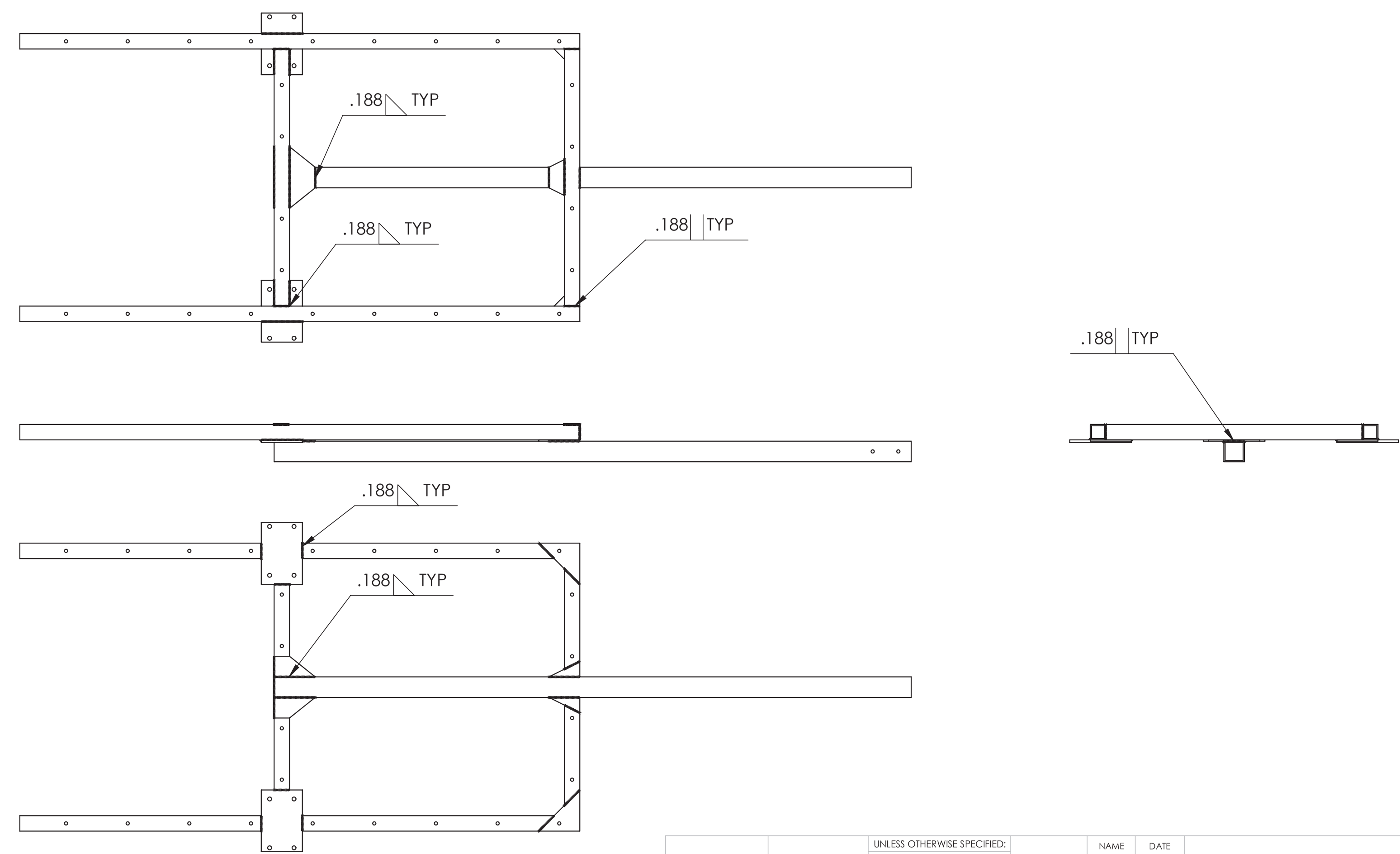
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
ALUMINU FRAME

SIZE B | DWG. NO. A01 | REV

SCALE: 1:20 WEIGHT: SHEET 1 OF 3



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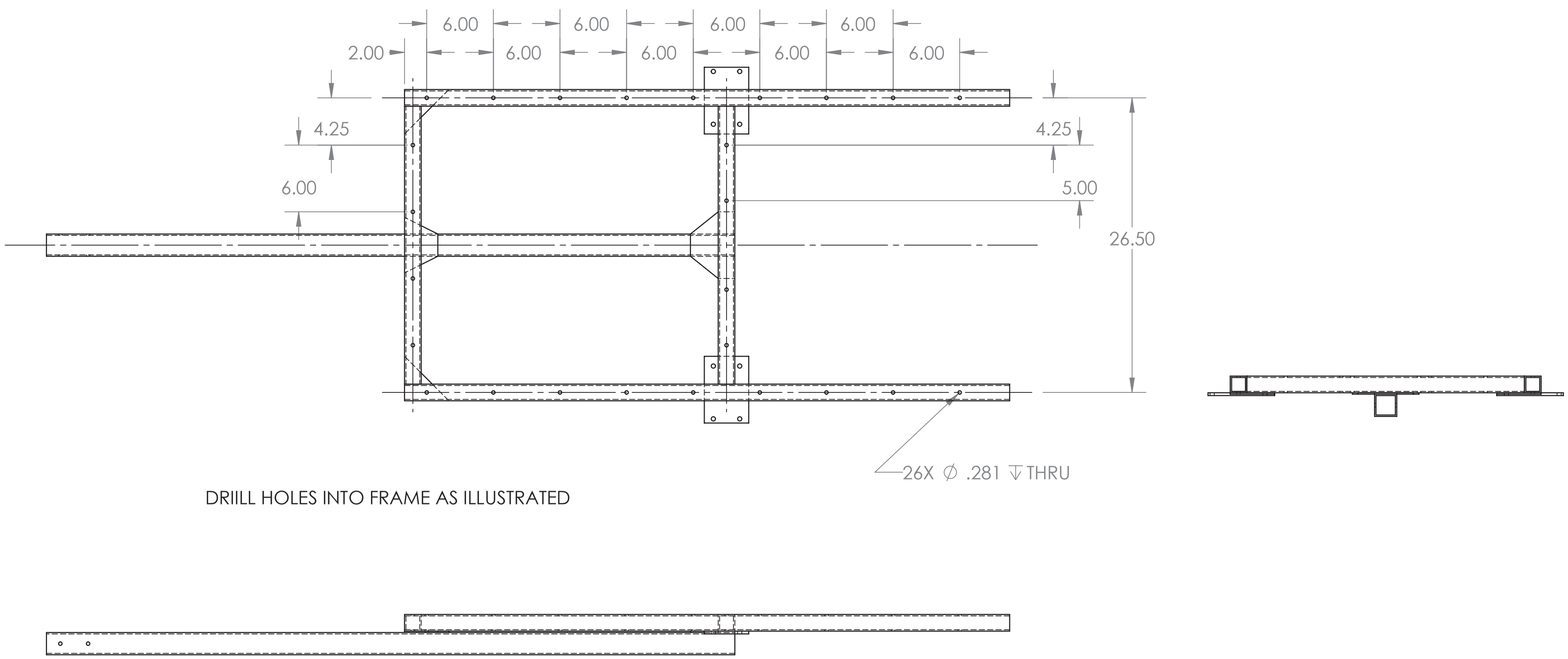
APPLICATION		INTERPRET GEOMETRIC TOLERANCING PER:		
		MATERIAL		
		FINISH		
		DO NOT SCALE DRAWING		

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

ALUMINU FRAME

SIZE	DWG. NO.	REV
B	A01	
SCALE: 1:20	WEIGHT:	SHEET 2 OF 3



DRIILL HOLES INTO FRAME AS ILLUSTRATED

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APPLICATION		DO NOT SCALE DRAWING	

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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

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

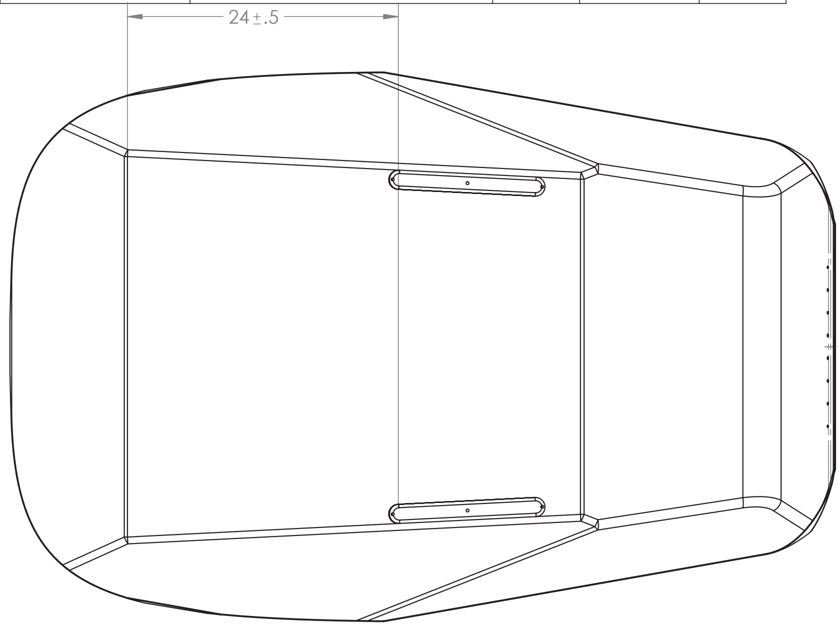
COMMENTS:

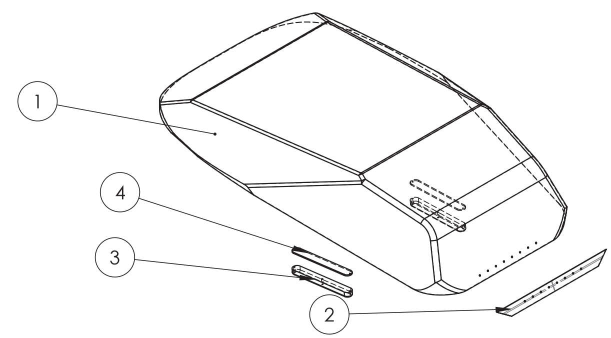
TITLE:

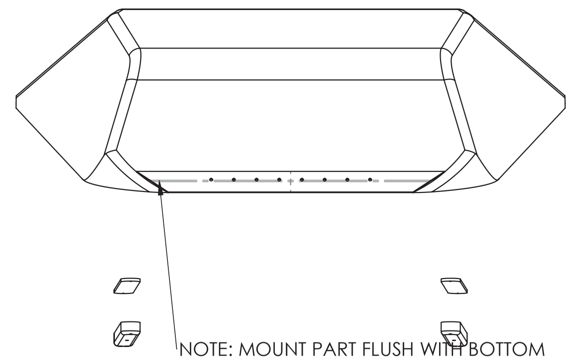
ALUMINU FRAME

SIZE	DWG. NO.	REV
B	A01	
SCALE: 1:20	WEIGHT:	SHEET 3 OF 3

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	VENDOR	VENDOR NO
1	B08	TRAILER LID	1	-	-
2	B10	LID HINGE MOUNT	1	-	-
3	I03	COURTESTY LIGHT WITH ROCKER SWITCH	2	TRUCKNTOW	LTL1206
4	B11	LIGHT BAR FIXTURE PLATE	2	-	-





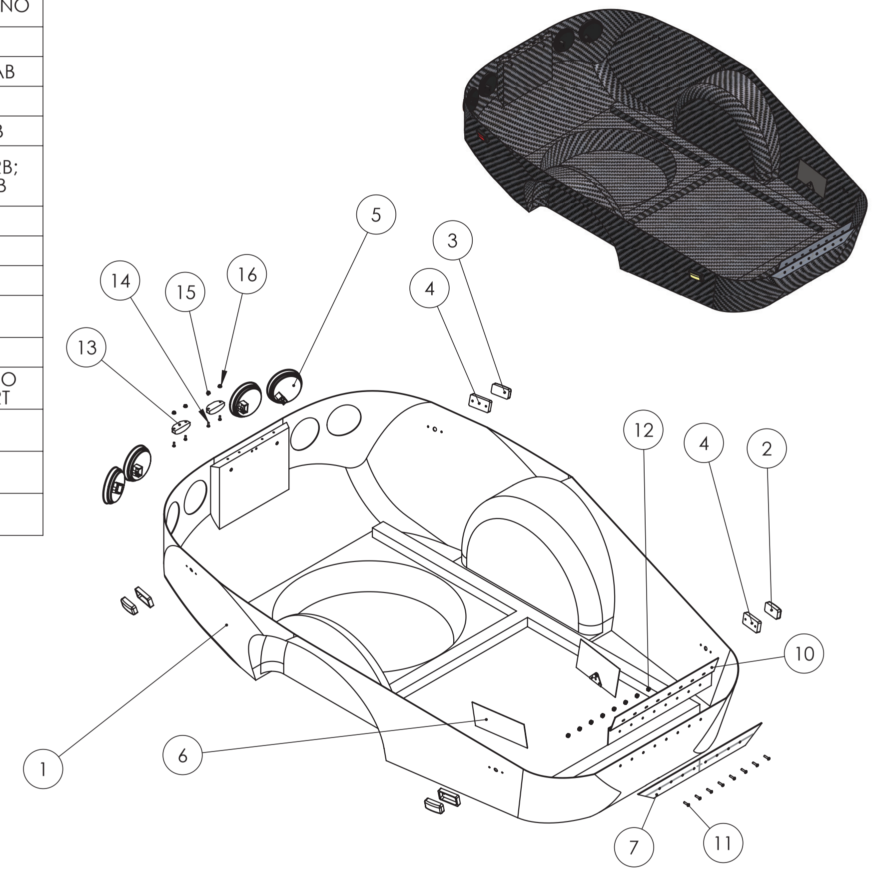


NOTE: MOUNT PART FLUSH WITH BOTTOM EDGE OF LID AS SHOWN AND ADHERE TO THE LID USING EPOXY XX AND CLAMP FOR XX MINUTES

LIGHTS MOUNT FIXTURE PLATES ARE MOUNTED FLUSH TO THE EDGES OF THE TOP OF THE LID AT THE LOCATIONS SHOWN. THESE PLATES ARE MOUNTED USING LCOTITE SPEED BONDER H8000 AND BONDED ACCORDING TO MANUFACTURERS DIRECTIONS. ALLOW 24 HOUR CURING PERIOD. LIGHT BARS ARE THEN MOUNTED TO THE PLATES USING THE #8 SCREWS PROVIDED BY THE LIGHT BAR MANUFACTURER.

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	CORMER GROUP
DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± .5 ONE PLACE DECIMAL: ±.05 TWO PLACE DECIMAL: ±.02 THREE PLACE DECIMAL: ±.005	DRAWN	PT	11/29/2014	TITLE:
	CHECKED	PT	11/29/2014	
	ENG APPR.			
	MFG APPR.			
	Q.A.			
MATERIAL	COMMENTS:			SIZE B DWG. NO. A07 REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:20 WEIGHT: SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	VENDOR	VENDER NO
1	B07	BODY BASE	1	-	-
2	E05	FRONT SIDE MARKER LIGHT	2	ETRAILER	AL191AB
3	E06	REAR SIDE MARKER LIGHT	2	ETRAILER	RED
4	E11	SIDE LIGHT BRACKET	4	ETRAILER	A91BB
5	E04	SEALED 4 INCH ROUND LED STOP, TURN AND TAIL LIGHT; GROMMET	4	ETRAILER	STL101RB; A45GB
6	A06	SHOCK MOUNT ASSEMBLY	2	-	-
7	B09	BASE HINGE MOUNT	1	-	-
10	I01-T	DOOR HINGE	1	-	-
11	TORX SECURTIY BOLT 10-32x0.75 HEX	TORX SECURTIY BOLT	8	-	-
12	10-32 HEX NUT	10-32 HEX NUT	8	-	-
13	E12	LICENSE PLATE LIGHT	2	TRUCKNTOW	REFER TO REPORT
14	CR-PHMS 0.164-32x0.5x0.5-N	8-32X.5 PHILIPS HEAD MACHINE SCREW	4	-	-
15	Preferred Narrow FW 0.164	#8 WASHER	4	-	-
16	MSHXNUT 0.164-32-S-N	8-32 HEX NUT	4	-	-



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INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

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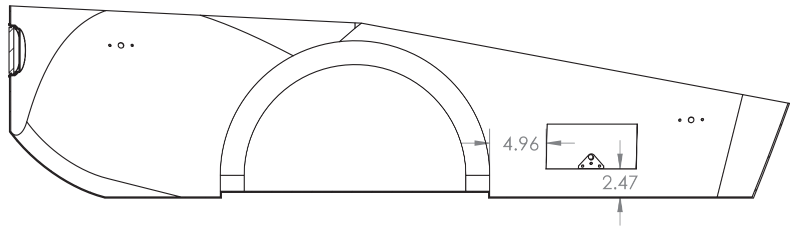
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

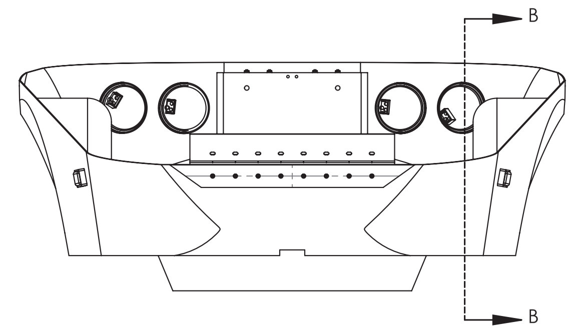
SIZE **B** DWG. NO. A03 REV

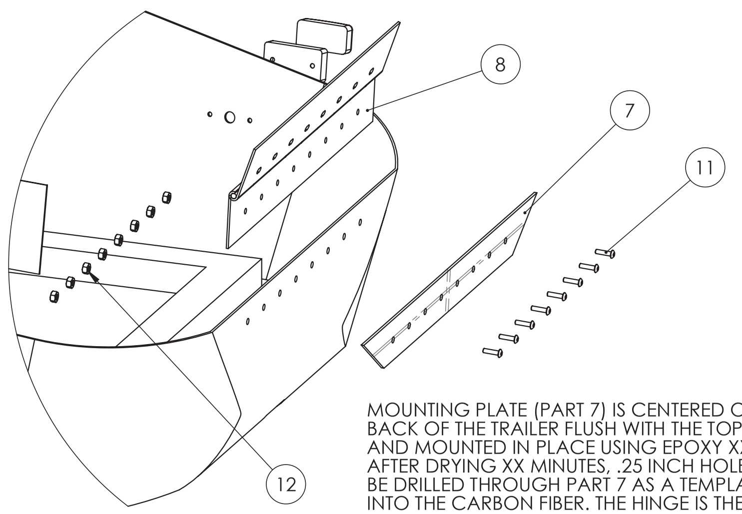
SCALE: 1:20 WEIGHT: SHEET 1 OF 3



SECTION B-B
SCALE 1 : 10

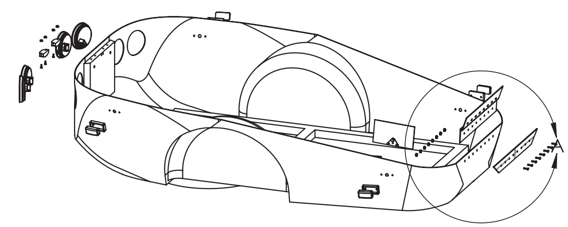
USING EPOXY XXX, MOUNT THE BRACKET TO THE SURFACE AT THE POSITION SHOWN FOLLOWING THE DIRECTIONS ON THE EPOXY (SAME PROCEDURE AND LOCATION ON BOTH SIDES OF TRAILER)





DETAIL A
SCALE 1 : 5

MOUNTING PLATE (PART 7) IS CENTERED ON THE BACK OF THE TRAILER FLUSH WITH THE TOP LIP AND MOUNTED IN PLACE USING EPOXY XXX. AFTER DRYING XX MINUTES, .25 INCH HOLES MUST BE DRILLED THROUGH PART 7 AS A TEMPLATE INTO THE CARBON FIBER. THE HINGE IS THEN BOLTED ON AS SHOWN



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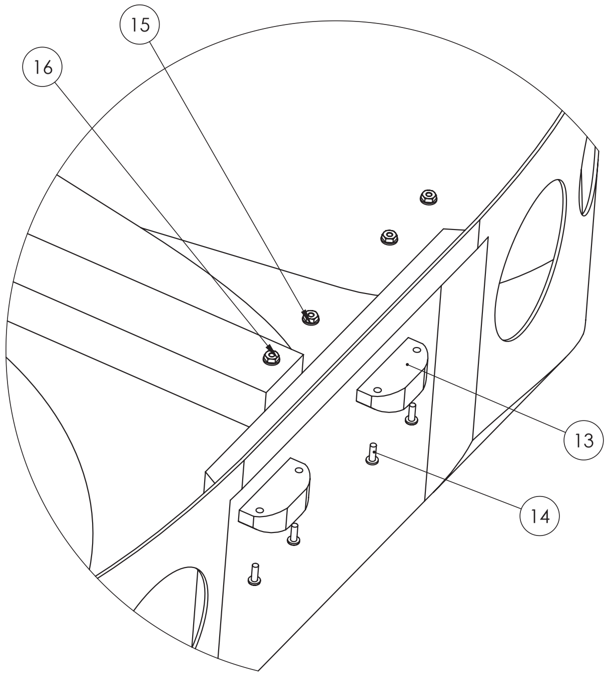
MFG APPR.		
Q.A.		
COMMENTS:		

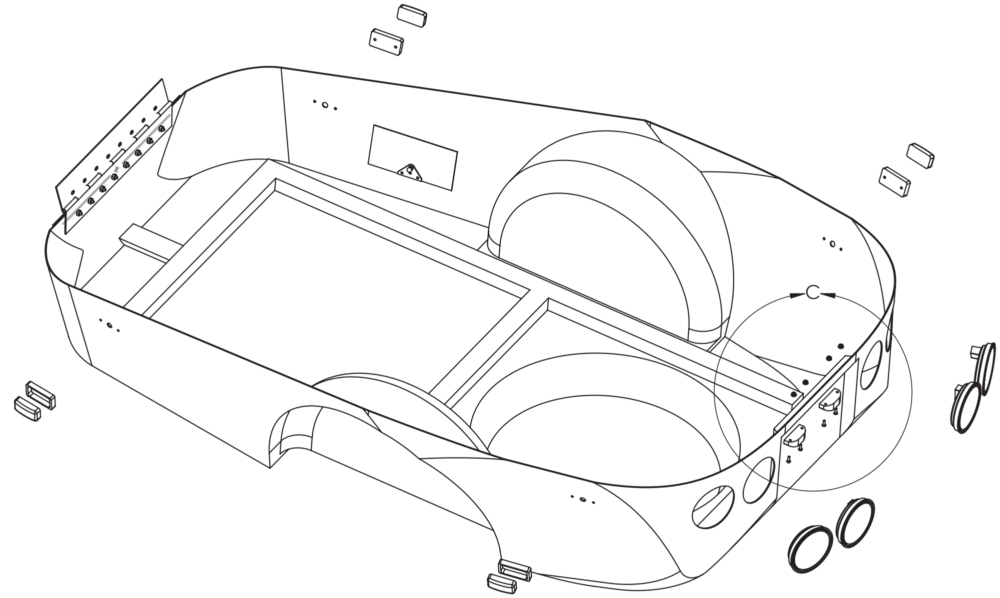
TITLE:

SIZE **B** | DWG. NO. A03 | REV

SCALE: 1:20 | WEIGHT: | SHEET 2 OF 3



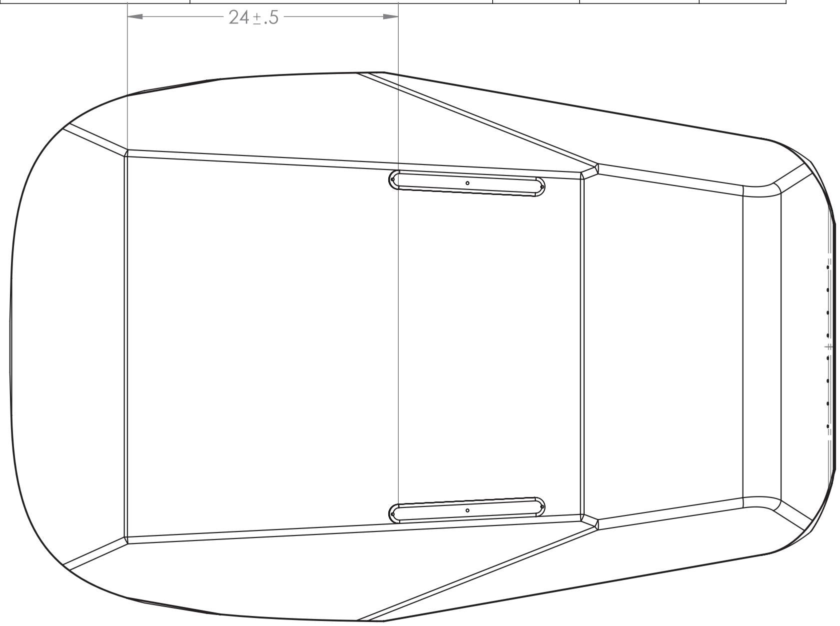
DETAIL C
SCALE 1 : 3

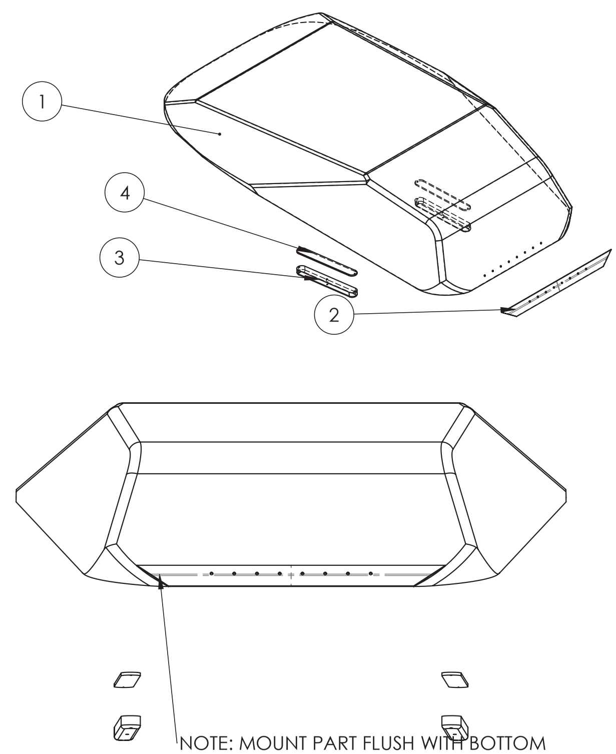


NOTE: LIGTS ARE INSTALLED AS FOLLOWING MANUFACTURERS DIRECTIONS. LOCATIONS ARE IDENTIFIED BY PREDRILLED HOLES.

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			TITLE:
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE **B** DWG. NO. A03 REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:20 WEIGHT: SHEET 3 OF 3

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	VENDOR	VENDOR NO
1	B08	TRAILER LID	1	-	-
2	B10	LID HINGE MOUNT	1	-	-
3	I03	COURTESTY LIGHT WITH ROCKER SWITCH	2	TRUCKNTOW	LTL1206
4	B11	LIGHT BAR FIXTURE PLATE	2	-	-





NOTE: MOUNT PART FLUSH WITH BOTTOM EDGE OF LID AS SHOWN AND ADHERE TO THE LID USING EPOXY XX AND CLAMP FOR XX MINUTES

LIGHTS MOUNT FIXTURE PLATES ARE MOUNTED FLUSH TO THE EDGES OF THE TOP OF THE LID AT THE LOCATIONS SHOWN. THESE PLATES ARE MOUNTED USING LCOTITE SPEED BONDER H8000 AND BONDED ACCORDING TO MANUFACTURERS DIRECTIONS. ALLOW 24 HOUR CURING PERIOD. LIGHT BARS ARE THEN MOUNTED TO THE PLATES USING THE #8 SCREWS PROVIDED BY THE LIGHT BAR MANUFACTURER.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± .5
ONE PLACE DECIMAL: ±.05
TWO PLACE DECIMAL: ±.02
THREE PLACE DECIMAL: ±.005

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	PT	11/29/2014
CHECKED	PT	11/29/2014
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

CORMER GROUP

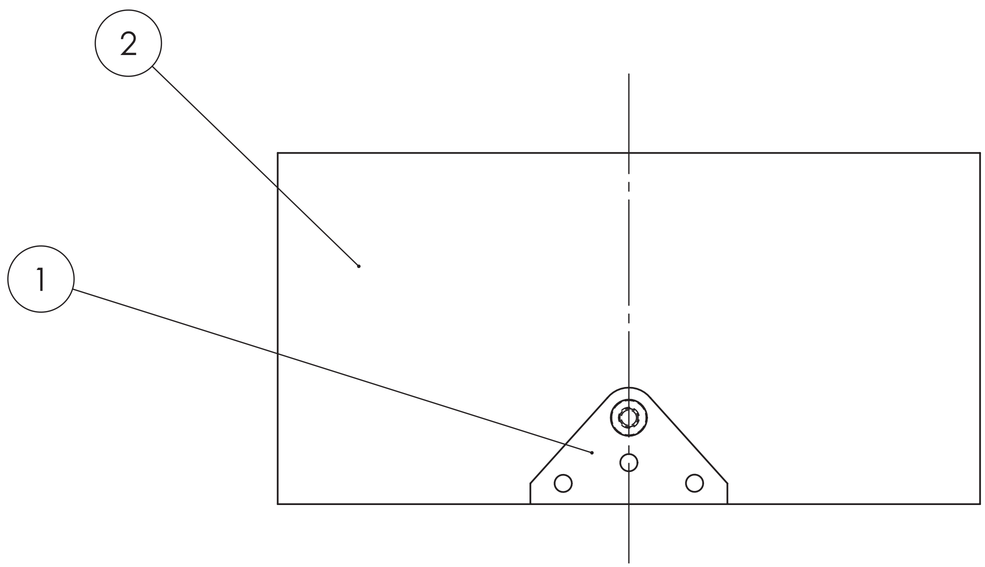
TITLE:

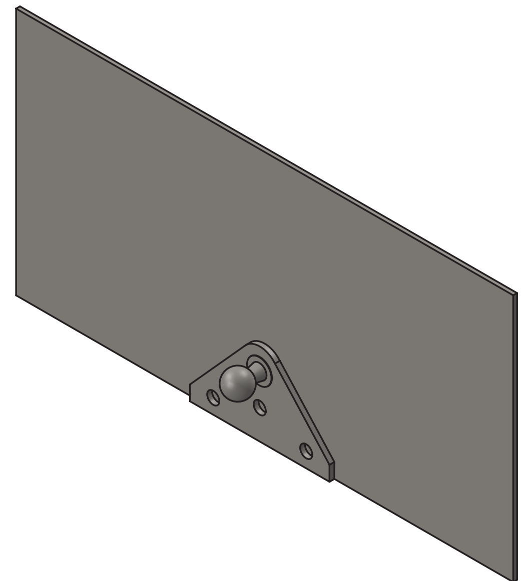
SIZE	DWG. NO.	REV
B	A07	

SCALE: 1:20 WEIGHT: SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	VENDOR	VENDOR NO.
1	I08	BALL STUD BRACKET	4	TCH	530-103800
2	B06	MOUNTING PLATE FOR SHOCK ASSEMBLY	4	-	-

MAKE 4 OF THESE PARTS





NOTE: TACK WELD PART (I08) ON TO MOUNTING PLATE (B06) AT LOCATION SHOWN

CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING

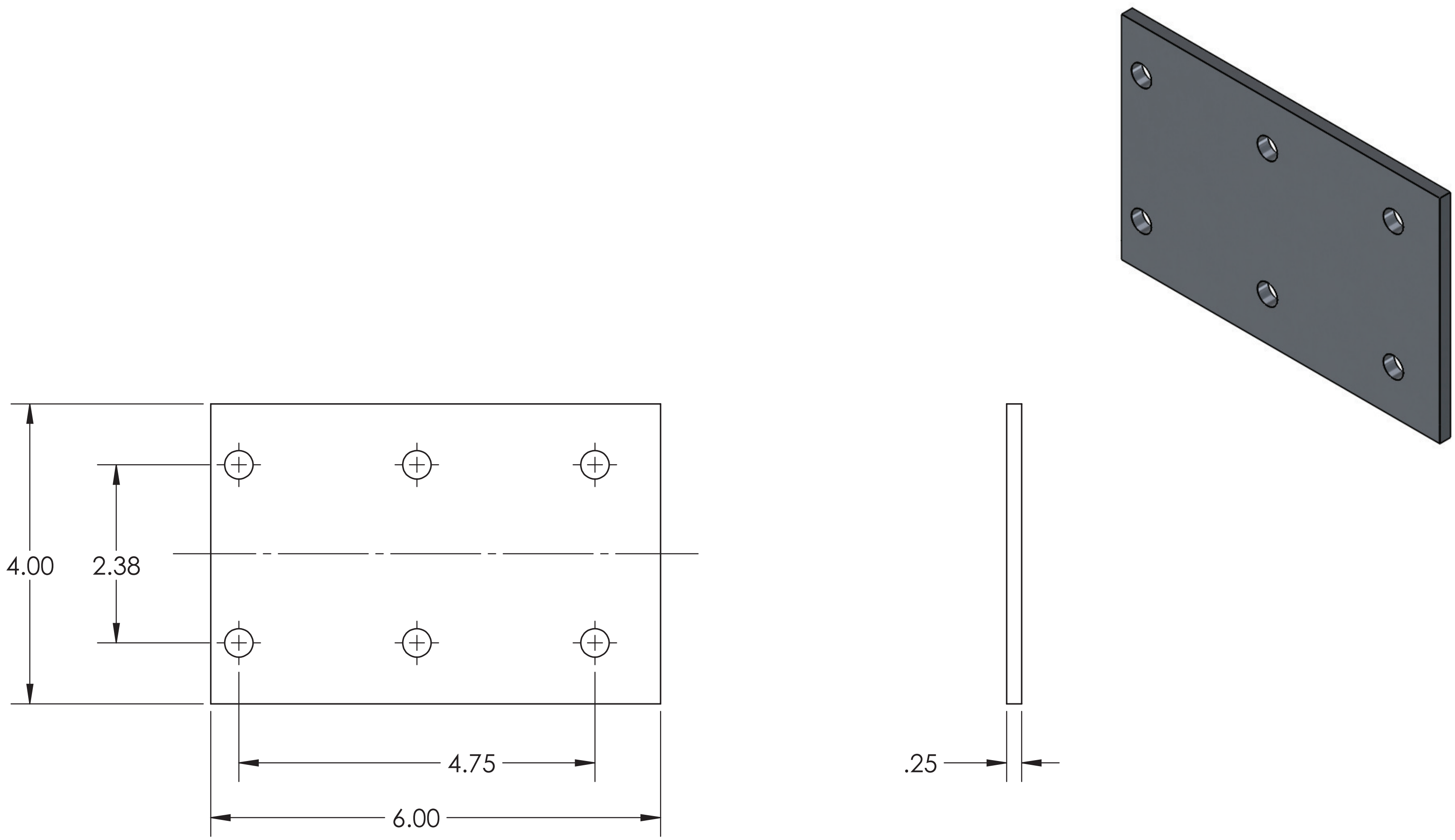
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	2014-11-30
MATERIAL	CHECKED	PT	2014-11-30
FINISH	NUMBER	A06	

TITLE: **A06**

SIZE	DISCRIPTION:	REV
A		**A**

SCALE: 1:5 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1



CUT FROM .125 INCH THICK ALUMINUM PLATE

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CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

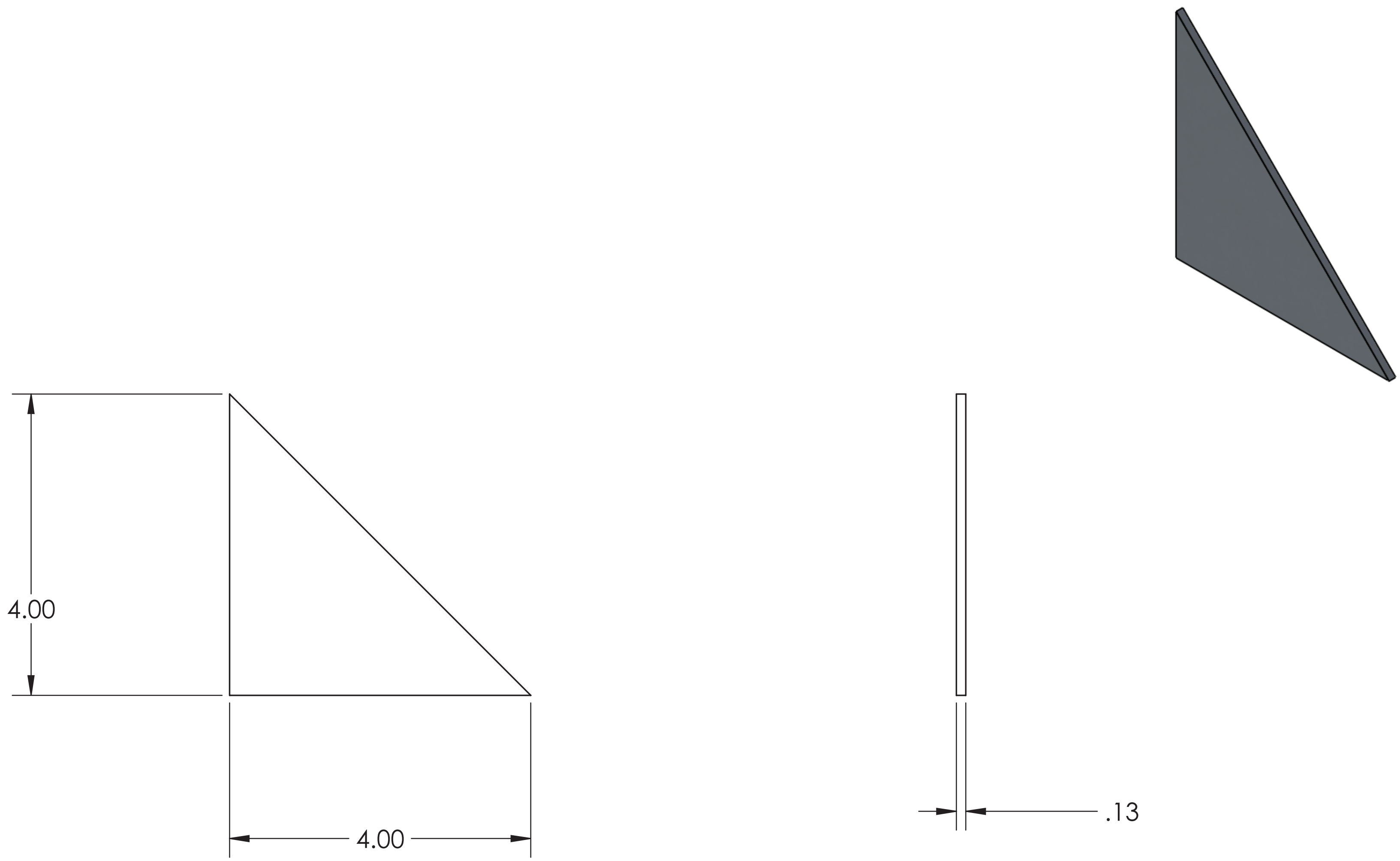
UofM MECHANICAL ENGINEERING

		NAME	DATE
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994			
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	F07	

TITLE: **F07**

SIZE	DISCRIPTION:	REV
A		**A**
SCALE: 1:2	WEIGHT:	SHEET 1 OF 19

5 4 3 2 1



CUT FROM .125 INCH THICK ALUMINUM PLATE

CORMER GROUP

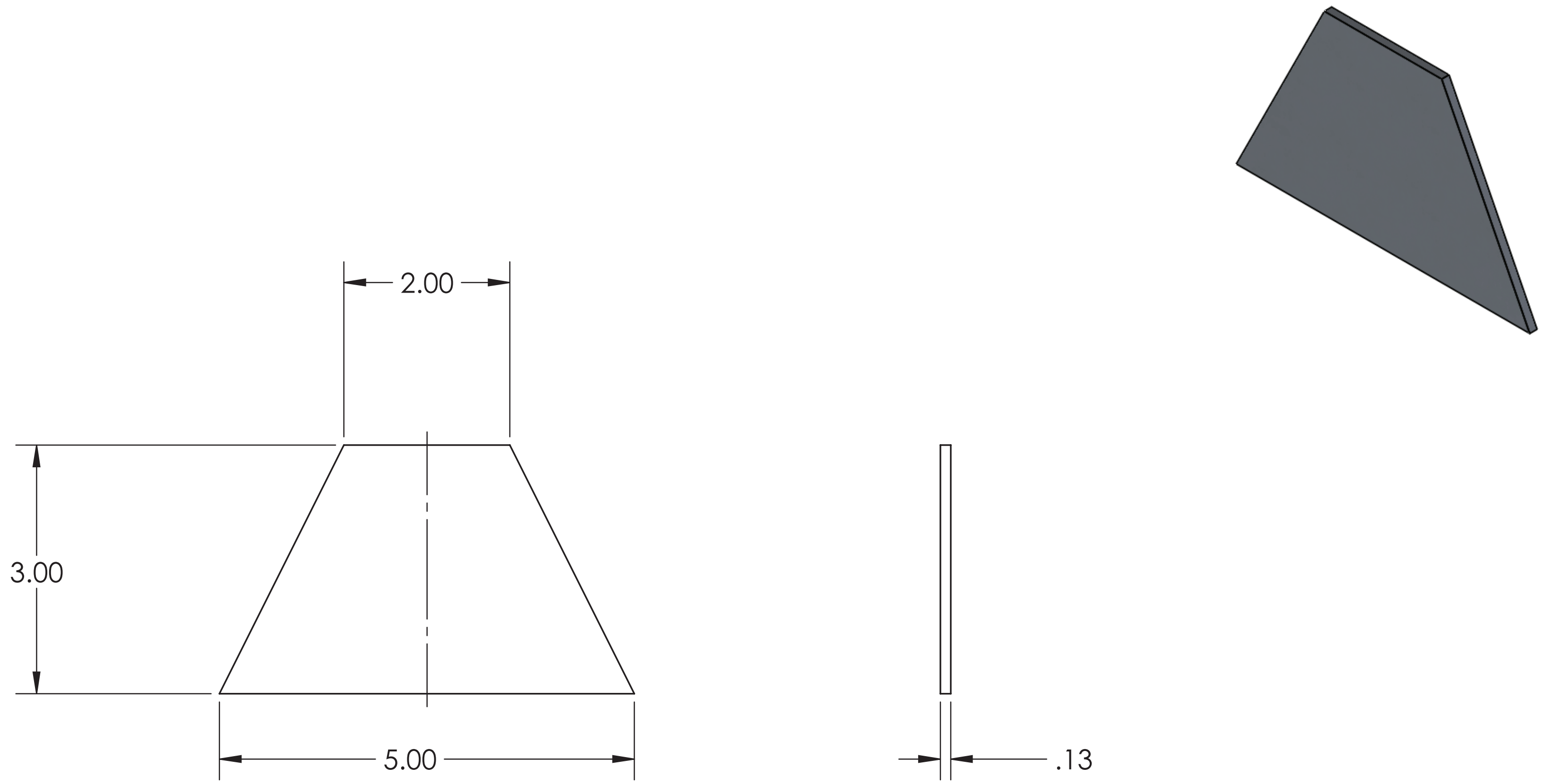
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	F06	

TITLE: F06		
SIZE A	DISCRIPTION:	REV A
SCALE: 1:2	WEIGHT:	SHEET 2 OF 19

5 4 3 2 1

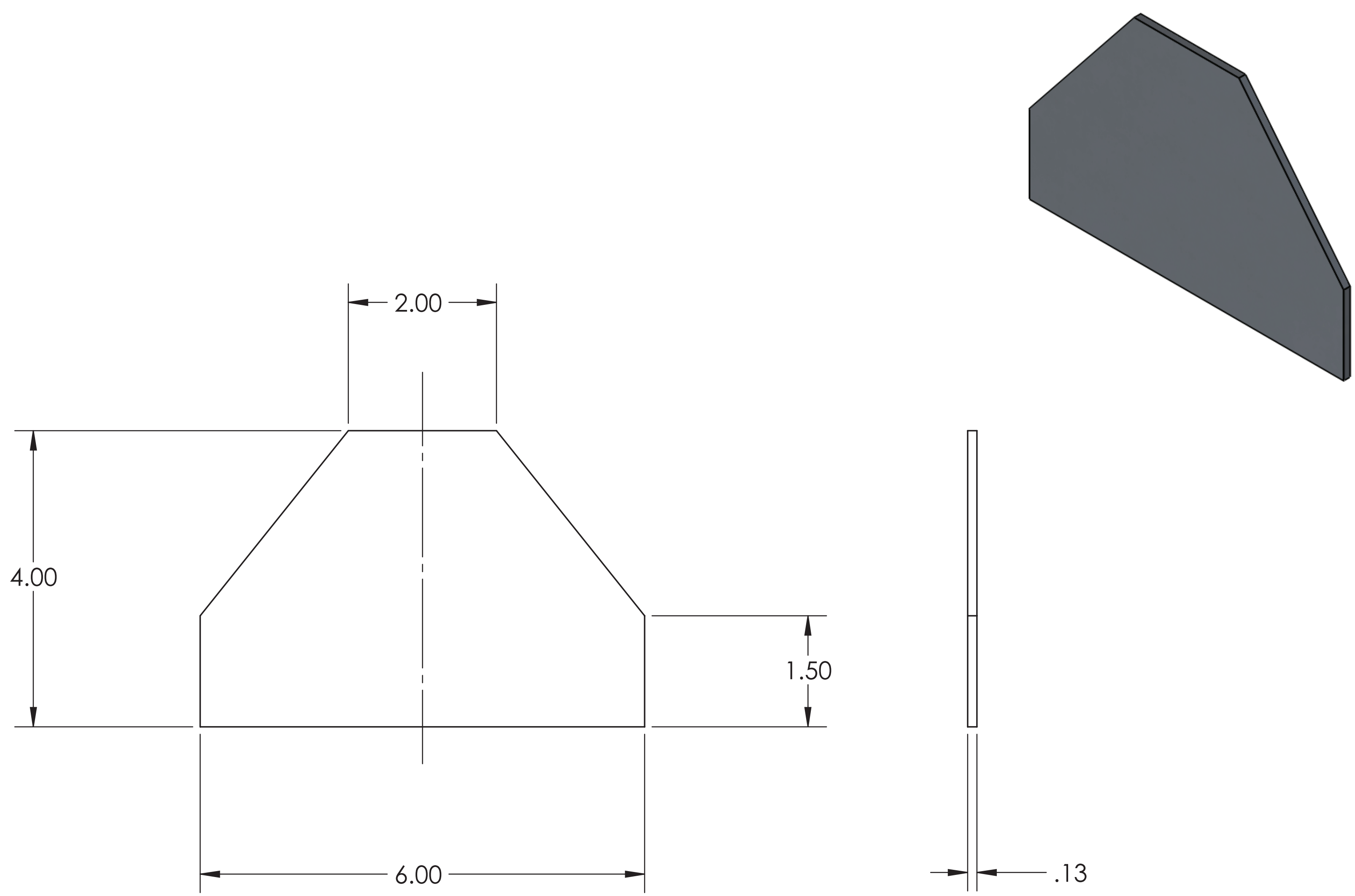


CUT FROM .125 INCH THICK ALUMINUM PLATE

SolidWorks Student Edition. For Academic Use Only.	CORMER GROUP	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACH±0° 30' ONE PLACE DECIMAL ±.05 TWO PLACE DECIMAL ±.02 THREE PLACE DECIMAL ±.005	UofM MECHANICAL ENGINEERING		
			INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994	NAME	DATE
			DO NOT SCALE DRAWING	DRAWN PT	29/11/2014
			MATERIAL	CHECKED PT	30/11/2014
			FINISH	NUMBER F05	

TITLE: F05		
SIZE A	DISCRIPTION:	REV A
SCALE: 1:2	WEIGHT:	SHEET 3 OF 19

5 4 3 2 1



CUT FROM .125 INCH THICK ALUMINUM PLATE

CORMER GROUP

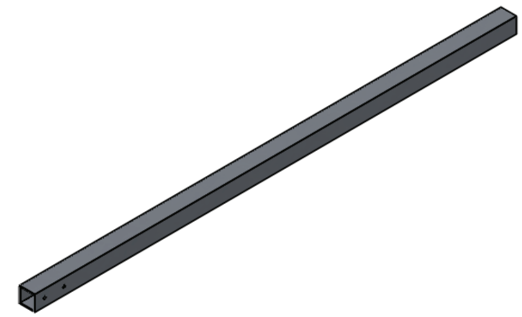
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

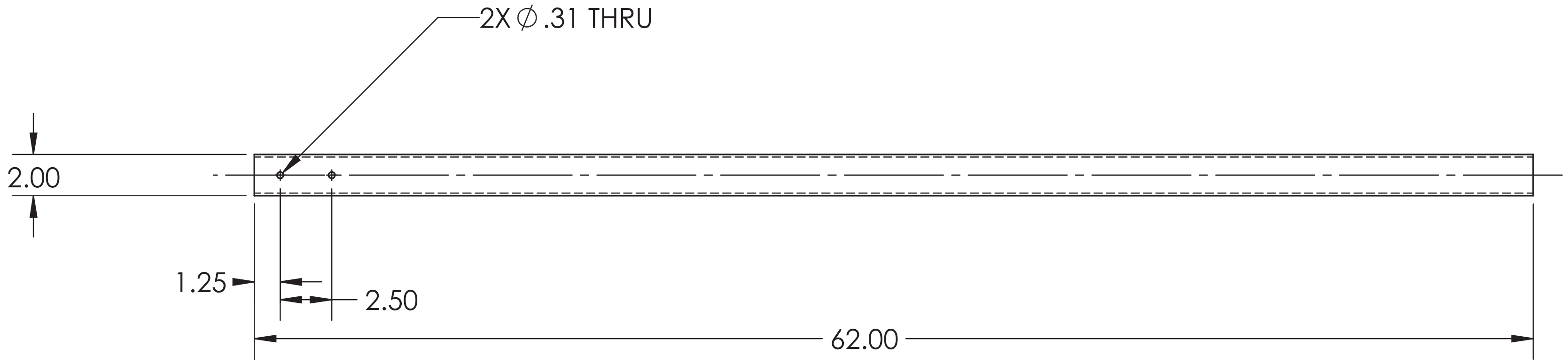
UofM MECHANICAL ENGINEERING			
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	F04	

TITLE: **F04**

SIZE	DISCRIPTION:	REV
A		**A**
SCALE: 1:2	WEIGHT:	SHEET 4 OF 19

5 4 3 2 1





2 INCH, 1/8 INCH THICKNESS SQUARE BAR - ALUMINUM 6061-T6

CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

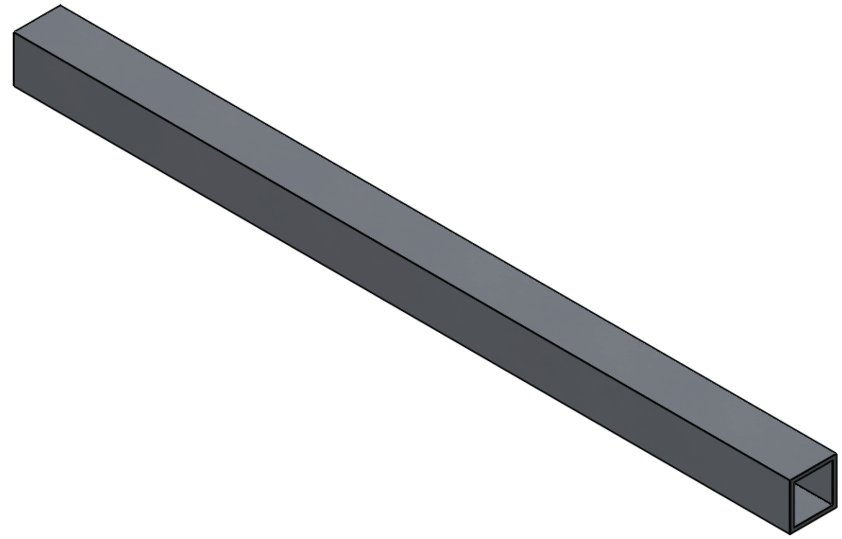
UofM MECHANICAL ENGINEERING

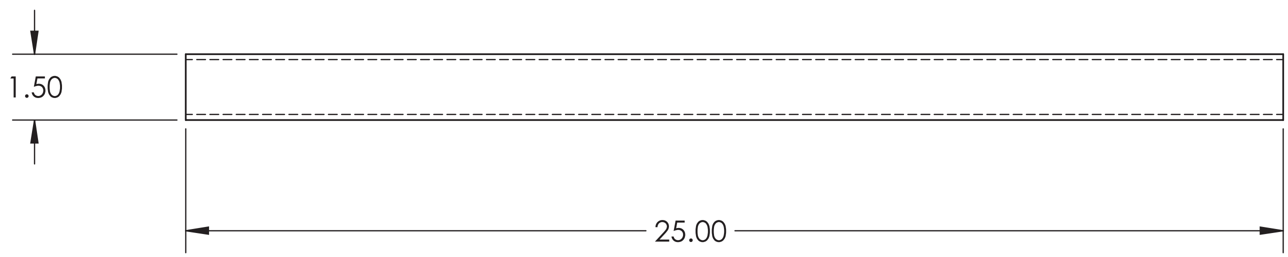
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	F03	

TITLE: **F03**

SIZE A	DISCRIPTION:	REV A
SCALE: 1:2	WEIGHT:	SHEET 5 OF 19

5 4 3 2 1





1.5 INCH, 1/8 INCH THICKNESS SQUARE BAR - ALUMINUM 6061-T6

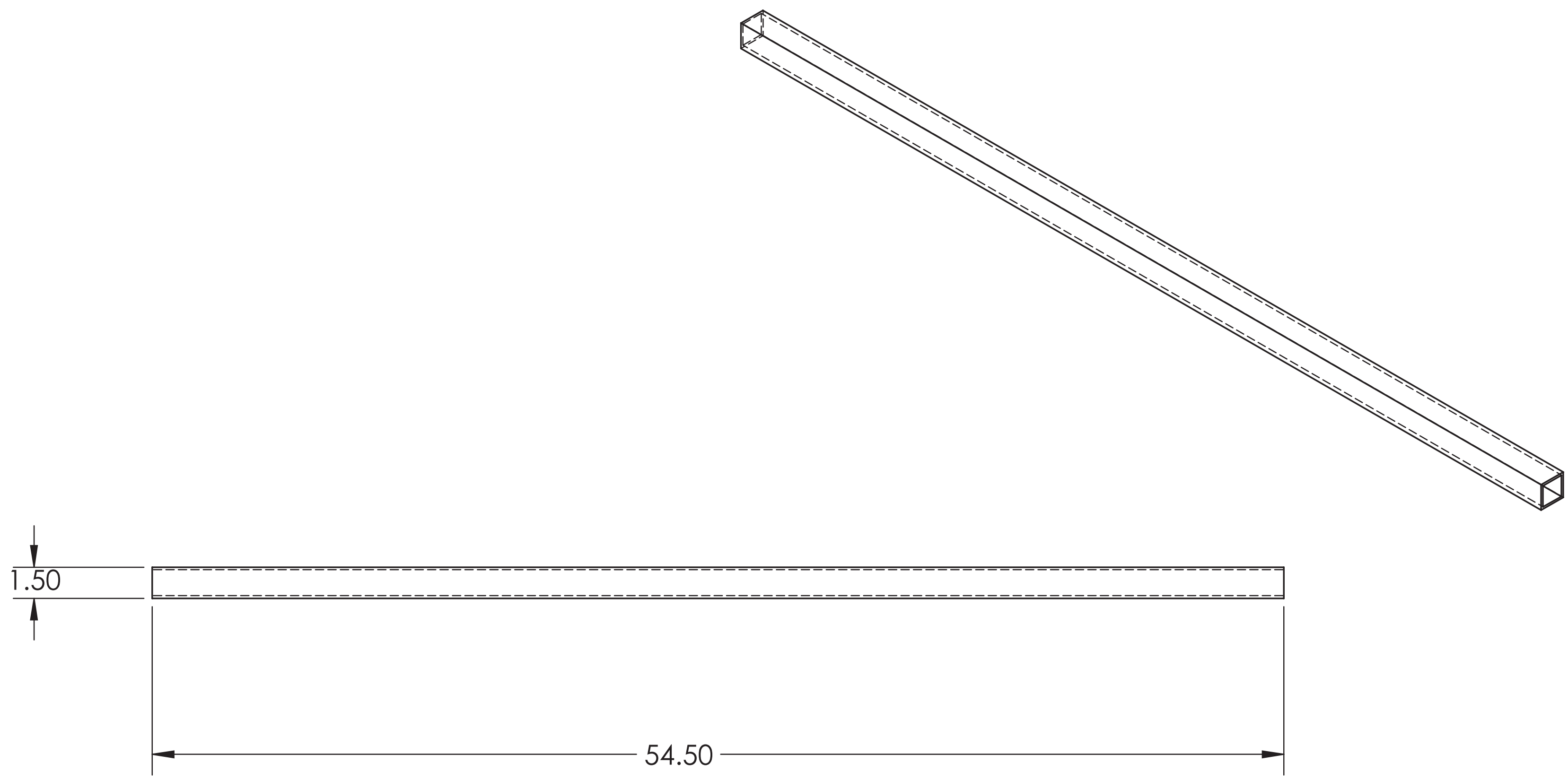
CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING			
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	F02	

TITLE: F02		
SIZE A	DISCRIPTION:	REV A
SCALE: 1:2	WEIGHT:	SHEET 6 OF 19

5 4 3 2 1



1.5 INCH, 1/8 INCH THICKNESS SQUARE BAR - ALUMINUM 6061-T6

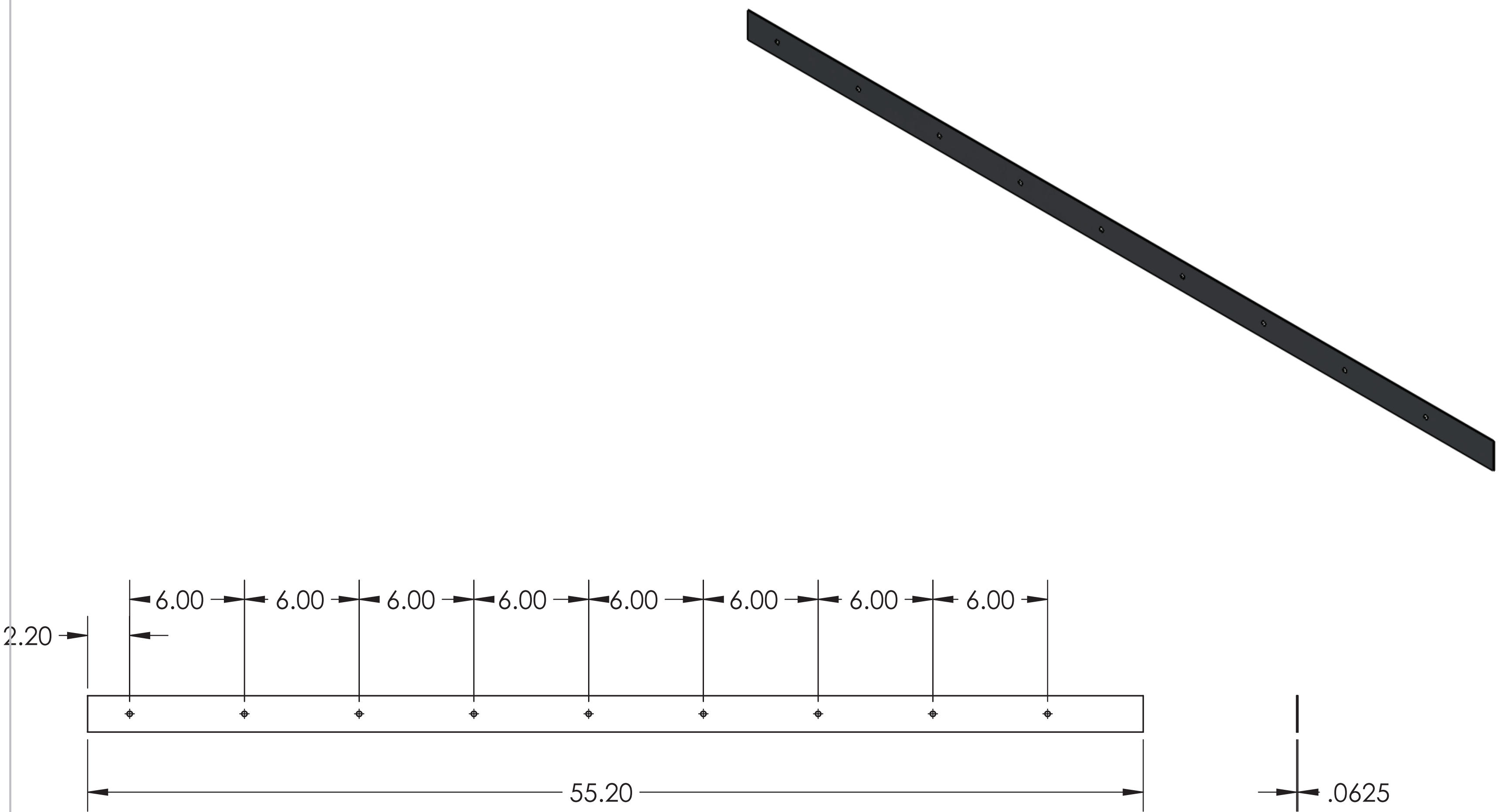
CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING			
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	F01	

TITLE: F01		
SIZE A	DISCRIPTION:	REV A
SCALE: 1:2	WEIGHT:	SHEET 7 OF 19

5 4 3 2 1



CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING

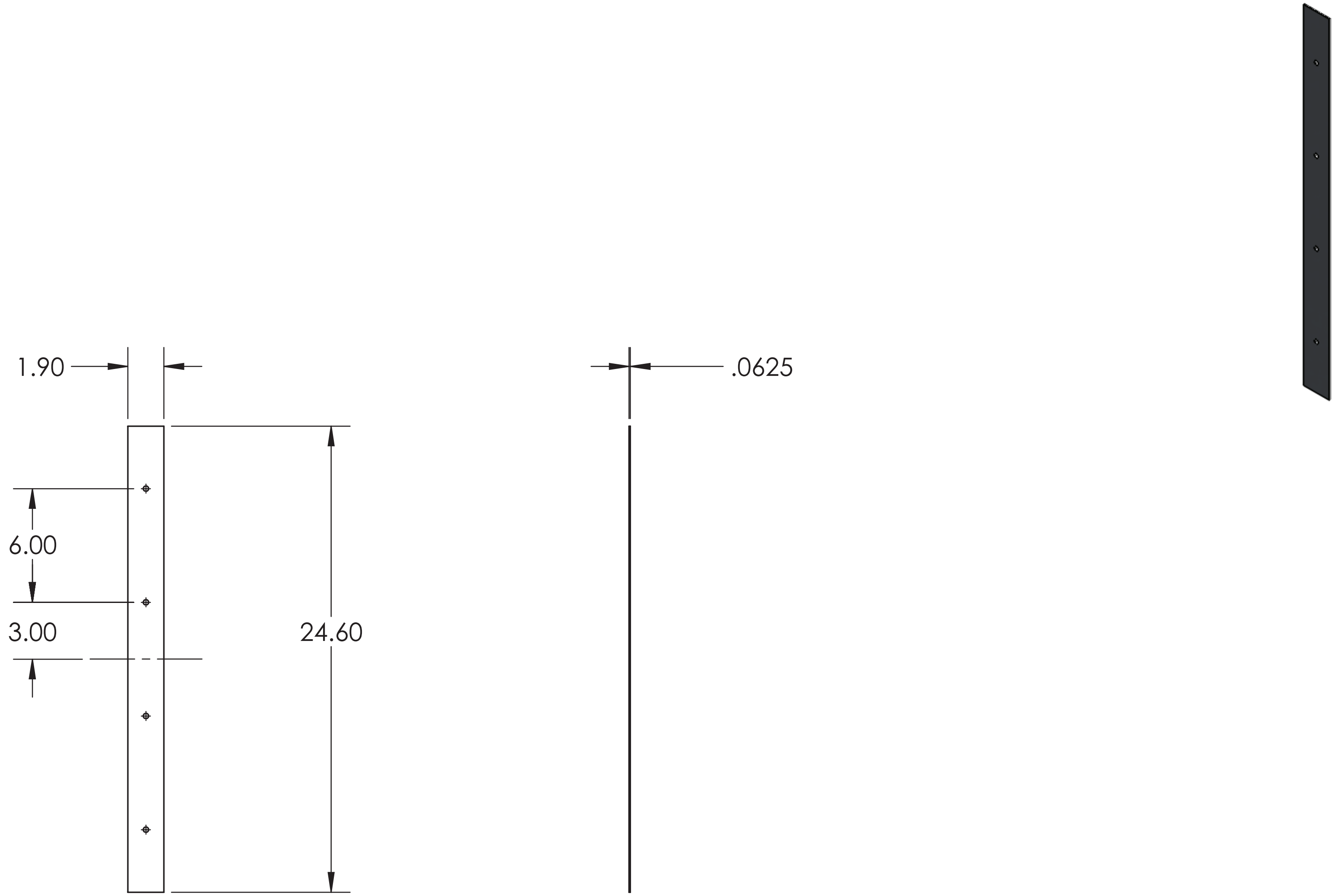
		NAME	DATE
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994			
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	B01	

TITLE: **B01**

SIZE	DISCRIPTION:	REV
A		**A**

SCALE: 1:2 | WEIGHT: | SHEET 8 OF 19

5 4 3 2 1



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CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING

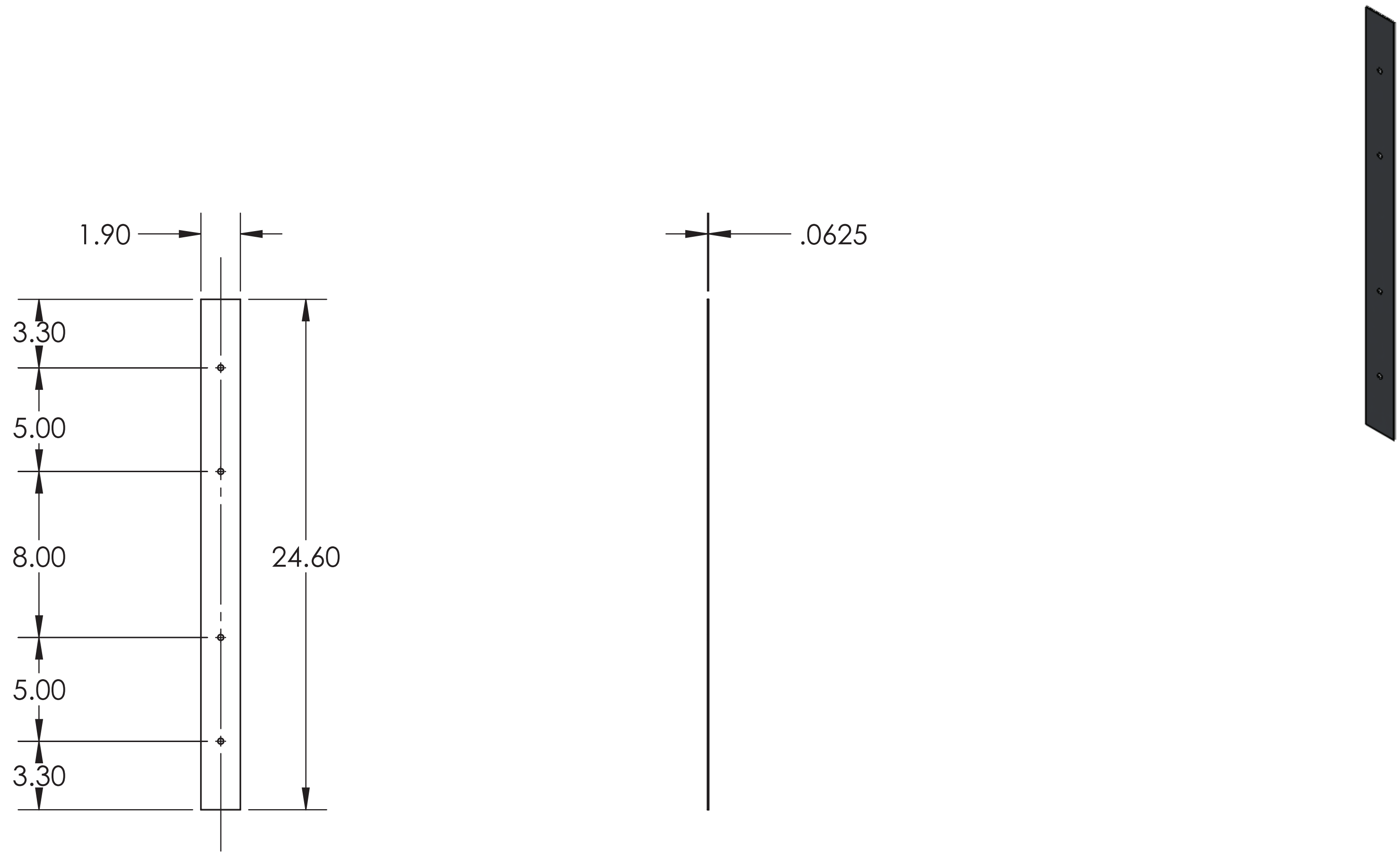
		NAME	DATE
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	B02	

TITLE: **B02**

SIZE	DISCRIPTION:	REV
A		A

SCALE: 1:2 | WEIGHT: | SHEET 9 OF 19

5 4 3 2 1

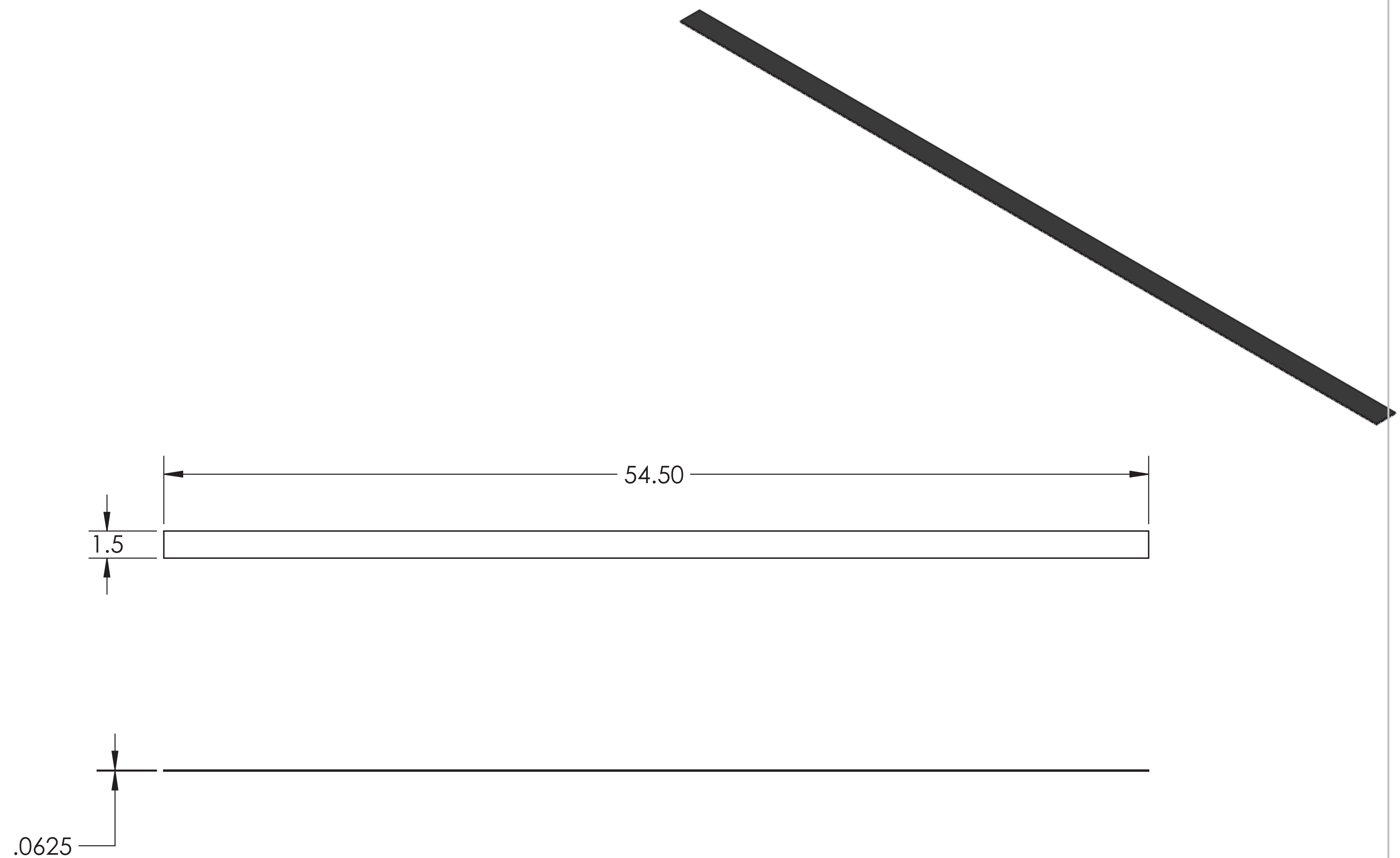


SolidWorks Student Edition. For Academic Use Only.	CORMER GROUP	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACH±0° 30' ONE PLACE DECIMAL ±.05 TWO PLACE DECIMAL ±.02 THREE PLACE DECIMAL ±.005	UofM MECHANICAL ENGINEERING	TITLE: B03

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	B03	

SIZE A	DISCRIPTION:	REV A
SCALE: 1:2	WEIGHT:	SHEET 10 OF 19

5 4 3 2 1



PURCHASED FROM JOHNSTON INDUSTIAL PLASTIC. COMES IN 3 INCH WIDTH, CUT IN HALF TO 1.5 INCH

CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING

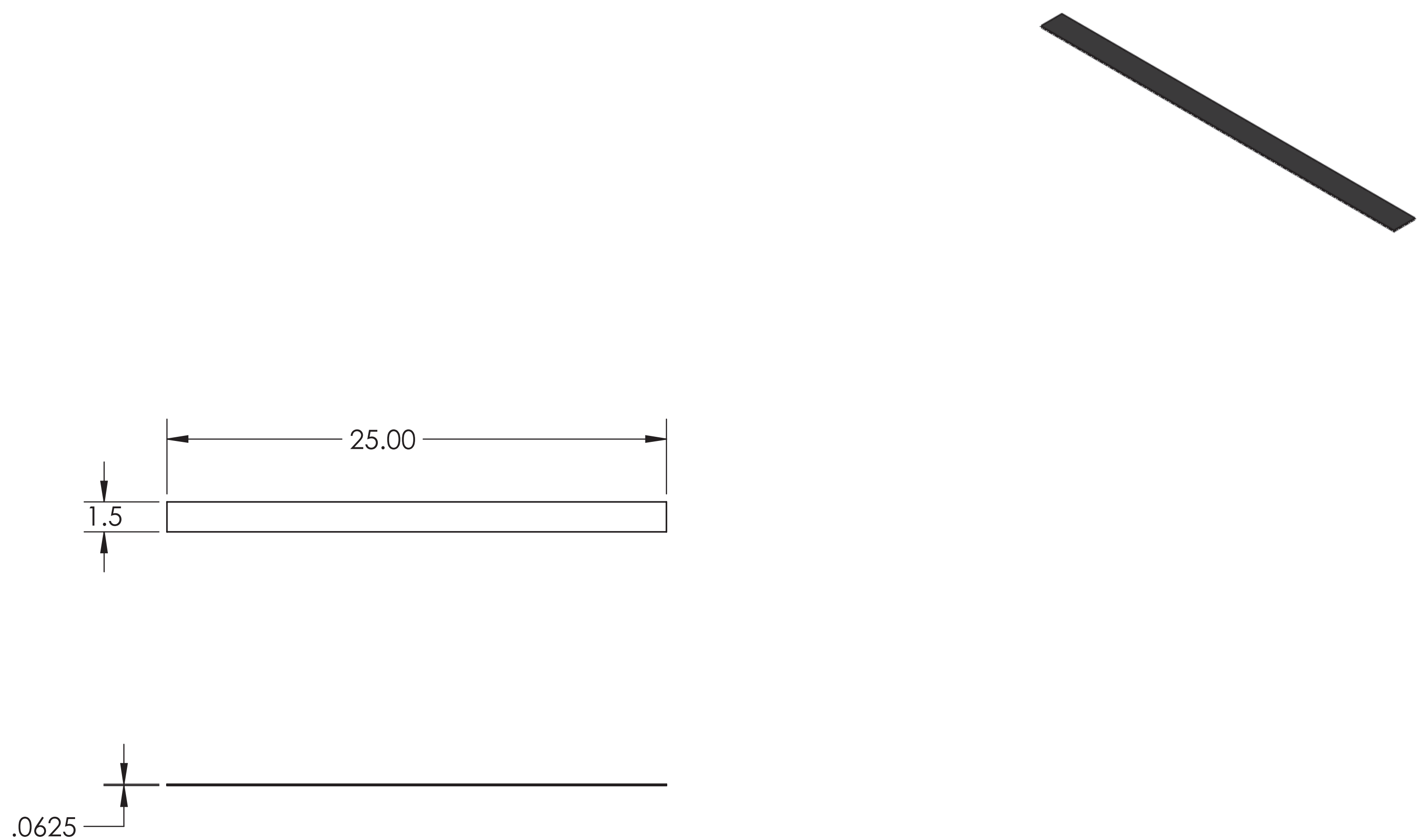
		NAME	DATE
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994			
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	B04	

TITLE: **B04**

SIZE	DISCRIPTION:	REV
A		**A**

SCALE: 1:2 WEIGHT: SHEET 11 OF 19

5 4 3 2 1



PURCHASED FROM JOHNSTON INDUSTIAL PLASTIC. COMES IN 3 INCH WIDTH, CUT IN HALF TO 1.5 INCH

CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING

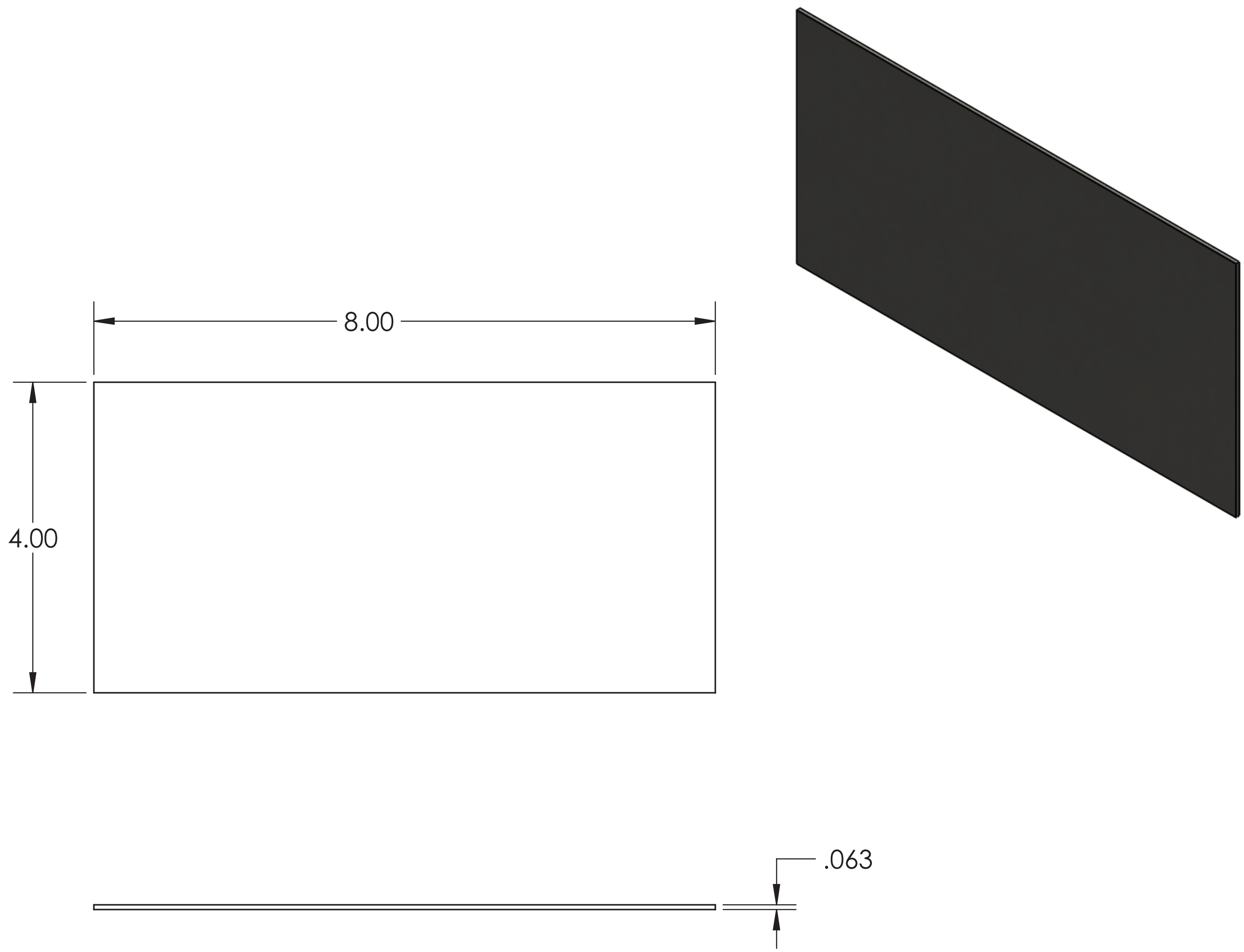
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	B05	

TITLE: **B05**

SIZE	DISCRIPTION:	REV
A		**A**

SCALE: 1:2 | WEIGHT: | SHEET 12 OF 19

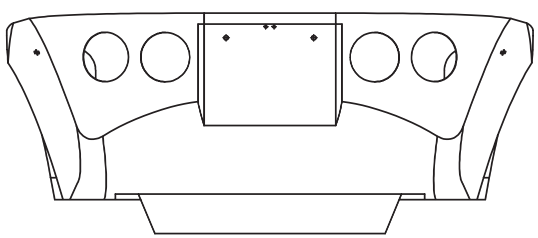
5 4 3 2 1

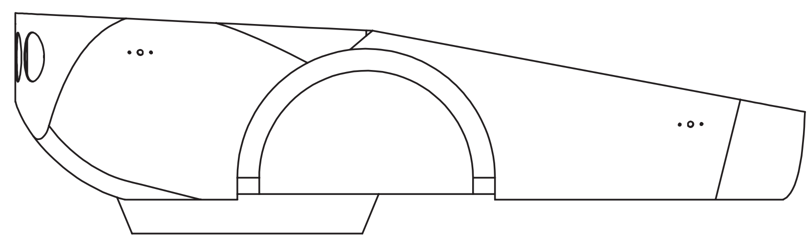


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACH±0° 30' ONE PLACE DECIMAL ±.05 TWO PLACE DECIMAL ±.02 THREE PLACE DECIMAL ±.005	UofM MECHANICAL ENGINEERING			TITLE: B06	
	INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994	NAME	DATE	SIZE A	DISCRIPTION:	REV A
	DO NOT SCALE DRAWING	DRAWN PT	29/11/2014		
	MATERIAL	CHECKED PT	30/11/2014		
	FINISH	NUMBER B06		SCALE: 1:2	WEIGHT:	SHEET 13 OF 19

CORMER GROUP

5 4 3 2 1





CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING

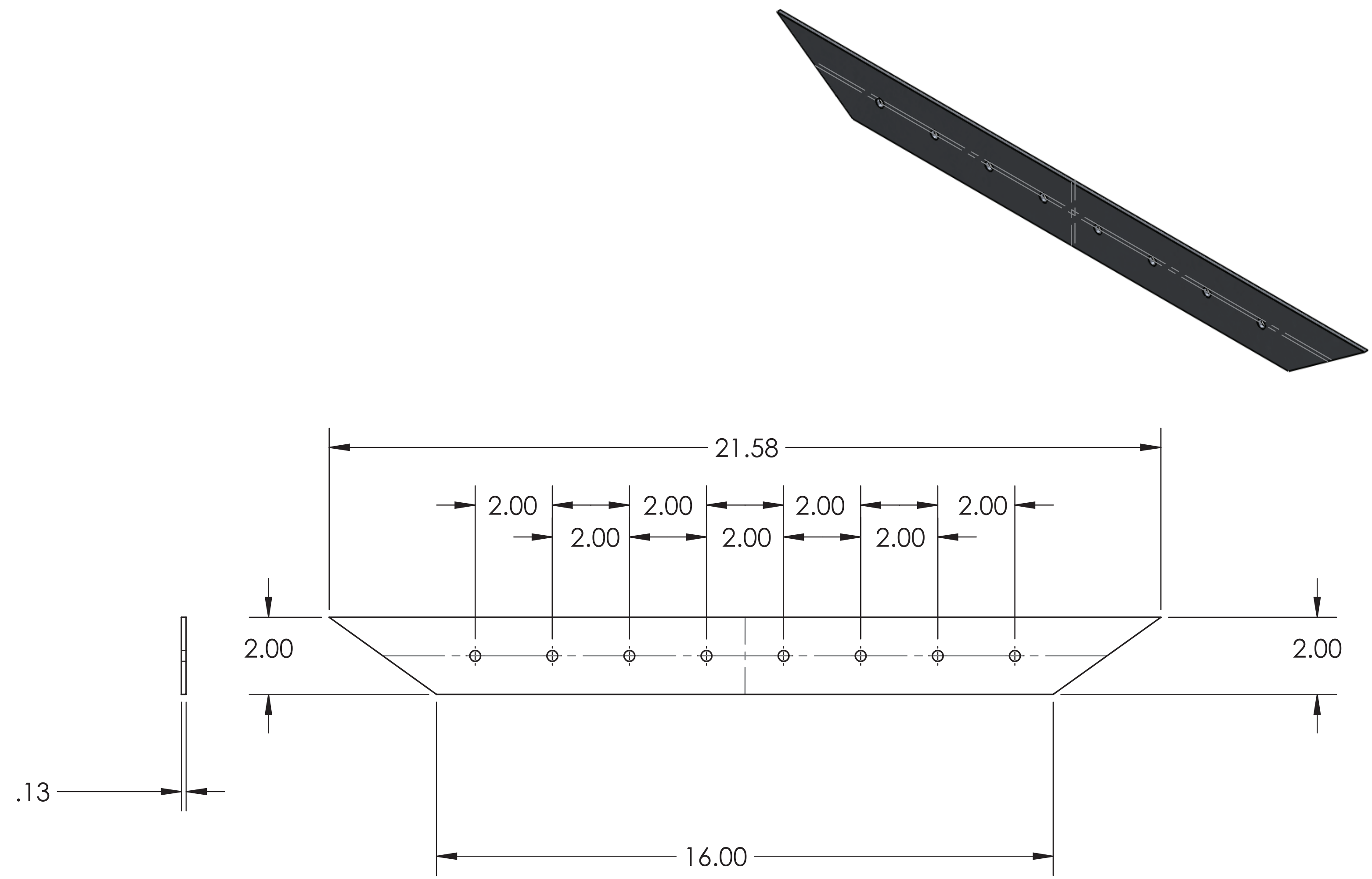
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	B07	

TITLE: **B07**

SIZE	DISCRIPTION:	REV
A		**A**

SCALE: 1:2 WEIGHT: SHEET 14 OF 19

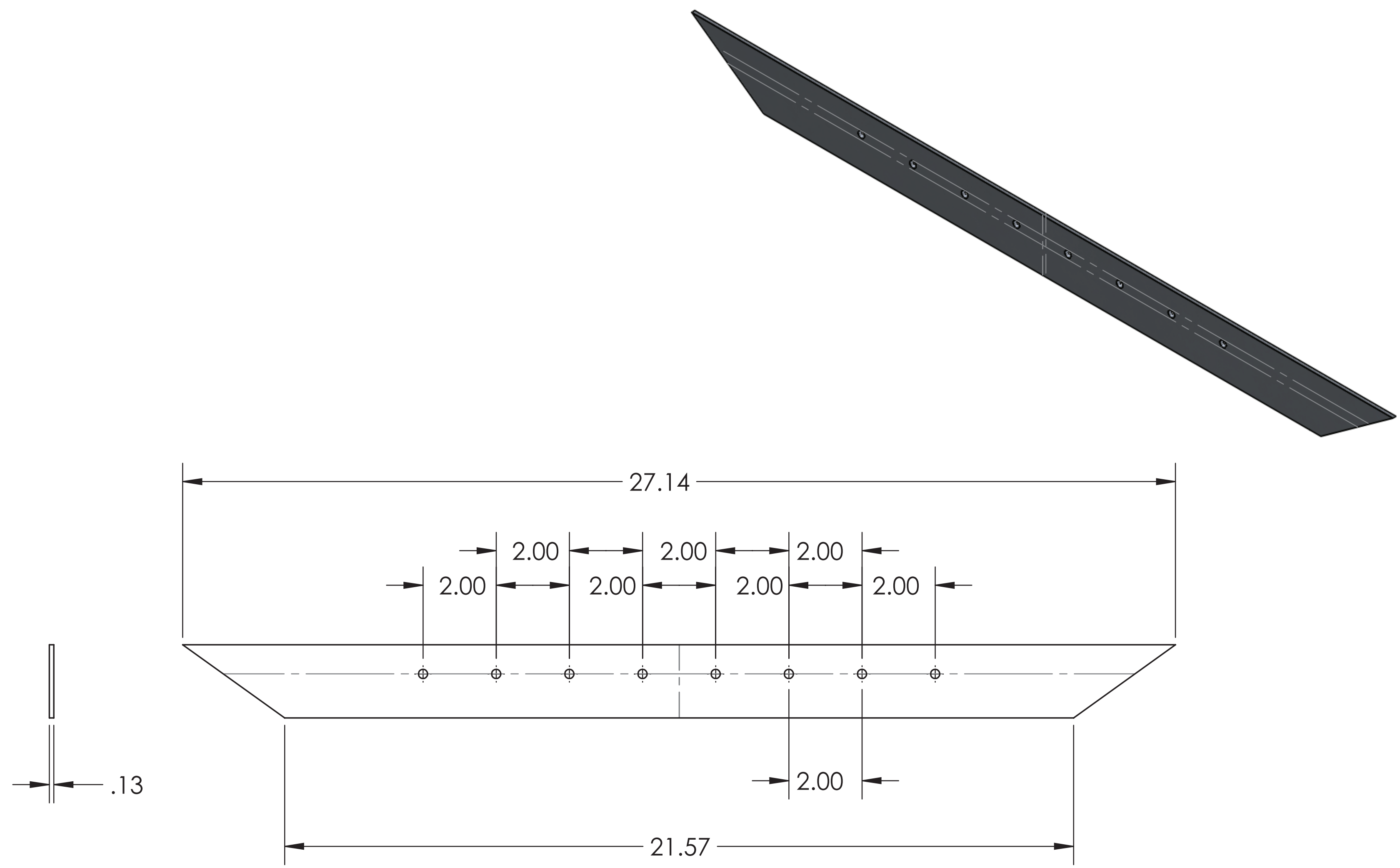
5 4 3 2 1



SolidWorks Student Edition. For Academic Use Only.	CORMER GROUP	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: MACH±0° 30' ONE PLACE DECIMAL ±.05 TWO PLACE DECIMAL ±.02 THREE PLACE DECIMAL ±.005	UofM MECHANICAL ENGINEERING		
			INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994	NAME	DATE
			DO NOT SCALE DRAWING / DRAWN	PT	29/11/2014
			MATERIAL / CHECKED	PT	30/11/2014
			FINISH / NUMBER	B09	

TITLE: B09		
SIZE A	DISCRIPTION:	REV A
SCALE: 1:2	WEIGHT:	SHEET 15 OF 19

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

CORMER GROUP

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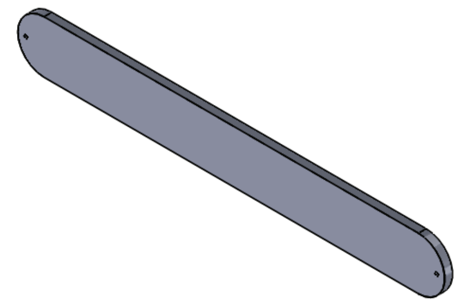
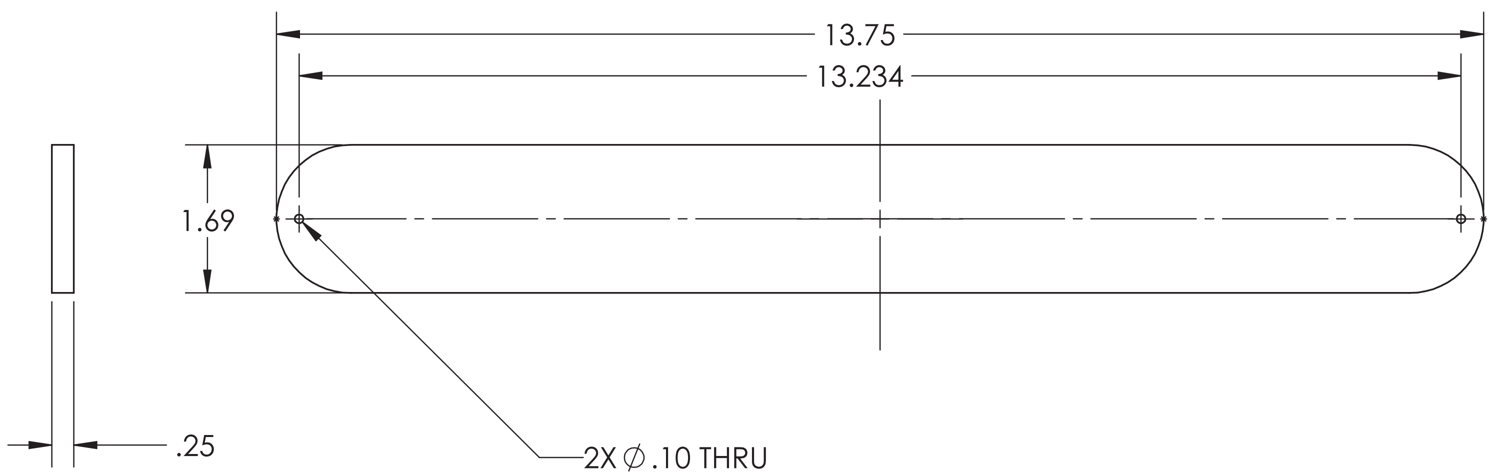
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994	NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	B10	

TITLE: **B10**

SIZE A	DISCRIPTION:	REV A
SCALE: 1:2	WEIGHT:	SHEET 16 OF 19

5 4 3 2 1





CUT OUT OF 4 FT X 8 FT SHEET OF .25 INCH ABS FROM JOHNSTON INDUSTRIAL PLASTIC

CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

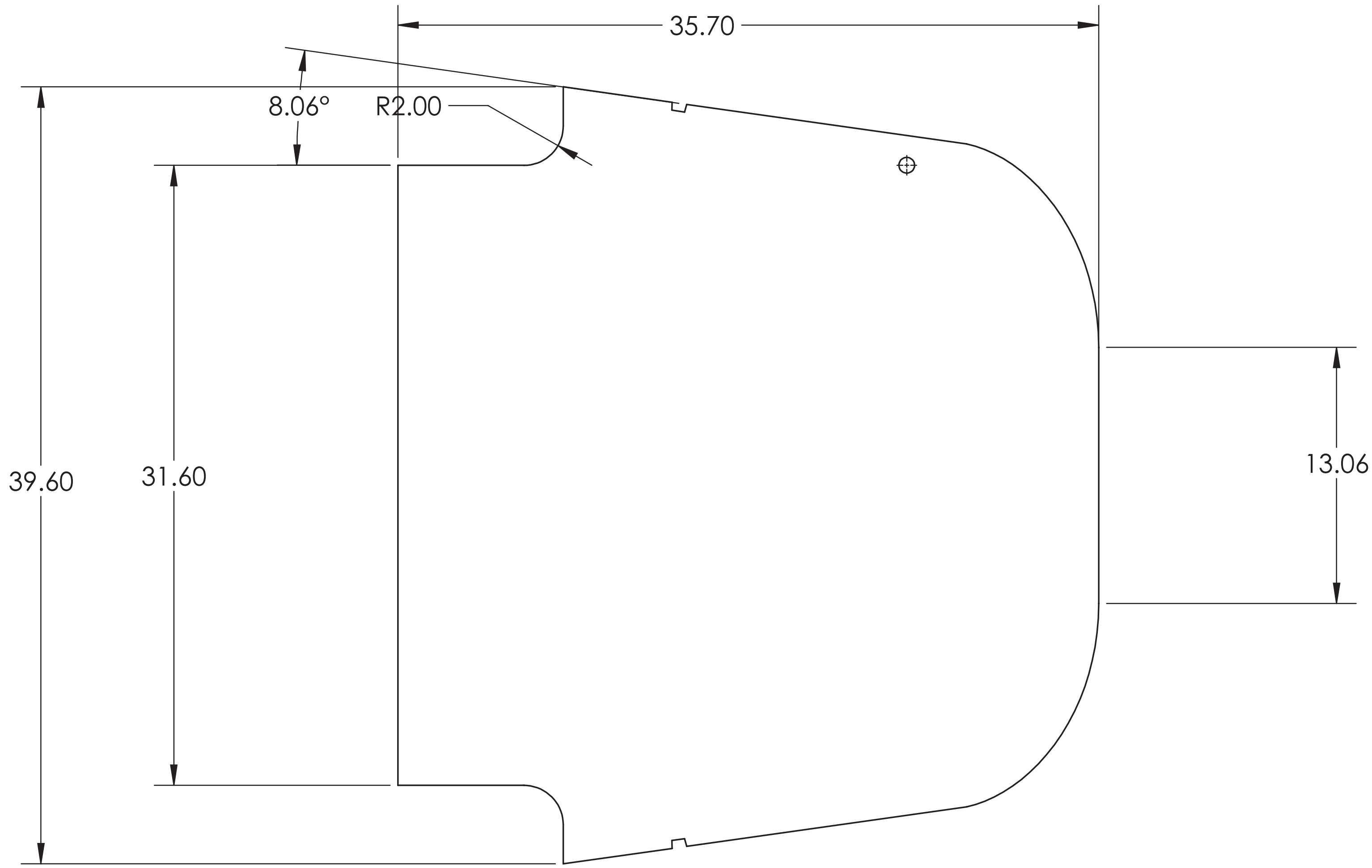
UofM MECHANICAL ENGINEERING			
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL ABS PLASTIC	CHECKED	PT	30/11/2014
FINISH	NUMBER	B11	

TITLE: **B11**

SIZE	DISCRIPTION:	REV
A	LIGHT BAR FIXTURE PLATE	A

SCALE: 1:2 | WEIGHT: | SHEET 17 OF 19

5 4 3 2 1



1/4 INCH ABS SHEET CUT ON CNC MACHINE. USE DXF FILE PROVIDED

CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

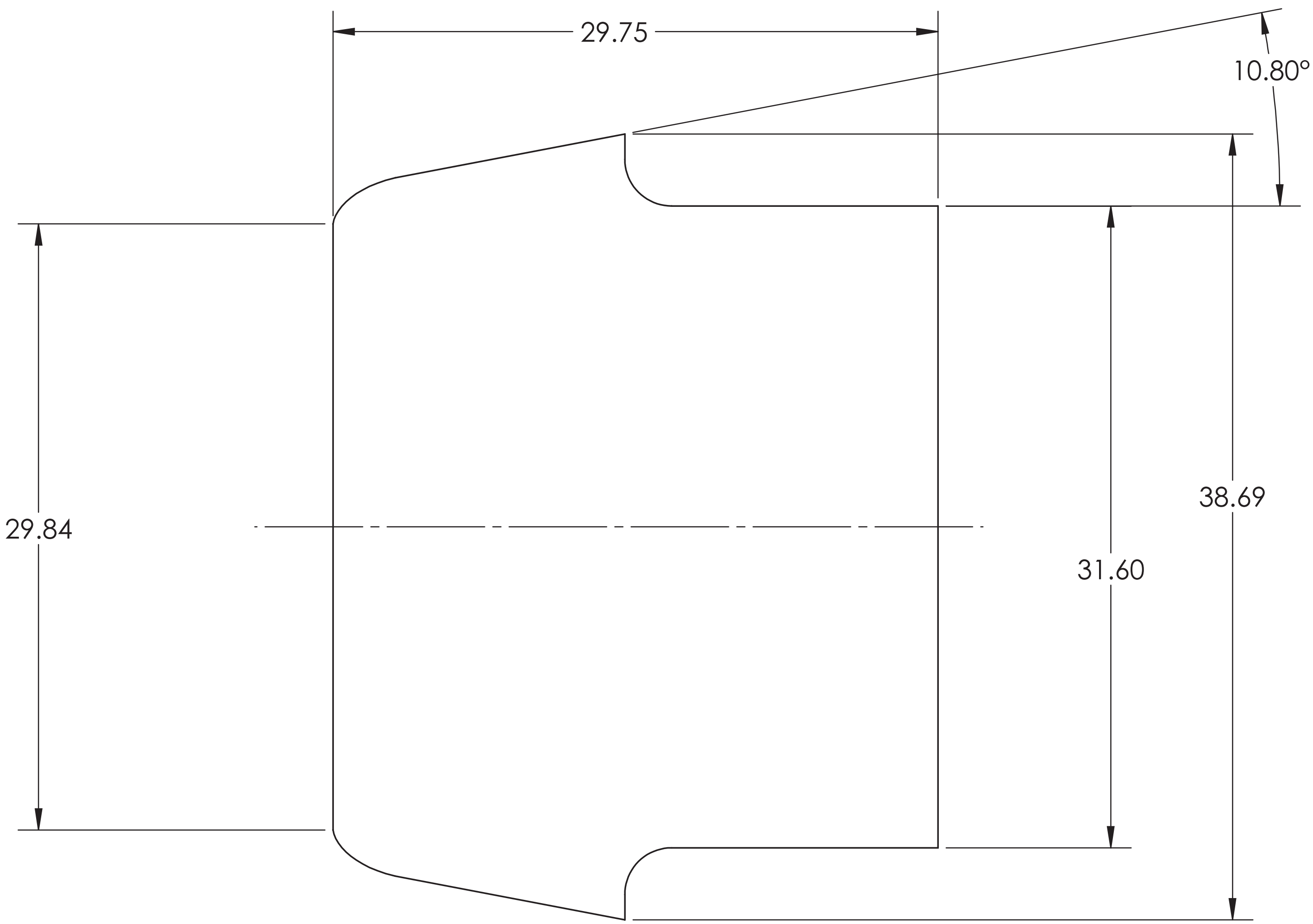
UofM MECHANICAL ENGINEERING

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994		NAME	DATE
DO NOT SCALE DRAWING	DRAWN	PT	29/11/2014
MATERIAL	CHECKED	PT	30/11/2014
FINISH	NUMBER	I05-NEW	

TITLE: **I05-NEW**

SIZE	DISCRIPTION:	REV
A		A
SCALE: 1:2	WEIGHT:	SHEET 18 OF 19

5 4 3 2 1



CORMER GROUP

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH±0° 30'
ONE PLACE DECIMAL ±.05
TWO PLACE DECIMAL ±.02
THREE PLACE DECIMAL ±.005

UofM MECHANICAL ENGINEERING

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14. 5M-1994

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	PT	29/11/2014
CHECKED	PT	30/11/2014
NUMBER	I06-NEW	

MATERIAL

FINISH

TITLE: **I06-NEW**

SIZE: A

DISCRIPTION:

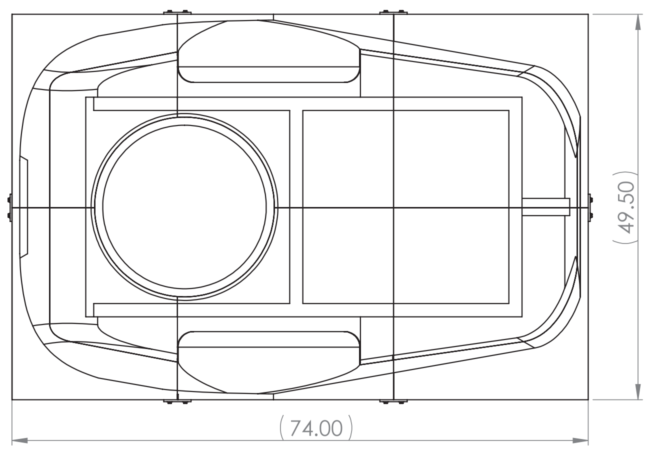
REV: A

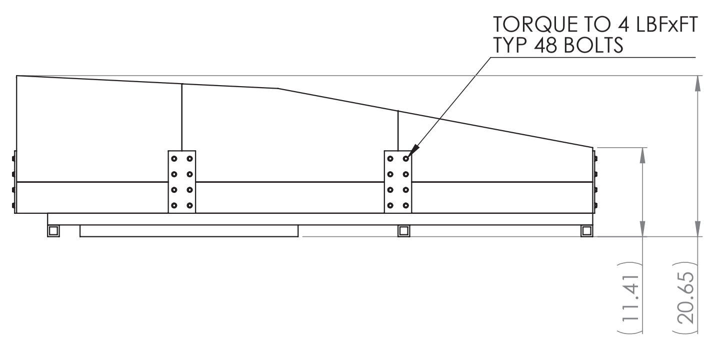
SCALE: 1:2

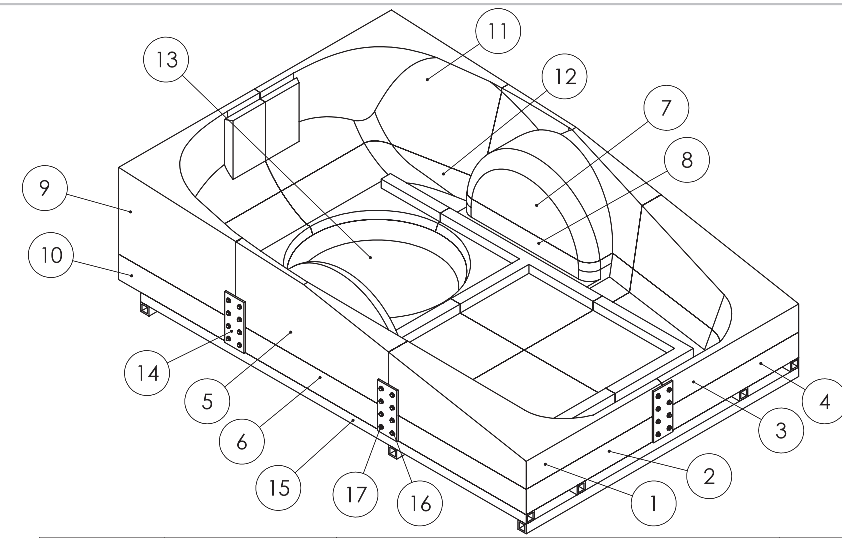
WEIGHT:

SHEET 19 OF 19

5 4 3 2 1







ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	M01	Base Mold Front Right Upper Block	1
2	M02	Base Mold Front Right Lower Block	1
3	M03	Base Mold Front Left Upper Block	1
4	M04	Base Mold Front Left Lower Block	1
5	M05	Base Mold Center Right Upper Block	1
6	M06	Base Mold Center Right Lower Block	1
7	M07	Base Mold Center Left Upper Block	1
8	M08	Base Mold Center Left Lower Block	1
9	M09	Base Mold Rear Right Upper Block	1
10	M10	Base Mold Rear Right Lower Block	1
11	M11	Base Mold Rear Left Upper Block	1
12	M12	Base Mold Rear Left Lower Block	1
13	M13	Base Mold Spare Wheel Block	1
14	M14	Mold Bracket	6
15	M15	Support Frame Assembly	1
16	H09	Flat Washer Selected A Narrow FW 0.266	48
17	H10	Hex Bolt 1/4-20x.75x.75	48
18	H11	Countersink Bolt 1/4-20x2.5x2.5	4

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: SPECIFIED IN COMPONENTS

A04

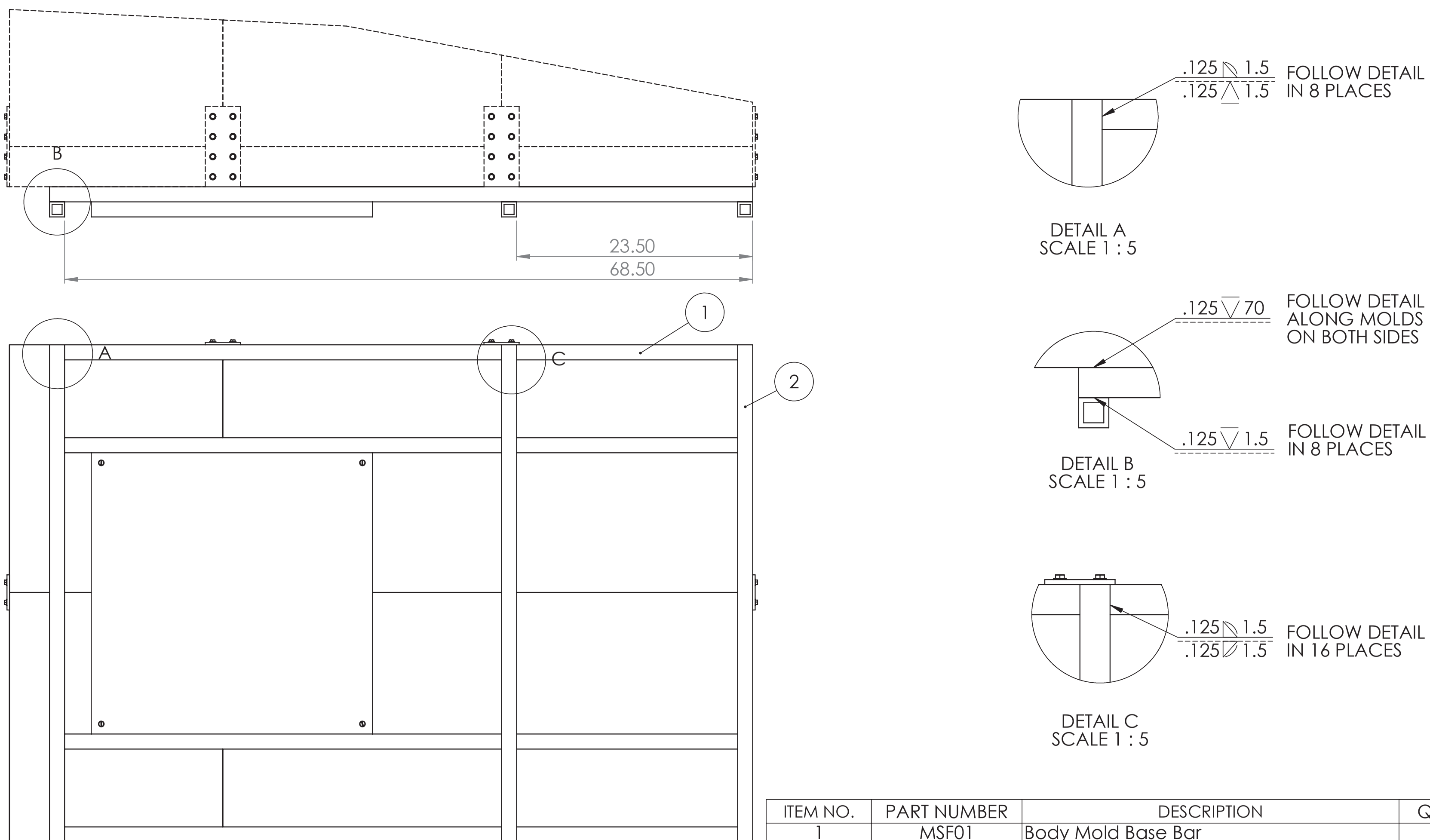
TITLE: BASE MOLD ASSEMBLY

DWG NO. DRAWING 1

A3

SCALE:1:15

SHEET 1 OF 18



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MSF01	Body Mold Base Bar	4
2	MSF02	Body Mold Resting Bar	3

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: SPECIFIED IN COMPONENTS

M15

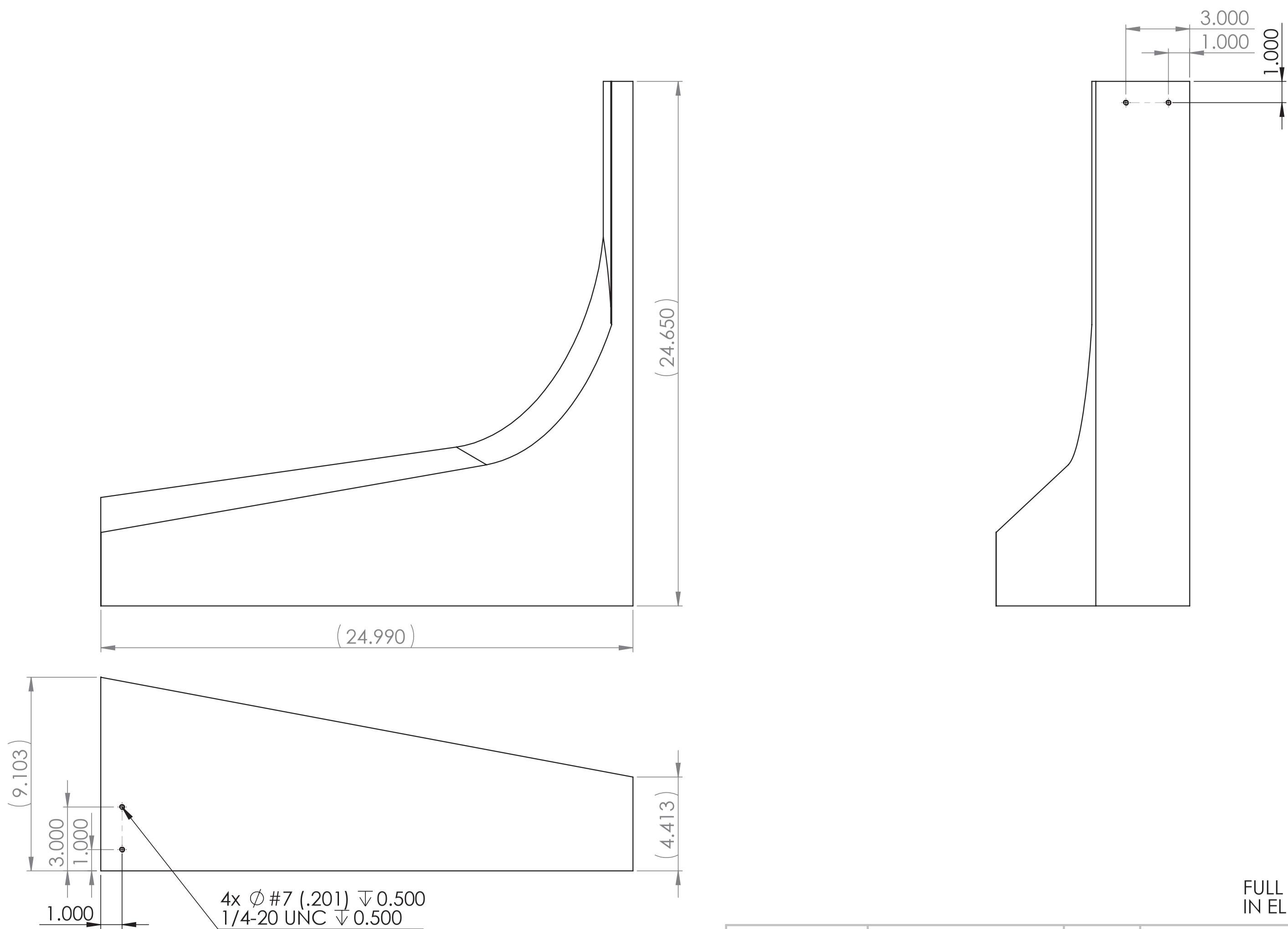
TITLE: SUPPORT FRAME SUBASSEMBLY

DWG NO. DRAWING 2

A3

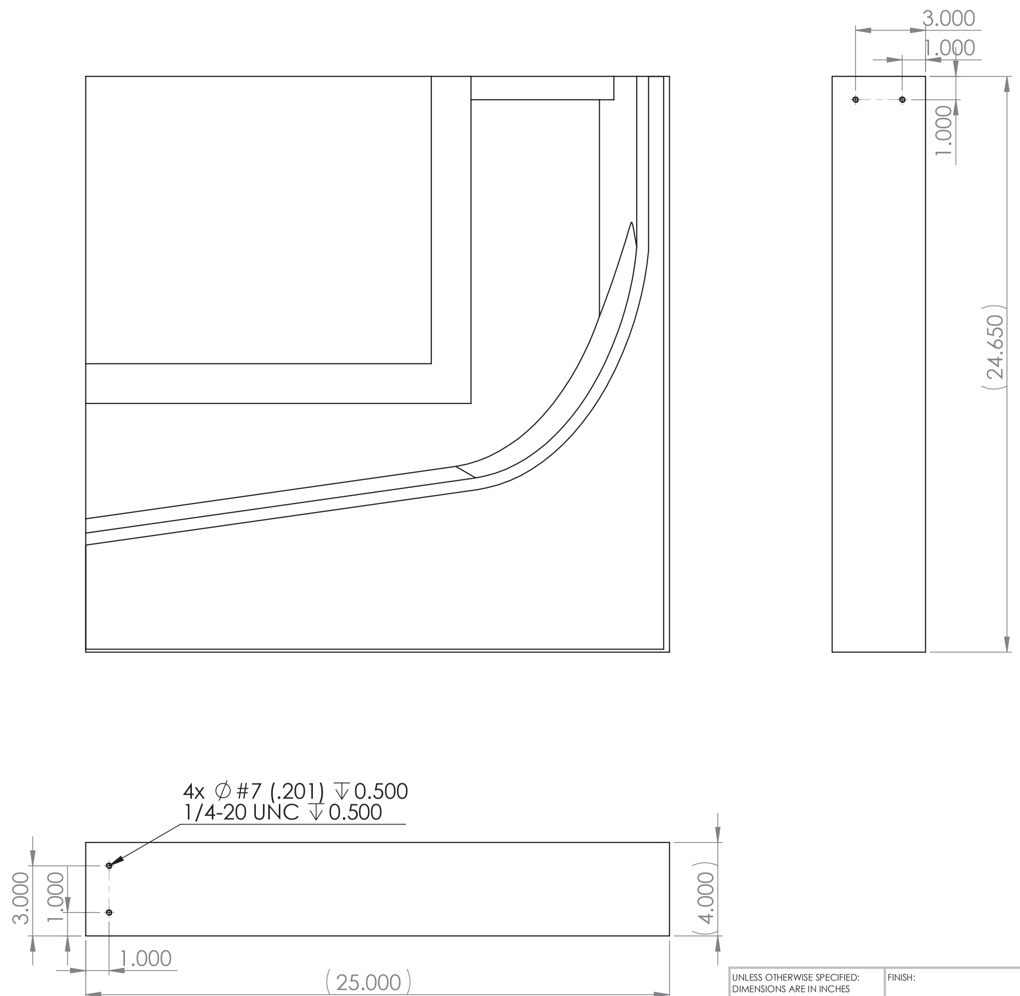
SCALE:1:10

SHEET 2 OF 18



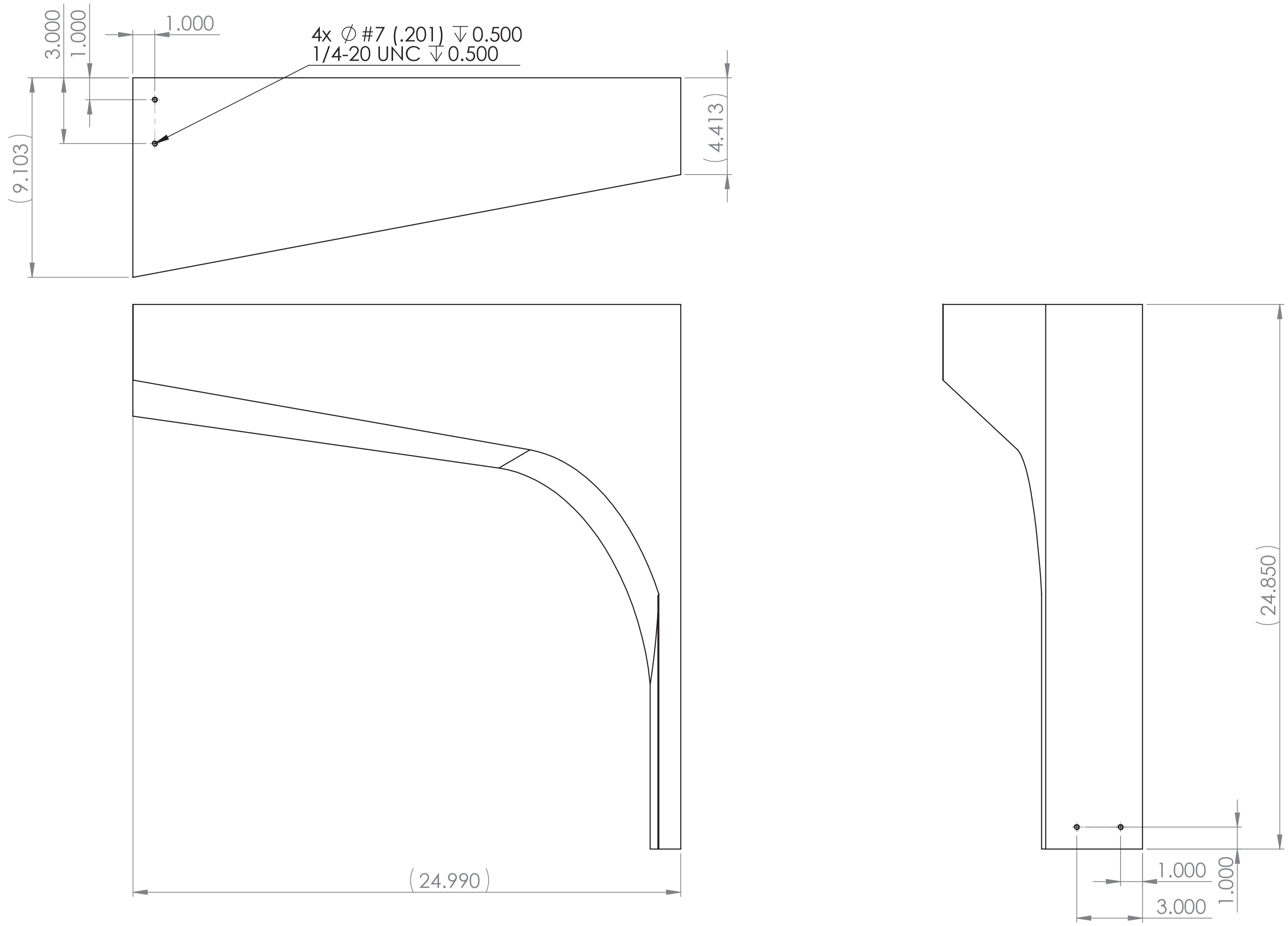
FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
			M01	
NAME / SIGNATURE / DATE			TITLE: BASE MOLD FRONT RIGHT UPPER BLOCK	
DRAWN: NIK PAULIC / NP / 27/11/14				
CHK'D				
APPV'D				
MFG				
Q.A	MATERIAL: ALUMINUM 6061-T6		DWG NO. DRAWING 3	A3
			SCALE:1:5	SHEET 3 OF 18



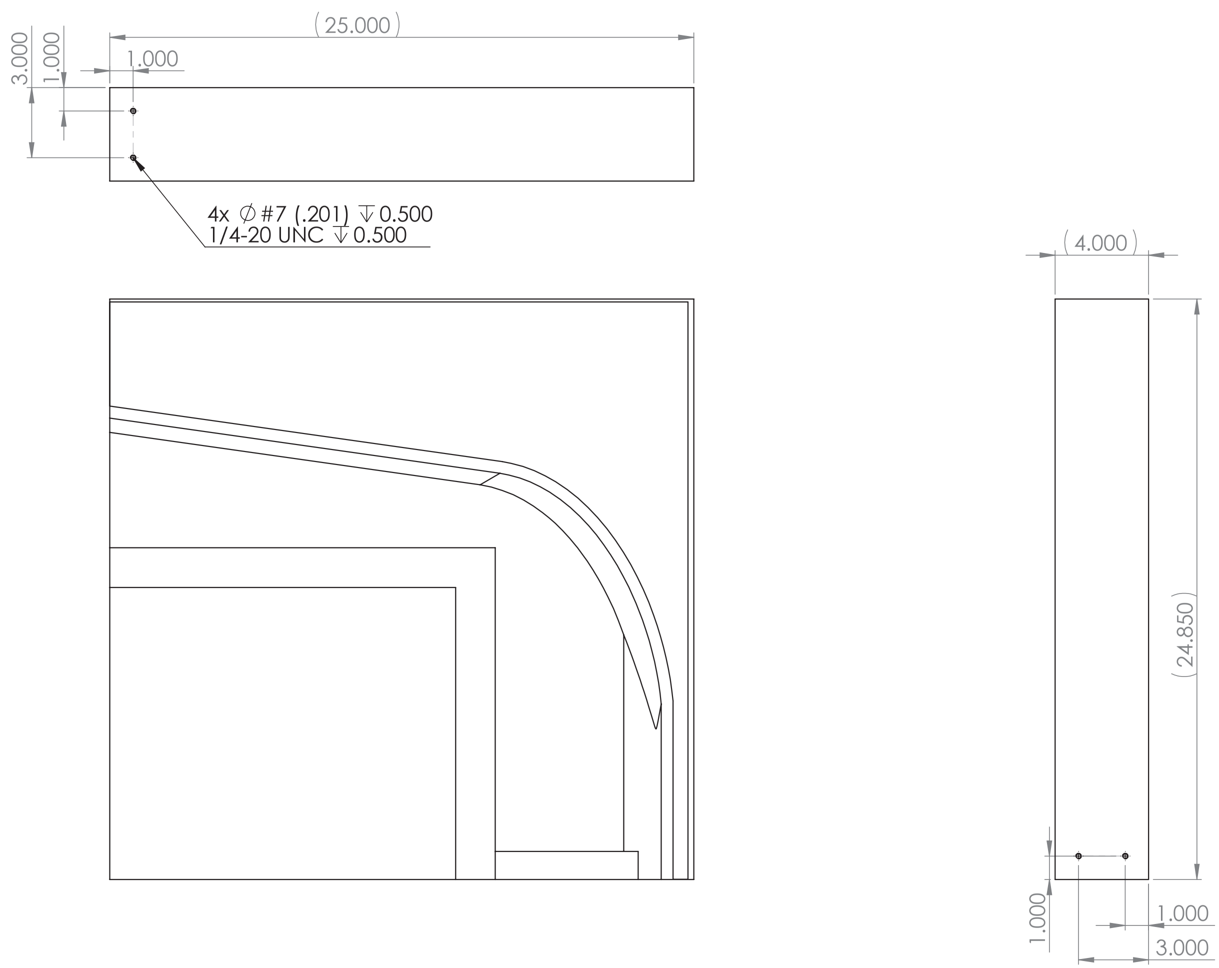
FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
				M02		
	NAME	SIGNATURE	DATE	TITLE: BASE MOLD FRONT RIGHT LOWER BLOCK		
DRAWN	NIK PAULIC	NP	27/11/14			
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 4	A3
				SCALE:1:5	SHEET 4 OF 18	



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

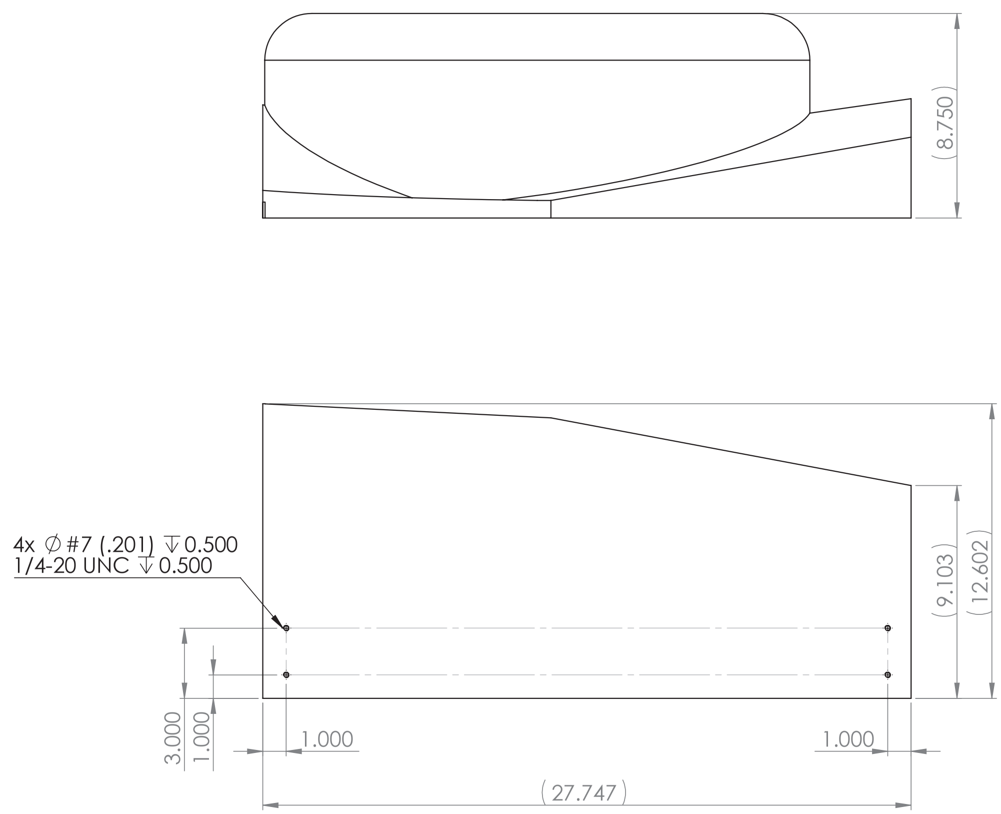
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE	M03
DRAWN	NIK PAULIC	NP	27/11/14	TITLE: BASE MOLD FRONT LEFT UPPER BLOCK
CHK'D				
APPV'D				
MFG				
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 5 — A3
				SCALE:1:5 — SHEET 5 OF 18



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

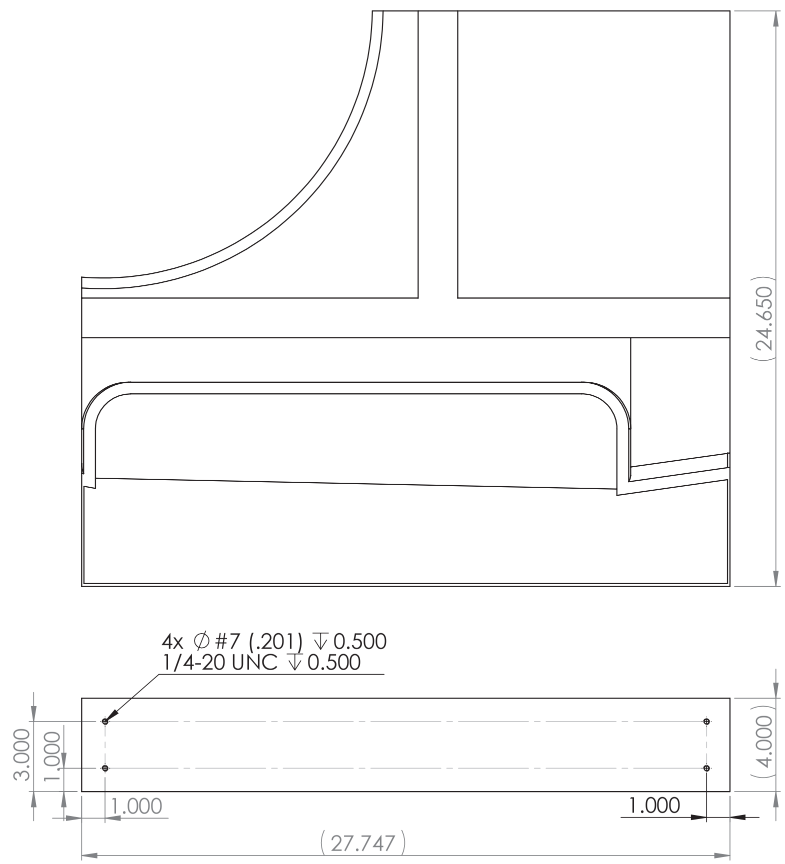
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	
	NAME	SIGNATURE	DATE	
DRAWN	NIK PAULIC	NP	27/11/14	
CHK'D				
APPV'D				
MFG				
Q.A				MATERIAL: ALUMINUM 6061-T6

DO NOT SCALE DRAWING	REVISION
M04	
TITLE: BASE MOLD FRONT LEFT LOWER BLOCK	
DWG NO. DRAWING 6	A3
SCALE:1:5	SHEET 6 OF 18



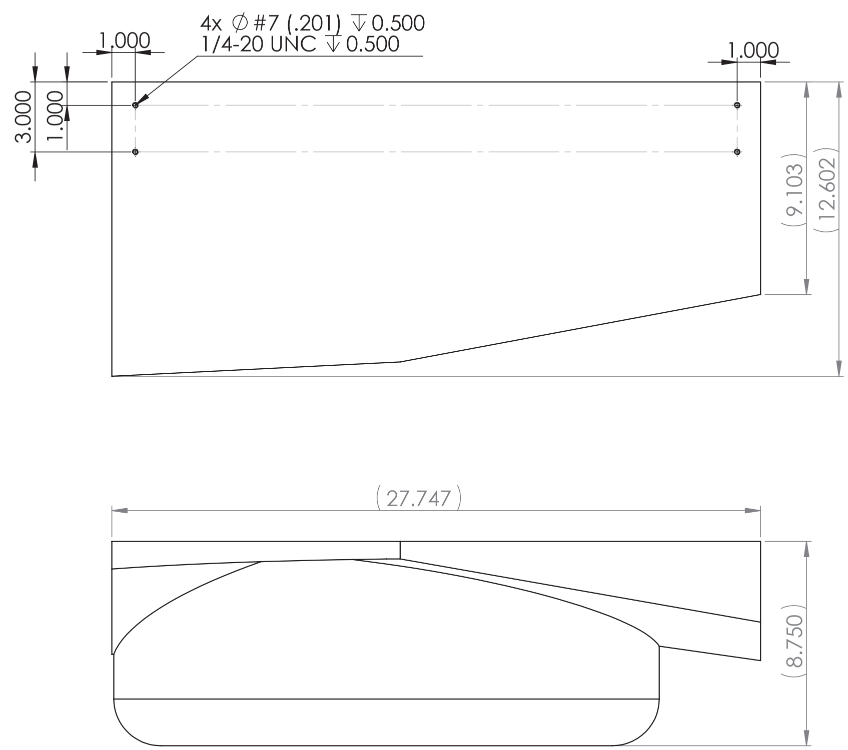
FULL DIMENSIONS DETAILED IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
			M05	
	NAME	SIGNATURE	DATE	
DRAWN	NIK PAULIC	NP	27/11/14	TITLE: BASE MOLD CENTER RIGHT UPPER BLOCK
CHK'D				
APPV'D				
MFG				
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 7 — A3
				SCALE:1:5 — SHEET 7 OF 18



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
			M06		
	NAME	SIGNATURE	DATE	TITLE: BASE MOLD CENTER RIGHT LOWER BLOCK	
DRAWN	NIK PAULIC	NP	27/11/14		
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 8	A3
				SCALE:1:5	SHEET 8 OF 18



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001		FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING — REVISION
	NAME	SIGNATURE	DATE		M07
DRAWN	NIK PAULIC	NP	27/11/14		TITLE: BASE MOLD CENTER LEFT UPPER BLOCK
CHK'D					
APPV'D					
MFG					
Q.A				MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 9 — A3
					SCALE:1:5 — SHEET 9 OF 18

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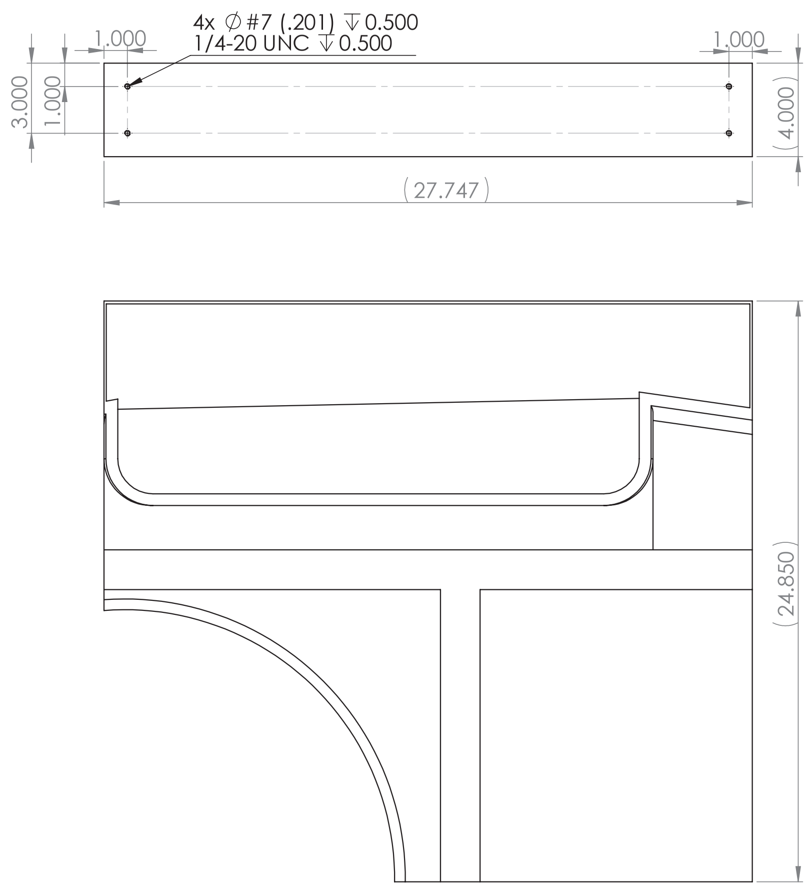
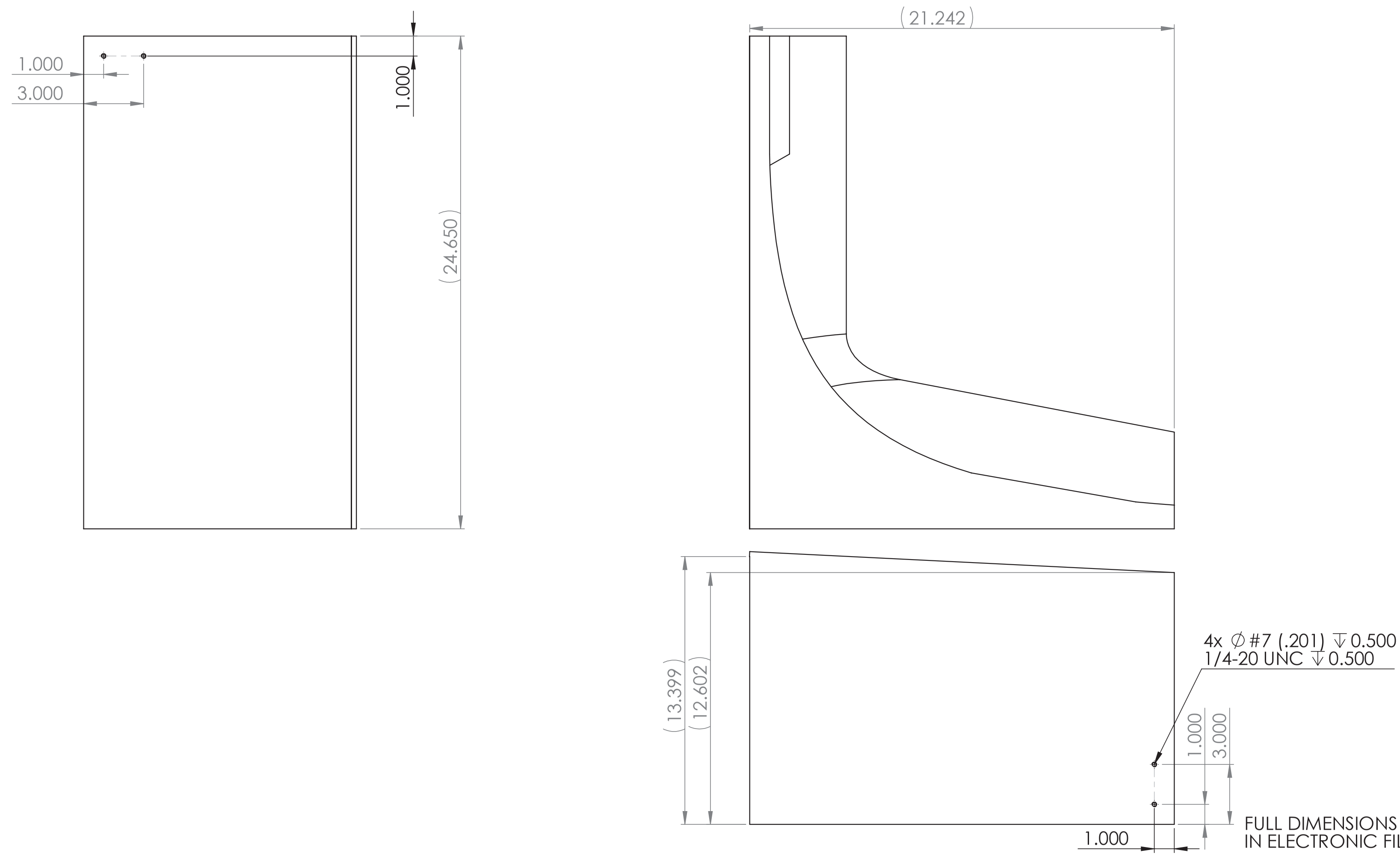


FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	M08	
DRAWN	NIK PAULIC	NP	27/11/14	TITLE: BASE MOLD CENTER LEFT LOWER BLOCK	
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 10	A3
				SCALE:1:5	SHEET 10 OF 18



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

M09

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:
ALUMINUM 6061-T6

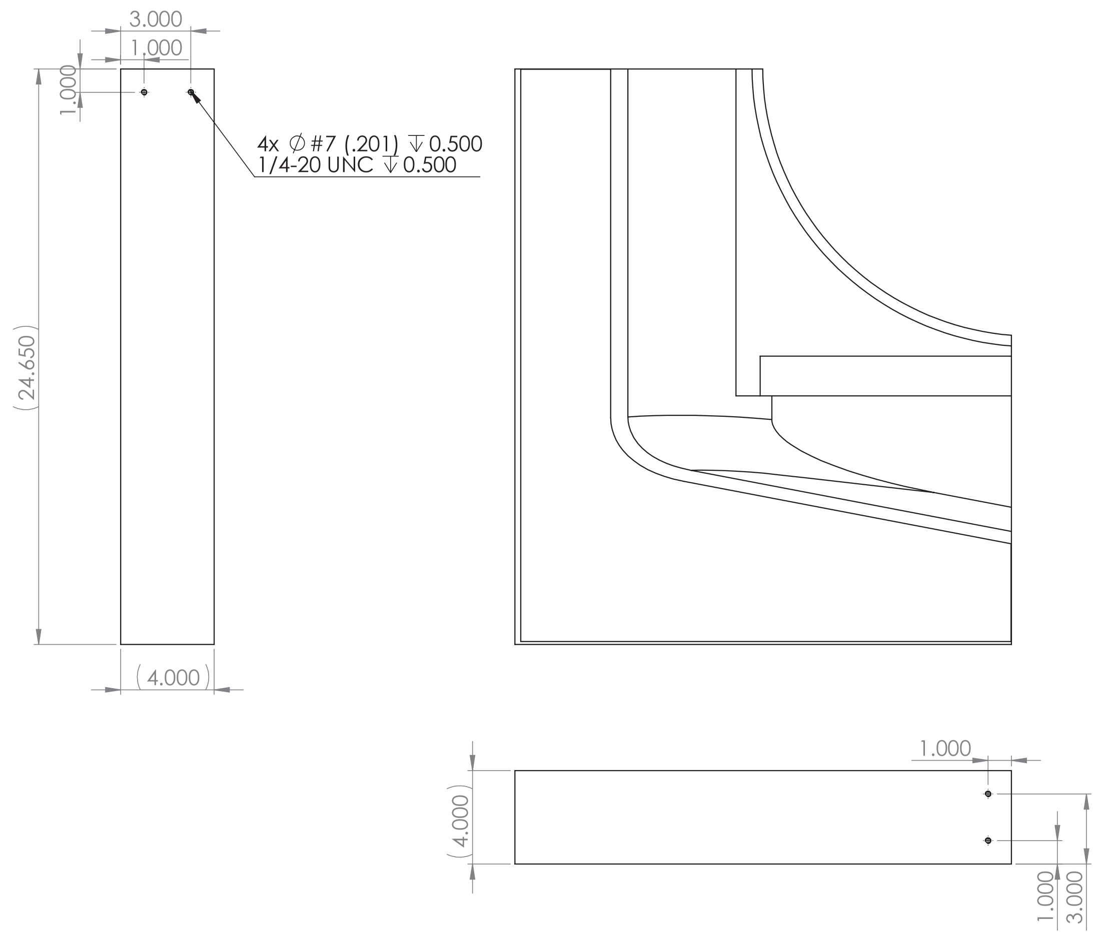
TITLE:
BASE MOLD REAR
RIGHT UPPER BLOCK

DWG NO.
DRAWING 11

A3

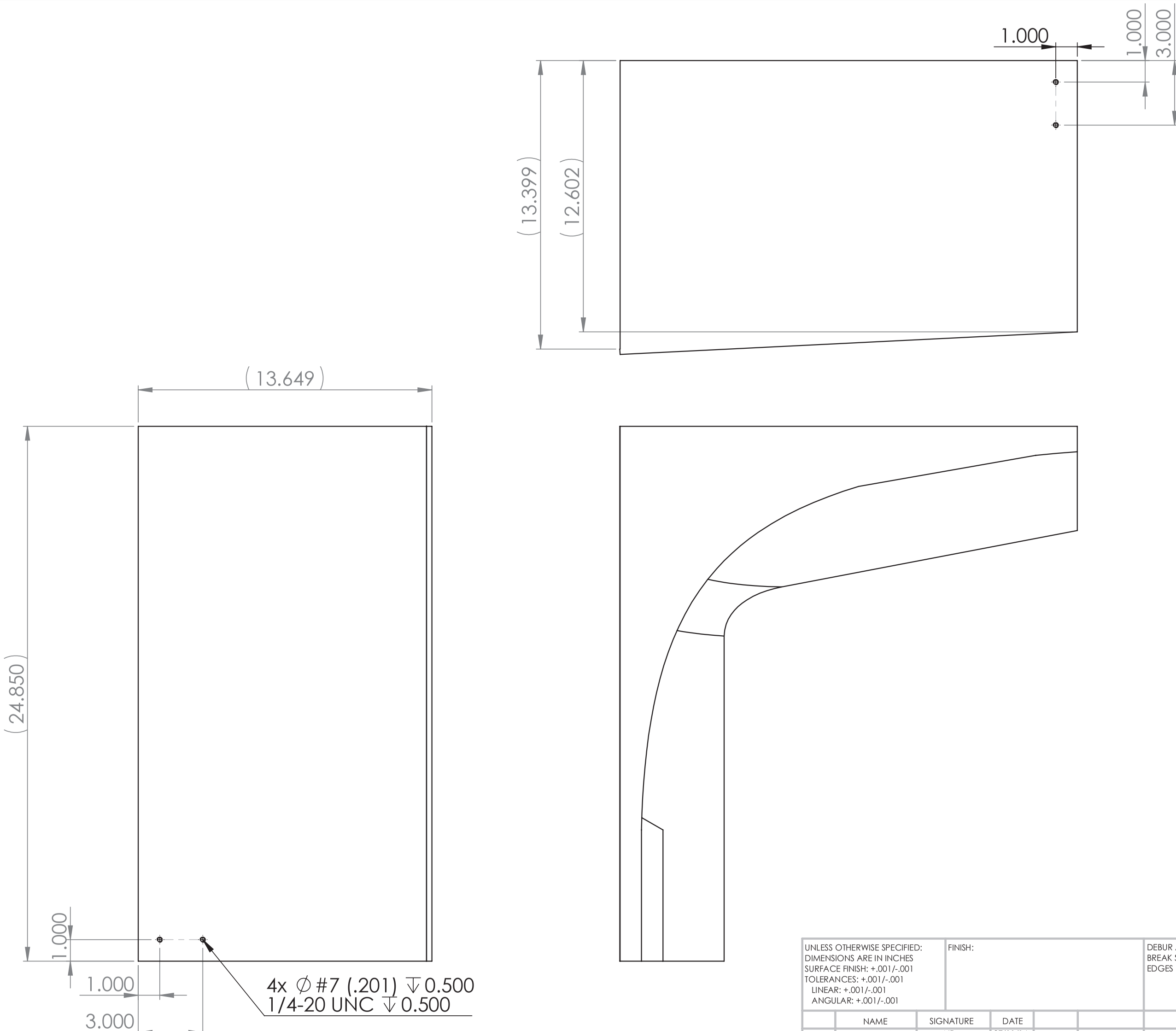
SCALE:1:5

SHEET 11 OF 18



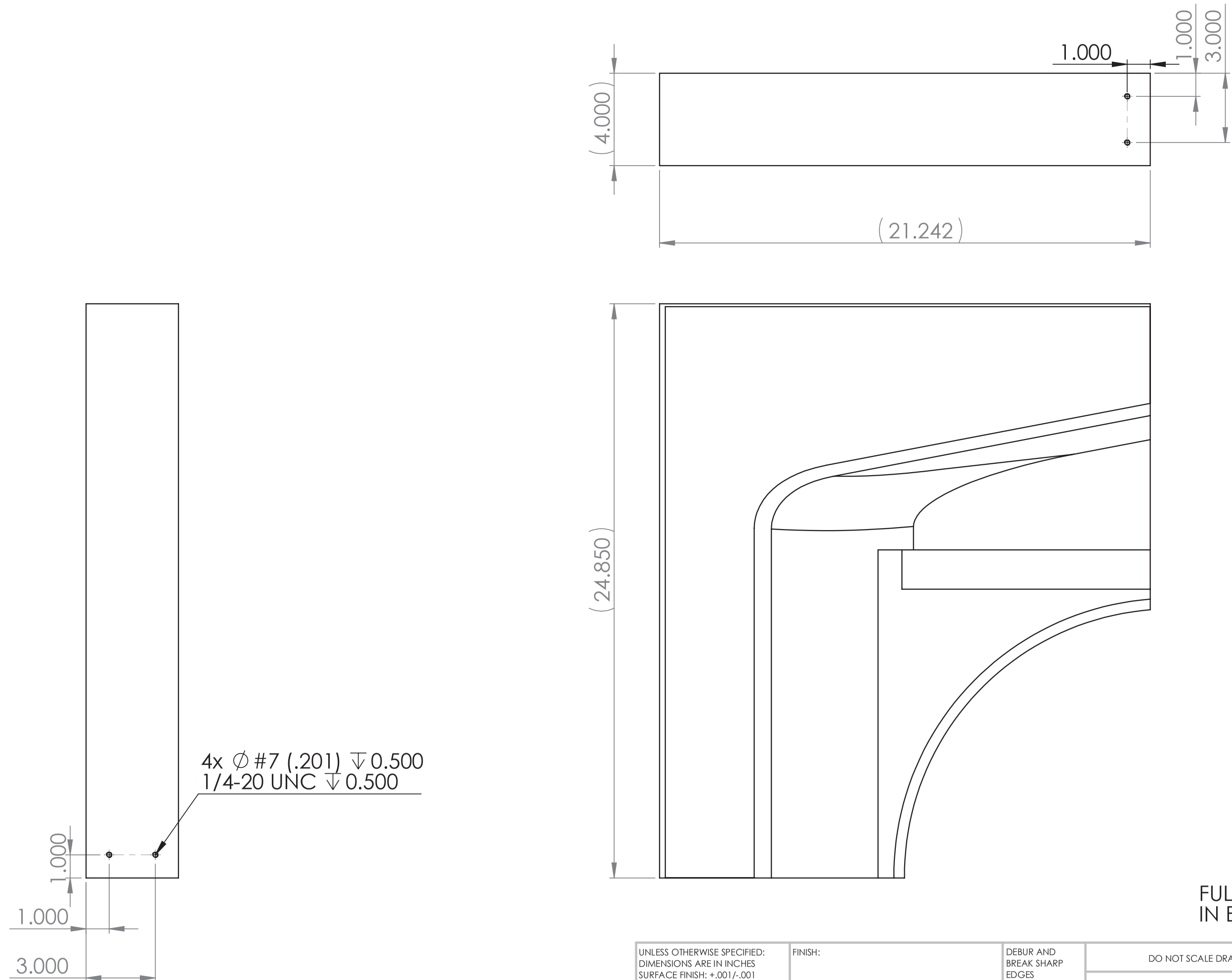
FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001		FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
					M10
	NAME	SIGNATURE	DATE		TITLE: BASE MOLD REAR RIGHT LOWER BLOCK
DRAWN	NIK PAULIC	NP	27/11/14		
CHK'D					
APPV'D					
MFG					
Q.A				MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 12 / A3
					SCALE:1:5 / SHEET 12 OF 18



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
				M11	
	NAME	SIGNATURE	DATE	TITLE: BASE MOLD REAR LEFT UPPER BLOCK	
DRAWN	NIK PAULIC	NP	27/11/14		
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 13	A3
				SCALE:1:5	SHEET 13 OF 18



FULL DIMENSIONS DETAILED IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

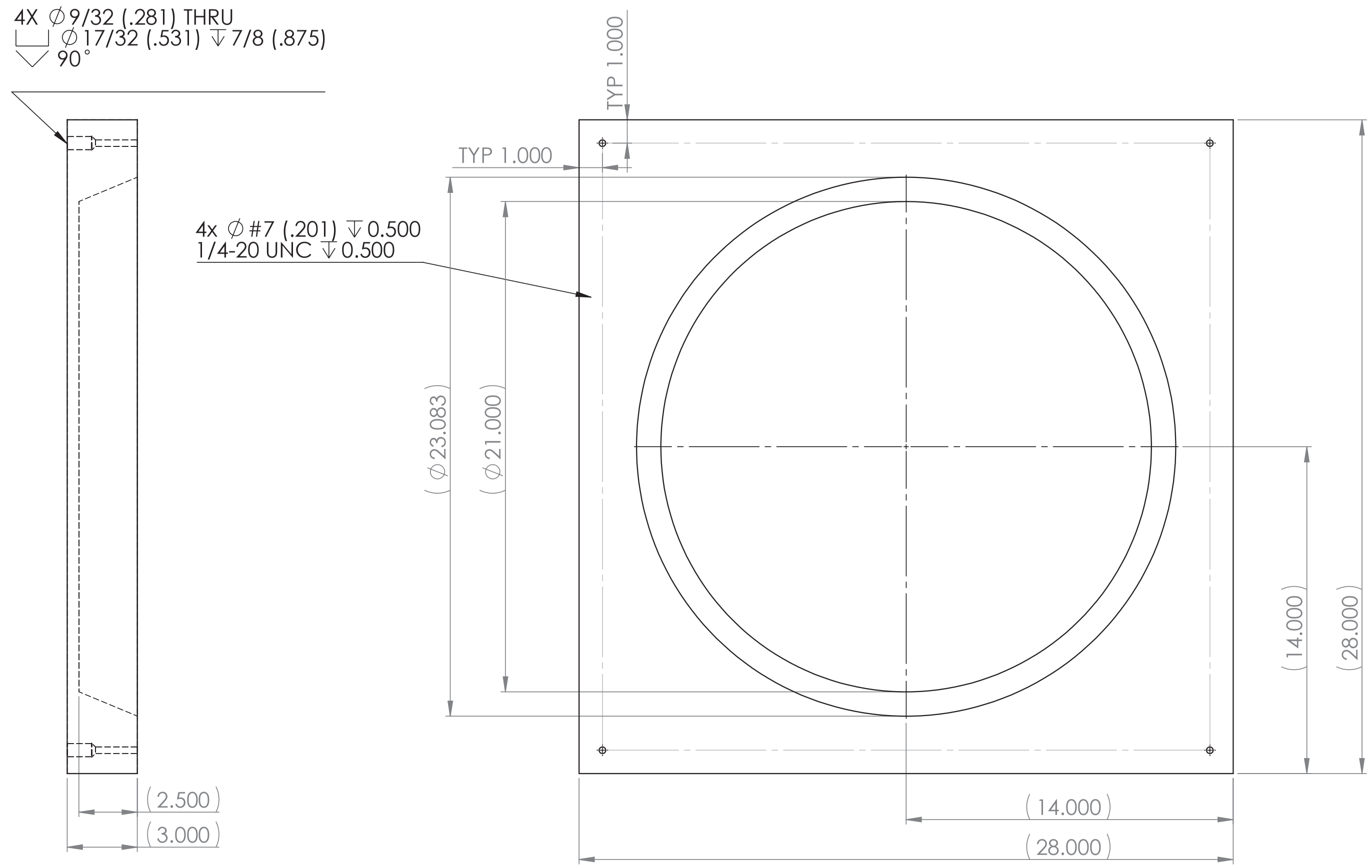
MATERIAL: ALUMINUM 6061-T6

M12

TITLE: BASE MOLD REAR LEFT LOWER BLOCK

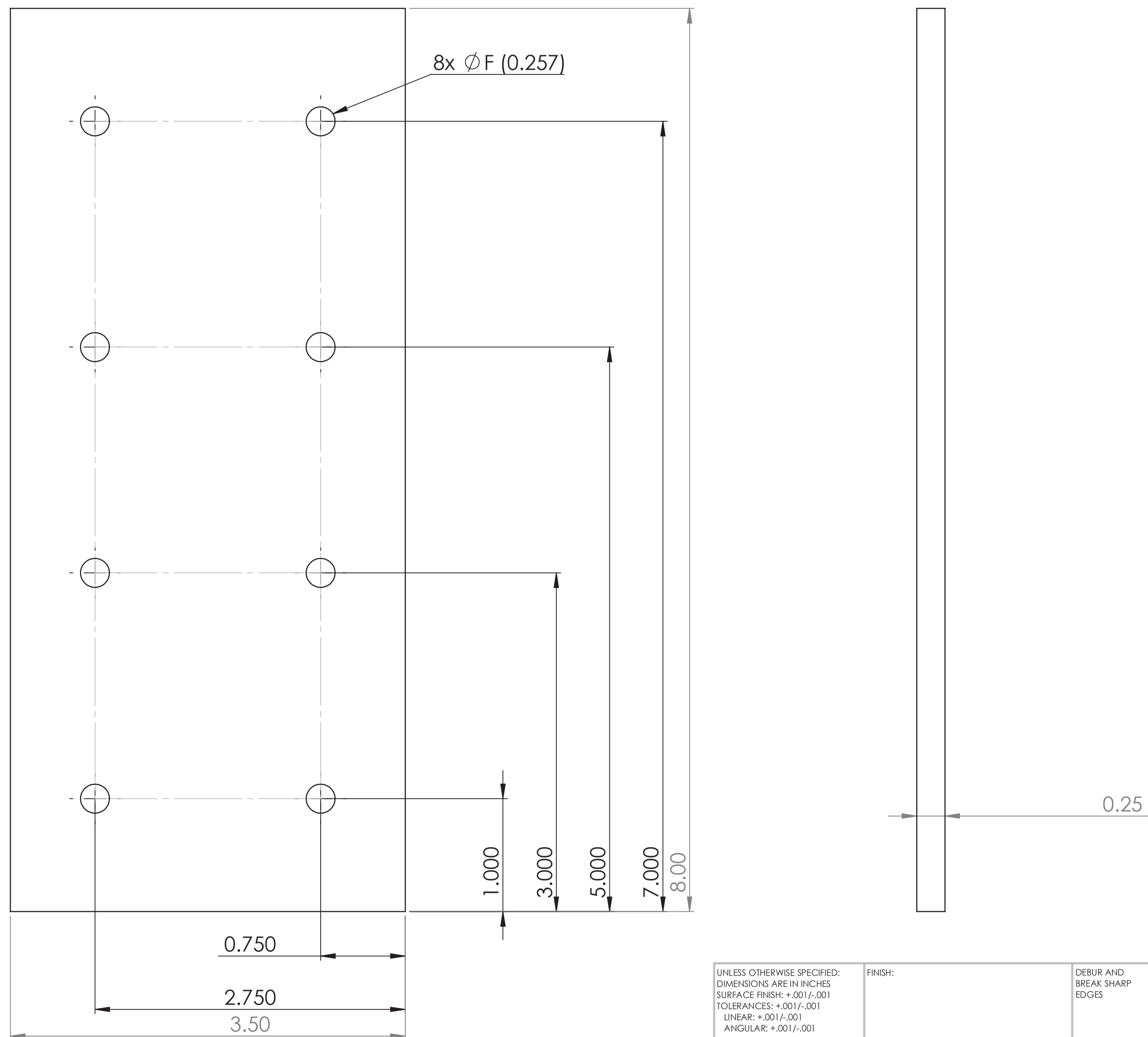
DWG NO. DRAWING 14 A3

SCALE:1:5 SHEET 14 OF 18

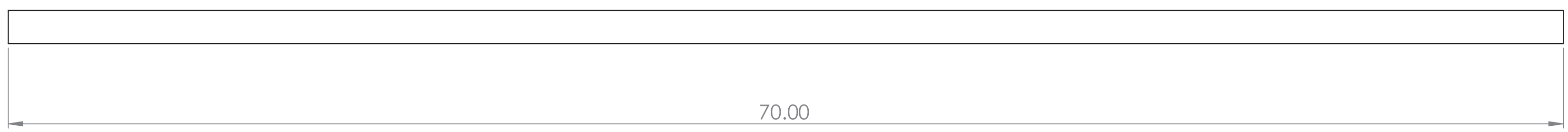


FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	M13	
DRAWN	NIK PAULIC	NP	27/11/14	TITLE: SPARE WHEEL MOLD BLOCK	
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 15	A3
				SCALE:1:5	SHEET 15 OF 18



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	M14	
DRAWN	NIK PAULIC	NP	27/11/14	TITLE: MOLD BRACKET	
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: PLAIN CARBON STEEL	DWG NO. DRAWING 16	A3
				SCALE:1:1	SHEET 16 OF 18



STANDARD 1.5x1.5 SQUARE TUBING

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: ALUMINUM 6061-T6

MSF01

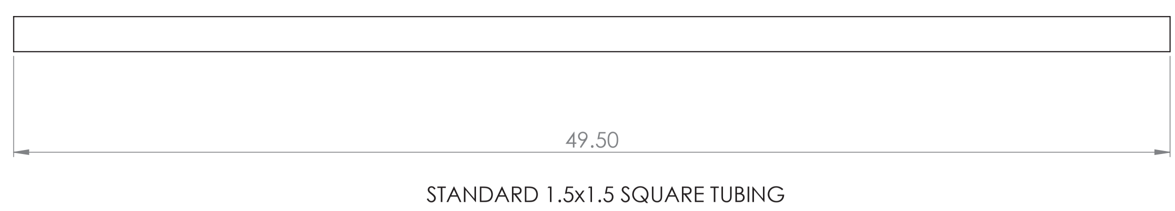
TITLE: SUPPORT FRAME BASE BAR

DWG NO. DRAWING 17

A3

SCALE:1:5

SHEET 17 OF 18



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MSF02

TITLE: SUPPORT FRAME RESTING BAR

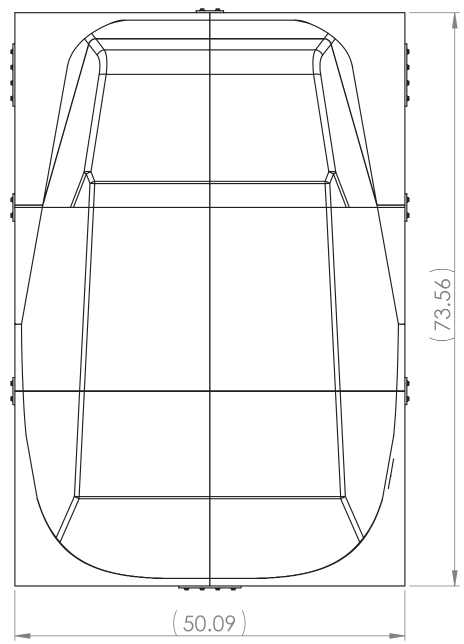
MATERIAL: ALUMINUM 6061-T6

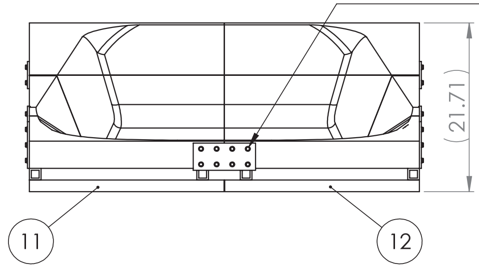
DWG NO. DRAWING 18

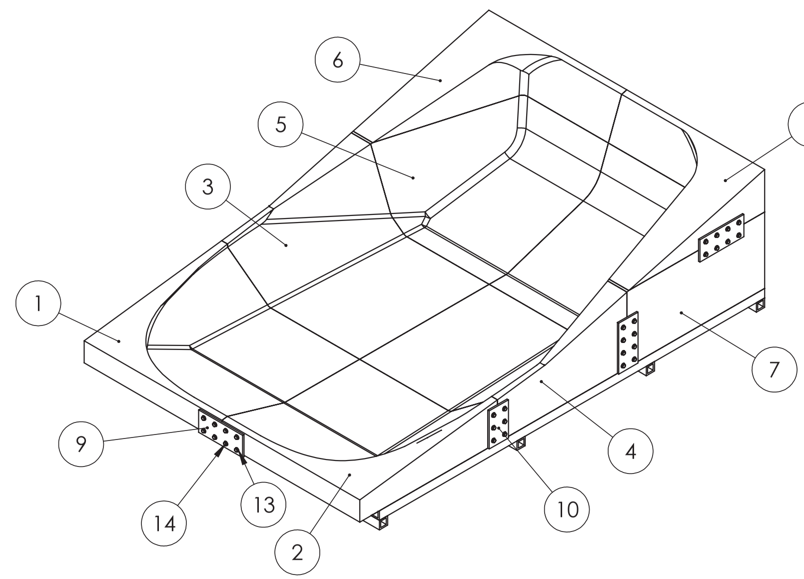
A3

SCALE:1:5

SHEET 18 OF 18







ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	M16	Lid Mold Front Right Block	1
2	M17	Lid Mold Front Left Block	1
3	M18	Lid Mold Center Right Block	1
4	M19	Lid Mold Center Left Block	1
5	M20	Lid Mold Rear Right Block	1
6	M21	Lid Mold Rear Top Right Block	1
7	M22	Lid Mold Rear Left Block	1
8	M23	Lid Mold Rear Top Left Block	1
9	M14	Mold Bracket	6
10	M24	Short Mold Bracket	2
11	M25	Right Support Assembly	1
12	M26	Left Support Assembly	1
13	H09	Flat Washer Selected A Narrow FW 0.266	60
14	H10	Hex Bolt 1/4-20x.75x.75	60

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

A05

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: SPECIFIED IN COMPONENTS

WEIGHT:

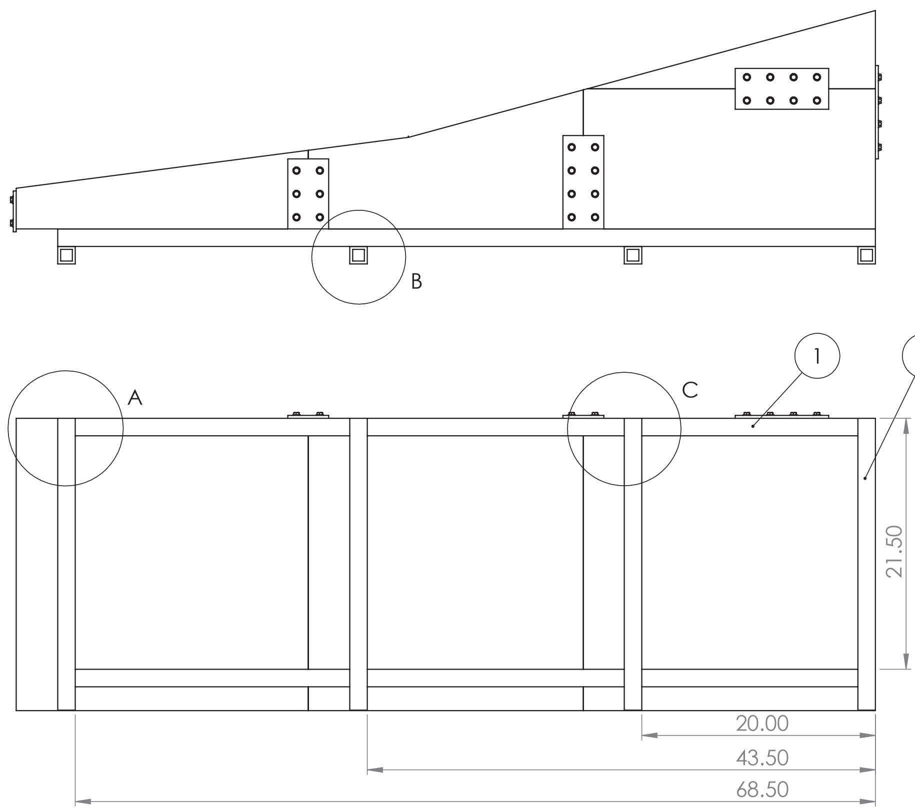
TITLE: LID MOLD ASSEMBLY

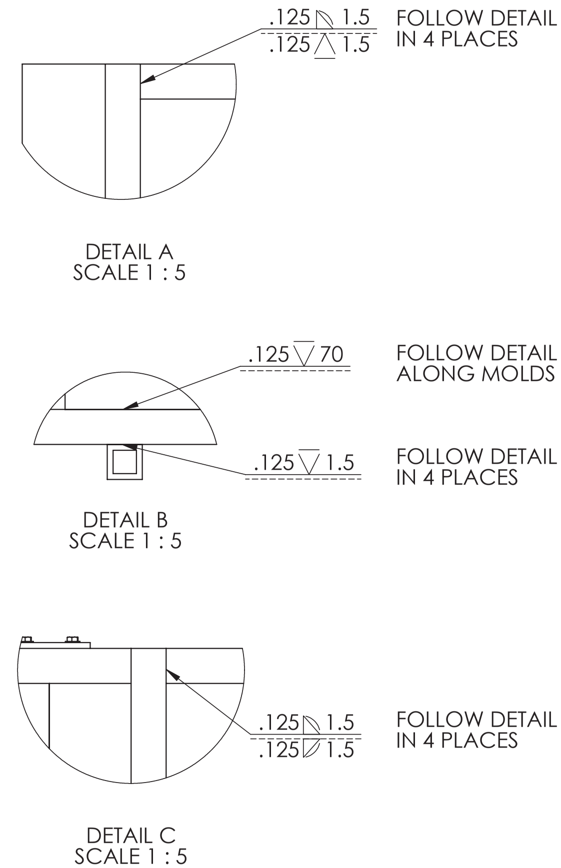
DWG NO. DRAWING 1

A3

SCALE:1:15

SHEET 1 OF 13





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MSF01	Body Mold Base Bar	2
2	MSF03	Lid Mold Resting Bar	4

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

M25

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:
SPECIFIED IN COMPONENTS

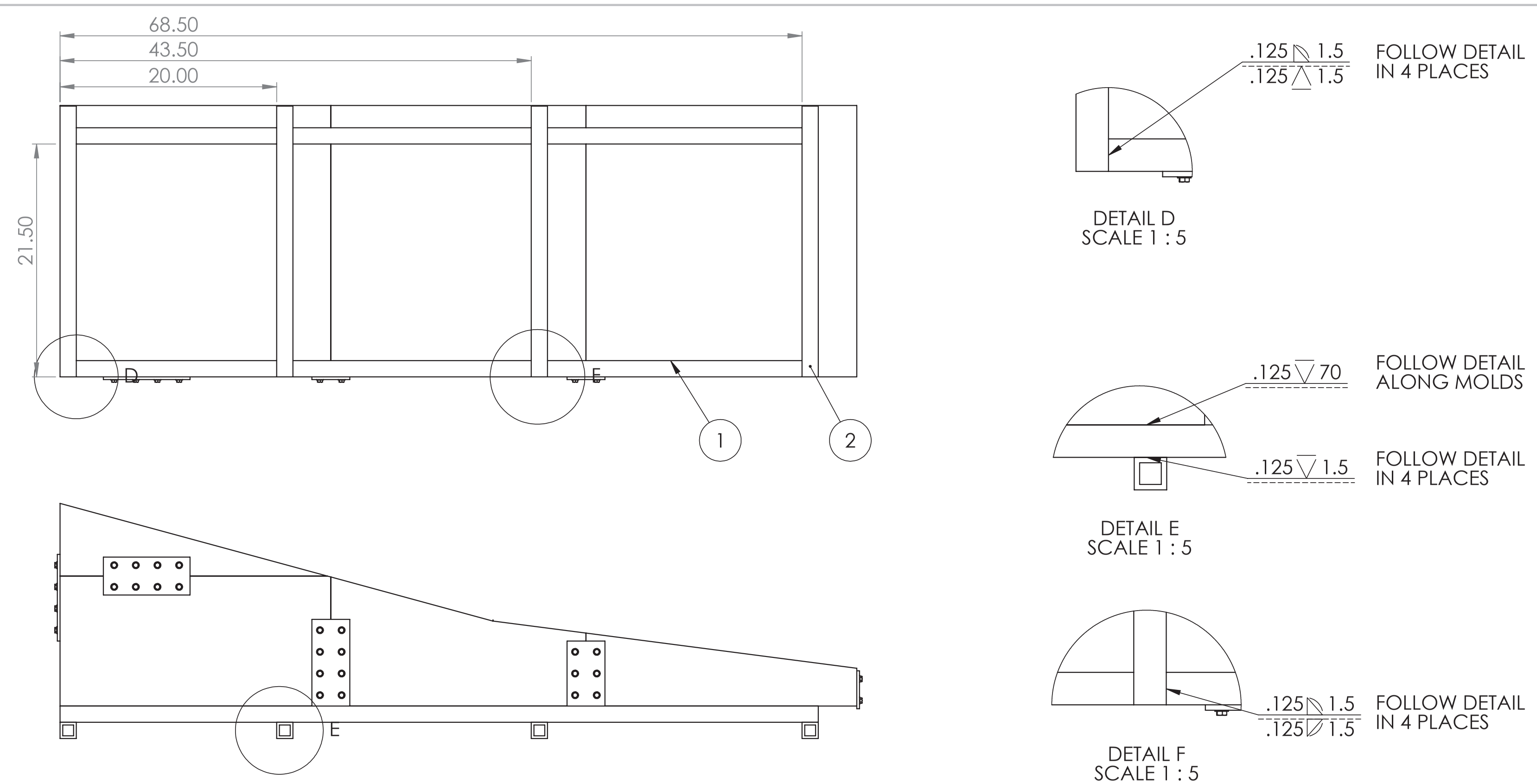
TITLE:
RIGHT SUPPORT ASSEMBLY

DWG NO.
DRAWING 2

A3

SCALE:1:10

SHEET 2 OF 13



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MSF01	Body Mold Base Bar	2
2	MSF03	Lid Mold Resting Bar	4

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

M26

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: SPECIFIED IN COMPONENTS

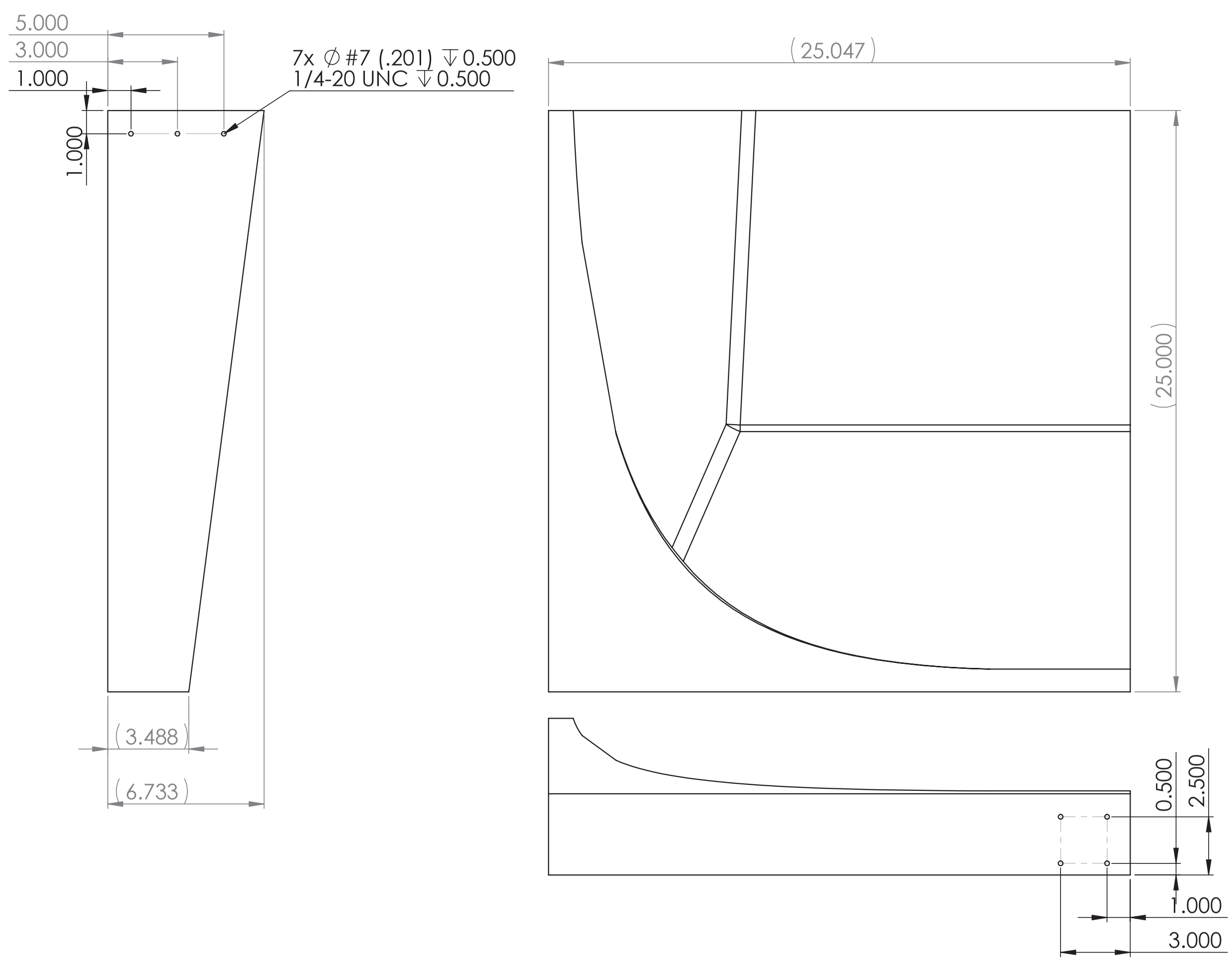
TITLE: LEFT SUPPORT ASSEMBLY

DWG NO. DRAWING 3

A3

SCALE:1:10

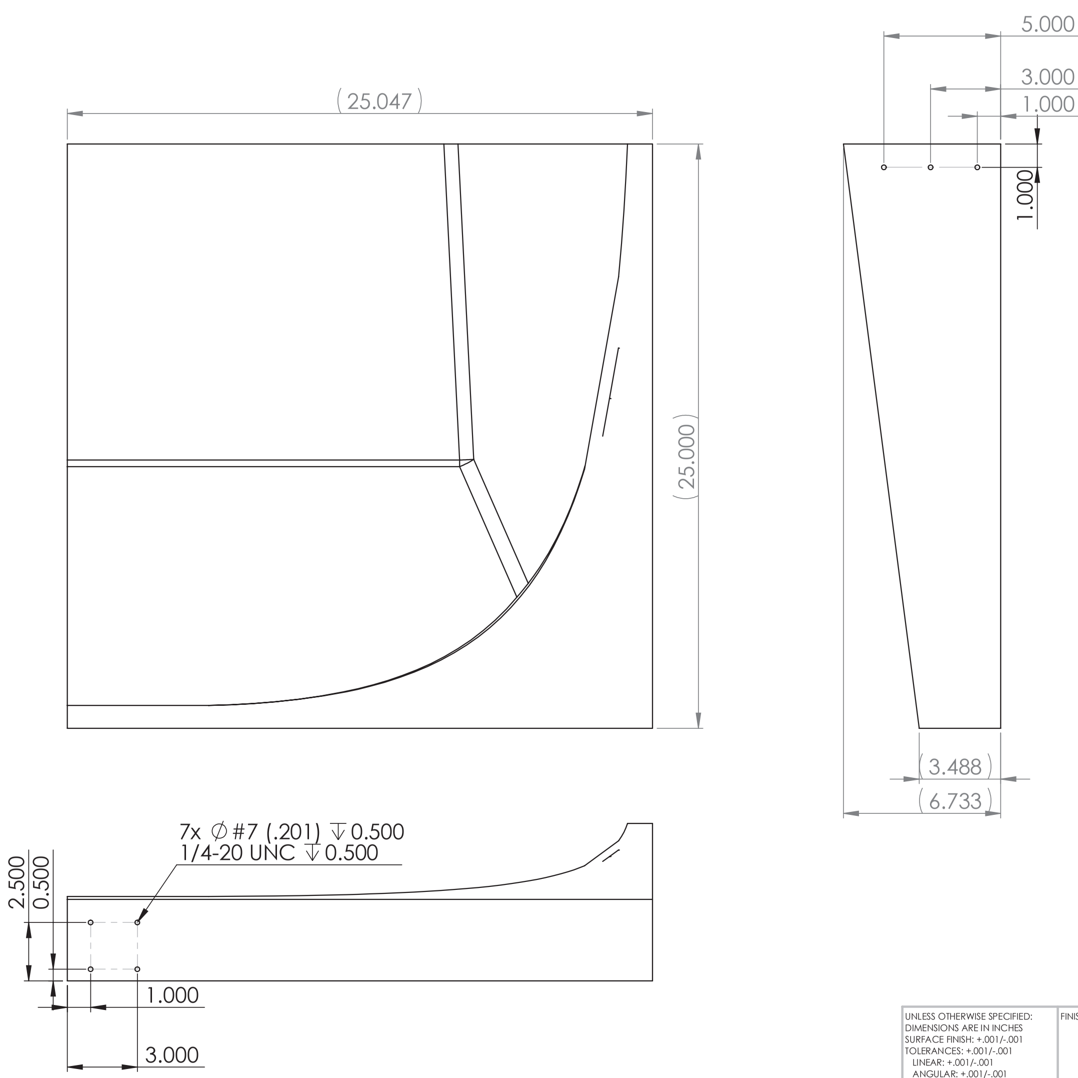
SHEET 3 OF 13



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

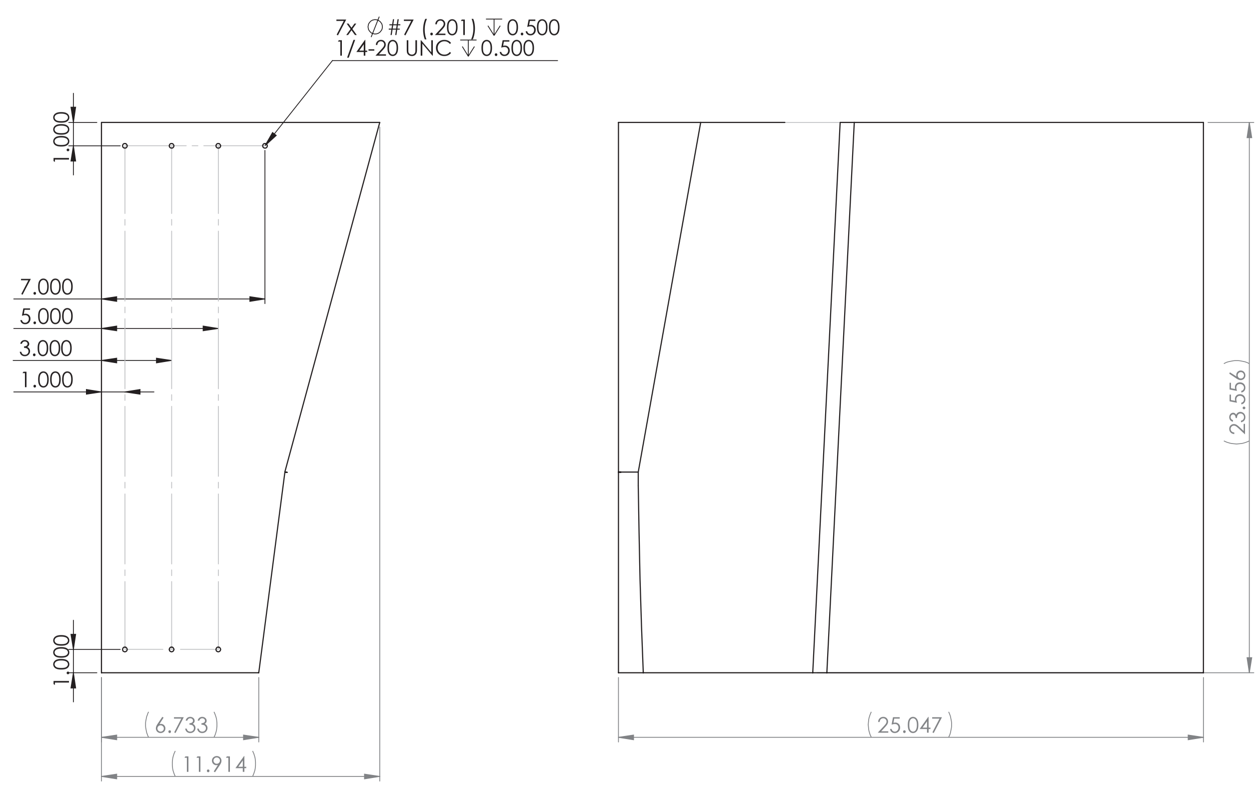
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001		FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE		TITLE: LID MOLD FRONT RIGHT BLOCK	
DRAWN	NIK PAULIC	NP	27/11/14			
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 4	A3
					SCALE:1:5	SHEET 4 OF 13

M16



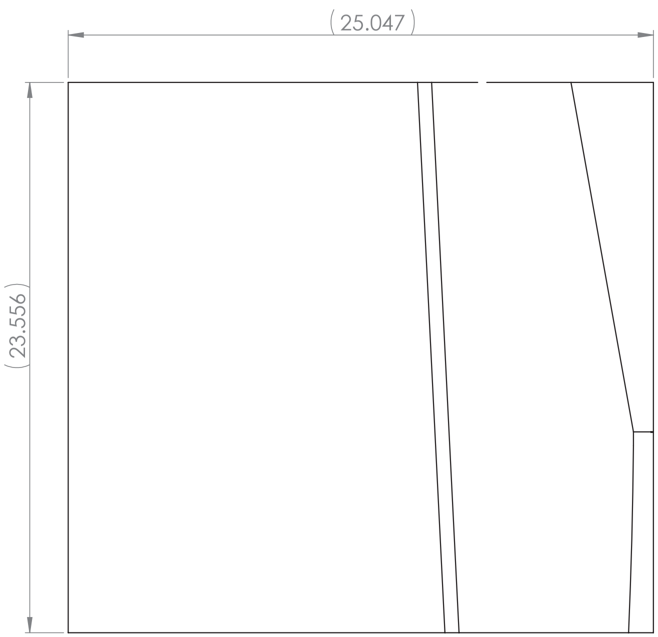
FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

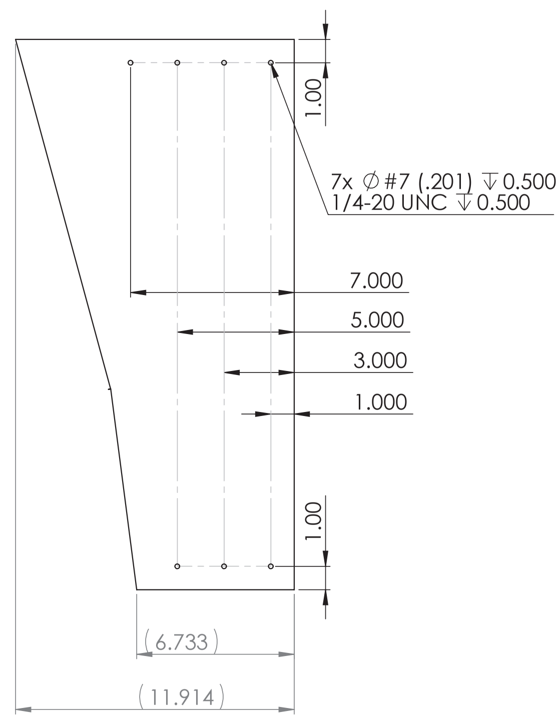
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001		FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE		M17
DRAWN	NIK PAULIC	NP	27/11/14		TITLE: LID MOLD FRONT LEFT BLOCK
CHK'D					
APPV'D					
MFG					
Q.A				MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 5 — A3
					SCALE:1:5 — SHEET 5 OF 13



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
				M18	
	NAME	SIGNATURE	DATE	TITLE: LID MOLD CENTER RIGHT BLOCK	
DRAWN	NIK PAULIC	NP	27/11/14		
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 6	A3
				SCALE:1:5	SHEET 6 OF 13





FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH: +.001/-.001
TOLERANCES: +.001/-.001
LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:
ALUMINUM 6061-T6

M19

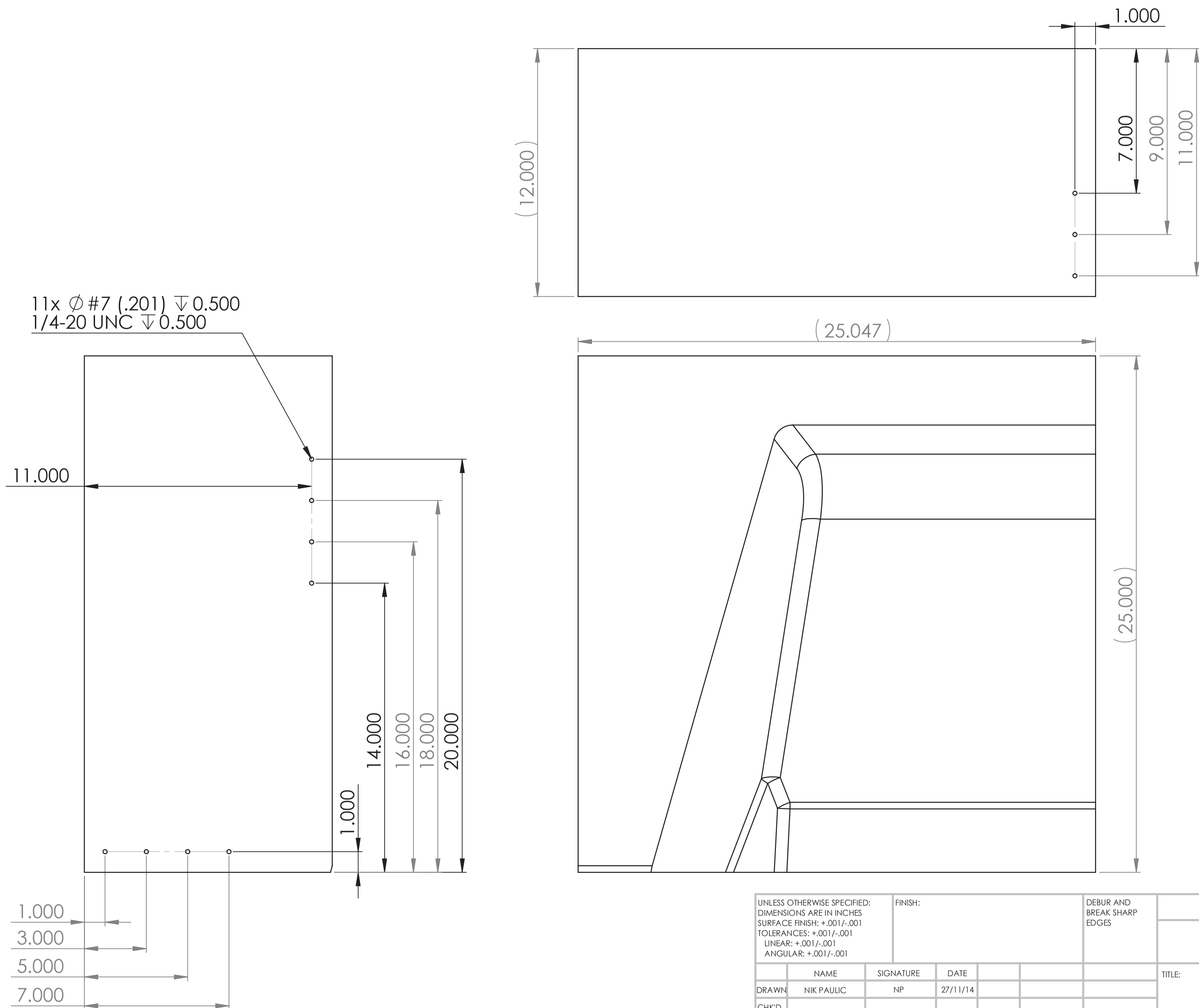
TITLE: LID MOLD CENTER LEFT BLOCK

DWG NO. DRAWING 7

A3

SCALE:1:5

SHEET 7 OF 13



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:			DEBUR AND BREAK SHARP EDGES
	NAME	SIGNATURE	DATE	
DRAWN	NIK PAULIC	NP	27/11/14	
CHK'D				
APPV'D				
MFG				
Q.A				MATERIAL: ALUMINUM 6061-T6

DO NOT SCALE DRAWING | REVISION

M20

TITLE: LID MOLD REAR RIGHT BLOCK

DWG NO. DRAWING 8 | A3

SCALE:1:5 | SHEET 8 OF 13

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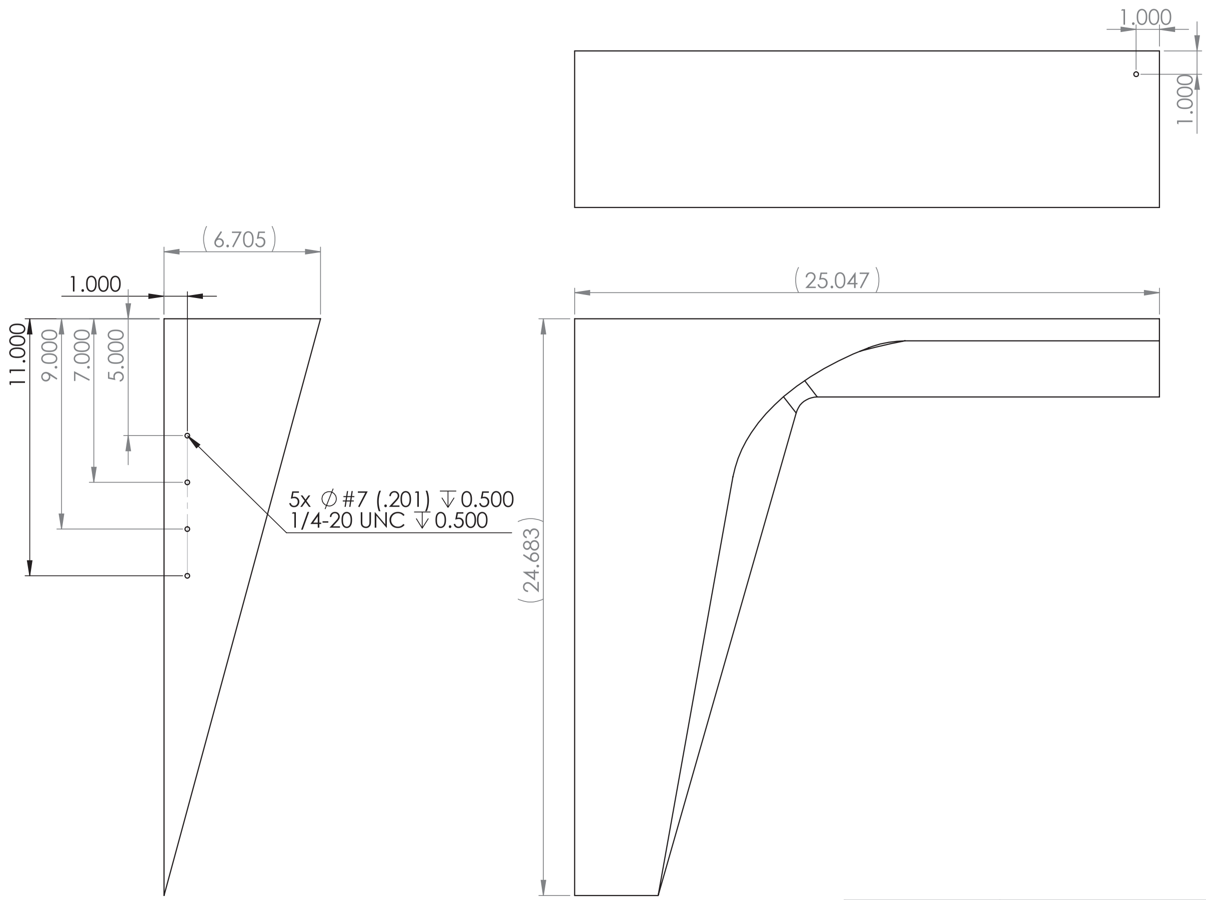
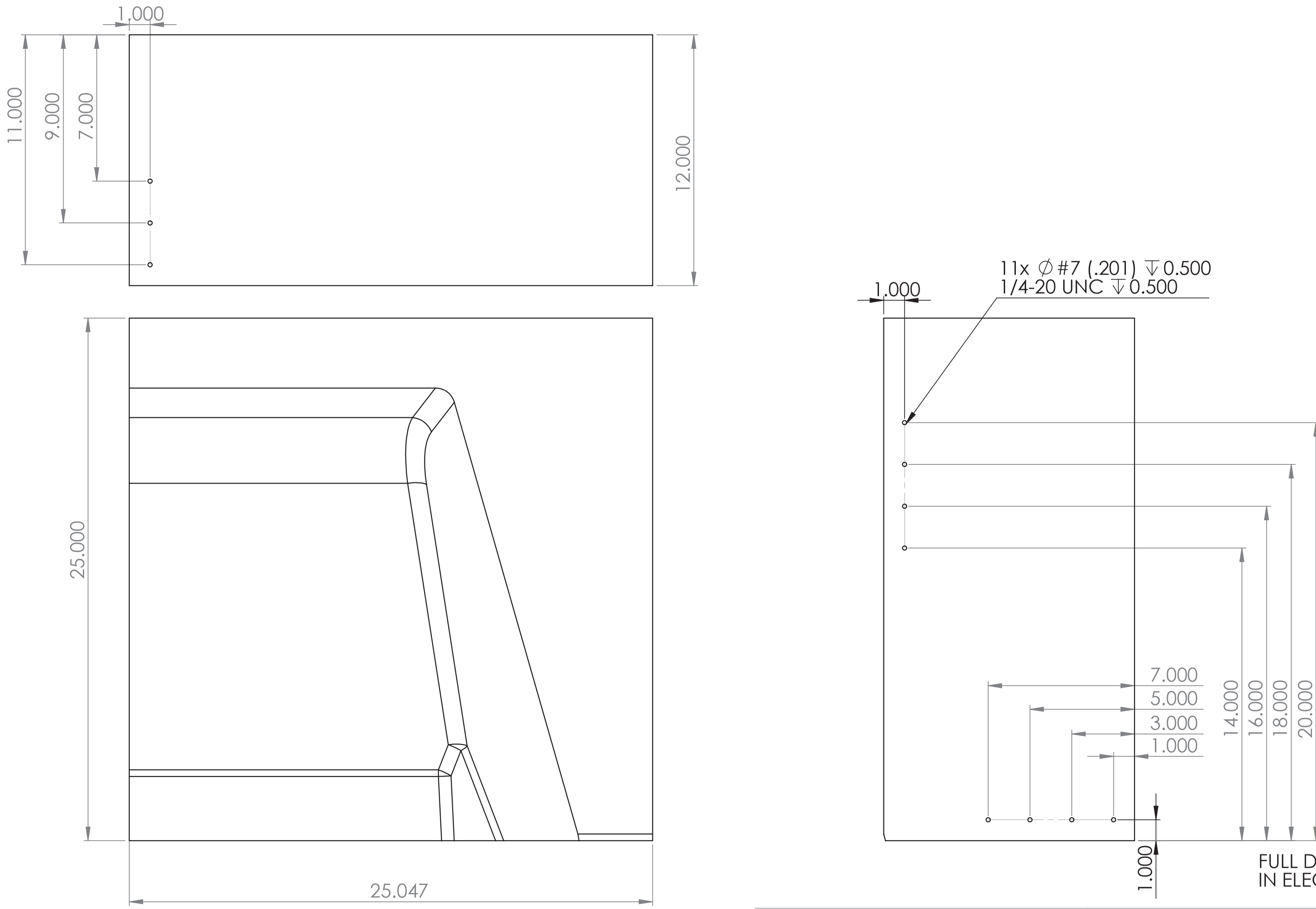


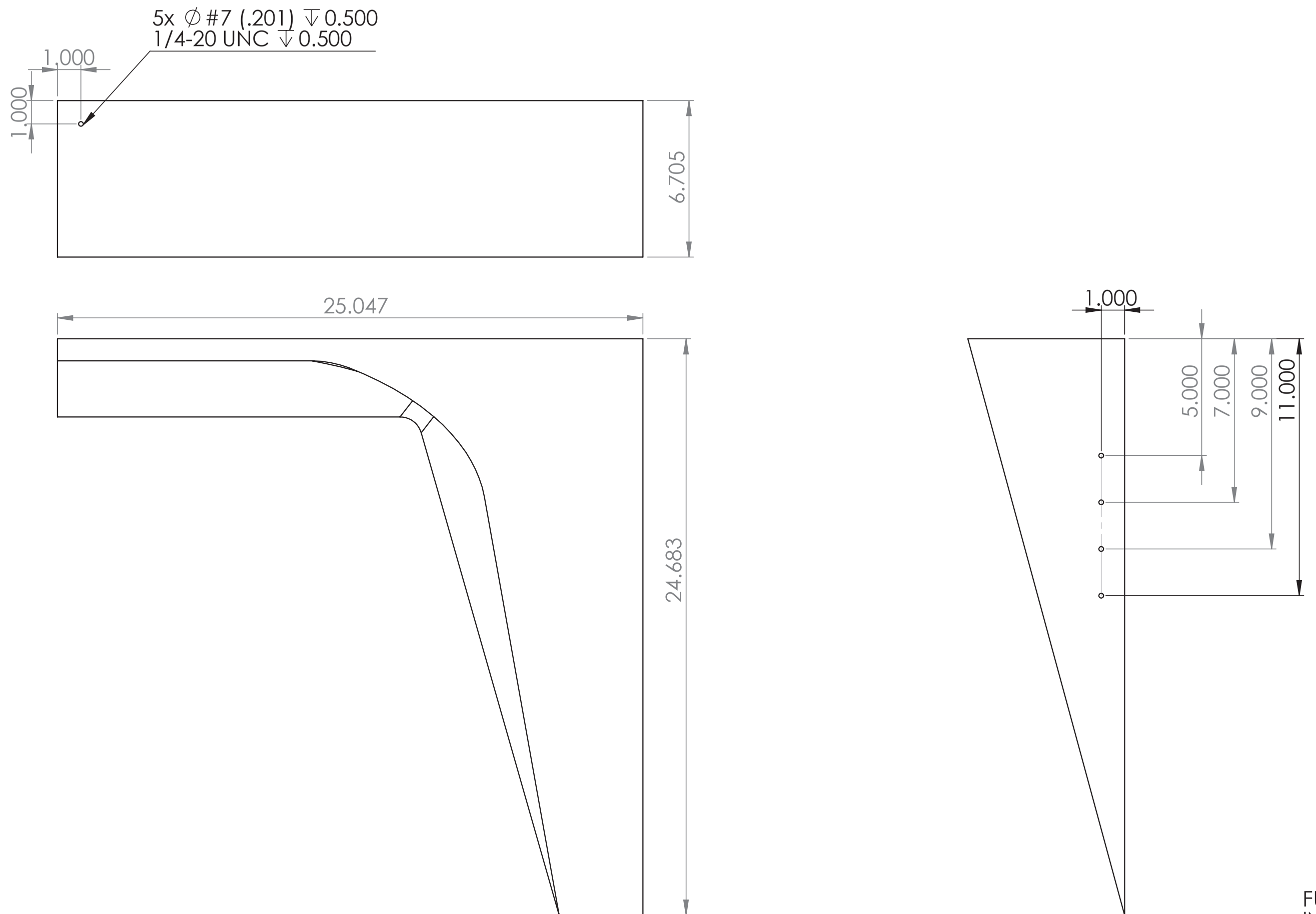
FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE		M21	
DRAWN	NIK PAULIC	NP	27/11/14		TITLE: LID MOLD REAR RIGHT TOP BLOCK	
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 9	A3
					SCALE:1:5	SHEET 9 OF 13



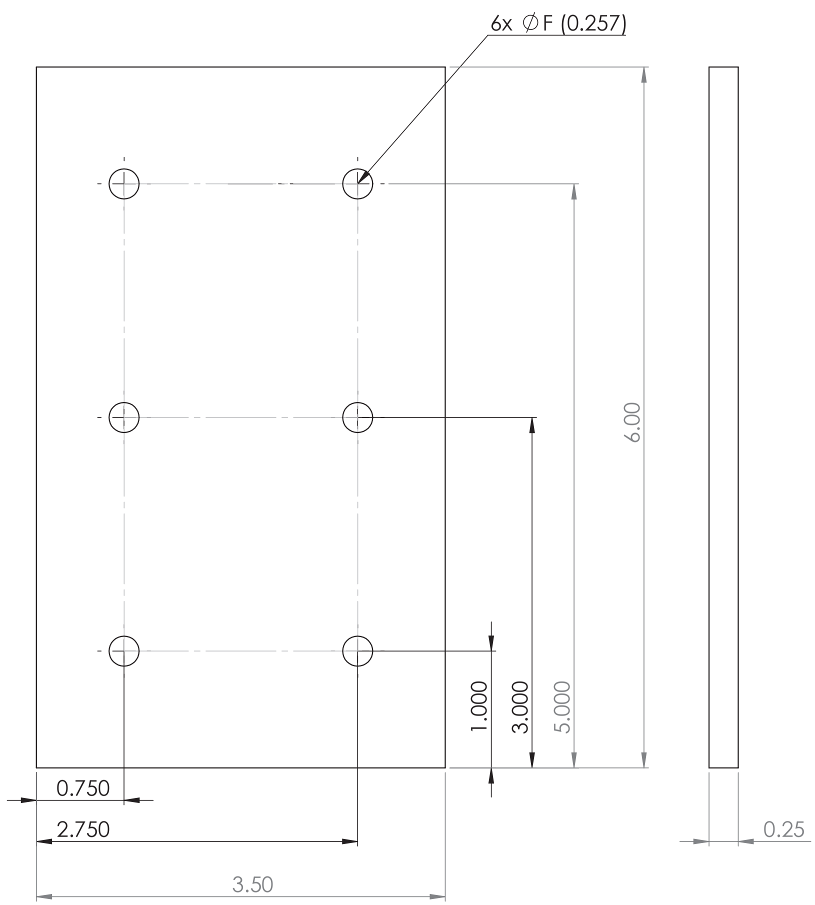
FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001		FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	M22	
DRAWN	NIK PAULIC	NP	27/11/14	TITLE: LID MOLD REAR LEFT BLOCK	
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 10	A3
				SCALE:1:5	SHEET 10 OF 13



FULL DIMENSIONS DETAILED
IN ELECTRONIC FILE

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	M23	
DRAWN	NIK PAULIC	NP	27/11/14	TITLE: LID MOLD REAR LEFT TOP BLOCK	
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 11	A3
				SCALE:1:5	SHEET 11 OF 13



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LINEAR: +.001/-.001
ANGULAR: +.001/-.001

FINISH:

DEBUR AND BREAK SHARP EDGES

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REVISION

	NAME	SIGNATURE	DATE
DRAWN	NIK PAULIC	NP	27/11/14
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: PLAIN CARBON STEEL

M24

TITLE: SHORTENED MOLD BRACKET

DWG NO. DRAWING 12

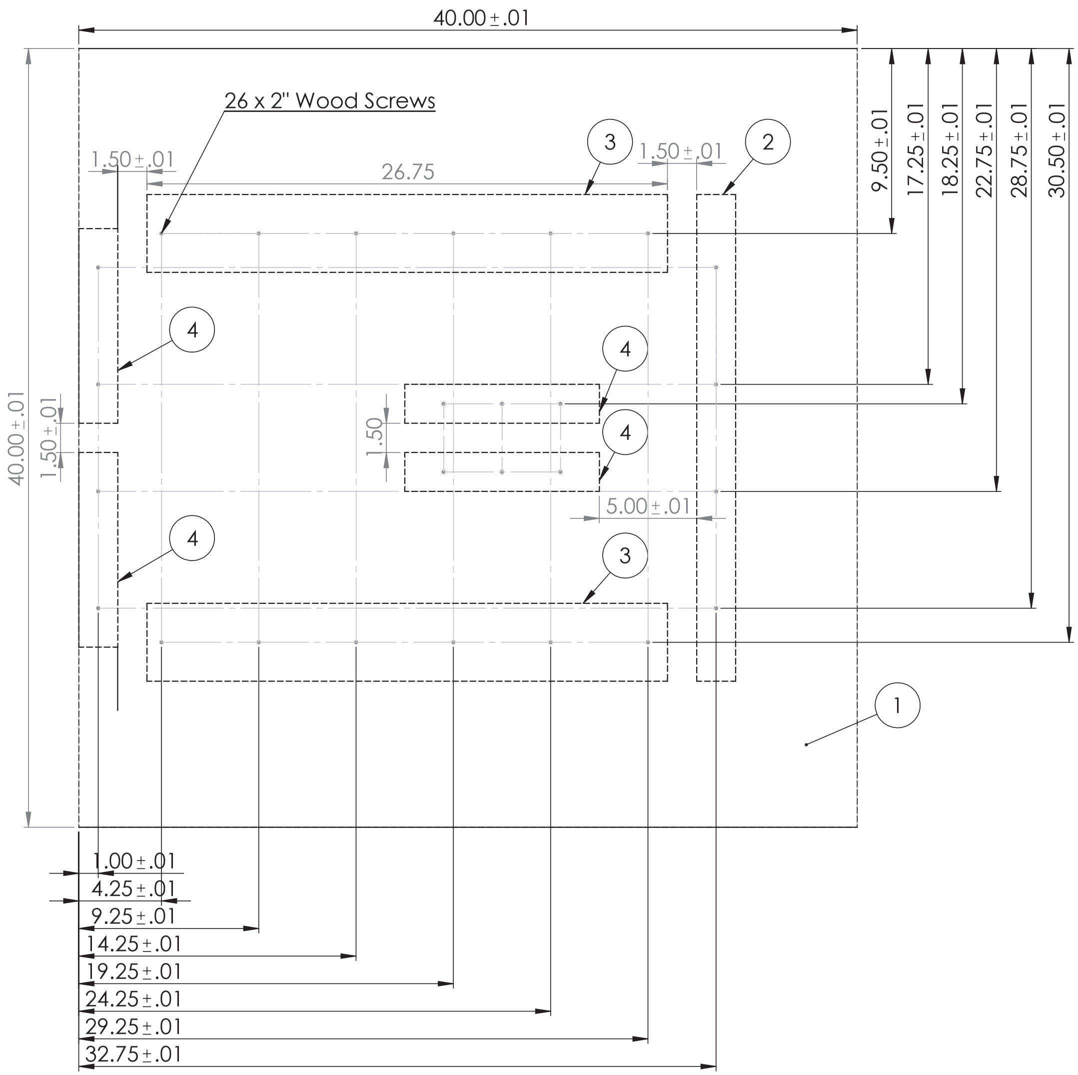
A3

SCALE:1:1

SHEET 12 OF 13

STANDARD 1.5x1.5 SQUARE TUBING

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: +.001/-.001 TOLERANCES: +.001/-.001 LINEAR: +.001/-.001 ANGULAR: +.001/-.001	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING		REVISION	
				MSF03			
	NAME	SIGNATURE	DATE	TITLE: LID MOLD RESTING BAR			
DRAWN	NIK PAULIC	NP	27/11/14				
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL: ALUMINUM 6061-T6	DWG NO. DRAWING 13		A3
					SCALE:1:5	SHEET 13 OF 13	



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Jig Base	40"x40"x3/4"	1
2	Rear Frame Jig	2"x4"x25"	1
3	Side Frame Jig	2"x4"x26.75"	2
4	Front Frame Jig	2"x4"x10"	4

DO NOT SCALE DRAWING

DWG NO. Jig Assembly A3

SCALE:1:20 SHEET 1 OF 1