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Electrathon: Body

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- Abstract
- The Electrathon Vehicle project is an ongoing project that dates back to 2012. This vehicle will be raced at events to see how many laps it can complete on a single battery charge. The existing body for the Central Washington University Electrathon vehicle required modifications to fit over the current frame. These modifications were required because the rear suspension design had changed. The rear panel of the body interfered with the rear suspension. Using a rotary cutting wheel, the panel was slotted so the body could slide over the suspension and drive chain. Additionally, spacers for various sizes were needed to mount the body to the frame. The body panels also needed to align with each other. Five pins were welded onto the frame for the body to slide over. To get the spacing, washers were welded onto the pins to prevent the body from sliding too far down the pin. The ends of the pins were then cross-drilled to run a hitch-clip through to secure the body. The body then had to have holes drilled in it so that it could slide over the previously mentioned pins. The body is now compatible with the electric vehicle. It has 5 fixed mounting points using pins and hitch-clips. In addition, the body has Velcro to hold the windshield as well as the sides of the tail to the main body. The entire body with its mounting hardware weighs approximately 15 lbs.

INTRODUCTION

Description:

Every year ASME hosts a nationwide electric vehicle competition between students. There is a need for a new and improved Electrathon vehicle at Central Washington University.

Motivation:

With global warming and pollution reaching peak levels, electric vehicles have grown increasingly important. Among the most vital factors involved with making an electric vehicle are its weight and aerodynamics.

One major problem that engineers often run into is making something lightweight and yet durable enough while factoring in costs. This project is a classic example of modern-day engineering. A device needs to have its efficiency maximized while keeping its costs low, all while competing entities are doing the same thing. This provides a great amount of experience and serves as a tool for future designs

Function Statement:

A device is needed that will surround the frame of the vehicle while protecting the rider from injury.

Team Function Statement:

To design, build, and field a car for the 2018/2019 Electrathon American Electric Vehicle Design Competition.

Requirements:

The body will…

- follow the Electrathon competition rulebook
- mount to the frame with at least 5 mounting points for the body
- weigh less than 30 pounds
- cost less than $150 out of pocket
- be able to withstand an impact of at least 20 joules

Engineering Merit: To calculate the vehicle's drag coefficient, the equation

$F_{drag} = -C_{drag}*A*0.5*\rho*v^2$ will be used, where…

F_{drag} is the force of the drag on the vehicle

C_{drag} is the coefficient of drag of the vehicle

A is the frontal area of the vehicle

ρ is the density of air at sea level

v is the velocity of the vehicle

(Eq.1)

Scope of Effort:

Will only include designing, building, and installing the body of the electric vehicle.

Success Criteria:

For the body, success entails a lightweight, aerodynamic body that mounts onto the frame (see above requirements for definitions). For the team, success entails a working electric vehicle that can be driven by an operator. The ultimate success would be winning the ASME Electrathon competition.

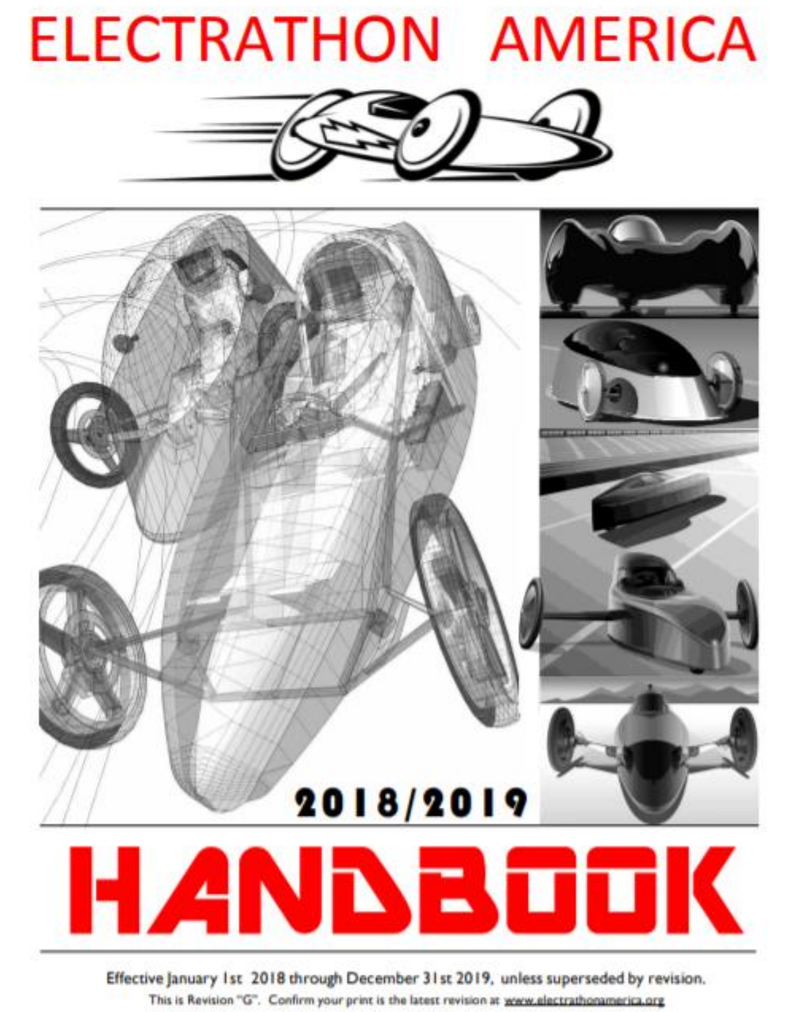


Figure 1

Figure 1 is the cover of the Electrathon America handbook.

DESIGN AND ANALYSES

Approach:

The body of the electric vehicle will be largely based off the previous electric vehicle at Central Washington University. For instance, the carbon fiber will be recycled and put to use in this design. This will cut costs drastically and provide an excellent lightweight material for the vehicle. The body of the vehicle will surround the frame's front, rear, sides, and bottom. This will help protect the driver from any foreign objects entering the vehicle and prohibit any of the driver's limbs from protruding out of the vehicle.

Design Description:

The design will be focusing on a cost-efficient, lightweight body for the electric vehicle. It is to be compatible with the frame of the vehicle and must be able to meet all the requirements previously stated on page 4.

One design looks at the ideal situation. This can be seen in A-3. Here, it assumes the entire body to be made out of carbon fiber, and it would be able to be made from scratch, which would result in an ultralightweight device. However, due to budgeting, a body made solely of new carbon fiber would prove to be too expensive.

For the actual design, modifications of Central Washington University's 'Catmobile' will be made. The 'Catmobile' is the current electric racing vehicle at Central. This design will consist of removing excess body material to reduce weight, and to ensure there is no interference with other team member's modifications on the other aspects of the vehicle. It will also need to be fully mountable to the frame while also being easily removable.

Benchmark:

There are a couple of benchmarks for this project. The first and primary one being the previous electric vehicle here at Central Washington University. The body being designed for this project must be at least 10% lighter than its previous state. Since the body from the old one is being used, this design must cut back on the overall amount of material being used.

Another benchmark is a typical, modern passenger vehicle. These are being used to determine a suitable coefficient of drag for the electric vehicle. For example, many modern sedans have a coefficient of drag of approximately 0.32. This electric vehicle's body must result in a coefficient of drag of less than 0.30.

Performance Prediction:

Assuming all the requirements have been met, the upgraded body for the electric vehicle should assist the new vehicle in achieving a top speed of at least 2% higher than the previous electric vehicle.

Description of Analyses:

The majority of the analyses had to be done for the weight and aerodynamics of the body. This is due to the fact that these two factors are the only two that effect the vehicle's performance. Lastly, some analysis of the material was done to see what would happen to various sections of the body in the result of a collision.

Scope of Testing and Evaluation:

The testing for the body will take place inside of Hogue hall and its adjacent parking lot. Here, various loads will be applied perpendicular to several sections of the body to see how it reacts, such as its deflection. Additionally, the vehicle will be driven on the parking lot to ensure the body's rigidity when the vehicle is in motion. It will be driven somewhat aggressively in the parking lot to emulate the circumstances of an actual race.

Analyses:

All analyses are represented in Appendix A. **It is worth noting that Figures A-1 through A-4 cover the first design, whereas Figures A-5 through A-12 cover the second design, which is the one being used.**

Figure A-1 represents the total frontal area of the body of the electric vehicle. Frontal area is an important factor when calculating a vehicle's drag. The purpose of this was to eventually find the coefficient of drag, so that it could then be compared to common vehicles on the market today. The goal was for the vehicle to have a coefficient of drag of less than 0.29 (as stated in the requirements section). In Figure A-1, the sums of the frontal area of each component of the front of the vehicle were added together. This resulted in the total frontal area, which came out to be approximately 336 in^2.

In Figure A-2, several materials were compared to see how much more/less they would make the vehicle weigh in comparison to each other. These results were then factored into a decision matrix (as well as other things such as cost), in order to pick the best material to use for the body of the electric vehicle. Carbon fiber came out to be the best material in regard to weight, considering it is only a quarter of the weight as steel and two-thirds the weight of aluminum.

Figure A-3 demonstrated just how much the body of the vehicle would weigh if it was made entirely of carbon fiber. To do this, the overall volume of the body was calculated and then multiplied by the density of carbon fiber. The body was required to weigh less than 40lbs. Assuming it was made entirely of carbon fiber, the body would only weigh 18.66lbs.

After further consideration, the cost of an entire carbon fiber body would be too great. Figure A-4 was intended to calculate the overall weight of the body if the flooring was switched to aluminum. Aluminum is significantly cheaper, and it was the second-best option for material according to the decision matrix. After doing similar calculations to the ones in Figure A-3, the weight of the vehicle would now be 21.12lbs.

Figure A-5 is the first analysis that covers the second design. For this analysis, the weight reduction from removing the tail-piece was found. The tail was deemed unnecessary for this design, so removal of it provided a slight decrease in the body's overall weight. It was found that by removing the tail, the body would weigh approximately 5.89 lbs. less.

Figure A-6 demonstrates the weight reduction that would come with cutting off a section of the side panels that cover the front wheels. The initial reason for deciding to cut a section out of the panel was to create enough clearance for the wheel to be able to turn without hitting the inside of the body. In the process however, this also created a slight reduction in weight. By cutting out those sections, the vehicle's body will lose approximately 1.96 lbs. of weight.

Figure A-7 covers the new frontal area of the vehicle for the second design. Like Figure A-1, this analysis relates to the drag of the vehicle. It is worth noting that this design has a much higher frontal area, but the first design didn't take the driver into consideration. This body encloses the driver entirely, so the driver won't be generating any drag. The frontal area calculated for the second design is approximately 1108 in^2.

During the manufacturing stage, it was discovered that the analysis done in A-6 is not necessary. The wheelbase was originally supposed to be widened, but the person in charge of the wheelbase decided to shorten it, therefore the body's side panels no longer need to be cut in order for there to be enough clearance for the wheels. This means that the body will no longer lose that additional 1.96 lbs. which is a negligible weight reduction anyways. Additionally, keeping the body's side panels intact will help keep it as aerodynamic as possible, which will likely help the vehicle's speed more than the weight reduction would have.

Design:

This design will have the overall appearance similar to a raindrop. Natural and organic shapes often prove to be the most streamline in physics. This body has a very organic curvature to it so that there will be laminar air flow around it. It will consist of two main pieces that will be fixed together with locking pins and hitch clips. This way it can be taken apart quickly and easily if necessary. Additionally, a windshield will be hinged to one of the pieces so that the driver can enter or exit the vehicle unassisted.

Calculated Parameters:

A calculated parameter for this design includes the thickness of body at several locations.

Device:

The device's purpose is to surround and protect the driver from any foreign objects coming at the vehicle, as well as keep the driver's extremities within the vehicle. It must do so while remaining relatively light and aerodynamic so as to not hinder the vehicle's speed and acceleration too greatly.

Device Assembly:

The device assembly is made of two main pieces, a tail, and a windshield. As stated earlier in the Design section, the device will have the appearance similar to a raindrop. It will allow laminar airflow to pass by and result in a low drag force. The two main pieces will be pinned together as well as onto the frame with locking pins and hitch clips. Each piece will have at least 2 mounting points to the frame to ensure rigidity. Since there will be many mounting points, the need for locking pins and hitch clips is prevalent since the body must be able to be removed quickly in the event of an emergency. Below is a computerized image of the device.

Tolerances and Ergonomics:

Tolerances:

- Carbon Fiber ➔ ± 0.125 in
- Machined Brackets ➔ ± 0.030 in

Ergonomics:

- Weight of each part must be ≤ 20 lbs. so that it can be carried by a single adult.

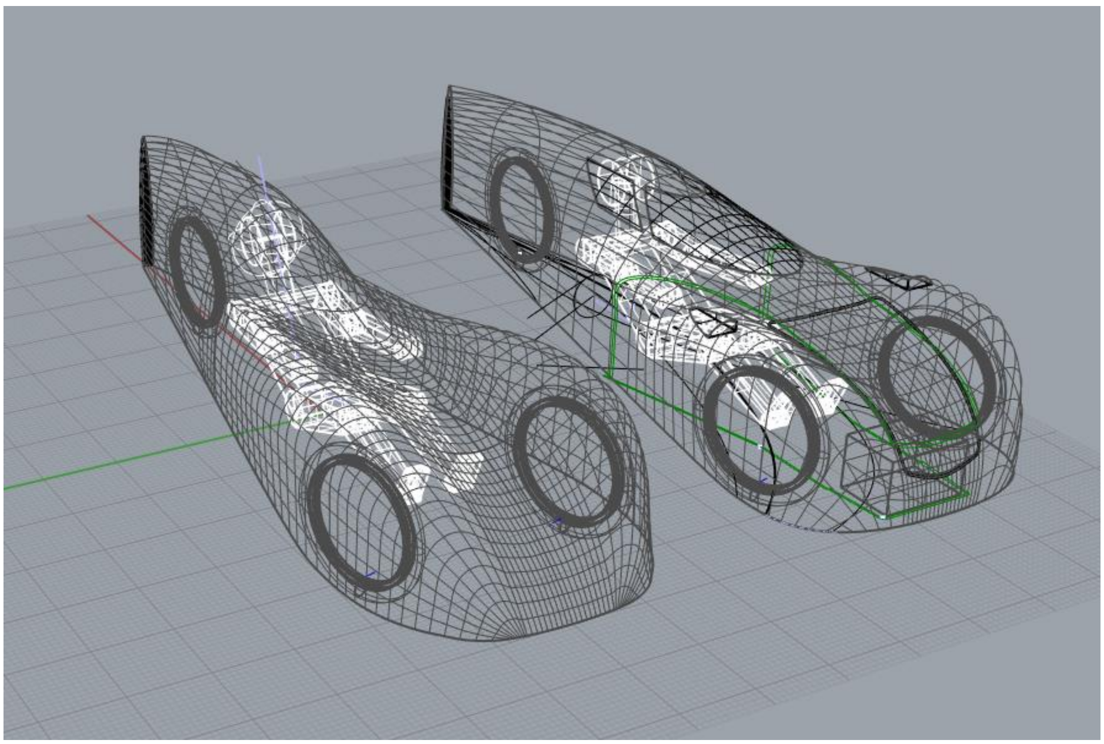


Figure 2

Figure 2 is a model of the original 'Catmobile'

Technical Risk Analysis:

It is likely that the cuts to be made on the sides of the front piece that cover the front wheels will need to be redone. The reason for this is that the curvature that the body possesses makes it difficult to determine the amount of clearance the wheel has. If cuts do need to be remade, this shouldn't result in any increased costs, but rather an increase in manufacturing time.

METHODS AND CONSTRUCTION

Construction:
Construction will begin and take place over the Winter Quarter of 2019. It will start with the construction of the mounting brackets for the body of the electric vehicle. Manufacturing these brackets will require cutting AISI 1020 steel flat-bar to spec and using a drill press to create the holes for the pins to slide through. Deconstruction of the previous electric vehicle at Central Washington University will take place next. The body of the old vehicle will be chopped up in order to reduce weight and ensure there is clearance for other moving parts. A Dremel tool with a diamond coated wheel will be used to do this. This will come with safety hazards, as noted in Appendix J-1. Once all the cutting is complete, then the modified body will need to be fastened together using pins and hitch clips. Both will be purchased. However, before the body can go on the frame, holes must be made in it from the pins to go through. Rubber grommets along with sheet metal with rivets will be used to help protect the body from wearing due to shear from the pins. It is worth noting that the fastening method described above had to be revised during the manufacturing process, as described in the ‘Encountered Manufacturing Issues’ section below.

Description:
This project consists of one main assembly and several sub-assemblies. It consists of a front piece, a center piece, and a windshield. Each part will be fastened to one another and mounted to the frame to ensure the assembly’s rigidity. The front and center pieces are being fastened with the pins and clips, whereas the windshield piece will only be fastened with Velcro, so that the driver can easily get in or out of the vehicle unassisted.

Each assembly and part will have an identification number. For instance, the main assembly has an identity of A.001 and the front piece has an identity of C.001. The A group indicates the main assembly, the B group indicates a sub-assembly, and the C group indicates a part. Identical parts will have the same identification number. Instead, there will be a quantity number next to their identification number.

Drawing Tree:
Appendix B-8 represents the main assembly and its parts that make up its sub-assemblies. Green will indicate the main assembly, blue will indicate a sub-assembly, and orange will indicate a part.

Parts List and Labels:
Appendix C shows all the necessary parts required for this design. This will include the carbon fiber, steel flat-bar, pins, clips, as well as the other small items such as the rubber grommets. The cost of the parts is relatively insignificant since the most expensive material (carbon fiber) is already provided. The final costs for each part are included in Appendix D.

Possible Manufacturing Issues:
Some manufacturing issues that may be encountered include…

- Cutting the panels to improper dimensions (since they will be hand-cut)
- Misalignment of the panels on the frame

- Damage to the carbon fiber body during the fastening process

Encountered Manufacturing Issues:

The main issue that was ran into during the manufacturing process was that the mounting brackets didn't work. There was too much space between the brackets and the body to fix them together properly with the locking pins. In order to bypass this issue, new pins had to be machined and welded onto the frame in a vertical position, and the body had to have holes drilled on the top for it to slide over those new pins. A hitch clip was then used to secure the body down onto the frame. An issue that was ran into with this solution is that the vertical pins were cut too short (2in) and they really needed to be 2.5in. New ones had to cut in order for the hitch clips to be able to secure the body down onto the frame.

Figure 3

Figure 3 is the body of the 'Catmobile' assembled together with the frame in the background

TESTING METHODS

Introduction:

The testing of the body for the electric vehicle will include subjecting it to impacts from various weights to see how it deflects and behaves, as can be seen in Appendix G. The first test, however, will be to find out how long it takes to remove the whole body, as well only the front and tail pieces.

Method/Approach:

The first test measures the amount of time it takes for two people to remove the whole body, just the front piece, and just the tail piece. It's important that the body can be removed quickly, in case something such as a flat tire occurs. The only way to access the tires is to remove the front or tail piece (depending on whether the front tires or rear tire needs to be changed). To do this test, each person will use a pair of needle-nose pliers so that they can remove the clips easier. The time starts when the two individuals begin to remove the piece(s) and ends once the piece(s) are set on the ground next to the vehicle. See Appendix G for more details.

The second test will measure the deflection of the body while a load is dropped on it. To do this, a 10 lb. weight will be released from several heights onto a piece of carbon fiber. The weight and location can be seen in Appendix G. The reason for this test is to help better understand what will happen to the body in the event of a collision.

These tests will take place inside of Hogue Hall. This provides an easy-access testing facility with all the necessary equipment readily available.

The required parts and equipment needed for the first test is as follows:

- Complete body of the electric vehicle
- 2 people
- 2 needle-nose pliers
- Stopwatch
- Excel document to keep track of results
- Adequate space to set body aside from vehicle

The required parts and equipment needed for the second test is as follows:

- Piece of carbon fiber that is on the body or similar to the pieces on the body
- 10 lb. glide weight
- Camera
- 2 people
- Excel document to keep track of results
- Tape Measure
- Marker

Test Procedures:

Below is the procedure to the first testing method

1. Ensure body is fully fixed to the frame (all pins are through the body and pinned down).
2. Provide yourself adequate space to be able to walk around the vehicle and set body components aside.
3. Each person must have needle-nose pliers readily available.
4. Start stopwatch and immediately begin removing the whole body by removing the clips with the pliers and setting the body pieces to the side.
5. Stop the stopwatch once all pieces have been removed.
6. Record time taken to remove the piece(s) in an Excel document.
7. Repeat all steps two more times and take the average time and record it in the Excel document.
8. After the three trials have been completed, repeat steps 1-7 except only remove the front piece.
9. Now, repeat steps 1-7 but only remove the tail piece.

Below is the procedure to the second testing method

1. Obtain the piece of carbon fiber as well as something to hold it up from two ends (at least 2.5 inches off the ground).
2. Provide yourself adequate space to be able to walk around the test piece.
3. Measure the piece of carbon fiber to mark its center point.
4. Place camera so that it is parallel to the top surface of the carbon fiber piece.
5. Have one person set the weight on the marked center point.
6. Begin recording with camera (slow motion is preferred).
7. Have the person lift the weight up halfway (9 inches) and release the weight.
8. Stop video recording.
9. Review video and look at how much the panel deflected.
10. Record the data and state whether the panel survived the impact (no noticeable damages).
11. Repeat all steps if the panel survived the impact, except do step 7 with the weight at full height (18 inches).

Risk/Safety (for test two):

As always, it is required to wear close-toed shoes and safety glasses in Hogue’s foundry. Since the load being used is relatively small, there isn’t any great dangers involved in the testing. However, there is a possibility of the weight landing on a foot or hand, so it is important that all testers keep their hands and feet away from the falling weight.

Test Summaries:

For the first test, two people timed how long it took for them to remove the entire body of the vehicle, just the front end, and just the tail end. Each part of the test had three trials to obtain an average. The testers were equipped with needle-nose pliers in order to remove the clips more efficiently. To remove the entire body took an average of 25.4 seconds. It was predicted that this should be done in around 30 seconds. As for the front end only, it took the testers an average of 5.4 seconds (8 seconds was the predicted value). The tail end took an average of 2.6 seconds (4 seconds was the predicted value). All of these times included how long it took the testers to set the pieces aside from the vehicle.

For the second test, a 10 lb. weight was dropped vertically onto the center of a scrap panel of carbon fiber that was left over from the body. The panel was raised 2.5” off the ground with wood beams holding it up at each end. The center of the panel was 11.25” away from each of the beams. The weight was initially dropped 9” above the panel to see if the panel could survive the impact. The weight possessed 10.20 joules of energy at this height. The panel was able to withstand this impact and it deflected approximately 0.5” before returning to its normal shape. Next, the weight was dropped from 18” (which equates to 20.35 joules of energy). Again, the carbon fiber panel survived the impact with no noticeable damages to either side of it. The panel deflected an approximate of 1.25” on this trial. It was predicted that the panel would only have deflected 1” and might even break, so the test showed that the carbon fiber is stronger than originally anticipated. This test demonstrated that the vehicle should be able to handle a collision at low speeds and still have its body intact afterwards.

Deliverables:

In the first test, it was found that it takes an average of 25.4 seconds for two people to remove the entire body. This is important for removing the driver in the event that they get stuck inside the vehicle. It took an average of 5.4 seconds to remove only the front end of the vehicle, which is useful if a front tire needs to be changed. If the rear tire needs to be changed or the motor/chain needs to be accessed, it takes roughly 2.6 seconds to remove the tail piece of the body.

In the second test, it was found that the carbon fiber can withstand an impact of 20 joules. The scrap piece of carbon fiber survived 20.35 joules of energy during the test and showed no damage. This means that the actual body should withstand a minor collision with a foreign object at low speeds.

BUDGET, SCHEDULE, and PROJECT MANAGEMENT

Proposed Budget:

The overall budget for this project is very low. Since the body is already provided by the school and the modifications are subtractive rather than additive, there isn't much of a need for purchasing. The only foreseeable costs include a diamond coated cutting wheel for a Dremel tool, the hitch clips, and the locking pins. The net cost of those items should remain below $100. All these costs are noted in both Appendix C and D.

Budget:

As of (3/11/19), approximately $65 had been spent on the project. This money came from the rivets and locking pins needed for the body and their shipping costs, as well as the ventilation masks needed for cutting the carbon fiber body. They arrived on February 2nd, 2019. The steel that was needed for the mounting brackets ended up not costing anything, which helped save on costs. It did take a while to receive the funds for the club, however, there was a setback on obtaining the funds because of a recent active shooter incident at Central on February 6th, 2019. The meeting to obtain the money was scheduled for that day but got cancelled. These funds were obtained the following week. The project ended up coming under budget, which is helpful because that allowed other group members to have more freedom with their budget (since it was a $1500 overall budget obtained from the club funds).

As of (5/16/19), no more money has been spent since the construction phase of the project. No testing required the purchasing of any material or parts. All materials and tools needed for testing were available at Central for no cost. This project ended up costing a total of $65, and $48 of that amount ended up being unnecessary purchases since the design changed part way through the construction phase. These items include the rivets and locking pins (although two pins did end up being used out of the dozen that were purchased). Had the design been correct the first time, this project would have only costed roughly $17. It still managed to come way under the $150 budget regardless.

Proposed Schedule:

To begin, coordination with the designer of the frame is important. Both the frame and body must be fully compatible with one another. It is required that both members are on the same page before any drawings and analyses could be completed. Once the dimensions as well as the mounting points are figured out, the next several weeks will be spent analyzing and drawing out parts of the device. In an effort to optimize the vehicle, this is where the majority of the first quarter was be spent (6-7 weeks).

Afterwards, obtaining the materials needed is the next step. This will include ordering new materials, such as the locking pins, hitch clips, steel flat bar, and cutting wheels. This step will take approximately 1-2 weeks, depending on the shipping speed of the purchased material. Once the materials have been obtained, cutting up the steel flat bar into the mounting brackets will take place. This will take approximately 1-2 weeks as well. Once all the brackets are complete, the cutting of the body can begin. This should take 1-2 weeks. After all the previous steps have been completed, everything can be assembled together accordingly. If something does not fit or isn't compatible with other parts, modifications may need to be made and could take several weeks depending on the severity.

Once the device has been fully assembled and everything is compatible, testing will take place. Testing should take 1-2 weeks. If requirements are not met, the device must be modified (modifications could take place over several weeks). Assuming modifications had to be made, more testing will be done until all requirements have been met.
As of January 31st, 2019, there has been no construction. The reason for this is because obtaining the funds for the EV club is taking longer than expected. However, the parts that must be shipped have already been purchased out-of-pocket, this way once they arrive the club's funds should be arriving too. After receiving both (estimated for next week), construction can begin. The remaining components needing to be purchased are all raw materials that are available at the university (steel flat bar). A large portion of the manufacturing is expected to be done the following week.

Schedule:

All manufacturing ended up taking place over the last two weeks of the Winter Quarter. The reason for this is because of how long it took to receive the club funds. The body couldn't be cut until all other components with possible interference were installed first, so that way the body could be cut accordingly. However, all of the necessary materials that needed to be purchased for the manufacturing were purchased the previous week so that they would arrive on time before the manufacturing actually began. Refer to Appendix E-1 and E-2 for the Gantt Chart.

All testing was done on time without any setbacks. The first test was done several days before it was originally scheduled for, and the second test was done the day before it was scheduled for. The second test, however, took longer than expected because the plans were changed right before it began. Originally it was going to be done on the body of the vehicle itself, but it was later decided that it could be done on a scrap piece of carbon fiber in order to ensure that no damage was done to the vehicle in the process. This can be seen in further detail in the testing section of this report. Refer to Appendix E-1 and E-2 for the Gantt Chart to see the timeline of the testing.

Project Management:

There are multiple safety considerations to take within this project. One of them being during the cutting of the carbon fiber. Not only does the cutter present a hazard (noted in Appendix J-1) of cutting the operator, but the particles from the carbon fiber can be inhaled or get in the operator's eye. To prevent this, eye protection and a ventilation mask must be worn at all times during cutting. Additionally, another trained person must be present in the room. This goes for the machining of the mounting brackets as well. An operator must be accompanied by a trained peer when operating equipment in the machine shop.

DISCUSSION

Design Evolution:

At the beginning, there were several ideas of the possible styles that the vehicle could be. For instance, the team had to decide on if the vehicle should have 2 wheels in the front or back. Once that was decided, the team wanted to make an entirely new Electrathon vehicle at Central Washington University. After much consideration, analyses, and cost comparisons, the team decided to instead modify the existing one.

The first design, for an entirely new vehicle, was much like a standard go-kart appearance, except for the fact that it had only one wheel in the back. This design proved to be too costly, considering that virtually all the parts would have to be purchased. This deterred the team away from that design and helped influence the current design.

The current design is a modification of the original Electrathon vehicle at Central Washington University. The existing vehicle provides a great base point, where there is still room for modifications without having to purchase everything. For the body, these modifications mostly include cutting back on the material being used. This leads to reduced weight, which in turn increases the vehicle acceleration and maximum speed. The existing vehicle already implemented carbon fiber into its body, which is what the original design had planned. This cuts back on costs drastically, considering the high prices on the market for carbon fiber.

Project Risk Analysis:

The main risk of this project is ensuring that all the components of the body will still be able to mount to their desired locations on the frame after cutting and modifying them. Not only that, but since other team members will be modifying various devices in the vehicle, the body must adhere to those changes as well. If not, new material will have to be purchased, and that can drastically raise the cost of this project. Careful planning and measuring were needed to confirm modifications will work before they are made.

Next Phase:

Money will need to be received before any manufacturing can begin. The money should be coming to the EV club around January 30^{th}, 2019. Once it has been granted to the club, the next step will be to begin cutting the fasteners that will have to be made and mounted onto the body. They will allow the body to be removed quickly and easily by a single person in the event of an emergency, as stated in the rulebook. The existing body of the 'Catmobile' vehicle will then need to be cut. The cuts being made are to ensure there is no interference with the other devices, and to reduce the weight of the vehicle.

Encountered Design/Manufacturing Issues:

A manufacturing issue discovered is that no member of the electric vehicle team is confident in welding. To solve this, Matt Burvee (the Hogue Technician) is scheduled to do the welding for the mounting brackets so that they can be fixed onto the frame. Having the holes line up between the mounting brackets and the body is an issue that is being avoided by waiting for the brackets to be welded onto the frame before the holes on the body are made, so that they can be lined up with the bracket before being drilled. In order to ensure that the brackets met specifications, they were scribed to give a layout of where to make the cuts using the band saw and to mark the hole locations for the quarter-inch holes using the drill press. Once it was discovered that the mounting brackets would no longer work, the method to fix the body as described in the 'Encountered Manufacturing Issues' was used to resolve the issue of fixing the body onto the frame.

Figure 4

Figure 4 is the body of the 'Catmobile' sitting on top of the frame

Encountered Testing Issues:

The first test was originally only supposed to be done with one person, however; it was discovered that using only one person to remove the body of the vehicle was unrealistic. So, a second person was recruited to help remove the body. It was found that if each person used needle-nose plyers to remove the clips then it would be much easier to remove the body quickly.

The procedure of the test had to be edited in order to accommodate for these changes. After the accommodations, the test didn't run into any problems. The results fell within the requirement set (removing the whole body in under 30 seconds). The body was removed in an average of 25.4 seconds over three trials.

The second test was originally to be done on the actual vehicle's body itself. However, not only would it have been more difficult to do it on the body (because of no flat surfaces), it also posed a risk to damaging the body. The solution was to use a scrap piece of carbon fiber instead that was left over. This way, there wouldn't be the risk of damaging the body and it still allowed for reliable results since it is the same kind of carbon fiber as the body is made out of. Once the test began, there were no encountered issues.

Figure 5

Figure 5 is the nose of the body with the pins and hitch-clips fastening it to the frame.

CONCLUSION

The motivation for this project came from the challenge it presented. Every day, engineers are tasked with making devices more efficient and sustainable. This project is no different. By taking an existing project, the 'Catmobile' at Central Washington University, and modifying it into something better, the university is provided a new and improved electric racing vehicle. The body of this Electrathon vehicle meets all the previously mentioned requirements.

- Weighs less than 30 lbs.
- Costs less than $150 out of pocket
- Has a coefficient of drag of less than 0.29
- Mount to at least 5 different points on the frame
- Can survive an impact of at least 20 joules of energy

The body is now compatible with its frame once again. Fitting it on, mounting it, and ensuring compatibility with all the other components proved to be difficult. However, through many hours of designing and manufacturing the edited body and its mounting points, it was successful in accomplishing the established requirements. It fits onto the frame, it is mounted onto the frame, and it ended up only costing about half of the proposed budget. With the manufacturing phase coming to an end, the testing stage will begin in the Spring Quarter of 2019 and it will make sure that the body will hold up against common stresses and strains it might experience while the vehicle is driving.

Figure-6

Figure 6 is the body of the 'Catmobile' fully fastened onto the frame.

ACKNOWLEDGMENTS

Team Members: Lathan Halaapiapi, Luis Hernandez, Sam Johnson, and Chris Clark
Charles Pringle: For helping with design and calculations
Craig Johnson: For helping with design and calculations
Matt Burvee: For helping with design and manufacturing
Club Senate: For funding the project

REFERENCES

Machine Elements in Mechanical Design, 6th edition. By Robert L. Mott
Marks' Standard Handbook for Mechanical Engineers. By Lionel Simeon Marks
'Catmobile' Project
Electathon America Rulebook

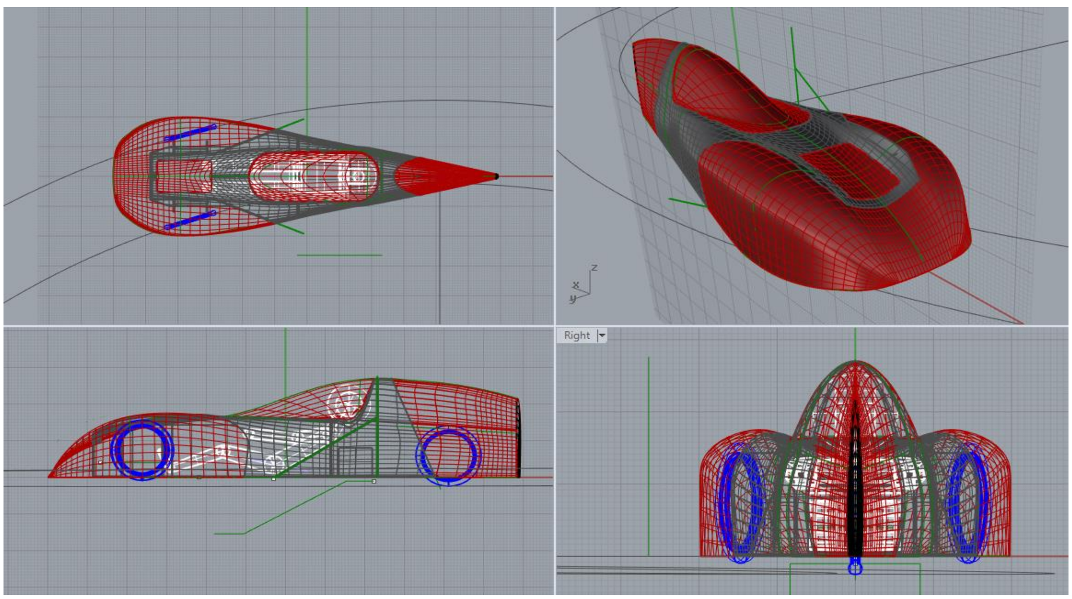


Figure 5

Figure 5 is a model of the original 'Catmobile'

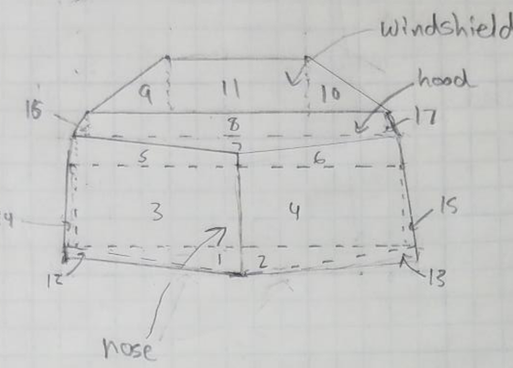
APPENDIX A – Analyses

Ryan Shiner | MET 489 A | 10-10-18 | 1/1

Design analysis #1 EV (body)

Frontal Area, A_F

(only the body) scale 1□ : 2in



All area calcs are estimates... ± 5%

$A_1 = A_2 = (\frac{1}{2})(2in)(13in) \Rightarrow \underline{A_1 = 13in^2}$ and $\underline{A_2 = 13in^2}$

$A_3 = A_4 = (12in)(6in) \Rightarrow \underline{A_3 = 72in^2}$ and $\underline{A_4 = 72in^2}$

$A_5 = A_6 \approx (\frac{1}{2})(12in)(2in) \Rightarrow \underline{A_5 = 12in^2}$ and $\underline{A_6 = 12in^2}$

$A_7 \approx 2(\frac{1}{2})(12in)(1in) \Rightarrow \underline{A_7 = 12in^2}$

$A_8 = (22in)(2in) \Rightarrow \underline{A_8 = 44in^2}$

$A_9 = A_{10} = (\frac{1}{2})(6in)(4in) \Rightarrow \underline{A_9 = 12in^2}$ and $\underline{A_{10} = 12in^2}$

$A_{11} = (10in)(4in) \Rightarrow \underline{A_{11} = 40in^2}$

$A_{12} = A_{13} \approx (\frac{1}{2})(14in)(1in) \Rightarrow \underline{A_{12} = 7in^2}$ and $\underline{A_{13} = 7in^2}$

$A_{14} = A_{15} = (\frac{1}{2})(1in)(6in) \Rightarrow \underline{A_{14} = 3in^2}$ and $\underline{A_{15} = 3in^2}$

$A_{15} = A_{16} = (\frac{1}{2})(1in)(2in) \Rightarrow \underline{A_{15} = 1in^2}$ and $\underline{A_{16} = 1in^2}$

$A_F = A_1 + A_2 + A_3 + A_4 \ldots$

$A_F = 5(12in^2) + 2(13in^2) + 2(72in^2) + (44in^2) + (40in^2) + 2(7in^2) + 2(3in^2) + 2(1in^2)$

$\boxed{A_F = 336in^2}$ ± 5%

Analysis #2
Material of body (weight)

Options	density
Sheet metal (steel)	~7.85 g/cm³
sheet metal (aluminum)	~ 2.7g/cm³
carbon fiber	~1.82 g/cm³

Examing above, carbon fiber would only weigh appox. 27% of what steel would weigh.

In comparison to aluminum, carbon fiber would weigh appox. 67% of what the aluminum would weigh.

As far as weight goes, carbon fiber is the best option, other factors will have to be considered and put into a desicion matrix...

Analysis #3
Weight of body (carbon fiber)

density of carbon fiber = .050 #/in^3

Volume of body...

(Front) $\Rightarrow$ $(272\,in^2)(\frac{1}{8}\,in) = \underline{34\,in^3}$

(Right side) $\Rightarrow$ $(494.7\,in^2)(\frac{1}{8}\,in) = \underline{61.84\,in^3}$

(Left side) $\Rightarrow$ $(494.7\,in^2)(\frac{1}{8}\,in) = \underline{61.84\,in^3}$

(bottom) $\Rightarrow$ $(1724.17\,in^2)(\frac{1}{8}\,in) = \underline{215.52\,in^3}$

$\underline{Vol \approx 373.20\,in^3}$

Weight = (Vol)(density)

Weight $\approx (373.20\,in^3)(.050\,\#/in^3)$

$\boxed{Weight \approx 18.66\,\#}$

Analysis #4
Changing the flooring to aluminum

density of aluminum = $0.098\ \#/in^3$

Volume of flooring = $(1724.17\ in^2)(\frac{1}{8}\ in)$

Volume of flooring = $215.52\ in^3$

Weight = Vol (density)

Weight = $(215.52\ in^3)(.098\ \#/in^3)$

$\boxed{\text{Weight} = 21.12\ \#}$ (for aluminum)

As found in A-3, the floor would weigh 10.78# if it was carbon fiber.

However, due to the challenge of costs, an aluminum floor may have to be incorperated.

A-4

Ryan Shiner	MET 489A	11-27-18

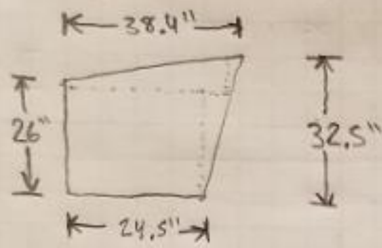
Design #2
Removing tail weight

Given: 'Catmobile' body with tail

Find: Weight loss from removing tail

Methods: 1. Volume of tail (V)
2. density of carbon fiber (d)
3. weight of tail (W)

Solution:



Side view of tail

$$\text{Volume per side} = \left((26\,in)(24.5\,in) + (38.4\,in)(6.5\,in)\left(\tfrac{1}{2}\right) + (26\,in)(13.9\,in)\left(\tfrac{1}{2}\right)\right)\left(\tfrac{1}{16}\,in\right)$$

$$\text{Volume per side} \approx 58.91\ in^3$$

$$\text{Volume of tail} = 2(\text{Volume per side})$$

$$\text{Volume of tail} = (2)(58.91\ in^3) \Rightarrow \underline{V \approx 117.81\ in^3}$$

density, $d = .050\ \#/in^3$ (online reference)

$$W = dV$$

$$W = (.050\ \#/in^3)(117.81\ in^3) \approx 5.89\ \#$$

$\boxed{W \approx 5.89\ lbs}$ which means a 5.89 lb weight reduction

A-5

Ryan Shiner | MET 489A | 11-26-18

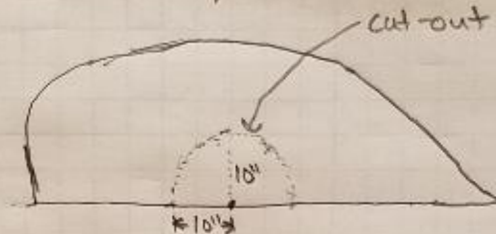
Design #2
Cutting side panels
for wheel clearance

Given: 'Catmobile' body with full-front side panels

Find: Weight loss from side panel cut-outs

Method: 1. Volume of cut-outs, V_{tot}
2. density of carbon fiber, d
3. Weight of cut-outs, W

Solution:



Side view of side panel

$A = \pi r^2 \left(\frac{1}{2}\right)$

$A = \frac{1}{2}(\pi)(10in)^2 \Rightarrow \underline{A \approx 157.08in^2}$

$V = A(t) \Rightarrow t = \frac{1}{8}in$

$V = (157.08in^2)(\frac{1}{8}in) \Rightarrow \underline{V = 19.64in^3}$ per side

$V_{tot} = 2(V) \Rightarrow V_{tot} = 2(19.64in^3) \Rightarrow \underline{V_{tot} \approx 39.27 in^3}$

$\underline{d = 0.050 \#/in^3}$ (online reference)

$W = d(V_{tot})$

$W = (.05\#/in^3)(39.27in^3)$

$\boxed{W = 1.96 lbs.}$ which means a 1.96 lb weight reduction

Ryan Shiner | MET 489 A | 11-26-18

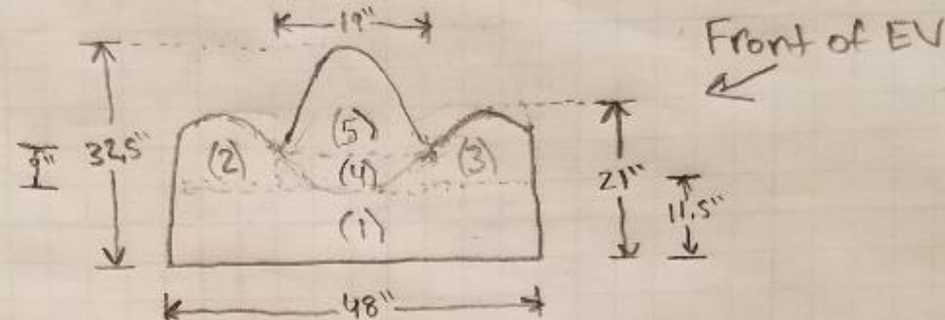
Design #2
Frontal Area

Given: 'Catmobile' body (drawing below)

Find: Frontal Area, A_F

Method: Find area of each piece & sum

Solution:



$A_1 = (48in)(11.5in) \Rightarrow \underline{A_1 \approx 552\,in^2}$

$A_2 = (9.5in)(14.5in)(0.9) \Rightarrow \underline{A_2 \approx 123.98\,in^2}$

$A_3 = A_2 \Rightarrow \underline{A_3 \approx 123.98\,in^2}$

$A_4 = (19in)(9in) \Rightarrow \underline{A_4 \approx 171\,in^2}$

$A_5 = (\frac{1}{2})(19in)(12in)(1.2) \Rightarrow \underline{A_5 \approx 136.8\,in^2}$

$A_F = A_1 + A_2 + A_3 + A_4 + A_5$

$A_F = 552in^2 + 123.98in^2 + 123.98in^2 + 171in^2 + 136.80in^2$

$\boxed{A_F \approx 1107.76\,in^2}$

A-7

Ryan Shiner	MET 489A	11-28-18

Design #2
Net body weight

Given: 'catmobile' body with removed tail & side panel cutouts

Find: Total weight of the body

Methods: 1. Volume of body & windshield
2. density of carbon fiber & plexiglass
3. Weight of body w/o tail & cut-outs

Solution:

Front area $= 3361.55 in^2$ (found on SolidWorks), A_1

center area $= 3401.62 in^2$ (found on SolidWorks), A_2

Hood area $= 277.73 in^2$ (found on SolidWorks), A_3

Windshield area $= 1177.21 in^2$ (found on SolidWorks), A_4

thickness of all $\approx \frac{1}{16} in$

Area of carbon fiber $= A_1 + A_2 + A_3 = \underline{7040.9\ in^2}$

Area of plexiglass $= A_4 = \underline{1177.21 in^2}$

$V = tA$

$d_{CF} = .050\ \#/in^3$, $d_{PG} = .043\ \#/in^3$

$V_{CF} = (\frac{1}{16}in)(7040.9 in^2) \Rightarrow \underline{V_{CF} = 440.06 in^3}$

$V_{PG} = (\frac{1}{16}in)(1177.21 in^2) \Rightarrow \underline{V_{PG} = 73.58 in^3}$

$W_{CF} = V_{CF} d_{CF}$

$W_{CF} = (440.06 in^3)(.050\#/in^3) \Rightarrow \underline{W_{CF} \approx 22.00\ \#}$

$W_{PG} = V_{PG} d_{PG}$

$W_{PG} = (73.58 in^3)(.043\#/in^3) \Rightarrow \underline{W_{PG} = 3.16\#}$

$W_{total} = W_{PG} + W_{CF}$

$W_{total} = 22.00\# + 3.16\# \Rightarrow \boxed{W_{total} = 25.16\#}$

A-8

Ryan Shiner	MET 489 A	11-29-18

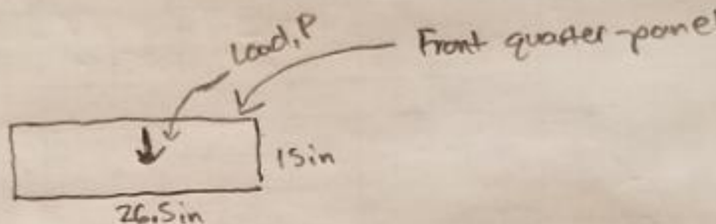
Design 2
Critical load at front quarter-panel

Given: 'Catmobile' body with side-panel cut-outs, load applied in center of front quarter-panel

Find: Critical load, P

Methods: 1. dimensions
2. variables
3. P

Solution:



$$\sigma_m = \frac{1.5P}{\pi t^2}\left[(1+\nu)\ln\frac{2b}{\pi} + 1 - K_2\right]$$

$\sigma_m = 500{,}000\,psi$, $t = \frac{1}{16}in$, $\nu = .27$, $b = 26.5in$, $K_2 = .072$

$$500{,}000\,psi = \frac{1.5P}{\pi(\frac{1}{16}in)^2}\left[(1+.27)\ln\frac{2(26.5)}{\pi} + 1 - .072\right]$$

$\boxed{P \approx 900\ lbs.}$

A-9

Ryan Shiner | MET 489A | 11-29-18

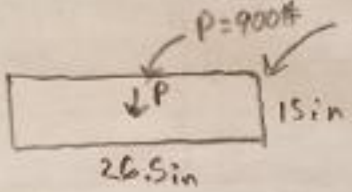
Design 2
Deflection at critical
point on front quarter-panel

Given: 'Catmobile' body, critical load, P = 900# (from last analysis)

Find: Deflection, Δ

Methods: 1. Dimensions
2. Variables
3. Δ

Solution:



$$\Delta = K_1 \frac{Pa^2}{Et^4}$$

$K_1 = 0.177$ (online ref.)

$P = 900\#$

$E = 33\ Msi$ (online ref.)

$t = 1/16\ in$

$a = 15\ in$

$$\Delta = 0.177\,\frac{(900\#)(15in)^2}{(33Msi)(\tfrac{1}{16}in)^4}$$

$$\boxed{\Delta \approx 0.280\ in}$$

A-10

Ryan Shiner	MET 489 A	11-29-18

Design 2
Critical load at
front of vehicle

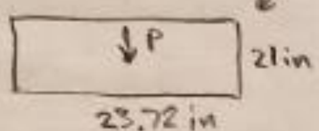
Given: 'Catmobile' body, load applied at the center of the front panel

Find: Critical load, P

Methods: 1. dimensions
2. Variables
3. P

Solution:

Front panel



$$\sigma_m = \frac{1.5P}{\pi t^2}\left[(1+\nu)\ln\frac{2b}{\pi} + 1 - K_2\right]$$

where...

σ_m = 500,000 psi (online ref.)
t = 1/16 in
ν = 0.27 (online ref.)
b = 23.72 in
K_2 = 0.280 (online ref.)

$$500{,}000\,\text{psi} = \frac{1.5(P)}{\pi\left(\frac{1}{16}\text{in}^2\right)}\left[(1+.27)\ln\frac{2(23.72\text{in})}{\pi} + 1 - 0.280\right]$$

$\boxed{P \approx 982 \text{ lbs.}}$

A-11

Ryan Shiner | MET 489A | 11-29-18

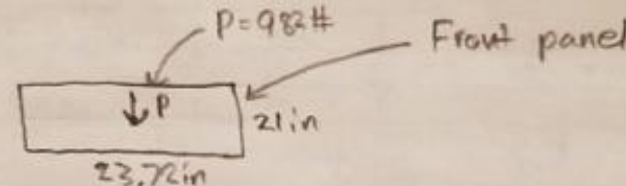
Design 2
Deflection at critical
point on front panel

Given: 'Catmobile' body, critical load, P = 982# (from last analysis)

Find: Deflection, Δ

Methods:
1. Dimensions
2. Variables
3. Δ

Solution:



$$\Delta = K_1 \frac{Pa^2}{Et^4}$$

$K_1 = 0.155$ (online ref)
$P = 982$ #
$E = 33$ Msi (online ref.)
$t = \frac{1}{16}$ in
$a = 21$ in

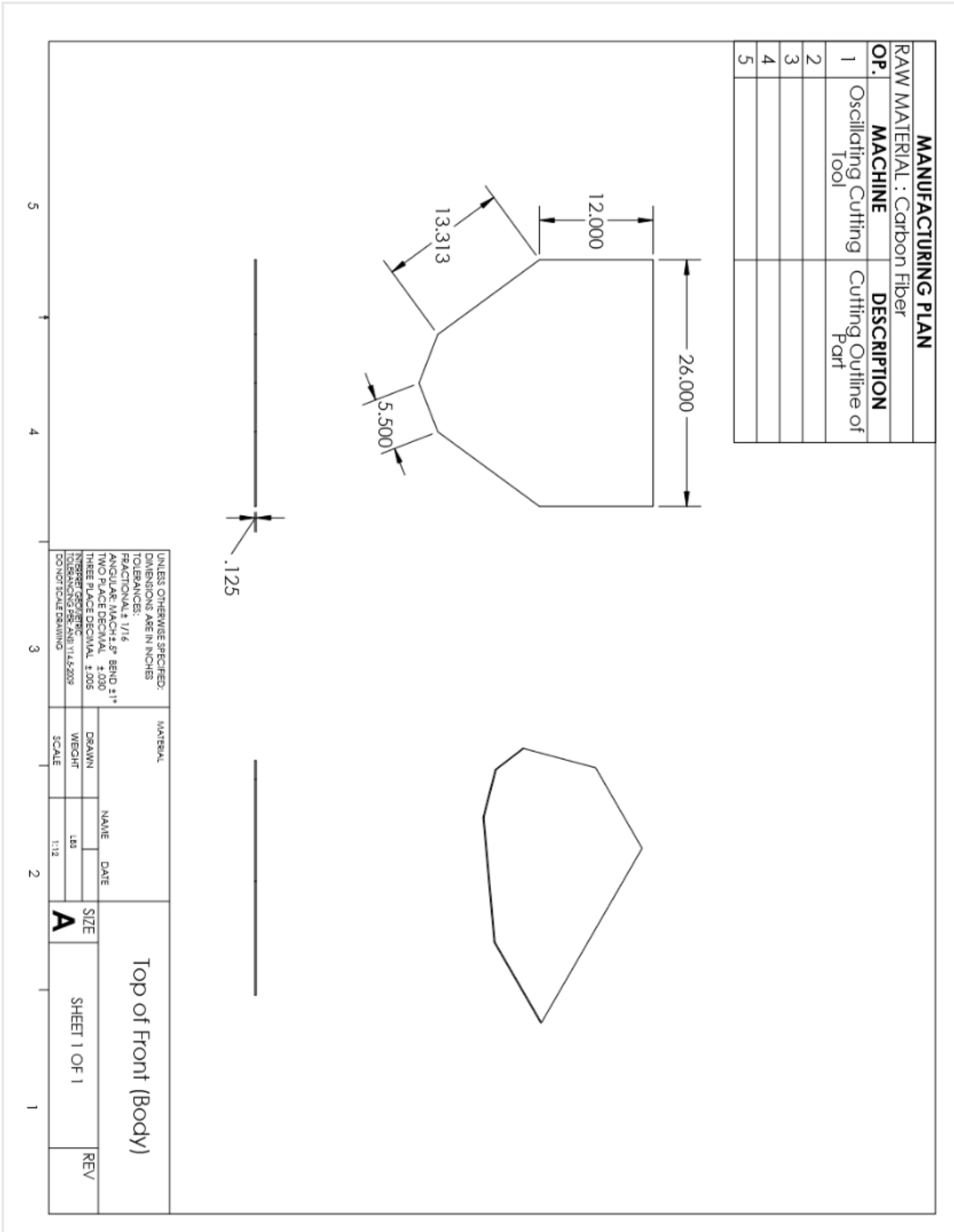
$$\Delta = 0.155 \frac{(982\#)(21in)^2}{(33Msi)(\frac{1}{16}in)^4}$$

$$\boxed{\Delta = 0.318 in}$$

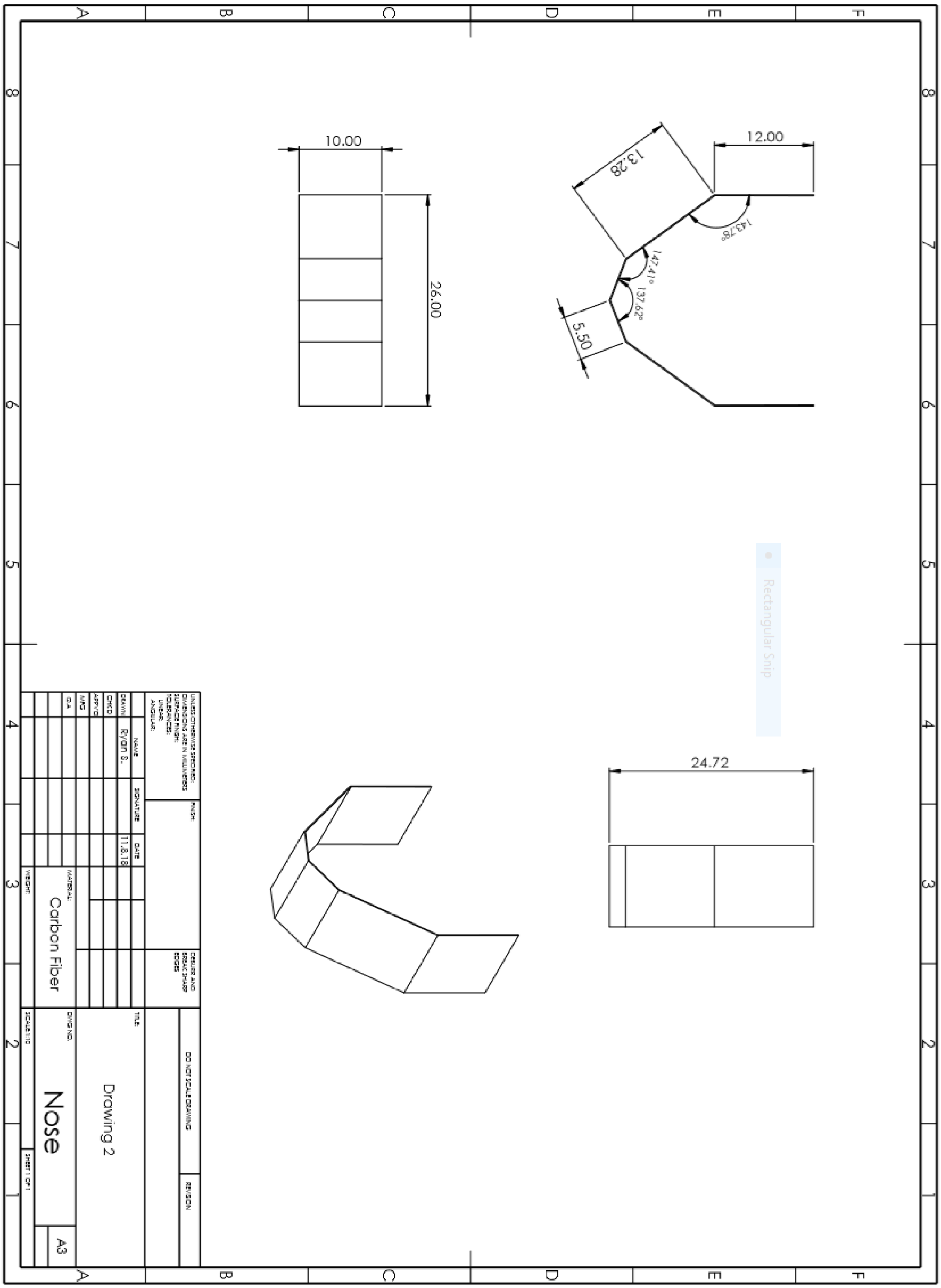
A-12

APPENDIX B – Sketches, Assembly drawings, Sub-assembly drawings, Part drawings

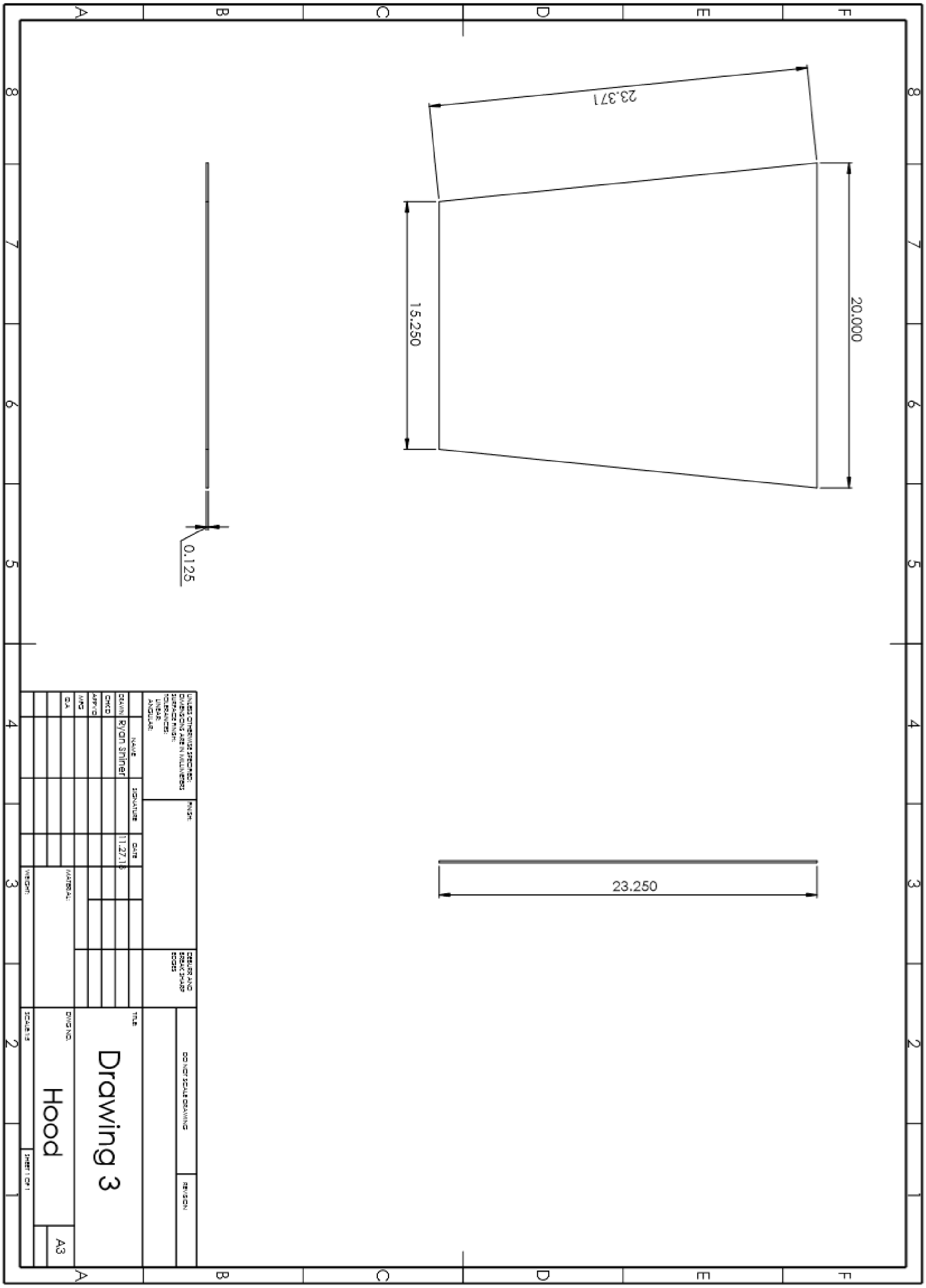
Please Note: Drawings B-1 - B-4 are for Design 1, whereas B-5 – B- are for Design 2 (the one being used).

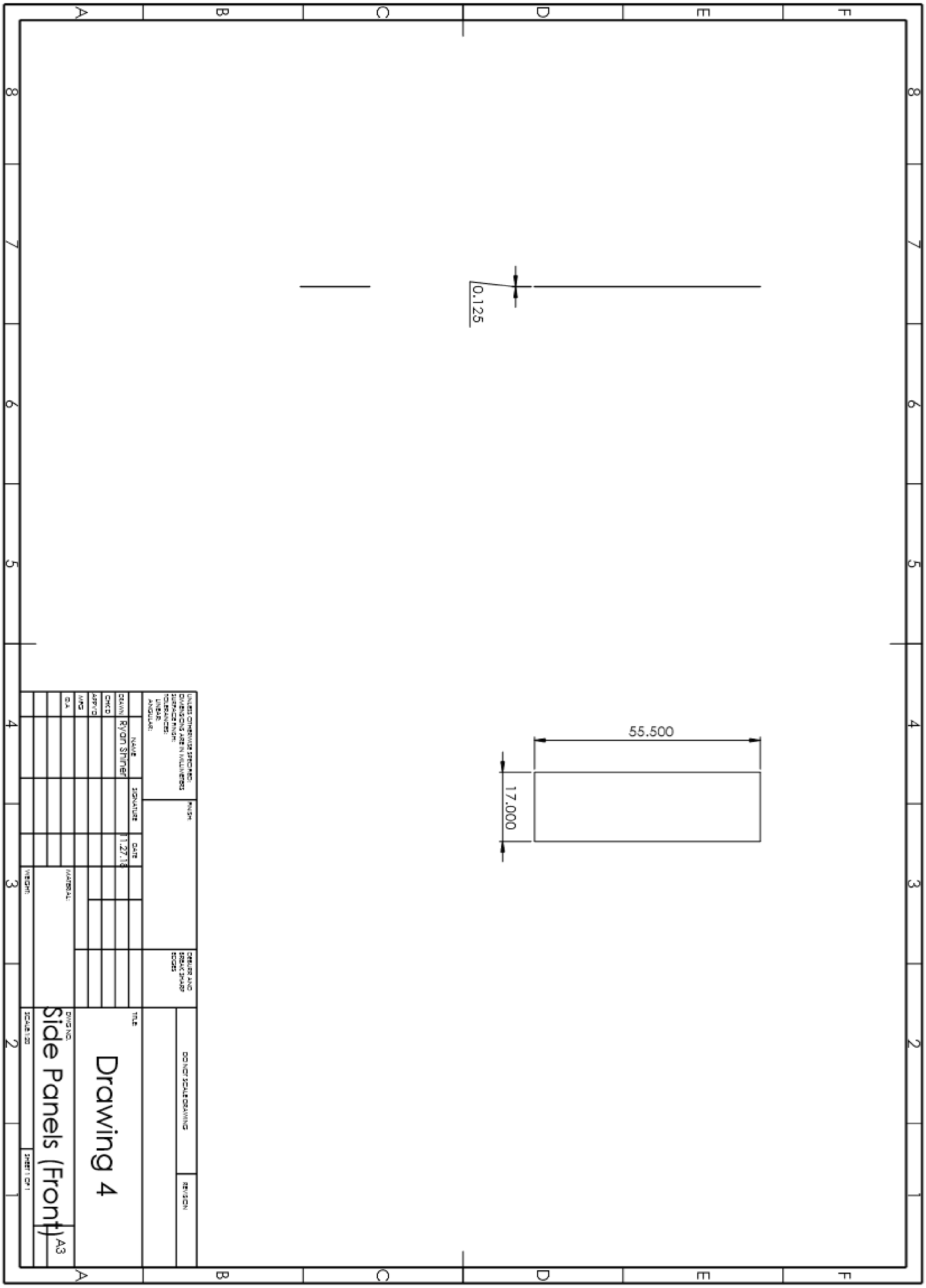


B-1

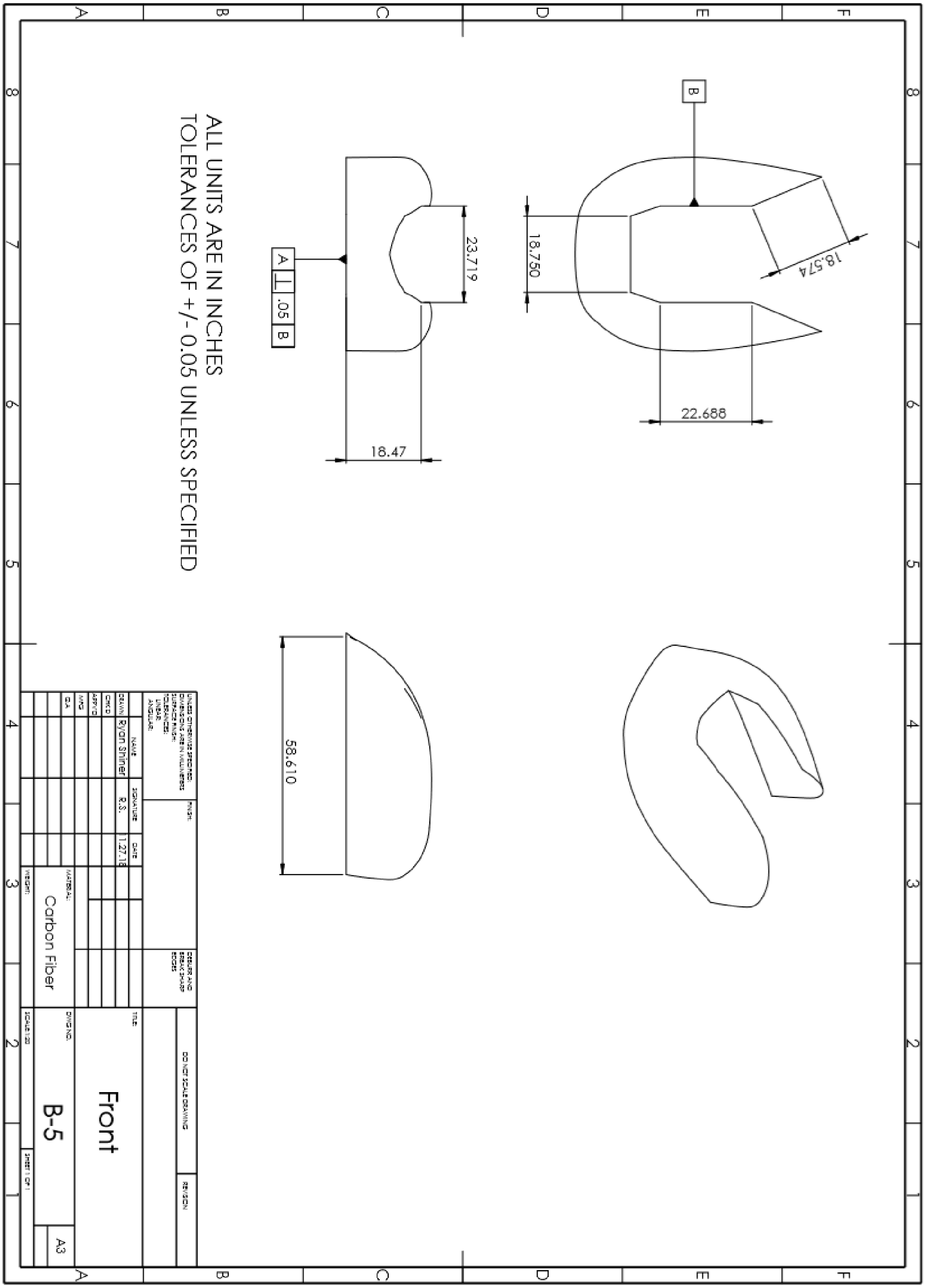

10.00
26.00
12.00
13.28
143.78°
147.41°
137.62°
5.50
24.72
Ryan S.
11.8.18
Carbon Fiber
Drawing 2
Nose
A3
DO NOT SCALE DRAWING

B-2

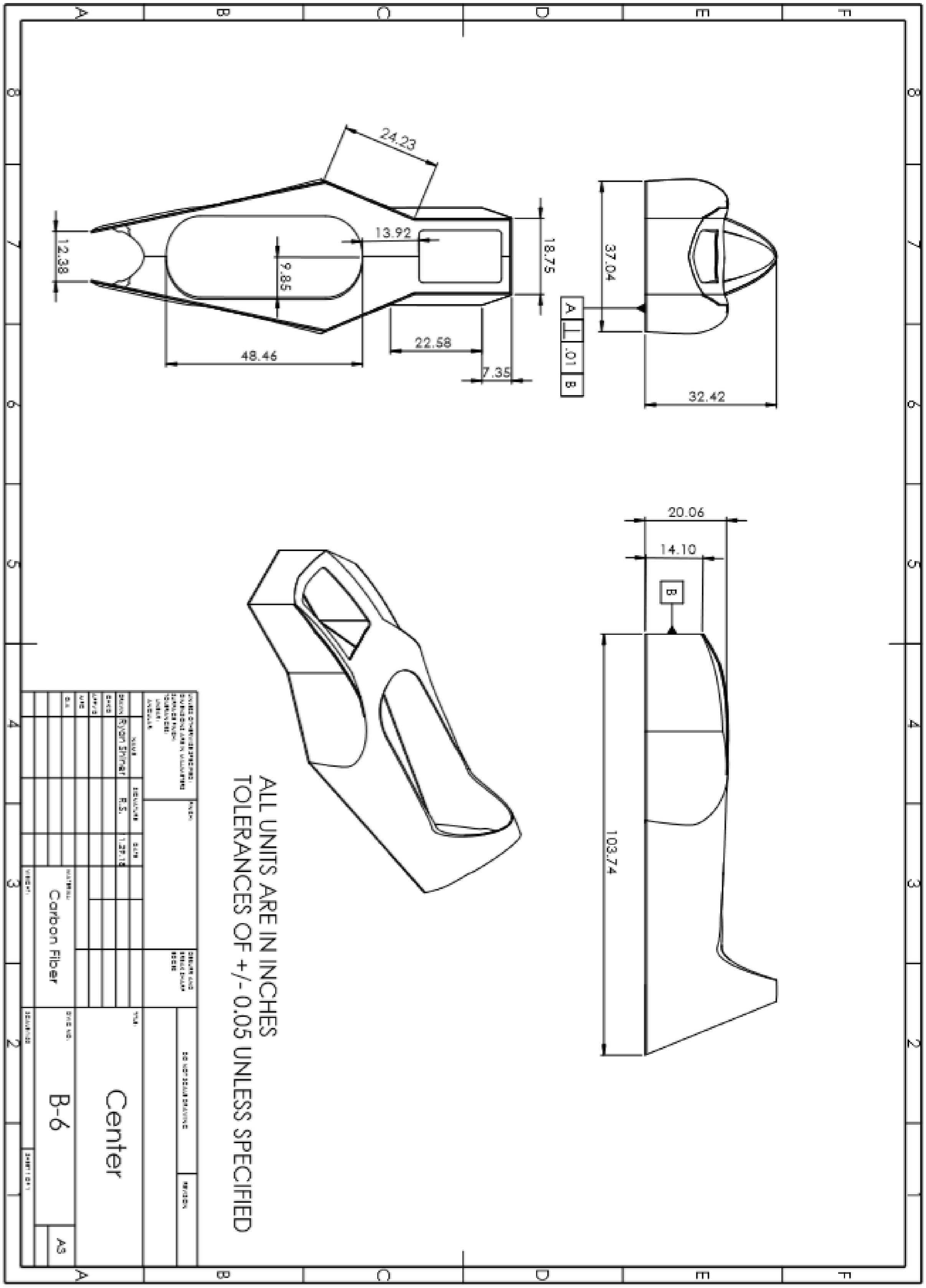

23.371
15.250
20.000
0.125
23.250
Ryan shiner
Drawing 3
Hood
A3
DO NOT SCALE DRAWING


0.125
55.500
17.000
Ryan Shiner
Drawing 4
Side Panels (Front)
A3
DO NOT SCALE DRAWING
REVISION

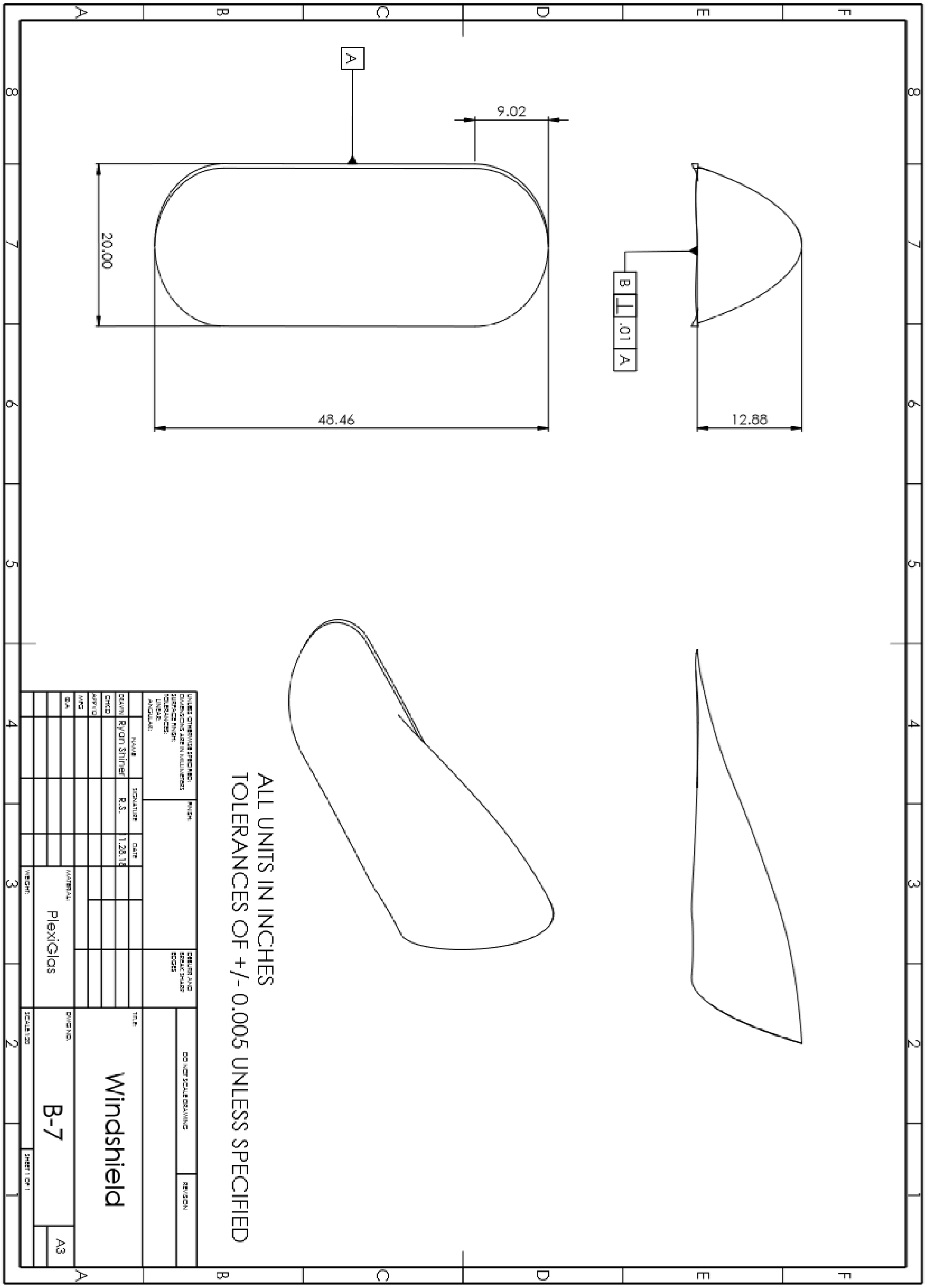
B-4


ALL UNITS ARE IN INCHES
TOLERANCES OF +/- 0.05 UNLESS SPECIFIED
23.719
18.750
18.574
22.688
18.47
58.610
A
.05
B
Ryan Shiner
R.S.
1.27.18
Carbon Fiber
Front
B-5
A3

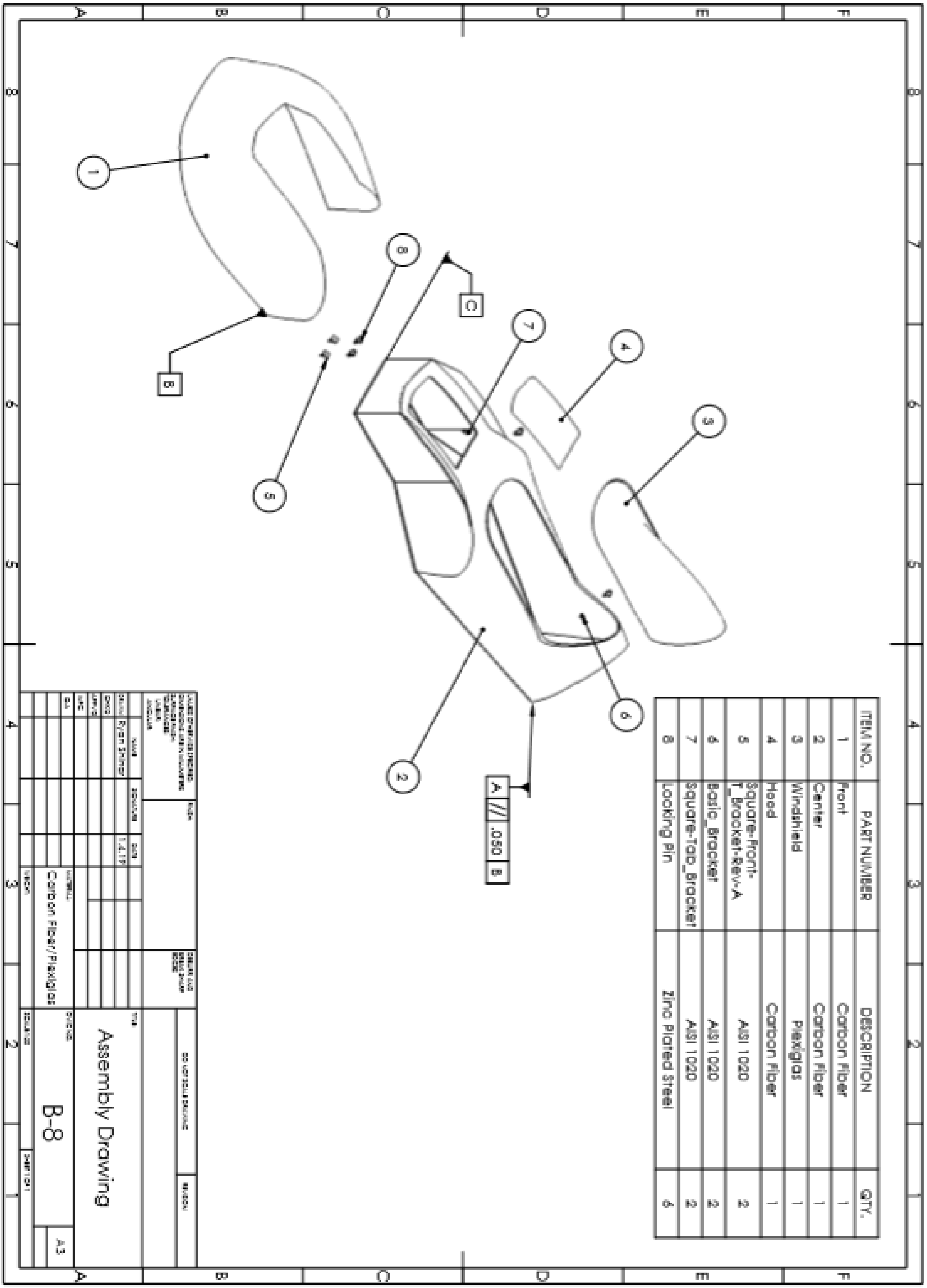
B-5


ALL UNITS ARE IN INCHES
TOLERANCES OF +/- 0.05 UNLESS SPECIFIED
24.23
13.92
12.38
9.85
18.75
37.04
48.46
22.58
7.35
.01
A
B
32.42
20.06
14.10
103.74
Ryan Shinier
R.S.
Carbon Fiber
Center
B-6
A3

B-6

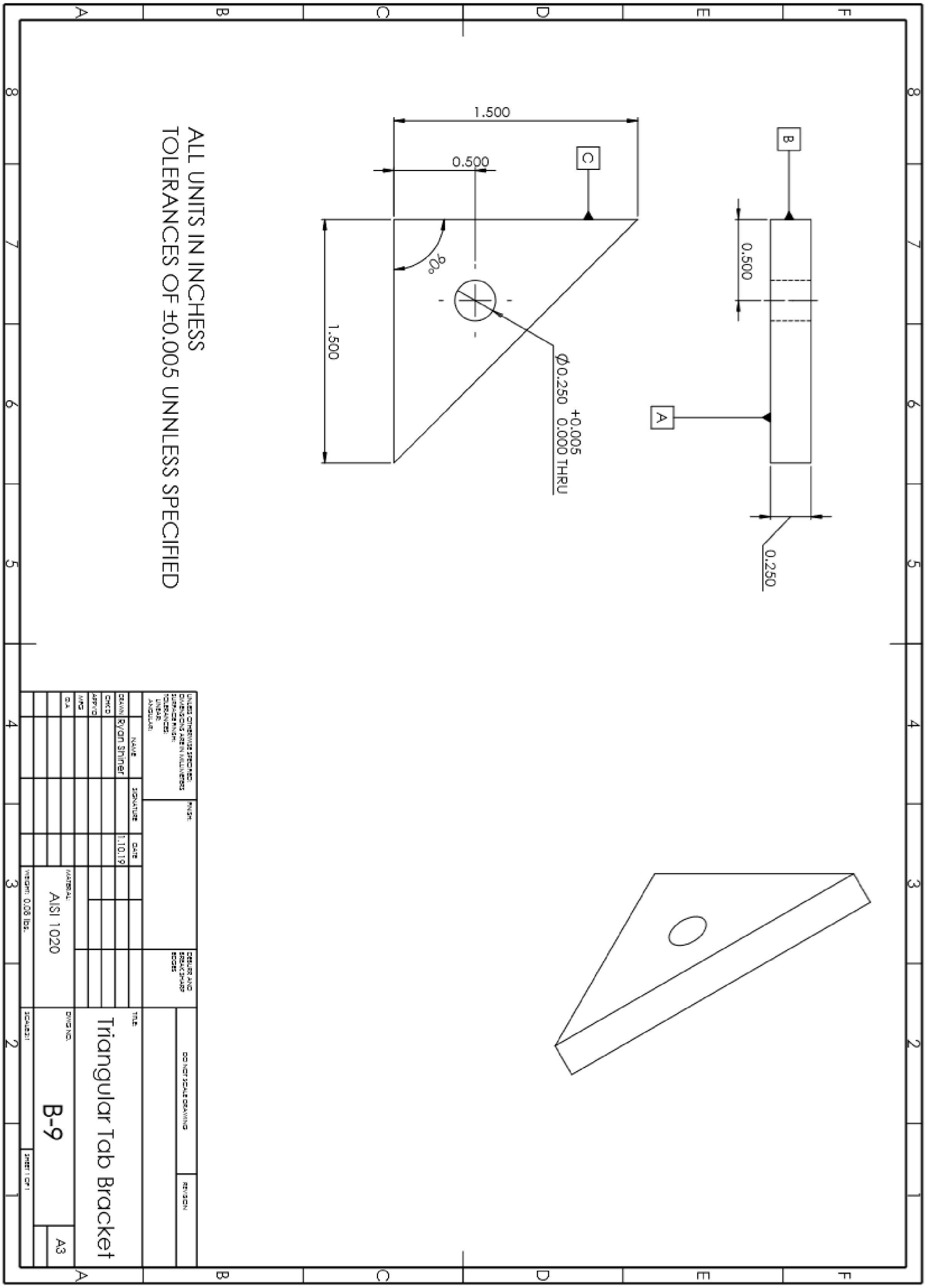

9.02
20.00
48.46
12.88
ALL UNITS IN INCHES
TOLERANCES OF +/- 0.005 UNLESS SPECIFIED
Ryan Shiner
R.S.
PlexiGlas
Windshield
B-7
A3

B-7

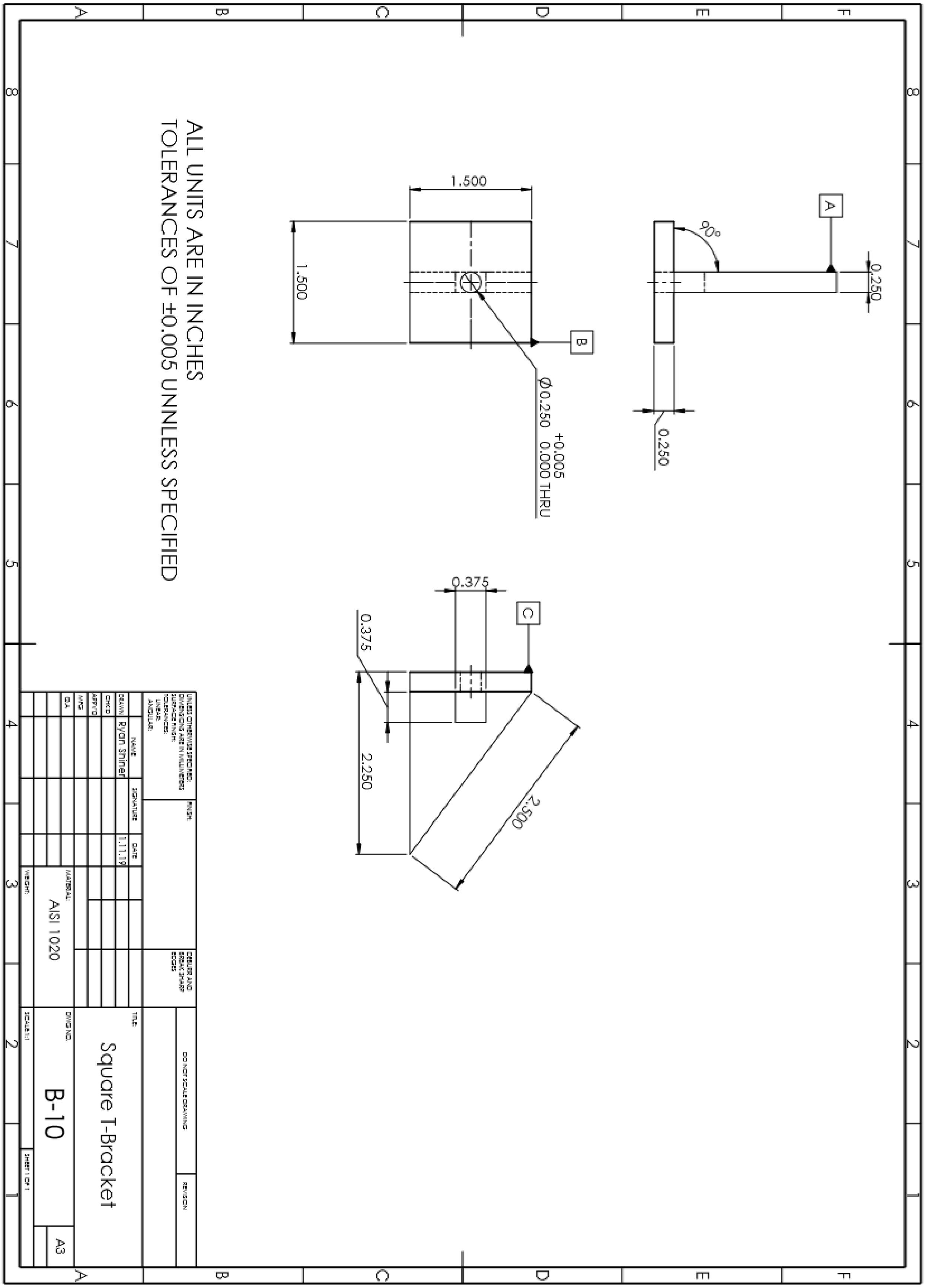


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Front	Carbon Fiber	1
2	Center	Carbon Fiber	1
3	Windshield	Plexiglas	1
4	Hood	Carbon Fiber	1
5	Square-Front-T_Bracket-Rev-A	AISI 1020	2
6	Basic_Bracket	AISI 1020	2
7	Square-Tab_Bracket	AISI 1020	2
8	Locking Pin	Zinc Plated Steel	6

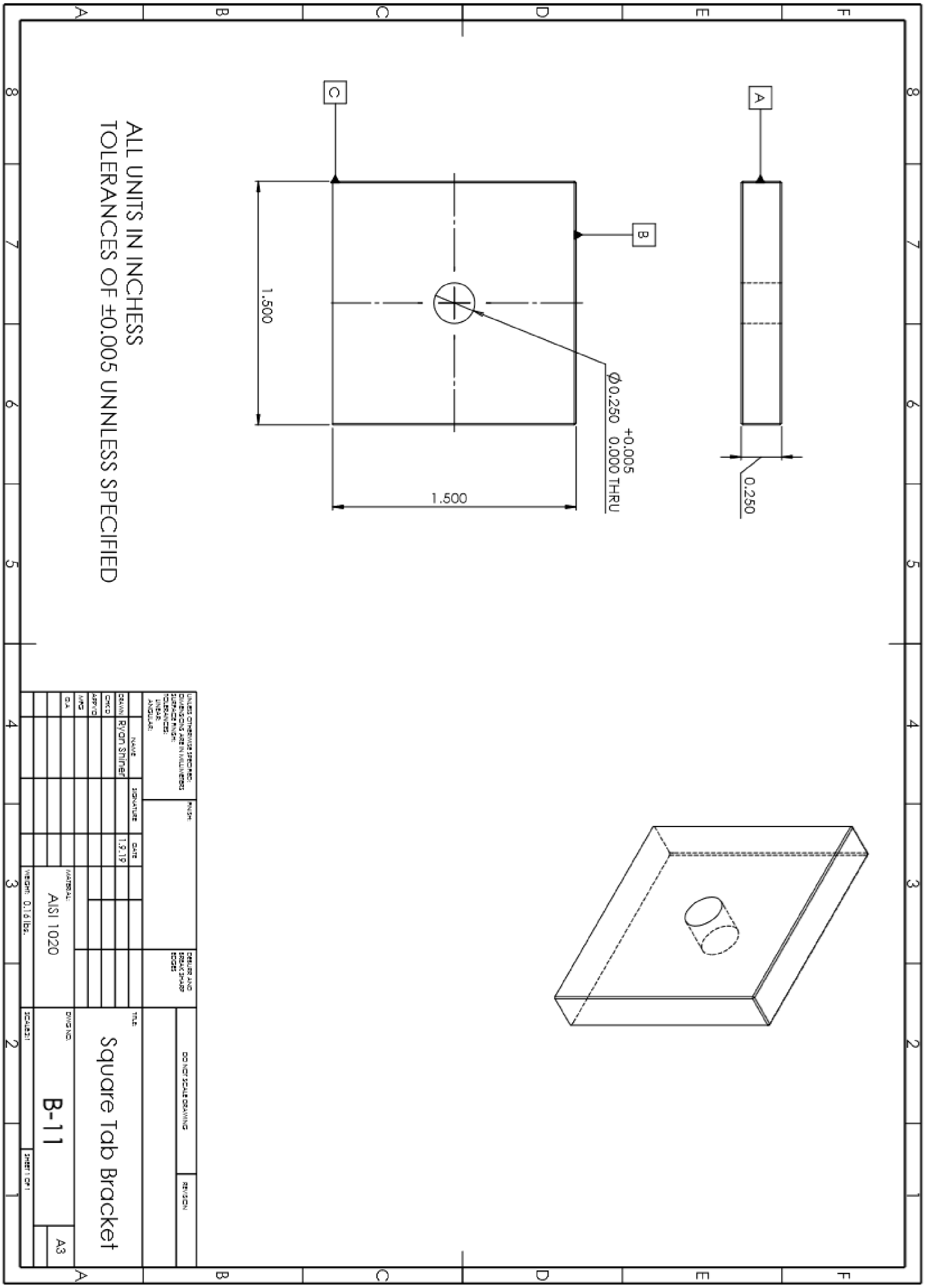
B-8


ALL UNITS IN INCHESS
TOLERANCES OF ±0.005 UNNLESS SPECIFIED
1.500
0.500
1.500
90°
C
B
A
0.500
0.250
Ø0.250 +0.005 0.000 THRU
Ryan Shiner
1.10.19
AISI 1020
Triangular Tab Bracket
B-9
A3
WEIGHT: 0.08 lbs.
DO NOT SCALE DRAWING

B-9

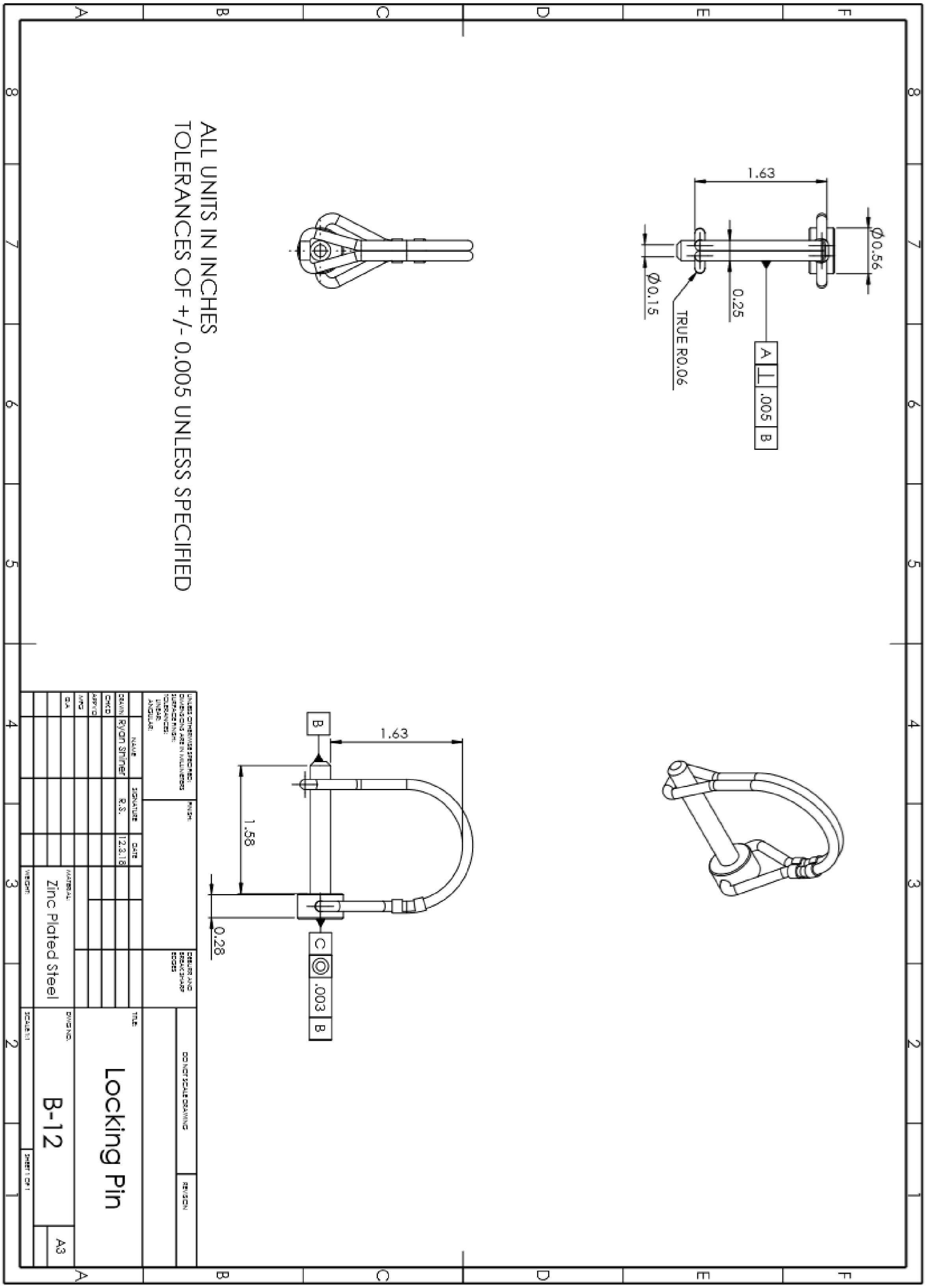


ALL UNITS ARE IN INCHES
TOLERANCES OF ±0.005 UNNLESS SPECIFIED
1.500
1.500
Ø0.250 +0.005 0.000 THRU
0.250
0.250
90°
A
B
C
0.375
0.375
2.250
2.500
NAME
SIGNATURE
DATE
DRAWN
Ryan Shiner
1.11.19
CHK'D
APPV'D
MFG
Q.A
FINISH:
DEBURR AND BREAK SHARP EDGES
MATERIAL:
AISI 1020
WEIGHT:
TITLE:
Square T-Bracket
DWG NO.
B-10
A3
SCALE:1:1
SHEET 1 OF 1
DO NOT SCALE DRAWING
REVISION

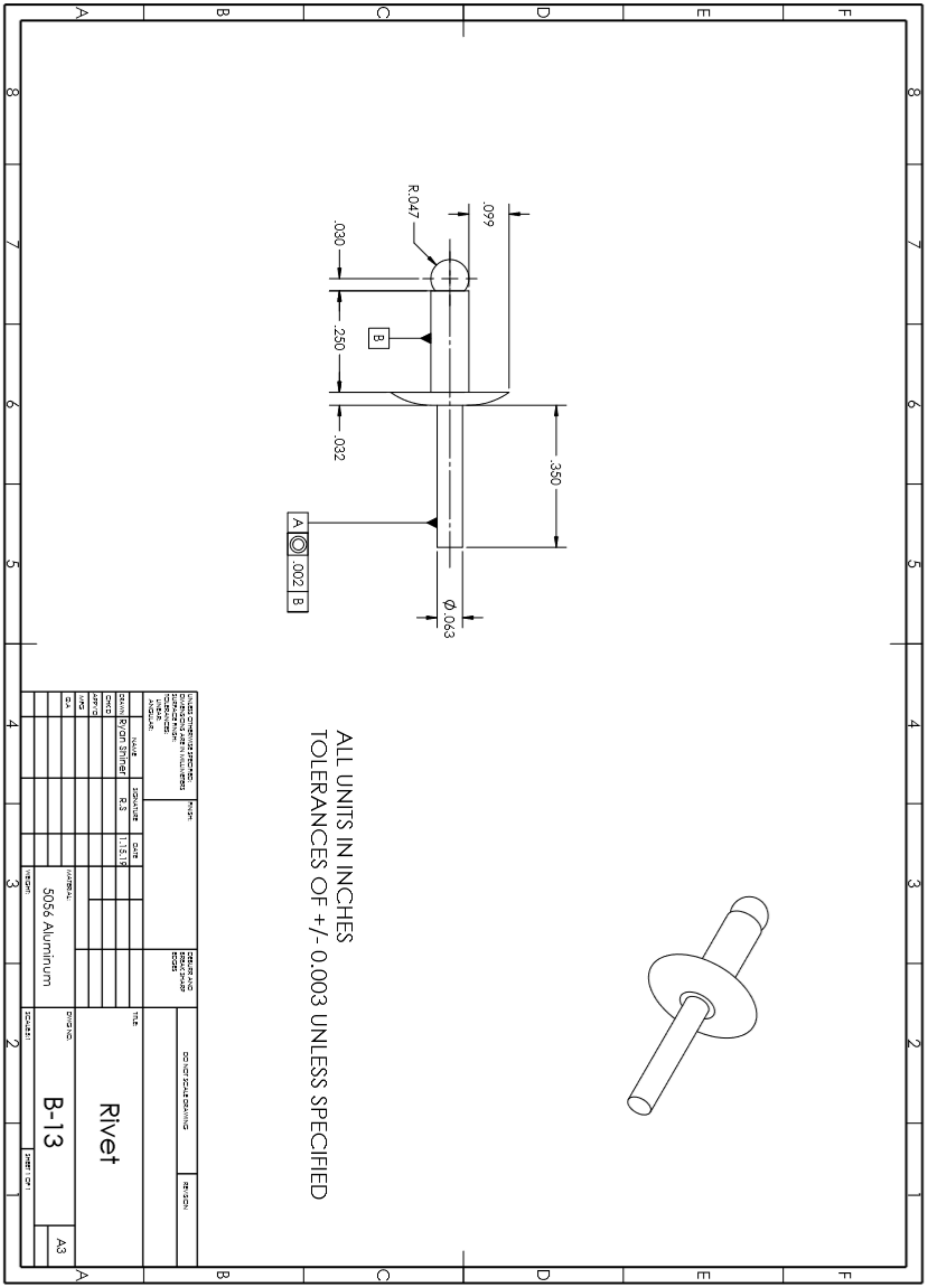


A
B
C
1.500
1.500
Ø0.250 +0.005 0.000 THRU
0.250
ALL UNITS IN INCHESS
TOLERANCES OF ±0.005 UNNLESS SPECIFIED
DRAWN
CHK'D
APPV'D
MFG
Q.A
NAME
SIGNATURE
DATE
Ryan Shiner
1.9.19
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
TITLE:
Square Tab Bracket
MATERIAL:
AISI 1020
WEIGHT: 0.16 lbs.
DWG NO.
B-11
A3
SHEET 1 OF 1

B-11

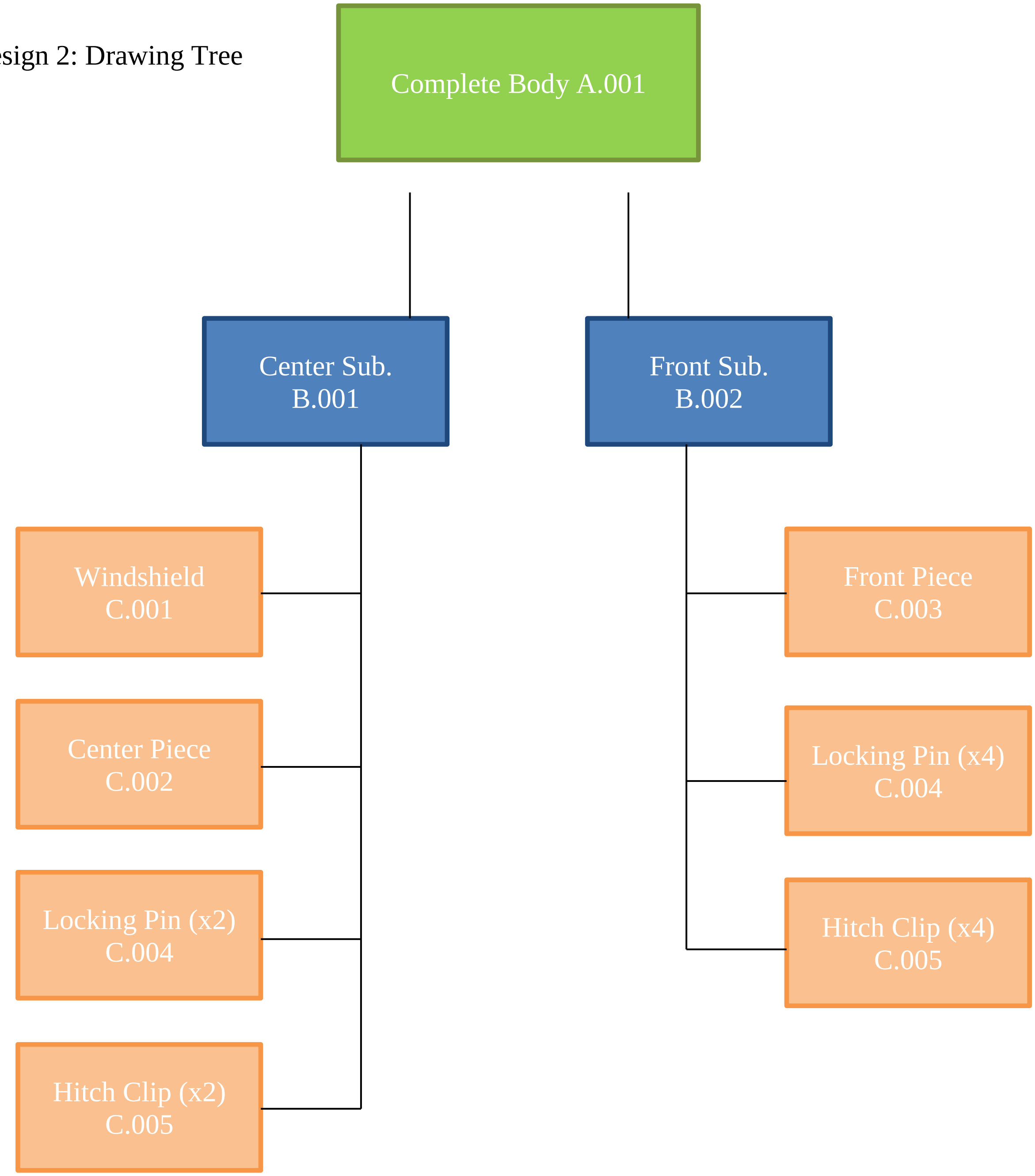

ALL UNITS IN INCHES
TOLERANCES OF +/- 0.005 UNLESS SPECIFIED
1.63
Ø0.56
Ø0.15
0.25
TRUE R0.06
A ⊥ .005 B
B
1.63
1.58
0.28
C ◎ .003 B
Ryan Shiner
R.S.
12.3.18
Zinc Plated Steel
Locking Pin
B-12
A3

B-12


.099
R.047
.030
.250
B
.032
.350
A
.002
B
Ø.063
ALL UNITS IN INCHES
TOLERANCES OF +/- 0.003 UNLESS SPECIFIED
Ryan Shiner
R.S
5056 Aluminum
Rivet
B-13
A3

B-13

Design 2: Drawing Tree



B-14

APPENDIX C – Parts List and Costs

Part Identity	Part Description	Source	Cost
Carbon Fiber	Catmobile Body	CWU	Free
Steel Locking Pins and Rivets	0.25” x 1.92”	McMasterCarr	$48
Hitch Clips	(12) 3/16in thick, 2 ¼in long	CWU	Free
Diamond Coated Cutting Wheel	(10) 25mm wheels, (2) 3mm mandrel	CWU	Free
		Cost Total:	$48
Notes: #1	Have access to the Dremel		

APPENDIX D – Budget

Budget for Electrathon Vehicle’s Body	
Parts Listed:	**Cost:**
Fasteners:	
Locking Pins	$48
Hitch Clips	Free
Tools:	
Diamond Coated Cutting Wheels	Free
Dremel Tool	Free
Body:	
Carbon Fiber	Free
Total Cost	$48

APPENDIX E – Schedule

PROJECT TITLE: Electrathon (Body)
Principal Investigator: Ryan Shiner

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	%Comp.	S.	October				November				Dec.		January			
1	Proposal																		
1a	Outline	0.5	1		X														
1b	Intro	3	2		X	X													
1c	Methods	6	5								X								
1d	Analysis	6	7.25				X	X	X	X		X	X	XX					
1e	Discussion	5	4.5										X						
1f	Parts and Budget	3	5							X									
1g	Drawings	8	10						X	X	X	X	X						
1h	Safety Form	1	1																
1i	Schedule	3	3							X									
1j	Conclusion	2	2										X						
	subtotal:	37.5	40.75																
2	Analyses																		
2a	Frontal Area (1st design)	1	1				X												
2b	Weight of Materials	0.25	0.5				X												
2c	Weight of Body (1st design)	0.25	0.5					X											
2d	Changing the Floor (1st design)	0.5	0.5					X											
2e	Removing Tail (2nd design)	0.5	0.5							X									
2f	Side Panel Cut-Outs (2nd design)	0.5	0.5							X									
2g	Weight of Body (2nd design)	0.5	0.75								X								
2h	Side Panel Critical Load (2nd design)	0.5	0.75								X								
2i	Front Panel Critical Load (2nd design)	0.5	0.75									X							
2j	Side Panel Deflection (2nd design)	0.5	0.5									X							
2k	Front Panel Deflection (2nd design)	0.5	0.5									X							
2l	Frontal Area (2nd design)	0.5	0.5									X							
	subtotal:	6	7.25																
3	Documentation																		
3a	Part 1 Top Drawing (1st design)	1	0.75						X										
3b	Part 2 Nose Drawing (1st design)	1	1							X									
3c	Part 3 Hood Drawing (1st design)	0.5	0.5								X								
3d	Part 4 Side Panel Drawing (1st design	0.5	0.5									X							
3e	Part 5 Front Drawing (2nd design)	1.5	4											X					
3f	Part 6 Center Drawing (2nd design)	2	4											X					
3g	Part 7 Windshield Drawing (2nd desig	1.5	3											X					
3h	Part 8 Mounting Brackets (2nd Design	4	7																
3i	Final Assembly (2nd design)	3	3													X			
	subtotal:	15	23.75																

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	subtotal:	15	23.75	
4	Proposal Mods			
4a	Project Scheduling	4	5	
4b	Project Inventory	2	2	
4c	Crit Des Review	5	3	
	subtotal:	11	10	
7	Part Construction			
7a	Buy Carbon Fiber	N/A	N/A	
7b	Cut Carbon Fiber	6	10.5	X X
7c	Mold Carbon Fiber	N/A	N/A	
7d	Buy Steel Flat Bar	1	1	X
7e	Buy Fastening Hardware	1	1	X
7f	Cut Mounting Hardware	12	14	X X
7g	Take Part Pictures	0.25	0.25	X
7h	Update Website	0.75	2	X
7i	Manufacture Plan	2	4	X X X X X X
	subtotal:	23	32.75	
9	Device Construct			
9a	Assemble Body to Frame	5	15	X X
9b	Assemble Aluminum to Body	N/A	N/A	
9e	Take Device Pictures	0.25	0.25	X
9f	Update Website	5	4	X
	subtotal:	10.25	19.25	

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10	Device Evaluation			
10a	List Parameters	1	1	X
10b	Design Test & Scope	5	5	X
10c	Obtain resources	3	2	X X
10d	Make test sheets	3	2	X
10e	Plan analyses	4	6	X X X
10g	Test Plan	2	2	X
10h	Perform Evaluation	6	6.5	X X X
10i	Take Testing Pics	0.5	0.5	X
10h	Update Website	1	1.5	X
	subtotal:	25.5	26.5	
11	495 Deliverables			
11a	Get Report Guide	1	1	X
11b	Make Report Outline	2	3	X X X X X X X
11c	Write Report	10	14	X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
11d	Make Slide Outline	2	3	X
11e	Create Presentation	4	3.5	X
11f	Make CD Deliv. List	2	3	X
11g	Write 495 CD parts	1	1	X
11h	Update Website	2	4	X
11i	Project CD	1	1	X
	subtotal:	25	33.5	
	Total Est. Hours=	153.25	193.8	=Total Actual Hrs

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APPENDIX F – Expertise and Resources

Expertise

All the following individual's expertise was counseled during this project:
Charles Pringle – General advisor for the entire EV project.
Matt Burvee – Construction phase assistant.

Resources

Electrathon America Handbook
Project Website: https://rshiner13.wixsite.com/mysite

APPENDIX G – Testing Data

Data for Test 1

Whole Body			Front End Only			Tail Only	
	Time (sec)			Time (sec)			Time (sec)
Trial 1			Trial 1			Trial 1	
Trial 2			Trial 2			Trial 2	
Trial 3			Trial 3			Trial 3	
Avg.			Avg.			Avg.	
(For getting driver out of vehicle)			(For changing front tires of batteries)			(For changing rear tire)	

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Data for Test 2

Impact Test			
Height Dropped (in)	Energy (J)	Pass/Fail	Deflection (in)
9	10.20		
18	20.35		

Notes: 10 lb. weight dropped onto center of panel.
11.25" away from both supporting beams.
Panel is 2.50" off the ground.
Pass Criteria: No visible damage to the panel.
Video recording in slow-motion to determine deflection.

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APPENDIX H – Evaluation sheet (Testing)

Data from Test 1

Whole Body			Front End Only			Tail Only	
	Time (sec)			Time (sec)			Time (sec)
Trial 1	25.2		Trial 1	5.6		Trial 1	2.7
Trial 2	26.7		Trial 2	5.5		Trial 2	2.7
Trial 3	24.3		Trial 3	5.2		Trial 3	2.5
Avg.	25.4		Avg.	5.4		Avg.	2.6
(For getting driver out of vehicle)			(For changing front tires of batteries)			(For changing rear tire)	

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Data from Test 2

Impact Test			
Height Dropped (in)	Energy (J)	Pass/Fail	Deflection (in)
9	10.20	Pass	~ 0.50
18	20.35	Pass	~ 1.25

Notes:	10 lb. weight dropped onto center of panel.
	11.25" away from both supporting beams.
	Panel is 2.50" off the ground.
	Pass Criteria: No visible damage to the panel.
	Video recording in slow-motion to determine deflection.

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APPENDIX I – Testing Report

Introduction (test one)

Requirements:
It is required that the entire body is capable of being removed by two people within 30 seconds.

Parameters of Interest:
This test looked at how long it took to remove the whole body, just the front end, and just the tail end. All three parts were done with three trials and the average was taken.

Predicted Performance:
It was predicted that it would take two people to remove the entire body within 30 seconds, just the front end within 8 seconds, and just the tail end within 4 seconds.

Data Acquisition:
The data acquired was the time it took to remove the part(s) of the body for each section of the test. This was done using a stopwatch and recorded into an Excel spreadsheet.

Schedule:
This test took place on April 6th, 2019. It took approximately 30 minutes to complete and was recorded in section 10h of the Gantt chart in Appendix E.

Test Procedure

Summary/Overview:
For this test, two people timed how long it took for them to remove the entire body of the vehicle, just the front end, and just the tail end. Each part of the test had three trials to obtain an average. The testers were equipped with needle-nose pliers in order to remove the clips more efficiently. To remove the entire body took an average of 25.4 seconds. It was predicted that this should be done in around 30 seconds. As for the front end only, it took the testers an average of 5.4 seconds (8 seconds was the predicted value). The tail end took an average of 2.6 seconds (4 seconds was the predicted value). All of these times included how long it took the testers to set the pieces aside from the vehicle.

Time/Duration:
This test took approximately 30 minutes to complete.

Place:
This test took place in the Fluke Lab of Hogue Hall at Central Washington University

Resources Needed:

- Complete body of the electric vehicle
- 2 people
- 2 needle-nose pliers
- Stopwatch

- Excel document to keep track of results
- Adequate space to set body aside from vehicle

Procedure:

1. Ensure body is fully fixed to the frame (all pins are through the body and pinned down).
2. Provide yourself adequate space to be able to walk around the vehicle and set body components aside.
3. Each person must have needle-nose pliers readily available.
4. Start stopwatch and immediately begin removing the whole body by removing the clips with the pliers and setting the body pieces to the side.
5. Stop the stopwatch once all pieces have been removed.
6. Record time taken to remove the piece(s) in an Excel document.
7. Repeat all steps two more times and take the average time and record it in the Excel document.
8. After the three trials have been completed, repeat steps 1-7 except only remove the front piece.
   Now, repeat steps 1-7 but only remove the tail piece.

Risk/Safety:
As always, it is required to wear close-toed shoes and safety glasses in Hogue's labs. Since there isn't any heavy lifting there is no real danger. Gloves are recommended however, because the bottom edges of the carbon fiber can be sharp.

Deliverables

Parameter Values:
The entire body was removed in an average of 25.4 seconds. The front end took an average of 5.4 seconds and the tail end took an average of 2.6 seconds to remove.

Success Criteria Values:
Success was considered to be anything less than the predicted times or no more than 10% greater than them. Since all times came in below their predicted values, the test was a success.

Conclusion:
This test demonstrated that the vehicle's body can be removed by two people in under 30 seconds. This is important because the body needs to be able to be removed quickly in the event of something such as a flat tire. Additionally, if the driver is stuck in the vehicle then they could be accessed quickly by rescuers.

Introduction (test two)

Requirements:
It is required that the body is able to withstand small impacts without fracturing (20 joules or less).

Parameters of Interest:
The carbon fiber's ability to withstand small impacts was the focus of this test. The deflection as well as the behavior of the carbon fiber was observed and recorded.

Predicted Performance:
It was predicted that the carbon fiber would deflect no more than 1 inch, and if it did deflect more than that then it would fracture due to its rigidity.

Data Acquisition:
The data acquired was the deflection of the carbon fiber panel and whether it survived the impact or not (pass/fail criteria).

Schedule:
This test took place on April 22nd, 2019. It took approximately 30 minutes to complete.

Test Procedure

Summary/Overview:
This test found the deflection and behavior of the carbon fiber with a known load impacting it perpendicularly. This was done using the 10 lb. glide weight at Central Washington University and a scrap piece of carbon fiber that was left over from the body. The 10 lb. weight was dropped vertically onto the center of the scrap panel. The panel was raised 2.5" off the ground with wood beams holding it up at each end. The center of the panel was 11.25" away from each of the beams. The weight was initially dropped 9" above the panel to see if the panel could survive the impact. The weight possessed 10.20 joules of energy at this height. The panel was able to withstand this impact and it deflected approximately 0.5" before returning to its normal shape.
Next, the weight was dropped from 18" (which equates to 20.35 joules of energy). Again, the carbon fiber panel survived the impact with no noticeable damages to either side of it. The panel deflected an approximate of 1.25" on this trial. It was predicted that the panel would only have deflected 1" and might even break, so the test showed that the carbon fiber is stronger than originally anticipated. This test demonstrated that the vehicle should be able to handle a collision at low speeds and still have its body intact afterwards.

Time/Duration:
This test took approximately 30 minutes to complete.

Place:
This test took place in the Machine Shop of Hogue Hall at Central Washington University
Resources Needed:

- Scrap piece of carbon fiber from the body

- 10 lb. glide weight
- Camera
- 2 people
- Excel document to keep track of results
- Tape Measure
- Marker

Procedure:

1. Obtain the piece of carbon fiber as well as something to hold it up from two ends (at least 2.5 inches off the ground).
2. Provide yourself adequate space to be able to walk around the test piece.
3. Measure the piece of carbon fiber to mark its center point, as well as its dimensions.
4. Place camera so that it is parallel to the top surface of the carbon fiber piece.
5. Have one person set the weight on the marked center point.
6. Begin recording with camera (slow motion is preferred).
7. Have the person lift the weight up halfway (9 inches) and release the weight.
8. Stop video recording.
9. Review video and look at how much the panel deflected.
10. Record the data and state whether the panel survived the impact (no noticeable damages).
11. Repeat all steps if the panel survived the impact, except do step 7 with the weight at full height (18 inches)

Risk/Safety:

As always, it is required to wear close-toed shoes and safety glasses in Hogue's foundry. Since the load being used is relatively small, there isn't any great dangers involved in the testing. However, there is a possibility of the weight landing on a foot or hand, so it is important that all testers keep their hands and feet away from the falling weight.

Deliverables

Parameter Values:

The carbon fiber panel deflected an approximated 1.25" when the weight was dropped from a height of 18". It also showed no damage on either side of the panel after it had withstood the impact.

Calculated Values:

From a height of 9" above the panel, the weight possessed 10.20 joules of energy. At its full height of 18", the weight had 20.35 joules of energy. This slightly exceeded the required 20 joules of energy that the body is required to withstand without failing.

Success Criteria Values:
Since the carbon fiber earned a pass in the pass/fail category, and it did this at an impact of 20.35 joules of energy, it was a successful test. This shows that the vehicle meets its requirement of being able to withstand an impact of 20 joules of energy.

Conclusion:
This test demonstrated that the vehicle’s carbon fiber body can survive an impact of 20 joules of energy. It also showed that the carbon fiber is more flexible than previously predicted. It deflected roughly a ¼” more than expected without breaking. This provides valuable information and allows the properties of the carbon fiber to be understood at greater lengths.

APPENDIX J – Safety Job Hazard Analyses

JOB HAZARD ANALYSIS
{Insert description of work task here}

Prepared by: Ryan Shiner	Reviewed by: Approved by:

Location of Task:	CWU: Materials Lab
Required Equipment / Training for Task:	Rotary Cutting Tool (Dremel with diamond coated wheel)
Reference Materials as appropriate:	https://www.elevatedmaterials.com/4-best-methods-for-cutting-carbon-fiber-by-hand-and-not-ruining-your-parts/

Personal Protective Equipment (PPE) Required (Check the box for required PPE and list any additional/specific PPE to be used in "Controls" section)						
Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
☒	☒	☒	☐	☒	☒	☒
Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.						

PICTURES (if applicable)	TASK DESCRIPTION	HAZARDS	CONTROLS
	Placing backing behind carbon fiber		
	Marking cutting lines with sharpie		
	Cut desired panels with Dremel tool	**Cutting hand/finger**	**Clamping down the carbon fiber for less moving pieces**

APPENDIX K – Resume

RYAN SHINER

17209 39th St. Ct. E Lake Tapps, WA 98391- 253-312-0561
rshiner13@gmail.com

OBJECTIVE

Strive to be an active contributor and diligent engineer. Continue to be exceptionally hard working and dedicated with a solid eye for detail. Demonstrate talents in designing and analyzing mechanical devices and projects. Acquire knowledge from work experience towards a successful professional career.

SKILLS

- Certified Engineer in Training
- Certified in SolidWorks
- Trained in AutoCAD
- Knowledgeable in PLC's
- Trained in Microsoft Suite (Word, Excel, PowerPoint)
- Knowledgeable in Mechanical Design
- Strong Communication
- Computer and Peripheral Operation Knowledge
- Able to Multi-Task

EXPERIENCE

JUNE 2018 – SEPTEMBER 2018
GENERAL ASSISTANT - HOMESTEAD BREW – SUMNER, WA
Primarily involved with retrieving orders from various businesses and delivering the items to Homestead Brew, ensuring all inventory was stocked. It also included miscellaneous tasks such as making Excel spreadsheets to keep track of business expenses, inventory, and payroll.

JUNE 2017 – SEPTEMBER 2017
PICKER - AMAZON – KENT, WA
Receiving orders for various goods that had to be retrieved, packaged, and shipped quickly. Have knowledge of the Kiva system used in warehouse. Prioritizing tasks to ensure maximum productivity. Meeting daily personal goals.

JUNE 2016 – AUGUST 2016
FLOORMAN - AUVIL FRUIT CO. – ORONDO, WA
Operating equipment designed to package and transport products. Worked at a fast pace ensuring orders were being met in a timely manner without sacrificing quality. Assisted other team members, confirming the overall operation ran smoothly.

EDUCATION

CENTRAL WASHINGTION UNIVERSITY
Mechanical Engineer Technologies, BS | 3.44 GPA |
2015 - 2019
Relevant Coursework: SolidWorks, AutoCAD, Mechanical Design, Information Technology, Engineering Project Cost Analysis, Business and Professional Speaking

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