Modular Hardtop

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Modular Jeep TJ Hardtop

By:

Dennis Fedorchuk
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Introduction:

Description:
The purpose of this project is to apply knowledge gained in the Mechanical Engineering Technology program at Central Washington University. It will address all the various aspects of engineering, from project management to designing a product that meets engineering standards. This project will address the complications involved in designing a modular hardtop for a vehicle. The courses in this program will help address the problem in many ways. Classes such as Strength of Materials, Mechanical design, Plastics and Composites, Statics, and Thermodynamics have led the class to a point where an individual can create a product that is viable.

Motivation:
The motivation behind this project was seeing a lack of diverse options on the market for Jeep TJ hardtops. There are three hardtop options for a Jeep TJ owner, an individual either buys an OEM hardtop, or one of the two other aftermarket options available. Out of the three options, there is only one hardtop that is modular, and it only has the capability to separate into two sections.

Function:
A device that protects a user from the elements.

The requirements for the hardtop are to:

1. Keep the profile of the modular hardtop as close to an original hard top profile as possible.
2. Have the capability to bolt a roof rack directly to the hard top with an option of going through the hardtop and bolting a roof rack to the roll cage.
3. Be able to handle a 150-200 lb. load (with a roof rack).
4. Have the tensile strength of the hardtop equal the tensile strength of an OEM hardtop.
5. Adapt existing windows for convenience.
6. Reduce noise level by 15%
7. Reduce heat loss by 20%
8. Be able to deconstruct the product into a storage space of 2.5 ft by 3 ft by 2 ft.
9. Be able to withstand water seeping through the connecting sections for a time period of 10 minutes of a constant supply of water.

Success Criteria:
This project would be considered successful if the hardtop can be constructed in a simple manner and meet most of the requirements listed above.
Scope:
The scope of the project is to create a hardtop that is functional, has the capabilities of a standard Jeep TJ hardtop and, is convenient for storage purposes.

Engineering Merit:
The engineering merit behind this project involves stress analysis, compression testing and tensile strength testing.

The Success of the Project:
The success of the project depends on the knowledge gained in the progression of the project, whether the hardtop requirements are met, and whether the product produces results that can either confirm that the idea is feasible or not. This project will educate an individual in processes such as laying-up fiberglass, engineering standards applied to creating an original hardtop and, calculating the forces involved in designing a practical hardtop. A final product that performs well under the set requirements will show how applying knowledge gained in the MET program has helped individuals become a better engineer. If the hardtop can be assembled and disassembled, then the project is a successful one.

Design and Analysis:
Approach
Design Description

Benchmark:
In this project, the benchmark product will be an OEM Jeep TJ Hardtop. The issues with an OEM hardtop are: 1. They are not modular. 2. Storage is an issue if an individual cannot use a hoist in your garage 3. They are not insulated. 4. They are not designed to handle more than 100 lbs. of weight.

Performance Predictions:
Description of Analyses:
Analysis: (Design Issues, Calculated Parameters, Best Practices)
Green Sheet 1:

Design Issue:
The Issue presented in the 1st Green Sheet was the design of a square tubular frame for the side panels that could handle a 400 lb. point load.

Calculated Parameters:
The parameters of the frame are that it must withstand a point load of 400 lb. With this value, the maximum shear and moment that would be applied can be found. The max. shear and moment values allow for the maximum stress, minimum stress, mean stress, alternating stress, and stress ratio to be calculated. The stress values give parameters to then find a material with material properties that suffice for the frame design.
**Best Practices:**
From the Machine Elements in Mechanical Design 6th Edition the material properties can be found in Table 15-15 for Hollow Tubing. The properties given are; the outside diameter, inside diameter, wall thickness, area, weight/ft, and section properties. These values are then applied in rougefab.com/tube-calculator to find materials that would work for the project. From the website, there were three suggestions for materials that should be used. The three materials are 7075-T6 Aluminum, DOM 1020, and 4130 N. Of these three, DOM 1020 will be used due to it being a material that would be easier to weld.

**Green Sheet 2:**
**Design Issue:**
Bolt size needed for a shear force load of 400 pounds at the center of the panel where panels Top Front and Top Rear connect.

**Calculated Parameters:**
From calculating the moment of inertia, Q and using the shear force given, the shear flow can be calculated. This gives the shear force per nail in the spacing they are orientated in. With this force, the bolt size requirement can be found.

**Best Practices:**
Using 4140 annealed steel will allow an individual to use ¼” bolts. Depending on the bolts used, the size of the bolts can vary. The other option is to use more bolts which will allow an individual to use a smaller diameter bolt.

**Green Sheet 3:**
**Design Issue:**
Calculating the critical load the side panel tubular frame can handle before it would buckle.

**Calculated Parameters:**
By calculating the radius of gyration, slenderness ratio, column constant and applying the fixidity of the beam structure an individual then has to choose the Johnson formula to calculate the critical load.

**Best Practices:**
With the value calculated there should not be a problem with the tubular frame buckling.

**Green Sheet 4:**
**Design Issue:**
Calculating the angle of deflection at a load to then calculate the flexural rigidity of the composite layup.

**Calculated Parameters:**
By applying the equation for beam deflection under a 3-point load an individual can find the angle of deflection with a certain load applied.
Best Practices:
To get more practical values a test specimen will be made to verify the value and then apply it to the flexural rigidity equation.

Green Sheet 5:
Design Issue:
Evaluating the things to consider when applying the lay-up process.

Calculated Parameters:
Layers Involved: (top to bottom)

Best Practices:
Remove excess resin
The epoxy to resin ratio is; for every 1 oz. of fabric that is used, 2.5 oz. of resin should be used.
If E-Z Epoxy is used, a 24-hour cure time is needed at 77 degrees Fahrenheit.

Green Sheet 6:
Design Issue:
Material Quantity

Calculated Parameters:
Fabric needed: Top Front: 7.8 yards, Top Rear: 10.2 yards, Rear: 1.4 yards, RH/LH: 8 yards Total: Approx. 27.4 yards (3 layers top and bottom for each part)
Epoxy Needed: 2.9 Gallons
Square Tubing: 180"

Best Practices:
1:2.5 Ratio for fabric to resin

Green Sheet 7:
Design Issue:
Top Rear Panel bolt size requirement/number of bolts

Calculated Parameters:
From calculating the moment of inertia, Q and, using the shear force given, an individual can calculate the shear flow. This allows an individual to calculate the shear force per
nail in the spacing they are orientated in. With this force an individual can then find the bolt size required.

*Best Practices:*
12” spacing. 5/32” Bolts. 3 Bolts on each side would be necessary for this size of bolt.

**Green Sheet 8:**

*Design Issue:*
Proper adhesive for installing the windows.

*Calculated Parameters:*
Shear force of the glued area.

*Best Practices:*
Standard 3M 08693 Auto Glass Urethane Windshield Adhesive will suffice. The tensile property needed in this case is 22 PSI, the tensile properties of 3M is 1200 PSI.

**Green Sheet 9:**

*Design Issue:*
Weight added on top of panels in storage.

*Calculated Parameters:*
Critical load that can be applied to a panel in storage.

*Best Practices:*
An overload of weight is unlikely.

**Green Sheet 10:**

*Design Issue:*
Welded Joints in the side panel tubular structure.

*Calculated Parameters:*
Weld Thickness

*Best Practices:*
1/8-1/4” welds are recommended for the welds.

**Green Sheet 11:**

*Design Issue:*
Heat loss of the hard top compared to the soft top on the Jeep currently.

*Calculated Parameters:*
Heat transfer with a soft top versus heat transfer with the modular hardtop.

*Best Practices:*
Use a infrared thermometer to measure the actual heat transfer through the materials.
Green Sheet 12:

**Design Issue:**
Noise Reduction calculation compared to the soft top on the Jeep currently.

**Calculated Parameters:**
Db level of each top.

**Best Practices:**
Use a decibel reader.

**Scope of Testing and Evaluation:**
The scope of the testing and evaluation of the parts made/constructed can be found in the testing/methods section.

**Device: Parts, Shapes, and Conformations:**
The device is comprised of 5 panels. For the construction of the panels, structural square tubing, fiberglass/resin, bolts, and windows make up the general parts of the hardtop. The individual panels will have to come together at the overlapping sections and the frame of the vehicle to support a 200 lb. load. In order to construct the hardtop in a manner that is structurally sound, the layup procedure, the square tubing, and welding method will have to conform to industry standards to ensure that the hardtop does not fail. To conform with these standards, materials such as approved structural square tubing will be used, proper welding techniques will be used and the proper layup procedure will be followed.

**Device Assembly: Attachments**
The device assembly will start with the side panels being bolted to the frame of the car, the rear panel being bolted to the car, the top rear panel being bolted to the side panels and the rear panel, last the top front panel being bolted in.

**Tolerances, Kinematics, Ergonomics**
Tolerances for the parts constructed can be found in the drawings provided in Appendix B.

**Methods and Construction:**

**Method:**
This project will implement standard composite layup procedures. The roof panels will be constructed of a structural foam core with a fiberglass layup on both sides. To get a high compression strength, the sandwich core is made of Polyurethane foam. Polyurethane foam is a high-density foam that provides great strength characteristics in a sandwich core layup. The E-glass fiberglass will be a four-layer layup on both sides of the foam core. E-glass is a great alternative to a material like carbon fiber which is 30% more expensive. For adhesion, an epoxy resin is used. Vacuum bagging the panels will get the layers to adhere to one another in a flat manner and alleviate anomalies in the characteristics of the bond. The side panels will be constructed in a similar manner.
There will be a tubular steel frame to support a load on the side panels as well. To create the molds of the individual sections, the use of an original hardtop will be used to get the profile of the hardtop.

Side Panel Process:

To get the profile of the side panels, an initial composite layup over an original hardtop will be made.

Stage 1: The process of getting the profile/shell entails:

1. The first step in achieving a mold is to cut the initial plastic layer, fiberglass layers (4), Breather Material, and Peel Ply to the correct dimensions. In general, an individual will want a few inches of material to overlap the edges.

2. Laying the first layer, the plastic layer over the original hardtop (to prevent the fiberglass layup from adhering to the hardtop)

3. Laying up the initial fiberglass layer in a 0-degree orientation. The resin to fiberglass ratio that will be used for the entire project is 2.5:1. For every ounce of fabric that is used 2.5 oz of resin is needed. To ensure that the proper amount of resin was used, use a measuring cup to mix the two-part resin/hardener. The pot life of the resin is two hours so, mixing the resin in small quantities is advised.

4. Laying up the second layer of the fiberglass in a -45-degree orientation. Follow the steps in step 3 to ensure the proper ratio of resin is used.

5. Laying up the third layer of the fiberglass in a 45-degree orientation. Follow the steps in step 3 to ensure the proper ratio of resin is used.

6. Laying up the peel ply layer. The peel ply layer prevents the breather material from adhering to the fiberglass layup also, it is perforated so the fiberglass layup can breathe and cure faster.

7. Laying up the breather material. The breather material allows the vacuum to be applied evenly.

8. Laying up the final plastic material. In this process, a hole(s) will be cut in the top to connect the vacuum. To seal the initial plastic layer to the top layer, tape will be applied around the perimeter of the layup.

9. Cure the layup for 24 hours. As the layup cures, test the edges for hardness. To make the trimming process easier, trim the excess material in the B-stage. The B-stage is when the material is around 75% cured.

10. Once the shell is 100% cured, the shell is ready for the next step in the process.

Stage 2: Applying the foam core material/Tubular Frame
1. Cut the foam material to size. For the contours a hot-knife or razer will be needed to trim the foam to the right size.

2. Glue bushings recessed in the foam in the bolt hole locations as illustrated in drawing 6.

3. Scuff up the interior of the mold with scotch-brite to ensure a good bond to the mold.

4. Use the epoxy used in Stage 1 to glue the foam core to the interior of the outside shell.

5. Wait 24 hours for the foam core to cure to the shell.

Stage 3: Applying the interior fiberglass layup

Repeat Steps 3-10 from the side panel process.

Top Panel Process:

Stage 1: The process of getting the profile/shell entails:

Repeat Steps 1-10 from the side panel process.

Stage 2: Applying the foam core material.

Repeat Steps 1-5 from the foam core material process described in the side panel.

Stage 3: Applying the interior fiberglass layup

Repeat Steps 3-10 from the side panel process.

Rear Panel Process:

Stage 1: The process of getting the profile/shell entails:

Repeat Steps 1-10 from the side panel process.

Stage 2: Applying the foam core material.

Repeat Steps 1-5 from the foam core material process described in the side panel.

Stage 3: Applying the interior fiberglass layup

Repeat Steps 3-10 from the side panel process.

Once all the panels are constructed, the holes in the panels should be lined up with one another and drilled.

To start this process:
1. Start with lining up the side panel hole locations with the factory per-drilled holes in the hub of the jeep body.
2. Once the holes are lined up, use a 3/8” drill bit to drill the holes located in the bottom of the panel.
3. Fasten the panel to the jeep and move to the other side panel.
4. Repeat Steps 1 and 2 for the other side panel.
5. Repeat Steps 1 and two for the rear panel. Drill the hinge holes for the rear window with the correct drill bit *TBD
6. Once all the bottom panels are attached place the top panels in the correct locations and repeat steps 1 and 2 for the top panels.

Painting Process:
1. Fill in areas that are not visibly appealing with body filler.
2. Sand the body filler with 320 grit sandpaper.
3. Once a smooth finish has been achieved, use scotch-brite to scuff up the entire panel.
4. Vacuum the dust off the panel.
5. Clean the panels with a tack cloth to remove residual dust from the panel.
6. Paint the panels with a fiberglass rated paint. Follow the instructions given by the manufacturer.

Installing the windows:
Once the panels are painted, they are ready for the windows to be installed.

1. Lay the side panels on the side and apply the 3M window adhesive to the perimeter of the window.
2. Lay the window in the correct orientation on the panels.
3. Wait 24 hours before moving the panels. Let the glue cure at room temperature.

Process Used:
The manufacturing process to produce the top shells:

1. The workspace needs to be in a dry area (preferably an area that maintains room temperature) In this case however, the preferred area is not available, so the workspace is in the garage. To ensure that the resin kicks off properly, the temperature of the layup will be maintained using a heated blanket and portable heaters. The recommended temperature is room temperature but by applying the resin to the fiberglass in the garage at a lower temperature, an individual will get more time to work with.
2. Cut the material(s) needed to length (material list and sizes needed located in the appendix k below)
3. Coat the hardtop with mold release.
4. Apply the base epoxy resin to the hardtop.
5. Apply the 1\textsuperscript{st} fiberglass layer and coat it with the epoxy quantity specified by the manufacturer. (For every oz of fabric 2.5 oz of resin)
6. Repeat Step 5 three more times for the remaining three fiberglass layers.
7. Apply the peel ply layer.
8. Apply the breather material.
9. Apply the bleeder material.
10. Apply the final plastic material.
11. Apply the sealant tape to the circumference of the layup. (ensure a good seal between the plastic layer and the hardtop)
12. Apply vacuum to the layup (until the shell hardens) to ensure uniform properties throughout the shell.
13. Wait 24 hours for the shell to harden. (May be longer depending on the temperature of the room or blanket)
14. Cut excess material off. During the B-Stage.
15. Cut the shell into the top front and top rear sections.

Issues encountered during this process:

A few issues that were encountered with this process is that to ensure a good vacuum seal, wooden strips were needed to get the fiberglass to lay down correctly with the door contours. Epoxy on the hardtop from the previous owner caused non-uniform areas in the top, and a broken section in the door arch. To deal with the epoxy resin from the previous owner, a razor blade was used to eliminate issues with uniformity. To prevent the broken section in the arch with providing a bad shell, the section had to be repaired with epoxy resin and bondo.

Construction:
Layup:


Reference drawing number 9 for a visual.

The method of the construction of the layup is described above in the method section.

Welding:

Standard welding procedures will be followed. To construct the tubular frame, tack weld the corners to ensure perpendicularity, then weld the frame as seen in appendix A-10
and Drawing 20-006. With the frame welded, it will be now ready to be installed in stage two in the side panel construction process.

Final Hardtop:

1. Install the side panels first.
   Bolt the bottom bolts into the frame of the vehicle.
2. Install the rear panel.
3. Bolt the bottom bolts into the frame of the vehicle.
4. Install the top rear panel.
5. Bolt the top rear panel to the side panels and the rear panel.
6. Install the top front panel.
   Bolt the top front panel to the top rear panel and clamp the front end to the vehicle with the clamps.

The method or construction of the panels had to have a few changes in the layup procedure. The major change in the construction of the panels is that a wet layup on the original hardtop was necessary. The original plan was to vacuum bag to get a shell. This was not possible due to the size of the mold and the complexity of sealing the vacuum bag. The original hardtop is made of separate panels and the seams would leak a significant amount so pulling a vacuum was not possible. Using a wet layup was a great alternative to get a mold. After the initial mold was made by using the wet layup method, the interior layup was done with the vacuum bagging method.

A change in the construction of the foam core for the side panels was made by changing the option of using insulation panels to an expanding foam. Making this change would save a lot of time in the shaping of the foam. Shaping the foam for the top front panel added a significant amount of time to the construction of the core. This experience suggested that using an expanding foam is a better option. The one con to using expanding foam is that the option was more expensive than using an insulation foam panel.

One modification made to the rear panel was changing the rear window from an original window to one made of polycarbonate. This decreased the budget by $250. The budget decrease was the deciding factor for this change.

The last modification was the change in the material and the store that the material was purchased at for the square tubing. By changing the material to ASTM A500 Gr. A 1" x 1" x .095" material. The safety factor decreased to a safety factor of 2 or to a maximum load of 400 lbs. from a safety factor of 4. This was justified by the cost decrease and that a maximum load of 400 lbs. is far greater than a load that someone would use. The cost decreased by $190 by purchasing the material at Moses Lake Steel and not on Mc-Master-Carr.
Figure 1 Top Panel(s) Layup

Figure 1 A Wetting out the fabric

Figure 1 B Top Rear Panel Foam Core Construction

Figure 1 C Top Front Panel Core Construction

Figure 1 D Top Two Shells
The first step in the layup process was covering the hardtop mold with plastic sheeting to prevent the mold from adhering to the hardtop.

The other option was to use mold release or waxing the surface of the mold. The reason this method was not used is due to the lack of availability of mold release spray in the area.

The second step was to cut all the material necessary to length.

With these shells completed, the next phase is to shape the interior foam. With the foam complete, the interior composite layup can be made.

Step 3: Shaping the Foam Core and Wrapping the Header Bar in Fiberglass

In order to shape the foam for the top two shells, the foam was cut to the overall dimensions needed and then sanded down to fit the interior of the shells. The next step in making the interior of the top front panel was to foam the interior of the header-bar with expanding foam, cutting the excess foam off and then laying-up/vacuum bagging the bar. This process ensures that the header bar adheres to
the panel. The problem was that plastic does not adhere to epoxy well. By covering the bar in its own shell, the epoxy will have something to cling to when the entire panel is layed-up.

Figure 2 A Material Cut for the Side Panels

Figure 2 B Prep work for the layup. The Windows were removed, and the surrounding area was taped off to prevent the epoxy resin from adhering to the hardtop

Figure 2 C The layup was taped down to get a mold

Figure 2 D The shell of the side panel
Figure 2 E A500 GR A 1” x 1” x .095” Steel was purchased and cut to length.

Figure 2 F Square tubing was welded up with nuts welded on the frame for the attachment points.

Figure 2 G Nuts were welded on to eliminate having to make a pocket in the foam core to get to the other side of the frame.

Figure 2 F The Rear Panel Foam Core was poured and then shaped to save time.

Figure 2 G the Poured Cores on the Side Panels.

Figure 2 H Shells of the Side(s) and Rear Panels.
In the process of creating the side panels: 1. The windows on the original hardtop had to be removed. 2. The material was cut. 3. The area was prepped to prevent the epoxy from adhering to the hardtop. 4. The layup was taped down to ensure the shape of the hardtop is transferred to the panel 5. Two frames were welded up from A500 Gr.A 1”x 1” x 0.095” steel. 6. Nuts were tacked in to simplify the design. By tacking in the nuts, access to the nuts will not be necessary. 7. Expanding Polyurethane foam was poured in and shaped to create the foam core.
This is the extent of the drawing tree for the individual parts for this quarter. In the next quarter the drawing tree will extend to the manufacturing of the individual parts.

The few items that could change on this list are the type of fiberglass that will be used. If E-Glass is used, the quantity or yards of material will change, but the total cost of the product will decrease if E-Glass is used. If E-Glass is used the epoxy resin that is needed will increase by roughly ½ a gallon so the cost of resin will increase by $100.
There were three different materials that were considered

**Manufacturing Issues:**
A few manufacturing issues that will be presented are; temperature restraints, springback of the material in the lay-up or vacuum bagging stage, contours of the edges.

The temperature restraint is due to the epoxy having the correct temperature so that it cures in a timely manner. With a low temperature the cure time increases significantly.

The spring back of the material comes at sharp corners in the design. At edges where the panels come together there will be sharp edges. The way fiberglass cures presents an issue due to the tendency of the material to want to spring back.

The contours of the edges become a visual problem. If the individual is not careful with the layup, the material will have a hard time laying up flat.

**Discussion of Assembly, Sub-Assembly, Parts, Drawings:**

**Testing Methods:**

**Introduction:**
To test the analysis data that was calculated a three-point bend test will be conducted, an infrared gun will be used, a decibel reader will be used, a compression test will be performed, and tensile tests will be done.

**Method/Approach:**

**Tensile Tests:**
A tensile test of the layup will be done to see how much the orientation of the plies and epoxy resin affects the material properties of the material. This will give actual values vs. the theoretical values calculated.

**Infrared Gun:**
An infrared gun will be used to get values of the surface temperatures on the inside and outside of the material to test for heat loss as the car heater is running.

**Decibel Reader:**
A decibel reader will be used to test the noise reduction between the hardtop and the soft top on the Jeep currently.

**Compression Test:**
The Tinius machine will be used to get compression values for the composite layup.
Testing Procedure:

Load:

To test the weight limit requirements, test samples of the composite layup will be made, and the final test will be to load the center of the hardtop with cement bags (up to 4) that weigh 100 lbs. each to ensure that the panels can handle a 200 pound load with a safety factor of two. The preliminary composite layup test samples will test for the optimal composite layup orientation with tests on the three-point bend instrument.

Noise Reduction:

To test for noise reduction, the vehicle operator will drive the Jeep at highway speeds with the soft-top and have an assistant measure the noise level with a decibel reader. Then, the modular hardtop will be installed and tested the same day in the same conditions to ensure accurate results.

Heat Reduction:

To test for heat loss reduction, the car heater will be set on maximum for 15 minutes when the vehicle is 100% warmed up and a Laser Infrared Thermometer will read the
temperature on the exterior of the soft top and hardtop. Comparing these two values will give an individual the heat loss reduction.

Compression Test:

To compare compression properties of an original hardtop to the modular one, there will be cutout sections of the original hardtop and laying up test samples made to compare structural integrity to an industry standard hardtop.

For this project, a few of the tests were done before the product was finished to ensure that the product will not have to be modified later.

To ensure that the hardtop composite layup has the strength characteristics necessary, two test samples were tested to failure. The samples were layed up two different ways. One sample had three layers of fiberglass over the foam core and the other sample had four layers. These were then tested on the Tinius machine. These samples both failed at an average of 50 PSI. This was far over the necessary strength required to carry a 200 lb. load.

For the welded frame made in the side panels, a preliminary test was made before the frame was installed in the panel. To ensure the frame and welds are good, the frame was loaded with a 185 lb. load. The maximum load that will be applied will be 200 lbs. and the frame held up under the 185 lb. load without bending. Later test will be made when all the panels are completed with 200 lbs. of weight. The test will comprise of loading the hardtop with two cement bags in various locations of the hardtop when the hardtop is bolted up to the jeep.

The compression tests to compare the properties of an original hardtop to the created hardtop will be done by testing sections of an original hardtop. The compression properties will then be compared to the compression properties of the layed up samples. This will ensure that the hardtop has the structural characteristics of an industry hardtop.

The last two tests of ensuring that the hardtop is waterproof and more soundproof will be done following the procedure shown in Green Sheet 11 & 12. By following a single procedure, the final product can be tested accurately.

**Deliverables:**
The deliverables from these tests are values that will confirm that the materials that are used in this project are adequate for the construction of the hardtop. The tests will provide insight in issues with the calculations and confirm that the function requirements are met.

**Testing Introduction:**
**Requirements:**
The requirements for the hardtop are to:
10. Keep the profile of the modular hardtop as close to an original hard top profile as possible.
11. Have the capability to bolt a roof rack directly to the hard top with an option of going through the hardtop and bolting a roof rack to the roll cage.
12. Be able to handle a 150-200 lb. load (with a roof rack).
13. Have the compression strength of the hardtop equal the compression strength of an OEM hardtop.
14. Adapt existing windows for convenience.
15. Reduce noise level by 15%
16. Reduce heat loss by 20%
17. Be able to deconstruct the product into a storage space of 2.5 ft by 3 ft by 2 ft.
18. Be able to withstand water seeping through the connecting sections for a time period of 10 minutes of a constant supply of water.

Parameters:
The parameters of interest are if original windows can be installed, how much the panels will deflect, whether the assembled panels are waterproof, how much noise reduction, in decibels there is with the hardtop on, and whether the hardtop can be deconstructed into an area of 2.5 ft by 3 ft by 2 ft.

Predicted:
For the first requirement, the hardtop’s overall dimensions will be compared to an original hardtop. The predicted dimensions of the new hardtop are that the hardtop will be within a ± ¼ of an inch in the overall length height and width of an original hardtop.

For the second requirement, the hardtop will be compared with roof racks out there to confirm whether there is a roof rack out there that will have the ability to be bolted to the roof of the hardtop. The prediction is that there is a roof rack out there that could be bolted to the hardtop.

For the third requirement, the roof of the hardtop will be loaded with weight up to 200 lbs. The prediction is that the hardtop will be able to handle that much weight without deflecting.

For the fourth requirement, the new hardtop’s compression strength will be compared to an original hardtop’s compression strength. The prediction is the compression obtained already, with a value of 50 PSI, is like that of an original hardtop.

For the fifth requirement, the prediction is that original windows will fit in the modular side panels constructed. The dimensions of the new hardtop window are predicted to be ± 1/8 of an inch around, which will allow the original windows to be installed.

For the sixth requirement, the prediction is that the noise reduction of the new hardtop will be more than 15%

For the seventh requirement, the prediction is that the hardtop will have a heat reduction of 20% compared to a soft top.

For the eight requirement, the prediction is that the hardtop will be able to be deconstructed and stored in an area of 2.5 ft by 3 ft by 2 ft.

For the ninth requirement, the hardtop is predicted to withstand more than 10 minutes of constant water.
Data Acquisition:
Tensile Tests:

A tensile test of the layup will be done to see how much the orientation of the plies and epoxy resin affects the material properties of the material. This will give actual values vs. the theoretical values calculated.

Infrared Gun:

An infrared gun will be used to get values of the surface temperatures on the inside and outside of the material to test for heat loss as the car heater is running.

Decibel Reader:

A decibel reader will be used to test the noise reduction between the hardtop and the soft top on the Jeep currently.

Compression Test:

The Tinius machine will be used to get compression values for the composite layup.

Load:

To test for the load limit, 10 lb. plates will be added to the rooftop to find whether the hardtop can safely handle the specified weight requirements.

Waterproof:

A constant supply of water will be directed onto the hardtop with a hose to ensure the hardtop is waterproof.

Window Compatibility:

An original window will be placed over the new side panels and measured around the circumference to ensure that it will fit before the window is installed.

Schedule:

The Gantt Chart for the schedule can be referenced below, in order to test the hardtop and complete the tests before the end of the quarter or June 13th, the tests will be broken up into 4 groups so that the test could be completed by the end of the quarter. This will allow for slight variations to be made to meet the requirements stated above.
Method/Approach:
The resources required to test the hardtop will be provided by CWU and any other material will be obtained at home. The resources provided by the school are the decibel reader, the Tinius Machine, and the Tensile Tester in the CWU Lab. Other required testing material such as the original window, water, measuring tape and weights will be obtained at home. To capture data for the tests, a personal smartphone will be used to record. Some operational or personal constraints are that the resources that the school has may not be available to use due to the corona virus. The data will be uploaded to the website and the Final Overview Document that has been made throughout this year. The data will be presented in video, photo and charts where applicable.

Test Procedure: Test 1: Overall Dimensions:

Summary/Overview: Comparing the Dimensions of an Original Hardtop to the Modular Hardtop

The overall dimensions of the Modular Hardtop will be compared to an original hardtop to ensure that the hardtop was designed to fit a Jeep TJ properly. These measurements will be done the week of April 12\textsuperscript{th}-18\textsuperscript{th}. The resource needed to test or compare the products is a measuring tape. The test will be done at home. Specifically, the measurements that will be taken are indicated above with the arrows. Each one of these measurements will be taken on an original hardtop and the modular hardtop to a precision of 1/8\textsuperscript{th} of an inch. These measurements will be then compared and evaluated in the Discussion section below.

Risk/Safety:

There is no safety risk involved with this test.
Discussion:
The overall dimensions of the Modular Hardtop were: Bottom Window: 44" Widow Rear: Bottom to Top: 29.5" Window Front: Bottom to Top: 30.5" Top Total Length: 71.25" Width: 57". The overall dimensions of an original hardtop are: Bottom Window: 44" Widow Rear: Bottom to Top: 28.5" Window Front: Bottom to Top: 28.5" Top Total Length: 71.5" Width: 56.5". The two significant differences between these values are in the Window Front & Rear: Bottom to Top. The values had a 2" and a 1" difference in comparison to the original hardtop. These values were different due to using a 1" core for the sandwich structure of the modular hardtop. Overall, the rest of the dimensions only had slight variations and were similar to an original hardtop.

Deliverables:
Parameter Values: The overall dimensions of an original hardtop are: Bottom Window: 44" Widow Rear: Bottom to Top: 28.5" Window Front: Bottom to Top: 28.5" Top Total Length: 71.5" Width: 56.5". These results give perspective on the methods taken to create the panels. With these values an individual can see that the method used created panels that were similar in overall dimensions.

Calculated Values: Bottom Window: 0" difference Widow Rear: Bottom to Top: 1" difference Window Front: Bottom to Top: 2" difference Top Total Length:.25" difference Width: .5"

Success Criteria: The dimensions of the Modular Hardtop will be deemed successful if the hardtop fits the Jeep.

Test Procedure: Test 2: Capability to Bolt a Roof Rack on:
Summary/Overview:

Based on the location of the bolts in the top panels of the hardtop a compatible roof rack will be sought. These measurements will be done the week of April 12th-18th. The measurements will be recorded in the discussion section below. The testing will be done at home.

Risk/Safety:
None. Research will be done to find a roof rack. One will not be installed.
Discussion:
Based on researching roof racks available for a Jeep TJ, the simplest option found to be able to attach a roof rack was by using the Perry Craft Heavy Duty Roof Rack (Model SQ5550). This roof rack would only require cutting their guide bars in order to still have the capability of taking the modular hardtop apart. Instead of using the bolt holes in the jeep, the guide bars can be mounted on the roof of the jeep.

Deliverables:
By measuring the bolt locations, a suitable roof rack can then be found based on the spacing.

Success Criteria: The Modular Hardtop design will be deemed successful if a suitable roof rack can be bought for the hardtop.

Test Procedure: Test 3: Load Capacity
Summary/Overview:

For the welded frame made in the side panels, a preliminary test was made before the frame was installed in the panel. To ensure the frame and welds are good, the frame was loaded with
a 185 lb. load. The maximum load that will be applied will be 200 lbs. and the frame held up under the 185 lb. load without bending. Later test will be made when all the panels are completed with up to 200 lbs. of weight. The test will comprise of loading the hardtop with two cement bags in various locations of the hardtop when the hardtop is bolted up to the jeep. These measurements will be done the week of April 19th-25th.

Risk/Safety: Weights. There is a risk of the weights slipping off the roof and landing on someone. To ensure that this does not happen, the individual loading the roof with weights will be ensuring no one walks into the area while the testing is taking place. The individual will also be avoiding walking around the edge of the vehicle. They will be loading the roof off of a ladder.

Discussion:
Instead of using weights the test was conducted by walking over the roof by an individual that weighs 185 lbs. This would demonstrate the test without the use of weights that could slide off. Overall, the hardtop held up the load and did not buckle.

Deliverables:
By demonstrating that the hardtop can handle a 200 lb. load, the test will be demonstrating that the hardtop was constructed/layed-up properly. Also, that the calculated weight that the hardtop can handle is correct.

Success Criteria:
The test will be considered successful if the hardtop can handle a 200 lb. load.

Test Procedure: Test 4: Compression Test Comparison of OEM Layup vs Modular Hardtop
Summary/Overview:
To compare compression properties of an original hardtop to the modular one, there will be cutout sections of the original hardtop and laying up test samples made to compare structural integrity to an industry standard hardtop. Specifically, the sections tested will be 1.5” by 6”. By keeping the samples the same size, more accurate results can be obtained. The testing will
be/has been done on campus at CWU. For this project, a few of the tests were done before the product was finished to ensure that the product will not have to be modified later. To ensure that the hardtop composite layup has the strength characteristics necessary, two test samples were tested to failure. The samples were layed up two different ways. One sample had three layers of fiberglass over the foam core and the other sample had four layers. These were then tested on the Tinius machine. These samples both failed at an average of 50 PSI. This was far over the necessary strength required to carry a 200 lb. load. The sections of the original hardtop will be done the week of *April 19th-25th*.

**Risk/Safety:** Fiberglass Breaking. To ensure that a shard of fiberglass does not go flying into your eyes, safety glasses need to be worn when testing on the Tinius machine.

**Discussion:**
The results for the layups used confirmed that the layups are enough for the application of constructing a hardtop. By testing sections of an original hardtop, the results will provide insight in how strong industry hardtops are.

**Deliverables:**
By testing the layup used for the modular hardtop, the results confirmed that the hardtop will be able to carry a 200 lb. load. By testing a section of an original hardtop, the construction used for the modular hardtop can be compared to industry standards.

**Success Criteria:**
The test will be considered successful if the hardtop layup performs with similar characteristics as a standard hardtop layup.

**Test Procedure: Test 5: Adapting OEM Windows**

**Summary/Overview:**
To ensure the OEM glass fits the modular panels the panels will be removed off the Jeep and placed flat on the ground. The OEM glass will then be placed onto the panel to ensure that it fits. Measurements around the window will be made to a 1/16" of an inch to ensure the window fits correctly and has equal spacing around the window. These measurements will be done the week of April 12th-18th.
**Risk/Safety:** Glass: To Prevent an accident with the glass breaking, gloves, pants and closed toe shoes will be worn. The Side Panel will also be removed, and the glass will be compared on the ground.

**Discussion:**
Measuring the window in its place revealed that there was a range between $-\frac{1}{16}$ of an inch to $+\frac{1}{16}$ of an inch gap around the mold area made for the window. The $-\frac{1}{16}$ of an inch spots made it hard to keep the window molding on, but it still fit nicely. However, this test also revealed that there was a $\frac{3}{4}$" gap in between the window and the panel. This gap forces an individual installing the window to use twice as much caulk as is typically needed.

**Deliverables:**
The results will confirm that the method used to create the panel is a valid way to create a side panel.

**Success Criteria:**
The test will be considered successful if the windows can be installed properly.

**Test Procedure: Test 6: Soundproofing**

**Summary/Overview:**
To test for noise reduction, the vehicle operator will drive the Jeep at highway speeds with the soft-top and have an assistant measure the noise level with a decibel reader. Then, the modular hardtop will be installed and tested the same day in the same conditions to ensure accurate results. These measurements will be done the week of April 19th-25th.

Specifically, the Jeep will be driven down the highway at 60 MPH and a passenger will measure the noise level in the jeep. This will be repeated with a soft-top on the jeep. Each run will consist of a 12 min run. At one-minute intervals, the passenger will record the decibel level and record the data on a spreadsheet. The two runs will be compared to determine if there is a decrease in noise level with the modular hardtop. If the desired 15% decrease in noise reduction is not met, methods such as adding sound proofing material will be considered.

**Risk/Safety:**
None. The machine operator will not be using the testing device.

**Discussion:**
There was an 8.1% decrease in noise level with the hardtop. This does not meet the 15% noise requirement. In order to fix this, additional sound proofing material would have to be used on a future build.

**Deliverables:**
The results will provide data on how much the foam core decreases noise. If the calculated data does not confirm a 15% decrease in noise levels, sound proofing will be used.

**Success Criteria:**
The test will be considered successful if the hardtop decreases noise levels by 15%

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**Test Procedure: Test 7: Heat Loss Reduction**

**Summary/Overview:**

To test for heat loss reduction, the car heater will be set on maximum for 15 minutes when the vehicle is 100% warmed up and a Laser Infrared Thermometer will read the temperature on the exterior of the soft top and hardtop. Comparing these two values will give an individual the heat loss reduction.

**Risk/Safety:** None, make sure to test outside.

**Discussion:**
There was a 42% decrease in heat loss on the hardtop. In comparison, the soft-top had a 2.8% decrease in heat loss through the fabric. The decrease in heat loss is more than double the set requirement of 20%. One way that would decrease the heat loss even further is by using sound proofing material. Since the sound proofing requirement was not met, the material would need to be used and with that, the added benefit of insulating the panels is added.

**Deliverables:**
By testing the temperature on the outside, the decrease in heat loss can be obtained.

**Success Criteria:**
The test will be considered successful if the hardtop decreases heat loss by 20%
Test Procedure: Test 8: Storage Capability

Summary/Overview:
The requirement for the storage was that the hardtop should be able to be stored in a space of 2.5 ft by 3 ft by 2 ft.

Risk/Safety:
Glass: The side panels must be handled with care in order to prevent the panels from falling and shattering the glass.

Discussion:
The panels were able to be combined into a 20” x 57” x 36” section for storage. The initial estimation was made before actual dimensions of the hardtop were taken so the dimensions of the storage area was a bit unrealistic. Overall, the goal was met, the hardtop was able to be deconstructed in a safe manner and stored in a confined space. An original hardtop takes up 57” x 62” x 28” of space. There is a 41.5% decrease in space taken up by the modular hardtop. The goal of this requirement was, that the hardtop can be stored in a corner of a garage instead of taking up an entire garage. That goal was met.

Deliverables:
The capability of storing the hardtop in a confined space.

Test Procedure: Test 9: Waterproof

Summary/Overview:
The requirement for the waterproofing was that the hardtop should be able to withstand water seeping through the connecting sections for a time period of 10 minutes of a constant supply of water.

Risk/Safety:
There is no risk factor involved in this test

Discussion:
The hardtop initially failed. There were a few spots where the water seeped through. However, these spots were fixed by adding weather stripping to those areas. The initial thought that weather stripping was not needed or there was enough weather stripping initially was made. Overall, the hardtop performed like it should and a watertight seal was achieved.

Deliverables:
By testing for cracks in the joint areas, the hardtop could then be made watertight. This would allow for actual use on the road with bad weather.

Testing Summary:
The tests performed looked to ensure the hardtop fulfilled these requirements.
The requirements for the hardtop are to:

1. Keep the profile of the modular hardtop as close to an original hard top profile as possible.
2. Have the capability to bolt a roof rack directly to the hard top with an option of going through the hardtop and bolting a roof rack to the roll cage.
3. Be able to handle a 150-200 lb. load (with a roof rack).
4. Have the compression strength of the hardtop equal the compression strength of an OEM hardtop.
5. Adapt existing windows for convenience.
6. Reduce noise level by 15%
7. Reduce heat loss by 20%
8. Be able to deconstruct the product into a storage space of 2.5 ft by 3 ft by 2 ft.
9. Be able to withstand water seeping through the connecting sections for a time period of 10 minutes of a constant supply of water.

By testing for these requirements a few small issues were brought to light. One issue during the waterproof test was that there was a leak in the rear top corners of the side panels. This indicated that a seal in the corners was necessary. The assumption that the panels did not need a seal in the corners were made initially. This mistake was easily fixed with some seal material. The next issue was that, when adapting the original windows to the side panels, the windows only had an 1/8” clearance between the window and the panels. This made for a tight fix. With this tight fit, the windows needed more caulk to ensure a good adhesion between the panel and the window. Even though the windows fit, the realization that the measurements should have been checked earlier was made. This would have decreased the cost of the project by $18. The last issue that came to light was that a few of the bolts had slight alignment issues that increased the time to assemble the panels. While a time requirement was not made, this issue could affect whether someone would want to assemble/disassemble the panels themselves. Overall, the hardtop performed well and fulfilled the requirements stated above.

Budget:

Part Suppliers, substantive costs, sequence/buying issues:

Final Budget List:
Initial Budget List:

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<th>Item Description</th>
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<td>S-Glass Fiberglass</td>
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<td>HelForce #533</td>
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   | Breathing Material | Aircraft Spruce | 4 oz Breather BLEEDER PLY | AV55460120 | 1.05 | 10 | 10 | 10.5 | 0 | Total Resin Needed. |

| 5       | Brushes/Rollers | Aircraft Spruce | Unbranded | *** | 0 | 0 | 0 | 0 | 0 | galress 2.390625 |
| 6       | Cutting/Shears | Aircraft Spruce | Industrial Fabric Shears | 18-WD L | 35.5 | 1 | 35.5 | 35 | 0 | Total Resin Needed. |
| 7       | Sanding Material | Aircraft Spruce | JM | 9096-DC-NA | 6.75 | 2 | 13.52 | 13.52 | 0 | 2.35 |
| 8       | Vacuum Bagging | Aircraft Spruce | Exempt | Exempt | 0 | 0 | 0 | 0 | 0 | 0 |
| 9       | Tape | Aircraft Spruce | Eco. Multi-Pur. Sealant | AT-200Y | 6.65 | 1 | 6.65 | 6.65 | 0 | 0 |
| 10      | Paint | Aircraft Spruce | HCL188 | 71.79 | 1 | 71.79 | 71.79 | 0.3 | 1.47 |
| 11      | Square Tubing | Aircraft Spruce | Mc Master | 8224200 | 87.5 | 2.5 | 218.75 | 218.75 | 0 | 0.3 |
| 12      | Rear Window | Aircraft Spruce | Lexan | B05-04Y525 | 61.71 | 1 | 61.71 | 61.71 | 0 | 0.3 |
| 13      | Side Windows | Aircraft Spruce | Cragleit | OET | 25 | 2 | 70 | 70 | 0 | 0 |
| 14      | Bolts | Aircraft Spruce | Mc Master | 97046432 | 17.3 | 1 | 17.3 | 17.3 | 0 | 0.3 |
| 15      | Insulation Foam | Aircraft Spruce | Home Depot | FOAMULAR | 5.98 | 1 | 5.98 | 5.98 | 0 | 0.3 |
| 16      | Seal | Aircraft Spruce | Home Depot | FOAMULAR | 9.71 | 1 | 9.71 | 9.71 | 0 | 0.3 |
| 17      | Rear Window Edge | Aircraft Spruce | Clawbuy | 13 | 17.07 | 1 | 17.07 | 17.07 | 0 | 0.3 |
| 18      | Side Window Trim | Aircraft Spruce | Painted Automotive | D14A8 | 17.29 | 1 | 17.29 | 17.29 | 0 | 0.3 |
| 19      | Window Silicon | Aircraft Spruce | Fermaflex | 81173 | 14.57 | 1 | 14.57 | 14.57 | 0 | 0.3 |
| 20      | Set Screws | Aircraft Spruce | Amazon | U-Turn | 8.19 | 1 | 8.19 | 8.19 | 0 | 0.3 |

Total: 799.58

Actual Cost (total so far): $711.82

List of the parts needed:

Part Suppliers:
- The S-Glass (*extra), Epoxy Resin, Square Tubing and Foam Core will be purchased on Aircraft Spruce. The Sanding Material (sandpaper) and Insulation Foam will be purchased at the Home Depot. The Rear and Side windows will be purchased on eBay. The Paint used in this project will be purchased on Amazon.
- The parts that will be supplied by CWU are: The release fabric, *Fiberglass, Cutting/Shears, Vacuum Bagging Pump, Plastic Material, Tape and Breather Material. By having the opportunity to use these supplies an approximate sum of $400 will be saved. This is without the cost of purchasing a Vacuum Bagging Pump/Parts that costs
$467.50 for a basic setup. Having access to these resources cuts the cost of the project in half.

**Substantive Costs:** The Epoxy Resin, Square Tubing, Rear and Side Windows. These three items add up to roughly $900. These items make up the majority of the cost for the project.

**Determine Labor, outsourcing rates & estimate costs:**

**Labor:**
The work done will be done without outsourcing work so there are no labor costs.

**Estimate total project cost:**

$1194. Depending on the quantity of material that will be provided/available to use from the donating parties this value can change.

There were three ways that money was saved. In order to decrease the total cost, the tubular frame for the side panels was changed and the rear window option was changed. Choosing a standard size of square tubing and lowering the safety factor from 4 to 2.2, decreased the cost by $162.75. Changing from an original rear window to a window made of polycarbonate decreased the cost by $240. These two changes decreased the estimated cost by 35%.

The last item or items that decreased the total cost of the project were the purchases of the side windows. The side windows cost a total of $70 on craigslist. The cheapest options online were an average of $90 for a single side window. By locating these items on craigslist, $110 or 9% was saved.

There were two items that increased the cost of the project. These are the foam option that were chosen for the construction of the panels. The cost of the foam core for the roof panels was estimated to be $88.94, the actual cost was $142.01. The reason for the increase in cost for the foam core was that the cost of shipping was $40. The other item that increased the cost of the project was the change from using insulation foam in the side panels to expanding foam. The cost of the insulation foam was estimated to be $5.98. The expanding foam cost was $53.94. While this is an increase in cost, the time to create the panels will decrease significantly. These two items increased the estimated cost for the foam by 11%.

Other minor increases or decreases to the total cost of the project were due to not adding tax costs. Overall, 33% of the budget was decreased.

**Funding Source(s):**

CWU lab resources, Family, Myself.

**Cost/Issues:**

There were multiple ways the cost of the project could have been decreased. One major way would have been by changing the method in which the panels were made. If the core(s) of the panel were CNC milled prior to the construction of the top and bottom layups, excess material
and resin would have been decreased. For instance, in the initial construction of the shells, excess material was needed around the panel section to ensure the panels would not need to have material added on later. With excess material, the panels would then be cut to size. With a premade foam core, there would be a decrease in excess material. This would significantly decrease the cost. In general, around 2-3” of excess material was around each individual outside shell. To construct the top panels, an excess area of 385.5 square inches would be used with just a single layer of an excess of 3” around the panels. At four layers thick, the excess material adds up to 1542 square inches. That would add up to 10.6 oz of material. At the necessary ratio of 2.5 oz of resin to an oz of fabric, 26.6 oz of excess resin would be used. An oz of resin costs $1.02. This means that $27.15 could have been saved in the construction of the outside shells of the top two panels alone. By having the cores of the shells made, there would not have to be as much excess material since the panels would be ready to be completed in one stage instead of completing an outside shell and a future inside shell.

Another way the cost of the project could have been decreased is if the door surrounds used on Jeep TJ soft-tops was incorporated into the design. By incorporating the door surrounds, the area that makes up the panels would decrease by an estimated amount of 672 square inches. With the math explained above, the cost would be decreased by $47.34.
Schedule:

Gant Chart:

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<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Project Close</td>
<td>6</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

*The Complete Gant Chart can be found in appendix E*
Define Specific Tasks, Identify Them, Assign Specific Times:

Task Dates:
The outline of the project was done from Sept. 25th - Oct. 3rd.
The introduction of the project was done by Oct. 4th.
The Methods of the project was done from Sept. 25th - Dec. 11th.
The Analyses of the project was done from Sept. 25th - Nov. 30th. *The analyses will be edited/corrected throughout the rest of the project (around May)
The Discussion of the project was done from Sept. 25th - May. *3rd. The discussion will be completed by the end of the project due date.
The Parts and Budget of the project was done from Nov. 5th - Nov. 30th.
The Drawings of the project will be done by the due date. A rough or first rendering of the drawings will be done by Dec. 11th but, the drawings will change as the design is modified.
The Schedule of the project was done from Sept. 25th - Dec. 5th. The schedule will change as issues come up. A reference for the project timeline will be done by the end of winter quarter.

The schedule for Spring Quarter comprises of purchasing the necessary parts required to construct the panels and constructing the panels by March *7th. The estimated time required to complete each individual panel was assessed to take an average of 5-6 hours per panel. That would make for a total time of 29.5 hours to complete the panels. So far, the top front and top rear panels have taken that much time alone. The reason for the panels taking a significant amount of time longer than the estimated time is due to the lack of experience working with complicated composite layups. The time estimated was based on working with simple layups. To keep the construction of the panels on schedule, time to work on the panels was increased on the weekend(s) to keep up with the deadlines.

One additional part that was added to the project was the header bar that was used in the construction of the top front panel. This part added a total of 5.3 hours to the project. By using this part, the time to construct the top front panel was most likely decreased. By incorporating a previously designed header bar, one less design for the panels was needed. To shape the foam for a new header bar would have taken at least two to three hours alone.

One major change in the schedule that could have been made to simplify the manufacturing of the panels was, creating all the outside shells before completing a single shell. Due to the structure of the class, an individual had to have one completed part every two weeks. With five panels, the thought was that a panel could be completed every two weeks and the project would be completed on time. This created
issues in the long run. By completing a panel, the following panels had to fit perfect with any mistake made with the completed panel. For instance, with a 1-inch thick panel, a bow had to be added to the panel in order to clear the roll bar cage in the Jeep. The thought was that by adding the bow to the Top Front Panel, (the panel that was completed first) the rest of the panels would just match up to it. The problem was that the bow could have had a smaller radius and that mistake was not caught until the side panels were made. While the final product still matched up well, it could have come out more aesthetically pleasing if all the outside shells were made prior to completing a panel. One other thing is that, by completing all the shells prior to starting the interior layups, the shells could have been cleco fastened together and cut to the correct dimensions instantly. By not doing so, there was a lot of wasted time remeasuring the panels to ensure they matched up perfectly.

Specify Deliverables, Milestones:
Milestones are having the material list, budget costs, analyses, design drawings, and the 5 individual hardtop pieces made. The final milestone would be assembling the pieces on the jeep.

The deliverables are having a product that can handle a 400 lb. point load, is waterproof, has a noise reduction value that is at least 15% less than a soft top, and a product that has a heat loss reduction of 20%.

Estimate Total Project Time:
The estimated time for this project is approximately 280 hours. The actual time for the project will not be known until the product is made. Based on the documentation and proposal sections the overall time estimated is close to the actual time spent on the sections/assignments.

Discussion:
Through the development of designing the modular hardtop, there were several evolitional processes that influenced the design and what materials will be used. One design aspect that evolved through the budget cost calculations was the decision of whether to use E-Glass Fiberglass, S-Glass Fiberglass, or Carbon Fiber for the fabric material. Based on several iterations, the decision to use E-Glass Fiberglass deemed to be an adequate material option to use based on material properties and cost of the material. The cost of using E-Glass is significantly less than the other two options. A few aspects of the design that choosing this option effects are the weight of the panels and the thickness of the layup. Weighing the pros and cons of the material, the decision to use E-Glass seems like a logical choice. Another aspect that evolved was the decision on how to translate a load from the top panels to the vehicle. To incorporate another method of design and simplicity, structural square tubing was chosen to support a load
that would be placed on the top panels. Choosing this option allows the side panels to incorporate insulation foam as the core material. Having this option will in turn assist in reducing the heat loss through the panels.

Through the project risk analysis process, this project seems like it will produce a product that will succeed in performing with the function requirements set. Through the documentation of this project, time management, budgeting and organizational skills were brought into perspective. By creating a Gant chart, time management became possible. Setting a timetable to complete tasks and comparing these values to the time that was spent completing the tasks gave insight on how individuals can overestimate how efficient one can be. Through the budgeting process, the cost of various materials became a factor that altered the design decisions. Through this process, addressing issues that come up in any design parameters were brought to attention. By organizing the document in this manner, the ability to communicate with others on the intentions of this project were made possible. The next phase in this project is to create test samples of the materials chosen for the construction of the panels and test for performance. With these values, an individual will then be able to conclude that the product will work and is ready to be construction or a different option will be needed.

There were a few issues that came up while making the first few panels.

Due to the size of the layup of the top panels, a good vacuum could not be made to get a mold of the shell. To eliminate this issue, a wet layup was made, and foam cutouts were placed on the contours to ensure the panels took the shape of the mold. This method provided a solution to the problem, but using this method made the top shells not as aesthetically pleasing as they could have been. While this did not affect the structural integrity of the panels, it revealed a practice bagging run over the layup surface, was a good idea.

Another issue addressed in the construction of the top front panel, was the mounting of an attach point to the Jeep. Instead of designing a new structure to support attachment points, a soft top header bar could be used as an effective alternative. This appeared to be the perfect solution to simplify the design. The header bar is completely made of plastic. The problem with that, is the epoxy resin does not adhere well to plastic. The solution to this problem was to layup fiberglass on the header bar. This will ensure that the epoxy will then adhere to the shell of the panel, the foam core, and the interior layup.

One modification made to the design, was changing the rear window from an original window to a window made of Lexan. Changing from a glass window to one made of Lexan adds another step to the project. That process includes cutting the Lexan with a jigsaw in order to get the right shape. Although this added a step, the Lexan also eliminated the need for adding hinges to the rear window. The design of the rear panel was still kept the same for the sake of having the ability of changing the rear window to
an original window in the future but, in the meantime, using a window made of Lexan decreased the budget by roughly $240.

To simplify the process of making the cores for the side panels the original idea of using an insulation foam board was changed to using an expanding polyurethane foam. This required only having to cut the excess foam off. By using expanding foam, time was saved in having to shape the foam from a board.

In order to eliminate the rough finishes on the panels, Bondo was used to smooth out the finish. This is a time-consuming process of adding Bondo and sanding it down multiple times to achieve the desired finish.

The last issue with the panels was the alignment of the panels. Getting a mold off the original hardtop was a great idea to get a shell of the parts needed. The problem was that all the shells were not completed before a panel was completed. This brought up issues in that there were spots with alignment issues. To fix these issues, the foam cores had to be adjusted before the interior of panels were layed up. This added a significant amount of time to the project.

Overall, the design of the hardtop performed well and met the projects success criteria. As the project progressed, the project was modified in quite a few ways. Some of the design modifications that were made were the use of a soft top header bar, the decision of welding on nuts in the side frame(s) and adjusting the seams where the panels came together on the top panels.

By applying a previously designed part to be used, the time to design a bracket for the front hinges to be attached to was eliminated. A soft bar header bar provided a product that was easy to implement into the top front panel and provided an attachment point that would line up perfectly with the font of the jeep.

One method used to optimize the strength of the side panels so that they could handle the load requirement was by welding the nuts onto the frame made for the side panels. By doing so, the foam core structure would make the side panels even stronger. Welding nuts onto the frame eliminated the need to make an access to both sides of the frame. While the strength of the square tubing is designed to handle the 200 lb load that would be applied to the roof of the hardtop, the steel frame does little to support a side load if someone were to step on the panel in storage. By using a foam core on the side panels, the panels become as strong as the other panels and they would be able to handle a 200 lb side load.

To simplify the seam where the top front and top rear panel met, the seam was modified from having an overlapping section of a 1/2" on both panels to having one panel having a 1/8" thick protruding section and the other section having a 3/4" section that overlapped on top. This gave the ability to create a section with just fiberglass. By doing so, the panels would have a 1/8" gap that would be perfect for a rubber seal. This made
the process of creating an overlapping section easier and was perfect for creating a water-tight seal.

One project modification that was made was welding on nuts onto the side panel frame for the bolts that secured the hardtop to the roof panels and the vehicle. The thought was that, by welding on the nuts, the design of the panels would be simplified, and the panels will not scratch the vehicle when the panels are getting installed. The issue that came up was that this made putting in the bolts hard. The area in the Jeep where the bolts had to go through gave little room to work with. This made locating the nuts a nuisance. To eliminate this issue, the decision was to use studs. That would allow the individual installing the panels to only need to install the nuts. While the studs could potentially scratch the paint on the vehicle, the realization that being careful took care of that issue. The time saved installing the panels was worth the risk. If another hardtop were to be made, welding in bolts would be done instead of welding on the nuts.

Another project modification that would simplify the cost and the ease of construction would be using pink insulation foam instead of the high-density polyurethane foam that was used on the construction of the top panels. The problem with the high-density polyurethane foam was that it is delicate to work with because it crumbles easily. The polyurethane foam has great structural properties, but after seeing another student using pink insulation foam for a different project, his test results indicated that the foam would have been structurally sound for the top panels. The reason the high-density foam was used was that testing has been done by the manufacturer to ensure its material properties. There was concern that the insulation foam properties could have anomalies in the uniformity of its density. For this project, making test samples and testing them to failure could have been done to ensure the pink foam would work. That would have made starting the panels easier, since the pink insulation can be found in any hardware store.

By testing for the requirements, a few small issues were brought to light. One issue during the waterproof test was that there was a leak in the rear top corners of the side panels. This indicated that a seal in the corners was necessary. The assumption that the panels did not need a seal in the corners were made initially. This mistake was easily fixed with some seal material. The next issue was that, when adapting the original windows to the side panels, the windows only had an 1/8” clearance between the window and the panels. This made for a tight fix. With this tight fit, the windows needed more caulk to ensure a good adhesion between the panel and the window. Even though the windows fit, the realization that the measurements should have been checked earlier was made. This would have decreased the cost of the project by $18. The last issue that came to light was that a few of the bolts had slight alignment issues that increased the time to assemble the panels. While a time requirement was not made, this issue could affect whether someone would want to assemble/disassemble the panels themselves. Overall, the hardtop performed well and fulfilled the requirements.
Conclusion:
This project has provided insight into what entails a document of this magnitude. By designing a modular hardtop and assessing the design calculations, this project seems like it is ready for the next stage of the project. The success of this project is based on the function requirements stated in the introduction. A few function requirements that analyses were done for are; function requirement 3: Be able to handle a 150-200 lb. load (with a roof rack) and function requirement 5: Adapt existing windows for convenience.
An analysis that was done to determine a method to carry the load was to construct a structural square tubing frame for the side panels. The design and analysis that represent the work done for the frame can be found in appendix A-1, A-2, A-10, and appendix B-6. A-1 calculates the max stress, max moment, and max shear stress that the design will have to withstand. A factor of safety of two was applied to ensure safe loading. These values are compared to actual material property values in A-1. The max stress value calculated was 56338 PSI. With this value, materials such as 7075-T6, Dom 1020 and 4140 N had yield values over 73 KSI so these options were deemed to be sufficient for the frame. A-2 calculated the critical load that the material could withstand without buckling. This value ensured that the frame was strong enough. A-10 calculated the weld size that would be recommended for the frame. The weld size recommended was ¼” welds. An analysis that was done to make the option of using original hard top windows was calculating the shear force that the glue needed to withstand for the weight of the window. The shear force was 23 PSI and the solution was to use 3M adhesive. The analysis may be found in appendix A-8. The actual performance of the materials selected in this project will be compared to test values that will be obtained in the first two weeks of spring quarter.

Acknowledgements:
The individuals that assisted in finding the resources and means of completing the project proposal this fall quarter are; Kelson Mills, Dr. Craig Johnson, Professor Charles Pringle and others that are not coming to mind at this moment. The background knowledge of Kelson Mills helped in this project immensely. By having the ability to communicate with Kelson daily, the thought process on multiple subjects that pertain to this project was streamlined. For instance, the experience of working with various composite layup structures in the past has provided insight on which material is best suited for the core material that will be used in the construction of the panels. Having the professors provided a guide in finding materials to reference to. Having these materials give the chance to find equations that are applicable to the analyses that were made and where to find items that will be used for the construction of the parts in this project.
Appendix A: (Green Sheets)

Appendix A-1: Green sheet 1 Calculations: Forces

1. Square Tubing Frame on side window to handle a load of 150 x 150.

\[ F_{1} = 200 \, \text{lb} \]
\[ F_{2} = 198.9 \, \text{lb} \]

\[ \sum M_{z} = -400 \, \text{lb} \times 28'' + F_{1} \times 48'' = 200 \, \text{lb} \]
\[ \sum F_{x} = 200 \, \text{lb} - 400 \, \text{lb} + F_{y} = 200 \, \text{lb} \]
\[ F_{y} = 200 \, \text{lb} \]
\[ F_{2} = 200 \cos \theta = 198.9 \, \text{lb} \]
Appendix A-1: Green sheet 1 Calculations:

Material Properties:

<table>
<thead>
<tr>
<th>Material</th>
<th>Yield Stress (psi)</th>
<th>Ultimate (psi)</th>
<th>Density</th>
<th>Safety Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>7075-T6 Al</td>
<td>75,000</td>
<td>83,000</td>
<td>.094</td>
<td>1.120</td>
</tr>
<tr>
<td>D6BN 1520</td>
<td>69,000</td>
<td>85,000</td>
<td>.289</td>
<td>1.35</td>
</tr>
<tr>
<td>4130 N</td>
<td>92,000</td>
<td>105,000</td>
<td>.289</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Yield Stress: Pressure level a material can take before it starts to bend but return to its original shape.

Ultimate Stress: Pressure level that will fracture a material.
Appendix A-1: Green sheet 1 Calculations:

\[
\text{Max Stress: } \sigma_{\text{max}} = \frac{M_{\text{max}}}{I} = \frac{4000 \text{ lb-in}}{1.0711^3} = 56.3\text{ ksi}
\]

\[
\text{Min Stress: } \sigma_{\text{min}} = \frac{M_{\text{min}}}{I} = \frac{0}{1.0711^3} = 0
\]

\[
\text{Mean Stress: } \sigma_m = \frac{\sigma_{\text{max}} + \sigma_{\text{min}}}{2} = \frac{56\text{ ksi} + 0\text{ ksi}}{2} = 28\text{ ksi}
\]

\[
\text{Alternating Stress: } \sigma_a = \frac{\sigma_{\text{max}} - \sigma_{\text{min}}}{2} = \frac{56\text{ ksi} - 0\text{ ksi}}{2} = 28\text{ ksi}
\]

\[
\text{Stress Ratio: } \rho = \frac{\sigma_{\text{min}}}{\sigma_{\text{max}}} = \frac{0}{56\text{ ksi}} = 0
\]
Appendix A-2: Green sheet 2 Calculations: Analysis of the Bolt Shear Force

Roof Panel Connecting Point = Bolt Shear / # of bolts required

Moment of Inertia: \( I = \frac{1}{12} bh^3 \)
\[ I = \frac{1}{12} \times 1'' \times 1''^3 = 0.083 \text{ in}^4 \]

\[ Q = \frac{1}{2} A \times (1'' \times 1'') = 5.12 \text{ in} \]

\[ q = \frac{1000 \times 5.12}{0.083 \times 9} = 2400 \text{ PSI} \]

\[ F = \frac{q}{\pi \times r^2} \times 5 = F = \frac{2400 \times 5}{\pi \times 0.4^2} = 9000 \text{ kN} \]

4140 Annealed Steel: Properties: Y = 111 ksi @ 54 kN

Bolt size: 54 ksi \( \times \pi \times r^2 = 9000 \text{ kN} \) \( r = 0.2378 \)

Use 1/4 in bolts.
Appendix A-3: Green Sheet 3 Calculations:


**Calculation:**

**Sketch:**

- Section A
- Section B
- Section C

**First Critical:**

**Assume Homogeneous Material**

**Method:** Least radius of gyration, Stiffness Ratio, $C_c$,

**Critical II, Allow 1%**

**Solution:**

$F_{dy} = k = 0.65$ (fixed - fixed)

Radius of gyration:

$R = \sqrt{\frac{I_y}{A}}$

Stiffness Ratio:

$\frac{kL}{Iy} = 0.55 - 25'' = 44.8$

Column Constant:

$C_c = \frac{2n^2E}{Sy} = \frac{2\pi^2 - 29200 \times 10^{3}}{92,000 \times 51} = 79.83$

$C_c > \text{Sr}$ so Johnson

**Critical L**:

$F_{cr} = A \frac{Sy}{E} \left[ 1 - \frac{Sy^2}{4n^2E} \right] = 442.3 \times 92,000 \times 51 \left[ 1 - \frac{92,000 \times 51 \times 442.3}{4 \pi^2 \times 29.7 \times 10^{3}} \right]

= 34,261.96 \text{ lb}

- Not going to buckle...

Times: 1 hr
Appendix A-4: Green Sheet 4 Calculations:

<table>
<thead>
<tr>
<th>Dennis Federich</th>
<th>Sr. Eng. Code</th>
<th>10-24-2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>Density</td>
<td>155 Kpsi</td>
</tr>
<tr>
<td>(in)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample Load = D rain + W (psi) (in)

<table>
<thead>
<tr>
<th>Compressive Stress</th>
<th>Compressive Modulus</th>
<th>Tensile Stress</th>
<th>Tensile Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>72</td>
<td>6215</td>
<td>160</td>
<td>625</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1700</td>
</tr>
</tbody>
</table>

Shear Stress = D rain

Beam Deflection Under Load: A = \( \frac{F_1 L^2}{48b} \)

Flanged Depth = \( \frac{F_1 L^2}{2(1.5)} \) Shear Stiffness = \( \frac{L}{6b} \)

Critical Length = \( \frac{L}{6} \)

\( G_r \) shear modulus of honeycomb
\( h \) = disk between face sheet & core (in)

\( E_r \) = face sheet modulus
\( E \) = flexural load
\( G \) = shear stiffness

\[ L = \frac{400 \times 16 \times 55}{98} + \frac{400 \times 55}{4 \times 1740 \times 55 + (\frac{1}{6} + 7.48 \times 10^{-3})} \]

\[ E \frac{t}{b} \]

\[ \frac{h \times \text{no. of layers}}{+ 2} \]

\[ \Delta \]

\[ 12.5 \times 10^6 \times (7.48 \times 10^{-3}) + \frac{1}{16 \text{ in} + 7.48 \times 10^{-3} \text{ in}} \times 2131.2 \]

\[ 2 (1.5 \text{ in}) \]

\( \Delta = 28.73 \text{ in} \) + way too much, need to stiffen up the panel

Time:
Too Long - 4.
Appendix A-5: Green Sheet 5 Calculations:

Things to Consider:
1. Resin type
2. Fiber type
3. Fiber orientation
4. Fiber to Resin Ratio
5. Curing Method

Overview (Subject to change):
The resin type that will be used is an epoxy resin.

Steps:
1. Lay a section of Teflon paper with enough surface area around the part to tape seal the final teflon paper on top.
2. Cut your fiberglass to the correct dimensions.
3. Mix some of your epoxy resin. For E-Z Epoxy, you will need to cure the resin for 24 hrs at 77 F.
4. The ratio of epoxy to fiberglass is 1:1. For every oz of fabric you will need 2.5 oz of resin.
5. Lay up the layers as shown in the drawing.
6. Remove Excess Resin
7. Use Teflon Paper on the top layer, seal the top/bottom with stainless tape.
8. Use the vacuum pump to create a vacuum seal.

Specifications:
- E-Z epoxy: 24 hrs @ 77 F
- 875: 8 days @ 77 F
- 876: 4 hrs @ 150 F

Oven Cure:
- Material Thickness: 1/16".
- Fiberglass S-glass: 5.8 oz. Thickness: 0.035" Weave: Plain.
Appendix A-6: Green Sheet 6 Calculations:

Dennis Fedorchuk  Sr. Proj. Calculations  11-1-2019

Material Quantities

Top Front Dim: 30.5" x 55" x 2 layers = 5.7 yds
Top Rear Dim: 40" x 55" x 2 layers = 6.9 yds
Rear Dim: 6" x 49" + 6" x 49" = 1.5 yds
RH/LH Dim: 28" x 38" = 7.7 yds

Foam Core Needed: 4 yds
Fiberglass Needed: 5 yds + 1.2 = 6.2 yds

Epoxy Needed: Resin Ratio 7.5oz:2oz

Square Tubing: 25" x 2 x 2 x 2 = 180"

Bolts: 1/4" Bolts = 4
Appendix A-7: Green Sheet 7 Calculations:

Dennis Fedorchuk | Sr. Proj (Calc. 7) | 11-5-2019

Top Rear Panel Bolt Size Requirements / # of bolts

<table>
<thead>
<tr>
<th>48&quot;</th>
<th>50&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>5&quot;</td>
<td></td>
</tr>
</tbody>
</table>

Side View

FRD

<table>
<thead>
<tr>
<th>1&quot;</th>
</tr>
</thead>
</table>

1" = 1/8" bottom panel

Moment of Inertia $I = \frac{1}{12}bh^3$

$= \frac{1}{12} \times 1" \times 2"^3$

$= 2/3"^4$

$Q = q \times 0.5" \times 0.25" = 4.5"^2$

$F = \frac{VQ}{I} = \frac{400 \times 14.5 \times 0.5}{2/3 \times 12} = 3000 \text{ lb in}$

4140 Annealed St. Crop: Y: 11 ksi @ 54 ksi

Bolt Size = 54 ksi $\pi \times r^2 = 3000 \text{ lb}$

$r = \frac{1452 \text{ in}}{54 \pi}$

Therefore, 5/32" bolts will work.
Appendix A-8: Green Sheet 8 Calculations:

Proper adhesive for installing the windows.

Weight of Window: 17 lb.

Area (glass): \(2(20'' \times 11/4'') + 2(50'' \times 11/4'') = 75\text{ in}^2\)

\[
F = ma = 171 \text{ lb} \cdot 3.2 \text{ in/s}^2 = 546.96 \text{ lbf}
\]

\[
\tau = \frac{F}{A} = \frac{546.96 \text{ lbf}}{25 \text{ in}^2} = 21.87 \text{ psi}
\]

3M 08693 Auto glass urethane windshield adhesive
Tensile properties: 1700 psi
Overlay shear strength:
- 6 hr: 61 psi
- 72 hr: 550 psi

- 3M adhesive will work for this application
Appendix A-9: Green Sheet 9 Calculations:

Stresses, Panels on Strings, Front/Off of the Vehicle (Rep: Front Panel)

\[ F_{L} = \text{Load/Max weight you can stack on top of the panels} \]

Stresses, Stacked Panels Position

\[ \text{Max: Least radius of gyration, stiffness, } E, \text{ } E_{s}, \text{ } I \]

\[ k = 1.5 \times (3.18) \]

\[ \text{Radius of gyration: } r = \sqrt{I \text{, in.} / \pi} \]

\[ \text{Length/diameter} = \frac{30}{5} + \frac{h}{k} \text{, in.} \]

\[ J = \frac{1}{3} b \times h^{3} = \frac{3}{12} \cdot 1.5^2 \times 30.5^3 = 1182.2 \text{, lb-in}^2 \times \frac{1}{E} \]

\[ A = 2 \times 55^2 \times 2 \pi \text{, in}^2 \]

\[ c = \sqrt{\frac{I}{A}} = \sqrt{\frac{1182.2}{2 \pi \times 2}} = 6.56 \]

Stiffness, Bending

\[ kI_{s, min} = 1.2 \times 6.56 = 4.65 \text{ in.} \]

Column, Bending

\[ \sqrt{-\frac{6E}{\pi E}} = 19.69 \]

\[ c_{c} > 5, \text{ so 3 studies} \]

\[ P_{cr} = A_{s} \left[ 1 - \frac{\left( \frac{E_{s}}{E} \right)^{2}}{19.69} \right] \]

\[ = 682.2 \times 682.2 \times \left[ 1 - \frac{682.2^2 + 4.65^2}{4 	imes 682.2^2 + 9.69^2} \right] = 115 \times 10^6 \text{ lb} \]

\[ \text{With a 0.015" thickness, you get a } P_{cr} \text{ of } 2.7 \times 10^6 \text{ lb - still seems way too high!} \]

\[ @ 0.015" \text{ } P_{cr} = 575.95 \text{ psi} \]

With these values, you shouldn't have to worry about putting weight on top of the panels.
Appendix A-10: Green Sheet 10 Calculations:

<table>
<thead>
<tr>
<th>Green Form</th>
<th>Sr Proj Calc</th>
<th>11-14-2019</th>
</tr>
</thead>
</table>

**Green Form**

1. **Tubular Frame**
2. **Wood Seat**
3. **Metal**

**Green Sheet 10 Calculations**

**Assume homogeneous material, max situation values**

**Tubular Frame**

- **Tensile Force**
  
  \[ T = \frac{400}{2} \text{ in} = 400 \text{ lb/in} \]

- **Bending Force**
  
  \[ m = \frac{400}{3} \text{ in} \]

- **Vertical Shear Force**
  
  \[ T = \frac{400}{3} \text{ in} \]

**Safety Factor**

- **Bending Force**
  
  \[ \text{Safety Factor} = 1.5 \]

- **Vertical Shear Force**
  
  \[ \frac{400}{15} = 66 \text{ lb/in} \]

**Recommended Clearance**

\[ T = \frac{400}{15} = 66 \text{ lb/in} \]
Appendix A-11: Green Sheet 11 Calculations:

**Calculations:**

- **Heat Loss through the Soft Top**
- **Heat Loss with/through the Modular Hardtop**
  - To fulfill the 20% heat loss reduction
- **Assume:** A reduction in heat loss through the modular hardtop

**Method/Steps:**

1. Allow the vehicle to warm up for 15 minutes with the heater on at full blast.
2. Test a specific spot on the interior of the softtop with an Infrared Laser Thermometer to obtain the temperature.
3. Test a specific spot on the exterior of the softtop with an Infrared Laser Thermometer to obtain the temp.
4. Compare the temperature difference.
5. Repeat steps 1-5 with the modular hardtop.
6. Compare the heat loss difference between the two.
7. If the heat loss reduction is not met, insulation will need to be added.
Appendix A-12: Green Sheet 12 Calculations:

- To ensure accurate results, perform the test on the same day.
  1. To test the noise level with the soft-top, drive down the highway at 60 mph and measure the noise level with a decibel meter.
  2. Repeat the test with the modular hardtop.
  3. Compare the results.
  4. If further noise reduction is needed, noise canceling material padding will be added.
Appendix B: (Sketches/Drawings/Assemblies)

Appendix B-1.1: Drawing Tree
Appendix B-1: Drawing 1 Top Front Sketch

[Sketch Image]

Fedorchuk

Top Front

30.5"

55"

1/4" + 1/2"
Appendix B-2: Drawing 2 RH LH Sketch
Appendix B-3: Drawing 3 Top Rear Sketch
Appendix B-4: Drawing 4 Rear Sketch
Appendix B-5: Drawing 5 Components Sketch
Appendix B.6: Drawing 20-006 LH RH Side Windows

Scale: 1:10

Detail:

Notes:
- Some (mirrored) side panel dimensions are for the LH side panel. The LH side panel has the same dimensions as the RH side panel.
- The pre-drilled holes in the panel are located as shown. The holes are concentric to the top edge of the panel. The holes will be filled with the window during assembly. The window dimensions will be found when the window is installed into the panel.

Drawing 20-006
Appendix B-6: Drawing 20-006 R1: Solidworks Tubular Frame Drawing
Appendix B.7: Drawing 20-007-01

Top Rear Core

Scale: 1:10

Detail C: 10

Modular Hardware
Appendix B-8: Drawing 20-008 Rear Panel Shell Solidworks:
## Appendix C: Parts

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### Appendix E: Schedule GANT

**Schedule for Senior Project:**

**Project Title:** Modular Hardtop  
**Principal Investigator:** Dennis Fedorchuk

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*Note: March x Finals  
Note: June y-z Spr Finals*
<table>
<thead>
<tr>
<th>1</th>
<th>Project/Mod</th>
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<tbody>
<tr>
<td>2a</td>
<td>Project Schedule</td>
</tr>
<tr>
<td>2b</td>
<td>Proposal Pack</td>
</tr>
<tr>
<td>2c</td>
<td>Cut/Draw Manuals</td>
</tr>
<tr>
<td>2d</td>
<td>subtotal</td>
</tr>
<tr>
<td>7c</td>
<td>Change Construction</td>
</tr>
<tr>
<td>7d</td>
<td>Build Panel (Dowel/Plywood)</td>
</tr>
<tr>
<td>7e</td>
<td>Make Top Front Panel</td>
</tr>
<tr>
<td>7f</td>
<td>Make Top Front Shell</td>
</tr>
<tr>
<td>8a</td>
<td>Make Top Front Foam Core</td>
</tr>
<tr>
<td>8b</td>
<td>Make Top Front Outer Layer</td>
</tr>
<tr>
<td>8c</td>
<td>Make Top Rear Panel</td>
</tr>
<tr>
<td>8d</td>
<td>Make Top Rear Panel Foam Core</td>
</tr>
<tr>
<td>8e</td>
<td>Make Top Rear Panel Foam Shell</td>
</tr>
<tr>
<td>8f</td>
<td>Make Top Rear Panel Interior Layer</td>
</tr>
<tr>
<td>8g</td>
<td>Make Side Panel</td>
</tr>
<tr>
<td>8h</td>
<td>Make Side Panel Shells</td>
</tr>
<tr>
<td>8i</td>
<td>Weld Square Tube</td>
</tr>
<tr>
<td>8j</td>
<td>Cut Welding-Ready Lengths</td>
</tr>
<tr>
<td>8k</td>
<td>Mold Tubular Frame</td>
</tr>
<tr>
<td>8l</td>
<td>Make Side Panel Foam Core</td>
</tr>
<tr>
<td>8m</td>
<td>Make Side Panel Interior Layer</td>
</tr>
<tr>
<td>8n</td>
<td>Make Rear Panel</td>
</tr>
<tr>
<td>8o</td>
<td>Make Rear Panel Shell</td>
</tr>
<tr>
<td>8p</td>
<td>Make Rear Panel Foam Core</td>
</tr>
<tr>
<td>8q</td>
<td>Make Rear Panel Foam Shell</td>
</tr>
<tr>
<td>8r</td>
<td>Paint the Panels</td>
</tr>
<tr>
<td>8s</td>
<td>Install Window</td>
</tr>
<tr>
<td>8t</td>
<td>Take Fan Pictures</td>
</tr>
<tr>
<td>8u</td>
<td>Update Website</td>
</tr>
<tr>
<td>8v</td>
<td>Manufacture Plan</td>
</tr>
<tr>
<td>8w</td>
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<tr>
<td>9a</td>
<td>Device/Construct</td>
</tr>
<tr>
<td>9a1</td>
<td>Assemble Side Panels</td>
</tr>
<tr>
<td>9a2</td>
<td>Assemble Rear Panel</td>
</tr>
<tr>
<td>9a3</td>
<td>Entire Assemblies</td>
</tr>
<tr>
<td>9a4</td>
<td>Assemble All Top Panels</td>
</tr>
<tr>
<td>9a5</td>
<td>Take Dev/Photos</td>
</tr>
<tr>
<td>9a6</td>
<td>Update Website</td>
</tr>
<tr>
<td>9a7</td>
<td>subtotal</td>
</tr>
<tr>
<td>10a</td>
<td>Daley Evaluation</td>
</tr>
<tr>
<td>10c1</td>
<td>Unit Parameters</td>
</tr>
<tr>
<td>10c2</td>
<td>Design Tool/Scope</td>
</tr>
<tr>
<td>10c3</td>
<td>Obtain resources</td>
</tr>
<tr>
<td>10c4</td>
<td>Make test sample</td>
</tr>
<tr>
<td>11c1</td>
<td>Plan strategies</td>
</tr>
<tr>
<td>11c2</td>
<td>Test Plans</td>
</tr>
<tr>
<td>11c3</td>
<td>Project Evaluation</td>
</tr>
<tr>
<td>11c4</td>
<td>Take Test Plans</td>
</tr>
<tr>
<td>11c5</td>
<td>Update Website</td>
</tr>
<tr>
<td>11c6</td>
<td>subtotal</td>
</tr>
<tr>
<td>12c</td>
<td>495 Deliverables</td>
</tr>
<tr>
<td>12c1</td>
<td>Test Report</td>
</tr>
<tr>
<td>12c2</td>
<td>Make Deep Outline</td>
</tr>
<tr>
<td>12c3</td>
<td>Write Report</td>
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<tr>
<td>12c4</td>
<td>Make Side Outline</td>
</tr>
<tr>
<td>12c5</td>
<td>Label of Complete Penetration</td>
</tr>
<tr>
<td>12c6</td>
<td>Make CD/DVD List</td>
</tr>
<tr>
<td>12c7</td>
<td>Write 495 CO Parts</td>
</tr>
<tr>
<td>12c8</td>
<td>Update Website</td>
</tr>
<tr>
<td>12c9</td>
<td>Produce CO</td>
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<tr>
<td>12c10</td>
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<table>
<thead>
<tr>
<th>Total</th>
<th>Hours</th>
<th>202.8</th>
<th>101</th>
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</thead>
</table>

- Deliverables
  - Draft Proposal
  - Analysis Mod
  - Document Mods
  - Final Proposal
  - Parts
  - Device Construct
  - Device Evaluation
  - 495 Deliverables

- Total Actual Hours: 202.8
Appendix F: Enterprise and Resources

Material/Parts:

Foam Core: https://www.aircraftspruce.com/catalog/cmpages/divinycellfoam.php

Fiberglass: https://www.aircraftspruce.com/catalog/cmpages/4533.php

Epoxy: https://www.aircraftspruce.com/catalog/cmpages/ezpoxy.php

Brushes: https://www.aircraftspruce.com/categories/building_materials/bm/menus/cm/brushes.html

Tape: https://www.aircraftspruce.com/catalog/cmpages/tape01-01602.php


Rear Side Window: https://www.ebay.com/itm/Jeep-Wrangler-TJ-Hardtop-side-window-Glass-97-06-OEM/123731179848?hash=item1ceef3f948-g:3hkAAOSw5dNWiADP

Paint: https://www.amazon.com/gp/product/B001001LUC/ref=ox_sc_saved_title_6?smid=ATVPDKIKX0DER&psc=1


Insulation Foam: https://www.homedepot.com/p/Project-panels-FOAMULAR-1-in-x-2-ft-x-2-ft-R-5-Small-projects-Rigid-Pink-Foam-Board-Insulation-Sheathing-PP1/203553730

Bolts/Screws: https://www.mcmaster.com/screws

Square Tubing: https://www.mcmaster.com/steel-hollow-bars

Layup:


Beam Deflection:

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19880000739.pdf

Appendix G: Testing Report

Appendix G1: Procedure Checklist:
The requirements for the hardtop are to:

1. Keep the profile of the modular hardtop as close to an original hard top profile as possible.
2. Have the capability to bolt a roof rack directly to the hard top with an option of going through the hardtop and bolting a roof rack to the roll cage.
3. Be able to handle a 150-200 lb. load (with a roof rack).
4. Have the compression strength of the hardtop equal the compression strength of an OEM hardtop.
5. Adapt existing windows for convenience.
6. Reduce noise level by 15%
7. Reduce heat loss by 20%
8. Be able to deconstruct the product into a storage space of 2.5 ft by 3 ft by 2 ft.
9. Be able to withstand water seeping through the connecting sections for a time period of 10 minutes of a constant supply of water.

Appendix G2: Data Forms:

<table>
<thead>
<tr>
<th>Testing</th>
<th>Temperature Reduction</th>
<th>Noise Reduction (Decibels)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hardtop</td>
<td>Softtop</td>
</tr>
<tr>
<td></td>
<td>Outside    Inside</td>
<td>Outside    Inside</td>
</tr>
<tr>
<td>Test 1</td>
<td>Avg.        Difference %</td>
<td>Avg.        Difference %</td>
</tr>
<tr>
<td>Test 2</td>
<td>Avg.        Difference %</td>
<td>Avg.        Difference %</td>
</tr>
<tr>
<td>Test 3</td>
<td>Avg.        Difference %</td>
<td>Avg.        Difference %</td>
</tr>
</tbody>
</table>

Overall Dimensions: (Storage)
Length: 
Width: 
Height: 

Waterproof
Duration: 10 min
Test 1:
Test 2:

Overall Dimensions:
Bottom Window: 
Window Rear: Bottom to Top:
Window Front: Bottom to Top:
Top Total Length:
Width:
Appendix G3: Raw Data:

<table>
<thead>
<tr>
<th>Testing</th>
<th>Temperature Reduction</th>
<th>Noise Reduction (Decibels)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hardtop Outside</td>
<td>Softtop Outside</td>
</tr>
<tr>
<td>Test 1</td>
<td>38.4</td>
<td>21.8</td>
</tr>
<tr>
<td>Test 2</td>
<td>32.8</td>
<td>20.8</td>
</tr>
<tr>
<td>Test 3</td>
<td>32.8</td>
<td>20.6</td>
</tr>
<tr>
<td>Avg.</td>
<td>36.333333339</td>
<td>21.06967</td>
</tr>
<tr>
<td>Difference</td>
<td>15.266666667</td>
<td></td>
</tr>
<tr>
<td>Overall Dimensions (in)</td>
<td>(Storage)</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

Waterproof:
Duration: 10 min
Test 1: Fail
Test 2: Pass

<table>
<thead>
<tr>
<th>Overall Dimensions:</th>
<th>Modular (in)</th>
<th>Overall Dimensions:</th>
<th>Original (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom Window</td>
<td>44</td>
<td>Bottom Window</td>
<td>44</td>
</tr>
<tr>
<td>Window Rear Bottom to Top:</td>
<td>29.5</td>
<td>Window Rear Bottom to Top:</td>
<td>28.5</td>
</tr>
<tr>
<td>Window Front Bottom to Top:</td>
<td>50.5</td>
<td>Window Front Bottom to Top:</td>
<td>28.5</td>
</tr>
<tr>
<td>Top Total Length:</td>
<td>71.6</td>
<td>Top Total Length:</td>
<td>71.25</td>
</tr>
<tr>
<td>Width:</td>
<td>57</td>
<td>Width:</td>
<td>56.5</td>
</tr>
</tbody>
</table>
Appendix G4: Evaluation Sheet:

<table>
<thead>
<tr>
<th>Temperature Reduction:</th>
<th>Noise Reduction (Decibels)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardtop</strong></td>
<td><strong>Softtop</strong></td>
</tr>
<tr>
<td>Outside</td>
<td>Inside</td>
</tr>
<tr>
<td>Test 1</td>
<td>38.4</td>
</tr>
<tr>
<td>Test 2</td>
<td>37.8</td>
</tr>
<tr>
<td>Test 3</td>
<td>32.8</td>
</tr>
<tr>
<td><strong>Avg.:</strong></td>
<td><strong>36.33333</strong></td>
</tr>
<tr>
<td><strong>Diff.:</strong></td>
<td><strong>15.33333</strong></td>
</tr>
<tr>
<td><strong>%</strong></td>
<td>42.01835</td>
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**Figure 2 Storage**

**Figure 2 Waterproofing**
Appendix G5: Gantt Chart:

Gantt Chart:

<table>
<thead>
<tr>
<th>Task</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>10th Device Evaluation</td>
<td></td>
</tr>
<tr>
<td>10i List Parameters</td>
<td>2</td>
</tr>
<tr>
<td>10h Design Testscript</td>
<td>3</td>
</tr>
<tr>
<td>Obtain resources</td>
<td>3</td>
</tr>
<tr>
<td>Make test samples</td>
<td>2</td>
</tr>
<tr>
<td>Plan analysts</td>
<td>2</td>
</tr>
<tr>
<td>11a Instrument</td>
<td>2</td>
</tr>
<tr>
<td>11b Test Plan</td>
<td>2</td>
</tr>
<tr>
<td>11c Perform Evaluation</td>
<td>2</td>
</tr>
<tr>
<td>11d Take Testing Pics</td>
<td>0.5</td>
</tr>
<tr>
<td>11e Update Website</td>
<td>2</td>
</tr>
<tr>
<td>11f Test: Hardtop Dim. Comparrison</td>
<td>1</td>
</tr>
<tr>
<td>11g Test: Roof Rack Compatibility</td>
<td>1</td>
</tr>
<tr>
<td>11h Test: Load Capability</td>
<td>1</td>
</tr>
<tr>
<td>11i Test: Compression Test Comparrison</td>
<td>1</td>
</tr>
<tr>
<td>11j Test: Window Compatibility</td>
<td>1</td>
</tr>
<tr>
<td>11k Test: Noise Reduction</td>
<td>1</td>
</tr>
<tr>
<td>11l Test: Heat Loss Reduction</td>
<td>1</td>
</tr>
<tr>
<td>11m Test: Storage Area Capability</td>
<td>1</td>
</tr>
<tr>
<td>11n Test: Water Proof</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 3 Weight Capability
Appendix H: Resume
# JOB HAZARD ANALYSIS

## Manufacturing Process: Welding

**Prepared by:**
Dennis Fedorchuk

**Reviewed by:**

**Approved by:**

### Location of Task:
Home

### Required Equipment / Training for Task:
1. Operation of arc welder
2. Operation of a fire extinguisher
3. Location and use of the fire alarm

### Reference Materials as appropriate:
[https://ehs.berkeley.edu/sites/default/files/jsa-library/fsarcweld_02.pdf](https://ehs.berkeley.edu/sites/default/files/jsa-library/fsarcweld_02.pdf)

### Personal Protective Equipment (PPE) Required

(Check the box for required PPE and list any additional-specific PPE to be used in "Controls" section)

<table>
<thead>
<tr>
<th>Gloves</th>
<th>Dust Mask</th>
<th>Eye Protection</th>
<th>Welding Mask</th>
<th>Appropriate Footwear</th>
<th>Hearing Protection</th>
<th>Protective Clothing</th>
</tr>
</thead>
<tbody>
<tr>
<td>✘</td>
<td>✘</td>
<td>✘</td>
<td>✘</td>
<td>✘</td>
<td>✘</td>
<td>✘</td>
</tr>
</tbody>
</table>

Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.

<table>
<thead>
<tr>
<th>PICTURES (if applicable)</th>
<th>TASK DESCRIPTION</th>
<th>HAZARDS</th>
<th>CONTROLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc Welding: Close off welding area.</td>
<td>Flashing</td>
<td>Close welding curtain to shield outsiders from flashing.</td>
<td></td>
</tr>
<tr>
<td>Arc Welding: Prepare for arc welding.</td>
<td>Inhalation of fumes, Flashing, Sparks, Slag splatter</td>
<td>Turn on exhaust fan and timer. Wear welding hood, welding jacket, apron, gloves, work shoes.</td>
<td></td>
</tr>
<tr>
<td>Arc Welding: Turn on power and unwrap wire.</td>
<td>Tripping</td>
<td>Take care to keep wire untangled and free from under feet.</td>
<td></td>
</tr>
<tr>
<td>Arc Welding: Insert arc welding rod in handle.</td>
<td>Pinch to fingers</td>
<td>Keep fingers away from pinch points.</td>
<td></td>
</tr>
<tr>
<td>Arc Welding: Strike arc.</td>
<td>Flashing, sparks, slag splatter</td>
<td>Wear welding hood, welding jacket, apron, gloves, work shoes.</td>
<td></td>
</tr>
<tr>
<td>Arc Welding: Allow material to burn to hands or fingers.</td>
<td></td>
<td>Wear glove. Chalk mark welded area “Hot.”</td>
<td></td>
</tr>
<tr>
<td>Arc Welding:</td>
<td>Burn to hands or fingers</td>
<td>Chalk mark welded area &quot;Hot&quot;</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td>Remove remainder of arc welding rod (if any) from handle, set aside on workbench to cool.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arc Welding:</td>
<td>Tripping</td>
<td>Take care to keep wire untangled and free from under feet</td>
<td></td>
</tr>
<tr>
<td>Wrap wire.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arc Welding:</td>
<td>Eye damage by flying debris from hammer strikes. Injuring fingers with hammer</td>
<td>Wear safety glasses. Use caution to avoid striking fingers or hands with hammer</td>
<td></td>
</tr>
<tr>
<td>Use chipping hammer to remove excess slag.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# JOB HAZARD ANALYSIS

**Manufacturing: Angle Grinder**

<table>
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<tr>
<th>Prepared by:</th>
<th>Reviewed by:</th>
<th>Approved by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dennis Fedorchuk</td>
<td></td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Location of Task:</th>
<th>Home</th>
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|----------------------------------------|--------------------------------------------------------------------------|

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<tr>
<th>Reference Materials as appropriate:</th>
<th><a href="https://ehs.berkeley.edu/sites/default/files/sa-library/fsangrnmcr.06.pdf">https://ehs.berkeley.edu/sites/default/files/sa-library/fsangrnmcr.06.pdf</a></th>
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## Personal Protective Equipment (PPE) Required

(Check the box for required PPE and list any additional/specific PPE to be used in "Controls" section)

<table>
<thead>
<tr>
<th>Gloves</th>
<th>Dust Mask</th>
<th>Eye Protection</th>
<th>Welding Mask</th>
<th>Appropriate Footwear</th>
<th>Hearing Protection</th>
<th>Protective Clothing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.

<table>
<thead>
<tr>
<th>PICTURES (if applicable)</th>
<th>TASK DESCRIPTION</th>
<th>HAZARDS</th>
<th>CONTROLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Angle Grinder:</strong> Check cord integrity</td>
<td>Hand cut from cut wires.</td>
<td>Wear leather gloves. Inspect slowly</td>
</tr>
<tr>
<td></td>
<td><strong>Angle Grinder:</strong> Check conditions of grinding wheel and appropriate RPM.</td>
<td>(None foreseen)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Angle Grinder:</strong> Check grinding wheel tightness.</td>
<td>Hand injury from inadvertent starting</td>
<td>Do not plug in the machine until inspection is complete</td>
</tr>
<tr>
<td></td>
<td><strong>Angle Grinder:</strong> Verify the guard is tight and appropriate for the job.</td>
<td>Foot injury from dropping the tool</td>
<td>Rest the tool on the bench. Wear steel-toed shoes</td>
</tr>
<tr>
<td></td>
<td><strong>Angle Grinder:</strong> Verify the</td>
<td>Foot injury from dropping the</td>
<td>(See controls for Task 4 )</td>
</tr>
</tbody>
</table>

**File Name:** MS-01  
**Page 1 of 1**  
**Revision Date:** February 2018 Revised MET489 October 2018
<table>
<thead>
<tr>
<th>Tool</th>
<th>Appropriate Handle Location</th>
<th>Injuries Associated with the Work Propelled by the Grinder and/or Landing on You</th>
<th>Verify the Work is Adequately Secured by Trying to Dislodge It with a Goved Hand (the Work Weight May Secure It Enough). Wear Steel-Toed Shoes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Angle Grinder:</strong> Plug-in the grinder</td>
<td>Eye and Skin Damage from Projectiles.</td>
<td>Check the Trigger Switch to Insure it is Off.</td>
<td></td>
</tr>
</tbody>
</table>
**JOB HAZARD ANALYSIS**

**Manufacturing: Drill/Cutting Tool**

<table>
<thead>
<tr>
<th>Prepared by</th>
<th>Reviewed by</th>
<th>Approved by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dennis Fedorchuk:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location of Task</th>
<th>Home</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Required Equipment / Training for Task</th>
<th>Drill</th>
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</thead>
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<th><a href="https://ehs.berkeley.edu/sites/default/files/jsa_library/ucps05.pdf">https://ehs.berkeley.edu/sites/default/files/jsa_library/ucps05.pdf</a></th>
</tr>
</thead>
</table>

**Personal Protective Equipment (PPE) Required**

(Choose the boxes 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.

<table>
<thead>
<tr>
<th>Pictures (if applicable)</th>
<th>Task Description</th>
<th>Hazards</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill:</td>
<td>Place drill bits into spindle.</td>
<td>Sharp blades and drill bits. Hold bit away from sharp edges.</td>
<td></td>
</tr>
<tr>
<td>Drill:</td>
<td>Cleaning damaged drill bit.</td>
<td>Sharp, spinning blades. Clear jam in the STOP position only or remove blade and clear jam with tool provided.</td>
<td></td>
</tr>
<tr>
<td>Cutting Tool:</td>
<td>Knife used to trim the foam core.</td>
<td>Sharp blades. Wear gloves.</td>
<td></td>
</tr>
</tbody>
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JOB HAZARD ANALYSIS
Manufacturing: Painting/Mixing Epoxy Resin

Prepared by: Dennis Fedorchuk
Reviewed by:  
Approved by:

Location of Task: Home/CWU Composites Lab

Required Equipment / Training for Task: Safety glasses, appropriate PPE, Operation of airless pressure sprayer

Reference Materials as appropriate: https://ehs.berkeley.edu/sites/default/files/jso-library/pptspainting138.pdf

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Personal Protective Equipment (PPE) Required
(Check the box for required PPE and list any additional/specific PPE to be used in “Controls” section)

<table>
<thead>
<tr>
<th>Gloves</th>
<th>Respirator</th>
<th>Eye Protection</th>
<th>Welding Mask</th>
<th>Appropriate Footwear</th>
<th>Hearing Protection</th>
<th>Protective Clothing</th>
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PICTURES (if applicable)

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<tr>
<th>TASK DESCRIPTION</th>
<th>HAZARDS</th>
<th>CONTROLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painting: Clean sprayer tip, scrape dried paint off stencils; coat stencils and hang to dry in shop</td>
<td>Pinch points for hands and fingers. Vision damage. Environmental damage</td>
<td>Wear gloves Avoid pinch points by keeping eyes on task. Wear safety glasses. Place dried paint scrapings inside dry paint buckets and deposit in dumpster.</td>
</tr>
<tr>
<td>Mixing Epoxy Resin:</td>
<td>Off-gassing</td>
<td>Work in a ventilated area. The garage at home and the composites lab. The composites lab has a ventilation system that will be used. Wearing glove, the appropriate PPE and a respirator will help protect an individual as well. Wear safety glasses. SOF</td>
</tr>
</tbody>
</table>

File Name: MS-01
Page 1 of 1
Revision No. 1
Revision Date: February 2018 Revised MET489 October 2018
## JOB HAZARD ANALYSIS
### Assembly Process

**Prepared by:**
Dennis Fedorchuk

**Reviewed by:**

**Approved by:**

### Location of Task:
Central Washington University/Home

### Required Equipment / Training for Task:

### Reference Materials as appropriate:

### Personal Protective Equipment (PPE) Required

<table>
<thead>
<tr>
<th>Gloves</th>
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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
--- | --- | --- | ---
Installing Panels | Glass Breaking | Make it a two-person job. Wear the appropriate PPE. Gloves should be used for this procedure. |
Installing Panels | Pinch Points | Wear the appropriate PPE. Gloves should be used for this procedure. |
Installing Bolts | Pinch Points | Wear the appropriate PPE. Gloves should be used for this procedure. |
Assembled Device | Load | Do NOT place a point load over 400 lb. |
Appendix K: Reference Material

Material Quantity (for the top shells):

1. Breather Material: $55'' \times 76.5'' + (6'' \times 8'') \times 2$
2. Peel Ply: $61'' \times 76.5''$
3. Plastic: $63'' \times 79.5'' + (9'' \times 8'')$
4. Fiber glass: $((61'' \times 76.5'') + (9'' \times 8'')) - 4$
5. Tape: $76.5'' + 60''$

[Diagram of top shell dimensions]