Retractable Hammock Final Design Report
ME 430-06
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Jesse Mandell
jessebmandell@gmail.com

Collin Richardson
collinrichardson11@gmail.com

Owen Guenther
oweng8@gmail.com

Sponsored by
Will Marchese
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Abstract

This Final Design Review will recap the objectives, background, design ideation, and concept development of the Retractable Hammock senior capstone project and continue to report on the final design and manufacturing that resulted in the final iteration of the Retractable Hammock.

1. Introduction

The outdoor recreation industry is of immense size and scale and provides nearly eight million jobs to the U.S. labor force. At an annual revenue of about $900 billion dollars, this market would rank in the top 20 of world economies if it were a stand-alone nation. As such, being the first to provide a new, highly-desired product would allow its proprietor to corner a small, yet substantial piece of a vast market. This project aims to achieve this through the design and prototyping of a portable, retractable hammock system. This first-of-its-kind product will be cheap and easy to manufacture and will allow the user to feed a hammock from an adaptable mount to an existing support, then easily retract it back into the system in a safe, smooth, and elegant process.

In this report, pertinent background information will be established, project objectives will be discussed, and a project timeline will be described, and a manufacturing plan for a final design will be presented all to give the reader a complete picture of the process that will ultimately yield the Retractable Hammock. The stakeholders in this endeavour are Will Marchese, the project sponsor, and Eileen Rossman, the project advisor.

2. Background

A hammock is almost always part of an outdoor recreationists repertoire of equipment. However, the enjoyment of lounging in one never comes without a cost. The ideal customer for the Retractable Hammock would be any outdoor enthusiast who has endured the monotony of setting up a hammock, and the annoyance of rolling it all back up, who had to find two, sufficiently spaced trees to lie under, only to experience an obstructed view of the sky. Finally, the user is someone who appreciates the functionality of the product and finds joy in a gadget that makes life a little easier.

2.1 Relevant Existing Products

A product does not exist yet that addresses these aforementioned points. Perhaps similar to the overall idea of the Retractable Hammock are car mounted hammock setups such Figure 1 and 2 found below.

Figure 1. Eagle Nest Outfitters Roadie Hammock Stand
ENO has manufactured a product that is arguably related to the Retractable Hammock. They boast a “beefy hammock stand that uses your car’s weight to anchor the stand.”[1.]

The purpose of our product precludes any presence of potential product competition. The point of the Retractable Hammock is ease of use. The ENO hammock stand not only requires the set up and stowing away of the hammock, but it also requires two bulky stand components. Additionally, the system is rated for a minimum vehicle weight and wheel diameter. Finally, at a cost of $200, the ENO Roadie is in a higher price range than that intended of the Retractable Hammock.

![Figure 2. TrailNest Roof Top Hammock Stand](Image)

The TrailNest Roof Top Hammock system poses problems of its own, the most obvious of which is potential damage to the roof of the car. Otherwise, issues with storage and setup are even greater than with the ENO stand. Finally, safety issues arise when considering that the user has to climb to the top of their car.

The Retractable Hammock system will improve upon these ideas through a car mounted hammock design that will be easier to deploy/retract than both of these designs, have minimal bulk, and will have a substantial degree of adjustability, allowing the user to decide how high and taut they want the hammock.

### 2.2 Patent Search

After an extensive patent search, nothing was found for an existing retractable hammock system, ensuring that the proposed product will truly be a first of its kind. However, there are patents surrounding certain hammocks and strap systems, such as Eno’s™ Atlas Strap’s “no-knots-needed set-up.” (Patent Number: US D573381 S1) These patents could become an issue when trying to integrate a preexisting hammock into our retractable system.

### 2.3 Vehicle List

Early in the research portion of this project, a list was created to contain the vehicles for which the Retractable Hammock system would be designed. A handful of vehicles proved to be viable;
however, it was decided that the scope of the system would be refined to only focus on a 2017 Jeep Wrangler with an exposed roll bar. This was done because deciding which vehicles to design for falls in the marketing capacity; this could prove a significant misuse of time and resources if considered in the engineering design process. As such, the result of the Retractable Hammock project will be a retractable system temporarily attached to a mounting system specific to the 2017 Jeep wrangler, but designed with a degree of variability to fit an array of mounting systems that could be designed later, as well as a compact, self supporting system. By designing an adaptable mounting system, the Retractable Hammock could be integrated into not only a long list of different all-terrain vehicles, but also for more suburban applications such as back patios and offices. Keeping the application flexible will allow for exploration of different markets as the product progresses.

2.4 Retraction Mechanism

It was noted early in the design process that the defining component of this product would be its retraction mechanism. There were many types of retraction that were viable, such as a motor powered system, a spring, counterweights, and the obvious hand-crank mechanism. These were all evaluated and compared during the ideation process of the project.

3. Objectives

This project aims to design an adaptable and versatile retractable hammock system that can safely, easily, and smoothly retract and stow a hammock. In doing so, it is necessary to define the boundary to which this system will be designed.

Below is a boundary diagram, Figure 3, illustrating the full extent of this project. The need for different types of mounting brackets as well as a need for a secondary support system is foreseeable. As a group, it was decided that splitting our focus away from the retraction capabilities would be detrimental to the overall quality of the product. Therefore, this process will focus on only the retraction mechanism, its housing, and the mounting system for a Jeep rollbar. The hammock will not be designed, it will still be included in the final project and thusly has been included in the diagram.

![Figure 3. Boundary Diagram](image-url)
The Quality Function Design Matrix, QFD, is a tool used to organize and compare information about one's product and other products on the market. Its purpose is to focus on the qualities of the product and identify where current options fall short. Found in Appendix A is the QFD created for the retractable hammock. It outlines the qualities deemed important and how they relate to other variables in the design. Then each quality is rated in how it relates to the design variables chosen. The qualities included are retractability; possibly the most important. Lightweight: the system is going to need to be attached and suspended so it must be light to make hanging it feasible. Durable: entire apparatus will be outside and exposed to the weather, both run and rain, and needs to be resistant to these conditions. Low cost: an important consideration in any engineering endeavor. Adaptable: there are multiple different mounting setups and the design should be able to interact with all of them. Aesthetic: this product will eventually be on store shelves. It will need to look good to catch the customer's eye. Simple operation: the competition is the standard hammock that requires setup, the retractable hammock must be superior in this department or the design would be a failure. Safe: this is a product used by people and already not the safest of seats you can sit on; it will need to be secure in its mounting and support. Portable and Compact: the retractable hammock should blend in with its surroundings and not stick out. To achieve this, the design will be as compact as possible without sacrificing functionality.

In every design there are ideas do not make it to the final product. They could be too difficult or too far from the scope of the project. It is critical to identify what pieces are mandatory and which can be optional. As such, the potential components and characteristics of the product have been broken up into customer wants and needs.

Mr. Marchese described a product that has a retractable system enclosed in a sleek, compact housing that could mount onto surfaces such as roof racks, RV back panels, office walls and would have its stand alone second support system.

From this the customer needs were defined as a durable, compact, and lightweight spring based retractable system designed to be low cost, safe and adaptable that should be completed by June 2018. Quantified descriptions of these points can be found in Table 1 below. What remained became customer wants that will be retroactively designed at a later juncture.
Table 1: Engineering Specifications Of Retractable Hammock System.

<table>
<thead>
<tr>
<th>Spec #</th>
<th>Parameter Description</th>
<th>Target</th>
<th>Tolerance</th>
<th>Risk</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight</td>
<td>40 lbs</td>
<td>Max</td>
<td>Low</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>Production Cost</td>
<td>$70</td>
<td>± 10</td>
<td>Med</td>
<td>A, S</td>
</tr>
<tr>
<td>3</td>
<td>Hammock Load Requirement</td>
<td>400 lbs</td>
<td>± 20</td>
<td>High</td>
<td>S, T</td>
</tr>
<tr>
<td>4</td>
<td>Distance Variability</td>
<td>3 ft</td>
<td>Min</td>
<td>M</td>
<td>T, I</td>
</tr>
<tr>
<td>5</td>
<td>Size of Housing</td>
<td>2.13 ft</td>
<td>Max</td>
<td>H</td>
<td>A, I</td>
</tr>
<tr>
<td>6</td>
<td>Durability (Drop Test Height)</td>
<td>3 ft</td>
<td>Min</td>
<td>L</td>
<td>T</td>
</tr>
<tr>
<td>7</td>
<td>Retraction Mechanism Life</td>
<td>500 Cycles</td>
<td>Min</td>
<td>L</td>
<td>A, T</td>
</tr>
<tr>
<td>8</td>
<td>Retraction Force</td>
<td>20 lbs</td>
<td>Max</td>
<td>M</td>
<td>T, A</td>
</tr>
<tr>
<td>9</td>
<td>System Opening Accessibility</td>
<td>2 in</td>
<td>Max</td>
<td>L</td>
<td>I, T</td>
</tr>
</tbody>
</table>

Each specification will be checked by a variety of approaches. These include analysis, A; testing, T; inspection, I; and already existing products, S. We will be able to hands-on test hammock load, distance variability, durability, life of mechanism and retraction force all with common tools. Weight and housing size will both be analyzed in SolidWorks using finite element analysis, FEA. Production cost will be calculated based off research of current market options and

The hammock load requirement and the size of the housing were ranked as high risk design specifications. The hammock load requirement is high risk not only due to safety concerns if this specification is not met, but also due to the variability of use. If a customer is to erect the hammock in an unconventional or extreme way, the design of the system should ensure total safety.

The size of the housing requirement was deemed high risk because it is dependent on many of the other specifications. The strength, mechanism, and geometry all have the potential to increase the housing size to an extent that may defeat the purpose of this product.

4. Concept Design Development

The ideation process of this project was challenging at times, but proved successful. It began with a functional decomposition, specifically for the system’s retraction and stow mechanisms. Then after a brain writing session and SCAMPER chart construction. These are both techniques used to facilitate idea generation. With these potential designs in mind, an initial prototype, Figure 4 pictured below, was constructed based on the results from the aforementioned ideation sessions. The exact components that were to be included were decided based on simplicity of construction. A cylindrical housing was used
with a rubber band powered retraction mechanism meant to represent spring based retraction, and a strap based mounting system was represented by the strings. The purpose of this concept model was to use easy-to-use materials to quickly gauge the quality of our potential designs.

Figure 4. Concept prototype

This step proved helpful as it supported the legitimacy of the current design and showed potential problems that may arise. The main takeaways were: precautions would have to be taken to minimize deflection of the shaft and stress experienced by the supports, the strap method of attachment worked well to both support the hammock and to give it a freedom of motion that other fastening methods would not allow, using energy stored in a spring when the hammock was extended to retract it also seemed to work well, and finally, the cylindrical shape and configuration of the supports not only uses minimal material, but it proved to be aesthetically pleasing.

From here, all considered alternatives had to be evaluated, compared, and ultimately decided on. This began by compiling final lists of alternatives considered for the mounting system, retraction system, and the hammock that was to be used. Once all unviable alternatives had been eliminated, Pugh matrices were constructed to evaluate ideas. Table 2 contains the Pugh matrix for the three types of retraction mechanisms that were considered.
Table 2: Pugh Decision Matrix for Retraction Mechanism.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weighting</th>
<th>Spring</th>
<th>Motor</th>
<th>Crank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>3</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Life</td>
<td>2</td>
<td>0</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Reliability</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Power Needed</td>
<td>2</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>4</td>
<td>0</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Compactness</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Safety</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>0</td>
<td>-3</td>
<td>-11</td>
</tr>
</tbody>
</table>

The above figure is a method of alternative evaluation that compares two ideas to a datum, in this case the spring based retraction mechanism, using a set of criteria assigned quantitative weightings. The results of this step showed that the spring mechanism was the recommended alternative.

This process was repeated for the mounting system and hammock selection as well. A weighted decision matrix (Appendix B) was constructed using the mounting and retraction system. These led to the decision of a spring powered (Figure 5), hose clamped system. With that said, a strap mounting system will remain in the project repertoire moving forward, as it is virtually as viable as the clamp mounting.
In an effort to be completely sure of the above decision the final structural prototype (Figure 6) was constructed with a hose clamp-crank combination (Figure 7).
This showed that the current size of the system would fit a hammock, but also revealed that the crank system was rather crude. Although the appearance of the hose clamps is also slightly unsightly, it will remain the prime alternative.

4.1 Proof Of Concept Testing

Once the design had been decided on, proof of concept testing began. A “roll up test” was conducted in order to test how the tension affected the compactness of the hammock when it is rolled up by attaching a hammock to the shaft and rolling it up under a varying degrees of tension. This test found that 2.69 lbs of tension resulted in a hammock diameter of about 4.7 inches compared to the no tension control diameter of about 7 inches. See Appendix C for test results.

Finally, the hammock was rolled up inside the structural prototype under tensile conditions similar to those during operation (Figure 8) to find that the wound up hammock fit compactly with no issue.
4.2 Selected Concepts

Using what was learned from the two prototyping phases and the proof of concept testing, the final selected design can be characterized by the following: a durable metal shaft on roller bearings secured to two circular supporting sidewalls enclosed by a weatherproof housing. The shaft will have a recoil spring on the outside of each sidewall, which are both fastened to a rear mounting plate. The mounting plate will be the site of adaptability, designed to an array of mounting fixtures including two hose clamps used to rigidly attach the entire system to a rollbar. Finally, for safety and reliability reasons, both recoil springs will have their own housing. See Figure 9 for a labeled drawing of the final design.

4.3 Meeting Project Goals

The customer needs defined in the beginning of this design process have successfully been met by this design.

A cylindrical can design efficiently fits to a wound-up hammock’s natural shape, while the added tension of a second recoil springs ensures a more tightly wrapped hammock, resulting in a significantly compact product. The presence of the rear mounting plate not only ensures adaptability, but adds rigidity. With a strong metal shaft and body robustly connected to the mounting plate, sound structural integrity can be achieved. This combined with a small front opening mitigates any foreseeable risk to the user achieving the predefined design safety
benchmark. Further safety considerations can be found in the Safety Hazard Checklist (Appendix I).

The final drawing of the retractable hammock can be found below, exploded and labeled for ease of viewing.

![Labeled Concept CAD Model](image)

**Figure 9. Labeled Concept CAD Model.**

4.4 Risks and Unknowns

There exist risks inherent to this product, fortunately, they are easy to define. Considering use of this product will involve a user suspended 2-3 ft off of the ground, the analysis to come must be certain and concise. Breakpoints will have to be analysed as well as shaft deflection and stresses at the support and mounting points. Reliability is another risk. With this design comes the assumption that a recoil spring can be found that, when in series with another, will offer sufficient tension and retraction. Although this assumption is considerably viable, it still imposes risk on the actual design itself.

5. Final Design

5.1 Functional Description

During an extensive analysis of the spring based retraction mechanism, it was found that having two recoil springs on either side failed to deliver the required number of revolutions needed to stow the 12-15 feet of hammock. After applying recoil spring design equations to the needs of the system, the resulting thickness, length, and width negated the compactness of the design as well as its low cost. As such the final design has been changed to include an adaptable hex end on one side of the shaft on which a drill or crank can be used to provide the power needed for retraction.
Additionally, the regularity of the hex shape, as well as the size to be used, adds further adaptability to the design. Below is an isometric view of the improved design, Fig 10.

![Isometric View](image)

Figure 10. Isometric View

The main assemblies remain the same for the most part. An analysis of stress experienced by the shaft precluded the use of aluminum for this component, and as such 12L14 steel will be used for its strength and machinability. Alternatively, the bearings were added to this shaft to improve ease of use and resist wear. Furthermore, a helical insert cut was made in the sidewall supports, allowing them to be fastened to the back support with flat washers and bolts to ensure structural integrity. Finally, the hammock was looped around the shaft and around itself to attach to the system to allow for easy replaceability.

Appendix H has a series of analyses used to finalize our design and to show that it does indeed provide the necessary strength to hold the user. In the calculations, a force of 600 lb was used for the bending moment calculation. This was used to provide a large force amplification factor due to a user “jumping” into the hammock. The results show that the greatest stress occurs with a magnitude of about 37,000 psi which is provides a Factor of Safety of about 2 compared to the listed yield strength for the shaft of 60,000 psi.

### 5.2 Safety, Maintenance, and Repair

#### 5.2.1 Safety

The Retractable Hammock’s Design is simple but that does not make it immune to danger. The main safety issues are:

1. User falling due to failure of hammock, shaft, or straps
2. The drill powered retraction mechanism being too fast, “whipping” straps or carabiners towards users
3. Pinch points and sharp corners can harm users

Since the hammock does not fall within the scope of this project, it is not of concern. The shaft will hold up to about 4 times the weight of a 300lb user. See Appendix H for more details. As for the straps, the manufacturer, Strapworks, rates their heavyweight polypropylene straps to hold up to 1,800 lbs, which with two of these straps, provides a Factor of Safety of 12 for a 300 lb user.

The true speed of retraction, the performance under this speed, and the volatility of the actual retraction will not be known until the final prototype is complete. Until then the following precautions could be taken to ensure a slow and steady retraction: gear step down, adding unidirectional spin resistance to the shaft, providing a low speed electric screwdriver with purchase, or including a label warning users to using drills maximum speed.

Although the pinch points of our design will not be known until the completion of our final prototype, fixing them is as easy as installing rubber pieced to not allow pinching to occur. Additionally, the extensive nature of the manufacturing process, which includes deburring and rounding of corners, precludes the need for any other precaution.

5.2.2 Maintenance

The hope during the design process for this project was to create a product that would ideally require no maintenance. The steel and aluminum offer great corrosion resistance, the ABS provides a stain-free finish, and the bearings are rated for millions of revolutions. Due to the low number of hours in use of the bearings, relubrication is not necessary.

5.2.3 Repair

The only foreseeable repairs needed for this product would be hammock replacement and fixing dents in the protective casing. Under correct usage of the system, neither of these situations should need to occur. In the case they do occur, the disassembling of the the hammock is easy. The bolt heads are standard sizes and the adhesive can easily be heated to remove the housing and then reheated to readhere.

5.3 Material Selection

This design uses mostly 6061 Aluminum, for the sidewalls and back support. This was chosen for the low weight and high corrosion resistance of aluminum as well as its low price. Since these components experience very light loads compared to the shaft, it was decided that aluminum was sufficiently strong.

The shaft was chosen to be 12L14 steel for its High yield strength and ultra-machinability. The 60,000 psi yield strength allows for a factor of safety of almost 2 on an already conservative stress analysis.

The ABS plastic was chosen for its low cost, high shock resistance, and aesthetic finish. It is also easy to form and cut and bonds well to the adhesive chosen. Finally, it’s weatherproof and lightweight properties allows for a more durable and lightweight design.
5.4 Cost Analysis

After organizing all of the necessary parts for this project, the estimated cost is $123.28. This is a reasonable amount for a product like the Retractable Hammock. The primary cost comes from the raw material, both aluminum and plastic. These two materials, three components, account for over 50% of the cost. If this product goes to mass production this cost would be greatly reduced with bulk options. Detailed cost analysis can be found in Appendices E and G.

5.5 Design Changes

The only design change made from the Critical Design Review was the implementation of a small velcro piece sewn into the end of the strap that would attach to its counterpart adhered to the shaft. The purpose of this was to provide initial friction for the hammock to begin wrapping around itself which effectively initiates a successful retraction process.

6. Manufacturing Plan

Since this design is ultimately intended to make it to the full scale production phase, a detailed manufacturing plan has been created which describes the entire manufacturing process. A description of it can be found below, however the full step-by-step manufacturing plan and engineering drawings for each part can be found in appendix E.

6.1. Procurement

All of the raw materials and parts used in the design can be ordered online. A table with the part, part number manufacturer, price and lead time can be found below in Table 3.

Table 3. Parts list

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Part</th>
<th>Manufacturer Part Number</th>
<th>Price/Part</th>
<th>Shipping Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>McMaster Carr</td>
<td>Sidewall</td>
<td>1610T56</td>
<td>$16.06</td>
<td>5 Bus. Days</td>
</tr>
<tr>
<td>McMaster Carr</td>
<td>Helicoil</td>
<td>94000A153</td>
<td>$0.04</td>
<td>5 Bus. Days</td>
</tr>
<tr>
<td>McMaster Carr</td>
<td>Bolt</td>
<td>92196A541</td>
<td>$0.12</td>
<td>5 Bus. Days</td>
</tr>
<tr>
<td>McMaster Carr</td>
<td>Back Plate</td>
<td>9246K492</td>
<td>$21.44</td>
<td>5 Bus. Days</td>
</tr>
<tr>
<td>McMaster Carr</td>
<td>Shaft</td>
<td>90075K232</td>
<td>$13.91</td>
<td>5 Bus. Days</td>
</tr>
<tr>
<td>McMaster Carr</td>
<td>Bearings</td>
<td>90075K232</td>
<td>$5.76</td>
<td>5 Bus. Days</td>
</tr>
<tr>
<td>Interstate Plastics</td>
<td>Housing</td>
<td>-</td>
<td>$15.85</td>
<td>1 week</td>
</tr>
<tr>
<td>Strap Works</td>
<td>Straps</td>
<td>-</td>
<td>$11.52</td>
<td>1-2 weeks</td>
</tr>
<tr>
<td>JB Weld</td>
<td>Glue</td>
<td>-</td>
<td>$4.75</td>
<td>1 week</td>
</tr>
</tbody>
</table>
6.2. Manufacturing

Once all the parts have been procured, it will be time to begin the actual manufacturing of each part. Of all of the parts in the assembly only four will have to be machined or altered in any way; the sidewalls, the shaft, the back plate and the plastic housing. As mentioned before, the complete package of engineering drawings can be found in Appendix E. All parts must be machined to the dimensions and tolerances indicated on these drawings in order to ensure full functionality and safety of the design. Once all the parts are machined the machinist must lastly deburr all edges and inspect the parts to ensure that they fit within the specified tolerance.

6.2.1. Sidewall Manufacturing

When the sidewall raw material is received from McMaster-Carr it will be in the form of a six inch diameter by half inch thick aluminum disk. Since the overall diameter will not be altered, the machinist must first measure the diameter and be sure that the part is within the listed tolerance. The first step of the machining process will be to drill and bore out the center hole in which the bearing will be mounted to. Since bearings will be press fit into these center holes their dimensions and tolerances are critical, which is why the hole must first be drilled then opened up to size using a boring bar. The next step will be to machine the flat edge in which the back plate will be bolted. Lastly two holes will be drilled and helicoiled on the flat edge for the mounting bolts. The machinist must be sure to break off and remove the tangs of the helicoils to allow the bolt to be fully threaded on. Since the alignment of the center holes is critical, given that a shaft will be pressed between them, special care must be taken to ensure accurate machining.

6.2.2. Shaft Manufacturing

The shaft that will be delivered by McMaster Carr will already by the right length at twelve inches. This means that all that will be required is turning down steps for the bearings and machining the hex for the mating with the drill bit. The first step will be to turn the two ends so the bearings will fit. Again, since this shaft will be press fit into the bearing the tolerance on this dimension is critical. Next, on on end, the shaft will need to be turned down again to prepare for the machining of the hex. The dimension of this second and smallest step was chosen to intentionally round off the corners on the hex. This will result in easier mating with the drill, without compromising the strength of the connection. Lastly the hex pattern will need to be cut into the small end of the shaft. This is suggested to be performed by either a CNC machine, or can be manually done by using a rotary vise and a mill. The main concerns with the shaft manufacturing are the tolerances, so the machinist must strictly adhere to the tolerances called out on the engineering drawing.

6.2.3. Back Mounting Plate Manufacturing

The raw material that will be received from McMaster Carr will be four inches wide by four feet long by half an inch thick. Because this is far too big to make just one back mounting plate out of, it is suggested that the manufacturer makes three per section of raw material. Given the large length of this stock of aluminum it is likely going to be cut using a bandsaw. Bandsaws typically provide an inadequate surface finish for this design
so it is suggest that first the machinist machines roughly one inch off each end of the stock. Once they have done this, they can cut three thirteen and a half inch sections can be cut per the drawings in Appendix E. The next step will be to machine down the width. If the surface finish of the top and bottom (thickness by length) sides of the stock are adequate, the machinist can do this using just one pass of the mill. However, if there is inadequate surface finish then a clean cut must be made on both the top and bottom. The next step will be drill the four counterbored mounting holes. Lastly, the two slots for locating the straps must be cut and the outer corners rounded off. While neither the overall length and height, or the strap slot locations are critical for the function of the design, the alignment of the four mounting holes is critical to ensure alignment of the shaft.

6.2.4. Plastic Housing Manufacturing

This is the only non metal part that requires altering. The only step for manufacturing this part will be to cut it to the dimensions listed in the drawing. Since the tolerances are looser on this part, the machinist can carefully cut it to size by hand using a razor blade or pair of industrial strength scissors. However, for a more precise cut, it is recommended that a laser cutter be used. 6.3. Assembly requires a molding of the housing to fit the system. It is recommended that the operator form the plastic around a 5.5 inch piper using a heat gun. Plastic bonder will be applied to the contact points of the sidewall while the contact points of the plastic will be scored or sanded to achieve maximum adherence. With the housing having achieved its uniform and circular form, its natural elasticity will allow the housing to easily ‘snap’ onto the system. Clamps are recommended to ensure the best potential bonding.

After all of the parts have been machined and inspected the assembly process can begin. First, the bearings will need to be press fitted into the sidewalls. Since the sidewalls are aluminum which is relatively soft, this should not take a tremendous amount of force, however a hydraulic press still must be used. Once the bearings are set in the sidewall, the shaft must then be press fitted into the bearings. The side without the hex should be fairly straightforward as the end of the shaft is at the edge of the bearing. Because of this, the sidewall can be set with the bearing flat on the hydraulic press and press the shaft straight into it. However, the side with the hex may require a special block to be made in order to allow the hex to pass through the bearing without hitting the flat surface on the bottom of the press. Next, the sidewalls will be aligned with the mounting holes on the back plate and the ¼-20 bolts will be threaded into place and torqued to the specified torque requirements listed in Appendix H. After the backplate is correctly mounted, it will be time to add the plastic housing. In order to do this, the plastic must be wrapped around the sidewalls and firmly attached into place. The suggested adhesive can be found in the bill of materials (Appendix E), which requires a five minute application time and a forty five minute set time. Lastly, once the adhesive has fully set the straps can be slotted through the locating slots in the mounting plate. Once the assembly process is complete, the assembler must be sure to visually check all the fits, test that the bearings are spinning properly, and ensure the bolts are torqued to the specified torque requirement.
7. Design Verification Plan

Testing a hammock does not sound too laborious. However, we will be testing much more than just how comfortable it is. There were multiple tests that the system had to overcome to be deemed successful and also safe to use. The following tests were conducted as described, each for its own purpose, and the results were tabulated in Table 5.

7.1 Load Bearing

The most important test by far is load bearing. The system transfers the load of the user in the hammock to the shaft, to the side walls, to the back plate, and then to the straps. Any one of these components failing spells disaster for the suspended user. The first load bearing test consisted of setting up the system with a hammock strung to a second support and gradually adding sandbags until the 400 lb load requirement was met. Throughout the test, the system was carefully monitored for any signs of deformation or damage. While it would be both interesting and insightful to push the system as far as it can go and see when it fails in comparison to when the analysis says it should; there is only one prototype to test and breaking it would be less than ideal.

After passing the basic load bearing test, a shock loading test was conducted to ensure the system can withstand the greater forces that occur when a user initially falls into the hammock. This was simulated by dropping 100 lb of the test sandbags from about 2.5 ft above the hammock.

The final load bearing test consisted of a side-to-side swing test. The goal of this test was to ensure the hammock and system can withstand the upper levels of natural swinging that might occur during use. The system was pushed up to 30 degrees and released. While the hammock and load swung, the straps and sidewalls were carefully observed for changes caused by the imbalanced load.

7.2 Retraction

The next set of tests challenged the retraction functionality. The hammock rolls and stores well under normal circumstances; this was tested using the concept prototype. This new test investigated worst case scenarios when rolling the hammock. These scenarios include fully spread out and also bunched in the middle. This test aimed to make sure the design can still function even when the hammock is rolled up as poorly as it can be. To conduct this test a team member fed the hammock in to the housing two ways: as spread out as it can be, and compact in the middle. This test would have been considered to fail if either method resulted in the hammock not being fully stored in the housing.

7.3 Vibration

Another category of testing that was conducted relates to vibration. The system will eventually be mounted to a car that experiences almost constant vibration while driving. In order to accurately replicate the vibrations it will experience during use, the system was mounted to a university facilities vehicle and driven both on paved roads and offroad. This provided both constant vibrations as a result of driving on a dirt road, as well as random shocks as a result of hitting potholes or speed bumps. It is important that the system can withstand both types of vibration
inputs. The test consisted of at least five hours of drive time on the vehicle. Once completed, the part was inspected for any signs of fatigue or joint loosening.

### 7.4 Retraction Time

In order to quantify some of our testing data, we conducted 10 time trials of the hammocks retraction system by deploying the hammock and timing its full retraction. The data was statistically analyzed to find an average retraction time along with the associated uncertainty for such a value.

The resources required to complete these tests are minimal. Anything can be used as excess weight for the load bearing tests. Nothing extra is required for the retraction tests. And a vibration table is accessible to us in the vibrations lab. All tests will be conducted on the final prototype to get realistic results. A summary of the test plan explained above can be found below in Table 4, the DVP&R.

Table 4. Design Verification Plan and Report
8. Project Management

The Retractable Hammock system was designed through a standard product development process described above. From here, final tests were completed to finalize smaller aspects of the design, at which point sponsor approval was sought in order for the design to continue and manufacturing to begin. Manufacturing was completed without any major problems and, with the final product in hand, future recommendations were made to dictate how the Retractable Hammock Team thought the product should move forward. Finally, a presentation will conducted upon the submission of this report at the Cal Poly, School of Engineering Spring 2018 Project Expo. Table 6 shows the completion dates of the major project milestones. A more complete timeline can be found in Appendix J.

Table 6: Deliverables And Completion Dates For Retractable Hammock Project.

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<td>3/13/18</td>
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<td>6/1/18</td>
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</table>

Since the Critical Design Review, there have only been testing deviations from our project management plan, namely, our initial round of retraction testing failed. Our testing dates were, as a result, set back a few days. This, however, was simply due to the use of the wrong hammock type. We attempted the test using the heavy-duty hammock we were conducting the load bearing tests on, which was a much less
compact test. It is therefore recommended that the use of an ENO type hammock is licensed to Mr. Marchese or simply recommended to the customer.

9. Conclusions and Recommendations

This document represents the Final Design Report for the Retractable Hammock system sponsored by Mr. Will Marchese. It contains the intended process that has resulted in a compact, portable, and durable retractable hammock system that is low cost and safe and allows its user to easily retract and stow a hammock from a car mount to a second, pre-existing support. It is at this point that we relinquish all parts and and ownerships to Mr. Will Marchese with the following recommendations.

9.1 Recommendations

The Retractable Hammock Team has compiled the following list of recommendations to be considered by Mr. Marchese that we believe will improve upon the various cornerstone qualities of our design.

1. Motor-Driven System - By incorporating a low-cost and compact motor package on the shaft hex, this product will become more elegant and easier to use. The major obstacles with this implementation include the choice of power source and ensuring that the electronics of the system can withstand the elements of weather the system is expected to experience.
2. Counterbored Bearing Holes - If one were to counter bore the sidewall holes on the outside of each wall, the bearings could be better protected against weather and other earthly elements.
3. Thrust Bearings - Using thrust bearings as opposed to the needle bearings in the design precludes any axial shaft movement that was a result of machining intollerances.
4. Injection Molded Housing - It is recommended that the housing is injection molded into the shape necessary to cut down on lead time and per part cost.
5. Shaft Friction- The implemented velcro system is effective in initiating the retraction process, however it prevents the user from using his/her own hammock without sewing velcro into his/her own hammock. It is therefore recommended that an alternative solution be used, such as rubber contact points on the hammock that would not require a counterpart on the hammock itself.
6. Multiple Hammock Contact Points - By using three points of contact between the hammock and the shaft, the necessary shaft strength would be significantly less. This may allow the use of aluminum for the shaft, lowering the cost and the weight of the system. This would, however, require that such points of contact be stagnant which may mean as much as making the points more permanent and therefore less adaptable on the consumer-side.
7. Ratchet Strap Lock - With the current design, the strap that mounts the system to the rollbar is free to slide out of the slots on the back of the mounting plate. Restranging these through the slots can be tedious, so the implementation of a rubber stopper that goes around the strap to prevent it from falling through the slots would prevent users from ever having to refeed it through the slots.
References


Appendices

Appendix A: QFD House of Quality

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Appendix C: Preliminary Analyses and Testing Details

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Appendix D: Concept Layout Drawing
Appendix E: Manufacturing Plan

Step-By-Step Guide to Manufacturing the Retractable Hammock

Note: Although the images in this document have dimensions on it, machinists MUST reference the engineering drawing package for the true dimensions and tolerances.
Appendix E

Backplate

Manufacturer/Part Number: McMaster Carr/9245K492
Material: 6061 Aluminum
Estimated Time: 1.5 hours

Raw material as received from manufacturer.

Step 1. Cut to Size
Suggested Method: Mill
Appendix E

Step 2. Drill counter bored

Suggested Method: Drill using a counterbore drill bit.

Step 3. Cut slots for locating straps

Suggested Method: Use a ¼” end mill at roughly 4480 rpm.

Step 4. Round corner edges to prevent sharp edges.

Suggested Method: Use a ¼” end mill at roughly 4480 rpm.

Step 5. Inspect and deburr all edges.
Appendix E
Shaf

Manufacture/Par Number: McMaster Carr/90075K232
Material: 12L14 Carbon Steel
Estimated Time: 1 hours
Quantity/system: 1
Material Cost:

Raw material as received from manufacturer.

Step 1. Turn down shaft to fit bearings.

Suggested Method: Turn down on lathe turning at 320 rpm.
Appendix E

**Step 2.** Turn down one end to prepare for hex.

**Suggested Method:** Turn down on lathe turning at roughly 900 rpm.

---

**Step 3.** Cut hex into shaft.

**Suggested Method:** Secure shaft in a rotary vise on a mill.

Measure and cut to size, turning the vise 60° each pass, with ¼” end mill turning at 4480 rpm.
Appendix E  

**Manufacturer/Part Number:** McMaster Carr/1610T56  
**Material:** 6061 Aluminum  
**Estimated Time:** 1 hours  
**Quantity/system:** 2  
**Material Cost:**

Raw material as received from manufacturer

---

**Step 1.** Drill center hole.

**Suggested Method:** Drill 3/4” hole on disc using a ¾” drill bit turning at roughly 1500 rpm.

Then open hole up to specified tolerance using a boring bar, still turning part at roughly 1500 rpm.
Appendix E

Step 2. Cut flat surface.

**Suggested Method:** Mill using a ¼” drill bit turning at roughly 4480 rpm.

Step 3. Drill mounting holes.

**Suggested Method:** Drill using a #7 drill bit turning at 5000 rpm.

Step 4. Add helicoils.

**Suggested Method:** Add ¼-20 helicoil, threaded below flush.

**Note:** Break off driving tang and remove from hole.
Appendix E  Plastic Housing

Manufacturer/Part Number: Interstate Plastic
Material: ABS
Estimated Time: 1 hr
Quantity/system: 1
Material Cost:

---

Step 1. Cut to size.

Suggested Method: Razor blade or laser cutter.
Appendix E

Assembly

Step 1. Press fit bearings into sidewalls.

Suggested Method: Hydraulic Press

Estimated Time: 15 mins

Step 2. Press fit shaft into bearing.

Suggested Method: Hydraulic Press

Estimated Time: 15 mins
Appendix E

Step 3. Align back plate and thread in bolts.

**Suggested Method:** Using a 7/16” socket and torque wrench, tighten to 118.6 ft-lbs (160.8 N-m).

**Estimated Time:** 5 mins

**Note:** Place ¼” split lock washer over bolt before threading into place.

---

Step 4. Wrap plastic around and glue in place.

**Suggested Method:** JB Weld Plastic Bonder

**Estimated Time:** Application: 5 mins

  **Set Time:** 45 mins

---

Step 5. Slide straps into slots.
## Appendix E

### Indented Bill of Material (BOM)

#### Retractable Hammock

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<th>Description</th>
<th>Matl</th>
<th>Vendor</th>
<th>Vendor Part #</th>
<th>Qty</th>
<th>Cost</th>
<th>Ttl Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>Final Assembly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>101</td>
<td>Main Housing</td>
<td>ABS Plastic</td>
<td>Interstate Plastics</td>
<td>——</td>
<td>1</td>
<td>$15.85</td>
<td>$15.85</td>
</tr>
<tr>
<td>1</td>
<td>102</td>
<td>Adhesive</td>
<td>Plastic Bond</td>
<td>J&amp;J Weld</td>
<td>——</td>
<td>1</td>
<td>$4.75</td>
<td>$4.75</td>
</tr>
<tr>
<td>1</td>
<td>103</td>
<td>6” D x 1/2” LG Disc</td>
<td>6061 Aluminum</td>
<td>McMaster</td>
<td>1610756</td>
<td>2</td>
<td>$16.06</td>
<td>$32.12</td>
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<tr>
<td>1</td>
<td>104</td>
<td>Helicoll</td>
<td>18-8 Stainless Steel</td>
<td>McMaster</td>
<td>540000153</td>
<td>4</td>
<td>$0.04</td>
<td>$0.17</td>
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<tr>
<td>1</td>
<td>105</td>
<td>Bolt</td>
<td>18-8 Stainless Steel</td>
<td>McMaster</td>
<td>62156541</td>
<td>4</td>
<td>$0.12</td>
<td>$0.49</td>
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<tr>
<td>1</td>
<td>106</td>
<td>Back Wall</td>
<td>60601 Aluminum</td>
<td>McMaster</td>
<td>92486092</td>
<td>1</td>
<td>$21.44</td>
<td>$21.44</td>
</tr>
<tr>
<td>1</td>
<td>107</td>
<td>1” D x 1 1/2” G Rod</td>
<td>12L14 Carbon Steel</td>
<td>McMaster</td>
<td>900752232</td>
<td>1</td>
<td>$13.91</td>
<td>$13.91</td>
</tr>
<tr>
<td>1</td>
<td>108</td>
<td>Bearings</td>
<td>Steel</td>
<td>McMaster</td>
<td>59056334</td>
<td>2</td>
<td>$5.76</td>
<td>$11.52</td>
</tr>
<tr>
<td>1</td>
<td>109</td>
<td>Ratchet Straps</td>
<td>Heavyweight Polypropylene</td>
<td>Strapworks</td>
<td>——</td>
<td>2</td>
<td>$11.52</td>
<td>$23.04</td>
</tr>
</tbody>
</table>

**Total Parts**

18 $123.28
### Appendix F: Purchased Parts Details

<table>
<thead>
<tr>
<th>Purchased Parts</th>
<th>Vendor</th>
<th>Product Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Housing</td>
<td>Interstate Plastics</td>
<td><a href="https://www.interstateplastics.com/Abs-Black-Extruded-Sheet-ABSDE-***ST.php">https://www.interstateplastics.com/Abs-Black-Extruded-Sheet-ABSDE-***ST.php</a></td>
</tr>
<tr>
<td>6” D x 1/2” LG Disc</td>
<td>Mcmaster</td>
<td><a href="https://www.mcmaster.com/#1610t56=/1bjj23e">https://www.mcmaster.com/#1610t56=/1bjj23e</a></td>
</tr>
<tr>
<td>Helicoil</td>
<td>Mcmaster</td>
<td><a href="https://www.mcmaster.com/#helicolls=/1bjk18c">https://www.mcmaster.com/#helicolls=/1bjk18c</a></td>
</tr>
<tr>
<td>Bolt</td>
<td>Mcmaster</td>
<td><a href="https://www.mcmaster.com/#92196a541=/1bjjzg">https://www.mcmaster.com/#92196a541=/1bjjzg</a></td>
</tr>
<tr>
<td>Back Wall</td>
<td>Mcmaster</td>
<td><a href="https://www.mcmaster.com/#92246k492=/1bji2tw">https://www.mcmaster.com/#92246k492=/1bji2tw</a></td>
</tr>
<tr>
<td>1” D x 1’ LG Rod</td>
<td>Mcmaster</td>
<td><a href="https://www.mcmaster.com/#90075k232=/1bji2z2">https://www.mcmaster.com/#90075k232=/1bji2z2</a></td>
</tr>
<tr>
<td>Bearings</td>
<td>Mcmaster</td>
<td><a href="https://www.mcmaster.com/#5905k334=/1bjk08z">https://www.mcmaster.com/#5905k334=/1bjk08z</a></td>
</tr>
<tr>
<td>Ratchet Straps</td>
<td>Strapworks</td>
<td><a href="http://www">http://www</a> strapworks.com/Ratchet Only Straps_s/658.htm</td>
</tr>
</tbody>
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**Appendix G: Budget / Procurement List**

<table>
<thead>
<tr>
<th>Purchased Parts</th>
<th>Vendor</th>
<th>Quantity</th>
<th>Cost Per Part</th>
<th>Cost Total</th>
</tr>
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<tbody>
<tr>
<td>Main Housing</td>
<td>Interstate Plastics</td>
<td>1</td>
<td>$15.85</td>
<td>$15.85</td>
</tr>
<tr>
<td>Adhesive</td>
<td>JB Weld</td>
<td>1</td>
<td>$4.75</td>
<td>$4.75</td>
</tr>
<tr>
<td>6&quot; D x 1/2&quot; LG Disc</td>
<td>McMaster</td>
<td>2</td>
<td>$16.06</td>
<td>$32.12</td>
</tr>
<tr>
<td>Helicoil</td>
<td>McMaster</td>
<td>4</td>
<td>$0.04</td>
<td>$0.17</td>
</tr>
<tr>
<td>Bolt</td>
<td>McMaster</td>
<td>4</td>
<td>$0.12</td>
<td>$0.49</td>
</tr>
<tr>
<td>Back Wall</td>
<td>McMaster</td>
<td>1</td>
<td>$21.44</td>
<td>$21.44</td>
</tr>
<tr>
<td>1&quot; D x 1' LG Rod</td>
<td>McMaster</td>
<td>1</td>
<td>$13.91</td>
<td>$13.91</td>
</tr>
<tr>
<td>Bearings</td>
<td>McMaster</td>
<td>2</td>
<td>$5.76</td>
<td>$11.52</td>
</tr>
<tr>
<td>Ratchet Straps</td>
<td>Strapworks</td>
<td>2</td>
<td>$11.52</td>
<td>$23.04</td>
</tr>
</tbody>
</table>

**Total** 18 $123.28
Appendix H: Final Analyses

**SHAFT ANALYSIS**

\[ \sum F_y = 0 \]

- **RE: REACTIONARY FORCES FROM SIDE WALL (LOAD FROM USER)**

\[ \sum F_y = 0 \]

\[ -L + 2T \sin \theta = 0 \]

\[ T = \frac{L}{2 \sin \theta} \]

\[ T_{\text{max}} = \frac{L_{\text{max}}}{2 \sin \theta} \Rightarrow L_{\text{max}} = 400 \text{ lb} \]  \text{(MAX WEIGHT FROM MANUFACTURER)}

\[ \text{FOR } \theta = 20^\circ \]

\[ L = T = 584.16 \text{ lb} \]

\[ \text{FOR } \theta = 40^\circ \]

\[ L = T = 311.14 \text{ lb} \]

Let \( F = 600 \text{ lb} \)

\[ \sum F_y = 0 \]

\[ F - 2R = 0 \]

\[ R = \frac{1}{2} F = 300 \text{ lb} \]

**M_{\text{max}}:**

\[ M_{\text{max}} = \frac{M_{\text{max}}}{R(\ell / 2)} \]

\[ \ell = 12'' \]

\[ M_{\text{max}} = 300 \text{ lb} \cdot 6''(2) \]

\[ M_{\text{max}} = 1800 \text{ lb} \cdot \text{in} \]

\[ \sigma_{\text{max}} = \frac{M_{\text{max}} E}{I} \]

\[ E = 30,000 \text{ psi} \]  \text{AND}  \[ I = \frac{\pi}{64} R^4 \]

\[ \sigma_{\text{max}} = 3666 \text{ psi} \]
Appendix H

\[ \sigma_{\text{max}} = \frac{3V}{\pi b t} \text{ Pure Solid Circle} \]

\[ \sigma_{\text{max}} = \frac{4(30014)}{\pi (0.065)^2} = 509.30 \text{ psi} \]

\[ \sigma_{1,2} = \frac{1}{2} \left( \sigma_x + \sigma_y \right) - \frac{1}{2} \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2} \]

\[ \sigma_x = 0 \]
\[ \sigma_y = \sigma_{\text{max}} \]
\[ \tau_{xy} = \tau_{\text{max}} \]

\[ \sigma_1 = 3667.6 \text{ psi} \]
\[ \sigma_2 = -3.5 \text{ psi} \]

\nu = 20 \quad n = 20

Proof strength = 85 KSI
Yield strength = 92 KSI
Modulus = 30 x 10^6 psi
Ultimate strength = 120 KSI
Tensile area = 0.031 in^2
Grip length = 1/2 in

Proof load = Proof strength \times Tensile area
= 85 KSI \times 0.031 in^2

Proof load = 2.635 Kips

Preload = 90\% proof load
= 0.9 \times 2.635 Kips

Pre load = \[ \frac{2.372 \text{ Kips}}{2.672 \text{ in lbs}} \times \frac{1 \text{ ft}}{12 \text{ in}} \]
= 14.8 ft lbs
= 268.5 Nm
Appendix I: Safety Hazard Checklist & FMEA

DESIGN HAZARD CHECKLIST

Team: _______ Retractable Hammock _______ Advisor: _______ Rossman _______ Date: _______ 11/9/17 _______

Y  N  
X  1. Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and shear points?
X  2. Can any part of the design undergo high accelerations/decelerations?
X  3. Will the system have any large moving masses or large forces?
X  4. Will the system produce a projectile?
X  5. Would it be possible for the system to fall under gravity creating injury?
X  6. Will a user be exposed to overhanging weights as part of the design?
X  7. Will the system have any sharp edges?
X  8. Will any part of the electrical system not be grounded?
X  9. Will there be any large batteries or electrical voltage in the system above 40 V?
X 10. Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
X 11. Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
X 12. Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
X 13. Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
X 14. Can the system generate high levels of noise?
X 15. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc?
X 16. Is it possible for the system to be used in an unsafe manner?
X 17. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

For any “Y” responses, add (1) a complete description, (2) a list of corrective actions to be taken, and (3) date to be completed on the reverse side.

<table>
<thead>
<tr>
<th>Description of Hazard</th>
<th>Planned Corrective Action</th>
<th>Planned Date</th>
<th>Actual Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revolving core potentially cause pinch points</td>
<td>The housing will have a small enough opening for the hammock to comfortably fit through but will not leave a lot of room for the user to get their hands inside</td>
<td>11/9</td>
<td></td>
</tr>
<tr>
<td>Spring pinch points</td>
<td>Spring will be contained in a separate housing that will be impossible to snag or catch on</td>
<td>11/9</td>
<td></td>
</tr>
<tr>
<td>Over hanging weights, mounted on top of jeep roll bar</td>
<td>Once mounted the device will be secure and should never fall onto user. If it does however fail during operation, the path is not directly over the user</td>
<td>11/9</td>
<td></td>
</tr>
<tr>
<td>Environmental - standard outside conditions</td>
<td>Device will be mounted to a car and therefore in outside conditions. Will be sure to choose materials that are resistant to environmental wear</td>
<td>11/30</td>
<td></td>
</tr>
<tr>
<td>Unsafe usage</td>
<td>Any hammock can be used in an unsafe manner, horseplay and the like by children or childish adults. Will have warnings attached of the potential dangers of unsafe operation</td>
<td>11/9</td>
<td></td>
</tr>
</tbody>
</table>
# Appendix I

<table>
<thead>
<tr>
<th>System / Function</th>
<th>Potential Failure Mode</th>
<th>Potential Effects of Failure Mode</th>
<th>Severity</th>
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</thead>
<tbody>
<tr>
<td>Housing / Protect Hammock</td>
<td>tear hammock</td>
<td>replace hammock</td>
<td>7</td>
</tr>
<tr>
<td>Housing / Stow Hammock</td>
<td>doesn’t fit right</td>
<td>inoperable / tear hammock</td>
<td>5</td>
</tr>
<tr>
<td>Housing / Protect User</td>
<td>pinch user</td>
<td>injury</td>
<td>8</td>
</tr>
<tr>
<td>Housing / Provide Aesthetic</td>
<td>be ugly</td>
<td>loss of interest</td>
<td>2</td>
</tr>
<tr>
<td>Retraction / Minimize Setup Time</td>
<td>extra effort</td>
<td>lose competitive edge</td>
<td>4</td>
</tr>
<tr>
<td>Retraction / Retract &amp; Deploy Hammock</td>
<td>stuck</td>
<td>damage system</td>
<td>5</td>
</tr>
<tr>
<td>Mounting / Support User</td>
<td>break</td>
<td>injury</td>
<td>8</td>
</tr>
<tr>
<td>Mounting / Protect Vehicle</td>
<td>scratch</td>
<td>costly repair</td>
<td>6</td>
</tr>
<tr>
<td>Mounting / Securely Fasten System</td>
<td>mobile system</td>
<td>unforeseen effects</td>
<td>5</td>
</tr>
<tr>
<td>Hammock / Support User</td>
<td>break</td>
<td>injury</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potential Causes of the Failure Mode</th>
<th>Current Preventative Activities</th>
<th>Occurrence</th>
<th>Current Detection Activities</th>
<th>Detection</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>sharp internal or opening</td>
<td>smooth internal features</td>
<td>3</td>
<td>check internal features</td>
<td>6</td>
<td>126</td>
</tr>
<tr>
<td>hole too small / hammock bunched in middle</td>
<td>rollers at opening of housing</td>
<td>4</td>
<td>operate using worst technique</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>hand entering</td>
<td>rollers at opening of housing</td>
<td>3</td>
<td>test and try to do wrong</td>
<td>3</td>
<td>72</td>
</tr>
<tr>
<td>poor material / color / design choice</td>
<td>design with appearance in mind</td>
<td>2</td>
<td>survey</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>internal failure</td>
<td>hatch-free design</td>
<td>8</td>
<td>time setup</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>moving component</td>
<td>snap free entrance</td>
<td>5</td>
<td>use it all sorts of ways/angles</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>weak component / too much weight</td>
<td>overdesign, use safety factor</td>
<td>5</td>
<td>place weights on end</td>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>rough surface contact</td>
<td>strap system, not metal</td>
<td>6</td>
<td>keep attachment</td>
<td>4</td>
<td>144</td>
</tr>
<tr>
<td>loose connect</td>
<td>find way to tighten completely</td>
<td>5</td>
<td>try to move it side to side</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>too much weight / misuse</td>
<td>fit system with durable hammock</td>
<td>4</td>
<td>add weights past warning label</td>
<td>2</td>
<td>64</td>
</tr>
</tbody>
</table>
Appendix K: Drawing Package
Appendix L: Operators’ Manual

Retractable Hammock Operators’ Manual

Installation:

To avoid damage to vehicle, be sure there is padding over the jeep roll bar. Feed the free side of each open strap around the roll bar and into the receiving end of the cam. Pull tight to ensure a snug and stable fit.

Hammock Deployment:

Ensure vehicle is between 9 and 15 feet from a sturdy tree that is capable of supporting the load of the hammock and occupants.

Unclip Carabiner from shaft and unroll the system. Wrap hammock strap around sturdy tree, roughly 5 to 8 feet off the ground and clip the carabiner through the preferred loop in the strap and ensure that the carabiner clips into place.

WARNING: Do not unclip or open the carabiner at any point during use!

Once system is set up, slowly lower your weight into the hammock to ensure that the hammock is set to the right height. Adjust the height of the strap around the tree and the loop which the carabiner is clipped to in order to adjust the height and angle of the hammock.

WARNING: Do not jump into hammock or apply unnecessary force to system!

Hammock Retraction:

WARNING: Ensure that nothing is left in the hammock before beginning retraction process.

Unclip carabiner from support tree and lay the hammock and straps flat on the ground.
If using an impact driver, ensure that it is the standard ¼” drive size and mate the drive over the hex head located on the exposed end of the shaft. If using a standard power drill insert loosened chuck over the hex head and slowly tighten ensuring a snug fit. Lightly engage drill in Appendix L

the clockwise direction to begin retraction process. Once retracted, ensure all hammock parts are enclosed within the outer housing.

**WARNING:** Before using vehicle, ensure all hammock parts are inside outer housing unit.

**Additional Precautions:**

Do not reach hand into system opening. There is a chance you will be cut or entwined in the rolled hammock.