X-Comb2000
Lockheed Martin
Edsgn 100
Section 25
Dr. Sarah Ritter
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The Skilled Sk8ers
Team #3

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Abstract and Executive Summary

As an engineering project, we were assigned with the task of redesigning a USB hub mounting bracket for Lockheed Martin. Lockheed Martin identified a reduction of parts as well as the ability for the bracket to fit more than one port as essential modifications to the product. In order to engineer this new part, we first collected a list of customer needs and brainstormed several prototypes. Using the list of customer needs, we evaluated the different prototypes and decided on a design that was best suited for Lockheed Martin. Using SolidWorks, we modeled the prototype and used the SolidWorks drop test simulation to evaluate our design. Overall, our product reduced the number of parts for the bracket from 38 parts to 5 parts (1 part bracket and 4 mounting screws). Additionally, our bracket increased the holding capacity from one port to two ports, meeting Lockheed Martin’s needs. As a result of this project, our team gained a greater understanding of the engineering process while creating a valuable part.

Problem Statement

As a team, we strive to design a final mounting bracket for the Lockheed Martin D-Link USB hub. The new design will be lightweight, versatile, and produced using additive manufacturing techniques. Originally, the mounting bracket had an inefficient design that was heavy, wasteful, and limited in orientation. To reach the goal of redesigning the mounting bracket, we will alter the old bracket so that it can be produced using additive manufacturing and so that it meets the new customer specifications. In the redesigning process, we will take into account all possible ideas to ensure that the new design maximizes the product’s efficiency.

Background

In the initial research stages of the design process, we began by learning about our customer, Lockheed Martin. The mission of Lockheed Martin is to innovate in the science field in order to keep people safe and give them a better life. Their vision is to improve global security and serve the people through scientific discovery. The values of Lockheed Martin are to do what’s right, respect others, and perform with excellence. The company is organized into five business areas: Aeronautics, Information Systems & Global Solutions, Missiles and Fire Control, Mission Systems and Training, and Space Systems. Lockheed Martin has been extremely successful with their manufacturing and has had $46.1 billion in sales over 2015 (Annual Report). Lockheed Martin gave a presentation at Penn State for the students of EDSGN 100 to explain what they had envisioned for the design project. They outlined each of the project options in order to help each group decide which project is the best fit. The projects included an additively manufactured heat exchanger, sensitive payload shock absorber, connector backshell, and USB hub mounting bracket. If none of these projects were a good fit, Lockheed Martin gave the option to choose any part or component that they create and redesign it in order to reduce weight, reduce part count, improve assembly, and improve performance.

After choosing the USB hub mounting bracket, the next stage was to research design possibilities. One patent we researched was a multipurpose combination USB hub and power adapter assembly. From this patent, we looked at possible ways to connect the individual hubs (Multipurpose). The second patent design was protective enclosure for electronic device. Using this patent, we were able to think about possible shapes of design that can protect the USB
hub as well as reduce the amount of vibration that affects the hub (Protective). After all of our research on Lockheed Martin and relevant patents, we were able to begin the design stages of the project.

Customer Needs

Lockheed Martin established a set of criteria that needs to be met in order to improve the USB hub mounting bracket to fit the new D-link system. The initial set of criteria that was established included reduced part count, vertical installation configuration, design for 7-port USB, vibration resistant, temperature independence, cable retention system, and stacking three hubs together. After working through these requirements, Lockheed Martin sent out a memorandum with an updated set of needs. The new requirements included 4-point screw mounting for base bracket, minimizing part count, and holding two hubs. As a team, we tried to combine all of the requirements and add some goals of our own that would make the product as effective as possible. Table 1 shows the Analytic Hierarchy Process matrix that allows us to decide what criteria are most important in the design process. After going through this process, we decided that minimizing weight is the most important quality because weight reduction leads to material reduction. Following weight is attachable units, vibration resistance, temperature independence, low cost, vertical mounting, and durability. Once we began designing, we used our weights from Table 1 to incorporate our personal requirements along with those of Lockheed Martin to create the final design.

Table 1 The following AHP Matrix prioritized Lockheed Martin’s needs by assigning each category relative weights. Using this matrix guided group design decisions.

<table>
<thead>
<tr>
<th></th>
<th>Durability</th>
<th>Low Cost</th>
<th>Lightweignt</th>
<th>Attachable Units</th>
<th>Temperature Independent</th>
<th>Versatile Mounting</th>
<th>Vibration Resistant</th>
<th>Cable Retention</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>1</td>
<td>.33</td>
<td>.5</td>
<td>.5</td>
<td>.33</td>
<td>1</td>
<td>1</td>
<td>.5</td>
<td>5.16</td>
<td>.065</td>
</tr>
<tr>
<td>Low Cost</td>
<td>3</td>
<td>1</td>
<td>.5</td>
<td>.5</td>
<td>.5</td>
<td>2</td>
<td>.5</td>
<td>.5</td>
<td>8.5</td>
<td>.106</td>
</tr>
<tr>
<td>Lightweight</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>15</td>
<td>.189</td>
</tr>
<tr>
<td>Attachable Units</td>
<td>2</td>
<td>2</td>
<td>.33</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>13.3</td>
<td>.167</td>
</tr>
<tr>
<td>Temperature Independent</td>
<td>3</td>
<td>2</td>
<td>.5</td>
<td>.5</td>
<td>1</td>
<td>1</td>
<td>.33</td>
<td>1</td>
<td>9.33</td>
<td>.117</td>
</tr>
<tr>
<td>Versatile Mounting</td>
<td>1</td>
<td>.5</td>
<td>1</td>
<td>.33</td>
<td>1</td>
<td>1</td>
<td>.5</td>
<td>.5</td>
<td>5.83</td>
<td>.073</td>
</tr>
<tr>
<td>Vibration Resistant</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>13</td>
<td>.163</td>
</tr>
<tr>
<td>Cable Retention</td>
<td>2</td>
<td>2</td>
<td>.33</td>
<td>.5</td>
<td>1</td>
<td>2</td>
<td>.5</td>
<td>1</td>
<td>9.33</td>
<td>.117</td>
</tr>
</tbody>
</table>
Concept Generation and Selection

After gaining an understanding of Lockheed’s expectations and prioritizing design requirements for this project, the brainstorming process began. Each member of the team took 15 minutes to individually conceptualize a few possible designs. This allowed for each individual to contribute unique ideas and perspective to aid the group objective. The group reconvened to discuss the positive and negative aspects of the different individual ideas. The top four designs were selected and rated using the design selection matrix shown in Table 2. According to the selection matrix, the “Stacking Boxes” design was the best fitting design. As a team, we made the decision not to select this design, but to incorporate different pieces from each of the designs and recreate an improved “Cross-magnetic” design.

Table 2 Design selection matrix shown below lists the most important customer needs and weights them according to determine the best suited design concept

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Cross-magnetic</th>
<th>Stacking Boxes</th>
<th>Interlocking</th>
<th>Vice</th>
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<tr>
<td>Vibration Absorption</td>
<td>30 5 1.5</td>
<td>4 1.2</td>
<td>3 0.9</td>
<td>4 1.2</td>
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<tr>
<td>Light Weight</td>
<td>30 5 1.5</td>
<td>5 1.5</td>
<td>3 0.9</td>
<td>3 0.9</td>
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<td>Connectable</td>
<td>20 3 0.6</td>
<td>5 1</td>
<td>5 1</td>
<td>4 0.8</td>
</tr>
<tr>
<td>Low-weight</td>
<td>10 4 0.4</td>
<td>5 0.5</td>
<td>4 0.4</td>
<td>3 0.3</td>
</tr>
<tr>
<td>Durability</td>
<td>10 4 0.4</td>
<td>4 0.4</td>
<td>3 0.3</td>
<td>5 0.5</td>
</tr>
<tr>
<td>Total</td>
<td>100 48 4.4</td>
<td>59 4.6</td>
<td>45 3.5</td>
<td>46 3.7</td>
</tr>
</tbody>
</table>

Description of Prototype

The decision to use a mixture of every design led to the creation of the X-Comb2000. Our initial prototype can be seen below in Figure 1. The main focus of the design was to use as little material as possible. This, in effect, would reduce the weight, cost, and production time which met all of our criteria. Therefore, we proceeded with the idea. The first idea we discussed was how to hold the hub itself in place. We accomplished this by using a cross design and designed it to only hold a single hub. At the ends of each leg, there is an extension. We filleted the ends and the extensions in order to keep the contained hub in place and reduce vibrations. At the bottom of the legs, we included perpendicular flaps with small circular incisions in them which allowed screws to fasten the frame in place. On the center section of the cross we included a knob to hold the cable retention in place. We modeled the retention system after that of a rake. The larger comb-like structure was meant to keep seven USB cables in place. The rear comb was designed to keep the power and USB cables in check.
After analyzing our initial prototype, we came up with our final design. This design extended the height of the bracket to two times its original height, allowing the bracket to fit an additional USB hub. This can be seen in Figure 2, under the “Main Bracket” arrow. Another aspect of our design was the cable retention system, which is unique in that the entire retention system for the bracket is combined into one part, including the USB cable retention and the power cable retention. The main purpose of the retention system is to prevent any cables that are plugged into the USB hub from falling out. Please refer to Figure 2, under the “USB cable retention” and “Power cable retention” arrows to see this design. The USB cable retention is capable of supporting up to 14 USB cables (7 from each port), and the power cable retention system is capable of supporting 4 power cables (2 from each port). The spaces in the combs of the cable retention system can each hold two cables, and the tongs on either side of the cable will prevent it from being knocked out of the port.

The cable retention system needed to allow the user to plug a cable into the hub without having to remove the retention system. This is why the cable retention comb was given the ability to slide back and forth along the bracket, giving easy access into any of the USB ports. The sliding cable retention system (Figure 2, under the “sliding retention system” arrow) includes two protruding cylinders which can be seen up close in Figure 3. These two cylinders allow two sliding bars to travel in a straight path for approximately 3 cm in one direction. The sliding bars, which can be seen up close in Figure 3, are attached to the cable retention comb.
on one end, and the power retention comb on the other end. This sliding system effectively allows both of the combs to be moved away from or towards the bracket as needed. This system eliminates the need for disassembling the entire bracket when a USB cable needs to be plugged in.

Additionally, the number of parts involved in the retention system as a whole was reduced from 9 parts in Lockheed Martin’s original bracket to 3 parts in our final design (2 cylinders, 1 sliding retention comb). The fastening site for our final product includes 4 tabs extruded from the 4 corners of the bracket (see Figure 3). Each of these tabs contains a 4mm screw hole. This fastening system is versatile, allowing our bracket to be attached to any surface that has the correct number of holes for screws.

To hold the USB hubs in place, our bracket utilizes the curvature of the USB ports in our design, similar to the second patent we researched (Protective). The USB hub used by Lockheed Martin contains a filleted edge on each of the 4 corners. Our bracket design is molded to this same curvature to fit tightly around the USB port. The curvature of the vertical edges of the bracket can be seen in Figure 3. Because this bracket shape fit the USB hub so well, we were able to cut out much unneeded material from the bracket. As seen in Figure 3, material from the top of the bracket was removed, leaving an X shape. Material from each of the sides was also removed leaving only the material on the four corners of the bracket. This removal of material comes as an additional benefit to Lockheed Martin, because removing unneeded material saves not only money, but also time in the manufacturing process. Although removing material was not specified as one of Lockheed Martin’s requirements, our product uses less material to provide an additional advantage on pricing; our product would be able to be sold at a lower price.

For Lockheed Martin to manufacture this product, it is recommended to use the material extrusion technique of additive manufacturing. This technique is quick and simple and could be easily implemented in any factor to begin producing the product. The downside to material extrusion is poor layer thickness, but this is not a concern as our part does not require an extremely small feature sizes. For the material, we recommend using PLA, an inexpensive and readily available polymer which would also provide the needed durability for the part. Another possibility would be nylon, a polymer of similar strength which could also be printed by the material extrusion technique. Since our 3D model was printed out of PLA, we foresee few differences that would occur between our prototype and the actual part. If anything, the actual part would contain finer layer sizes, as it could be printed using any layer size needed.
**Figure 2** Final Solidworks model

- **Main Bracket:** can hold two 7-port USB Hubs
- **Power Retention:** supports up to 4 power cables
- **USB Cable Retention:** supports up to 14 USB cables (7 from each port)
- **Sliding Retention System:** cable retention and power retention can slide back and forth as one piece
- **Fastening Site:** provides a stable base to attach the bracket, vertically or horizontally, to an exterior surface

**Figure 3** Final Bracket
Our team’s design underwent a peer design review evaluation. We were paired with another group in our class who were working through a different design project assignment. This allowed the reviewing group members to offer unbiased feedback pertaining to our design. As a group, we clearly explained Lockheed’s project expectations and pitched our design so the review team understood the guidelines and how our proposed design met the needs of Lockheed Martin. The reviewing group, overall, was impressed with our presentation and design concept. They came to the conclusion that our design met Lockheed Martin’s needs while taking a creative approach to compose a sleekly designed final product.

One specific piece of the feedback they provided was that we should work to improve the design so it could be printed in one piece. Unfortunately, due to our limited printer access, we were unable to print our model as one cohesive unit. Ideally, with access to higher quality printers, our SolidWorks model would print in one piece. At this stage of the design process, our team had not yet decided on a final material for our piece. The review team suggested that our team agree on a final material for our product. We came together and decided that a rubberized PLA plastic would be the optimal material for our final product in order to satisfy both the durability and vibration resistance demands of our customer.

Once the final SolidWorks model was assembled, a drop test was run. Figure 4 displays the results of the drop test. Our model is mostly low risk because the main color is blue. Figure 5 shows the displacement from the stress test. This image raised a few concerns, but when holding the USB hubs, the model will be more supported and less of a risk. From these tests, we decided on possible design modifications for the future.
Conclusions

Every design has its pros and its cons. However, with enough research and deliberation, our design fit our main criteria. Although the reduction of material did lead to possible issues in regard to its durability, it was still lightweight, low cost, and reduced vibrations. Future iterations would most likely focus on concerns of the structural integrity, however, they are not of great risk. Another possible improvement could be made to the retention system to ensure it stays in place and is overall more secure. Lastly the design could be modified to include connectability between multiple brackets.

In the process of creating our design, we learned many valuable lessons that will help us in the future. One of the most important lessons was that, as a team, we need to identify clear objectives from the start. Without doing so leads to the implementation of unnecessary features and/or exclusion of necessary features on a design. Ultimately it could lead to the creation of product that is effective or useless. This was a problem we had to deal with which, inevitably, led to a couple early iterations of our design to be thrown out. Another important takeaway from the project is to be open minded to other’s ideas as they may lead to new ways of thinking and finding a solution that is much more efficient. Nevertheless, the collaboration of the members of our team brought us to an end result that we would categorize as a success.
References

