Lockheed Martin USB Hub Mounting Bracket

Figure 1 Final USB hub bracket design
Executive Summary

Lockheed Martin, an American-based global defense, security, aerospace, and advancing technologies company with worldwide interests, approached Penn State University with various items to redesign with specified requirements using additive manufacturing. Team 3, choosing the fourth posed option of the USB hub mounting bracket, set out to redesign the bracket for a two-stacked 7-port USB hub. While Lockheed Martin initially emphasized the vertical orientation, retention abilities, and stacking capabilities, a memo released on March 28, updated the project to stress the minimizing of parts within the assembly. After researching the project to understand the previous design of the bracket, the team went about constructing an Analytical Hierarchy Process (AHP) matrix to rank the determined customer needs. Using these customer needs, the team went about developing various proposed solutions to the problem. To construct these solutions the team employed a concept selection tree to organize and evaluate the solutions. Upon selecting a solution using a concept selection matrix, the team went about prototyping the design.

Through the SolidWorks program, Team 3 successfully created and 3D printed the first prototype of the design. Through a design review process, the team was able to improve the initial prototype and implement further ideas including an added thickness for additional support and a lattice structure to reduce material, cost, and weight. Incorporating the ideas into the design, the team was able to construct a second prototype and successfully 3D print it. Moreover, by using SolidWorks, the team was able analyze the design for heat, weight, and force distribution. The final design would use a ABS plastic and material extrusion manufacturing. Overall, the design was determined to have fit the requirements set out by Lockheed Martin. For a future design, the team could work to improve the cable retention within the design to reduce and hopefully eliminate any effects of vibration.
Introduction and Problem Statement

The goal of the project is to create a lightweight bracket for a USB Hub Mounting Bracket for Lockheed Martin using additive manufacturing. This bracket hopes to maintain the same structural integrity and strength of the current design while minimizing the part count. Moreover, with the construction of the new differently dimensioned 7-port USB hub, the future bracket design hopes to accommodate the size of the hub, different orientations of the bracket, and certain stacking capabilities.

Currently, Lockheed Martin uses subtractive manufacturing techniques for its 4-port USB hub mounting bracket. Lockheed Martin recently released a 7-port COTS USB hub that requires a new bracket design. Used as a debug and auxiliary mounting device for a custom avionics mission system, the new COTS USB hub bracket requires a redesign for two 7-port hubs with cable retention for the USBs and power cables.

The project will explore and investigate various means of achieving the future goal. These means will include researching current bracket designs and additive manufacturing techniques. Furthermore, a thorough evaluation of the customer needs will help lead to an understanding of the problem and its impact on all stakeholders. Then, by applying this research to the design construction, the bracket can be constructed.

Background

To properly redesign the bracket, proper research had to be conducted. The previous design of the USB Hub dimensions were 257.9 (W) x 170.2 (D) x 60.6mm (H) [1]. The various bracket designs included two mounting brackets secured by four screws per each bracket on both ends. A rear panel secures the panel with three screws. The bracket fitted the edges of the hub and secured to the wall in a horizontal position. The previous USB hub brackets were typically constructed with metal materials. The current COTS USB hub design has seven ports and is 100 x 57 x 23 mm [2]. The design is significantly slimmer, smaller, and has rounded edges.
Three common methods of mounting a USB hub are the Din Rail, rack mount, and flange mounting [3].

- Din Rail: flat bracket or a din rail clip; bracket or clip is attached to the hub for mounting
- Rack mount: set of rack mount brackets to be attached via screws to either end of the hub and then attached to the rack
- Flange mounting: mounting by an attached flange or sometimes called an ear so that flat surface mounting can be implemented

The current Lockheed Martin bracket design employs the second methodology— the rack mounting.

Lockheed Martin made no specification as to the material of the proposed design except that it had to withstand approximately 25°C, so various methods of additive manufacturing needed to be researched for their relevance to the intended materials. The additive manufacturing methods that seemed applicable were powder bed fusion, material extrusion, and material jetting. As to the specific materials, titanium, ABS plastic, and PLA were considered for their strength and durability. Titanium, while determined to be superior in strength and heat resistance, was also determined to have a higher cost. Furthermore, with additive manufacturing, certain design ideas would be very difficult to replicate. Therefore, ABS and PLA, which are cheaper options that still maintain structural integrity, will be considered.

**Customer Needs**

When evaluating the customer needs, the team needed to keep in consideration that the bracket fit the current, dual-stacked, 7-port USB Hub. Furthermore, it was required that the bracket be able to withstand any vibrations, resist temperatures up to approximately 25°C, minimize part count from the original prototype, and use additive manufacturing. Two future needs included the possibility of being able to stack three hubs within the bracket and a vertical and horizontal mounting capability. However, these previously mentioned customer needs are revised from those the team originally constructed. Prior to receiving a memo from Lockheed
Martin, the team’s main concern was adding a vertical mounting capability to the bracket, which Team 3 hoped to achieve through a bracket with a rotational base. Therefore, the Analytical Hierarchy Process (AHP) matrix seen in Table 1 does not accurately represent the importance of specific customer needs; instead, it represents the importance of certain customer needs developed before receiving a memo that instructed the team that the focus of this project is to reduce the part count. As demonstrated below, “Additive Manufacturing (ease of manufacturing)” and “Fits New Design” were the most important needs in the AHP matrix while the least important was “Cost.” The cost would probably still be the least ranked on importance if a new AHP matrix were constructed because cost was never a focal point of the redesign construction. The highest ranked criteria still rank relatively high even after receiving the memo since these are still customer needs that the team needed to fulfill. However, it is expected that a reduction of part count would probably have been the highest ranked in the revised AHP matrix.

Table 1 AHP Matrix

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Durable</th>
<th>Lightweight</th>
<th>Stackable</th>
<th>Vertical</th>
<th>AM (ease of manufacturin g)</th>
<th>Fits New Design</th>
<th>Horizontal and Vertical</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>1</td>
<td>0.33</td>
<td>0.5</td>
<td>0.25</td>
<td>0.25</td>
<td>0.2</td>
<td>0.5</td>
<td>3.23</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Durable</td>
<td>3.030303</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>11.53</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Lightweight</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>3.100</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Stackable</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.140</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.140</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>AM (ease of manufacturin g)</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.150</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Fits New Design</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.150</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Horizontal and Vertical</td>
<td>2</td>
<td>0.33333333</td>
<td>0.33333333</td>
<td>0.33333333</td>
<td>0.33333333</td>
<td>0.33333333</td>
<td>0.33333333</td>
<td>0.33333333</td>
<td>1</td>
<td>5.00</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>87.76</td>
<td></td>
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</tr>
</tbody>
</table>

**Concept Generation**

Taking the background research and customer needs into account, the team went about generating concepts for the design project. When the team first started this project the main focuses were determining a proper construction of the bracket compatible with additive manufacturing, material for the construction, the actual design of the bracket, and a way to incorporate both horizontal and vertical mounting capabilities. To begin the design review
process, the team began with using a classification tree, which can be seen in Figure 2, came into play. Using the aforementioned categories, the team put down different possible options for each topic. As with the AHP matrix, the classification tree was developed prior to receiving the memo. Therefore, since the memo slightly changed the goals for this project, the team used the classification tree twice to make an initial prototype and then eventually the prototype that led to the final project. Utilizing the classification tree and the results from the customer needs, the team could generate numerous ideas for the bracket design. After sketching a few of the potential designs that would be later evaluated, the team moved to choosing the material and additive manufacturing technique with the assistance of the classification tree. The team decided to use material extrusion as the method of additive manufacturing because it would be the most practical for all of the potential designs. Since the team had determined that a lattice would be placed on the design to utilize additive manufacturing capabilities and to minimize material, material extrusion was deemed the most appropriate and effective method to manufacture the part. This decision also helped the team determine the material that for the project--plastic. Specifically, the team would use ABS plastic for the USB hub bracket because it can withstand temperatures up to about 100° C which would eliminate worry that the hub would melt the plastic. Furthermore, in reference to the lattice design, it was decided to make three of the sides a honeycomb lattice to reduce weight and material use.
Concept Development and Selection

After completing the design concept generation, the team was prepared to advance to the concept development and selection phase of the project and commence construction of the first prototype. The team had several ideas for a prototype for the design of the bracket after making the classification tree. The team put these designs into a design selection matrix seen in Table 2 to determine which design would meet the requirements of this project the best. The final four ideas included a traditional bracket, a bracket with a rotating base, a bracket that would hold the HUB on all four sides and would be printed using one material, and a bracket that would be printed using two materials. After assigning weights and ratings to each design, the team determined that the second design, the winged bracket, would ultimately fit Lockheed Martin’s customer needs the best. The benefits of this design included that the team determined that it would be durable, lightweight, have both vertical and horizontal mounting while still fitting the design and using additive manufacturing. The only negative aspect of this design was that the team was unsure whether or not a stacking capability would be possible.
The team also determined that both models with four sided supports would not be as durable and would definitely be incapable of being stacked. However, it was decided that these designs would be very lightweight and would be capable of having different mountings. Determining that the negative aspects of those two designs outweighed the positive aspects, neither of these models were the final pick. The last possible choice for a bracket was a traditional styled bracket, although it scored high in durability, ease of manufacturing, and fitting the new design; it scored low in the categories of lightweight, stackable, and its capability of having a horizontal and vertical mount. Therefore, the second design was the clear choice for a final design.

Using the scores obtained from the concept scoring matrix, the team confirmed that the highest scoring design was, in fact, the best concept. However, it was at this time that the team received a memo from Lockheed Martin. Therefore, using an abridged version of the customer needs and adjusting them to better fit the memo, the team went to constructing a number of new sketches. Instead of repeating the previous process of the concept scoring matrix, the team used an informal selection process and picked the bracket with the fewest parts, which was the most emphasized requirement from the customer’s memo.

Following this selection process, the team was able to construct the design within SolidWorks. Furthermore, to test the capabilities of the 3D printer, the team prepared a sample plate. The sample part included scale models of USB ports with various thicknesses, a sample curve of the USB Hub, and a thinly modeled hinge. The results of the test plate helped inform the construction of the initial prototype because it was seen that some of the thicknesses were much more durable than others. Moreover, two of the very thin, elevated parts broke off, so it was necessary for the future design to have a much stronger thickness.
Table 2 Concept Selection Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
<th>Rating</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durable</td>
<td>14.40%</td>
<td>5</td>
<td>0.72</td>
<td>4</td>
<td>0.576</td>
<td>3</td>
<td>0.432</td>
<td>3</td>
<td>0.432</td>
</tr>
<tr>
<td>Lightweight</td>
<td>12.60%</td>
<td>2</td>
<td>0.252</td>
<td>4</td>
<td>0.504</td>
<td>5</td>
<td>0.63</td>
<td>5</td>
<td>0.63</td>
</tr>
<tr>
<td>Stackable</td>
<td>17.60%</td>
<td>2</td>
<td>0.352</td>
<td>4</td>
<td>0.704</td>
<td>2</td>
<td>0.352</td>
<td>2</td>
<td>0.352</td>
</tr>
<tr>
<td>Vertical and Horizontal</td>
<td>17.60%</td>
<td>2</td>
<td>0.352</td>
<td>5</td>
<td>0.88</td>
<td>5</td>
<td>0.88</td>
<td>5</td>
<td>0.88</td>
</tr>
<tr>
<td>Additive Manufacturing</td>
<td>18.90%</td>
<td>5</td>
<td>0.945</td>
<td>5</td>
<td>0.945</td>
<td>5</td>
<td>0.945</td>
<td>5</td>
<td>0.945</td>
</tr>
<tr>
<td>Fits New Design</td>
<td>18.90%</td>
<td>5</td>
<td>0.945</td>
<td>5</td>
<td>0.945</td>
<td>5</td>
<td>0.945</td>
<td>5</td>
<td>0.945</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>21</strong></td>
<td><strong>3.566</strong></td>
<td><strong>27</strong></td>
<td><strong>4.554</strong></td>
<td><strong>25</strong></td>
<td><strong>4.184</strong></td>
<td><strong>25</strong></td>
<td><strong>4.184</strong></td>
</tr>
</tbody>
</table>

Description of Prototype

The first prototype focused on keeping the design one part and allow stacking of 3 USB hubs. It also aimed to provide reinforcement for the power cords and USB cords. The design accomplished this by being one part and tall enough to slide in 3 USB hubs (Figure 1). Holes were placed in the sides; just large enough for the USB cords and power cords. This would, in theory, provide reinforcement for the cords, not letting them slide out with vibrations. This capability is illustrated in Figure 3. Furthermore, the design also maintained the four point mounting bracket, as specified in the requirements.
The product was then printed and took 5 hours and 45 minutes to complete (Figures 4 and 5). This design satisfied more requirements than the other designs considered, perhaps the only lacking ability was with the support provided by the bracket.
Design Review

Following the construction of the prototype, the team went through a design review process so as to improve upon the current model. After discussing with Team 4, the following action items were proposed as possible implementations to the design:

Proposed Action Items

- Visual representation of parts and benefits of USB for customers
- Additional support for the USBs and power cords
- Consider horizontal and vertical mounting
- Define material choice

After receiving this feedback, the design was reevaluated for the structural support it will provide to the cords and USB HUBs. The first decision was to extend the USB support structure to a greater thickness so as to provide additional support for the USBs. Furthermore, to reduce the amount of material used in the design, a lattice pattern was implemented into the design. In regards to the horizontal and vertical mounting and stacking abilities, the future design concept could include three horizontal bars on the opposite side of the vertical bars with the same thickness as the increased thickness on that opposite side. To properly support the power cords, an additional piece will be created as a support mechanism for the power cords. By having the capability to place this piece in any orientation about the structure, it will be helpful for either horizontal or vertical mounting. Regarding the material choice, using SolidWorks tools, the two material choices—metal and plastic—can be tested. Further tests for force and weight analysis were also considered so as to have a more thorough understanding of the design and its ability to meet all the proposed customer needs and requirements.

Description of Final Design

With the design review considerations in mind, the final prototype was created. This design incorporated a thicker outer shell (doubled in thickness) in order to provide a definite
reinforcement for the power and USB cords. In order to reduce weight and utilize the advancement of additive manufacturing, a honeycomb lattice structure was created on the supporting walls of the structure (Figures 6 and 7). This took 5 hours and 55 minutes to manufacture, and with the doubled thickness, this would have been a time decrease in manufacturing time.

![Final design CAD model](image1)
![Makerbot set up of final design](image2)

On the model, stress and displacement tests were performed in SolidWorks, and it was found that the weight of the 3 USB hubs would not cause a maximum amount of stress (Figure 8) and the displacement was centered in the outside wall of the structure (Figure 9). Using the mass analysis tool in SolidWorks, the mass of the structures were determined. The mass of the first prototype was 88.30g, and after doubling the thickness, was 128.75g, increasing the mass significantly. After cutting out the lattice structure, the mass was reduced to 98.49g.

![SolidWorks stress tested final design](image3)
![SolidWorks displacement tested final design](image4)
The printed part was an improvement from both the current Lockheed Martin model and the original design of the team. The new design (Figures 10 and 11) is much more sturdy than the original design and is fewer parts; 19 as opposed to the original 35. Furthermore, for printing purposes, the team would suggest using material extrusion with ABS plastic due to its aforementioned heat resistance. The final product, as compared to the PLA printed model seen in Figures 10 and 11 would be very similar. However, with the different material and the fitted bracket, it would function much better than the prototype. Furthermore, it would potentially include an additional segment on the bracket to better support the USB and power cables.

**Conclusions**

The final USB Hub Mounting Bracket was determined to have met Lockheed Martin’s needs. It effectively minimized the part count from 35 to 19, thus meeting the customer’s most emphasized concern. Furthermore, it effectively reached both of the “future bonus” goals presented by Lockheed Martin to vertically mount the device and stack three hubs. The added thickness more effectively stabilized the USBs within the port. Within a future design, the team would use the testing analysis to improve the design structure. Furthermore, an improved cable retention piece could be implemented to stabilize the USB cords.
The project taught the team the importance of meeting customer needs effectively and thoroughly. Moreover, the team had to work under rather vague constraints in the beginning of the project, which caused some confusion in the beginning of the project. However, taking the given information, the team was able to develop multiple solutions. Perhaps the most important lesson came when the team received the updated memo from Lockheed Martin. Within the future career paths of the team, design goals will inevitably change and adjust according to customer needs. This experience of adjusting to new information was a very important and effective lesson. Finally, the exposure to 3D printing was invaluable, as it is such a new and prominent feature within engineering that the team is excited to work with in the future.
References

