Cord Keeper
Lockheed Martin

EDSGN 100 Section 022
Dr. Sarah Ritter
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Team 7-Eleven

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Executive Summary

Lockheed Martin came to us with the challenge of reinventing a product they currently use. Lockheed Martin uses USB hubs in a lot of their avionic systems. They currently use 4-port USB hubs but would like to improve their systems by increasing their capacity to 7-port USB hubs. In order to do that, the old USB hub bracket will have to be redesigned to meet certain criteria while utilizing the process of additive manufacturing.

After their criteria was weighted by an AHP matrix, it was put into a classification tree in order to come up with features that the concepts had to include. The concept that met most of the criteria was then modeled and prototyped. Two iteration processes later, the final design was attained. Further analysis showed that final design met certain criteria so stretch goals were created to fully meet them in the future.

Introduction and Problem Statement

Lockheed Martin is a large company involved in many innovative areas with diverse work and research. Some specific areas of development are Aerospace and Defense, Energy, Information Technology, Space and Emerging Technology. This project tasked groups to redesign specific parts utilized by Lockheed Martin. These parts were to be made by means of additive manufacturing, and the item being evaluated in this project is a USB hub bracket. The bracket will have to be created to house 7-port USB hubs and be capable of retaining cables under vibrational stress due to avionic use [1].

Lockheed Martin currently uses a 4-port USB hub mounting bracket design with limited cable retention. This design is specifically made for a generic 4-port USB hub and is not compatible with the new 7-port USB hubs. This outdated design has a part count of 38, which is considered to be high.

The new 7-port USB hub will be created by means of additive manufacturing so as to reduce waste and implement designs that cannot be created using traditional manufacturing processes. In order to create the most effective design, the needs will be weighted by an AHP matrix and then be used in a scoring matrix to choose the best concept. Then the concept will be modeled in SolidWorks to produce prototypes. By the process of iteration, the final design will be produced and analyzed.
Background

In order to better understand the geometry the bracket, we had to choose a commercial off-the-shelf hub to base it on. The hub that we chose was D-Link 7-PORT USB 2.0 HUB that uses standard Type-A USB ports. Conveniently, the D-Link website provided a vast amount of information regarding the hub. The dimensions of the hub are 100 x 57 x 23 millimeter. The weight of the hub was found to be 85 grams. The issue we faced in this stage was that fact that we could not find the dimensions of the curved edges of the hub (Figure 1). In order to continue with the design process we had to estimate the radius of the arc to be 13 millimeter [2].

![Figure 1. Commercial off-the-shelf USB hub [2].](image)

Research was also done on the Type-A USB cord itself in order to understand and design the cable retention part. A patent revealed the dimensions of the cord and the plug. The dimensions of the plug are 12.0 x 15.7 x 7.5 millimeter, as seen in Figure 2, while the cord has a diameter of 4.6 millimeter. The dimensions were crucial to obtain in order to create a tight fit for the plug as well as a system to prevent the cable from being unplugged [3].

![Figure 2. USB Type-A Specification [3].](image)
Lockheed Martin issued a memorandum regarding some additional information about the bracket currently used for mounting two 4-port USB hubs (Figure 3). The original bracket consisted of a total unique part count of seven. The total part count was thirty eight consisting of one base hub closure, two power USB uplink retention bars, one USB retention bar, ten screws, ten washers, ten lock washers, and four nuts. This bracket is made from metal through the process of subtractive manufacturing [4].

![Image of original dual-stacked, 4-port USB hub bracket]

**Figure 3.** Original dual-stacked, 4-port USB hub bracket [4].

**Customer Needs**

Lockheed Martin’s customer team set forth a series of priorities for the improved USB cable retention bracket. Due to the short time frame of this project, the Lockheed Martin team placed a strong emphasis meeting certain design goals over others. They placed a primary focus on reducing the number of parts from the individual design. Other design criteria included: design for 2, 7 port USB hubs, maintain 4 point-screw mounting base, and to minimize the quantity of any other screw/mounting holes required in the structure. Stretch goals for this project include vertical mounting capabilities and the ability to stack up to three brackets together (horizontal or vertical orientation).
Table 1. AHP Matrix

<table>
<thead>
<tr>
<th></th>
<th>Ease of use</th>
<th>Ease of Manufacturing</th>
<th>Integrity</th>
<th>Cable retention</th>
<th>Vertical Mounting</th>
<th>Horizontal Mounting</th>
<th>Stackability</th>
<th>Cost</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use</td>
<td>1</td>
<td>0.5</td>
<td>0.333333</td>
<td>0.25</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>12.08333</td>
<td>0.130068</td>
</tr>
<tr>
<td>Ease of Manufacturing</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>0.2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>9.7</td>
<td>0.104413</td>
</tr>
<tr>
<td>Integrity</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>15.50003</td>
<td>0.166649</td>
</tr>
<tr>
<td>Cable retention</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1.25</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>27.25</td>
<td>0.293326</td>
</tr>
<tr>
<td>Vertical Mounting</td>
<td>1/2</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>13.3</td>
<td>0.143165</td>
</tr>
<tr>
<td>Horizontal Mounting</td>
<td>1/3</td>
<td>0.5</td>
<td>0.5</td>
<td>0.25</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5.08333</td>
<td>0.054718</td>
</tr>
<tr>
<td>Stackability</td>
<td>1/2</td>
<td>0.5</td>
<td>0.333333</td>
<td>0.2</td>
<td>0.333333333333333</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.866667</td>
<td>0.052368</td>
</tr>
<tr>
<td>Cost</td>
<td>1/3</td>
<td>1</td>
<td>0.333333</td>
<td>0.2</td>
<td>0.25</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5.116667</td>
<td>0.055077</td>
</tr>
</tbody>
</table>

The criteria for the AHP matrix was decided on the basis of the aforementioned design requirements, as well as a few other considerations. Ease of Use, Ease of Manufacturing, Cost and Integrity were all additional criteria that were considered during the design process. Upon comparison, Cable Retention and Horizontal Mounting stood out as the most important features. These designs features were top priorities for the Lockheed Martin customer team.

Concept Generation

Initially the team brainstormed preliminary ideas to aid in the process of designing the bracket. Once sketches were generated by each team member, an analysis of different aspects of each of the drawings were performed. Some key attributes that were being analyzed were the constraints and needs desired by the customer, Lockheed Martin. These features included the mounting orientation, cable retention, and reduction of parts and the utility of additive manufacturing. These features were examined on each of the preliminary drawings in order to choose the best qualities from the initial concept generation. During the analysis certain attributes were discussed based on the quality of the idea. Characteristics of each design during the concept generation phase aided in the selection of an idea for the first prototype. Three initial drawings were produced (depicted below). As illustrated by the concept generation matrix, idea 2 outweighed the other designs, so this idea progressed into the first prototype. Some key features to note about this design are the reduction of parts, mounting capabilities and utilization of an efficient cord retention system.

![Figure 4. Concept 1.](image1)

![Figure 5. Concept 2.](image2)

![Figure 6. Concept 3.](image3)
Figure 7. Classification Tree.
Concept Development and Selection
The final design was decided on by comparing and contrasting different design ideas generated by group members. Each of the designs was generated by taking concepts from the classification tree and creatively incorporating these design features into three separate and unique designs. Each design included different features that suited certain customer needs better than others. In order to objectively determine the most suitable design, each design was compared using a concept comparison matrix. The points of comparison and weight of each design feature were taken from the AHP matrix.

Table 2. Concept Scoring 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>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Retention</td>
<td>0.29</td>
<td>4</td>
<td>1.16</td>
<td>3</td>
<td>0.87</td>
<td>4</td>
<td>1.16</td>
</tr>
<tr>
<td>Horizontal Mount</td>
<td>0.055</td>
<td>3</td>
<td>0.165</td>
<td>4</td>
<td>0.87</td>
<td>5</td>
<td>0.275</td>
</tr>
<tr>
<td>Integrity</td>
<td>0.17</td>
<td>4</td>
<td>0.68</td>
<td>5</td>
<td>0.85</td>
<td>2</td>
<td>0.34</td>
</tr>
<tr>
<td>Vertical Mount</td>
<td>0.14</td>
<td>1</td>
<td>0.14</td>
<td>4</td>
<td>0.56</td>
<td>5</td>
<td>0.7</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>0.13</td>
<td>3</td>
<td>0.39</td>
<td>3</td>
<td>0.39</td>
<td>3</td>
<td>0.39</td>
</tr>
<tr>
<td>Ease of Mfg.</td>
<td>0.1</td>
<td>2</td>
<td>0.2</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Stackable</td>
<td>0.052</td>
<td>2</td>
<td>0.104</td>
<td>4</td>
<td>0.208</td>
<td>4</td>
<td>0.208</td>
</tr>
<tr>
<td>Cost</td>
<td>0.055</td>
<td>3</td>
<td>0.165</td>
<td>2</td>
<td>0.11</td>
<td>3</td>
<td>0.165</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>3.004</td>
<td>4.158</td>
<td>3.538</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8. Initial 3D print.
Description of Prototype (3D Model + 3D printed Prototype)

First Prototype
The first prototype created was a total of three parts consisting of two cable retention parts and one total part to hold the two brackets. There were many faults with the first prototype. It was found that when the prototype was accidently dropped one of the horizontal mounting brackets broke off. Because of this it was noted that the horizontal mounting brackets need to be reinforced with a stronger geometry. It was also noted that the hub holder itself was too pliable due to the weak geometry of the cross section between the hub holders.

Figure 9. Prototype 1 SolidWorks model.

Figure 10. Prototype 1 printing.

Figure 11. Prototype 1 Printed.
Second Prototype

The second prototype was based on iterations after evaluating the first model. Slight variations were made, but the overall design remained the same. One large alteration made was the thickness of the bracket. Since the first bracket was weak due to thin material, the thickness was increased in order to increase durability. This can be illustrated by the comparison picture below. Another change in design was the thickness of the slots for the cable retention. These openings were increased slightly in order to accommodate better the thickness of wires. This is depicted in the second picture below.

![Comparison of power retention and bracket for Prototypes 1 and 2](image)

**Figure 12.** Comparison of power retention and bracket for Prototypes 1 and 2

Design Review

The design review process proved to be relatively quick and efficient due to the additive manufacturing process. The first model created and printed allowed for a physical evaluation of the bracket. This first analysis proved that while the integrity of the design was structurally sound, the thickness proved to be a weakness. The iteration of the first design allowed for thicker walls of the bracket, along with the cable retention holes being widened. This second prototype satisfied all of Lockheed Martin’s requirements, however the design was not tailored to additive manufacturing, and therefore could have been made via a different method such as casting. This problem led to the third and final design where diamond-like geometries were extruded in order to fully utilize the additive manufacturing process. The design process was efficient because the variations were made via SolidWorks, and physical evaluations were able to be performed for each iteration.
Description of Final Design (3D Model)

The third model of the bracket was the final design created. This model utilized aspects of both prototypes along with iterations made for the final design concept. Some key aspects were redesigned for the creation of the third model. This model catered to the advantages of utilizing additive manufacturing. The third model was designed in such a way that the weight of the bracket was lowered using diamond-like extrusions. These geometries embedded in the model not only reduce the weight, but cannot be produced as efficient as additive manufacturing. This lattice-like structure allowed the team to fully design the bracket with additive manufacturing as the desired manufacturing process. Below is a rendered version of the third prototype that was created on SolidWorks.

![Figure 13. Final Rendered Model](image)

![Figure 14. Stress test of final model](image)
Analysis

After further analysis of the team’s final design, certain strengths and weaknesses were evaluated. The final design fulfilled all the required criteria set by Lockheed Martin; however, the only feature that was not met was the bonus feature of stackability. Multiple evaluations of the prototypes were performed. The final design analysis judged the model based on how well it met each required criteria. Some critical evaluations were: the part count, cable retention functionality, and mounting orientation. The part count was reduced from 38 to 24, the cable retention functioned as intended, and the mounting holes allowed for dual orientation mounting. Next, a Solidworks evaluation was performed for a stress test on the bracket as illustrated in Figure 14. The load applied illustrated that the connecting bar was weak and bowed, however this part was not critical to the integrity of the design, it merely allowed for a reduction of parts. Looking ahead the bar could be reinforced with carbon fiber in order to strengthen the cross section. The weight reduction was measured from the second prototype to the final model. The second prototype weighed 78.2 grams while the final prototype weighed 60.5 grams, reducing the weight by 17.7 grams. The reduction of this weight not only reduces print time, it reduces cost. Looking ahead, the final prototype can be altered in order to reinforce the cross section, increase the number of hubs held per bracket, and accommodate for stackability.

Conclusion

The third and final model illustrated a combination of the first two prototypes. Iterations were made to better the final model, and this is evident in the qualities contained by the final design. The third model contains both strengths and weaknesses, however the team believes that the positive outweighs the negative. The third model excels in the fact that it reduces the number of parts used for the bracket. It is made from one piece to hold the USBs and two pieces that are used for cord retention. The only other parts used are the mounting hardware such as screws, bolts, nuts etc. Additionally the third model is capable of being mounted in any orientation, specifically horizontally and vertically. The third model (along with the first and second) is capable of holding two seven-port USB hubs, and it is also designed utilizing the capabilities of additive manufacturing. This model was designed in order to reduce weight and print time due to the lattice geometry that is extruded from the bracket. These attributes all fulfill the requirements set by Lockheed Martin. The disadvantage of this design is that it is not currently able to be stacked with additional units. If additional models were to be created this feature would be addressed. This would be the next step of the iteration process in order to completely comply with Lockheed Martin’s expectations. There were many lessons learned by the team during this design process. One is that since the process of additive manufacturing allows for quick testing, the team was able to obtain an initial idea and apply the iteration process multiple times because the 3D printing process is very responsive. Another lesson learned is that collaboration is necessary. Often times it is difficult to visualize another’s ideas, and this is where SolidWorks and sketches were useful. The allocation of time and resource was also key to designing three models. Making efficient use of time and dictating tasks was crucial to success.
Works Cited