Lockheed Martin: USB Hub Bracket

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Team 5: Sleepless in PA
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- Design allows for multiple brackets to be stacked with aluminum screws
- Built in cable retainers support USBs and cut down on parts
- Cutouts reduce weight and cost, and improve ventilation
- Hard plastic outer shell wraps around corners of hub, similarly to a phone case, and protects from damage
- Rubber inner layer to prevent
Executive summary

In this report, we outline the process we went through to create a new USB hub bracket design to be 3D printed for Lockheed Martin, required because of a recent change in the model of USB hub they use. We used various stages of brainstorming and design selection matrices to come up with our prototype design idea, which we modeled using the 3D modeling software SolidWorks. We then printed out a test prototype, and made the necessary changes to fine tune the product. Upon completion of the project, we have concluded that ours is a competent design, though some work could go into creating greater stacking capabilities.

Introduction and problem statement

Lockheed Martin has recently switched over to a different type of USB hub system. Due to this, their previous series of mounting equipment is now unusable due to size and dimensional changes. Thus a new mounting bracket needs to be designed that is able to hold the new hub system safely, created with additive manufacturing. This involves preventing the cables from falling out or becoming damaged as well as dampening vibrations from the surrounding aircraft. This system should be able to mount into a wall or table and still keep the hub from moving, falling, or otherwise sustaining damage. Ideally this bracket could hold multiple hubs without needing more parts.

Currently the system Lockheed Martin uses involves a different USB hub that fits inside a purely metal mounting bracket, in which several faces are individually screwed onto the shape. This bracket holds two hubs against each other (vertically stacked) directly against the metal structure, and against the mounting surface (wall or table). This bracket, along with being larger for the old hubs, does not prevent vibration damage, and requires many individual parts to be assembled.

We plan to create a hub that can more snugly hold each individual hub in the way a phone case does. This implies a hard outer “shell-like” structure with a rubber inner lining. The shell could be printed as one piece in order to lower the total number of parts. The rubber lining could also act as both protection as well as dampen vibrations from the rest of the aircraft. Having a uniform and symmetrical shape would also allow multiple brackets to be stacked for however many hubs necessary.

Background

Previous USB mounting brackets, as well as most other types of mounting brackets, are traditionally made with bent metal plates screwed together. Plates are welded of the proper size with right angles, and are then connected around the hub. Usually this is done to ease manufacturing and assembly, as screwing together plating is simpler than three dimensional geometry in traditional manufacturing. The major drawback of this system is the large amount of parts required, considering the assembly of multiple plates requires extra screws and washers for each connection. However, due to the switch to additive manufacturing, the entire casing can be printed as one part, instead of assembled from metal sheets. This can be more effective as it reduces the total number of parts and assembly time. The new USB hub is also smaller than the previous one, which can speed up the process for three dimensional printing.

Customer Needs

Lockheed Martin needed a very specific type of assembly for the mounting bracket. First, the bracket needed to have minimal parts to ease the transition to additive manufacturing. It
needed to be able to stack vertically for multiple hubs. Seven ports needed to be accessible through the bracket. The construction had to be lightweight, since it is to be used in aircrafts. It then had to be able to absorb shock and vibration due to turbulence in the aircraft's travels. Lastly, the cables had to be able to be retained during such vibrations as well as in case of general force applied. To manage these needs, we made an analytic hierarchy process matrix (AHP) shown below in Table 1. We considered having the proper port placement was the most important, as without it the bracket would cut off the functionality of the hub.

### Table 1: The Analytic Hierarchy Processing matrix

<table>
<thead>
<tr>
<th>Concept</th>
<th>light weight</th>
<th>7 ports</th>
<th>mount vertical</th>
<th>withstand temperature</th>
<th>reduce vibration</th>
<th>stack 3</th>
<th>swap mounting</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light weight</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>13.00</td>
<td>0.21</td>
</tr>
<tr>
<td>7 ports</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>16.00</td>
<td>0.25</td>
</tr>
<tr>
<td>Mount vertical</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>15.00</td>
<td>0.24</td>
</tr>
<tr>
<td>Withstand temperature</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>0.5</td>
<td>2</td>
<td>2</td>
<td>7.00</td>
<td>0.11</td>
</tr>
<tr>
<td>Reduce vibration</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>8.33</td>
<td>0.13</td>
</tr>
<tr>
<td>Stack 3</td>
<td>0.333333</td>
<td>0.25</td>
<td>0.25</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>3.83</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>63.17</td>
<td></td>
</tr>
</tbody>
</table>

### Concept Generation

When we initially learned of the goals of this project, we immediately started brainstorming some basic ideas for the bracket. We had a few entirely unfeasible ideas, such as a bracket that was suspended with wires and was essentially a disco ball, but we soon moved onto more serious proposals. The classification tree below (figure 1) outlines each idea and includes crude sketches as well.

Our ideas could be broken into three main categories: frames, meshes, and solids. We didn’t invest too much faith in the idea of a solid bracket, because we knew that it would be much too heavy, have too much material cost, and could potentially lead to ventilation problems. In addition, it would waste the capabilities of the 3D printing technology we were instructed to use. After the solid bracket, we were left with meshes and frames. Our mesh frame idea was further broken down to two categories: mesh over the whole hub, and mesh over only part of the hub. Then the specific pattern of mesh could be determined, either triangular, rectangular, or a mix. Our final main idea was a frame bracket. Our two ideas within this were to have the frame cross only at the center of each edge, not touching the corners, or to have the frame wrap around each edge, somewhat like a phone case. We focused on this idea, because we thought it would be easier to reduce vibration with the more secure hold the bracket would have on the hub. In order to create that vibration reduction, we had to either add air pockets or rubber at the corners, and we believed rubber would be much more effective at this.
All in all, we ended up with 4 contenders for the bracket design, shown in figure 2: a frame bracket enveloping the corners with a rubber inner layer, a solid rectangular mesh, a cutout rectangular mesh, and a solid bracket. These were the 4 designs that would be tested in our concept design matrix.

In addition to the bracket design, we had to come up with a way to stabilize the cords plugged into the USB. We deliberated between a latch design and a prong design, either stationary or removable. We believed a latch would be more effective, but would also be much more difficult to manufacture and might be more prone to breaking. Furthermore, since one of the primary directives of the project was to reduce part count, we felt the removable prongs would cause unnecessary extra parts. Therefore, we settled on a stationary prong design to stabilize the cables.

![Figure 1: The classification tree](image)

**Concept Development and Selection**

Once we had generated a number of potential final designs, we went into a selection process to determine which one was best. We began by printing a very small sample of what our mesh could be, because we felt that it was the structure that was most likely to fail. Unfortunately, we were right, and the mesh pattern came out completely mangled and fallen apart.
With this data in mind, we created a design selection matrix using the weights generated in our AHP, shown above. This matrix is shown in table 2 below.

**Table 2: The design selection matrix**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Frame Rating</th>
<th>Frame Weighted Score</th>
<th>Mesh Rating</th>
<th>Mesh Weighted Score</th>
<th>Solid Mesh Rating</th>
<th>Solid Mesh Weighted Score</th>
<th>Solid Rating</th>
<th>Solid Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightweight</td>
<td>0.21</td>
<td>4</td>
<td>0.84</td>
<td>5</td>
<td>1.05</td>
<td>0.63</td>
<td>1</td>
<td>0.21</td>
</tr>
<tr>
<td>7 Ports</td>
<td>0.25</td>
<td>5</td>
<td>1.25</td>
<td>5</td>
<td>1.25</td>
<td>1.25</td>
<td>5</td>
<td>1.25</td>
</tr>
<tr>
<td>Mount Vertical</td>
<td>0.24</td>
<td>5</td>
<td>1.21</td>
<td>4</td>
<td>0.96</td>
<td>5</td>
<td>1.21</td>
<td>5</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.11</td>
<td>4</td>
<td>0.44</td>
<td>4</td>
<td>0.44</td>
<td>4</td>
<td>0.44</td>
<td>5</td>
</tr>
<tr>
<td>Vibration</td>
<td>0.13</td>
<td>4</td>
<td>0.52</td>
<td>3</td>
<td>0.39</td>
<td>4</td>
<td>0.52</td>
<td>5</td>
</tr>
<tr>
<td>Stacking</td>
<td>0.06</td>
<td>4</td>
<td>0.24</td>
<td>2</td>
<td>0.12</td>
<td>2</td>
<td>0.12</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>4.5</td>
<td>4.21</td>
<td>4.17</td>
<td>4.11</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We carefully ranked each design on each of the 6 criteria we had chosen (Lightweight, 7 port capacity, vertical mounting, operating temperature, vibration dampening, and stacking capabilities). The frame design scored consistently high on everything, with its only cons being that other designs were slightly lighter, we weren’t sure about operating temperatures due to warping, the vibration dampening might be reduced by the cutouts, and the stacking might be difficult.

The next design, the mesh, scored well on being lightweight and having 7 port capacity, but scored poorly on vibration dampening due to its flimsiness, and extremely low on stacking because there would be no way to attach multiple brackets together securely.

The solid mesh, our third design, scored very well on having a 7 port capacity and mounting vertically, but poorly on being lightweight (due to the increase in material), and extremely low on stacking for reasons similar to those given for the mesh design.

The last design, the solid bracket, did very well in 4 out of the 6 criteria. It had a 7 port capacity, could mount vertical, could operate under the given temperature constraints, and would be able to stop almost all dampening. However, it got the lowest score possible in the lightweight category.

Ultimately, the frame scored highest with the weighted points, because it was consistently high everywhere. It also had the highest score possible in the most heavily weighted categories, which really made the difference. The lower scored all around hurt both mesh designs, and while the solid bracket had almost the same amount of unweighted points as the frame, its 1 out of 5 score in one of the most heavily weighted categories really hurt it, and dropped it to last place. Because of this, we decided to move forward with the frame as our final design.

**Description of Prototype (3D Model + 3D printed Prototype)**

Our chosen design of a hard shell outer case was better than the other designs considered for many different reasons. When compared to the solid mesh case, it was lighter, used less material so it would be cheaper and faster to make, and we thought it would be sturdier. If compared to the mesh frame case it was heavier but we thought that sacrifice would be worth it since there would be less weak points in a solid frame then in a mesh frame. Therefore, providing a more protective but still easy to manufacture and lightweight design as shown in figures 2-5.
Figure 2 is an image of our first prototype fully assembled with the hard plastic outer shell encasing the softer, rubber inner shell. You can see the cable retention fence in the front and back to keep the USB cables from being accidentally knocked out as well as the screw holes on the four corners for actually mounting.

Figure 3 is an image of the same prototype as in Figure #, just viewed from the back. This gives a better view of the cable retention for the power and Ethernet cables.
Figure 4 is an image of the first prototype disassembled into the two different shells. The soft rubber case would fit around the USB hub to increase protection when it falls and provide some vibration dampening while the aircraft is in motion.

Figure 5 is a picture of the first prototype 3D printed. The design was promising but with a few flawed dimensions that were corrected in the final product.

Description of Final Design (3D Model)
Our final model was based off of the idea of making a phone case like structure that would wrap around the USB hub and then be mounted to the wall. We came to the conclusion that the bracket would have two layers. One made out of a rubber material, to reduce vibrations from the plane, and one made out of a hard plastic that is mounted to the wall. Our design has improved the bracket by reducing the number of parts that are necessary for assembly from thirty-eight to ten. It also requires cheaper material and can be produced at a faster rate through additive manufacturing.
We would advise that Lockheed Martin use the material extrusion method of additive manufacturing when building this product. They should use a rubber material for the internal shell of the casing, because this is meant to help dampen the possible vibrations that come from the movement of a plane, and a hard plastic material for the external shell of the casing, to ensure that the bracket is mounted properly and that there is a hard structure that can support the weight and maintain the shape of the bracket.

The only major difference in performance that we could foresee for this product would be the orientation of the hub. Depending on what you mount it to the hub will either be oriented horizontally, if mounted to say a table, or vertically, if mounted to say a wall. However, this was an option that we wanted Lockheed to have in case they needed the option to mount it in different orientations.

Conclusions

The major pros of our product were the fact that it is lightweight, it has minimal parts, and it does a good job of dampening the vibrations that could affect the hub in any way. The only major con to our design is that you can only fit one hub in each bracket, so if Lockheed wants to stack multiple hubs, they will need multiple brackets. From here Lockheed could alter the design to better fit more than one hub with each bracket. The main lessons that we learned were that dimensioning is a very important factor when it comes to additive manufacturing, because the first prototype we made was dimensioned poorly and that lead to the hub not fitting in the bracket. We also learned that material extrusion does not work very well with small, thin structures. The very first idea that we had printed fell apart because the printer was not able to make supports for such small walls.

References