USB Hub

Mounting Bracket

Team #6: The I.E.s

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Executive Summary:

The following report explains an engineering design project handled by the I.E.s (Team #6) at Pennsylvania State University, University Park. The overall goal of this project was to design a USB mounting bracket that was suitable enough to meet the needs of the customer, Lockheed Martin. The primarily goal was to reduce the amount of parts as possible. However, the team also had other specifications, including the possibility of designing a bracket that can house multiple USB Hubs, that can be printed via Additive Manufacturing, while providing a stable/secure shelter for the Hubs. In order to create a suitable design, multiple concepts were developed by the team. From these concepts, one was ultimately chosen, which combined all aspects of the different idea. The first prototype was made and modeled on SolidWorks. After a design review, the prototype was further improved from the initial design to the final design, which was also modeled on SolidWorks. As a result, this report summarizes the entire design process that led up to the finished product.

Introduction and Problem Statement:

Lockheed Martin is a global security company engaged in the research, design, development, manufacture, integration and sustainment of advanced technology systems, products and services. They provide solutions across multiple lines of business, in this case the IEs were asked to solve a problem regarding a USB Hub Mounting Bracket; used as a debug and auxiliary mounting device for avionic mission system. Primarily, the goal is to reduce the number of parts as possible, to provide a greater capability of connections, to allow installation in different platforms, to reduce the number of parts and to provide a vertical installation.

The IEs would like to redesign a USB Hub Mounting Bracket that can withstand the pressure and the environment in the aviation industry. At the moment, we are facing USB Brackets that are not as durable and efficient as they should be; under harsh conditions these products fail to fulfill the customer needs. For example, the Brackets are not providing enough support to the USB and power cables, because of which the
previously mentioned cables tend to unplug. The product designed will be created using additive manufacturing. Furthermore, the IEs will search for solutions and methods to make the Brackets more appropriate for the situations they are required for. Research is going to be carried out to determine the flaws on the design and in this way reduce vibration and improve cable retention.

**Background:**

Nowadays, people are consuming a very large amount of electronics from webcams, printers and smartphones to other devices that have to be plugged in so they can be used or charged. Thus, this situation initiates an increasing demand for USB Hubs since each computer has a limited number of USB Ports. At the same time this creates a demand for USB mounting brackets in order to store multiple USB Hubs in one place.

Based on the project guidelines, it was given that Lockheed Martin changed their old USB Hub and Bracket to new 7-Port USB Hub, which is produced by D-Link corporation. With this in mind, the team researched about the specifications of that product in order to fulfill design requirements. Current USB Hub [3] was weighed 0.19 Lbs (85g) and dimensions of the product were 3.94 x 2.2 x 0.9 inches (L x W x H). Moreover, the team was able to measure 0.3 inches distance between the ports when the same USB Hub was provided during the class. It was relevant to measure that distance since the team was aiming to design walls that can organize the plugged in cables.

During the process of choosing the material for the USB Mounting Bracket, commonly used materials for computer equipment were researched and it was found that Polycarbonate (PC) High Viscosity Plastic [1] would be the proper material to use because of its wide application in this area, including iPhone cases.
Customer Needs:

When designing the USB Hub Bracket the EIs had to take into consideration several specifications that the products needed to include. Among these ones are the following:

- The new Hub Bracket must be designed for Additive Manufacturing.
- It needed to have a vertical mounting.
- Designed for 7-port USB Hub.
- It needed to increase the cable retention for USB and power cables.
- Reduce the number of parts for the assembly.

Taking into consideration the requirements, the EIs made a AHP (Analytical Hierarchy Process) Matrix about the final concept comparing the relevance of the features of the design. They considered safetiness, cost, durability, versatility, easiness to use, weight and vibration reduction. Two customer needs were compared at a time. If the feature in the left column is more important, value should be greater than 1. If the left column feature is less important, the value is between 0 and 1. And if the feature in the left column has the same importance, the value should be 1. For the inverse comparison, the value should be the reciprocal. The results are shown below:

<table>
<thead>
<tr>
<th></th>
<th>Safeness</th>
<th>Cost</th>
<th>Durability</th>
<th>Reduce Vib.</th>
<th>Versatility</th>
<th>Easiness to use</th>
<th>Space b/ports</th>
<th>Weight</th>
<th>Total</th>
<th>Weight</th>
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<tr>
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<td>3</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>0.2</td>
<td>0.2</td>
<td>2</td>
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<td>0.08</td>
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<tr>
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<td>1</td>
<td>0.2</td>
<td>0.4</td>
<td>1</td>
<td>0.3</td>
<td>0.2</td>
<td>3</td>
<td>6.43</td>
<td>0.06</td>
</tr>
<tr>
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<td>5</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>0.2</td>
<td>0.3</td>
<td>4</td>
<td>14</td>
<td>0.15</td>
</tr>
<tr>
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<td>2.5</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>0.2</td>
<td>1</td>
<td>5</td>
<td>13.2</td>
<td>0.13</td>
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<tr>
<td>Versatility</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
<td>0.2</td>
<td>3</td>
<td>10.2</td>
<td>0.1</td>
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<tr>
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<td>3.3</td>
<td>5</td>
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<td>1</td>
<td>1</td>
<td>0.5</td>
<td>3</td>
<td>23.18</td>
<td>0.23</td>
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<tr>
<td>Space b/ports</td>
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<tr>
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<td>1</td>
<td>6.88</td>
<td>0.06</td>
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</tbody>
</table>

As shown in Table 1, the highest ranked feature was Easiness to Use, followed by Space Between Ports and Vibration Reduction.
**Concept Generation:**

After targeting the customer needs, the team tried to establish a set of product features to facilitate the concept generation. The initial goal of the team was to maintain stabilization of USB Hubs. Therefore, the team wanted to expand this topic into subtopics that may affect this issue. As a result, AM process and type of material that has to be used for the final product was determined. Furthermore, the following flow chart encouraged the team to generate three creative concepts that could fulfill the customer needs.

![Classification Tree](image)

**Figure 1. Classification Tree.**

**Concept Development and Selection:**

During the process of designing first and final prototype, the objects that are commonly used today, guided the IEs to come up with creative ideas. The first design was inspired by a monkey wrench [4] and the idea of stabilizing plugged in USBs, shown in Figure 2. Therefore, a bracket system that can compress the USBs was
targeted. With those ideas in mind, the team came up with a design that contains two separate bodies. The body on the left imagined as a stationary part attached to the bracket. Since all thumb drives have unique shapes, the right part was imagined as an adjustable body. Moreover, the team decided to include serrated edged to both sides of the bodies in order to grab the USBs by exerting more friction force on their surface. The logic behind this design was to grip the plugged in USBs in case of vibrations that can cause disconnectivity issues.

For the next design, the monitor cables that have screwable pins inspired IEs. A bracket that can screw in USBs without causing any damage was created, as seen in Figure 3. In this concept, the goal was similar to previous design, which was to increase the stability of plugged in USBs. In this design, USB Hub was inserted into bracket either from the right or left side, however, a support for the USB Hub was missing in order to use the bracket horizontally. Considering the extra material that has to be printed and assembled, this design couldn’t get the approval of IEs. Focusing on the extra components, the team discussed for a simpler design that would require less effort to support thumb drives.
Figure 3. Screwable bracket design concept.

After discussing the design issue of the second model, it was decided that the concept of printing additional materials should be changed and a simpler design that can hold three USB Hubs should be focused. Thus, a prototype looking like a bookshelf was designed to satisfy those needs, shown in Figure 4. However, this design didn’t get the approval of the team either since it was conflicting with the goal of this project which was to create complex and lightweight structures by using less material. Still each of these designs guided IEs to give an idea about what components and features should be included in the first prototype.

Figure 4. Bookshelf design concept.
**Description of Prototype:**

In order to create the first prototype, the team tried to combine characteristics of all the other designs so that the overall design was efficient and followed the customer's needs in the best way possible. The one design that was ultimately chosen to be the basis of the prototype was the bookshelf design. It was decided that this design concept was the least flawed and can be further developed in the long run.

The team just didn’t want the design of the bracket to be limited to just one hub. The shelf idea allowed for more than one USB Hub to be place together, thus maximizing the bracket’s use to its full potential. This design can accompany more than one hub by stacking and because of this, less brackets would need to be used, providing adaptability and efficacy. Also, the design that involved the screws was implemented. But, instead of screwing in the USBs, the screws would be placed on the bottom of the final design, allowing the prototype to be able to be screwed/bolted down on any surface. This would provide an even more stable bracket for the USB Hubs. In addition, the prototype design minimized the total amount material needed, resulting in a quicker printing time of 4 hours and 21 minutes. Finally, the team decided that the bracket design should also mimic a typical iPhone case. From this decision, the material chosen for the prototype was a PC High Viscosity Plastic, which is a similar material that the iPhone cases utilize. Likewise, the design also applied the curves present in the cases. These curves allow the case to lock in the iPhone and be able to easily take out the phone whenever the user wanted. The first Prototype’s design also employed the curves on the side walls to really lock in and shelter the USB Hubs, while allowing people to easily put in or take out the hubs. The final design for the first prototype is shown below.
After the first prototype was designed on SolidWorks, a simulation was conducted using the same program to test the strength and resilience of the model. A drop test was conducted. The variable were that the dropping height was 2 meters and the constant of gravity was applied, 9.8 m/s$^2$. The results of the drop test inferred that even though the design retained its structure, it took a lot of damage, especially on the side wall and the top bar. This is shown below in Figure 7, with the prevalence of the color green in those specific areas.
Design Review:

In order to further improve upon the first prototype, the team conducted a design review. This design review was completed with the help and constructive criticism of another group (Team #8: The Outsiders). From the review, Pros and Cons were distinguished. The good things of the prototype was that it can fit more than 1 hub, it provided a safe case for the hubs, and the overall simple design aids in the hubs’ protection. However, a negative aspect of the design was that the durability of the material came into question, with some believing that the “top bar” ceiling may break off after a little wear and tear. Another con was that the bar wasn’t adjustable, so if one wanted to just put one USB hub in the bracket, the gap between the hub and the “top bar” ceiling would be too immense to provide protection. Plus, the team felt that to much amount of material was being used for the prototype. So, using less material, decrease the printing time even more. Additionally, the dimensions of the prototype were too small to fit 3 hubs all together. Thus, the overall dimensions of the prototype had to be enlarged to compensate for the hub sizes. The final con was that it was hard to see how many hubs can actually be placed in the bracket. From all of these improvements
coming from the design review, our team wanted to implement all of the amendments/upgrades for the bracket’s final design.

**Description of Final Design:**

After the concept review, The IEs considered the improvements that could be made on the first prototype. Brainstorming ideas were taken into consideration to eventually develop an improved design. *Figure 8* shows the final design for the USB Hub Mounting Bracket. Even though the first prototype fit the customer needs previously mentioned, it needed some changes to make it as adequate as possible; there is always room for improvement.

*Figure 8. Final Design USB Hub Mounting Bracket.*

However, some features of the initial designed were maintained. The overall design was the same one, it provided the same simple structure the team was pursuing with the first prototype, but it maximized the product performance. The team believes that simplicity is a key to create a successfully adequate design because it is not overwhelming to the components of the actual USB Hub but instead complements the purpose of the Mounting Bracket.
The curvature present on each of the side walls of the Bracket was conserved, this shape provides more stability to the Hubs when placed into the product. It would work similar to an iPhone case, in which the case is perfectly fitted so the phone won’t slide or move. The curvatures were made to fulfill the same purpose as the phone case. Additionally, the IEs kept the screw holes on the bottom of the design. In this way, the Mounting Bracket can be easily attached to any surface, making it easier to stay steady and also to reduce its overall movement.

In the other hand, the horizontal bar in top of the Bracket was redesigned. To increase the versatility of the product, the bar is now adjustable. It can now fit a maximum of three Hubs but it can also fit only one or two. This feature is a huge improvement considering that in the previous design, the Bracket was only worked when three Hubs were used. The Hub can be placed into the product without having to worry about its stability; the perfect fit between the top bar and the slit make the Hub to remain immobile.

Additionally, material was removed from the side walls of the Bracket, this improvement not only reduces the weight of the product, but also reduces the amount of material used; which reduces the production cost. Furthermore, the holes on the sides lower the printing time of the complete part to four hours and eight minutes. Being able to produce a piece at the lowest price and fastest time possible is a goal for every company, including Lockheed Martin. Moreover, a wall of vertical bars was added to the product. The bars will work as vibration reducer for the USB and power cables. The space provided matches the size of the average USB, making it a perfect fit. The bars will provide stability to the cables and it will increase its retention.

When comparing the original Lockheed Martin’s design [2] shown in Figure 9, with the final design by The IEs the advantages are noticeable. First, the original design was made out of metal, which is considerably heavier than plastic; specifically PC High Viscosity. As a result, the new design is not only lighter, but it is also cheaper to produce. Secondly, Lockheed Martin’s design is only efficient and functional with only two Hubs, if the number is decreased, the product fails to fulfill the expectations, while
the IEs’ design is completely functional with one or even three USB Hubs; which makes it more versatile. Moreover, the new design only possesses five parts, including the four extra screws, while the original design counts with 7 parts.

![Image](image.jpg)

*Figure 9. Notional Prototype USB Mounting Bracket*

The improvements in the design clearly provide benefits to the customer while also filling the expectations of the customer needs. Because printing the product with additive manufacturing is less expensive than producing it in an industry, it reduces the overall cost of the part, as well as the manufacturing time.

To completely test the benefits of the new design, The IEs performed a drop test on the product using the simulator available in Solid Works. The part was dropped from rest at a high of 2 meters. The bottom part was the face chosen to collide with the surface and the only force acting on it was the gravity (9.8 m/s²). The results are shown below.
As seen in Figure 10, the product had a satisfactory result. The majority of the peace had zero to minimal damage when dropped and non red areas are seen, so if the Bracket is exposed to harsh conditions it will remain firm and intact, unlike the first design that showed multiple weak stops shown previously on its own drop test. Consequently, it can be affirmed that the material used to construct the product (PC High Viscosity) is highly effective and appropriate for the design.

Considering the Bracket’s purpose, the IEs believe that the ideal technique to successfully print the design would be Material Extrusion. In this procedure a heated nozzle melts plastic filament and extrudes it onto the build tray. Additionally, it does not require much post-processing to remove the supports, it is easy to use and it is highly adaptable. Even though it does not have maximum feature size, the design of USB Hub Mounting Bracket does not own features that require optimal and extremely detailed finish.

**Conclusion:**

The final product itself is able to secure a maximum of 3 USB Hubs. Not only that but because of the adaptable horizontal bar on the top, the bracket can firmly keep 2 USB Hubs or just 1 hub. The additional back wall also provides support and retention to
the USB cables of each of the 7 ports to provide maximum security. Finally, this design utilizes less plastic in its structure, so the printing time diminishes from 4 hours and 21 minutes to 4 hours and 8 minutes. Plus, because of its simple design, the bracket does not require an extremely detailed finish when printing. The only negative aspect to the product is since it is able to fit the 3 hubs, the size might be an issue and can’t be squeezed into really tight spaces. To move on further from this final design, a possible improvement that can be made is to try and decrease the dimensions in such a way where it is thinner/sleeker and able to provide the same about of durability and security.

From this overall project, the group learned many things. One was how to handle unexpected obstacles with calm and poise. During the beginning of Design Project 2, the team initially started off with 4 members. But from unforeseen circumstances, one member quit. So, the team had to make due with 3 members and still finish all the work with as much efficiency as 4 members, which did happen. Another lesson was that the team was able to keep an open mind throughout the whole process. During the design phases, there were so many initial ideas. Due to this, there were many conflicts with the group. But, the team looked past this, found a way to get past all of the differences, and just implement the many ideas into one cohesive design. Overall, this project taught this team valuable lessons and because of this, the members are better leaders and workers that are able to adapt and function under extreme pressures, such as deadlines.
References:


