Figure 6: Mount Design 3

5 Evaluation of Design Alternatives

5.1 Feasibility of Mount Designs

To compare the three designed mount alternatives against the feasibility criteria set forth in the section above, a matrix was created. The project team considered all options and assigned each method of manufacturing a rating of pass or fail with respect to the project scope.

Table 1: Feasibility Analysis for Three Mount Designs

	Mount Feasibility Criteria		
	Technical	**Payload**	**Operational**
Design 1	Pass	Pass	Fail
Design 2	Pass	Pass	Pass
Design 3	Pass	Pass	Pass

Based on the technical, financial, and operational criteria set forth by our client, Design 1 failed for its inability to rotate separately from the rest of the robot. The remaining two designs were compared using merit criteria.

5.2 Merit Evaluation of Mount Designs

All mount merit criteria were scored on a scale of 1 to 10. Each merit criteria was deemed important, and thus were equally weighted for the calculation of total merit values.

5.2.1 Aesthetics

The two designs were evaluated based on looks. The top deck of the chassis sits nine and a half inches from the ground, and has a four-inch antenna, bringing the total height of the robot to 13.5". Attaching design 2 to the top deck will bring the total height of the robot to 14.5", allowing the camera to clear the antenna, and maintaining a compact look to the Thumper. Design 2 was awarded a score of 8.

Attaching Design 3 to the top deck off the chassis brought the total height of the robot to 20.5". This is about knee height for an average person. This height is not unreasonable, but it is noticeably higher than Design 2. An arm sitting this high off the deck begins to appear unstable and may prevent to robot from navigating narrow environments. For this reason, Design 3 was awarded a score of 4.

5.2.2 Material Density

Steel, carbon fiber, PVC and aluminum were all considered for the mount material. 4140 Steel has a density of 0.284 lb/cubic inch, carbon fiber-0.06, PVC-0.05, and 6061-0.1. Plotting these values of Figure 7, the merit scores for each material can be determined.

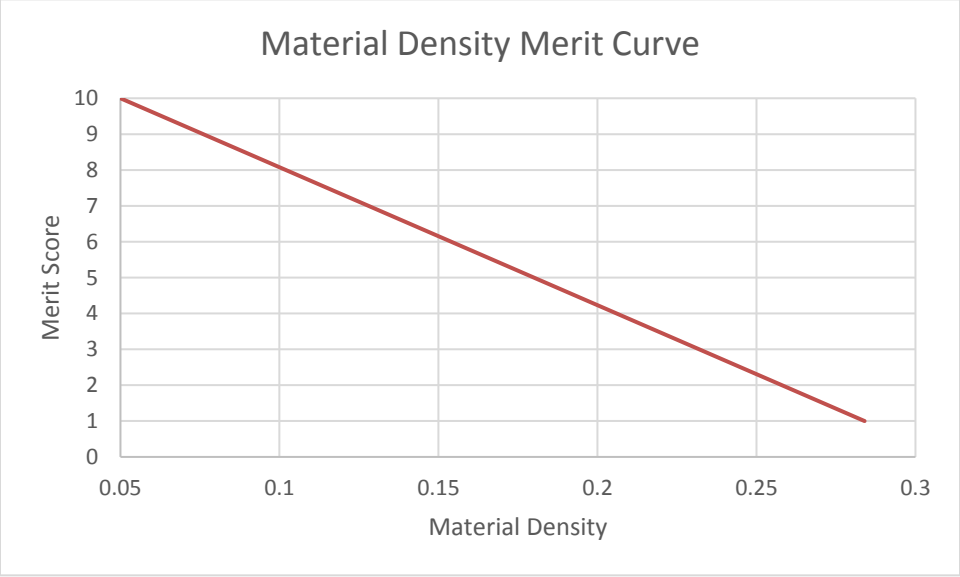

Figure 7: Material Density vs. Merit Score. The value merit score is inversely related to the density because of the weight limit for the Thumper

From the graph, the PVC scores a merit value of 10, Carbon fiber scores a merit value of 9, steel scores a merit value of 1, and aluminum scores a merit value of 8. It can be concluded that PVC is the preferred material with which to build the arm. For the rest of the merit analysis, the designs will be assumed to be constructed from PVC and both designs will be given a merit score of 10 for material density.

5.2.3 Arm Length

Arm length is important for several reasons. First, it effects the Thumper's ability to fit into confined spaces. Second, the increased lever arm also increases the moment within the cross section of the arm at the base. The arm length for Design 2 is five inches and the arm length for Design 3 is 11 inches. Figure 8 shows the merit score for arm length is inversely related to arm length because of the weight limitation of the thumper chassis and the fact that arm length is related directly to the moment cause be the force applied at the top of the arm. The arm length starts at four inches because the camera platform would be unable to rotate fully because of the antenna.

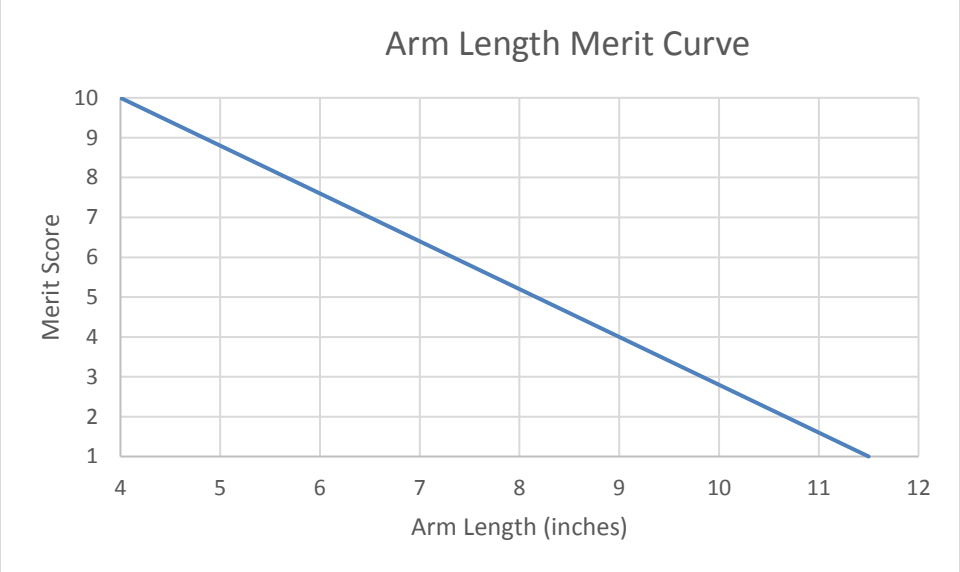

Figure 8: Merit Curve for Arm Length

Plotting the respective arm lengths on the curve, Design 2 receives a merit score of 9 and Design 3 receives a merit score of 2.

5.2.4 Ease of Attachment

Both designs have similar assembly. For this reason, their merit scores for ease of attachment will be similar. Design 3 has one extra step when it comes to attaching the camera. The cage designed to hold the camera in place requires slightly more work than the nylon strap from the other design. This causes the merit score for Design 3 to fall. Design 2 scored a merit value of 7. Design 3 scored a merit value of 6.

5.2.5 Cost

Assuming the mount arm will be constructed using PVC, the total cost of each design was calculated to determine the merit score for cost. Ideally, the mount would be constructed for free, so a perfect merit score is obtained when the cost of materials is $0. The maximum budget provided is $300, so if materials cost $300, a merit score of 1 is obtained. The cheaper design is desirable, so the merit score is inversely related to cost.

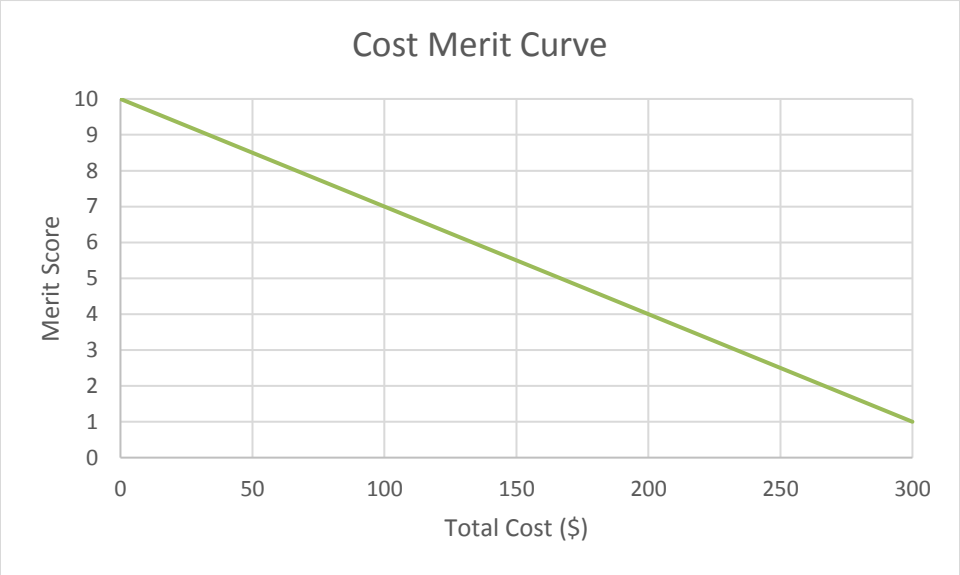

Figure 9: Cost Merit Curve

Only the cost of raw materials was assessed for this merit score. The total cost of materials for Design 2 is $115. The total cost for Design 3 is $125. Design 2 was awarded a score of 7, and Design 3 was awarded a score of 6.

5.2.6 Conclusion

Table 2: Merit Analysis for Three Mount Designs

	Mount Merit Criteria					
	Aesthetics (5%)	**Material density (35%)**	**Arm Length (30%)**	**Ease of Attachment (20%)**	**Cost (10%)**	**Total**
Design 2	8 (0.4)	10 (3.5)	9 (2.7)	7 (1.4)	7 (0.7)	8.7
Design 3	4 (0.2)	10 (3.5)	2 (0.6)	6 (1.2)	6 (0.6)	6.1

**** Merit value (Weighted value)***

Design 2 is the preferred design based on merit analysis. The length of the arm plays an important role in keeping the weight at a minimum. The increasing length of the arm also causes the aesthetics score to decrease. The material chosen for the attachment arm is PVC pipe, which will

keep the weight down and provide the necessary strength to support the ZED Stereo Camera and motor during any acceleration of the Thumper.

5.3 Feasibility of Systems

To compare the three SLAM systems against the feasibility criteria set forth in the section above, a matrix was created. The project team considered all options and assigned each SLAM system a rating of pass or fail with respect to the project scope.

Table 3: Feasibility Analysis for Three SLAM Systems

	System Feasibility Criteria		
	Technical	**Financial**	**Operational**
ZED and Jetson TX1	Pass	Pass	Pass
GMapping	Pass	Pass	Pass
eDVS	Pass	Pass	Fail

Based on the technical, financial, and operational criteria set forth by our client, eDVS was eliminated as a possible design alternate. The remaining two systems were compared using the determined merit criteria.

5.4 Merit Evaluation of Systems

Table 4: Merit Analysis for Three SLAM Systems

All merit criteria were scored on a scale of 1 to 5. The data processing rate, weight and size, and memory criteria were weighted at 30%. Cost was only weighted at 10% because the client placed emphasis on performance of the system and had little concern for the overall cost. For simplicity, the ZED Stereo Camera and Jetson TX1 is referred to as System 1 and GMapping is referred to as System 2.

5.4.1 Data Processing Rate

System 1 contains a quad-core ARM Cortex-A57 MPCore Processor that is able to run at 2.3 GHz or higher, as required by the ZED camera. System 2 includes a raspberry pi which contains a 1.2 GHz 64-bit quad-core ARM Cortex-A53 processor. The maximum merit value of 5 was awarded to System 1, and a score of 3 was awarded to System 2.

5.4.2 Weight and Size

System 1 includes the ZED Stereo Camera weighing 0.35 pounds and measuring 7 x 7 x 1 inches and the Jetson TX1 weighing 1.5 pounds and measuring 6.6 x 6.6 x 3 inches. System 2 includes the raspberry pi 3 weighing 0.1 pounds and measuring 3.4 x 2.2 x 0.8 inches and an Arduino

weighing 0.1 pounds and measuring 2.7 x 2.1 x 0.1 inches. System 2 was awarded a score of 5 while System 1 was awarded a score of 3.

5.4.3 Memory

System 1 has 4 GB of RAM, significantly higher than the 496 MB of RAM in System 2. System 1 was awarded a merit value of 5 while System 2 was awarded a value of 1.

5.4.4 Cost

The components in System 1 and their prices include the following: Jetson TX1, $599; ZED Stereo Camera, $449. The combined cost of System 1 is approximately $1,040. The components in System 2 and their respective prices include the following: Raspberry Pi 3 Model B, $40; Arduino UNO, $20; laser rangefinder, $220; motor shield, $20; compass, $20; mouse sensor, $10. The combined cost of System 2 is approximately $220. System 1 was given a merit value of 1 and System 2 was given a merit value of 5.

5.4.5 Conclusion

	System Merit Criteria				
	Data Processing Rate (30%)	**Weight/Size (30%)**	**Memory (30%)**	**Cost (10%)**	**Total**
ZED and Jetson TX1	5 (1.5)	3 (0.9)	5 (1.5)	1 (0.1)	4.0
GMapping	3 (0.9)	5 (1.5)	1 (0.3)	5 (0.5)	3.2

**** Merit value (Weighted value)***

After scoring each system according to the merit criteria, it was determined that System 1 was the preferred alternative.