Final Report

Spring 2014

Modular Accessory Attachment System

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Executive Summary

The objective of the Showers Pass Capstone Team was to design and build an accessory attachment system that reduces the long configuration time common with bicycle racks. This modular attachment system enables cyclists to quickly and easily add or remove accessories. Many cyclists use bicycles for multiple purposes, such as commuting and race training. Such variance in bicycle function requires different accessory configurations. Currently accessories are mounted in a semi-permanent fashion, and the length of time required to add or remove such accessories restricts reconfiguration. This lengthy reconfiguration time gives the avid cyclist an incentive to acquire multiple bikes, each configured for a different purpose.

The prototype design developed by the Showers Pass Capstone Team employs a quick releasing mechanism to facilitate reconfiguration with a significant reduction of install time required for a typical rear-of-bike pannier rack. This proof-of-concept design is capable of being expanded to other accessories.

Design specifications were generated through collaboration with Showers Pass CEO, Kyle Ranson. The key requirements specified were size, weight, cost, and install time. The team was to examine alternative options available on the market. This helped to refine the design areas of materials, manufacturing process, attachment types, and aesthetics.

The first prototype and testing of the modular accessory attachment system has been completed successfully. The next step is to debrief Showers Pass on the final design, and deliver all project documentation. Possible future design developments could include integrating the current attachment system to a proprietary Showers Pass rack and developing accessory mounts for a front rack, lights, and fenders.

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Introduction

Showers Pass is a Portland based company that designs and sells gear for urban bicyclists, specializing in waterproof jackets and other apparel. Recently, they have progressed into the bicycle accessory market through their innovative hydration system, the VelEau, which is shown in Fig. 1. This seat-mounted accessory provides riders with a convenient, backpack-free way to access their water supply while on the go.

Figure 1. VelEau – This hydration system was designed by Showers Pass, and is their first bicycle mounted accessory. [Ref. 1]

The company is now looking for a solution to a major shortfall within the bicycle accessory market. In the current market, accessories such as pannier racks, fenders, and seat bags are very labor intensive to install or uninstall. Avid bicyclists often perform multiple activities on their bikes, such as commute, race, tour, and pleasure ride. The current best method for the avid cyclist to participate in these activities is to collect multiple bikes to support multiple configurations.

The scope of this project was to design and develop a quick-release mechanism which would enable a cyclist to quickly employ multiple configurations on a single bicycle for multiple activities. Showers Pass has expressed desire in market viability; therefore design focus was on low weight, high strength, carbon bike frame compatibility, aesthetics and cost. Under these constraints a detailed design was created. Multiple iterations of prototypes were made. The final prototypes were tested versus the initial design specifications, producing satisfactory results.

Mission Statement

The Showers Pass Capstone Team will design and prototype the Modular Accessory Attachment System (MAAS). This system will enable a cyclist to quickly and efficiently attach and detach a rear pannier rack. In addition to a rack, MAAS will be capable of supporting other accessories such as fenders, seat bags, and lights. The team will document each step of the project, and provide periodic progress reports. A final summary will be issued to Showers Pass in June of 2014, including specifications, analysis, drawings, testing data, bill of materials, production schedule, and cost analysis.

Product Design Specification

The Product Design Specifications (PDS) were developed in collaboration with Showers Pass during interviews in January 2014. These requirements were divided into primary and secondary functions. The primary functions of the design were to allow the mounting of a standard pannier rack to any bicycle regardless of frame eyelets, while employing a quick disconnect mechanism. The secondary functions are to provide compatibility with other accessories such as fenders and possible integration into a propriety rack.

Major constraints requested by the customer are as follows. A complete list is located in Appendix A.

Cost: The retail price is not to exceed $80 for an integrated rack, $40 for the quick disconnect system, and production cost not to exceed 25% of the retail price.

Performance: Safely load two side mounting panniers with a combined weight of 40 lbs. in all weather conditions.

Aesthetics/Weight: When not in use, attachment points on frame are to be of low profile and add minimal weight.

Top Level Design Considerations

The requirements presented in the PDS directed the scope of potential solutions. Primary concerns centered on the ability of the system to be easily removed from the bicycle, while maintaining carrying capabilities when attached. External and Internal search documentation, outlined in Appendices C & D, produced several concepts for fasteners that could be utilized in the desired application. A concept scoring matrix, as seen in Appendix C, was used to narrow the design considerations to best satisfy the PDS requirements. The design considerations can be broken into three separate sections; the bike to connection interface, the quick-release connection interface, and the connection to accessory interface.

The bike-to-connection interface focused on the issue that no two bike models are exactly alike in mounting positioning. Fortunately, the rear of most bicycles have three structures that are constant from model to model. These structures are the wheel to frame interface at the axle, the brake mounting bolt, and the seat post. The seat post is a poor choice as there is potential for damage or failure from clamping forces on carbon fiber seat posts. This led to the remaining two locations for the connection interface.

The quick-release connection interface is the most important design requirement. The style of the connection desired would be highly intuitive, aesthetically pleasing, and offer a level of security comparable with semi permanently mounted accessories. The use of the quick release type fasteners present on bicycle skewers and seat posts were good candidates.

The connection-to-accessory interface focused on proper alignment at the quick-connect location. Bolts could be used in a fashion similar to traditional accessory mounting in the presence of eyelets between the system and the accessories. The angle from the accessory to the system was considered due to the geometry of the frame which has clearance issues from a cyclist's heel during pedaling.

Final Design

The final design uses two different types of connections. At the bottom, on either side of the bicycle's skewer, there is a passive mechanical lock that the rack fits in to. At the top, the upper mount consists of an active locking mechanism. Figures 2 – 5 below show a 3D-printed ABS plastic prototype that was created as a proof of concept.

To install, the tabs attached to the rack, shown in Fig. 2, are inserted into the slots in the lower mount, shown in Fig. 3, at an angle, and then rotated towards the front of the bike. As the rack is rotated forward, the passive lock on the bottom of the rack is engaged, and then the upper attachment point on the rack aligns with its mate on the bike frame. This secures the lower attachment and locks the top in place, as shown in Fig. 4. Figure 5 below shows the rear bike rack in its installed position.

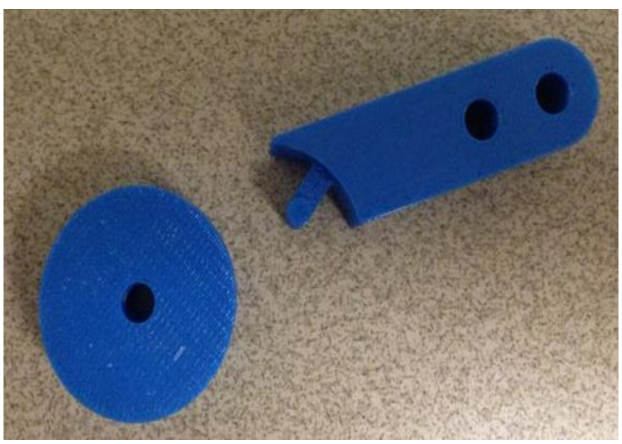


Figure 2: Main Components of the Lower mount. The circular part (left) installs on the skewer, and the part on the right attaches to the rack. The male post from the rack locks into the channel on the skewer mount, and rotates to lock into place.

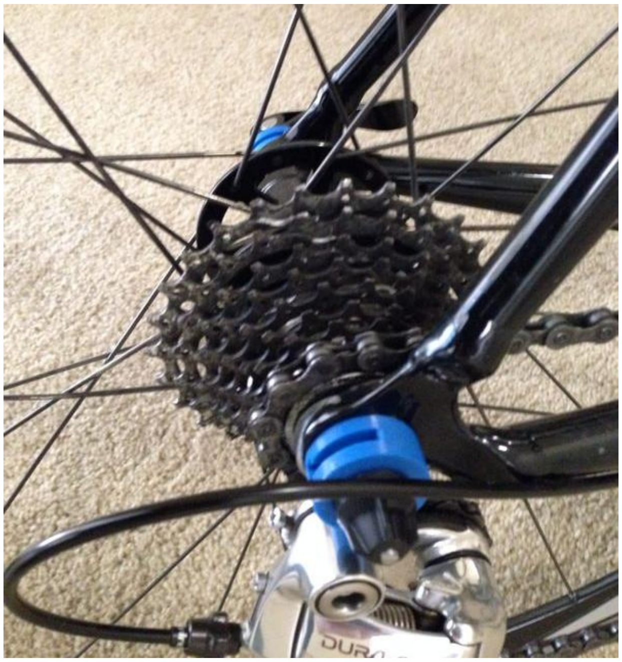


Figure 3: Close-up of lower mounting points. These mounting points install on the bike's rear quick-release skewer. The round "donut" remains on the bike when the rack is not installed. It contains a channel in which tabs from lower mate lock into when installed. This part of the system uses a passive lock.

Figure 4: Close-up of the upper mounting point. This mounting point shares the brake bolt mounting hole. The male post remains on the bike when the rack is not installed. This upper mount uses an active lock. When the rack is moved into its installed position, the collar slips onto the post, and the user tightens the collar to secure the rack.

Figure 5: Bike Rack installed. When the rack is installed, it is constrained from moving in all directions. The rack sits in a traditional position, and can support panniers and other accessories. The bottom mounts are angled away from the rider to maximize heel clearance when riding.

Evaluations

The final design meets all of the major PDS requirements. It was evaluated for compliance specifically in the areas of cost, weight added to the bike, time to install, and load carrying capacity.

Cost: Price quotes were obtained from a rapid-prototyping facility, based on the solid models of the parts. The detailed price breakdown can be seen in Appendix F. The original requirement was that the finished product cost no more than $20. If the pieces are injection molded, they only cost $6 per unit to manufacture. If the pieces are made of machined aluminum, they cost about $100 each. The upper collar is an off-the-shelf part found online, which cost $8 each. The total cost to prototype this system comes to between $14 and $108. The facility that the quote came from is in the United States, and not set up for high-volume production. If Showers Pass were to have the parts manufactured overseas, the cost could reduce significantly.

Weight of the System: The system was to weigh no more than 100 grams. As seen in Appendix H, the predicted total weight of the system is 124 grams. While the weight of the entire system exceeds the PDS requirement, the weight remaining on the bike when the rack is uninstalled is less than the requirement at 59 grams.

Time to Install / Uninstall: The PDS required the rack to be installed or uninstalled in less than 5 minutes. The real system far exceeds this requirement, and can be installed or uninstalled in less than 30 seconds, with no tools.

Weight Capacity: The system was required to carry a bike rack loaded with 40 pounds, with a factor of safety of 1.5. A Finite Element Analysis was completed on the weakest component, which can be seen in Appendix G. The minimum factor of safety of the final design when manufactured of Aluminum was 12. The part therefore exceeds the PDS requirement for weight capacity.

Future Design Considerations

A prototype of the final design was selected and constructed to demonstrate proof of concept and meet PDS requirements. The following sections describe further design considerations needed to manufacture the system for retail sale.

Material Selection

The prototype was generated via a 3D printer with ABS plastic as the material used, which would allow deflection and yielding under low loading conditions. To meet the PDS requirements for loading and cycles, a stainless steel or aluminum alloy coated to prevent oxidation should be used.

Elimination of Stress Concentrations

The design used for final selection suffers from stress concentrations at the locations shown in Appendix G. Further refinement could reduce stress concentrations in the upper bike to attachment point and lower attachment interface. This could be accomplished through the use of fillets and/or material reinforcement.

Cost of Production Reduction

Currently the upper attachment interface utilizes an off the shelf part used in shaft collar machining processes. The tight tolerances required for such operations are not needed for the current application; therefor costs are greater than necessary. Alternate sources or dedicated parts at high enough volume could increase profit margins. Current design strives to reduce complicated machining processes that would drive up production costs.

Accessory Integration/Expansion of Application

To provide a seamless user experience proprietary accessories could be designed with attachment interface points incorporated. Additionally the design could be applied to accessories for the front wheel.

Conclusion

The Modular Accessory Attachment System designed by the Showers Pass capstone team fulfills all major requirements set by the product design specifications. The quick attach system withstands loading requirements, is lightweight, low profile, and low cost. The final prototype developed in conjunction with the detailed design analysis proves the concept is feasible. To continue this product to market, an experimental testing fixture would be required to assess longevity and reliability during normal use across varying environmental conditions. Additional solid modeling work would be needed if Showers Pass planned to incorporate this design into a proprietary rack system.

References

[1] VelEau Hydration System

http://www.showerspass.com/catalog/accessories/veleau-42

[2] Quick Disconnect Attachment Systems

http://www.mcmaster.com/

[3] Skewer Mounted Pannier Rack

http://www.cyclebasket.com/m5b0s144p2367/BLACKBURN_EX1_Disc_Compatible_Pannier_Rack_

[4] Quick Disconnect Fenders

http://www.excelcycle.com/planet-bike-speedez-700c-narrrow-quick-on-fenders.html

[5] Arkel Seatpost Mounted Rack

http://www.adventurecycling.org/cyclosource-store/equipment/sp/arkel-randonneur-rack

Appendix A – Product Design Specification

Listed Below is the Product Design Specification developed with the help of Showers Pass. The customer has express that the priority of each specification be equally important. Table A1 demonstrates the detailed engineering criteria including the weighted totals.

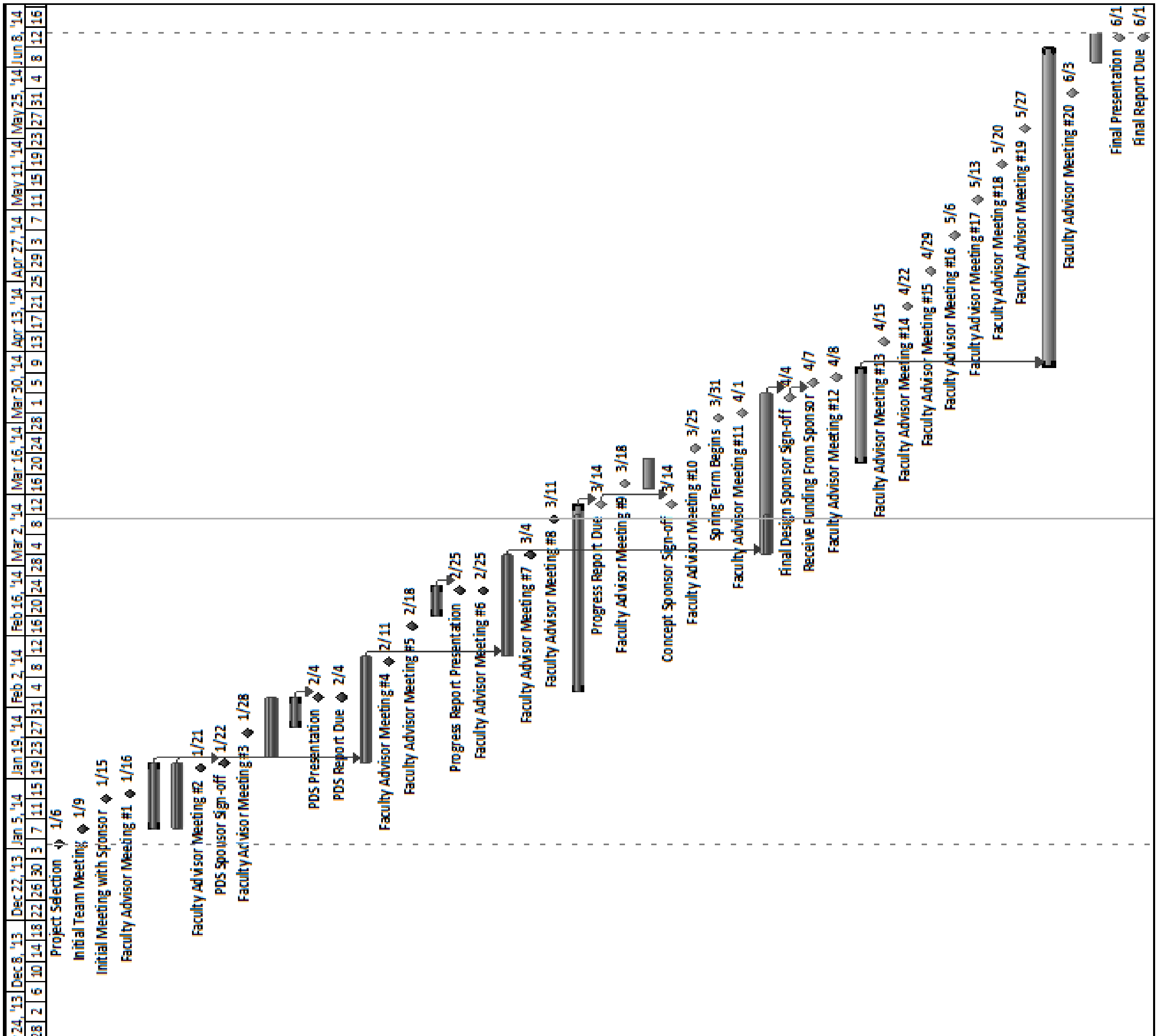
Table A1: Highest Priority PDS Requirements

Priority [1-5]	Requirement	Customer	Metric	Target	Target Basis	Verification
Performance						
5	Support two loaded panniers	Showers Pass	Weight [lbs.]	40 lbs.	Weight of two loaded panniers	Testing
5	Attach to carbon bikes	Showers Pass	Yes / No	Yes	Showers Pass Requirement	Prototyping
5	Attach to bikes without eyelets	Showers Pass	Yes / No	Yes	Showers Pass Requirement	Prototyping
Environment						
5	Withstand all weather conditions	Showers Pass	Yes / No	Yes	Weather in Portland	Testing
Costs						
5	Production cost	Showers Pass	Money [dollars ($)]	1/4 Retail Cost	Room for profit	Prototyping
Size/Shape/Weight						
5	Minimal size	Showers Pass	Attachment size [in^3]	3	1 in^3 per mounting point	Design
Safety						
5	Structural integrity	Showers Pass	FOS	1.5	Max loading of competitor's racks	Testing

Table A2: Product Requirements, & Influential Engineering Criteria

Priority	Requirement	Customer	Metric	Target	Target Basis	Verification
Performance						
5	Support two loaded panniers	Showers Pass	Weight [lbs.]	40 lbs.	Weight of two loaded panniers	Testing
5	Attach to carbon frame bikes	Showers Pass	Yes / No	Yes	Showers Pass Requirement	Prototyping
5	Attach to bikes without eyelets	Showers Pass	Yes / No	Yes	Showers Pass Requirement	Prototyping
Environment						
5	Withstand all weather conditions	Showers Pass	Yes / No	Yes	Weather in Portland	Testing
3	Life in service	Showers Pass	Time [years]	5 years	Industry standard	Testing
Maintenance						
3	Replacement Parts	Showers Pass	Yes / No	Yes	Avoid repurchasing entire system	Prototyping
Costs						
3	Retail cost	Showers Pass	Money [dollars ($)]	≈ $50.00	Approximate cost of popular racks	Prototyping
5	Production cost	Showers Pass	Money [dollars ($)]	1/4 Retail Cost	Room for profit	Prototyping
Size/Shape/Weight						
3	Minimal size	Showers Pass	Attachment size [in^3]	3 in^3	1 in^3 per mounting point	Design
3	Low weight	Showers Pass	Weight [grams]	<100 grams	Ability to leave on bike	Design
2	Minimal shipping costs	Showers Pass	Packaging size	Padded envelope	Minimize cost to end-user	Prototyping
Ergonomics/Ease of Use						
3	Set-up time	Showers Pass	Time [min.]	<30 min.	Length of time for initial installation	Prototyping
2	Tools needed	Showers Pass	-	Common Tools	Avoid specialty tools purchases	Prototyping
4	Quick Connect/Disconnect	Showers Pass	Time [min.]	<5 min.	Length of time to attach two panniers	Prototyping
Manufacturing & Materials						
2	Readily available parts/materials	Showers Pass	Time for Arrival	3-5 days	Length of ground shipping times	Design
3	Manufacturing at PSU	Showers Pass	Yes / No	Yes	Minimal prototyping costs	Design
3	Quantity needed	Showers Pass	-	1 prototype	Proof of concept	Prototyping
Compatibility / Standards						
3	Compatible with multiple racks	Showers Pass	Yes / No	Yes	Maximize product market	Design
Safety						
5	Structural integrity	Showers Pass	FOS	1.5	Max loading of competitor's racks	Testing
Documentation						
5	PDS	Dr. Sung Yi	Deadline	2/4/2014	Due Date	Grade
5	Progress Report	Dr. Sung Yi	Deadline	3/13/2014	Due Date	Grade
5	Final Report	Dr. Sung Yi	Deadline	6/9/14	Due Date	Grade

Appendix B – Detailed Project Schedule

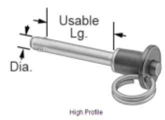
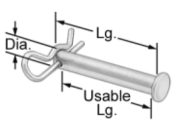
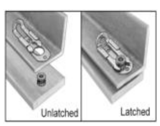
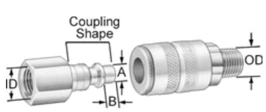
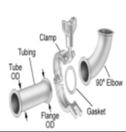


ID	Task Name	Start
1	Project Selection	Mon 1/6/14
2	Initial Team Meeting	Thu 1/9/14
3	Initial Meeting with Sponsor	Wed 1/15/14
4	Faculty Advisor Meeting #1	Thu 1/16/14
5	Define Product Design Specifications	Thu 1/9/14
6	External Search	Thu 1/9/14
7	Faculty Advisor Meeting #2	Tue 1/21/14
8	PDS Sponsor Sign-off	Wed 1/22/14
9	Faculty Advisor Meeting #3	Tue 1/28/14
10	Write PDS Report	Thu 1/23/14
11	Prepare for PDS Presentation	Wed 1/29/14
12	PDS Presentation	Tue 2/4/14
13	PDS Report Due	Tue 2/4/14
14	Internal search (Brainstorming)	Wed 1/22/14
15	Faculty Advisor Meeting #4	Tue 2/11/14
16	Faculty Advisor Meeting #5	Tue 2/18/14
17	Prepare for Progress Report Presentation	Thu 2/20/14
18	Progress Report Presentation	Tue 2/25/14
19	Faculty Advisor Meeting #6	Tue 2/25/14
20	Concept Evaluation/Selection	Wed 2/12/14
21	Faculty Advisor Meeting #7	Tue 3/4/14
22	Faculty Advisor Meeting #8	Tue 3/11/14
23	Write Winter Term Progress Report	Wed 2/5/14
24	Progress Report Due	Fri 3/14/14
25	Faculty Advisor Meeting #9	Tue 3/18/14
26	Finals Week (Winter)	Mon 3/17/14
27	Concept Sponsor Sign-off	Fri 3/14/14
28	Faculty Advisor Meeting #10	Tue 3/25/14
29	Spring Term Begins	Mon 3/31/14
30	Faculty Advisor Meeting #11	Tue 4/1/14
31	Detail Design	Tue 3/4/14
32	Final Design Sponsor Sign-off	Fri 4/4/14
33	Receive Funding From Sponsor	Mon 4/7/14
34	Faculty Advisor Meeting #12	Tue 4/8/14
35	Finalize Design BOM	Sat 3/22/14
36	Faculty Advisor Meeting #13	Tue 4/15/14
37	Faculty Advisor Meeting #14	Tue 4/22/14
38	Faculty Advisor Meeting #15	Tue 4/29/14
39	Faculty Advisor Meeting #16	Tue 5/6/14
40	Faculty Advisor Meeting #17	Tue 5/13/14
41	Faculty Advisor Meeting #18	Tue 5/20/14
42	Faculty Advisor Meeting #19	Tue 5/27/14
43	Prototyping and Testing	Thu 4/10/14
44	Faculty Advisor Meeting #20	Tue 6/3/14
45	Finals Week (Spring)	Mon 6/9/14
46	Final Presentation	Sat 6/14/14
47	Final Report Due	Sat 6/14/14

Appendix C - Internal Search

The objective of this analysis was to determine if any pre-existing quick attachment mechanisms could be utilized within the design. Table C1 shows the ranking of six market options with respect to five design considerations. Each design was rated based on vibrational sensitivity, cost, ease of use, strength, and resistance to dirt and grime.

Table C1: Design Matrix – Based on the total, the ranking in order of best design options are the ball lock, pipe clamp and slide lock. [Ref. 3 & 5]

Visual	Connector Type	Cost [1 - 5]	Vibrational Sensitivity [1 - 10]	Ease of Use [1 - 10]	Load Bearing [1 - 3]	Environmental Durability [1 - 2]	Total [30]
	Push Pin	4	2	6	3	2	**17**
	Cotter Pin	5	2	3	3	1	**14**
	Slide Lock	2	6	8	2	2	**20**
	Rubber Latch	1	10	1	1	1	**14**
	Ball Lock	3	8	8	3	1	**23**
	Pipe Clamp	3	8	6	3	2	**22**

Appendix D - External Search

The purpose of the external search was to explore, identify and examine existing products that relate to MAAS. There is a significant market specific to bicycle accessory options, however, there are no products that satisfy the PDS requirements of a quick, universal attachment mechanism. The absence of products like MAAS demonstrates that this design is a needed innovation towards increasing bicycle functionality.

Related Technologies

Some accessory manufacturers have begun to incorporate easy attachment into their designs. The following figures are a sample of currently available bicycle accessories that employ "easy attachment" designs.

Figure D1. Skewer Mounted Rack – This design utilizes the rear skewer as a loading point and is for use on bicycles that do not have eyelets. It is relatively easy to use, but requires time, and removal of the rear wheel to dissemble. [Ref. 2]

Figure D2. Fender – Current market option for quick disconnect fenders on bicycles without eyelets or where weight of fender accessory is a concern. This mechanism will not withstand repetitive use, or excessive loading. [Ref. 3]

Figure D3. Seatpost Rack – An alternative to the traditional eyelet mounted rack. However, the design is not universal for other accessories, carries significantly less load than a traditional rack, and is not compatible with panniers [Ref. 4]

Appendix E - Design Evaluation and Concept Selection

After researching existing latching mechanisms, three concepts were chosen to meet the PDS requirements. The design metrics used for evaluating the designs can be found in the PDS criteria. The slide lock, ball lock, and pipe clamp were identified as viable design choices.

The first critical implementation issue was to define the location of the mounting points on the bike frame. Some bicycles have eyelets to facilitate mounting accessories, but MAAS must work without them. It was desired to use a triangulation loading method which will lead to increased stability. Two of the three points were to be located at the ends of the rear wheel's quick-release skewer. Figure E1 shows the collar mounting bracket with one half of the quick-release mechanism attached to the skewer. This mounting point was to remain on the frame when the attachment system is not in use. Figure E2 shows the final design for the skewer mount that was chosen to be prototyped.

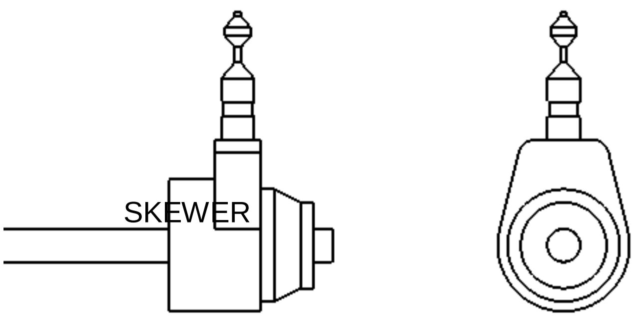


Figure E1. Skewer Mounts Initial Design – Skewer add-on to employ the MAAS system. The component is a bracket that collars the original skewer shaft with a quick attach point ready for mating to the desired bicycle accessory. This design meets most of our specs, and the basic concept of mounting to the skewer was carried through to the final design.

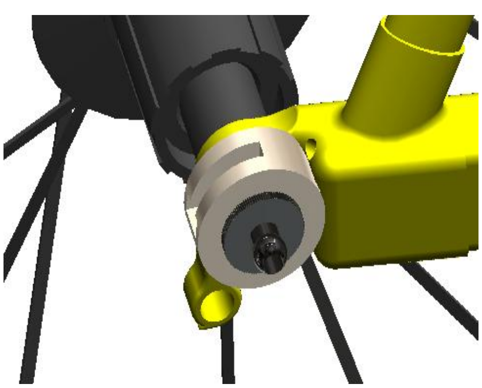


Figure E2. Skewer Mounts Final Design–The final design is also a collar that installs on the skewer. The latching mechanism has been modified, switching from an active lock to a passive lock. Also, the male end of the lock was relocated to the rack side. The skewer mount now contains a channel instead of a post, and is significantly more low profile.

The third mounting point was to be attached to either the seat post or share the rear brake bolt. Current market rack implementations have used these two locations with success. A preliminary design, which utilizes the seat post as a mount, is shown in Fig. E3. Figure E4 shows the final design, which is installed on the rear brake bolt.

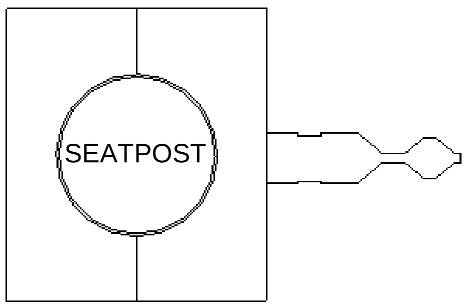


Figure E3: Seat Post Mount – The first design utilized the seat post for the upper mounting location for MAAS. The quick mount system would achieve stability through a third point by utilizing the strength of the seat post through a tube bracket.

Figure E4: Final Upper Mount Design – The final design shares the brake mounting hole. This location was chosen because some seat posts are made of carbon fiber. This material does not do well with clamping forces, and can easily fail with this type of loading. Every bike frame has the upper brake bolt, and it is a much safer spot to carry additional load.
A female quick-connect collar is attached to the rack, and a male "pigtail" attaches to the bike frame.

Appendix F - Cost: Prototype Production Quote

The next steps are to have a small batch of prototypes produced for testing. ProtoLabs (www.firstcut.com), a US rapid prototype company was consulted for production costs. CNC machined aluminum and injection molded plastic were examined as possible options. The major breakdown of the costs quoted by Proto Labs can be examined below in Table F1. A sample cost selection from the manufactures website located in Figure F1.

Table F1: The price breakdown for prototyping the design, using either injection molded plastic or CNC machined aluminum. A manufacturing facility set up for mass production would be able to make these at a significantly reduced cost.

Injection Mold						
Lower Male						
Lot Size		Cost Each	Subtotal	Tooling	Total	Each
1 to	1000	$ 2.82	$ 2,820	$ 1,610	$ 4,430	$ 4.43
1000 to	5000	$ 2.82	$ 14,100	$ 1,610	$ 15,710	$ 3.14
Lower Female						
Lot Size		Cost Each	Subtotal	Tooling	Total	Each
1 to	1000	$ 2.27	$ 2,270	$ 3,405	$ 5,675	$ 5.68
1000 to	5000	$ 2.27	$ 11,350	$ 3,405	$ 14,755	$ 2.95
CNC Aluminum						
Lower Male						
Lot Size		Each	Total			
	1	$ 82.00	$ 82			
	10	$ 41.00	$ 410			
	100	$ 35.00	$ 3,500			
Lower Female						
Lot Size		Each	Total			
	1	$ 131.00	$ 131			
	10	$ 76.00	$ 760			
	100	$ 69.00	$ 6,900			

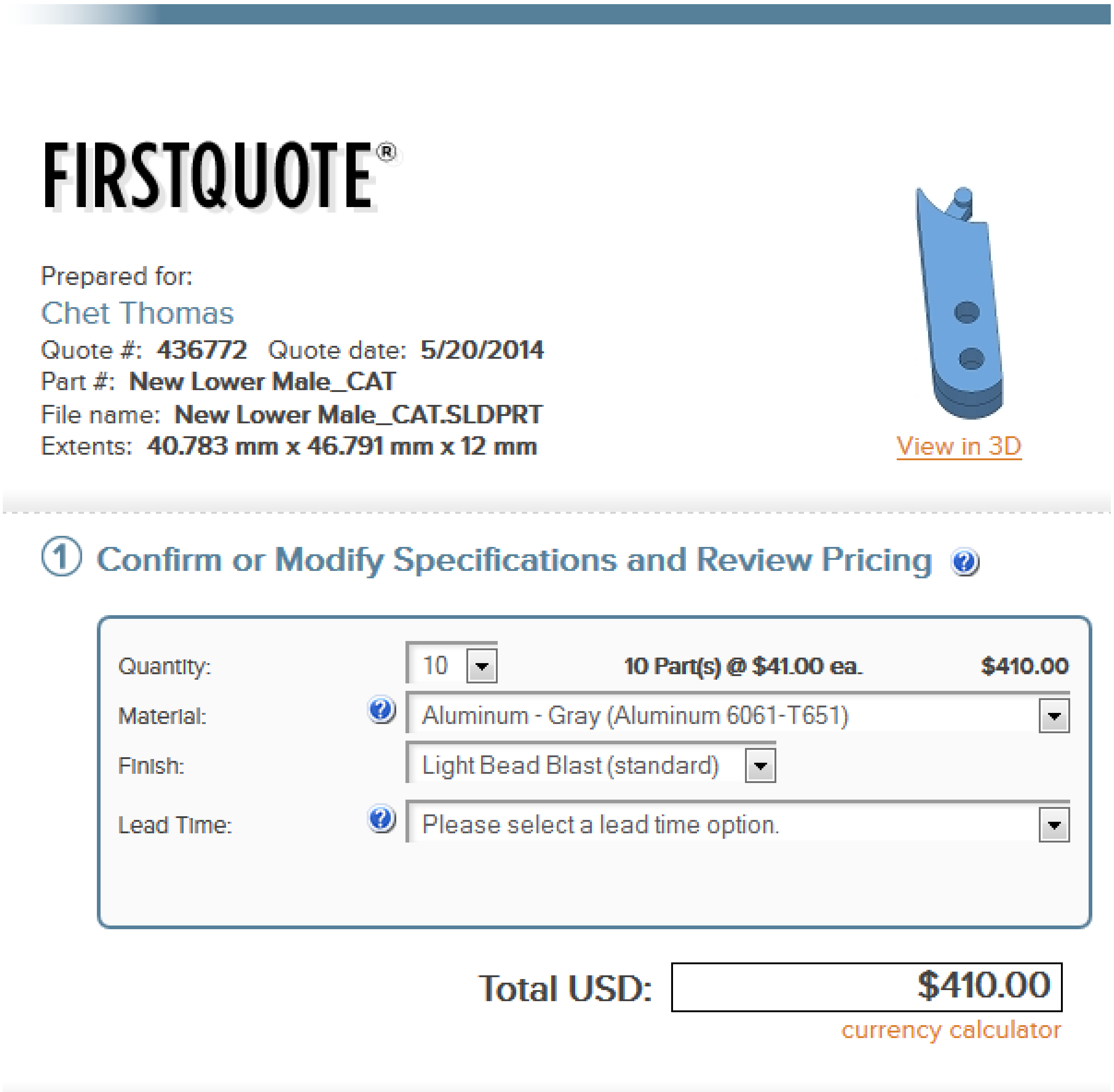


Figure F1: A screen capture of the ordering process complements of First Quote.

Appendix G – Lower Attachment Point Stress Analysis

Summary

The objective of this analysis is to validate the designed geometry, and whether or not it is capable of withstanding the 40 pound load (20 pounds per side) as required by the product design specifications.

Figure G1 – The entire bicycle and rack assembly. The piece which is to be analyzed is shown in blue.

Figure G2 – A close-up image of the part to be analyzed, and it's orientation in the total assembly.

The result of this analysis determines that the part is capable of withstanding the 20 pounds as required by the PDS, and does so with a minimum factor of safety of 12.

Formulation

The model represents the scenario in which the 20 pounds is oriented vertically downward, causing a moment reaction on the force, pivoting about its lower corner.

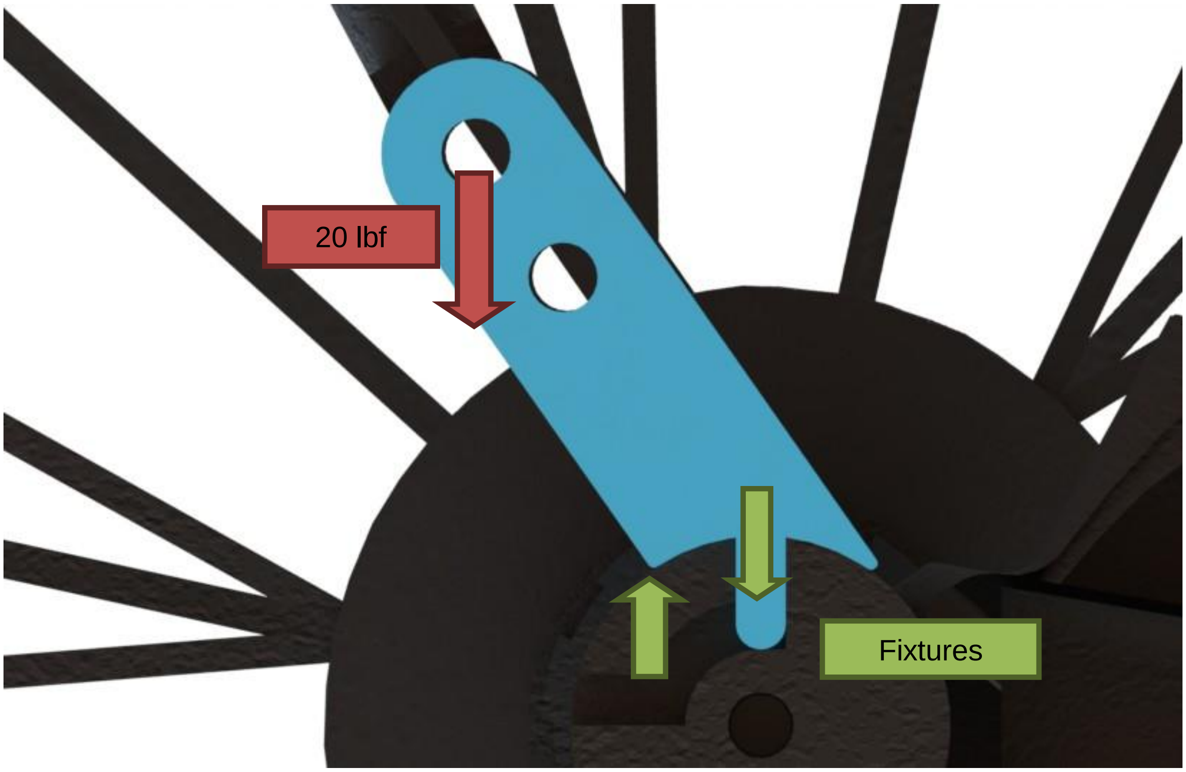


Figure G3 – Loads and fixtures and their application for the component being analyzed.

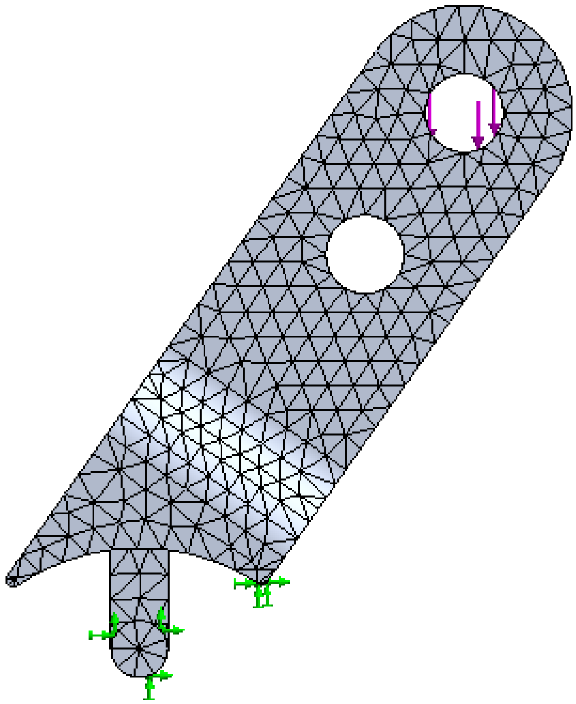


Figure G4 – The component being meshed, with fixtures and loads applied in Solidworks Simulation

Solution

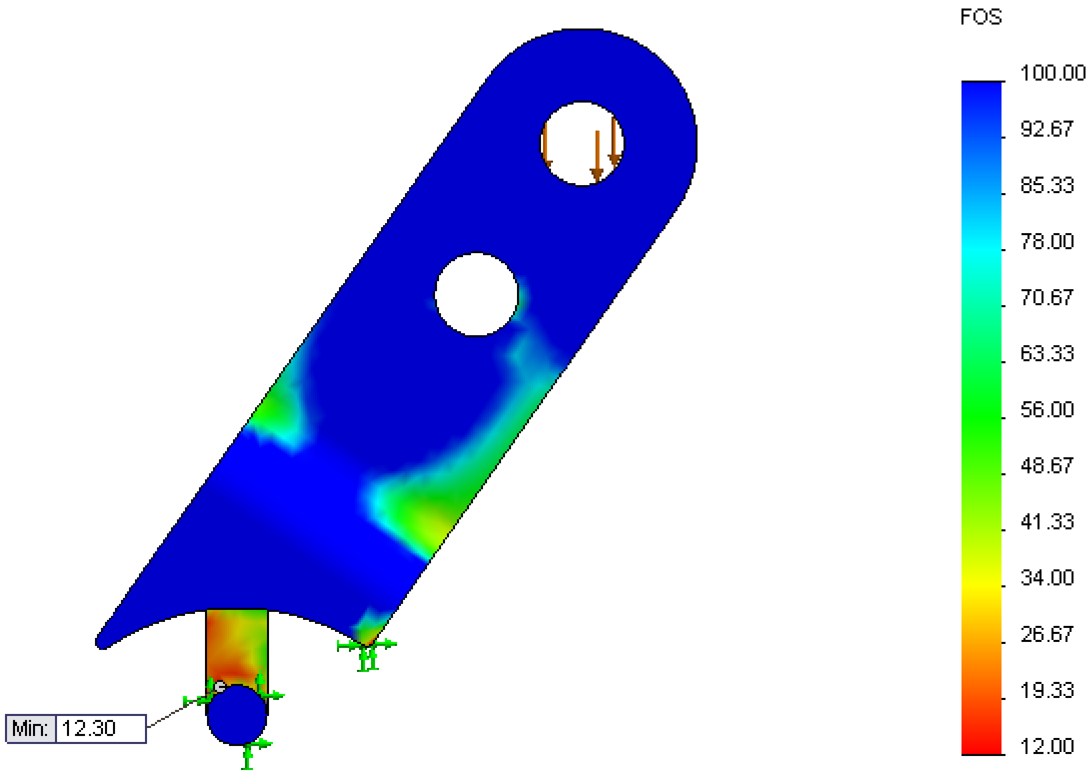


Figure G5 – Factor of Safety plot for the component. The minimum FOS is 12.30, with an applied load of 20 pounds.

Conclusion

The minimum factor of safety of 12.30 for the component with an applied force of 20 pounds computes to a maximum allowable force on the rack before failure of the attachment points of 492 pounds. There is not a rack currently available on the market which is capable of withstanding that amount of force.

Appendix H – Weight & Volume Analysis

Summary

The objective of this analysis is to calculate the weight and volume of the designed attachment points. The attachments can be classified into two separate categories; those left on the bike when not in use, and those removed from the bike when not in use.

Figure H6 – All of the attachment points. Those dark in color are left on the bike when not in use, and the lighter components are attached to the accessory and therefore removed from the bike when not in use.

The result of this analysis determines that the total weight of all components is 124 grams. This is 24 grams above the target weight assigned in the product design specification. The components have a total volume of 2.79 cubic inches, which is less than the target of 3.0 cubic inches maximum.

The total weight of the attachments left on the bike when not in use is 60 grams, therefore 64 grams of weight are removed with the accessory when the attachments are not in use. In addition, the components left on the bike when not in use have a total volume of 1.33 cubic inches, and 1.45 cubic inches are removed with the accessory.

Formulation

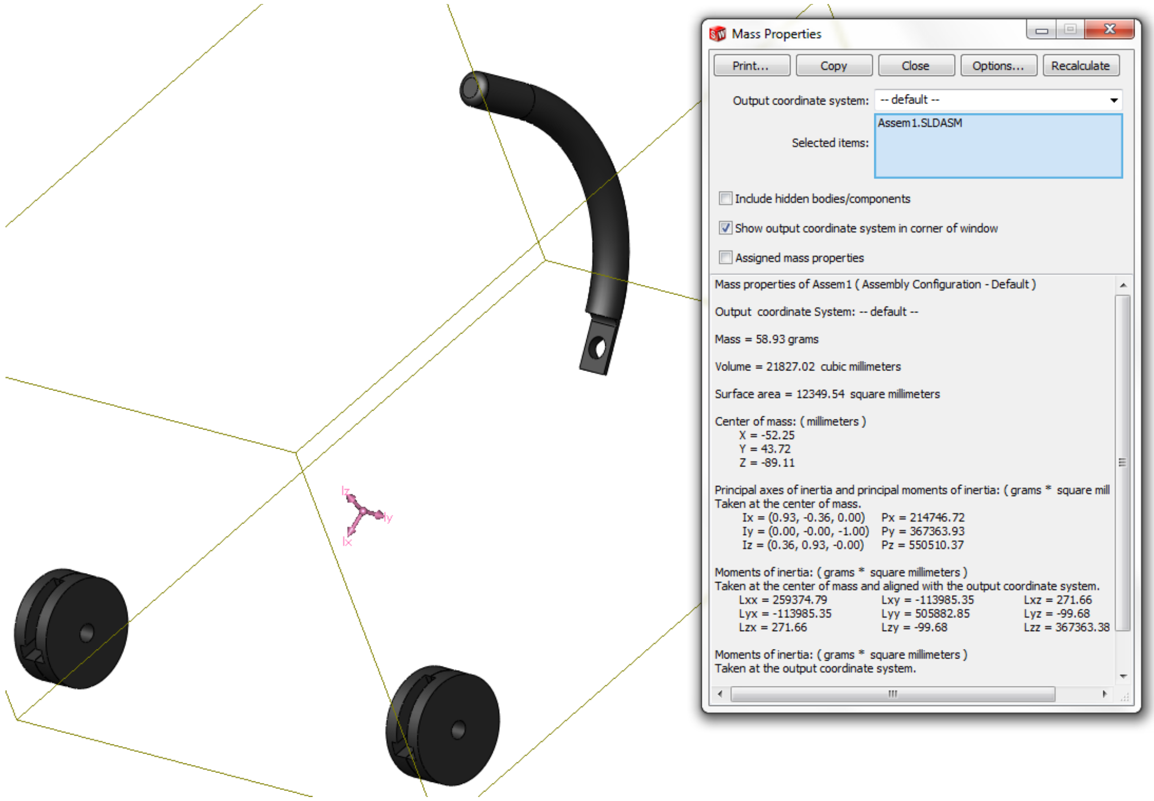


Figure H7 – Parts left on the bike when not in use. Mass = 58.93 grams, Volume = 1.33 cubic inches.

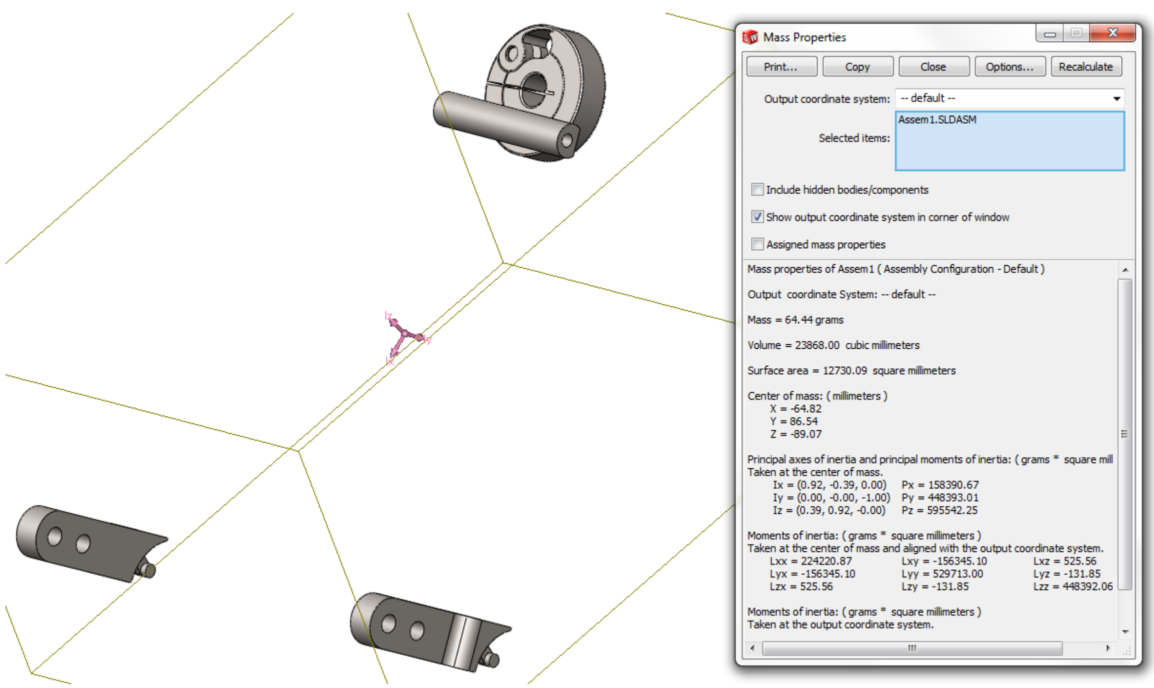
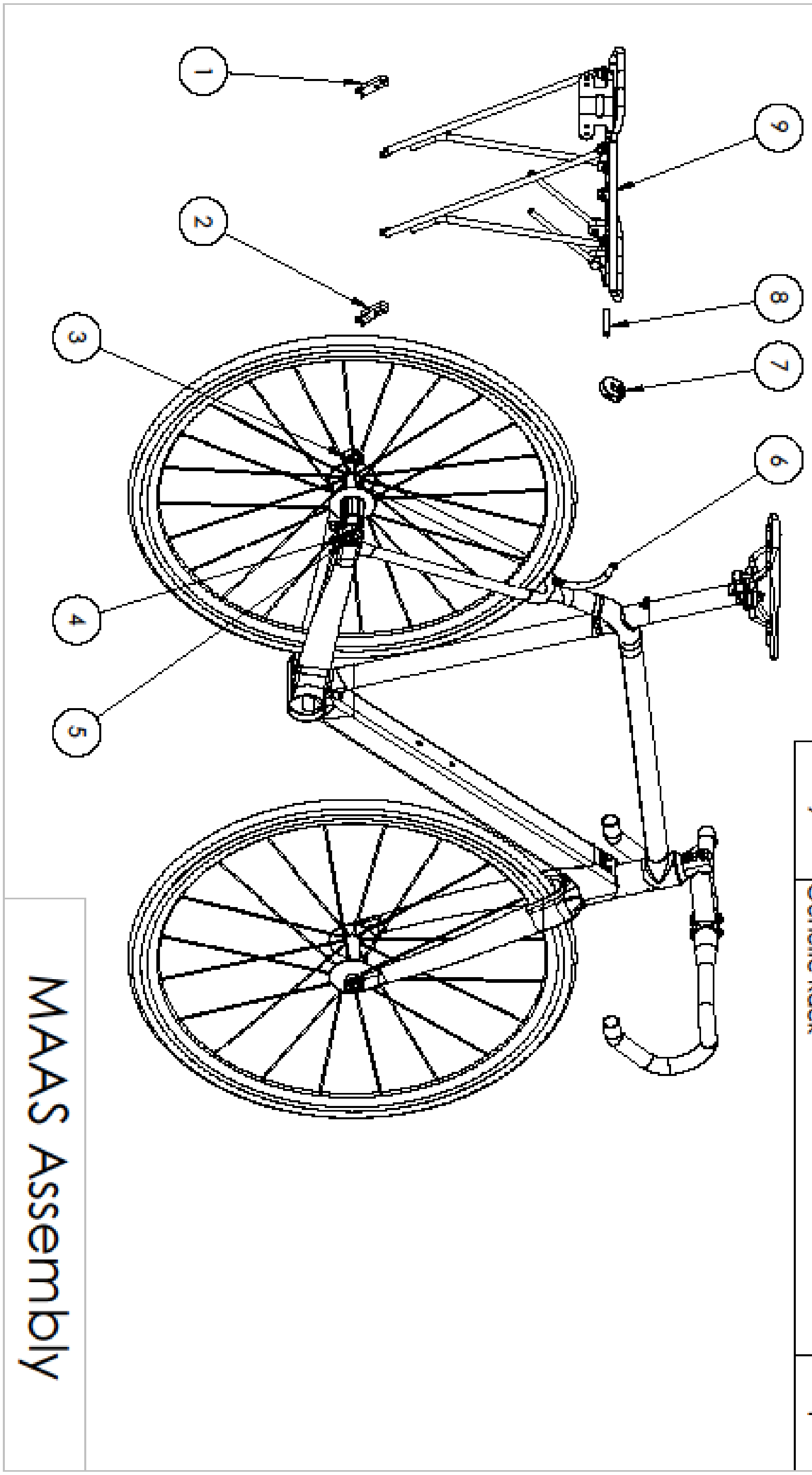
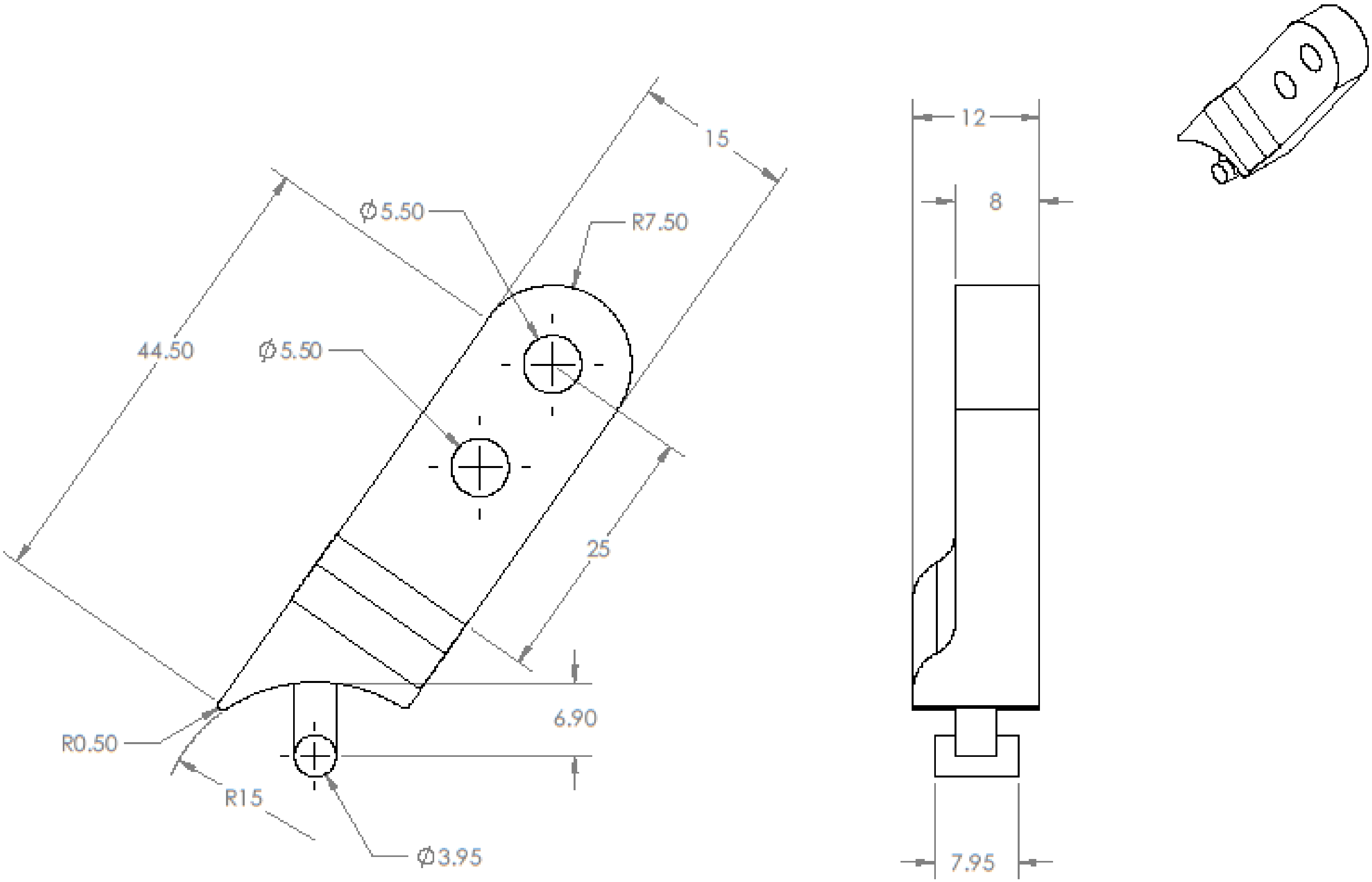


Figure H8 – Parts removed from the bike when not in use. Mass = 64.44 grams, Volume = 1.45 cubic inches.

Appendix I – Detailed Assembly Drawings & Bill of Materials

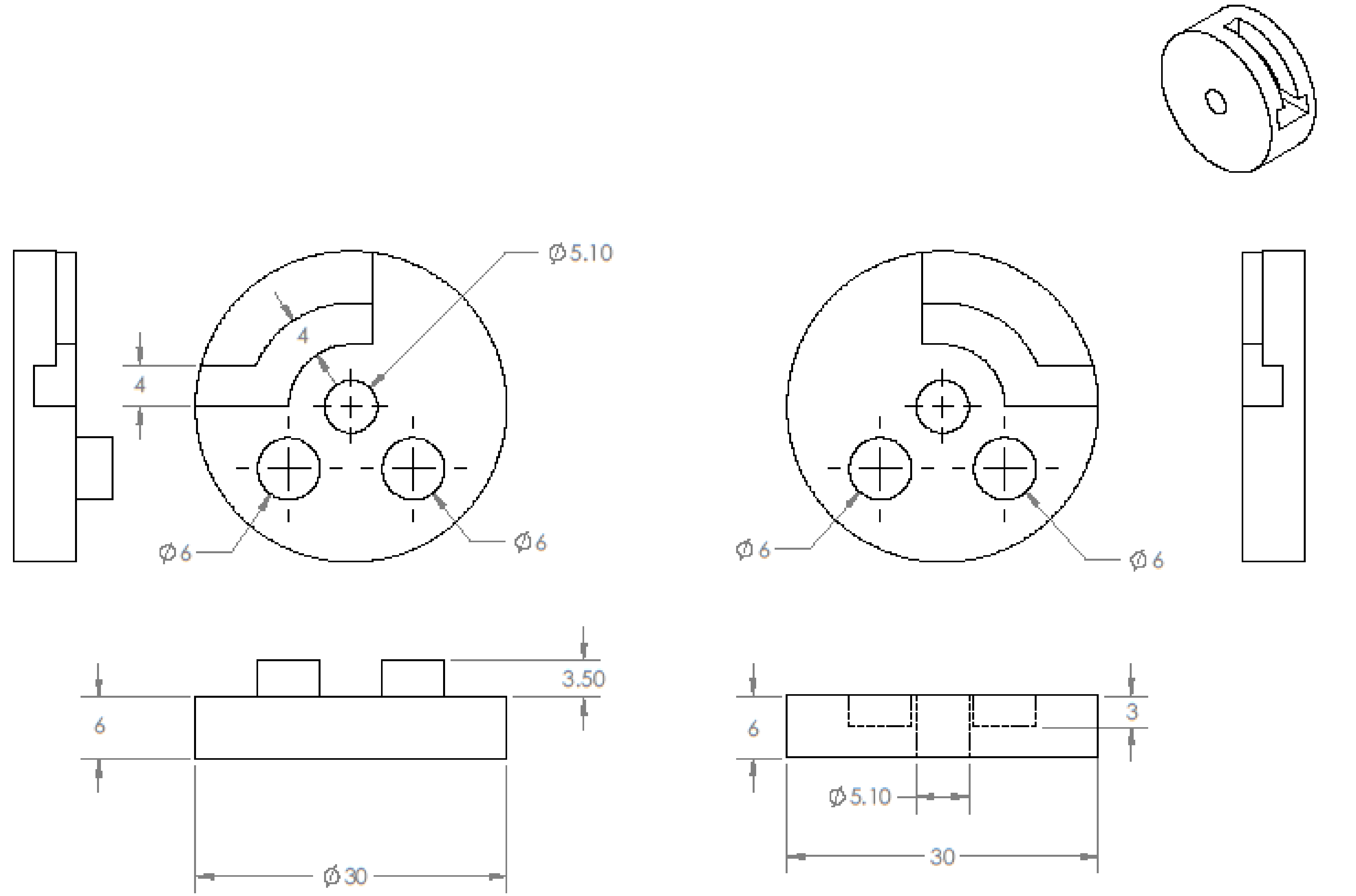


ITEM NO.	PART NAME	QTY.
1	Left Lower Attachment_Upper	1
2	Right Lower Attachment_Upper	1
3 & 4	Lower Attachment_Lower	2
5	199mm Quick-Release Skewer	1
6	Upper Attachment_On Bike	1
7	Upper Attachment_Quick Release – McMaster Carr Part #1511K11	1
8	Upper Attachment_Universal Bar	1
9	Generic Rack	1

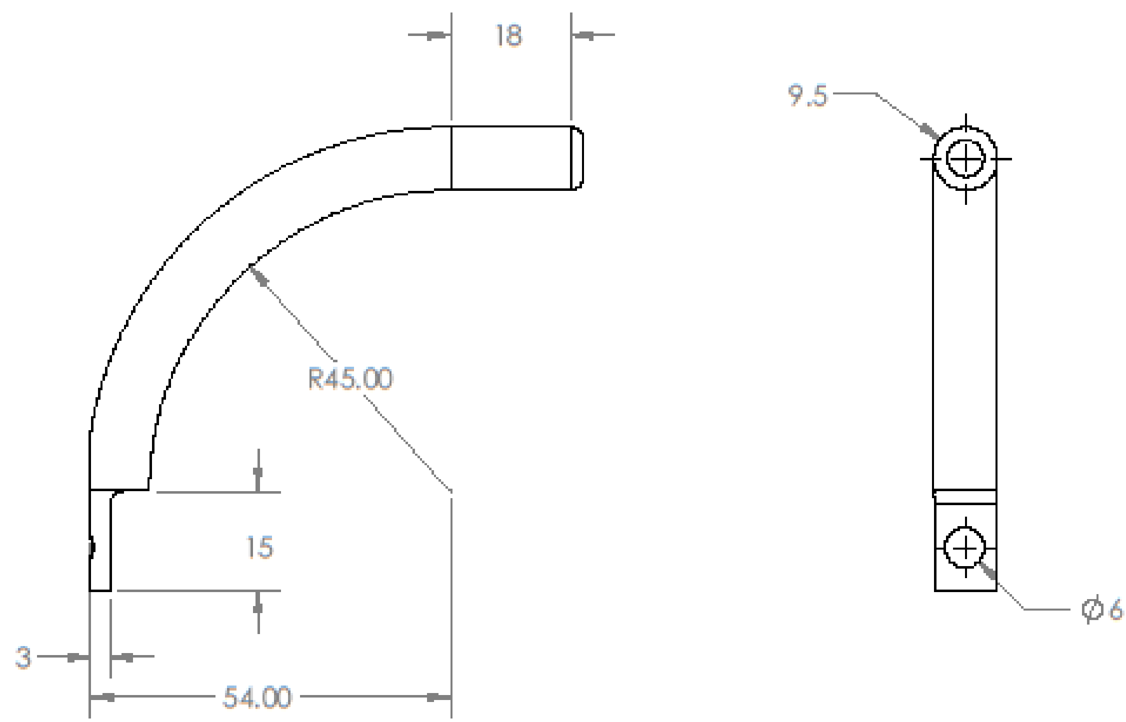


1 & 2 - Lower Attachment_Upper

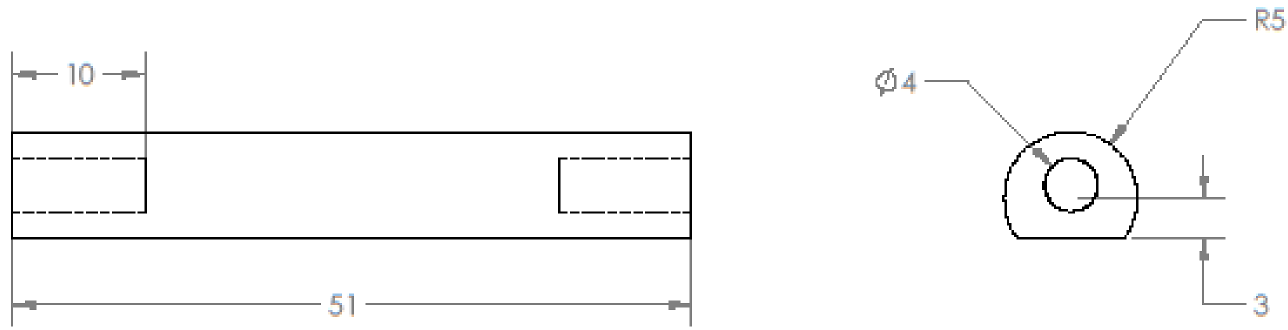
Note: Right Lower Attachment_Upper is Opposite Hand



3 & 4 - Lower Attachment_Lower



6 - Upper Attachment_On Bike



8 - Upper Attachment_Universal Bar