2018 University of Cincinnati SAE Baja

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Bachelor of Science

in Mechanical Engineering Technology

by

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ABSTRACT

For 2018 the previous year's Baja car needed some updates to be compliant with new rules that were changed. Particularly, changes to the gas tank and splash pan configuration, as well as the powertrain guard. The car originally had and engine mounted gas can and no splash pan or catch pan. The powertrain guard was present, but rubbed the clutch and was unable to be removed without the removal of the rear left suspension. After understanding the technicalities of the rules and contemplating a few different designs. I developed a solution that solved both of these problems. The tank was mounted up high and away from the engine. This allowed a small splash pan to be mounted below it which effectively diverts all gasoline away from hot engine components. The powertrain guard was constructed into a two-piece design that meets all rules and also allows removal and clutch service without disassembling the rear suspension. Overall, both components meet or exceed the 2018 rules and customer expectations.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The #6 University of Cincinnati Baja car currently has many different flaws in its design. Included in these are problems with the powertrain guard and gas tank mounting As it sits now neither of these components work well or meet the new rules for 2018 Baja SAE. The gas tank needs to be remotely mounted and a splash guard needs designed. The powertrain guard needs redesigned so that it doesn't rub the clutch and allows easier access to service the clutch while meeting the revised rules.

BACKGROUND

The goal in Baja SAE is to design, build and race off-road vehicles that can withstand elements of rough terrain against many different colleges around the country. These vehicles are often similar in appearance to dune buggies with large tires and a complete role cage that completely protects the driver. One main component of these cars is the suspension which allows for the cars to travel over rough terrain at high speeds by conforming to the terrain. This is made possible by combining long wheel travel, high ground clearance, strong structural frame ect.

The University of Cincinnati currently has three cars that are in various stages of their life. The most recent is the #6 car which currently sits as a completed car however it has never been certified for competition and has many design flaws. The remaining two completed cars are both still fully functional and certified, which will serve as great models for testing.

We are proposing a redesign of multiple aspects of the #6 Baja car that include but not limited to; front and rear suspension, cage design, ergonomics and a dynamometer. These improvements are needed for the car to be fully capable within the requirements for the 2018 SAE Baja competition. These will be completed in time for the Spring 2018 competition where we will have the car certified for competition, as well as be competing.

RESEARCH

SCOPE OF THE PROBLEM

The problem with the #6 Baja is that the current design of the car does not meet the requirements of the Baja SAE 2018. This problem is being addressed so the Baja team will be able to compete in the 2018 competition in Maryland. Each individual project is important due to the car needing to meet the requirements given in the Baja SAE Collegiate Design Series 2018 Rules (1) to be certified to compete.

Rules regarding Fuel Tank and Splash Pan mounting and guidelines

Figure 1

B.6.5 - Fuel Tank

One fuel tank is permitted on the vehicle. Fuel tanks shall be unmodified and free from injurious defects. Fuel tanks are restricted to Briggs and Stratton part 799863. All fuel tanks shall be remote mounted, and not affixed to the engine. Fuel tank mounting shall be fixed. Removable tanks are explicitly prohibited.

Note: 799863 is the tank supplied with the Briggs and Stratton Model 20 engine during the 2016 season.

The retail price of the fuel tank must be included in the cost report.

B.6.5.1 - Mounting

Fuel tanks shall be mounted directly to a tube or tubes meeting the requirements of at least a secondary member. Cantilever mounting of fuel tanks to the vehicle frame is explicitly prohibited.

All four mounting holes on the fuel tank shall be used to mount the tank to the vehicle frame. Tabs used to join the fuel tank to the tubes of the vehicle frame shall be less than 50.8 mm (2.0 in) long, when measured along the tab from the center of the mounting hole to the outside of the attached frame member.

Any and all fasteners used to mount the fuel tank to the vehicle frame shall meet the requirements in

B.6.7 - Splash Shields

Splash shields are required to prevent fuel from accidentally being poured directly on the engine or exhaust while refueling or preparing to refuel the vehicle.

The splash shield shall be either metallic material (greater than 0.5 mm or 0.02 inches thick) or fuel-resistant non-metallic material (greater than 1.5 mm or 0.060 inches thick). Shields must be generally rigid, shaped such that any spilled fuel runs towards the outside of the vehicle, and does not pool on the shield. An example arrangement of splash shielding is shown in two views in Figure B-40.

Splash shields shall be mounted so they are engaged and effective at all times and are not adjustable. The splash shield must be mounted lower than the structural member supporting the fuel tank.

If the fuel line passes through the splash shield, it must either pass through a grommeted hole in the shield, or utilize a metallic barbed bulkhead union (recommended). With either method, the hole must be sealed to prevent spilled fuel from leaking to the engine.

Figure 2

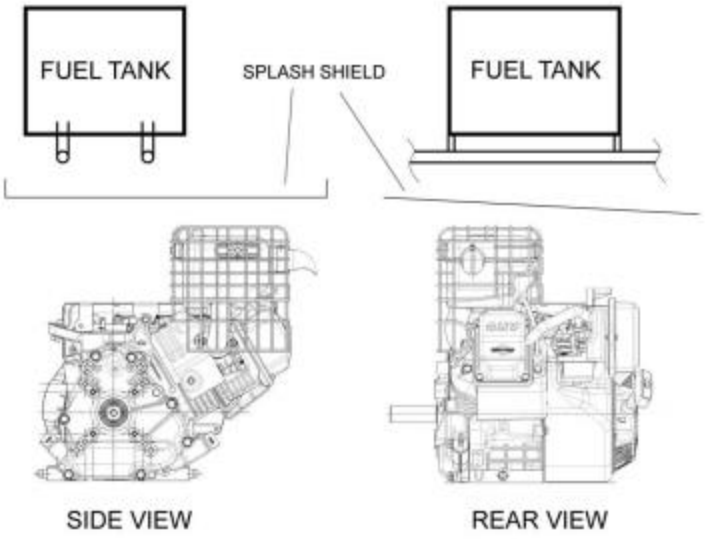


Figure B-40: Fuel System, Splash Guard Installation Example

Rules regarding Powertrain Guard mounting and guide lines:

Figure 3

Article 9 - Powertrain Guards

B.9.1 - Powertrain Guards

All rotating powertrain components (CVTs, Gears, Sprockets, Belts and Chains) shall be shielded to prevent injury to the driver, track workers, or bystanders. Guards shall protect against hazardous release of energy should rotating components fail. Guards shall also protect against fingers, loose clothing, or other items from being entangled in the rotating components (pinch points). Universal joints, CV joints, hubs, rotors, wheels and bare sections of shafts are exempt from the requirements of B.9.1 and B.9.2.

B.9.2 - Hazardous Release of Energy

Powertrain guards and shields protecting against hazardous release of energy shall extend around the periphery of the rotating components (chains, gears, sprockets, belts, and CVT's) and have a width wider than the rotating part the guard is protecting.

Note: This means the entire periphery of the primary CVT pulley, not just the belt width.

All powertrain guards shall be constructed of one or both of the following required materials:

- Aluminum, at least 3.0 mm (0.12 in.) thick, meeting or exceeding the strength of 6061-T6 aluminum.

Holes and/or vents in the portion of the powertrain guard surrounding the rotating components are acceptable provided that in the event of a powertrain failure, no parts can escape. No direct path shall exist tangent to any rotating components.

Powertrain guards shall be mounted and secured with sound engineering practices in order to resist vibration and shock.

B.9.3 - Pinch Points and Entanglement

Rotating parts in the powertrain system rotating faster than the final drive shall be guarded on all sides, in addition to the guard around the periphery. Guarding for pinch points shall prevent small, searching fingers from getting entrained in any rotating part. Flexible, non-rigid, fabric coverings such as "Frogskin", Ceconite, and neoprene are unacceptable for use as finger guards. Powertrain covers fastened with adhesive, ratcheting tie-downs, and other temporary methods are explicitly prohibited. All powertrain covers shall have resilient and durable mountings with easily accessed and actuated fastening devices.

A complete cover around the engine and drivetrain is an acceptable shield for pinch points, but does not relieve the requirement for release of hazardous energy.

Figure 4

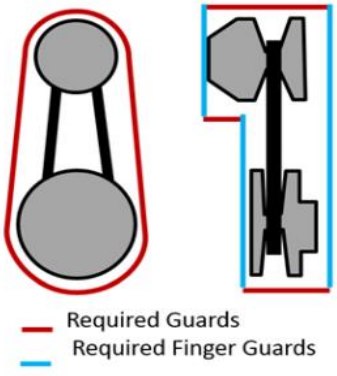


Figure B-42: Powertrain Guard Extents

Figure 5

Figure B-43: Powertrain Guard Example

CURRENT STATE OF THE ART

SAFETY / ERGONOMICS

Previous cars here at U.C. use two different designs. One car uses a drip pan which funnels the gas back towards the gas tank. The other car uses a drip pan that directs the gasoline away from the engine. On top of this pan is a removable gas tank, used for quick change pit stops. Both of these concepts have been abolished this year due to new rule changes for the 2018 competition. This year the tank must be mounted remotely from the engine, above a drip pan. The pan must divert all gasoline away from the engine and other hot surfaces.
All moving parts must be shielded to prevent user injury. The current car needs a shield around the drive belt and clutch assembly. Most teams create a quickly removeable shield out plastic, metal, or composite material. This design has been proven and we will most likely use a variant of one of these styles.

END USER

The objective of BAJA SAE is to not only design a car competitive for competition, but to design it for the recreational user market. We are competing to have our car selected for manufacture by a fictitious firm. The prototype vehicle needs to demonstrate reliability, ergonomics, and competitiveness all while being economically valuable for manufacture and profitability by the fictitious firm.

The end user will be the drivers, team, and anyone that works on the cars. Implementing shields and splash guard will help protect our team and improve the safety of anyone in or near the vehicle.
Ergonomic features will be geared towards driver comfort. Pedal and steering may be modified to capture the 95^{th} percentile of males. Also E-stop button may be moved to a better position to ensure safe operation in an emergency.

CONCLUSIONS AND SUMMARY OF RESEARCH

As the 2018 University of Cincinnati Baja team we are going to address the stated problems above. Each of these issues will be addressed individually with different team members, each member's projects are listed below. Each project was chosen to complete an integral part that is needed to compete in the 2018 competition. (1)

REAR SUSPENSION:

Gabe Archer

I am proposing a complete redesign of the rear suspension of the #6 car that will address and fix the issues stated above. This will be completed in time for the Spring 2018 competition and will be key in getting the #6 car ready to be certified for competition.

CAGE DESIGN:

Connor Mulholand

I am proposing a redesign of the cage of the #6 car that will address the 2018 updates as well as concerns addressed by the 2017-2018 Baja team. This cage redesign will be completed no later than the competition and the senior project deadlines.

SAFETY / ERGONOMICS:

Vincent Gardner

I am proposing to address both the fuel tank assembly as well as the belt drive guarding. These issues must be addressed according to the rule book to compete in 2018 competition. They will be completed before vehicle inspection 2018.

DYNAMOMETER DESIGN:

Dennis Dickerson

I am proposing a design of a Dynamometer for the UC Baja team. There is currently no way for the Baja team to know which clutch configuration (total of 10) is the best for the Baja. This design will be based off the Baja teams needs and will be completed on time before the Spring 2018 competition

CUSTOMER FEATURES

Weighted importance of design specifications:

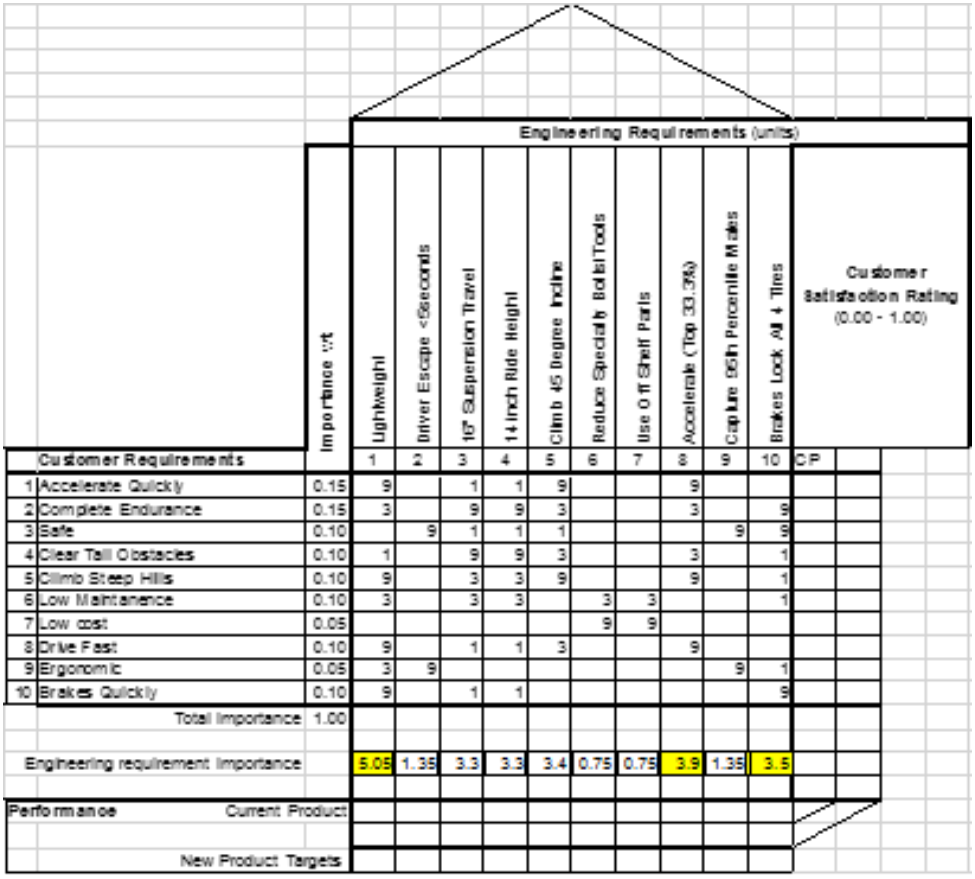
- 0.35 - Safety
- 0.10 - Weight
- 0.15 - Ground Clearance
- 0.10- COG
- 0.15 - Durability
- 0.10- Maintenance/Ease of Replacement
- 0.05 - Cost

PRODUCT OBJECTIVES

- Safety
    - Design will adhere to SAE rules
    - Design will prevent dangerous gasoline spills
    - Design will protect team from moving parts
- Weight
    - Total weight will be <10 lbs
- Ground Clearance
    - Belt Drive guard will be placed as high as possible
- COG
    - Gas tank will be placed low to maintain low COG
    - Splash pan will be lightweight to reduce COG
- Durability
    - Both projects will remain intact throughout competition
- Maintenance/Ease of Replacement
    - Both parts will remove easily
    - Standard fasteners will be used
- Cost
    - Parts built inhouse to reduce costs
    - Will not exceed BAJA budget

QUALITY FUNCTION DEPLOYMENT

Figure 6



	Customer Requirements	Importance Wt	Lightweight	Driver Escape <5seconds	10" Suspension Travel	14 inch Ride Height	Climb 45 Degree Incline	Reduce Specialty Bolts/Tools	Use Off Shelf Parts	Accelerate (Top 33.3%)	Capture 95th Percentile Males	Brakes Lock All 4 Tires	Customer Satisfaction Rating (0.00 - 1.00)	
			1	2	3	4	5	6	7	8	9	10	CP	
1	Accelerate Quickly	0.15	9		1	1	9			9				
2	Complete Endurance	0.15	3		9	9	3			3		9		
3	Safe	0.10		9	1	1	1				9	9		
4	Clear Tall Obstacles	0.10	1		9	9	3			3		1		
5	Climb Steep Hills	0.10	9		3	3	9			9		1		
6	Low Maintenance	0.10	3		3	3		3	3			1		
7	Low cost	0.05						9	9					
8	Drive Fast	0.10	9		1	1	3			9				
9	Ergonomic	0.05	3	9							9	1		
10	Brakes Quickly	0.10	9		1	1						9		
	Total Importance	1.00												
	Engineering requirement importance		5.05	1.35	3.3	3.3	3.4	0.75	0.75	3.9	1.35	3.5		
	Performance Current Product													
	New Product Targets													

DESIGN

Design alternatives and selection

Gas Tank Mounting

For mounting the gas tank, the main decision I had was to determine the height of the tank. In all cases, the mount required the addition of four bars to the cage to avoid a cantilever design. I wanted the height to allow easy service of the engine and hopefully provide a window that allowed the engine to be removed. At the same time, it had to be low enough to avoid shoulder injuries and excess fuel spillage from lifting a gas can too high.

In the end, I mounted the tank just barely high enough to allow engine removal and it is about shoulder height on an average male. The tank is easy to fill and should be able to prevent excess spillage due to height constraints.

Splash Pan Mounting

I was able to choose between various shapes and a few different materials for the splash pan. Material selection could have been a composite shape which would have allowed a very custom design. It also would be very light weight, but tough to manufacture. I ultimately went with the thinnest gauge aluminum allowed by the rules. Aluminum is also tough and very lightweight. Ultimately, the decision was made based on material availability and ease of manufacture. Aluminum is very easy to bend and shape to a desired application.

I was also flexible in what shapes were allowed of the splash pan. The pan has to divert gas in any direction away from the engine, except towards the driver. I contemplated different shapes that would divert gas to one side, or both sides. Ultimately, I chose a shape that diverted towards the rear. This allowed me to keep the design narrow and have more control of where the fuel went. Running off the sides risked fuel splashing off the cage and suspension and still hitting the engine. Towards the rear seemed much more controlled and seemed to provide the least amount of risk.

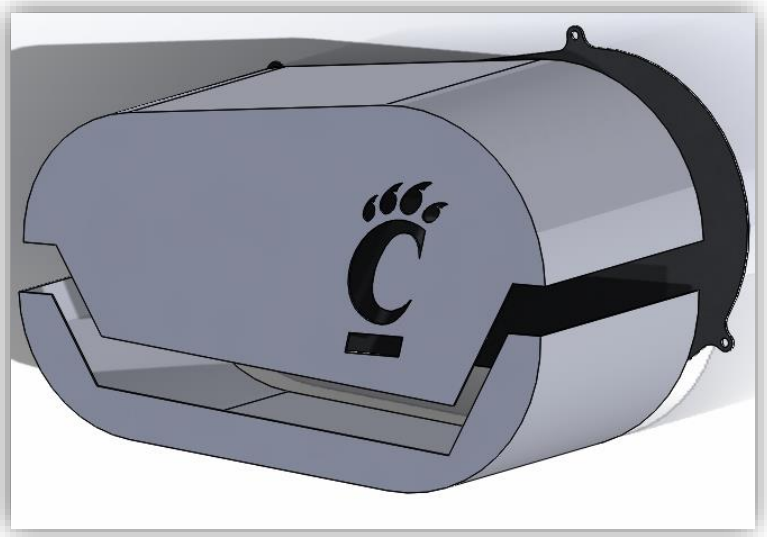
Powertrain Guard Mounting

The current powertrain guard was a one piece design. It was not able to be removed without removing the rear suspension. It also rubbed against the clutch when the clutch expanded. I had the option of making an entirely new guard. I opted to modify the existing powertrain guard. I cut it into two pieces so that it was more easily removed. This allowed the clutch to be serviced without any other components being removed. To avoid the clutch rubbing the bolts, I used a quarter inch spacer that pushed the clutch a little bit further from the engine. This allowed just enough space between the clutch and the bolt heads.

3-D Designs

Figure 7

Figure 8



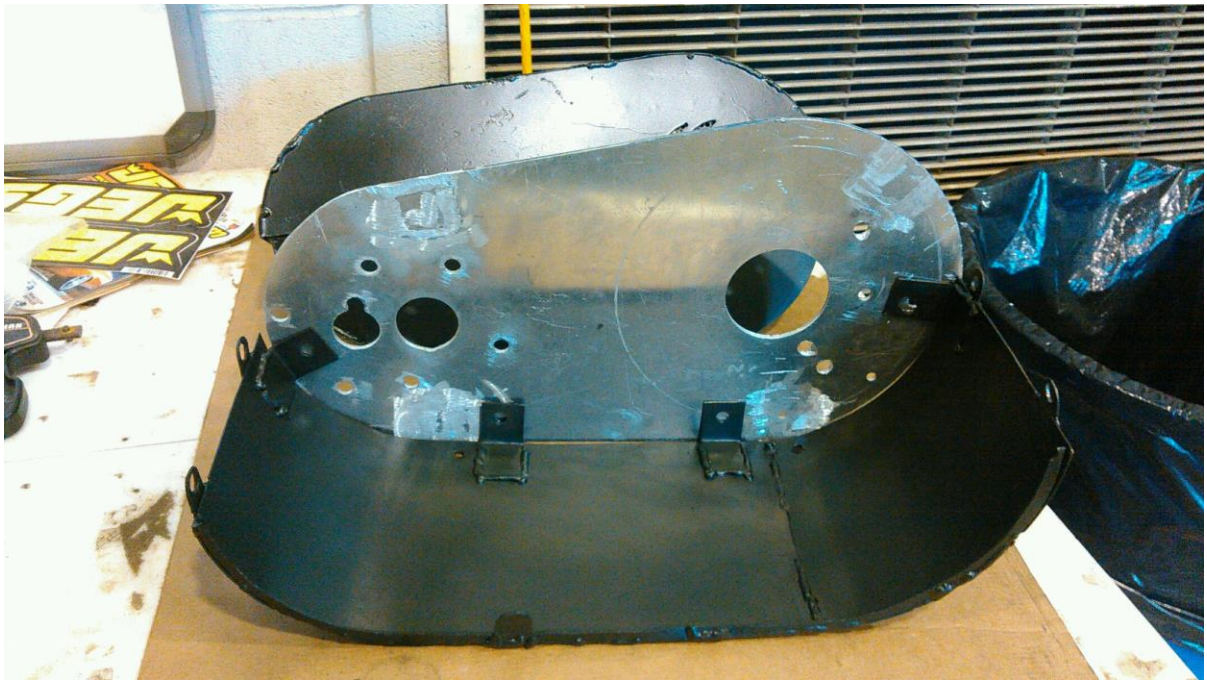
Final Components

Figure 9

Figure 10

Figure 11

Figure 12



Loading Conditions

- Gas Tank
    - Tank Weight: 2.28 lbs
    - Fuel Weight: 4.95 lbs
    - Weakest point at plastic tank mounts
    - Less vibration than when engine mounting
- Splash Pan
    - Pan Weight: <2 lbs
    - Vibration
- Factor of Safety
    - No failure allowed

- Powertrain Guard
    - Guard Weight: TBD <5lbs
    - Vibration
    - Rock impact
- Factory of Safety
    - Slight Deformation allowed
    - Addition of ribs if needed

Design Test Statement

- Gas Tank
    - Ensure Gas tank and Splash pan are mounted and operate as required by BAJA SAE 2018 updated rules.
    - Testing will be done by pouring water on various areas of tank and pan to ensure no drops end up on engine or exhaust.
    - Components will survive normal vehicle usage.
- Clutch Guard
    - Ensure Clutch Guard is mounted and operates as required by BAJA SAE 2018 updated rules.
    - Guard will prevent body parts from entering area with rotating parts.
    - Guard will have enough clearance to not rub clutch surfaces.
    - Guard will be removable without disassembling other components.

Component Selection

For the most part, component selection on these components was dictated by the rules for 2018 Baja SAE. For all components I chose what was the minimum requirement in order to save weight.

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Cost

The total cost for these projects should remain under $500. All parts will be made in house to keep costs down.

Table 1

Design Budget			
Item	Quatity	Cost	Source
14 g Steel	5 sq ft	$ 22.83	OnlineMetals.com
24 g Aluminum	5 sq ft	$ 30.00	OnlineMetals.com
Rubber Grommet .25"	1	$ 6.75	McMasterCarr
Steel Tube	7 ft	$ 23.65	OnlineMetals.com
Various Bolts	16	$ 25.00	McMasterCarr
Fuel Line 395051R	2 ft	$ 2.90	Amazon.com
Miscellanious	Various	$ 25.00	Various
		$ 136.13	

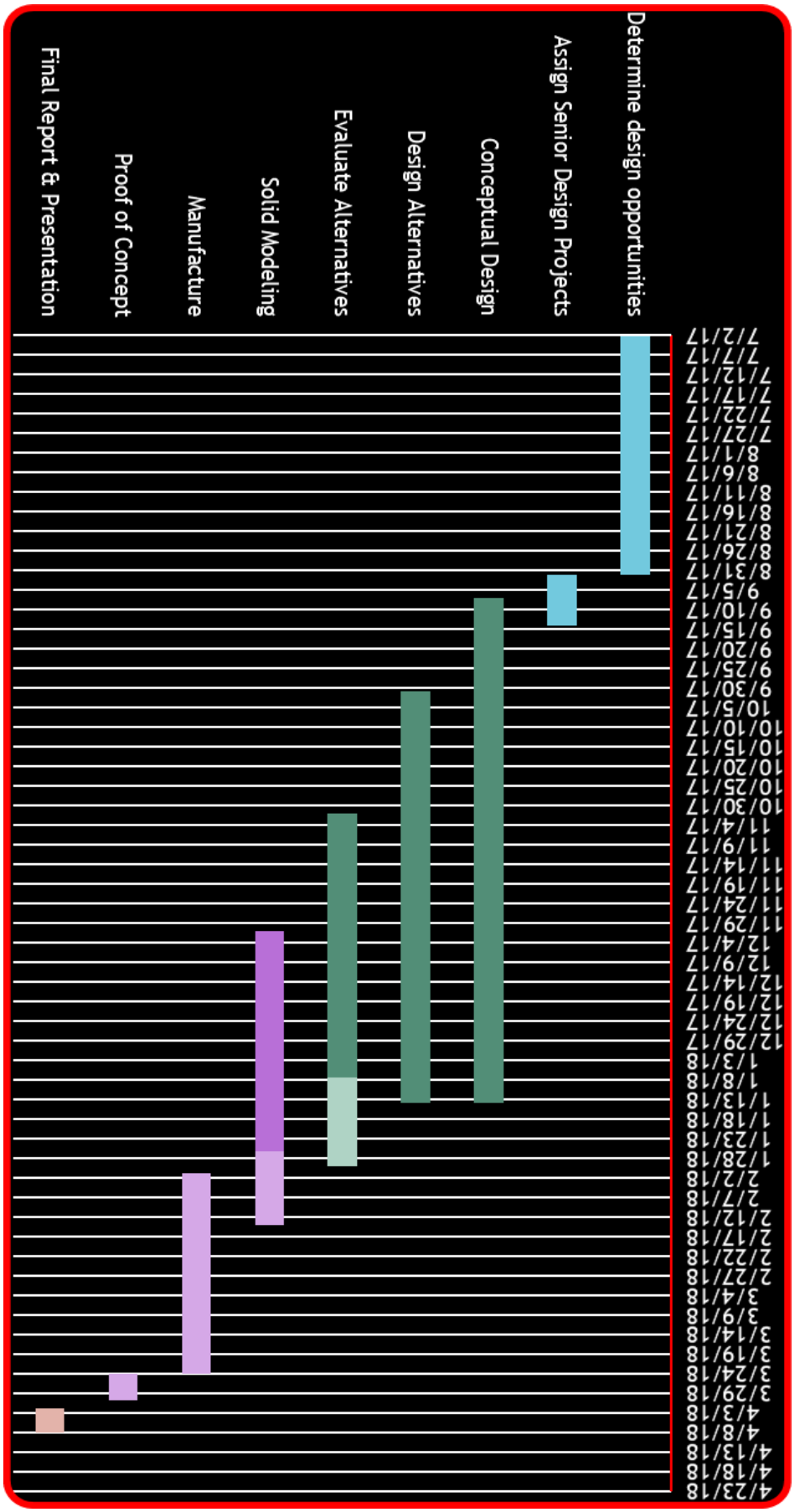
As seen from above, the actual budget came in well under the proposed budget. This was due to the ability to reuse many components or having materials on hand for manufacture.

SCHEDULE, PROPOSED /ACTUAL

Table 2

	Septemebr	October	November	December	January	February	March	April
Research								
Design								
Modeling/FAE								
Ordering of Materials								
Manufacturing								
Testing								

Table 3


Determine design opportunities
Assign Senior Design Projects
Conceptual Design
Design Alternatives
Evaluate Alternatives
Solid Modeling
Manufacture
Proof of Concept
Final Report & Presentation
7/2/17
7/7/17
7/12/17
7/17/17
7/22/17
7/27/17
8/1/17
8/6/17
8/11/17
8/16/17
8/21/17
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3/4/18
3/9/18
3/14/18
3/19/18
3/24/18
3/29/18
4/3/18
4/8/18
4/13/18
4/18/18
4/23/18

Overall, the team stuck very close to the updated schedule. The original schedule is too generic to comment on. We spent long hours over Spring break and during the last couple weeks of our scheduled manufacturing time to complete our individual projects on time. We may have pushed just beyond what was scheduled with our manufacturing. Testing was completed a week later than expected due to health complications with one of our team members. We had a gab built in between our scheduled testing and the final report being due, so we utilized this time to test.

FINAL TESTING

- Gas Tank
    - Mounted securely according to all rules
    - Splash guard effectively diverts all liquid away from engine.
    - Survived initial test runs in Victory Parkway lot
- Drivetrain Guard
    - Meets all rules of Baja SAE 2018
    - 2 piece design allows clutch service without removal of extra components
    - Protects against any extremities making it into rotating parts
    - Clutch does not rub any bolts or surfaces
    - Survived initial test runs in Victory Parkway lot

CONCLUSION

The main goal of this project was to address these components and make them compliant with the rules for competition in Baja SAE 2018. Further goals were to make the components as light as possible while maintaining a very minimal budget. These components were small and don't add much weight to the car, so there is very little to gain in using expensive materials. Throughout the project I shifted my focus onto using components that were still lightweight but were easier and cheaper to manufacture. In the end, the only weight the car gained was from the four secondary members that had to be added in order to remotely mount the gas tank. All components were designed and successfully implemented to make us compliant to compete in 2018 Baja SAE. They all survived normal driving and endured the tests done to other team members components, such as dropping the car from 2.5 foot wall multiple times. In the end this project was completed right on time and survived all testing that was needed to prove the design. It was also completed significantly under budget due to inhouse manufacturing and recycling old components.

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APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D