



ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA
(ICAI)

MASTER EN INGENIERÍA INDUSTRIAL

COST OPTIMIZATION ANALYSIS OF A FORMULA SAE VEHICLE

Autor: Alberto Carralero Moya

Director: Rafael Rodríguez Dosal

Madrid

June 2018

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Fdo.: Alberto Carralero Moya

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Autor: Alberto Carralero Moya

Director: Rafael Rodríguez Dosal

Madrid

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OPTIMIZACION DE COSTES DE UN VEHÍCULO DE FSAE

Autor: Carralero Moya, Alberto.

Director: Rodríguez, Rafael.

Entidad Colaboradora: Embry-Riddle Aeronautical University.

RESUMEN DEL PROYECTO

El objetivo principal del proyecto es elaborar un análisis de costes para la competición de FSAE en Michigan. Formula SAE es una competición de diseño de ingeniería en la que universidades de todo el mundo desarrollan un coche de carreras. Cada universidad diseña, construye y prueba prototipos basados en una serie de reglas, cuyo propósito es garantizar la seguridad en la carretera y promover la resolución inteligente de problemas. Además, está el análisis de costes y fabricación del prototipo que es uno de los principales objetivos de este proyecto.



El objetivo del evento de análisis de costes y fabricación es mostrar a los jueces un informe de costos lógico del vehículo, elaborando una lista de materiales detallada de todas las partes del automóvil. El proyecto está basado en el vehículo del año pasado y los desafíos serán solucionar los problemas que tuvo el equipo el año pasado para buscar las mejores soluciones en términos de rendimiento y coste.

El coste actual del vehículo de producción previsto es de \$ 16,431.95 siendo más alto que el presupuesto de \$ 14,000 que era el objetivo del equipo a principio de año. A lo largo del proceso de diseño y fabricación, nos enfrentamos repetidamente con cuestiones de costo, diseño, eficiencia y confiabilidad. Se tomaron las mejores

decisiones para optimizar esos factores y el resultado neto es un costo mayor de lo previsto.

El equipo hizo un gran esfuerzo para reducir el costo del vehículo modelo ER03 (año 2017) de \$18,128 a \$16,432 para el modelo ER04 (año 2018). Con base en el desempeño del año pasado, el equipo analizó las posibles mejoras y diseñó el nuevo prototipo. Los costos de cada sistema del automóvil se muestran en la siguiente tabla.

Area Totals	Materials	Processes	Fasteners	Tooling	Total
Brake System	\$ 1.461,20	\$ 137,39	\$ 4,49	\$ -	\$ 1.603,08
Engine & Drivetrain	\$ 2.809,77	\$ 421,04	\$ 26,12	\$ -	\$ 3.256,93
Frame & Body	\$ 2.355,63	\$ 1.195,16	\$ 53,69	\$ 130,13	\$ 3.734,61
Instruments & Wiring	\$ 3.481,84	\$ 136,52	\$ 2,23	\$ 0,67	\$ 3.621,26
Miscellaneous, Fit & Finish	\$ 494,08	\$ 103,65	\$ 44,76	\$ 3,57	\$ 646,06
Steering System	\$ 136,46	\$ 109,40	\$ 1,66	\$ -	\$ 247,52
Suspension & Shocks	\$ 1.480,13	\$ 148,66	\$ 9,42	\$ 41,34	\$ 1.679,55
Wheels & Tires	\$ 1.062,32	\$ 574,86	\$ 5,76	\$ -	\$ 1.642,94
Total Vehicle	\$ 13.281,43	\$ 2.826,68	\$ 148,13	\$ 175,71	\$ 16.431,95

El sistema más costoso del vehículo es el cuerpo o carrocería. Sin embargo, es el sistema donde el equipo redujo más costos al pasar de \$ 5,215 (ER03) a \$ 3,621 (ER04), lo que significa un ahorro de casi \$ 1,600.

Además, se estudian metodologías de diseño como QFD, Ingeniería y análisis de valor y DFMA para comprender qué sistemas y conjuntos son los más importantes para los futuros clientes. El objetivo de estos métodos es reducir el costo en el diseño y desarrollo de los productos y su impacto en el costo de fabricación a lo largo del ciclo de vida del producto. Aplicando estas metodologías se conseguirán mejores soluciones de ingeniería para la producción y ensamblaje de las distintas piezas. Estas metodologías se pueden aplicar tanto a prototipos o piezas en fase de diseño añadiendo nuevas funcionalidades o a mejoras en el rendimiento o reducción de costes a piezas ya producidas.

En el caso de la metodología QFD, ésta ayudó al equipo a priorizar las necesidades y deseos del cliente potencial, traduciendo esas necesidades a especificaciones técnicas. El equipo realizó un estudio para analizar las necesidades del cliente en coches de carreras y, basándose en eso y aplicando la metodología QFD, los sistemas más importantes del coche son:

No	Technical Systems	%
1	Engine & Drivetrain	23%
2	Frame & Body	22%
3	Misc, Safety & Finish	16%
4	Steering system	14%
5	Brake system	8%
5	Wheels & Tires	8%
7	Electrical system	6%
8	Suspension system	3%

Por último, se estudian diferentes casos de problemas Make vs. Buy para explicar la decisión del equipo en la compra o fabricación de las piezas o sistemas. Además, se analizan las diferencias entre los procesos de fabricación como el láser, chorro de agua o corte por plasma para ver cuál es el más adecuado en cada caso.

COST OPTIMIZATION ANALYSIS OF A FSAE VEHICLE

Author: Carralero Moya, Alberto.

Director: Rodríguez, Rafael.

Collaborating Institution: Embry-Riddle Aeronautical University.

PROJECT SUMMARY

The main purpose of the project is to elaborate a cost report for the FSAE competition in Michigan. Formula SAE is an engineering design competition where universities all over the world develop a race car. Each student team designs, builds and tests a prototype based on a series of rules, whose purpose is both ensuring on-track safety and promoting clever problem solving. In addition, there is the cost and manufacturing event that is the goal of this project.



The objective of the cost and manufacturing event is to show the judges a logical cost report of the vehicle. It has a detailed BOM of all the parts of the car. The project is based on last year's vehicle and the challenges will be to fix the problems that the team had last year in order to look for the best solutions in terms of performance and cost.

The actual predicted production vehicle cost is \$16,431.95 being higher than the budget cost of \$14,000. Throughout the design and manufacturing process, we were repeatedly faced with questions of cost, design, efficiency and reliability. We made the best choices to optimize among those factors and the net result is a higher cost than predicted.

The team did a great effort reducing the cost of the vehicle from \$18,128 (ER03) to \$16,432 (ER04). Based on the performance of last year, the team analyzed the possible improvements and designed the new prototype. The costs of every system of the car are shown in the following table.

Area Totals	Materials	Processes	Fasteners	Tooling	Total
Brake System	\$ 1.461,20	\$ 137,39	\$ 4,49	\$ -	\$ 1.603,08
Engine & Drivetrain	\$ 2.809,77	\$ 421,04	\$ 26,12	\$ -	\$ 3.256,93
Frame & Body	\$ 2.355,63	\$ 1.195,16	\$ 53,69	\$ 130,13	\$ 3.734,61
Instruments & Wiring	\$ 3.481,84	\$ 136,52	\$ 2,23	\$ 0,67	\$ 3.621,26
Miscellaneous, Fit & Finish	\$ 494,08	\$ 103,65	\$ 44,76	\$ 3,57	\$ 646,06
Steering System	\$ 136,46	\$ 109,40	\$ 1,66	\$ -	\$ 247,52
Suspension & Shocks	\$ 1.480,13	\$ 148,66	\$ 9,42	\$ 41,34	\$ 1.679,55
Wheels & Tires	\$ 1.062,32	\$ 574,86	\$ 5,76	\$ -	\$ 1.642,94
Total Vehicle	\$ 13.281,43	\$ 2.826,68	\$ 148,13	\$ 175,71	\$ 16.431,95

As it is seen before, the most expensive system of the vehicle is the frame & body. However, it is the system where the team reduced more costs going from \$5,215 (ER03) to \$3,621 (ER04), meaning savings of almost \$1,600.

Furthermore, design methodologies such as QFD, Value Analysis & Value Engineering and DFMA are studied to understand which systems and assemblies are the most important for potential customers. The objective of these methodologies is reducing the cost in the design and development of the products and their impact in the manufacturing cost through the life cycle of the product. These methodologies can be used in prototypes in the design phase by adding new functionalities or improvements in the performance or reduction of costs in parts that were already produced.

In the case of the QFD methodology, it helped the team to prioritize the needs and wants of the potential customer with the product, translating those needs to technical specifications. The team did a study to analyze the customer needs and based on that and applying the QFD methodology, the most important systems of the car are:

No	Technical Systems	%
1	Engine & Drivetrain	23%
2	Frame & Body	22%
3	Misc, Safety & Finish	16%
4	Steering system	14%
5	Brake system	8%
5	Wheels & Tires	8%
7	Electrical system	6%
8	Suspension system	3%

Different cases of make versus buy problems are studied to explain the decision of the team in the purchase or manufacturing of the part. In addition, differences between manufacturing processes such as laser, water jet or plasma cutting are analyzed to see which one is more suitable in each case.

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I would like to express my sincere gratitude to Embry-Riddle Aeronautical University and especially to Professors Rafael Rodriguez and Dave Spitzer for giving me the opportunity to work with the ERAU Motorsports team, for his continuous encouragement, help and for the patient guidance and advices.

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List of Acronyms

FSAE – Formula SAE competition

ER04 – Version 4 of the Embry Riddle FSAE vehicle (year 2018)

ER03 – Version 3 of the Embry Riddle FSAE vehicle (year 2017)

BR – Brake system

EN – Engine & Drivetrain system

FR – Frame & Body system

EL – Instruments, Wiring & Accessories system (Electrical system)

MS – Miscellaneous, Safety, Finish and Assembly system

ST – Steering system

SU – Suspension system

WT – Wheels, Wheel Bearings & Tires system

VA – Value Analysis

VE – Value Engineering

DFMA – Design for Manufacturing and Assembly



1. Introduction

This project is based on the 2017 cost analysis of our Formula car (ER-04). This report is intended to communicate the expected production cost for our production vehicle and is based on the construction methods used for the prototype.

As you will see in the report, our actual predicted production vehicle cost is \$16,431.95 and this is higher than our budget cost of \$14,000. Throughout the design and manufacturing process, we were repeatedly faced with questions of cost, design, efficiency and reliability. We made the best choices to optimize among those factors and the net result is a higher cost than predicted.



Figure 1 – ER04 vehicle

To address this cost difference in terms of Sales and Marketing, we will offer our customers the data acquisition system as an option and this will close the remaining gap. This cost report follows the Formula SAE rules, and reflects our decision to compete with full data acquisition in place while we build our knowledge base.



1.1 Formula SAE Competition

Formula SAE is an engineering design competition where universities all over the world develop a race car. Each student team designs, builds and tests a prototype based on a series of rules, whose purpose is both ensuring on-track safety and promoting clever problem solving. In this competition, students enhance their engineering design and project management skills with the guide of their professors. The competition gives the teams the freedom and flexibility on the vehicle design in order to show the creativity and imagination of the students.

The competition has two main sections. The first one is the dynamic events which include the acceleration, autocross, fuel economy and endurance events. Here, the engineering effort of the students shown in the vehicle performance is evaluated by the judges. The vehicle should have very high performance in terms of acceleration, braking and handling and be sufficiently durable to successfully complete all the events:

- Acceleration event: This event evaluates the car's acceleration in a straight line on flat pavement. The acceleration course length will be 75 m (246 ft.) from starting line to finish line. A well-tuned engine, lightweight designs, and efficient shifts are critical to this event.
- Skid-pad event: The objective of this event is to measure the car's cornering ability on a flat surface while making a constant radius turn.
- Autocross event: The objective of the autocross event is to evaluate the car's maneuverability and handling qualities on a tight course without the hindrance of competing cars. The autocross course will combine the performance features of acceleration, braking, and cornering into one event.
- Endurance event: It is designed to evaluate the overall performance of the car and to test the car's durability and reliability. The drivers must race the car for 22km, roughly 15 laps, against other teams without breaking down, losing any



parts, or running out of fuel. Not only does the car need to be fuel efficient but the racers need to be able to drive at a competitive pace to score well against the rival teams. In this event, it is where most of the cars break and lose points for the global event. Last year, our team only got 11 out of 275 points due to a failure of the braking system.

- Efficiency event: This event is only for the teams that have success in the endurance event. The amount of fuel consumed is measured and scored against other team's performance.

Second, the static events include a design presentation, a business logic case, and a cost and manufacturing event that will be the purpose of this project:

- Design event: All of the research, innovation, and final designs are presented to a panel of senior engineers from multiple disciplines and industries. Each subsystem is critically analyzed and the team must defend and promote their designs, effort, and execution. The car that shows the best use of engineering knowledge and meets all the design goals will win this event.
- Presentation event: The students have to simulate a company studying the market (sales volume, profitability and other features) in order to meet the demand of the amateur and weekend competition market.
- Cost and manufacturing event: The objective is to show the judges a logical cost report of the vehicle. It has to have a detailed BOM of each part of the car. In addition, in this section, cost saving challenges will be studied by the students and they have to find the best solution for each challenge.

1.2 State of art

This year will be the fourth year of Embry-Riddle car in competition. As our team is one of the youngest, we are trying to improve in big steps in order to accomplish our



objective that is finishing the completion in the top 30 universities out of 120 that participate in the Formula SAE Michigan event.

Last year, our team got decent results but we finished the competition in the 70th position. The team has two main objectives related to the cost and manufacturing event. The first one is to prepare accurate bills of materials the most accurate because we realize that there are different parts and assemblies that are missing components of the production process. The second one is to optimize the cost of the car with the different materials and manufacturing changes, from those used last year. Last year our car cost \$18,000 that was above the average of all the participants. This year, the goal is to reduce this cost to \$14,000 that is the average cost of the teams. We need to reduce the cost because, the lowest cost you have the highest points you get in the cost event. However, the lowest cost we obtained in order to achieve all the competition requirements and to get a good performance of the car is \$16,431.

1.3 Motivation

This project mainly requires business knowledge but as all the background of the design of the car also requires engineering knowledge, I think it was the perfect mix between the MBA that I am doing at Embry Riddle Aeronautical University and the Master in Industrial Engineering at ICAI.

Working in this project, makes me motivated because you see the development of the car and how things are getting done. In my specific part, it is a big opportunity to work in the cost analysis report because at the end, the team will be presenting in Michigan in front the judges all the work done through the year showing them an accurate engineering and manufacturing cost of the vehicle. This will give an opportunity to meet people from different companies and universities involved in the automotive industry.



1.4 Project objectives

The purpose of the project is to analyze the cost of a Formula SAE team car. The challenges will be to prepare accurate bills of materials trying to optimize the cost of the vehicle. The main points that the project will cover are the listed below:

- Prepare a bill of materials that includes all parts, materials, processes, fasteners or tooling for every system in the car. If we miss something, the judges will penalize it in the cost event.
- Analyze last year's cost report trying to look for any missing parts and introduce the new improvements that the team has done during this year.
- Analyze the different design methodologies such as QFD, Value Analysis and Value Engineering (VA/VE) and DFMA.
- Analysis of the suppliers that provide the different systems to our team explaining the difference between manufacture the parts in the university or purchase them from other companies (Make vs. Buy problems)

1.5 Methodology

During the first month, the tasks were the familiarization with the competition rules, in particular, the cost analysis report. The FSAE competition uses a database where all the different parts, materials, processes, tools and fasteners from all the teams are included. This database allows the teams to use similar manufacturing processes and common parts use in the industry. Then, an analysis of the last year's report is performed to look for possible improvements and to do a better and more accurate cost report. The bill of materials of each part is done in the database and MS-Excel. The deadline to hand in the cost report is the 2nd of April. From this date until the competition, the judges will study the report and in May 9th when the car will be in



Michigan, they will check, if what is included in the cost report makes sense with the car. Depending on the accuracy of it, each team will have a different valuation.

After that, the competition gives each team 3 challenges. I will be working on them trying to look for different engineering and cost solutions for each case and then presenting our final solution in the event. At the same time, I will be working on the Cost Analysis Presentation which I will present on May 10th.

Table 1 illustrates the project timelines for the tasks to be executed between February and May 2018.

TASKS	FEBRUARY		MARCH		APRIL		MAY	
	1st-15th	16th-28th	1st-15th	16th-31th	1st-15th	16th-30th	1st-15th	16th-31th
Introduction								
Competition rules								
Familiarization with the FSAE database								
Analysis of last year's cost report								
Analysis of possible improvents								
Preparation of the BOMs								
Hand in the BOMs (deadline April 2nd)								
Make vs Buy problems								
Study of the 3 real cases								
Elaboration of the real cases								
Cost Analysis Presentation								
Presentation in Michigan (May 10th)								
Final Report								

Table 1 – Project timeline



1.6 Resources

In this project, different resources from my Master in Industrial Engineering will be used. First, I need the knowledge of Finance and Cost Analysis to build the BOMs. In addition, an engineering background is needed to understand the materials, fasteners and tools used in each part of the car in order to see that the dimensions introduced in the database makes sense and are not over or under estimated. The Production and Manufacturing Systems course will help in the study of the real cases and in the Make vs. Buy problems. From the MBA, I am using some content of accounting class in order to do the cost analysis report. Furthermore, Marketing and Economics courses will be used in some aspects.



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Introduction



2. Cost report

The competition requires each team to do a bill of material listing every part of the vehicle. This bill of material includes cost information of the purchased parts, raw materials and different processes of the car.

Many aspects of ER-04 were produced in ways that would reduce the manufacturing costs. This was done on three fronts: fabrication time, tooling requirements and efficient use of stock material.

Most of the tabs, tubes, plates and other components that required 2 dimensional fabrication were laser or water jet cut. This led to the majority of metal components simply being received in the mail, ready for post processing requirements (e.g. welding, forming, etc.)

Another way in which our team reduced cost of manufacturing was in the tooling requirements of the system. A new method of laser cutting locating tabs and slots into each component yielded low tolerances while reducing the need of fixtures for the system.

From the cost challenge at the 2017 competition, we learned about how to reduce the cost of our wheel assemblies by purchasing the stock material closer to the dimensions of the final product, as well as utilizing and mixing manufacturing methods for coarse material removal with inexpensive methods, such as laser cutting, prior to the final precision machining.

This year's vehicle production method also was produced in a much more parallel method than previous years. Instead of building a chassis before beginning on other systems, due to the accuracy of the CAD model, all systems began at once. This meant that shortly after the chassis was welded, which is the single most time consuming task, the rest of the systems were already being test fitted prior to paint.



With more time and manufacturing capabilities in house, cheaper methods for manufacturing that would be more representative of an actual production run process would have been used. This would have lowered the theoretical manufacturing cost.

2.1 Cost tables

ER04 is broken down into 8 systems that are explained with detail in section 2.2. Then, these systems are made up of assemblies and these ones are subdivided in the different parts of the vehicle.

Following the rules of the competition, parts consist of materials, processes and fasteners. Furthermore, some processes require tooling, so it is considered another section in every part of the car.

The competition has a data base with all the materials, processes, fasteners and tools. For every part, the dimensions and material properties (e.g. type, density, etc.) were introduced in the data base. When you introduce all the parameters, the data calculates an estimated cost of the part. These costs have been compiled to represent the cost of parts that a manufacturing company could be expected to pay for manufacturing a vehicle at 1000 units per year. These values represent around half of the manufacturer's suggested retail price (MSRP) for finished parts. The cost of the materials bought in the university represents the production volume of a company and not the purchase price of the university team. [1]

Figure 2 illustrates the structure of the cost report.

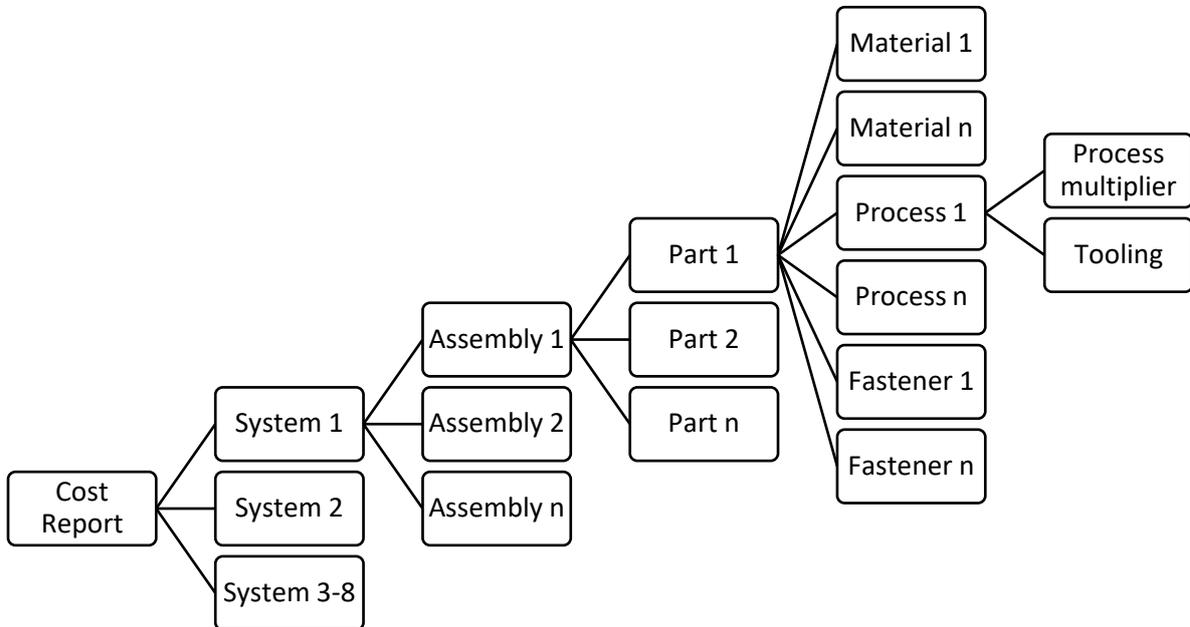


Figure 2- Structure of the cost report

It is very important to understand how the competition defines material, process, process multiplier, fastener and tooling. So a brief definition of each section is explained below. [2]

- Materials: It is divided in two main sections:
 - Raw materials used to manufacture parts built at the university or use by an outside supplier. An example is the carbon fiber bought to build the frame of the vehicle.
 - Finished parts purchased by the university such as the engine control system or the tires.
- Processes: Represent operations that modify the raw materials bought by the university. Some examples are:
 - Lamination, resin infusion or curing for composites.
 - Material removal: laser cutting, waterjet or plasma cutting.
 - Joining: welding, bonding.



- Process multipliers: Modify the standard costs of some operations taking into account differences in the materials and geometry. There are only included in some processes.
- Fasteners: It goes from traditional fasteners such as bolts, nuts and rivets to adhesives and retaining rings. Fasteners are costed by:
 - Grade: There are some requirements such as the fasteners in the driver's cell, in the steering and in suspensions systems must exceed SAE Grade 5 (Metric Grade 8.8)
 - Nominal thread size
 - Length
- Tooling: There is a difference that the students have to understand and it is the difference between tools and tooling:
 - Tools refer to hand or power tools used to assemble the vehicle. The costs of the tools are not included in the cost report.
 - Tooling is the production associated with processes that are specific to the part geometry. These costs must be included in the cost report.
Some examples are:
 - Molds
 - Welding Jigs

Annex A - ER04 Bill of Materials shows the cost of materials, processes, fasteners and tooling of every part of the car. This annex is a section of the cost report that the team sent to Michigan for the Cost and Manufacturing event of the FSAE 2018 competition.

2.2 Organized list of systems and assemblies

The cost report must follow an organized list of systems and assemblies given by the competition. In this section, a brief explanation of each system is given explaining the improvements and details introduced this year's model. In addition, the



cost of every part and assembly are shown and explained. There are eight systems which include all the assemblies and parts of the car.

2.2.1 Brake System (BR)

This assembly is mainly based in two subassemblies: brake system and pedal assembly. The ER-04 braking system and pedal assembly design is an iteration of ER-03's system. The brake fluid system is a continuation of the system used on ER-02. This year our team has made some improvements in order to improve the performance of the assembly:

- A nearly linear pedal ratio.
- The master cylinders size was correctly calculated.
- A nominal balance that can be adjusted rearwards to function in wet conditions.
- A functioning brake over travel switch.

The calculations for the brake system balance component sizing were re-done, along with the pedal geometry. For refinement of the fluid system sizing, the desired motion ratio, and options comparison were conducted utilizing calculations in MS-Excel. The pedal ratio was simulated in order to calculate the travel of the pedal, linearity of the pedal ratio and the change in height of the pedal.

The pedal's lateral play in the pedal assembly was reduced by changing the type of bearings used in the throttle pedal. The play in the brake pedal was reduced by the inclusion of thrust washers on the pivot point to replace the bronze bushings and allow a higher clamp to be applied at the pivot to limit the play. This was required due to the high loads in the pedal pivot, and the only bearing able to be packaged being a needle bearing, which has little to no lateral stiffness. Figure 3 illustrates the pedal assembly, including adjusting features of the same.



Figure 3 - Pedal Assembly

The pedal slide method was changed to accommodate an easier method of adjustment, though the new pedal geometry meant that the full 8 inches of travel was unachievable. Due to this reason, the new assembly achieves 6 inches of travel.

The brake system was designed to utilize existing components to reduce cost. This meant not swapping calipers or brake pressure sensors to save nearly \$2,500. In the case of the pedal assembly, its cost has been reduced from ER-03' vehicle.

Overall the system learned immensely from the errors of the ER-03 iteration and was improved drastically. Current analysis shows that the assembly will be lighter by .5 lbs., meet stricter lateral pedal play requirements, and have a significantly improved drivability due to the reworked pedal ratio and the fluid system cylinder resizing.

The brake system was divided in four assemblies where the pedal assembly has half of the cost of the system. Figure 4 illustrates a detailed cost breakdown of each assembly.

BRAKE SYSTEM

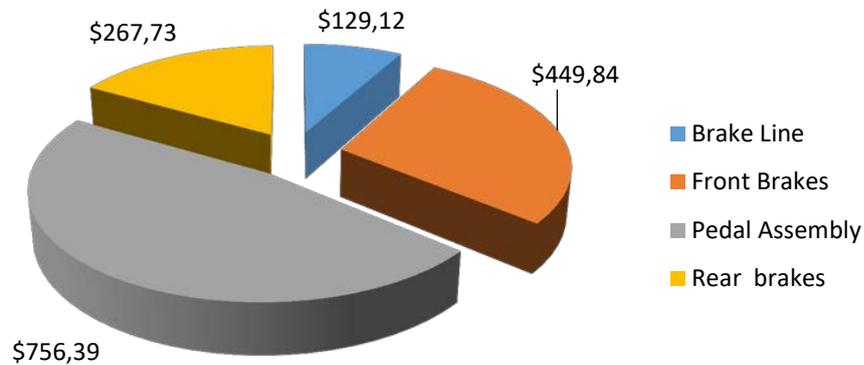


Figure 4- Brake system cost

2.2.2 Engine and Drivetrain (EN)

This assembly is one of the most important and is divided in different subassemblies such as engine, cooling system, differential, drivetrain, exhaust and intake assembly and fuel and oil systems.

The engine used is the Honda CBRA600RR with 599 cc. The cost of this engine was \$1,497.5.

The differential system was re-designed comparing with last year trying to improve the shortcomings of the ER-03 vehicle. The team has built a new design that will be able to tension the chain accurately while maintaining the alignment of the differential. This is done while improving the structural integrity of the mounting system by optimizing part geometry to minimize weight and prevent yielding. This reduction of the weight will carry on a reduction in the cost of the assembly and a better performance of the car. This design also had to improve upon bearing retention and encompass mounting the jack bar. Bearing retention is addressed by added an

internal shoulder to allow the bearing to be pressed to. Figure 5 illustrates the driveline system used in the ER04 model.



Figure 5 - Driveline system

Last year car had four even length headers brought to a 4-1 collector. The last version had 4 mufflers that were selected for their noise cancelling attributes, without too much consideration to the added weight. The figure below shows the ER-03 exhaust assembly.

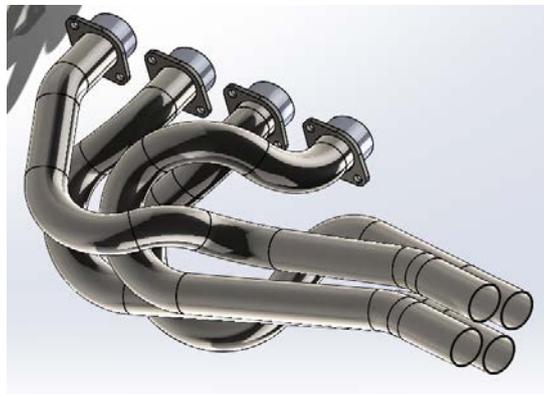


Figure 6 – ER03 exhaust assembly

The weight of the exhaust system was 17.04 lbs. Half of the weight came from the mufflers, so the team decided to redesign the assembly using only one muffler. The new exhaust design is based on a 4-2-1 system. The new system allows a more compact design which aids in the packaging of various other powertrain system components, yielding an overall cleaner package. The figures below show CAD images of the ER-04 design.

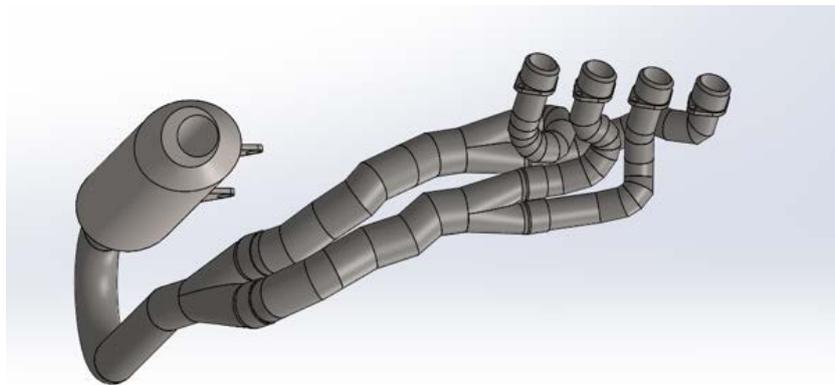


Figure 7 - ER04 exhaust assembly

The new exhaust assembly meets all the goals set for the system and improve the car powertrain package. In addition, it will be cheaper because the material used is less and because the new system only uses one muffler.

Beyond the engine, drivetrain and exhaust assemblies; the cooling system, differential, fuel system, intake assembly and oil system complete all the assemblies of the system. The assembly drawings of some systems such as the cooling system or the oil tank are shown in section **¡Error! No se encuentra el origen de la referencia.** inside the Annex C – Dimensional & Assembly Drawings. The cost of each assembly is represented in Figure 8.

ENGINE & DRIVETRAIN

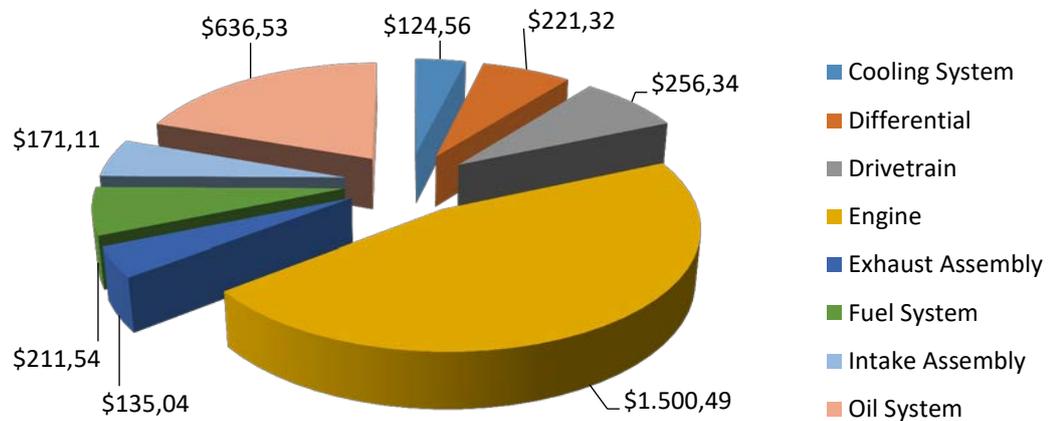


Figure 8 - Engine & Drivetrain system cost

The total cost of this system is \$3,256.3 where almost 50% of the total cost corresponds with the purchase of the engine. Then, the oil system is the second in terms of cost because the oil pump bought in Dailey engineering has a cost of \$429. The rest of assemblies have a cost between \$124 and \$256.

2.2.3 Frame & Body (FR)

The frame is the largest single component of any vehicle. It is the main structure of the car and it gives support to the other assemblies of the car in order to improve their handling characteristics and to reduce weight. There are some specifications given by the competition that the frame has to achieve:

- All primary structure shall be triangulated.
- The frame defining the driver's cell shall not have any gaps greater than or equal to 10 inches in diameter.

- A line from the top of both roll hoops shall be at least two inches away from the top of the tallest driver's head.
- The frame material shall meet the baseline material requirements of mild steel.
- Any holes drilled into the primary structure shall have a welded steel tube insert that shall bring the tube back to the minimum baseline requirements.

Based on the requirements and goals in the design set by the team, the frame is designed and built. Figure 9 and Figure 10 show the side and top view of the frame:

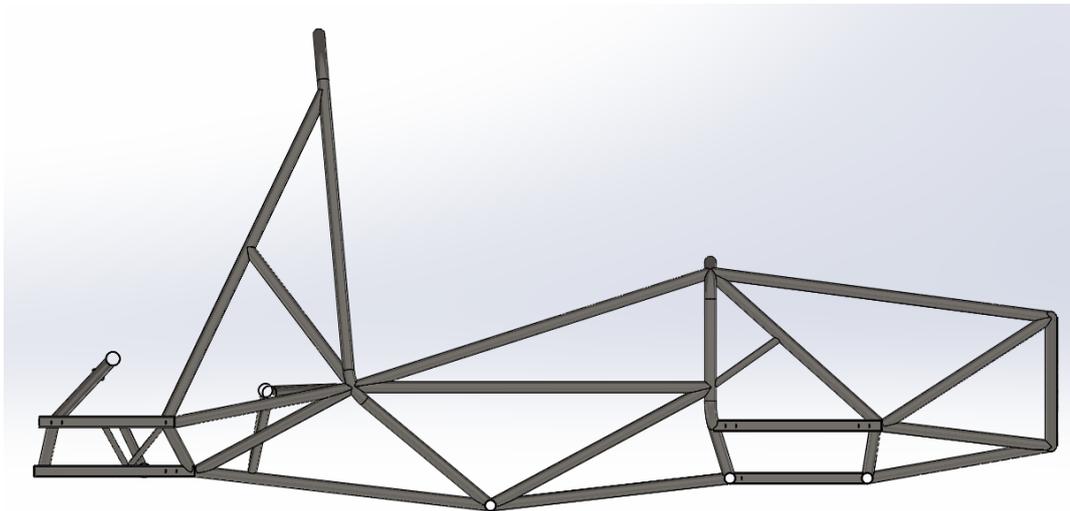


Figure 9 - Frame side view

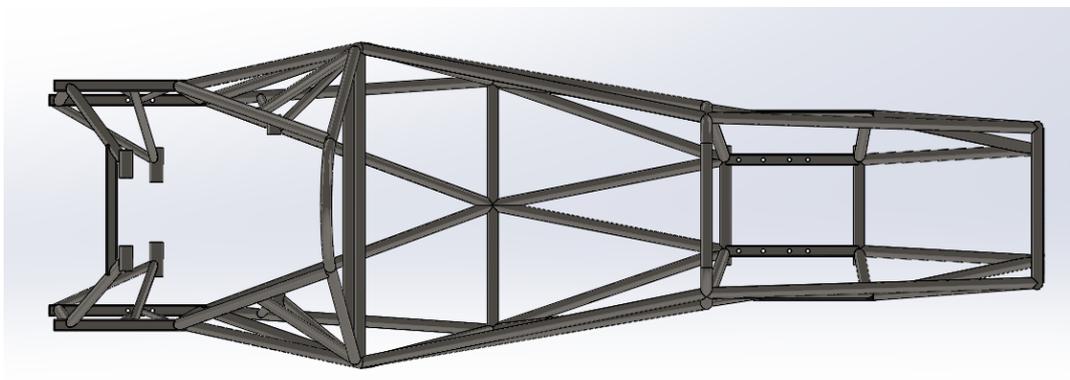


Figure 10 - Frame top view



The combination of the criteria mentioned before created a unique design challenge of designing a lighter and stronger frame without altering the core geometry of the frame. Each criteria was met during design based on analysis conducted utilizing FEA. Many of the requirements were accomplished by redesigning the rear suspension box. The frame was shortened and the full length jack bar tube was removed to reduce weight. These and other improvements from last year were done to achieve the new goals of the team and to reduce the weight of the frame in order to reduce the mass of carbon fiber used in the assembly. This reduction on the mass of the carbon fiber will save the team a lot of money because 1 lb. of carbon fiber has a cost of \$90.72.

Taking into account that the frame is the most expensive assembly of the ER-04 vehicle (\$3,734.61), our team looked for the better and lighter design to get the lowest possible cost of the car. Most of this amount comes from the purchase of the carbon fiber but also from the processes used to transform it such as resin application (infusion molding). ER03's frame weighed 71.5lbs and this year's frame weighs 65 lbs. The vehicle shall retain the same bodywork and aero pack as ER03's, limiting the geometry of the frame. Any mounting points for high stress applications shall have triangulated tubes to ensure the loading does not hinder driving performance.

The 65 lbs. are not only carbon fiber because this assembly has other subassemblies such as the tube space frame made by steel. In this subassembly, due to the high cost of manufacturing it, the team had different options to fabricate the part. The first one was to subcontract a company to build the assembly. The company charged us around \$1,000 for the part. However, the team decided to buy the steel and with different processes such as tube bends, laser cut and weld-round tubing, the team fabricated the part in the university. Here, the university spent most of the money in the weld-round tubing (\$784) but less than the company tried to charge the university to build the assembly.

The frame and body is the system where the team put more effort trying to reduce costs. Last year the cost of this system was \$5,215.18 being one of the most

expensive systems of the competition. As the carbon fiber is a very expensive material, the team tried to reduce the mass of this material as much as possible. This effort became in savings of almost \$1,600 compared with last year's frame.

FRAME & BODY

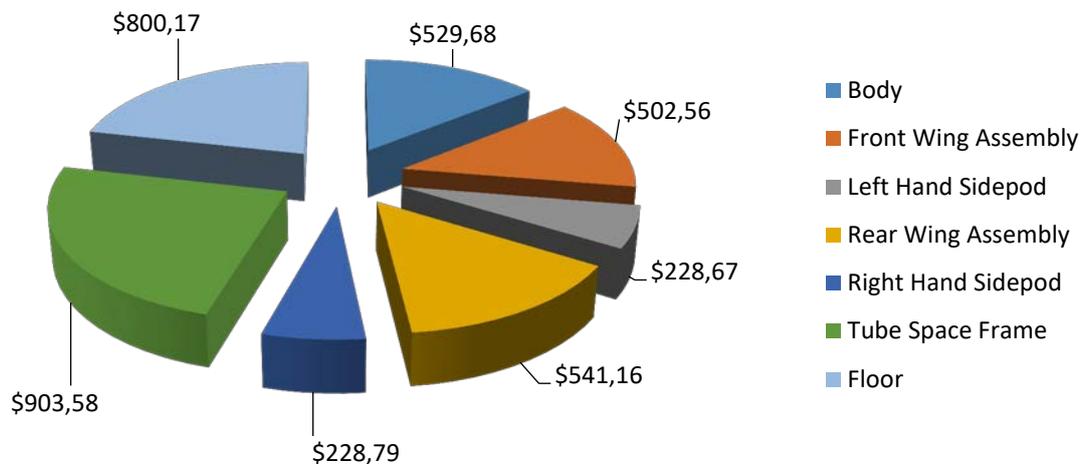


Figure 11 - Frame & Body cost

2.2.4 Electrical (EL)

This assembly includes all the electrical parts and wiring assembly such as engine data control systems, dash, battery and switches. One of the competition requirements is that the vehicle has to have two switches for the shutdown system where if the driver switches either of them, it must stop the engine.

The ER04's primary electrical system consists of Moty 8 Cell LiFePO4 12V Battery, MoTeC M130 Engine Control Unit (ECU), MoTeC C125 Data Logger and MoTeC E816 I/O Box.



Figure 12 – Motec M130 ECU and Motec C125 Data Logger [3]

In order to optimize an already functional electrical and data system, the focus for ER-04 will be to have better cable management, increase thermal management for the engine control unit, documenting the wiring harness, and properly supporting the data acquisition system.

As in most of the other assemblies, the data acquisition system of the ER-04 vehicle will be a continuation of what was intended for use with ER-03. This includes all of the essential measuring components for race monitoring of vehicle behavior. The data acquired will be very important and allow the team to tune the car to perform the best of its capabilities. This system will be very important to analyze the results of the competition in order to improve for the following years.

The electrical system of ER03 was fully functional, and the focus of the electrical system for ER04 will be to reduce unnecessary wires, present a more professional image, and thermal management. ER03 lost points due to poor cable management, and poor thermal management resulted in wires frying out on multiple occasions.

Our team spent \$3,621.26 in this assembly, a number much higher than most of the teams. Reviewing other teams cost analysis report, the big difference between others and our team is that we are using the data logger, Motec, C125 (inside the dash subassembly) that cost \$1,555. If our team does not use this data logger, the total

price of the cost would go down to less than \$15,000, an amount much closer to the goal of the team (\$14,000). For this reason, next year the team may not include this data logger in order to get better results in the cost event.

ELECTRICAL SYSTEM

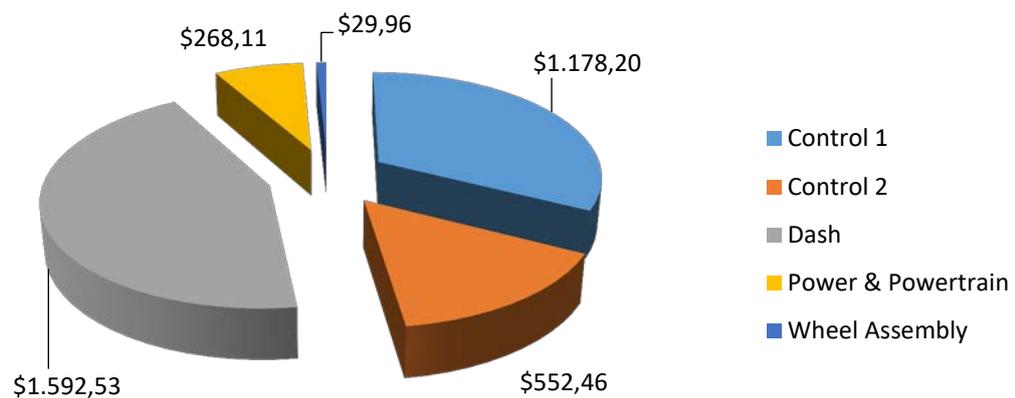


Figure 13 – Electrical system cost

The total cost of this system is \$3,621.26. This number is higher than last year's because this year the team has included an ignition expander module that cost \$482. This module increases the ignition output capacity of the MoTec ECU M130. It will give the team important data that can be analyzed during the tests and the race and it can be important for the design of the next year's vehicle.

2.2.5 Miscellaneous, Finish and Assembly (MS)

This assembly has different subassemblies with completely different functions. There are assemblies from head restraint, seatbelts and seat to impact attenuator, firewall and shifter. The two most complex and the ones analyzed in the report are the firewall testing plan and the shifter.

First, due to the requirements of the firewall by FSAE, it is crucial to find out the temperature on the driver's side of the firewall. For this, the team has used Thermax Temperature Strips, which work by permanently changing color when the strips are exposed to the specified temperature levels. The goal is to have the driver's back to be at a temperature below 60 C, per FSAE regulations.

The second system analyzed in this section is the shifter. Last year the team had several problems with the shifter during the competition. So this year the team put a lot of effort to correct those deficiencies.

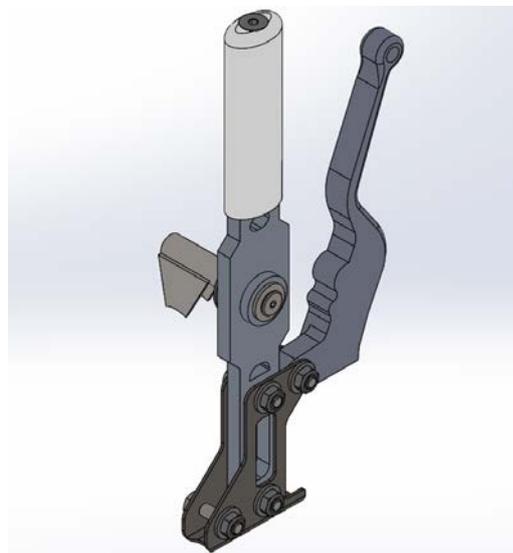


Figure 14 – ER04 shifter

The lack of a shift lever grip in previous design caused drivers discomfort over prolonged use- causing drivers to develop blisters. The improvements designed this year are grip ergonomics, space and weight efficiency, and reduction of x-axis rotation (left to right) of the shift lever. A lightweight, inexpensive grip sleeve is designed to cover the metal of the top half of the shift lever where the driver's hand is placed during operation. This grip will assist the driver in completing the endurance course at the Formula SAE competition. In addition, the profile of the shift lever has been reduced in size and profile. This reduction in size and weight will reduce the cost of the assembly. Finally, the connection between the shift lever and the mounting shaft that



it rotates around was redesigned to limit x-axis rotation to less than 1 degree. The shift lever rotates on two ball bearings spaced out laterally by a housing sleeve. These improvements successfully correct deficiencies in previous shifter assembly design and will aid the ERAU Motorsports team at FSAE Michigan 2018 event.

This system includes the head restraint, seatbelts, firewall, impact attenuator, paint, seat and shifter. The total cost of the system is \$646.6 which is very close to last year's cost.

MISCELLANEOUS, SAFETY & FINISH

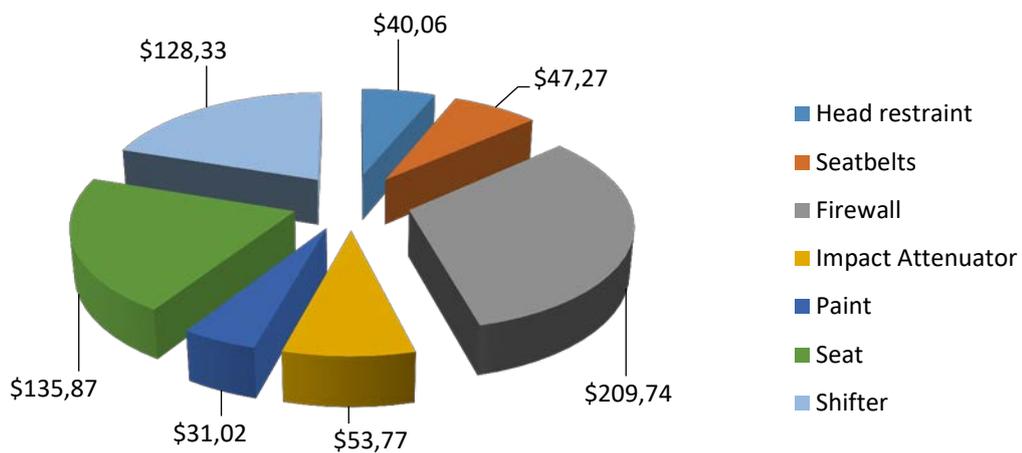


Figure 15 – Miscellaneous, safety & finish system cost

2.2.6 Steering System (ST)

As in some other assemblies, the goal in the design of this assembly was not to redesign the entire system. Instead, the team tried to solve the problems found last year improving the functionality of the system. Last year the team found two main problems in this assembly.

The first was that the steering rack had to be mounted in the center. This caused moments to develop on each side due to the tie rod forces leading to system



instability. The second problem was the overall bulkiness of the system, which led to some difficulties when getting the car to pass the competition rules. In order to solve the first problem, a new steering rack which would allow end mounting had to be selected. This changed the steering arm, and the Ackermann had to be calculated for the rack to be placed within ER-04's chassis. Once this was done, the steering column was redesigned. Previously two aluminum U-Joints were used, with steel tubes connecting them to each other, to the steering rack, and to the steering wheel. In the new design, a single steel U-joint was used. This was placed at the top of the column to reduce the angle it had to operate at. The final part of the system is the upper support. This component on ER-03 was over-designed, and able to withstand a far greater load than it would ever see. This added unnecessary weight to the system and also ended up making it too large for the pass-through template. The new support was designed to be small enough to easily fit the pass-through template. Additionally, it was designed to support much closer to the loadings that it would actually see. The final system is much simpler, more compact, and more stable than that of ER-03.

Figure 16 shows the cost of the different assemblies in the steering system. The price is \$247.52 which is very similar to last year's. It is the cheapest system of the car representing 1% of the total cost.

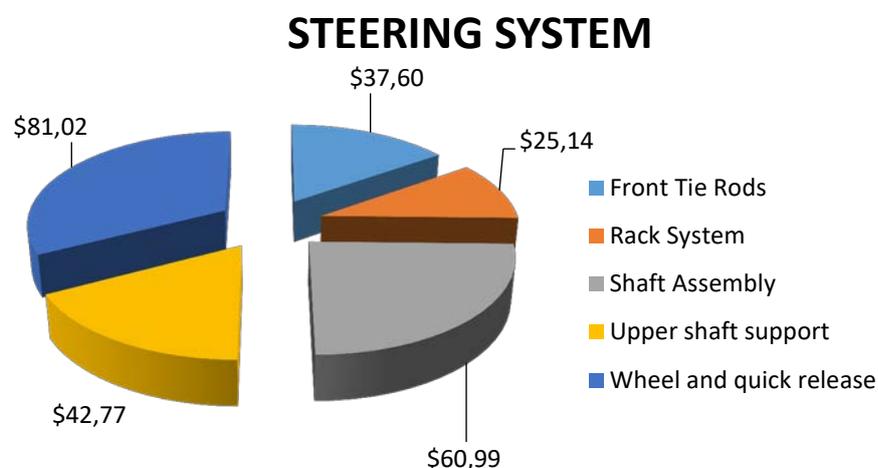


Figure 16 – Steering system cost



2.2.7 Suspension System (SU)

The main function of this assembly is to support the weight of the other assemblies while connecting the vehicle to its wheels and allows motion between the two. This assembly is divided in 3 other subassemblies that are the control arms, front shock and rear shock.

Most of the suspension assembly of the ER-03 will carry over to ER-04. This year the team has been working in the flags presented in last year competition. Two of the main ones are the poor interference fit of spherical bearing at A-Arm joints and sources of friction in rotating components and clearance with surrounding systems such as the uprights and steering rack.

In order to meet all the requirements given by the competition and to achieve a good performance of the car in the competition, the team had a goal of spending \$1,400 in the assembly. However, the team spent a total of \$1,679.55 in this assembly.

Different analysis in ER-03 vehicle demonstrated that there were different parts that had numerous stress concentrations at critical locations such as the tie rod mounting point. The team redesigned the uprights in order to solve these issues. In the ER-03, the uprights were designed without caster angle which had a significant impact on optimization of suspension loading during turns. In order to improve the performance of the car, this year the team has added the caster to the assembly that allows for increased grip in a turn.

The purchase of the dampers represents most of the cost of the assembly. Each damper costs \$305, so the 4 dampers have a total cost of \$1,220. The model used for the dampers is the Ohlins TTX 25 model from KAZ Technologies.



Figure 17 – ER04 dampers [4]

In addition, this system has 8 rod ends with a total cost of \$65.2 and 24 spherical bearings with different metrics and a total cost of \$146. The cost of every assembly of the system is shown in Figure 18.

SUSPENSION SYSTEM

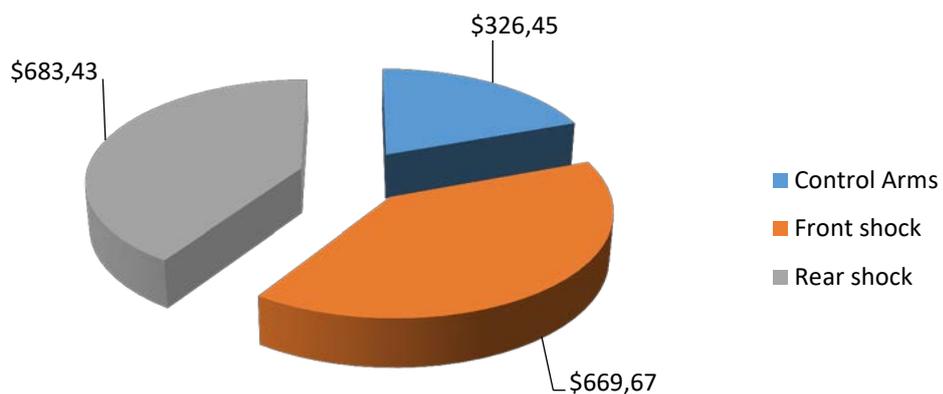


Figure 18 – Suspension system cost

2.2.8 Wheels, Wheel Bearings and Tires (WT)

Regarding to the rules, the vehicle must be open-wheeled and open-cockpit (a formula style body). The “Open Wheel” concept means that the wheels must be unobstructed when seen from the sided and vertically as it is shown in next picture [1].



Figure 19: Definition of open wheel [1]

In addition, no part of the vehicle may enter a keep-out-zone defined by two lines extending vertically from positions 75mm in front of and 75mm behind, the outer diameter of the front and rear tires in the side view elevation of the vehicle, with tires steered straight ahead [1].

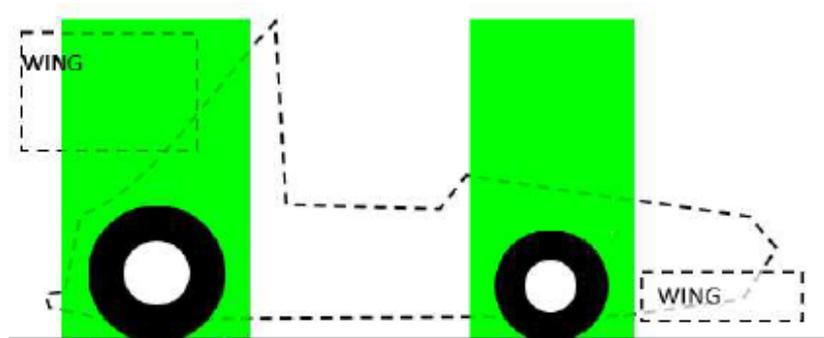


Figure 20: Keep Out Zones [1]

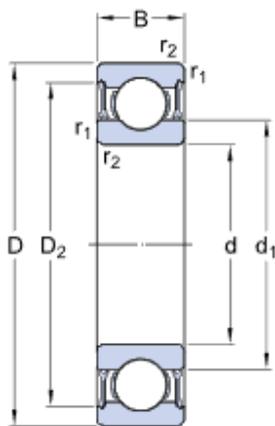
Comparing the front with the rear wheels, the first ones are \$80 more expensive each because less machining in the uprights and wheel center parts was needed.

The tires used are Hoosier and the model is R25B, 10"-18.0 x 6.0. The cost of each tire is \$85.



Figure 21: Hoosier tire [5]

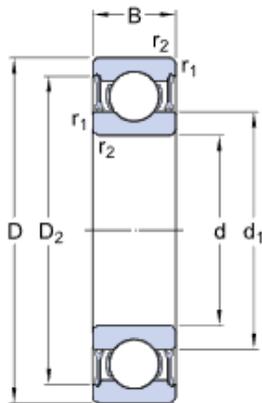
The bearings used in the front and rear wheels are different. The front wheels use the SKF 61813-2RZ model and its dimensions are:



d	65	mm
D	85	mm
B	10	mm
d ₁	≈ 71.4	mm
D ₂	≈ 80.5	mm
r _{1,2}	min. 0.6	mm

Figure 22: SKF 61813-2RZ bearing [6]

On the other hand the rear wheels use the SKF 61813-2RZ model. The dimensions are:



d	80	mm
D	100	mm
B	10	mm
d ₁	≈ 86.7	mm
D ₂	≈ 95.7	mm
r _{1,2}	min. 1.3	mm

Figure 23: SKF 61816-2RZ bearing [7]

Figure 24 shows the total cost of each wheel of the ER04.

WHEELS AND TIRES

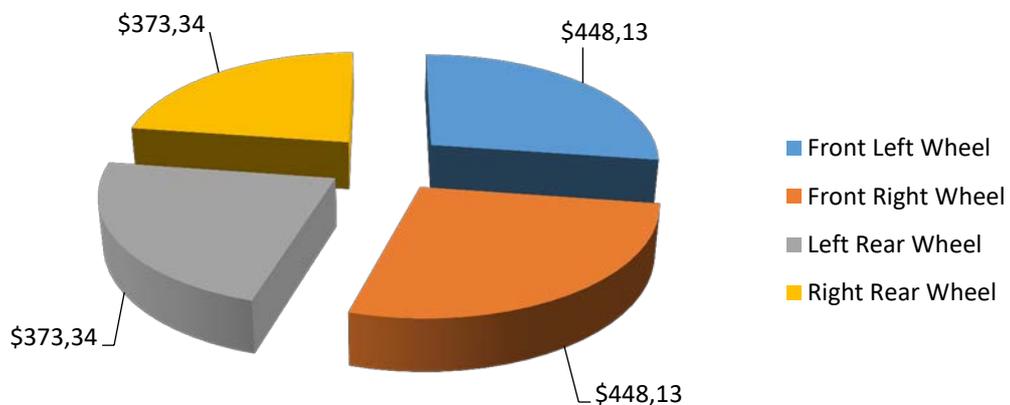


Figure 24 – Wheels and tires system cost

2.3 Cost Summary

This section shows the total costs of every system summarized in a table. It is possible to see the total costs of the materials, processes, fasteners and tooling. As it is seen in Table 2, most of the cost comes from the materials because this section



includes the raw materials and also the parts bought from other companies such as the engine or the control system.

Area Totals	Materials	Processes	Fasteners	Tooling	Total
Brake System	\$ 1.461,20	\$ 137,39	\$ 4,49	\$ -	\$ 1.603,08
Engine & Drivetrain	\$ 2.809,77	\$ 421,04	\$ 26,12	\$ -	\$ 3.256,93
Frame & Body	\$ 2.355,63	\$ 1.195,16	\$ 53,69	\$ 130,13	\$ 3.734,61
Instruments & Wiring	\$ 3.481,84	\$ 136,52	\$ 2,23	\$ 0,67	\$ 3.621,26
Miscellaneous, Fit & Finish	\$ 494,08	\$ 103,65	\$ 44,76	\$ 3,57	\$ 646,06
Steering System	\$ 136,46	\$ 109,40	\$ 1,66	\$ -	\$ 247,52
Suspension & Shocks	\$ 1.480,13	\$ 148,66	\$ 9,42	\$ 41,34	\$ 1.679,55
Wheels & Tires	\$ 1.062,32	\$ 574,86	\$ 5,76	\$ -	\$ 1.642,94
Total Vehicle	\$ 13.281,43	\$ 2.826,68	\$ 148,13	\$ 175,71	\$ 16.431,95

Table 2 – Cost summary

As it is seen in Table 2, the most expensive systems of the car are the frame, the instruments and wiring system and the engine and drivetrain. On the other hand, the cheapest system of the car is the steering system. To compare all the systems, Figure 25 shows the cost percentage of each system.

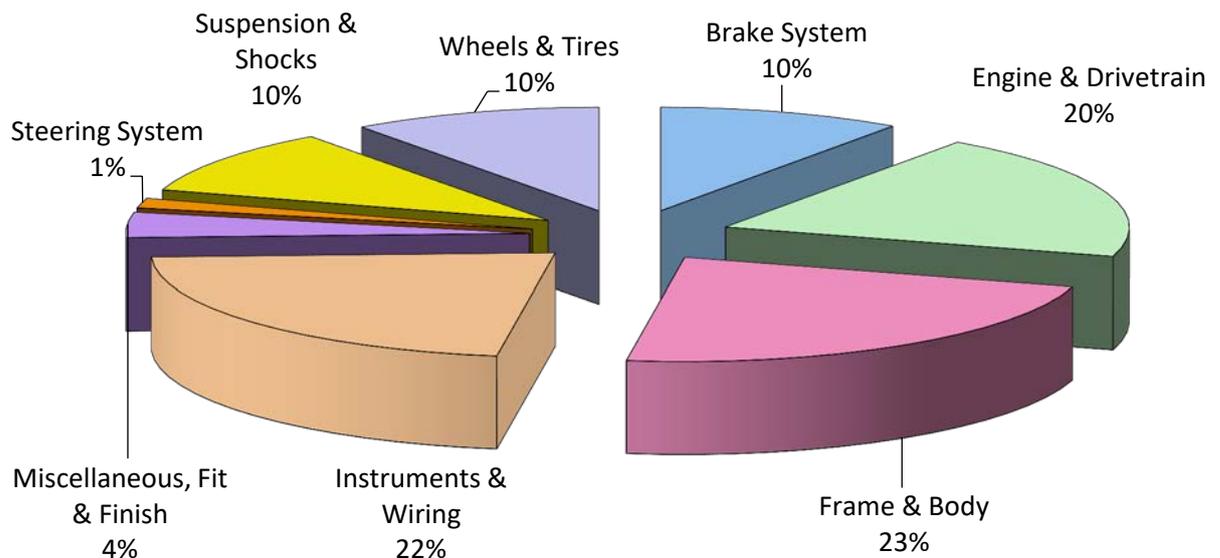


Figure 25 - Area Percentages



The frame is the most expensive system of the vehicle (23% of the total cost). The main reason of the high cost is the high price of the carbon fiber and its process (mainly resin infusion and curing). Then, instruments and wiring system is the second one due to the high cost of the engine controls (\$1,582) and the data logger (\$1,555). The third most expensive system and very close to the first two is the engine and drivetrain. In this system, the cost of the engine represents half of the price of the system.

The cost of the brake system, suspension & shocks and wheels and tires is very similar (10% each). The cheapest systems are the miscellaneous, fit and finish system with 4% of the total and the steering system with only 1%.

Comparing the totals between materials, processes, fasteners and tooling, Figure 26 shows the percentage of each section, where materials represents 81% of the total cost, processes the 17% and fasteners and tooling only represent 1% each.

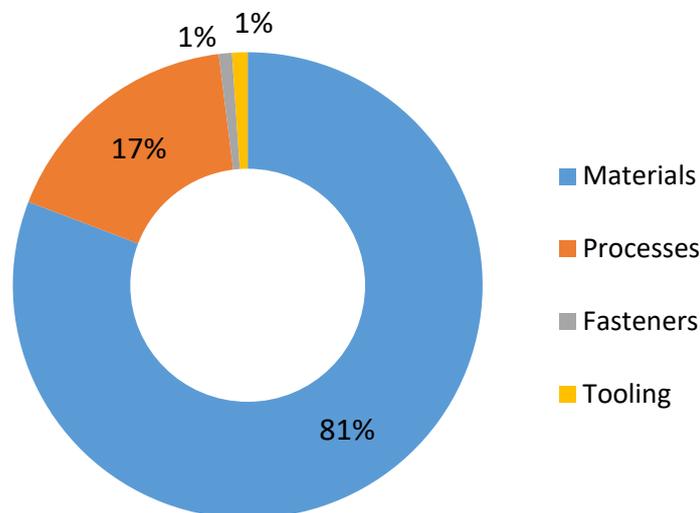


Figure 26 - Section totals





3. Design Methodologies

The objective of these methodologies is reducing the cost in the design and development of the products and their impact in the manufacturing cost through the life cycle of the product.

The concurrent engineering requires the coordinated work of the different departments in order to get a good impact in the design and development process of the product. If these methodologies are applied, the company will have long term benefits [8].

3.1 Quality Function Deployment (QFD)

The first methodology studied is Quality Function Deployment. Based on the preferences of the customers, this methodology will relate them with the different systems of the vehicle in order to see which elements of the car are the most important for the customers.

This methodology has three main objectives [9]:

- Prioritize the expressed needs of customers with respect to the product.
- Translate those needs in terms of characteristics and technical specifications.
- Design, produce and deliver a quality product or service, focusing on customer satisfaction.

The team went to different racing events in Central Florida where we could speak and ask different questions to different fans of the racing world that may be potential customers for the vehicle. After going to these events and doing some research, the main needs of a potential driver are shown in Table 3. Each need goes with a weight (from 1 to 5); being 5 the most important need of the potential driver.



No	Customer Needs	Weight
1	Speed	2
2	Durability	3
3	Simpliicity	2
4	Cost	3
5	Handling	4
6	Performance	5
7	Weight	3
8	Comfort	1
9	Safety	5
10	Fuel Consumption	1

Table 3 – Customer Needs

As it is seen in Table 3, the most important needs of a race car (FSAE vehicle) are performance and safety. The less important needs are fuel consumption and comfort. Surprisingly, speed is not very important for most of the drivers. They prefer other aspects such as good performance and handling, where they say they can get better results in the competition. As these competitions are a hobby for most of the drivers, they all agree that safety is always one of the most important aspects in the car.

Table 4 illustrates the customer-design QFD. The client needs and their weight are located on the left of the matrix and the different systems of the car are on the top of the matrix. Then, the relations between the needs and the systems are established with the following code:

- 9: High relation between the customer need and the system of the car.
- 3: Medium relation between the customer need and the system of the car.
- 1: Low relation between the customer need and the system of the car.



After setting the relations between the customer needs and the vehicle systems, the importance of each system is calculated multiplying the weight of the need by the relation with the system (1, 3 or 9). For example, the importance of the steering system is calculated as:

$$\text{Steering system importance} = 9 * 4 + 3 * 5 + 1 * 5 = 56 \quad \text{Eq. 1}$$

Following this methodology for each system, it is seen in Table 4 that Engine & Drivetrain and Frame & Body are the most important assemblies of the vehicle. Then, Miscellaneous, Safety & Finish and steering system are next in the list with 16% and 14% of the total points. The four systems left are not very important for the customers with less than 8% of the total points. Table 5 shows the importance of the vehicle systems based on the customer needs.

No	Technical Systems	%
1	Engine & Drivetrain	23%
2	Frame & Body	22%
3	Misc, Safety & Finish	16%
4	Steering system	14%
5	Brake system	8%
5	Wheels & Tires	8%
7	Electrical system	6%
8	Suspension system	3%

Table 5 – Vehicle systems importance

In addition, the triangle on the top of the matrix shows how related are the different systems of the vehicle. The bulk point shows a high relation between the systems and the superficial point shows a low relation.



Once the importance of the vehicle systems is calculated, next step is to see the importance of some of the most important specific components of the vehicle based on the weights of the vehicle systems shown in Table 5.

The next QFD is the Design-Components matrix. The car systems with their weight are located now on the left of the matrix and the specific components on the top of the matrix. As the vehicle has thousands of components, ten of the most important are chosen to be studied in the QFD matrix.

Following the same process as in the other QFD, the relation between systems and components is established with 9, 3 or 1 depending on the degree of relation.

Table 6 illustrates these relations and the importance of each specific component following the same method as before. An example of the importance of the specific component is:

$$\text{Balance Bar importance} = 8 * 9 + 14 * 1 + 3 * 3 = 95 \quad \text{Eq. 2}$$



No	Technical Systems	Weight	Specific Components										Importance	%			
			Engine	Shifter	Dumpers	Engine Control Unit (ECU)	Oil Pump	Sensors & Switches	Firewall	Balance bar	Differential	Steering wheel					
1	Brake System	8															
2	Engine & Drivetrain	23	9	3		3	9	1									
3	Frame & Body	22	1	1	1				3					1			
4	Electrical System	6	3	1		9	1	9									
5	Misc. Safety & Finish	16		3					9								
6	Steering system	14										1		9			
7	Suspension system	3											3	1			1
8	Wheels & Tires	8															
Importance			247	145	87	123	213	125	210	95	151	129	1525				
%			16%	10%	6%	8%	14%	8%	14%	6%	10%	8%	100%				

Table 6 – Design-Components QFD



As it is seen in Table 6, the engine is the most important part of the car followed by the oil pump and the firewall. This makes sense with the results obtained before because the engine and the oil pump are in the Engine & Drivetrain system that is the most important system of the vehicle. In addition, most of the drivers agreed that safety was one of main aspects in a race car. Due to this, the firewall is also one of the most important parts of the car.

Table 7 shows the importance of the 10 specific components of the car chosen to analyze the Design-Components QFD matrix.

No	Specific Components	%
1	Engine	16%
2	Oil Pump	14%
3	Firewall	14%
4	Differential	10%
5	Shifter	10%
6	Seering Wheel	8%
7	Sensors & Switches	8%
8	Engine Control Unit	8%
9	Balance Bar	6%
10	Dumpers	6%

Table 7 – Specific components importance

The next step in the analysis would be the manufacturing process and quality plan QFD matrixes. However, the manufacturing process is not the goal of this project. With this analysis, now the team is able to understand the following aspects:

- Customer needs and wants.
- Most important and valuable systems of the vehicle.
- Relations between customer needs and vehicle systems.



3.2 Value analysis/Value engineering (VA/VE)

Value Analysis and Value Engineering can be defined as the systematic application of a set of techniques that identify necessary functions, establish values for them and develop alternatives to perform them, at the least possible cost. Its objective is to make available the appropriate tools to the managers of the company for the correct use of its resources.

Value engineering is based on the improvement of the design and product specifications in the research, development and design stage. In other words, VE is concerned with new products [10].

On the other hand, value analysis is focused on the improvement of the design during the production. It looks for improvements to get a better or a cheaper product. VA is concerned with existing products.

The main differences between Value Analysis and Value Engineering are shown in Table 8.

Value Analysis	Value Engineering
Existing product or service	New product or service
Manufacture, After sales	Prototyping, Design or Pre-manufacture
Process innovation	Function breakthrough
Unnecessary cost, Improvement in performance	Increase Value

Table 8 - Differences between VA & VE [10]

Applying this methodology to your situation will have some of the following benefits [8]:

- Less complexity in the prototype.
- Increase in standardization of the elements.
- Improvement in the functional aspects of the product.
- Better maintenance.

- It can improve the product life.
- Cost reduction.

An example of Value Analysis is shown in the redesign of the front uprights of the ER03's suspension system. They were tested in order to see if they had suffered during the competition in 2017. The results of the Finite Element Analysis (FEA) are shown in the following figure.

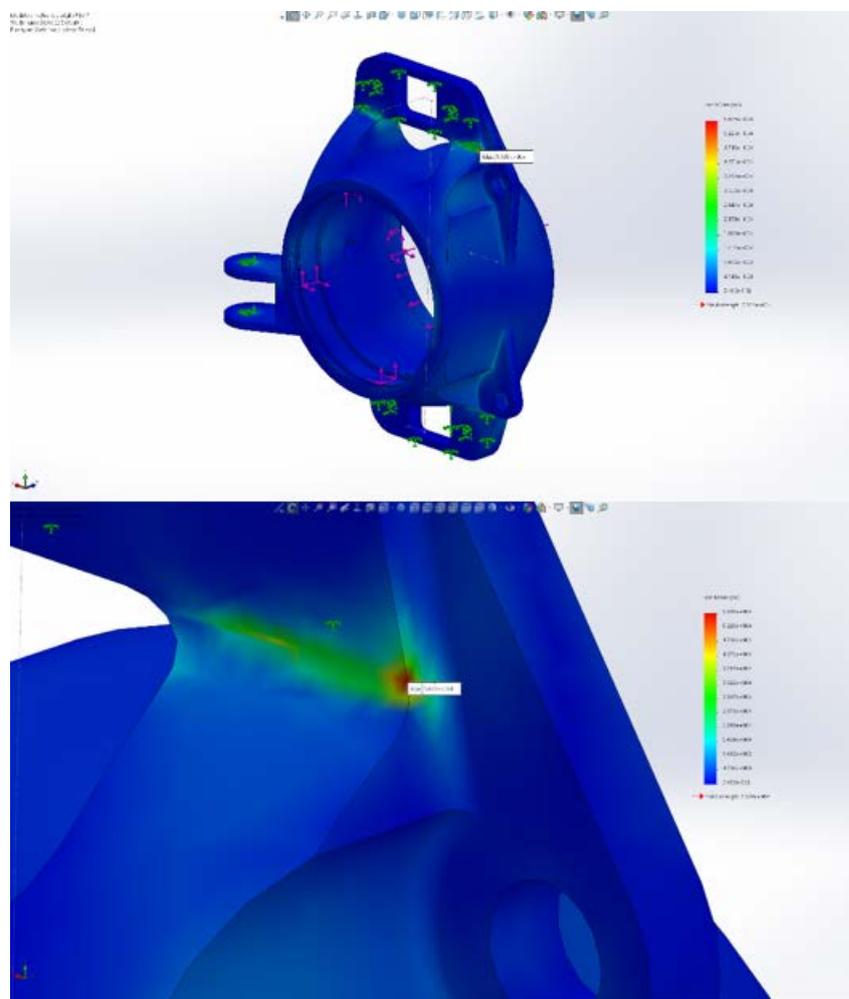


Figure 27 – FEA of ER03 Uprights

It is seen that the edge suffered during the competition. In addition, the part was not designed for ease of manufacturing; requiring multiple fixtures and complex

3D contour machining resulting in an expensive part. Due to these two reasons, the part was redesigned. The ER04's uprights are shown in Figure 28.

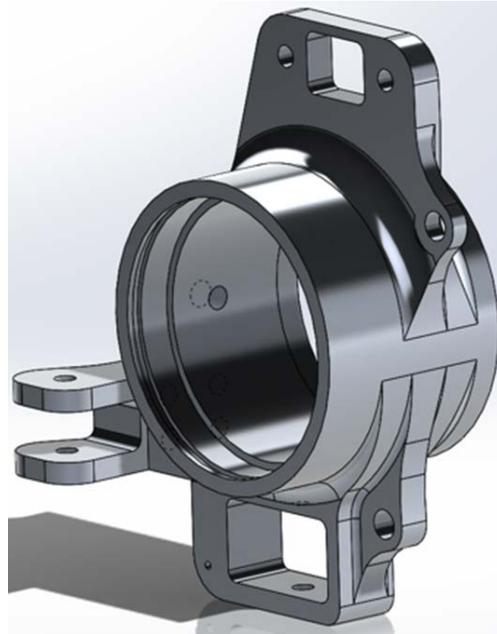


Figure 28 – ER04 Upright

This model solved the problems in the edge and it was easier and cheaper to manufacture. In addition, the upright was designed as a two-piece part in order to have an easier manufacturing. By creating two pieces that can be manufactured with 2.5D machining, versus the complex 3D contour machining required to produce ER-03's uprights, the time and cost of the pieces could be substantially reduced.

3.3 Design for Manufacturing and Assembly (DFMA)

This methodology is an application of the Concurrent Engineering oriented to manufacturing and assembly. It consists of a set of techniques and methodologies for improving the design (or redesign) of a product that, while respecting its essential functions, aims to improve the aspects of manufacturing, assembly and costs. The main objectives of this methodology are [11]:

- Improve manufacturing and assembly operations.

- Reduce manufacturing and assembly costs.
- Optimize the use of equipment.
- Reduce the investments in equipment.

On the one hand, DFM is the technique that looks for the right compatibility between product design and manufacturing process trying to reduce the manufacturing costs.

An example of DFM is shown in the brake pedal (Figure 29), where it is seen that the new design is less complex so it needs less maintenance and the manufacturing is cheaper.

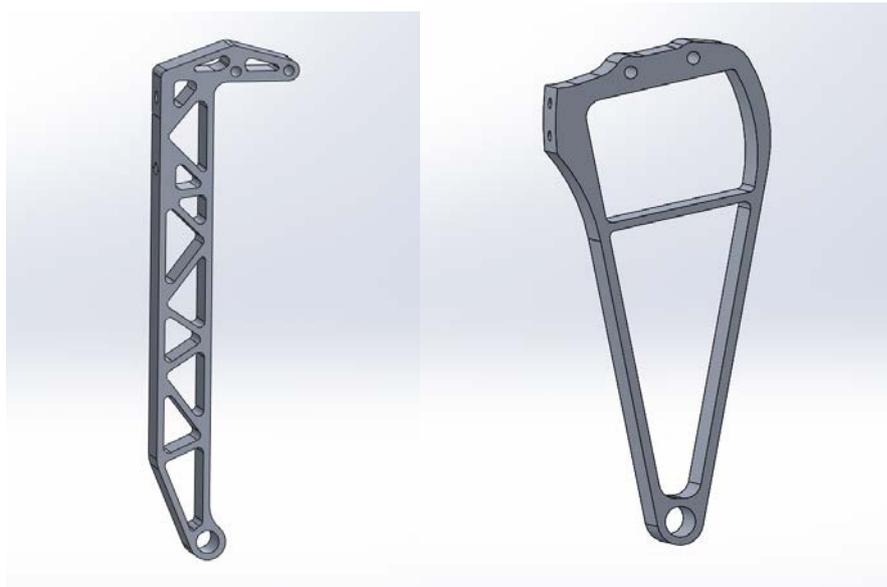


Figure 29 - ER03 brake pedal (left) vs. ER04 brake pedal (right)

On the other hand, DFA tries to modify the geometry of the part in order to ease the handling or insertion of the assembly components and reducing the numbers of components.

An example that includes DFM and DFA is the differential mounting system. In this case, the team had three options. In order to choose the right one, the team did a study of weight, complexity, manufacturability and functionality of each system. Table



9 shows the decision matrix where 2 means optimum or ideal, 1 means that it will work (but not ideal) and 0 means that the system needs significant improvement.

Differential Mounting System		Weight	Number of Components/Complexity	Manufacturability	Functionality	Total
1	Rigid Mounts with Chain Tensioner	2	1	2	1	6
2	Rotating Mounts with "in-sync" turnbuckles	2	2	2	1	7
3	Rotating Mounts with Eccentric Adjustment systems	2	0	1	1	4

Table 9 – Decision Matrix for ER04 Differential Mounting System

Based on the DFMA analysis the team decided to use the rotating mounts with “In-sync” turnbuckles. This system had the same characteristics as the first one. However, the one chosen by the team had less number of components so the assembly operations are easier and cheaper.



4. Make vs Buy analysis

The parts of the car can be classified as made or bought. This designation does not necessarily refer to whether a team actually purchased or fabricated a part. It is a classification designed by the competition of how the part must be cost in the cost report for the competition [1].

In this section, the difference between manufacturing one or a big set of cars is analyzed. In addition, the main attributes in make versus buy problems are discussed.

4.1 Manufacturing vs Prototype

Two different points of view are analyzed in this section because it is completely different when you are manufacturing 100 cars than when you are only building one prototype. The FSAE competition requires each team to present a business plan where each university has to simulate a business plan. In this case, the university is a company that manufactures and sells cars to different buyers. Some members of the team went to different racing events in central and north Florida to analyze the possible buyers. The team prepared a set of questions to look for information about the buyers such as how much money they are willing to pay for a FSAE vehicle or the most important characteristics in the car (safety, speed or balance). Once the research was done, the next step was to compare the costs with the revenues analyzing the profit in the following five years.

However, the business plan is the main point of a different project. Here, the main goal is to analyze the cost of the car manufactured in the university.

The main parts discussed in this section are the following:

- The resin infusion is an expensive method to fabricate composites parts. So in the case that the university manufactures a big number of cars, this process will be much cheaper than if there is only one car manufactured.



- The second point studied is the frame. It is a very complex part of the car, so it is easier to manufacture it at the university instead of asking an outside company to weld it. This will carry on a better design making sure that the manufacture of the frame is exactly what the team wants. In addition, as the university has the equipment needed, it is cheaper to weld the prototype in the university. However, in the hypothetical case that our university manufactures 100 FSAE cars, as the outside company already knows how to weld the frame, the cost of welding the frame with the outside company would be cheaper.

In conclusion, when Make vs. Buy problems are analyzed, it is very important the number of products produced in order to decide to buy the parts from other companies or to make them at home.

4.2 Main attributes to analyze

4.2.1 Quality

Quality is always the main attribute. The competition has different rules that specify the minimum weight and other different regulations to make sure that the driver is always safe. Some examples are the driver's seat, seatbelts or the steering wheel. In this specific event there were no luxury items such as audio system or in some cases the vehicles did not have dashboards because it increases the cost of the car and this penalizes the score in the cost report. [12]

In the case of our university, there is the opportunity of manufacturing some parts with plasma cutting in the university. However, with this process it is very difficult to get the settings needed by the team. In addition, this process changes the material properties and this would be harmful for the parts. At the end, the team did not obtain good quality with this process, so we decided to manufacture these parts



outside the university with laser cutting and water jet, having higher quality in the parts than when the plasma cutting was used in the university.

4.2.2 Control over time

A good example of this is when in the ER-02, the university decided to weld the frame outside. This took a lot of time because the frame is a complex part that others may not know as the ones that designed it. In addition, the frame came incomplete to the university. From that year, the university decided to weld the frame in the university obtaining much quicker and better results.

4.2.3 Skills

In the team there were two professors that supervise the work of the students. One professor has been working in the racing world since he was 18. In addition, he participated and won the competition as a student with Cornell University. So he had the ideal skills to lead the team. However, the students were the main responsible in the design of the car. The main skills needed were [13]:

- a) An interest in motor vehicle engineering and design.
- b) A high level of numeracy and technical competency, with an understanding of the applications used within design and production.
- c) The ability to analyze and interpret data to help with problem-solving.
- d) Good time management and organizational skills to make sure design projects and production run to schedule.
- e) The ability to work within cost constraints. This skill is the one more related with the project because the students had to manufacture the car trying to get the different parts as cheap as possible in order to get a good result in the cost report.
- f) A commitment to keep up to date with design and engineering technology to meet the competition deadlines.



4.2.4 Equipment

The equipment needed for the processes is basic in the election of making or buying the part of the car. The prices of the equipment are completely different depending on the process. The following examples show the prices of some equipment.

- a) Welder: The price of a welder may be around \$4,000. This is cheap equipment that the university can afford, so most of the processes that need welding are done in the university in order to save costs.

- b) Laser cutter: In this case the purchase of this equipment is around \$500,000. The university does not have this equipment so the parts that required laser cutting were done in an outside company located in New Smyrna Beach (Florida, USA).



5. Manufacturing processes

This section explains some of the processes used in the manufacturing of the ER04. It is divided in two main parts: The first one includes processes used in the transformation of metal parts (steel and aluminum plates). The second one studies the processes for the composite parts that are the most expensive parts in the car.

Annex B - Formula SAE Manufacturing Outline shows the processes done in every part of the vehicle. Some of them are cutting (laser, water jet or plasma), machining, assemble, 3D print, layup or welding. In addition, material source, lead time and number of parts bought or manufactured are shown in the annex.

5.1 Metal parts

The main cutting processes were used depending on the type of material and the desired settings of the part. The best process depends on what is most valuable to you going from the cost of the equipment to operating cost, quality, precision or production rate [14]. The cutting processes used in the manufacturing of the ER04 were laser cutting, water jet and plasma cutting. The university only has equipment for plasma cutting. However, the results obtained with this method were worse than with the other two. These three methods are studied in order to decide which method was used for each part.

Annex C – Dimensional & Assembly Drawings shows the dimensional drawings of three different parts of the vehicle manufactured with the three different cutting methods.

5.1.1 Laser cutting

The equipment for this process is the most expensive starting at \$350,000 and in some cases it can exceed \$1,000,000. Due to the high cost of the equipment, the university does not have this machine, so the parts that need laser cutting were

manipulated in an outside company (JD Laser). As the quality of the parts was good enough for our goals, it was the main method used because the operating cost was less than using water jet. In addition, the production rate that is judged by measuring cutting speed is higher when using this method.

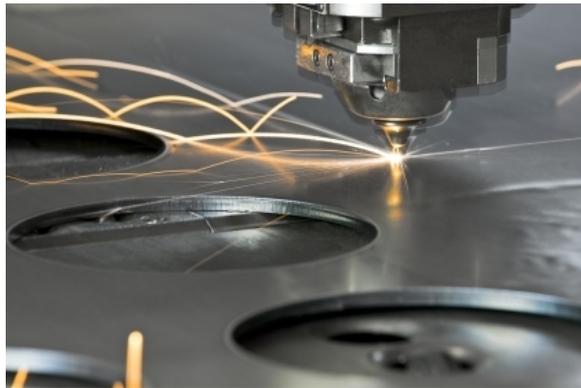


Figure 30 - Laser cutting [15]

This method can be used with metals, some plastics and fiberglass. The cut part precision is very close to water jet, being around $\pm 0.005''$ and it can cut thin and thick metals at the same time.

The main disadvantages of this method are the high cost of the equipment, the micro fracturing on some materials (very important for other industries such as the aviation industry) and a high cost for cutting assist gas that can be more than \$15 per hour. [16]

The parts done with this method are very easy to produce in an outside company because you only have to provide them the CAD file in Solidworks.

Table 10 shows all the parts manufactured with laser cutting. It shows the material of the part, which in this case are 4130 and 4130N steel depending on the part. Furthermore, it shows the quantity, thickness of the plate or tube and supplier. JD Laser is the supplier that manufactured all the parts. They have 2D, 3D and tube laser machines that manufacture the part based on the CAD model. These lasers are



able to cut at high speed being a very cost-effective method resulting in lower costs for the university [17].

Some examples where laser cutting was used are the brake pedal mount or the outer differential mount bracket which dimensional drawing is in Annex C – Dimensional & Assembly Drawings. Others are shown in next table.



Formula SAE Manufacturing Outline - Laser Cutting					
Item Number	Description	Material	Quantity	Thickness	Supplier
1	Seat belt mounts - thick steel	4130	2	0,25	JD LASER
2	E-Stop Bracket	4130	1	0,065	JD LASER
3	Mount Tube	4130	1	0,065	JD LASER
4	Brake Pedal Mount	4130	2	0,160	JD LASER
5	Master Cyl Mount	4130	2	0,100	JD LASER
6	Brake Overtravel Mount	4130	2	0,063	JD LASER
7	Thick Rail	4130	1	0,160	JD LASER
8	Slider 1	4130	2	0,125	JD LASER
9	Slider 2	4130	2	0,071	JD LASER
10	Thin Rail	4130	2	0,080	JD LASER
11	Throttle Pedal Mount	4130	2	0,100	JD LASER
12	Throttle Linkage Bracket	4130	2	0,080	JD LASER
13	Heel Plate Mount	4130	2	0,063	JD LASER
14	Thottle Cable Mount	4130	2	0,063	JD LASER
15	rear upper a-arm	4130	4	0,07	JD LASER
16	REAR LOWER AARM	4130	2	0,07	JD LASER
17	FRONT UPPER AARM MOUNT	4130	4	0,07	JD LASER
18	FRONT LOWER AARM MOUNT	4130	4	0,07	JD LASER
19	REAR LOWER AARM/TIE	4130	2	0,07	JD LASER
20	FRONT RIGHT UP FOR AARM	4130 N	2	0,049	JD LASER
21	FRONT RIGHT UP AFT AARM	4130 N	2	0,049	JD LASER
22	FRONT RIGHT LOW FOR AARM	4130 N	2	0,049	JD LASER
23	FRONT RIGHT LOW AFT AARM	4130 N	2	0,049	JD LASER
24	REAR LEFT UP FOR AARM	4130 N	2	0,049	JD LASER
25	REAR LEFT UP AFT AARM	4130 N	2	0,049	JD LASER
26	REAR LEFT LOW FOR AARM	4130 N	2	0,049	JD LASER
27	REAR LEFT LOW AFT AARM	4130 N	2	0,049	JD LASER
28	Outer Diff Mount Bracket	4130 N	2	0,250	JD LASER
29	Inner Diff Mount Bracket	4130 N	2	0,250	JD LASER
30	Push Rod Tabs REAR	4130 N	6	0,060	JD LASER
31	Push Rod Support Plate	4130 N	4	0,100	JD LASER

Table 10 – Manufacturing Outline: Laser Cutting

5.1.2 Water Jet

This method was used for the parts that need the best accuracy. This method has two main advantages respect to the other two methods:



- It does not heat the part, so there are not high temperatures that could change the properties of the material.
- It does not cause micro fracturing.

In addition, in terms of the equipment, the investment can be less than half of the price of a laser cutting machine, the maintenance is very simple and it is very easy for the operators. [16]



Figure 31 - Water Jet [18]

The cut edge quality and the precision of this method is the higher and it can cut almost any material. However, the cutting speeds are very slow compared with plasma and laser and the operating cost is usually the most expensive.

Following the same process than with laser, the CAD files were sent to an outside company in order to get the parts. In this case, the supplier was Advanced Machining, a local company located in New Smyrna Beach, which is only 20 minutes away from the university. They have a 90,000 Psi Water Jet cutting system that can cut almost any material. This technology creates a clean, burr-free cut that does not require secondary finishing and does not leave a heat-affected zone as it happens with plasma cutting [19].



Figure 32 – 90,000 PSI Water Jet Machine [19]

As it is seen in Table 11, the material used in this method is mainly Aluminum 6061-T6. In addition, the material is sometimes 4130 steel. However, as it is seen in section 5.1.1, most of the 4130 steel parts are manufactured with laser cutting.



Formula SAE Manufacturing Outline - Water Jet Cutting					
Item Number	Description	Material	Quantity	Thickness	Supplier
1	Diff mount LEFT	6061-T6	1	0,75	Adv. Machining
2	Diff mount RIGHT	6061-T6	1	0,75	Adv. Machining
3	ARB ends (lever arms)	6061-T6			ER03
4	Shift lever	6061-T6	1	0,32	Adv. Machining
5	ARB mounts (pillow blocks)	6061-T6	4	0,80	Adv. Machining
6	Brake Pedal	6061-T6	1	0,75	Adv. Machining
7	Throttle Pedal	6061-T6	1	0,50	Adv. Machining
8	Throttle Linkage Bar	6061-T6	1	0,25	Adv. Machining
9	A-ARM FORK	4130	22	0,25	Adv. Machining
10	FRONT UPPER BALL JOINT FORK	4130	4	0,25	Adv. Machining
11	FRONT LOWER BALL JOINT FORK	4130	4	0,25	Adv. Machining
12	REAR UPPER BALL JOINT FORK	4130	4	0,25	Adv. Machining
13	REAR LOWER BALL JOINT FORK	4130	4	0,25	Adv. Machining
14	Front Wing Ribs	6061-T6	8	0,25	Adv. Machining
15	Rear wing internal inner ribs	6061-T6	2	0,25	Adv. Machining
16	Rear Wing Secondary Rib	6061-T6	2	0,5	Adv. Machining
17	Rear wing internal outer ribs	6061-T6	2	0,5	Adv. Machining
18	Front wing Chassis Tabs	6061-T6	2		Adv. Machining
19	Front wing Spar Tabs	6061-T6	2		Adv. Machining
20	Tilton Mount Jig	6061-T6	2	0,86	Adv. Machining
21	Acceleration Rod Jig	6061-T6	1	0,35	Adv. Machining
22	Acceleration Pedal Mount Jig	6061-T6	1	0,63	Adv. Machining
23	Brake Pedal Mount Jig	6061-T6	1	1,34	Adv. Machining

Table 11 - Manufacturing Outline: Water Jet Cutting

5.1.3 Plasma cutting

As the cost of the machine is not very expensive, the university has this equipment in the laboratories. However, this process changes the properties of the materials because of the high temperatures during the process. It is very difficult to get high quality and all the settings established in the CAD design.



Figure 33 - Plasma cutting [20]

The machinery is very cheap compared with the other two methods and it only requires simple maintenance. The production rate is much higher going until 200 inches per minute. The operating cost is cheaper but the cut edge quality and precision is lower than laser and water jet cutting.

As the quality is not very high using this method, only the parts that do not require high precision are manufactured with plasma cutting.

Table 12 shows the parts manufactured with plasma. The materials used are more varied: 4130 chromoly steel, mild steel, 4130 steel, 1018 steel and 5052 aluminum for the fuse box panel. The gauge size used for each part is also in the table.

Some examples manufactured with plasma are the water pump mounts or the fuel tank tabs on the chassis and on the tank.



Formula SAE Manufacturing Outline - Plasma Cutting					
Item Number	Description	Material	Quantity	Thickness	gauge size
1	Tube Endplates	4130 Chromoly	10	0,060	16
2	AI Plate	4130 Chromoly	1	0,100	
3	Rear shock mounts CROSS BAR	4130 Chromoly	2	0,100	12
4	FRONT FOR SHOCK MOUNTS	4130 Chromoly	4	0,080	13
5	FRONT AFT SHOCK MOUNTS	4130 Chromoly	4	0,080	13
6	Panel bracket	Mild Steel	2	0,030	22
7	FRONT BELL CRANK MOUNT	4130 Chromoly	4	0,125	11
8	REAR BELL CRANK MOUNTS	4130 Chromoly	4	0,125	11
9	Steering Upper Support Chassis Mounts	4130 Chromoly	2	0,125	11
10	FRONT BELL CRANK PLATE	4130 Chromoly	4	0,100	12
11	REAR BELL CRANK PLATE	4130 Chromoly	4	0,100	12
12	Harness Mount	4130	2	0,375	11
13	Diff Mount Brackets (Lower)	4130 Steel	4	0,100	11
14	Diff Mount Bearing Retention Bracket (Left)	1018 Steel	1	0,063	
15	Diff Mount Bearing Retention Bracket (Right)	1018 Steel	1	0,065	11
16	Turnbuckle Adapter (Left)	1018 Steel	2	0,160	
17	Turnbuckle Adapter (Right)	1018 Steel	2	0,100	
18	Water pump mount 2	4130	1	0,095	
19	Water pump mounts	4130	1	0,095	
20	Radiator mounts	4130	1	0,095	
21	Key Mounting Plate	4130 Chromoly	1	0,050	
22	Shift cable bracket	4130 Chromoly	1	0,063	15
23	Fuse Box Panel	5052	1	0,063	15
24	Electronics Mount	4130 Chromoly	1	0,063	15
25	FWD Shift cable mount	1018 Steel	1	0,063	15
26	REAR Shift cable mount	1018 Steel	1	0,063	15
27	Shift Shaft Tab 1	1018 Steel	1	0,063	15
28	Shift Shaft Tab 2	1018 Steel	1	0,063	15
29	Shift Shaft Tab 3	1018 Steel	1	0,063	15
30	Rear Wing Upper Chassis Tabs	1018 Steel	4	0,080	
31	Rear Wing Lower Chassis Tabs	1018 Steel	4	0,080	
32	Jack bar brackets	1018 Steel	4	0,125	11
33	Muffler mounts	4130	2	0,095	11
34	Front wing Chassis Tabs	1018 Steel	2	0,080	
35	Front wing Spar Tabs	1018 Steel	8	0,080	
36	throttle boby mount	1018 steel	1	0,080	
37	fuel tank tabs on tank	4130	1	0,080	
38	fuel tank tabs on chassis	4130	3	0,080	
39	Rear Push Rod Support and Tabs	4130	1	0,065	
40	Front Push Rod Tabs	4130	2	0,065	

Table 12 - Manufacturing Outline: Plasma Cutting



Finishing this section, next table shows the different characteristics of each process that were explained individually before:

	Laser Cutting	Water Jet	Plasma Cutting
Purchase Cost [\$]	350,000-1,000,000	100,000-350,000	50-100,000
Operating Cost [\$/hr]	20	30	15
Production Rate (ipm)	20-70	< 15	60-200
Cut Edge Quality	Medium	High	Low
Cut Part Precision (")	0,005	0,005	0,02
Materials	Metals, some plastics and fiberglass	Almost any material	Conductive materials

Table 13 – Cutting Processes [14]

5.2 Composite parts

Since Embry-Riddle started competing in Formula SAE four years ago, the team has used steel tube construction for the vehicle's chassis. Currently, ER04 still utilizes a steel tube frame under the outer bodywork panels. This is not the most efficient way of constructing a car as the strength to weight ratio is not as high as that of having a carbon fiber monocoque structure. According to Formula SAE, different areas of the monocoque have different strength requirements based on the expected forces that would be exerted onto them in the event of an accident.

It is very expensive to manufacture the composite parts outside the university and there is not a high cost in the equipment to make these parts in the university. So most of the composites parts were manufactured in the university. There are two main methods in the transformation of the composites: resin infusion and wet layup.

5.2.1 Resin infusion

It is a process in which a pressure below atmospheric is used to distribute the resin in the mold cavity where the piece is manufactured and integrate it with the reinforcement system.

This process offers the possibility of manufacturing large pieces in a very short time. Thanks to the infusion we can manufacture high quality pieces with fiber percentages of up to 60%, at a relatively low cost, since with the infusion it facilitates the impregnation of fabrics with high thickness [21]. Figure 34 shows the process schematic.

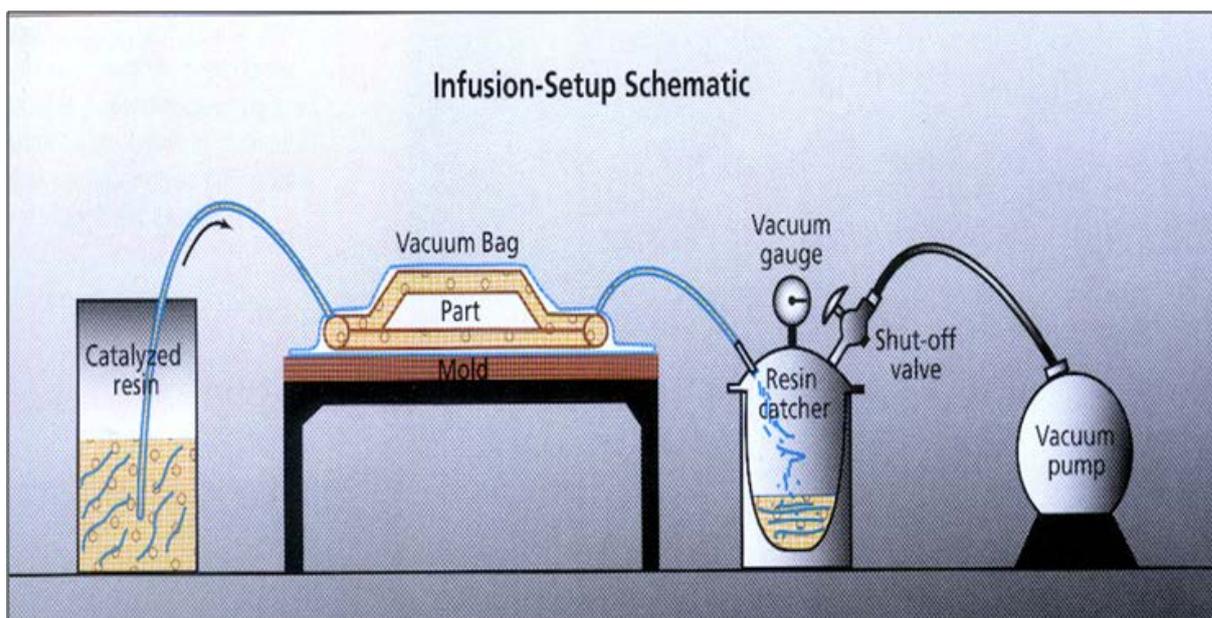


Figure 34 – Resin Infusion [21]

A disadvantage is the relatively long time of preparation of the consumables, especially the sealing of the vacuum bag. Therefore, this method is only suitable for the production of small series. However, this method is used more often in the industry where you have to produce very detailed parts.

It is a process that is beginning to be widely used in the manufacture of high performance boats and in the manufacture of wind blades.

5.2.2 *Wet layup*

In the industry it is being replaced by resin infusion and resin transfer molding in order to get faster production rates. Automation is introduced wherever is possible. However, as the team is only manufacturing one vehicle, this method is the most used technique in composites.



Figure 35 – ER04 Composites



6. Conclusions

First, with this project I had the opportunity to be part of a team where we participate in a real project. Working on it, you realize all the difficulties that entails and that in many cases theory does not agree with real manufacturing, more specifically, 3D designs at the time of manufacturing and assembling them are not as easy as it seems in the computer. In this way, many parts and assemblies have to be redesigned in order to achieve the correct settings of the system.

Regarding to the cost report, at the beginning of the project the budget of the vehicle was \$14,000. However, as it happens in most of the projects in real life, then you need more money to finish the project. In this case, the final cost of the vehicle was \$16,432 being \$1,600 cheaper than last year's vehicle but it is still higher than the average cost of the vehicles in the FSAE competition.

Manufacturing processes were analyzed in order to look for the best solution in terms of cost and performance. Starting with cutting processes, laser and water jet were used for the parts that needed high quality. The university does not have the equipment for those processes, so outside companies manufactured those parts. On the other hand, the university has plasma cutting equipment so different parts with less quality such as the fuse box panel were manufactured in the university. In addition, as the university only manufactures one vehicle and most of the composite parts does not need high quality, wet layup was used to manufacture composite parts. The main reason is because it was cheaper than manufacture composite parts with resin infusion in an outside company.

The results of the competition were not the expected. However, in the cost report the team got one of the highest grades (19.6/20 points). The cost event also depends on the cost of the vehicle. Due to the high cost of our car compared with others, the team did not get good results in this event.



Working on this project alongside Dr. Spitzer, Dr. Rodríguez and the rest of the team has helped me to put into practice the concepts of different courses of the Master in Industrial Engineering and the MBA.



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Annex



8. Annex A - ER04 Bill of Materials [22]

Embry-Riddle Aero University - Daytona Beach

ERAU Motorsports

2018 Cost Report

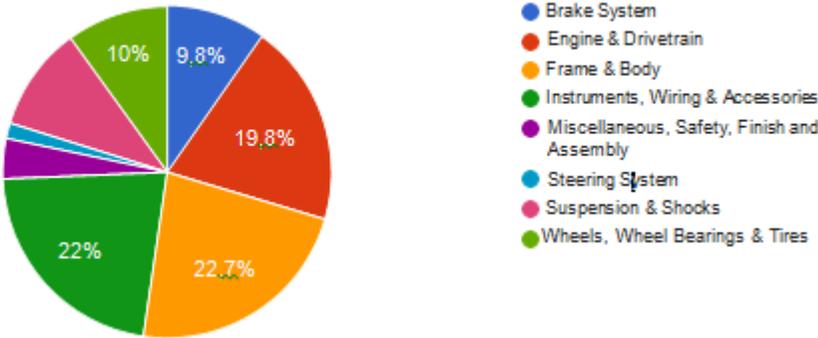
ER04

Formula SAE Michigan 2018 – Car #78

Cost Summary

System	Materials	Processes	Fasteners	Tooling	Totals
Brake System	1461.2000	137.3900	4.4900	0.0000	1603.0800
Engine & Drivetrain	2809.7700	421.0400	26.1200	0.0000	3256.9300
Frame & Body	2355.6300	1195.1600	53.6900	130.1300	3734.6100
Instruments, Wiring & Accessories	3481.8400	136.5200	2.2300	0.6700	3621.2600
Miscellaneous, Safety, Finish and Assembly	494.0800	103.6500	44.7600	3.5700	646.0600
Steering System	136.4600	109.4000	1.6600	0.0000	247.5200
Suspension & Shocks	1480.1300	148.6600	9.4200	41.3400	1679.5500
Wheels, Wheel Bearings & Tires	1062.3200	574.8600	5.7600	0.0000	1642.9400
	13281.4300	2826.6800	148.1300	175.7100	16431.9500

Cost Summary – Area Totals



System	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Material Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost
Brake System	FSAEM- 18078	BR-A0000	Pedal Assembly			662.89	1	607.20	52.56	3.13	662.89	2
Brake System	FSAEM- 18078	BR-A0002	Front Brakes			420.90	1	419.96	0.26	0.68	420.90	
Brake System	FSAEM- 18078	BR-A0003	Rear Brakes			230.93	1	229.99	0.26	0.68	230.93	
Brake System	FSAEM- 18078	BR-A0004	Brake Line			129.12	1	128.74	0.38		129.12	2
Brake System	FSAEM- 18078	BR-00007		Brake Pedal		6.56	1	3.08	3.48		6.56	
Brake System	FSAEM- 18078	BR-03001		Rear Brake Rotor		8.95	2	2.64	6.31		17.90	
Brake System	FSAEM- 18078	BR-02001		Front Rotor		5.02	2	2.04	2.98		10.04	
Brake System	FSAEM- 18078	BR-03002		Brake Buttons		1.89	10	0.17	1.72		18.90	
Brake System	FSAEM- 18078	BR-02002		Brake Button		1.89	10	0.17	1.72		18.90	2
Brake System	FSAEM- 18078	BR-00024		Throttle Pedal		6.45	1	1.26	5.19		6.45	
Brake System	FSAEM- 18078	BR-00020		Left Skid		1.24	2	0.33	0.91		2.48	
Brake System	FSAEM- 18078	BR-00022		Right Skid		0.54	2	0.19	0.35		1.08	2
Brake System	FSAEM- 18078	BR-00015		Left Rail		0.86	1	0.19	0.67		0.86	
Brake System	FSAEM- 18078	BR-00023		Right Rail		0.76	1	0.09	0.67		0.76	
Brake System	FSAEM- 18078	BR-00025		Throttle Pedal Mount Tab		0.19	2	0.09	0.10		0.38	2
Brake System	FSAEM- 18078	BR-00026		Throttle Link		1.32	1	0.07	1.25		1.32	
Brake System	FSAEM- 18078	BR-00027		Throttle Link Mount Tab		0.08	2	0.03	0.05		0.16	

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
Brake System	FSAEM-18078	BR-00033		Throttle Cable Mount		2.27	1	0.35	1.92			2.27	
Brake System	FSAEM-18078	BR-00028		Heel Plate Bracket		0.45	2	0.03	0.42			0.90	
Brake System	FSAEM-18078	BR-00030		Heel Plate		22.74	1	18.60	4.14			22.74	2
Brake System	FSAEM-18078	BR-00032		Pedal Face		15.77	2	14.80	0.97			31.54	
Brake System	FSAEM-18078	BR-00008		Brake Pedal Mount		0.48	2	0.19	0.29			0.96	
Brake System	FSAEM-18078	BR-00010		Master Cylinder Mount		0.18	2	0.04	0.14			0.36	2
Brake System	FSAEM-18078	BR-00013		Brake Overtravel Switch Mount		1.56	1	0.10	1.46			1.56	
Brake System	FSAEM-18078	BR-00001		Cross Tube		0.97	1	0.50	0.47			0.97	
Brake System	FSAEM-18078	BR-00009		Conical Spacer Sm		1.32	2	0.01	1.31			2.64	2
Brake System	FSAEM-18078	BR-00011		Conical Spacer Lg		1.31	2		1.31			2.62	
Brake System	FSAEM-18078	BR-00012		Center Spacer		0.03	1	0.03				0.03	
Brake System	FSAEM-18078	BR-00050		Reservoir		3.43	2	3.43				6.86	2
Brake System				[Area Total:]				1461.20	137.39	4.49		1603.08	
Engine & Drivetrain	FSAEM-18078	EN-A7000	Drivetrain			48.10	1	17.65	30.03	0.42		48.10	
Engine & Drivetrain	FSAEM-18078	EN-A9000	Engine			1500.49	1	1497.50	1.88	1.11		1500.49	2
Engine & Drivetrain	FSAEM-18078	EN-A1000	Intake Assembly			38.93	1		36.48	2.45		38.93	
Engine & Drivetrain	FSAEM-18078	EN-A5000	Oil System			178.92	1	177.32	0.38	1.22		178.92	
Engine & Drivetrain	FSAEM-18078	EN-A2000	Exhaust Assembly			8.23	1		8.00	0.23		8.23	
Engine & Drivetrain	FSAEM-18078	EN-A3000	Cooling System			64.85	1	53.54	4.98	6.33		64.85	2
Engine & Drivetrain	FSAEM-18078	EN-A4000	Fuel System			105.57	1	101.00	4.12	0.45		105.57	

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
Engine & Drivetrain	FSAEM-18078	EN-A6000	Differential Assembly		Differential assembly	204.29	1	178.00	24.88	1.41		204.29	
Engine & Drivetrain	FSAEM-18078	EN-62001		Differential Bearing Carrier - L	Left Differential Mount	4.19	1	1.39	1.73	1.07		4.19	
Engine & Drivetrain	FSAEM-18078	EN-4001-		Fuel Tank		44.93	1	9.08	35.85			44.93	
Engine & Drivetrain	FSAEM-18078	EN-5001		Oil tank		5.42	1	0.84	4.58			5.42	2
Engine & Drivetrain	FSAEM-18078	EN-3001-		Radiator		35.19	1	7.58	27.61			35.19	
Engine & Drivetrain	FSAEM-18078	EN-1001-		Runners		0.36	4	0.35	0.01			1.44	
Engine & Drivetrain	FSAEM-18078	EN-2001-		Adaptors		5.60	4	2.70	2.90			22.40	2
Engine & Drivetrain	FSAEM-18078	EN-7001-		Axle Assembly		93.51	2	91.48	1.57	0.46		187.02	
Engine & Drivetrain	FSAEM-18078	EN-7004		Sprocket assembly		17.55	1	5.25	11.24	1.06		17.55	
Engine & Drivetrain	FSAEM-18078	EN-1002-		Runner Flanges		0.90	2	0.31	0.59			1.80	2
Engine & Drivetrain	FSAEM-18078	EN-2002		Exhaust Flange		1.53	4	1.17	0.36			6.12	
Engine & Drivetrain	FSAEM-18078	EN-5002		Oil pump		429.00	1	429.00				429.00	
Engine & Drivetrain	FSAEM-18078	EN-6008-		Turn Buckle		1.65	2	0.11	0.38	1.16		3.30	2
Engine & Drivetrain	FSAEM-18078	EN-4002-		Fuel Lines		42.55	1	42.29	0.26			42.55	
Engine & Drivetrain	FSAEM-18087	EN-3002-		Radiator Mount		9.87	1	3.26	6.48	0.13		9.87	
Engine & Drivetrain	FSAEM-18078	EN-1003-		Bellmouth		5.50	4	1.39	4.11			22.00	
Engine & Drivetrain	FSAEM-18078	EN-2003		Manifold		23.35	1	5.69	17.66			23.35	2
Engine & Drivetrain	FSAEM-18078	EN-7003-		Jackbar Assembly		3.67	1	0.69	2.23	0.75		3.67	
Engine & Drivetrain	FSAEM-18078	EN-3003-		Radiator Line In		6.64	1	3.92	2.72			6.64	
Engine & Drivetrain	FSAEM-18078	EN62002A		Differential Bearing Carrier- R	Right Differential Mount	3.96	1	1.43	1.60	0.93		3.96	2

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
Engine & Drivetrain	FSAEM-18078	EN-4003-		Fuel Rail		8.74	1	2.62	6.12			8.74	2
Engine & Drivetrain	FSAEM-17073-EN	02003AA		Oil Pan		13.19	1	4.20	8.54	0.45		13.19	
Engine & Drivetrain	FSAEM-18078	EN-1004-		Runner Mount		3.17	1	1.30	1.87			3.17	
Engine & Drivetrain	FSAEM-18078	EN-3004-		Radiator Line Out		4.12	1	0.97	3.15			4.12	2
Engine & Drivetrain	FSAEM-18078	EN-2004		Collector		15.54	1	1.12	14.42			15.54	
Engine & Drivetrain	FSAEM-18078	EN-4004-		Fuel Tank Tabs		3.25	3	0.03	3.22			9.75	
Engine & Drivetrain	FSAEM-18078	EN62006		Bearing Retention Brackets	Bearing Retention Brackets	1.66	2	0.12	0.02	1.52		3.32	2
Engine & Drivetrain	FSAEM-18078	EN-5003		Puke tank		10.00	1	10.00				10.00	
Engine & Drivetrain	FSAEM-18078	EN-1005-		Plenum		13.93	1	4.31	9.62			13.93	
Engine & Drivetrain	FSAEM-18078	EN-2005		V-Band Clamp		17.26	1	0.58	15.97	0.71		17.26	
Engine & Drivetrain	FSAEM-18078	EN-3005-		Water pump mounting tabs		3.89	1	0.36	3.53			3.89	2
Engine & Drivetrain				Upper Differential Brackets		2.26	1	0.49	1.77			2.26	
Engine & Drivetrain	FSAEM-18078	EN-1006-		Wrap Around Pipe		7.12	1	0.72	6.40			7.12	
Engine & Drivetrain	FSAEM-18078	EN-2007		Tailpipe		27.05	1	2.45	24.60			27.05	2
Engine & Drivetrain	FSAEM-18078	EN-2006		Muffler		9.53	1	3.59	5.82	0.12		9.53	
Engine & Drivetrain	FSAEM-18078	EN-1007-		Restrictor Flange		0.35	1	0.17	0.18			0.35	
Engine & Drivetrain	FSAEM-18078	EN-1008-		Restrictor		51.11	1	11.49	39.62			51.11	2
Engine & Drivetrain	FSAEM-18078	EN-2008		Muffler Mounting Sys		3.02	1	0.92	1.25	0.85		3.02	
Engine & Drivetrain	FSAEM-18078	EN-2009		Exhaust Exit Shroud		2.54	1	1.14	1.25	0.15		2.54	
Engine & Drivetrain	FSAEM-18078	EN-1009-		Throttle Body		9.10	1	2.17	6.93			9.10	

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
Engine & Drivetrain	FSAEM-18078	EN-1010-		Throttle Flange		0.43	1	0.27	0.16			0.43	
Engine & Drivetrain	FSAEM-18078	EN-1012-		Fuel Rail Tab		0.19	2	0.04	0.15			0.38	
Engine & Drivetrain	FSAEM-18078	EN-1013-		injector seats		0.22	4	0.08	0.14			0.88	2
Engine & Drivetrain	FSAEM-18078	EN-1014-		Throttle body mount		2.10	1	0.13	1.97			2.10	
Engine & Drivetrain	FSAEM-18078	EN-1015-		Air Filter	FSAEM-18078	18.37	1	18.37				18.37	2
Engine & Drivetrain	FSAEM-18078	EN-1016		Throttle Cable			1						
Engine & Drivetrain				[Area Total:]				2809.77	421.04	26.12		3256.93	
Frame & Body	FSAEM-18078	FR-23002	Right Hand Sidepod			10.49	1		0.12	4.80	5.57	10.49	
Frame & Body 18078	FSAEM-	FRA-2300	Body			15.60	1		8.40	7.20		15.60	2
Frame & Body 18078	FSAEM-	FRA-2100	Rear Wing Assembly			7.67	1		6.30	1.37		7.67	
Frame & Body	FSAEM-18078	FR-00001	Tube Space Frame				1						
Frame & Body	FSAEM-18078	FR-23003	Left hand Sidepod			10.37	1			4.80	5.57	10.37	2
Frame & Body 18078	FSAEM-	FRA-2200	Front Wing Assembly			50.14	1		48.00	2.14		50.14	
Frame & Body				Left Hand Side Pod		218.30	1	206.42	11.88			218.30	
Frame & Body	FSAEM-18078	FR-01001	Endplate			51.02	4	43.54	6.60	0.88		204.08	2
Frame & Body	FSAEM-18078	06001AA	Right Hand Sidepod			218.30	1	206.42	11.88			218.30	
Frame & Body	FSAEM-18078	FR-00001	Complete Tube Frame			903.58	1	69.73	826.73	0.12	7.00	903.58	
Frame & Body	FSAEM-18078	FR-21001	Primary Airfoil			133.11	2	95.22	15.59		22.30	266.22	2
Frame & Body	FSAEM-18078-FR	23004-AA	Nose	Nose/hood assembly		299.62	1	235.87	41.82	4.80	17.13	299.62	
Frame & Body	FSAEM-18078	FR-21002	Secondary Airfoil			90.29	1	74.06	9.54		6.69	90.29	

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost
Frame & Body	FSAEM-18078	FR-01002		Primary Airfoil		53.79	2	43.16	10.63			107.58
Frame & Body	FSAEM-18078	FR-04002		Driver Cell Panels		85.78	2	70.76	9.51	4.80	0.71	171.56
Frame & Body	FSAEM-18078	FR-04003		SUS Bay Closeout Panel		21.45	2	19.87	1.58			42.90
Frame & Body	FSAEM-18078	FR-01003		Secondary Airfoil		37.83	2	33.07	4.76			75.66
Frame & Body	FSAEM-18078	FR-23017		End Plates		83.49	2	66.77	8.36		8.36	166.98
Frame & Body	FSAEM-18078	FR-02004		Gooseneck Upper Mount		4.12	2	1.69	2.43			8.24
Frame & Body	FSAEM-18078	FR-01007		Primary Airfoil Insert		1.90	4	1.58	0.32			7.60
Frame & Body	FSAEM-18078	FR-01008		Secondary Airfoil Insert		2.75	4	2.25	0.50			11.00
Frame & Body	FSAEM-18078	FR-02005		Gooseneck Vertical Rods		0.11	2	0.05	0.06			0.22
Frame & Body	FSAEM-18078	FR-02006		Mounting tabs		0.15	4	0.03	0.12			0.60
Frame & Body	FSAEM-18078	FR-01009		Wing Spar		20.84	2	16.27	4.57			41.68
Frame & Body	FSAEM-18078	FR-02007		Primary Airfoil Inserts		0.19	2	0.03	0.16			0.38
Frame & Body	FSAEM-18078	FR-01010		Wing Mount		1.95	2	0.20	1.75			3.90
Frame & Body	FSAEM-18078	FR-01011		Wing Chassis Tabs		0.46	2	0.29	0.17			0.92
Frame & Body	FSAEM-18078	FR-02008		Secondary Airfoil Inserts		0.28	2	0.03	0.25			0.56
Frame & Body	FSAEM-18078-FR	2500AA	Floor			19.38	1		0.54	18.84		19.38
Frame & Body	FSAEM-18078	FRA2500		Floor		522.34	1	467.51	40.21	0.02	14.60	522.34
Frame & Body	FSAEM-18078	FR-03003		Upper Flat Panel		11.51	2	5.81	4.32		1.38	23.02
Frame & Body	FSAEM-18078	FR-03004		Outer Skirt		17.89	2	8.71	9.18			35.78
Frame & Body	FSAEM-18078	FR-03005		Under Tray Skirt		11.51	2	10.16	1.35			23.02

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
Frame & Body	FSAEM-18078	FR2501		Front Floor		176.63	1	161.84	10.24		4.55	176.63	2
Frame & Body				[Area Total:]				2355.63	1195.16	53.69	130.13	3734.61	
Instruments, Wiring & Accessories	FSAEM-18078-EL	A06000AA	Front Right Wheel Assembly			3.40	1	1.50	1.90			3.40	
Instruments, Wiring & Accessories	FSAEM-18078-EL	A07000AA	Power			30.04	1	8.70	21.34			30.04	2
Instruments, Wiring & Accessories	FSAEM-18078-EL	A05000AA	Front Left Wheel Assembly			3.40	1	1.50	1.90			3.40	2
Instruments, Wiring & Accessories	FSAEM-18078-EL	A02000AA	Control 1			1155.69	1	1146.20	9.24	0.25		1155.69	
Instruments, Wiring & Accessories	FSAEM-18078-EL	A08000AA	Powertrain			10.96	1		10.76	0.20		10.96	2
Instruments, Wiring & Accessories	FSAEM-18078-EL	A03000AA	Rear Right Wheel Assembly			3.40	1	1.50	1.90			3.40	
Instruments, Wiring & Accessories	FSAEM-18078-EL	A01000AA	Dash			1585.59	1	1565.80	19.79			1585.59	
Instruments, Wiring & Accessories	FSAEM-18078-EL	A04000AA	Rear Left Wheel Assembly			3.40	1	1.50	1.90			3.40	
Instruments, Wiring & Accessories	FSAEM-18078-EL	A09000AA	Control 2			551.40	1	504.40	46.75	0.25		551.40	2
Instruments, Wiring & Accessories	FSAEM-18078	EL-01003		Estop Bracket		2.69	1	0.21	2.31		0.17	2.69	
Instruments, Wiring & Accessories	FSAEM-18078-EL	09002AA		Rectifier Mount		1.06	1	0.05	0.68		0.33	1.06	
Instruments, Wiring & Accessories	FSAEM-18078-EL	04002AA		Wheel Speed		4.00	1	4.00				4.00	2
Instruments, Wiring & Accessories	FSAEM-18078-EL	07001AA		Battery		39.50	1	39.31		0.19		39.50	
Instruments, Wiring & Accessories	FSAEM-18078-EL	05002AA		Wheel Speed		4.00	1	4.00				4.00	
Instruments, Wiring & Accessories	FSAEM-18078-EL	02002AA		Electronics Mount		22.51	1	21.32	1.07	0.12		22.51	2
Instruments, Wiring & Accessories	FSAEM-18078-EL	08001AA		Injector		5.44	1	4.00	1.44			5.44	
Instruments, Wiring & Accessories	FSAEM-18078-EL	03002AA		Wheel Speed		4.00	1	4.00				4.00	
Instruments, Wiring & Accessories	FSAEM-18078-EL	06002AA		Wheel Speed		4.36	1	4.00	0.36			4.36	2

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost
Instruments, Wiring & Accessories	FSAEM-18078-EL	08002AA		Coil		5.44	1	4.00	1.44			5.44
Instruments, Wiring & Accessories	FSAEM-18078-EL	07002AA		circuit breaker		8.82	1	8.80		0.02		8.82
Instruments, Wiring & Accessories	FSAEM-18078-EL	01004AA		Switch Box		4.25	1	2.33	1.76	0.16		4.25
Instruments, Wiring & Accessories	FSAEM-18078-EL	08003AA		Manifold Air Pressure Sensor		5.36	1	5.00	0.36			5.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	07003AA		Safety Switches		5.71	1	5.43		0.28		5.71
Instruments, Wiring & Accessories	FSAEM-18078-EL	08004AA		Throttle Position Sensor		5.36	1	5.00	0.36			5.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	07004AA		Contactora		4.13	1	4.00		0.13		4.13
Instruments, Wiring & Accessories	FSAEM-18078-EL	07005AA		Fusebox		16.12	1	16.00		0.12		16.12
Instruments, Wiring & Accessories	FSAEM-18078-EL	08005AA		Intake Air Temperature		5.36	1	5.00	0.36			5.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	08006AA		Engine Speed Sensor		5.36	1	5.00	0.36			5.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	07006AA		Brake Light		4.50	1	4.11		0.39		4.50
Instruments, Wiring & Accessories	FSAEM-18078-EL	08007AA		Crank Position Sensor		5.36	1	5.00	0.36			5.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	07007AA		Brake Pressure Switch		8.00	1	8.00				8.00
Instruments, Wiring & Accessories	FSAEM-18078-EL	07008AA		Brake Pressure Sensors		8.00	1	8.00				8.00
Instruments, Wiring & Accessories	FSAEM-18078-EL	08008AA		CAM position Sensor		5.86	1	5.50	0.36			5.86
Instruments, Wiring & Accessories	FSAEM-18078-EL	08009AA		Neutral Switch		2.36	1	2.00	0.36			2.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	07009AA		Brake Light Mount		1.73	1	1.38	0.35			1.73
Instruments, Wiring & Accessories	FSAEM-18078-EL	08010AA		Water Temperature Sensor		11.36	1	11.00	0.36			11.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	07010AA		Corner Con Mount		2.55	1	0.45	2.10			2.55
Instruments, Wiring & Accessories	FSAEM-18078-EL	08011AA		Oil Pressure Sensor		11.36	1	11.00	0.36			11.36

Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost
Instruments, Wiring & Accessories	FSAEM-18078-EL	08012AA		Fuel Pressure Sensor	11.36	1	11.00	0.36			11.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	08013AA		O2 Sensor	36.36	1	36.00	0.36			36.36
Instruments, Wiring & Accessories	FSAEM-18078-EL	08014AA		Radiator Fan	1.36	1	1.00	0.36			1.36
Instruments, Wiring & Accessories	FSAEM-18078	EL-08015		Coil Driver Mount	3.34	1	0.06	3.11		0.17	3.34
Instruments, Wiring & Accessories	FSAEM-18078	EL-08016		Key Mounting Plate	7.01	1	4.79	2.10	0.12		7.01
Instruments, Wiring & Accessories				[Area Total:]			3481.84	136.52	2.23	0.67	3621.26
Miscellaneous, Safety, Finish and Assembly	FSAEM-17073-MS	A05000AA	Seatbelts		47.27	1	45.43	1.84			47.27
Miscellaneous, Safety, Finish and Assembly	FSAEM-17073-MS	A03000AA	Head restraint		40.06	1	38.67	1.39			40.06
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-00009	Seat		135.87	1	115.20	12.79	4.80	3.08	135.87
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	A07000AA	Paint			1					
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-A0001	Impact Attenuator		24.10	1		22.43	1.67		24.10
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-A0600	Firewall		36.09	1			36.09		36.09
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-A3501	Shifter		18.04	1	9.66	8.38			18.04
Miscellaneous, Safety, Finish and Assembly	FSAEM-17073-MS	07001AA	Paint		31.02	1	31.02				31.02
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-00006	Impact Attenuator		23.95	1	23.25	0.70			23.95
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06001	Bottom Left Firewall		19.54	1	16.76	2.71		0.07	19.54
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-35002	Shift Lever		2.41	1	0.48	1.40	0.53		2.41
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06002	Bottom Middle Firewall		51.27	1	45.90	5.27		0.10	51.27
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-00002	Anti-Intrusion Plate		5.72	1	1.78	3.94			5.72
Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR35004	Clutch Lever		20.00	1	20.00				20.00

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR35043		Clutch Cable	14.25	1	14.25				14.25	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06003		Bottom Right Firewall	11.33	1	9.92	1.33		0.08	11.33	2
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06004		Middle Firewall	36.41	1	36.29			0.12	36.41	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR35013A		Shift Cable to Chassis Tab	2.64	1	0.02	2.62			2.64	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR35042		Shift Cable to Engine Mount	9.35	1	1.18	8.17			9.35	2
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06005		Top Firewall	23.26	1	21.22	2.00		0.04	23.26	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06006		Mid-Top Firewall Union	17.78	1	17.78				17.78	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-35015		Shift Cable Linkage to Engine	7.66	1	0.15	7.40	0.11		7.66	2
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-35032		Shift/Clutch Cable Mount Bracket	12.07	1	0.16	10.95	0.96		12.07	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06007		Bottom Left Firewall Top Mount	2.44	1	2.22	0.20		0.02	2.44	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR35026A		Shift Lever Grip Sleeve	1.09	1	0.09	0.44	0.56		1.09	2
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06008		Bottom Left Firewall Bottom Mount	3.38	1	3.08	0.28		0.02	3.38	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06009		Middle Firewall Right Mount	4.12	1	3.76	0.34		0.02	4.12	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-35030		Shift Lever Shaft	6.44	1		6.40	0.04		6.44	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-35036		Front Shaft Mount tab	1.45	1	0.02	1.43			1.45	2
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	MS-06010		Middle Firewall Left Mount	4.12	1	3.76	0.34		0.02	4.12	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-35037		Rear Shaft Mount tab	0.50	1	0.02	0.48			0.50	
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-35039		Long Shaft Mount tab	0.43	1	0.01	0.42			0.43	2
	Miscellaneous, Safety, Finish and Assembly	FSAEM-18078	FR-35027		Shift Cable	32.00	1	32.00				32.00	
	Miscellaneous, Safety, Finish and Assembly				[Area Total:]			494.08	103.65	44.76	3.57	646.06	

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost
Steering System	FSAEM-18078	ST-A0003	Upper shaft support		Supports Upper steering shaft and locks the system in place	29.04	1	25.16	3.88		29.04	
Steering System	FSAEM-18078	ST-A0005	Front Tie Rods			18.80	2	14.23	4.51	0.06	37.60	
Steering System	FSAEM-18078	ST-A0001	Rack System		Steering from frame to rack pinion	0.72	1			0.72	0.72	2
Steering System	FSAEM-18078	ST-A0002	Shaft assembly		Complete shaft assembly from U-joint adapter to lower U-joint	52.18	1	40.00	12.18		52.18	
Steering System	FSAEM-18078	ST-00001		Rack Pillow Blocks		5.70	2	1.68	4.02		11.40	2
Steering System	FSAEM-18078	ST-00012		Steering Column	Steering Column	0.38	1	0.38			0.38	
Steering System	FSAEM-18078	ST-00011		Bearing Housing		6.49	1	0.56	5.93		6.49	
Steering System	FSAEM-18078	ST00009		Chassis Supports		2.94	2	0.41	2.53		5.88	
Steering System	FSAEM-18078	ST-00020		U-Joint adapter		4.25	1	0.11	4.14		4.25	2
Steering System	FSAEM-18078	ST-00027		Rack	Z-Rack 358 S+	12.35	1	1.32	11.03		12.35	
Steering System	FSAEM-18078	ST-00015		Bearing Spacer		1.36	1	0.06	1.30		1.36	
Steering System	FSAEM-18078	ST-00016		Rack Bump Stops	Bump Stops to achieve desired rack movement	0.67	1	0.01	0.66		0.67	2
Steering System	FSAEM-18078	ST-00010		Torque Transfer		4.18	1	0.26	3.92		4.18	
Steering System	FSAEM-18078-ST	A0004	Wheel and quick release		Steering wheel and Quick release mechanism	2.56	1		2.38	0.18	2.56	
Steering System	FSAEM-18078	ST-01001		Steering Wheel		64.75	1	34.00	30.75		64.75	2
Steering System	FSAEM-18078	ST-01002		Quick Release		13.71	1	1.96	11.11	0.64	13.71	
Steering System				[Area Total:]				136.46	109.40	1.66	247.52	
Suspension & Shocks	FSAEM-18078	SU-A0200	Front shock and Anti-Roll Bar Actuation		All components related to the actuation of the spring/Damper and anti-roll bar.	12.16	1	9.74		2.42	12.16	
Suspension & Shocks	FSAEM-18078	SU-A0000	Control Arms			215.20	1	211.21		3.99	215.20	2
Suspension & Shocks	FSAEM-18078	SU-A0100	Rear Shock and Anti-Roll Bar Actuation		All components related to the actuation of the rear spring and anti-roll bar.	12.75	1	9.74		3.01	12.75	

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
Suspension & Shocks	FSAEM-18078	SU-01001		Conical Spacers 1 (0.125)		0.05	4	0.01	0.04			0.20	
Suspension & Shocks	FSAEM-18078	SU-A0001		Front Upper A-Arm		4.12	2	0.85	3.27			8.24	
Suspension & Shocks	FSAEM-18078	SU-02001		Conical Spacers 1 (0.156)		0.42	12	0.01	0.41			5.04	
Suspension & Shocks	FSAEM-18078	SU-01002		Conical Spacers 2 (0.0625)		0.04	4	0.01	0.03			0.16	2
Suspension & Shocks	FSAEM-18078	SU-02002		Conical Spacers 2 (0.0936)		0.36	4	0.01	0.35			1.44	
Suspension & Shocks	FSAEM-18078	SU-A0012		Front Lower A-Arm RIGHT		8.42	1	1.14	3.28		4.00	8.42	
Suspension & Shocks	FSAEM-18078	SU-01003		Conical Spacers 3 (0.0938)		0.07	4	0.04	0.03			0.28	2
Suspension & Shocks	FSAEM-18078	SU-02003		Front Dampers		305.00	2	305.00				610.00	
Suspension & Shocks	FSAEM-18078	SU-A0022		Front Lower A-arm LEFT		8.37	1	1.14	3.23		4.00	8.37	
Suspension & Shocks	FSAEM-18078	SU-02004		Front Anti-Roll Bar		0.35	1	0.35				0.35	2
Suspension & Shocks	FSAEM-18078	SU-A0003		Rear Upper A-Arm		4.05	2	0.78	3.27			8.10	
Suspension & Shocks	FSAEM-18078	SU-01004		Conical Spacers 4 (0.1875)		0.04	4	0.02	0.02			0.16	
Suspension & Shocks	FSAEM-18078	SU-02005		Front Bell Crank		1.01	2	0.22	0.79			2.02	2
Suspension & Shocks	FSAEM-18078	SU-A0014		Rear Lower A-Arm LEFT		4.11	1	0.85	3.26			4.11	
Suspension & Shocks	FSAEM-18078	SU-01005		Conical Spacers 5 (0.1425)		0.05	4	0.01	0.04			0.20	
Suspension & Shocks	FSAEM-18078	SU-A0024		Rear Lower A-Arm RIGHT		8.11	1	0.85	3.26		4.00	8.11	2
Suspension & Shocks	FSAEM-18078	SU-01006		Conical Spacers 6 (0.15625)		0.05	4	0.01	0.04			0.20	
Suspension & Shocks	FSAEM-18078	SU-02006		Front Bell Crank Mounts		0.51	4	0.09	0.42			2.04	
Suspension & Shocks	FSAEM-18078	SU-10001		A-arm Chassis mounts		1.60	16	0.02	1.58			25.60	
Suspension & Shocks	FSAEM-18078	SU-01007		Rear Dampers		305.00	2	305.00				610.00	2

	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost
Suspension & Shocks	FSAEM-18078	SU-02007		Front Anti-Roll Bar Bushing		0.62	2	0.09	0.53			1.24
Suspension & Shocks	FSAEM-18078	SU-02008		Front Anti-Roll Bar Rocker Arms		1.04	2	0.18	0.86			2.08
Suspension & Shocks	FSAEM-18078	SU-A2000		Rear Tie rods		4.41	2	0.89	0.85		2.67	8.82
Suspension & Shocks	FSAEM-18078	SU-01008		Rear Shock Tower Support Tubes		1.20	2	0.90	0.30			2.40
Suspension & Shocks	FSAEM-18078	SU-30012		Tie rod chassis mounts		5.95	4	0.01	0.61		5.33	23.80
Suspension & Shocks	FSAEM-18078	SU-01009		Rear Shock Tower Main Tube		0.78	1	0.63	0.15			0.78
Suspension & Shocks	FSAEM-18078	SU-02009		Front Shock Mounts		3.17	4	0.03	2.47		0.67	12.68
Suspension & Shocks	FSAEM-18078	SU-01010		Rear Bell Cranks		3.40	2	2.25	1.15			6.80
Suspension & Shocks	FSAEM-18078	SU-02010		Front Push Rods		1.87	2	1.64	0.23			3.74
Suspension & Shocks	FSAEM-18078	SU-12027		Outboard conical spacers		0.22	16	0.08	0.14			3.52
Suspension & Shocks	FSAEM-18078	SU-12028		Inboard conical spacers		0.13	32	0.07	0.06			4.16
Suspension & Shocks	FSAEM-18078	SU-02011		Push Rod Threaded Inserts		2.11	8	0.07	2.04			16.88
Suspension & Shocks	FSAEM-18078	SU-01011		Rear Shock Supports		1.96	2	0.21	1.75			3.92
Suspension & Shocks	FSAEM-18078	SU-01012		Cross Bar Engine Support		0.53	1	0.07	0.46			0.53
Suspension & Shocks	FSAEM-18078	SU-01013		Rear Anti-Roll Bar Bushings		0.62	2	0.09	0.53			1.24
Suspension & Shocks	FSAEM-18078	SU-01014		Rear Anti-Roll Bar Rocker Arms		1.04	2	0.18	0.86			2.08
Suspension & Shocks	FSAEM-18078	SU-01015		Rear Anti-Roll Bar		0.69	1	0.65	0.04			0.69
Suspension & Shocks	FSAEM-18078	SU-01016		Rear Bell Crank Mounts		0.67	4	0.06	0.61			2.68
Suspension & Shocks	FSAEM-18078	SU-01017		Rear Drop Link Shafts		0.14	2	0.11	0.03			0.28
Suspension & Shocks	FSAEM-18078	SU-01018		Rear Push Rods		0.26	2	0.21	0.05			0.52

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	Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
Suspension & Shocks	FSAEM-18078	SU-01019		Push Rod Threaded Inserts		3.13	12	0.07	3.06			37.56	
Suspension & Shocks				[Area Total:]				1480.13	148.66	9.42	41.34	1679.55	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-A0100	Left Rear Wheel Assembly		Components within the left rear wheel assembly	227.75	1	223.76	2.60	1.39		227.75	2
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-A0002	Front Right Wheel Assembly		The components of the front right wheel assembly.	211.60	1	207.95	2.16	1.49		211.60	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-A0200	Right Rear Wheel Assembly		Components within the right rear wheel assembly	227.75	1	223.76	2.60	1.39		227.75	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-A0001	Front Left Wheel Assembly		The components within both of the front wheel assemblies of ER03.	211.60	1	207.95	2.16	1.49		211.60	2
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1002		Front Right Upright		92.75	1	21.00	71.75			92.75	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0201		Right Rear Upright		50.50	1	21.56	28.94			50.50	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1001		Front Left Upright		92.75	1	21.00	71.75			92.75	2
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0101		Left Rear Upright		50.50	1	21.56	28.94			50.50	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1103		Spindle		61.19	1	13.77	47.42			61.19	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1103		Spindle		61.19	1	13.77	47.42			61.19	2
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0102		Wheel Nut		22.42	1	4.69	17.73			22.42	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0202		Wheel Nut		22.42	1	4.69	17.73			22.42	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1101		Wheel Nut		5.08	1	1.31	3.77			5.08	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0203		Left Rear Spindle		27.40	1	9.03	18.37			27.40	2
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1101		Wheel Nut		5.08	1	1.31	3.77			5.08	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0103		Left Rear Spindle		27.40	1	9.03	18.37			27.40	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0104		Suspension Mount		4.02	1	0.37	3.65			4.02	2
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1203		Suspension Mount		0.65	1	0.08	0.57			0.65	

Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0204		Suspension Mount	4.02	1	0.37	3.65			4.02
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1203		Suspension Mount	0.65	1	0.08	0.57			0.65
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1105		Bird Cage	7.24	1	0.36	6.88			7.24
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1105		Bird Cage	7.24	1	0.36	6.88			7.24
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0205		Birdcage	5.98	1	0.40	5.58			5.98
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0105		Birdcage	5.98	1	0.40	5.58			5.98
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1103		Drive Pin	2.19	5	0.21	1.98			10.95
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1103		Drive Pin	2.19	5	0.21	1.98			10.95
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0106		Camber Spacer	0.38	2	0.08	0.30			0.76
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0206		Camber Spacer	0.38	2	0.08	0.30			0.76
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1108		Wheel Center	46.38	1	8.78	37.60			46.38
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0107		Wheel Center	18.91	1	10.31	8.60			18.91
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0207		Wheel Center	18.91	1	10.31	8.60			18.91
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1108		Wheel Center	46.38	1	8.78	37.60			46.38
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0208		Spindle Back Nut	8.42	1	3.15	5.27			8.42
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1107		Back Nut (Spindle)	11.53	1	2.30	9.23			11.53
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0108		Spindle Back Nut	8.42	1	3.15	5.27			8.42
Wheels, Wheel Bearings & Tires	FSAEM-18087	WT-1107		Back Nut (Spindle)	11.53	1	2.30	9.23			11.53
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0209		Spindle Back Cap	7.18	1	0.97	6.21			7.18
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-0109		Spindle Back Cap	7.18	1	0.97	6.21			7.18

Asm/Part #	Rev. Lvl.	Assembly	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost	
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1203	Camber Spacer		0.38	2	0.08	0.30			0.76	<input type="checkbox"/>
Wheels, Wheel Bearings & Tires	FSAEM-18078	WT-1203	Camber Spacer		0.38	2	0.08	0.30			0.76	
Wheels, Wheel Bearings & Tires			[Area Total:]				1062.32	574.86	5.76		1642.94	
			[Vehicle Total:]				13281.43	2826.68	148.13	175.71	16431.95	<input type="checkbox"/>



9. Annex B - Formula SAE Manufacturing Outline

ER04 Manufacturing

System	Part	Process	Material Source	Lead Time (day)	Quantity
Front Aero					
	Endplates	Composite	Solarcomposites.com	7-10 days	4
	Front Wing Primary Element	Composite	Solarcomposites.com	7-10 days	2
	Front Wing Secondary Element	Composite	Solarcomposites.com	7-10 days	2
	Front wing Chassis Tabs	Plasma, Welded	Alro/McMaster	3 days	4
	Front wing Spar Tabs	Plasma, Welded	Alro/McMaster	3 days	8
	Front wing Spars	Purchased Assembled	Dragonplate.com	7-10 days	2
	Front wing ribs	WaterJet	Alro/McMaster	3 days	8
Frame					
	Chassis	Tube Laser	VR3/JD Laser	14	1
	Hole Inserts	Welded	McMasterCarr	2 Days	12
	IA	Composite, Assembled	Plascore	2 Weeks	1
	AI Plate	Plasma, Welded	In House	1 Week	1
	AI Washers (AN5-6A)	Purchased Assembled	McMasterCarr	2-3 Days	16
	AI Nuts (AN5-6A)	Purchased Assembled	McMasterCarr	2-3 Days	8
	AI Bolts (AN5-6A)	Purchased Assembled	McMasterCarr	2-3 Days	8
	Paint	Order	In House	2	1
Pedal Assembly					
	Balance Bar				
	Master Cylinders				
	Throttle Cable				
	Mount Assembly	Laser	Supplier	1	
	Rails	Laser	Supplier	1	
	Brake Pedal	WaterJet	Supplier	0,25	
	Throttle Pedal	WaterJet	Supplier	0,25	
	Throttle Linkage	WaterJet	Supplier	0,25	
	Pedal Faces	Composite	Team	2	
	Reservoirs	Assemble	McMasterCarr	0,25	
	BOT Mount	Laser	Supplier	0,25	
Steering					
	Rack		FSAE Parts		1
	Pillow Blocks	Machined	McMasterCarr	1	2
	Steering Shaft	Fabricated	Apex, McMasterCarr	0,5	1
	Bearing Mount	Machined	McMasterCarr	0,5	1
	Bearing shaft	Machined	Sweet	1	1
	Bearing Assembly	Assemble	McMasterCarr	1	1
	Rack Bump Stop	Machined	McMasterCarr		2
	Steering wheel and QD		Transfer		1
	Tie Rods	Machined, Welded	McMasterCarr	2	2
Brakes					
	Front Calipers	Assemble	ER03		
	Rear Calipers	Assemble	ER03		
	Brake Pads	Assemble	Essex		6
	Front Brakes Lines	Assemble	BMRS		
	Rear Brakes Lines	Assemble	BMRS		
	T-Joints for switches	Assemble	BMRS		2
	T-Joints for sensors	Assemble	BMRS		2
	T-Joint to split Front L/R (Soft Line)	Assemble	BMRS		1
	T-Joint to split Rear L/R (Hard Line)	Assemble	BMRS		1
	Brake Switches	Assemble	ER03		
	Brake sensors	Assemble	ER03		
	Banjo Bolt	Assemble	BMRS		1
	Flexible-Rigid Hose Fittings	Assemble	BMRS		4
Front Suspension					
Shock Mount Upper					
	Shock Mount Plate Forward	Plasma	Bill's Shop	7	2
	Shock Mount Plate Rear	Plasma	Bill's Shop	7	2
	Shock Mount Bolt		CoastFab	7	2
	Shock Mount Nylock		CoastFab	7	2
	Shock Mount Tapered Washer	Machined	In House	14	4
	Shock Mount External Washer		CoastFab	7	4
Shock					
	Shock			In Stock	2
Rocker Arm					
	Rocker Arm	Welded	In House	2	2
	Rocker Arm Body	Welded	In House	2	2
	Rocker Arm Bearings		Alpine Bearings	7	4
	Shock Mount External Washers		CoastFab	7	4
	Push Rod External Washers		CoastFab	7	4
	Pivot External Washers		CoastFab	7	4

	Shock Mount Bolt		CoastFab	7	2
	Shock Mount Tapered Washer	Machined	In House	14	4
	Pivot Bolt		CoastFab	7	2
	Pivot Nut		CoastFab	7	2
	Push Rod Tapered Washers	Machined	In House	14	4
	Push Rod Bolt		CoastFab	7	2
	Push Rod Nut		CoastFab	7	2
Push Rod	Push Rod	Welded	In House	2	2
	Push Rod Fork	Laser			4
	Push Rod Bearing		Aurora		4
	Push Rod Upper/Lower	Fabricated	In House	7	4
	Push Rod Mid	Fabricated	In House	7	2
	Load Cell		Futek	In Stock	2
	Push Rod Turnbuckle	Machined	In House	14	2
	Push Rod Middle Insert	Machined	In House	14	2
	A-Arm Spacer Forward	Machined	In House	14	2
	A-Arm Spacer Rear	Machined	In House	14	2
	A-Arm Bolt		CoastFab	7	2
	A-Arm Nut		CoastFab	7	2
	A-Arm External Washers		CoastFab	7	4
Upper A-Arm	Upper A-Arm	Welded	In House	2	2
	Chassis Mount	Laser			4
	Chassis Side Bolt		CoastFab	7	4
	Chassis Side Nut		CoastFab	7	4
	Chassis Side Washers		CoastFab	7	8
	Chassis Side Tapered Washer	Machined	In House	14	8
	Chassis Side Tuning Fork	Laser			4
	Chassis Side Bearing		Aurora		4
	Front Tube	Laser			2
	Rear Tube	Laser			2
	Wishbone	Laser			2
	Wheel Side Bearing		Aurora		2
	Wheel Side Tapered Washers	Machined	In House	14	4
	Wheel Side Bolt		CoastFab	7	2
	Wheel Side Washers		CoastFab	7	4
	Wheel Side Nylock		CoastFab	7	2
Lower A-Arm	Lower A- Arm	Welded	In House	2	2
	Chassis Mount	Laser			4
	Chassis Side Bolt		CoastFab	7	4
	Chassis Side Nut		CoastFab	7	4
	Chassis Side Washers		CoastFab	7	8
	Chassis Side Tapered Washer	Machined	In House	14	8
	Chassis Side Tuning Fork	Laser			4
	Chassis Side Bearing		Aurora		2
	Front Tube	Laser			2
	Rear Tube	Laser			2
	Wishbone	Laser			2
	Wheel Side Bearing		Aurora		2
	Wheel Side Tapered Washers	Machined	In House	14	4
	Wheel Side Bolt		CoastFab	7	2
	External Washer		CoastFab	7	2
	Rocker Arm Mount Forward	Plasma	Bill's Shop	7	2
	Rocker Arm Mount Rear	Plasma	Bill's Shop	7	2
	Rocker Arm Mount Back	Plasma	Bill's Shop	7	2
Upright	Upright	Machine, Assemble			2
	Upright Body	Machined	Alro		1 - RHS, 1 - LH
	Control Arm Mounting Block	Machined	Alro		2
	Control Arm Mounting Bolts		McMaster	3	8
	Upper A-Arm Mounting Bracket		Transfer	In Stock	2
	Upper A-Arm Shim Plate		Transfer	In Stock	6
	Upper A-Arm Mounting Bolt		CoastFab	7	4
	Upper A-Arm Mounting Nut		CoastFab	7	4
	Upper A-Arm Mounting Washer		CoastFab	7	8
	Snap Ring		McMaster	3	2
	Wheel Bearings		SKF	14	4
	Wheel Speed Cage		Transfer	In Stock	2
	Wheel Speed Sensor		Transfer	In Stock	2
Brake Mounting	Brake Bolts		CoastFab	7	4
	Brake Washer		CoastFab	7	8
	Brake Nuts		CoastFab	7	4

Spindle Assembly	Spindle	Machine, Assemble	Transfer		2
	Front Spindle		Transfer	In Stock	2
	Castle Retention Nut		Transfer	In Stock	2
	Castle Nut Pin		McMaster	3	2
	Brake Rotor		Transfer	In Stock	2
	Brake Floats		Transfer	In Stock	10
	Brake Float Snaprings		Transfer	In Stock	10
	Wheel Castle Nut		Transfer	In stock	2
	Wheel Castle Nut Retention Pin		McMaster	3	2
Wheel Assembly	Wheel	Machine, Assemble			2
	Wheel Center	Machine	Transfer	In Stock	2
	Drive Pin	Machine	McMaster/Alro		10
	Wheel Center Bolt		McMaster	3	24
	Wheel Center Nut		McMaster	3	24
	Wheel		Transfer	In Stock	1
Measurement Tools	Toe Measurement Rods	Machine/Assemble			2
	Caster Measurement Rod	Machine			
Front ARB					
	Front ARB Pillow Blocks	WaterJet	DONE	DONE	2
	Front ARB (3 bars?)	Machined	ER03	N/A	3
	Front ARB Lever Arms	WaterJet, Machined	ER03	N/A	2
	Front ARB Spherical Rod End - Male		McMaster	1	2
	Front ARB Spherical Rod End - Female		McMaster	1	2
	Upper Bell Crank Bolt		CoastFab	3	2
	Upper Bell Crank Washer		CoastFab	3	4
	Upper Bell Crank Nut		CoastFab	3	2
	Conical Spacers		McMaster	14	4
	Lever Arm Bolt		CoastFab	3	2
	Lever Arm Washer		CoastFab	3	8
	Lever Arm Nut		CoastFab	3	2
	Front Pillow Block Bolt		CoastFab	3	4
	Front Pillow Block Washer		CoastFab	3	8
	Front Pillow Block Nut		CoastFab	3	4
	Pillow Block Bushing	Machined	McMaster	7	2
	Front ARB Links	Machined, Welded			
Rear Suspension					
Shock Mount Upper	Rear Cross Bar Forward	Plasma			1
	Rear Cross Bar Rear	Plasma			1
	Rear Cross Bar Bolt		CoastFab	7	2
	Rear Cross Bar Washer		CoastFab	7	2
	Rear Cross Bar Nut		CoastFab	7	2
Shock	Shock Assembly				
Rocker Arm	Bell Crank	Welding			2
	Bell Crank Plate Forward	Plasma			2
	Bell Crank Plate Rear	Plasma			2
	Bell Crank Welded Seperating Plate	Plasma			2
	Bell Crank Shock Conical Spacers	Machined			4
	Bell Crank Shock External Washer		CoastFab	7	4
	Bell Crank Shock Bolt		CoastFab	7	2
	Bell Crank Shock Nut		CoastFab	7	2
	Bell Crank Pivot Tab Forward	Plasma			2
	Bell Crank Pivot Tab Rear	Plasma			2
	Bell Crank Bearings		Apline	7	4
	Bell Crank Bearing Spacer	Machined			2
	Bell Crank Pivot Washer		CoastFab	7	4
	Bell Crank Pivot Bolt		CoastFab	7	4
	Bell Crank Pivot Nut		CoastFab	7	4
Push Rod	Push Rod				2
	Push Rod Shock Fork	Plasma/Water			2
	Push Rod External Washer Bell Crank		CoastFab	7	4
	Push Rod Bolt Bell Crank		CoastFab	7	4
	Push Rod Nut Bell Crank		CoastFab	7	2
	Push Rod Conical Spacer	Machined			4
	Push Rod Shock Bearings (Aurora)		Aurora		2
	Push Rod Upper Tube	Machined			2
	Push Rod Threaded Insert	Machined			2
	Push Rod Jam Nut		McMaster	1	2
	Push Rod Load Cell				2
	Push Rod Lower Tube	Machined			2
	Push Rod A-Arm Fork	Laser/Water			2

	Push Rod Threaded Insert	Machine			2
	Push Rod A-Arm Conical Spacer	Machine			4
	Push Rod A-Arm Bearings (Aurora)		Aurora		2
	Push Rod External Washer A-Arm		CoastFab	7	4
	Push Rod Bolt A-Arm		CoastFab	7	2
	Push Rod Nut A-Arm		CoastFab	7	2
	Push Rod A-Arm Tab Forward	Plasma			2
	Push Rod A-Arm Tab Rear	Plasma			2
	Push Rod A-Arm Tab Plate	Plasma			2
Lower A-Arm	Lower A-Arm				
	Frame Mount Forward	Laser			2
	Frame Mount Bolt Forward		CoastFab	7	2
	Frame Mount External Washers Forward		CoastFab	7	4
	Frame Mount Nut Forward		CoastFab	7	2
	Frame Mount Conical Spacers Forw:	Machined			4
	A-Arm Spherical Bearing Frame Forward		Aurora		2
	A-Arm Fork Forward	Plasma/Water			2
	A-Arm Tube Forward	Laser			2
	A-Arm Fork Ball Joint	Plasma/Water			2
	A-Arm Spherical Bearing Ball Joint		Aurora		2
	Ball Joint Conical Spacers	Machined			4
	Ball Joint Washers		CoastFab	7	4
	Ball Joint Bolt		CoastFab	7	3
	A-Arm Tube Rear	Machine	CoastFab	7	2
	A-Arm Fork Rear	Plasma/Water			2
	A-Arm Spherical Bearing Frame Rear		Aurora		2
	Frame Mount Rear	Plasma/Water			2
	Frame Mount Bolt Rear		CoastFab	7	2
	Frame Mount External Washers Rear		CoastFab	7	4
	Frame Mount Nut Rear		CoastFab	7	2
	Frame Mount Conical Spacers Rear	Machined			4
Upper A-Arm	Upper A-Arm				
	Frame Mount Forward	Laser			2
	Frame Mount Bolt Forward		CoastFab	7	2
	Frame Mount External Washers Forward		CoastFab	7	4
	Frame Mount Nut Forward		CoastFab	7	2
	Frame Mount Conical Spacers Forw:	Machined			4
	A-Arm Spherical Bearing Frame Forward		Aurora		2
	A-Arm Fork Forward	Plasma/Water			2
	A-Arm Tube Forward	laser			2
	A-Arm Fork Ball Joint	Plasma/Water			2
	A-Arm Spherical Bearing Ball Joint		Aurora		2
	Ball Joint Conical Spacers	Machined			4
	Ball Joint Washers		CoastFab	7	4
	Ball Joint Bolt		CoastFab	7	2
	A-Arm Tube Rear	Laser			2
	A-Arm Fork Rear	Plasma/Water			2
	A-Arm Spherical Bearing Frame Rear		Aurora		2
	Frame Mount Rear	Laser			2
	Frame Mount Bolt Rear		CoastFab	7	2
	Frame Mount External Washers Rear		CoastFab	7	4
	Frame Mount Nut Rear		CoastFab	7	2
	Frame Mount Conical Spacers Rear	Machined			4
Brake Mounting	Brake Bolts		CoastFab	7	2
	Brake Washer		CoastFab	7	4
	Brake Nuts		CoastFab	7	2
Spindle Assembly	Spindle				
	Front Spindle				
	Castle Retention Nut				
	Castle Nut Pin				
	Brake Rotar				
	Brake Floats				
	Brake Floats Snap Rings				
	Wheel Castle Nut				
	Wheels Castle Nut Retention Pin				
Wheel Assembly	Wheels				
	Wheel Center				
	Drive Pints				
	Wheel Center Bolt				
	Wheel Center Nut				
	Tire				

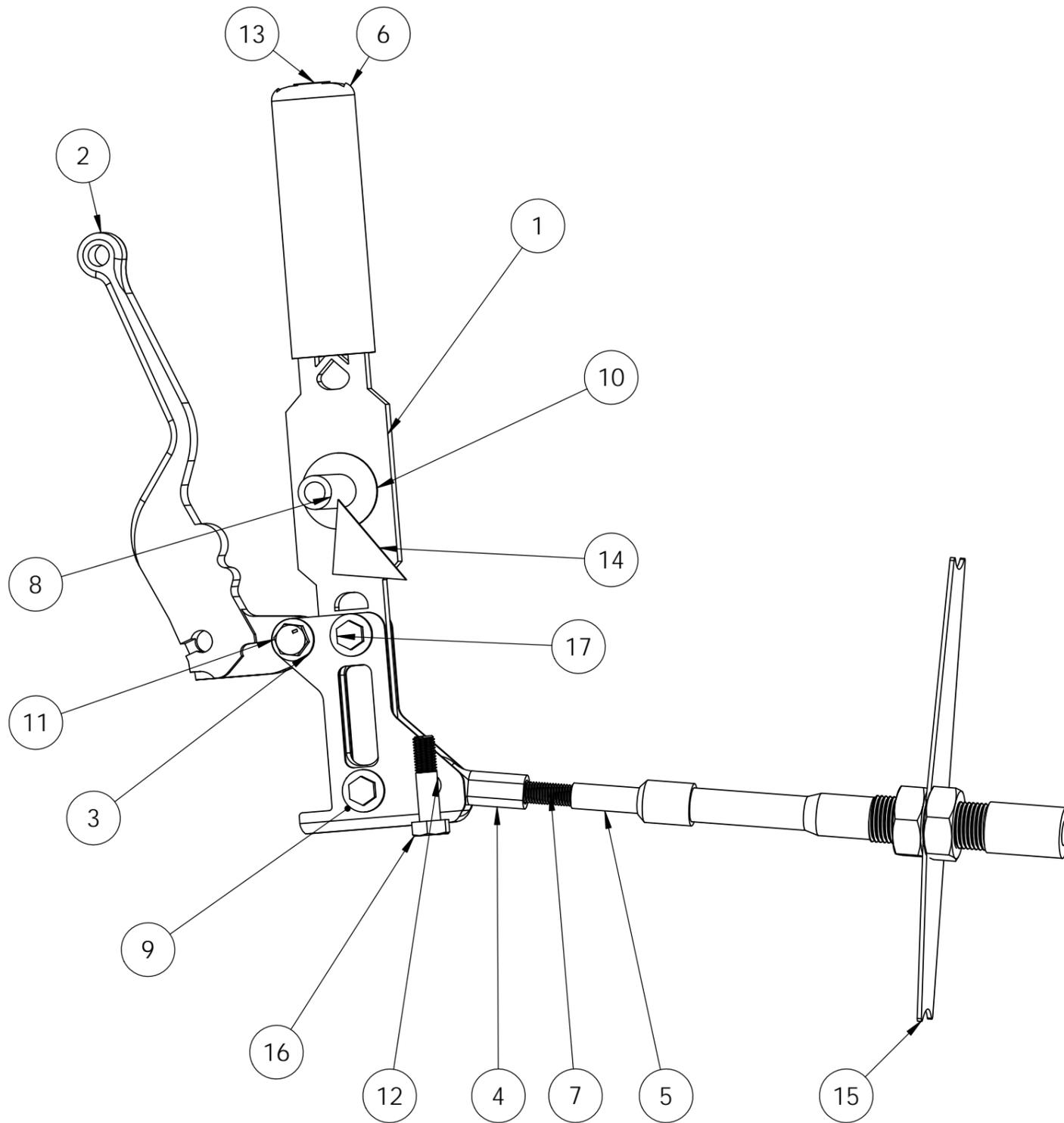
Uprights	Upright				
	Upright Body				
	Upright Upper Ball Joint Mounting				2
	Upright Upper Ball Joint Washers		CoastFab	7	4
	Upright Upper Ball Joint Bolt		CoastFab	7	2
	Upright Upper Ball Joint Nut		CoastFab	7	2
	Upright Upper Ball Joint Conical Spacers	Machined			4
	Upright Lower Ball Joint Washer		CoastFab	7	4
	Upright Lower Ball joint Bolt		CoastFab	7	2
	Upright Lower Ball Joint Nut		CoastFab	7	2
	Upright Lower Ball Joint Conical Spacers	Machined			4
	Upright Tie Rod Washer		CoastFab	7	4
	Upright Tie Rod Bolt		CoastFab	7	2
	Upright Tie Rod Nut		CoastFab	7	2
	Upright Tie Rod Conical Spacer	Machined			4
Rear Tie Rod	Rear Tie Rod				
	Tie Rod Inboard Rod End		McMaster		2
	Tie Rod Inboard Conical Spacers	Machined			4
	Tie Rod Inboard Washers		CoastFab	7	4
	Tie Rod Inboard Bolt		CoastFab	7	2
	Tie Rod Inboard Nut		CoastFab	7	2
	Tie Rod Inboard Threaded Insert	Machined			2
	Tie Rod Inboard Jam Nut		McMaster	1	2
	Tie Rod Outboard Threaded Insert	Machined			2
	Tie Rod Outboard Jam Nut		McMaster	1	2
	Tie Rod Outboard Rod End		McMaster	1	2
Rear ARB					
	BellCrank Bolt		CoastFab	3	2
	BellCrank Washer		CoastFab	3	4
	BellCrank Nut		CoastFab	3	2
	Conical Spacers		McMaster	14	4
	Spherical Rod End Male (Upper)		McMaster	1	2
	Spherical Rod End Male (Lower)		McMaster	1	2
	Jam Nuts		McMaster	1	4
	Threaded Inserts		McMaster	7	4
	Drop Link Shaft		McMaster	7	2
	Lever Arm Bolt		CoastFab	3	2
	Lever Arm Washer		CoastFab	3	8
	Lever Arm Nut		CoastFab	3	2
	Rear Pillow Block Bushing	Machined	McMaster	7	2
	Rear ARB Pillow Blocks	WaterJet, Machined		1	2
	Rear ARB (3 bars?)	Machined		1	3
	Rear ARB arms	WaterJet, Machined		1	2
	Rear ARB Links	Machined, Welded		1	2
Body					
	Nose	CFRP Layup	Solarcomposites.com	7-10 days	1
	Nose Top Mounts	CFRP Layup	Solarcomposites.com	7-10 days	2
	Nose Side Mounts	CFRP Layup	Solarcomposites.com	7-10 days	2
	Side Panels	CFRP Layup	Solarcomposites.com	7-10 days	2
	Side Panel Mounts	CFRP Layup	Solarcomposites.com	7-10 days	8
	Under Nose	CFRP Layup	Solarcomposites.com	7-10 days	1
	Under Nose Mounts	CFRP Layup	Solarcomposites.com	7-10 days	2
	Front Suspension Close out Panels	CFRP Layup	Solarcomposites.com	7-10 days	2
	Front Sus close out Panel Mounts	CFRP Layup	Solarcomposites.com	7-10 days	4
	Side Pods	CFRP Layup	Solarcomposites.com	7-10 days	2
	Side Pods Mounts	CFRP Layup	Solarcomposites.com	7-10 days	10
Cockpit					
	Head Rest Mounts	Fabricated, Welded			1
	Head Rest Padding				1
	Head Rest Plate	CFRP Layup	Solarcomposites.com	7-10 days	1
	Seat	CFRP Layup	Solarcomposites.com	7-10 days	1
	Seat Mounts	Welded			4
	Harness				1
	Harness Mounts	Plasma, Welded			2
	Driver Inserts	Formed (Foam)	Morris Materials		4
Shifter					
	Shifter	WaterJet, Machined			1
	Shifter Sleeve	Machined	McMaster		1
	Shifter Shaft	Machined	McMaster		1
	Shifter Mount Bracket	Plasma, Welded			1

Shifter Engine Mount	-				1
Shift Cable	-				1
Shift Cable aft mount	Plasma, Welded				1
Shift Cable fore mount	Plasma, Welded				1
Shift Shaft Tab 1	Plasma, Welded				1
Shift Shaft Tab 2	Plasma, Welded				1
Shift Shaft Tab 3	Plasma, Welded				1
Clutch Cable	-				1
Clutch Lever	-				1
Shift Lever Grip	3D Print	ERAU Makerspace	7 Days		2
Clutch sensor	?				1
Shift Sensor	?				1
No-Lift-Shift Module	?				1
Cooling					
Radiator	Purchased Assembled	n/a		0	
Radiator Mount	Laser, Welded	McMaster		5	
Cooling Lines	Assemble	n/a		0	
Water Pump	Purchased Assembled	n/a		0	
Water Pump Mount	Laser, Welded	McMaster			
Overflow Tank	Laser, Welded	n/a			
Overflow Tank Mounts	Fabricated, Welded	n/a			
Cooling System Cap	Welded	n/a			
Exhaust					
Exhaust Primaries	Cut, Welded	n/a			
Merge Collector	Purchased Assembled	n/a			
Muffler	Purchased Assembled	n/a			
Exhaust Muffler Pipe	Cut, Welded	Burns Stainless		0	
Muffler Mount	Laser, Welded	McMaster			
O2 Sensor Bung	Welded	n/a			
Engine					
CBR600RR	Purchased Assembled	Sketchy Place in Ocala		0	
Intake				1 day	
Restrictor					
Throttle Body				Assemble	
Engine Mounts	Welded			1 day	
Throttle Body Mount	Plasma, Welded			1 day	
Air Filter		n/a		0	
Oil System - overall, this system needs about 20 more lines of detail. Lots missing here.					
Oil Tank	Plasma, Welded			3 days	
Oil tank mounts	Plasma, Welded			1 day	
Oil Lines	Assemble	BMRS		14 days	
Oil Pump	Purchased Assembled			0	
Oil Tank Cap		Summit			
Oil Filter	Purchased Assembled			0	
Oil Catch Tank	Cut, Weld			20 days	
Oil Pan	Machine			5 days	
Oil Inlet Adapter	Machine			5 days	
Driveline					
Differential Mounts	WaterJet, Machined	Manufacturer		21 days	1 Left, 1 Right
Diff Mount Upper Brackets	Plasma, Welded	Manufacturer		7-10 Days	4
Diff Mount Turn Buckles	Assemble	McMaster		7 days	2
Bearing Retention Brackets	Plasma	Manufacturer		7-10 Days	4
Jackbar Brackets	Plasma	Manufacturer		7-10 Days	2
Do we need to order a section of tube for the jackbar itself, or do we have stock?					
Jackbar Assembly	Welded	Manufacturer		7-10 Days	1
Diff Lower Chassis Engine Brackets	Plasma	Manufacturer		7-10 Days	4
LH RH Turn Buckle	Drill Press Tapped	McMaster		0	2
These need to appear on the machining list, even though they are pretty easy. Please add them ASAP.					
Drexler	Purchased Assembled			0	1
Drexler Tripod Cups		RCV Comp		0	2
Driveline Chain		Cycle Gear		7 Days	1
Chain Guard Aft	Fabricated, Welded	Alro/McMaster			1
Chain Guard Fore		Alro/McMaster			1
Inner and Outer Tripods		RCV Comp	7-10 ordered 11/21		4
Tripod Boots		RCV Comp	7-10 ordered 11/21		2
Halfshafts				0	2
Front Sprocket		PBI Sprockets		7-10 days	1
Rear Sprocket		PBI Sprockets		7-10 days	1
Sprocket Carrier				0	1

Undertray					
	Undertray	CFRP Layup	Solarcomposites.com	7-10 days	1
	Undertray Mounts	CFRP Layup	Dragonplate.com	10 Days	6
	Undertray Access Panel?	CFRP Layup	Solarcomposites.com	7-10 days	1
	Undertray Skirts	CFRP Layup	Solarcomposites.com	7-10 days	2
	Side Skirts	CFRP Layup	Solarcomposites.com	7-10 days	2
Rear Wing					
	Rear Wing Primary Element	CFRP Layup	Solarcomposites.com	7-10 days	1
	Rear Wing Secondary Element	CFRP Layup	Solarcomposites.com	7-10 days	1
	Rear Wing End Plates	CFRP Layup	Solarcomposites.com	7-10 days	2
	Rear Wing Internal Inner Ribs	WaterJet	Alro/McMaster	3 days	2
	Rear Wing Internal Outer Ribs	WaterJet	Alro/McMaster	3 days	4
	Rear Wing Conical Spacers	Lathe	Alro/McMaster	4 days	8
	Rear Wing Internal Spars	Purchased Assembled	Dragonplate.com	7-10 days	2
	Rear Wing Upper Mounts	Plasma, Welded	Alro/McMaster	3 days	4
	Rear Wing Lower Mounts	Plasma, Welded	Alro/McMaster	3 days	4
	Foam Internal Support	Hot Wire		3 Days	5
	Rear Wing Spar Tabs	Plasma, Bonded	Alro/McMaster	3 days	8
	Goosenecks	N/A	N/A	0	2
	Gooseneck rods	N/A	N/A	0	2
Front Wing					
	Front Wing Secondary Element	CFRP Layup	Solarcomposites.com	7-10 days	2
	Front Wing Internal Spars	Purchased/Assembled	Dragonplate.com	7-10 days	2
	Front Wing Endplates	CFRP Layup	Solarcomposites.com	7-10 days	4
	Front Wing Fish	Waterjet / Tapped	Manufacturer	3 Days	
	Front Wing Mounts	Laser	Alro/McMaster	3 Days	2
Fuel System					
	Fuel tank			0	
	Fuel Pump		Walbro, GSL393	5-7 Bus Days	
	Fuel Feed Lines	Assemble	BMRS	14 days	
	Fuel Return Lines	Assemble	BMRS	14 days	
	Fuel Filler Hose			1 hr	
	Fuel Filler Cap			2hrs	
	Fuel Rail			0	
	Injectors		Babbitts Online	0	
	Fuel Tank Mounts - Tank Side			0	
	Fuel Tank Mounts - Chassis Side	Fabricated, Welded		1 day	
	Fuel Filter			1 hr	
	Fuel Pressure Regulator			0	
All Electrical					
	Grounding Tabs	Purchased	Mcmaster		
	Heat Shrink Junctions	Purchased	BMRS Wiring		
	Grommets	Purchased	McMaster		
	Wire Tire Down Mounts	Fabricated			
	Paint Connector Caps	Paint	Hobby Lobby		
Engine Electrical					
	ECU			0	
	Engine Harness	Assemble		7	
	Coil Driver			0	
	Coil Driver Mount	Fabricated	Carbon?	2	
	Coils			0	
	Engine Harness Mounting		Carbon	2	
	Engine No-Lift-Shift Integration	Assemble	DynoMax	1	
	Oil Pressure Sensor			0	
	Water Temp S			0	
	Oil Temp S			0	
	MAP			0	
	IAT			0	
	O2 S		Pegasus/Summit	0	
	Gear Position?	Assemble		2	
	Rectifier Mount		Carbon	2	
	Engine Specific Connectors	Purchased	Corsa Technic	7	
	Butt Splice Crimps	Purchased	BMRS Wiring	14	
	Ring Terminal	Purchased	BMRS Wiring	14	
	Heat Shrink	Purchased	BMRS Wiring	14	
	Lay out wire		BMRS Wiring	4	
	Terminate Wires		BMRS Wiring	2	
	Seal Harness		BMRS Wiring	1	
	Test Harness			1	

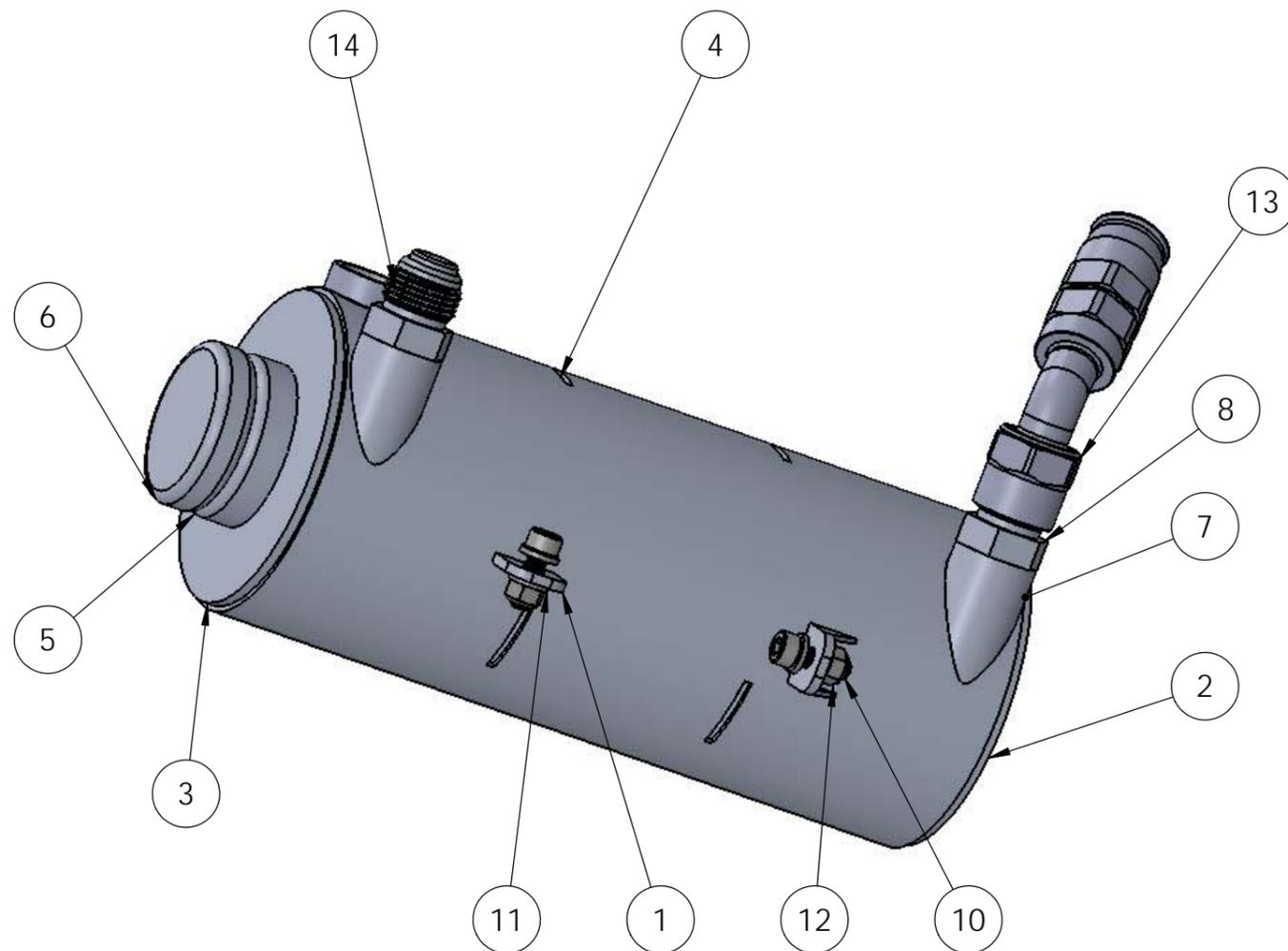
Sensor Electrical					
	C125	Program			
	C125 mount		carbon	3	1
	C125 Harness	Assemble			
	E816	Program			
	E816 Mount		Carbon		
	E816 Harness	Assemble	BMRS Wiring		
	E816 Auxiliary Harness	Assemble			
	Wheel Speed Sensors				
	LVDTs				
	Brake Pressures				
	Load Cells				
	Load Cell amp board				
	Pitot Tube	Assemble			
	Corner Bulk Head Connector Mount	Layup			
	ECU Mount		Carbon		
	Butt Splice Crimps	Purchased	BMRS Wiring		
	Ring Terminal	Purchased	BMRS Wiring		
	Connectors	Purchased			
	Heat Shrink	Purchased	BMRS Wiring		
	Lay out wire		BMRS Wiring		
	Terminate Wires		BMRS Wiring		
	Seal Harness		BMRS Wiring		
	Test Harness				
Power Electrical					
	Fuse and Relay Box	Assemble			
	Fuse and Relay Box Mount	Laser/Waterjet			
	E Stop				
	Driver E Stop				
	Battery				
	Battery Mount	Plasma			
	Harness	Assemble			
	Harness Mounts				
	BOT				
	Jump Start Plug	Assemble,Plasma			
	Print Battery Top	3D Print			
	Print Button Housing	3D Print			
	Dash	Plasma			
	Key Mount	Carbon			
	Switches (driver/BOT)	Purchased			
	Brake Light	Design, Purchased			
	Butt Splice Crimps	Purchased	BMRS Wiring		
	Ring Terminal	Purchased	BMRS Wiring		
	Connectors	Purchased			
	Heat Shrink	Purchased	BMRS Wiring		
	Lay out wire		BMRS Wiring		
	Terminate Wires		BMRS Wiring		
	Seal Harness		BMRS Wiring		
	Test Harness				
Fire Wall					
	Bottom Left Firewall	CFRP Layup	Donated Pre-Preg	2	
	Bottom Right Firewall	CFRP Layup	Donated Pre-Preg	2	
	Bottom Mid Firewall	CFRP Layup	Donated Pre-Preg	2	
	Mid Firewall	CFRP Layup	Donated Pre-Preg	2	
	Top Firewall	CFRP Layup	Donated Pre-Preg	2	
	Bottom Firewall Mounts	CFRP Layup	Donated Pre-Preg	2	
	Mid Firewall Mounts	CFRP Layup	Donated Pre-Preg	2	
Radio					
	Radio				
	Radio Mount	Fabricated, Welded			
	Push to talk Harness	Assemble			
	Push to talk button mount	Fabricated, Welded			
	Curly Wire	Purchased			

10. Annex C – Dimensional & Assembly Drawings



N.º DE ELEMENTO	N.º DE PIEZA	DESCRIPCIÓN	CANTIDAD
1	FSAEM-18078-FR35002	Shift Lever	1
2	FSAEM-18078-FR35004	Clutch Handle	1
3	90770A029		8
4	60645K331		1
5	FSAEM-18078-FR35014	Shifter Cable Assembly	1
6	FSAEM-18078-FR35026	Shifter handle	1
7	FSAEM-18078-FR35001	Shifter assembly	1
8	FSAEM-18078-FR35030	Lever shaft and mount	1
9	FSAEM-18078-FR35032	Sheet metal mount	1
10	90107A032		1
11	94622A414		1
12	90566A210		4
13	91253A540		1
14	FSAEM-18078-FR35039	Long Shaft mount tab	1
15	FSAEM-18078-FR35013	FWD Shifter Cable Mount	1
16	94622A423		1
17	AN3-12A		2

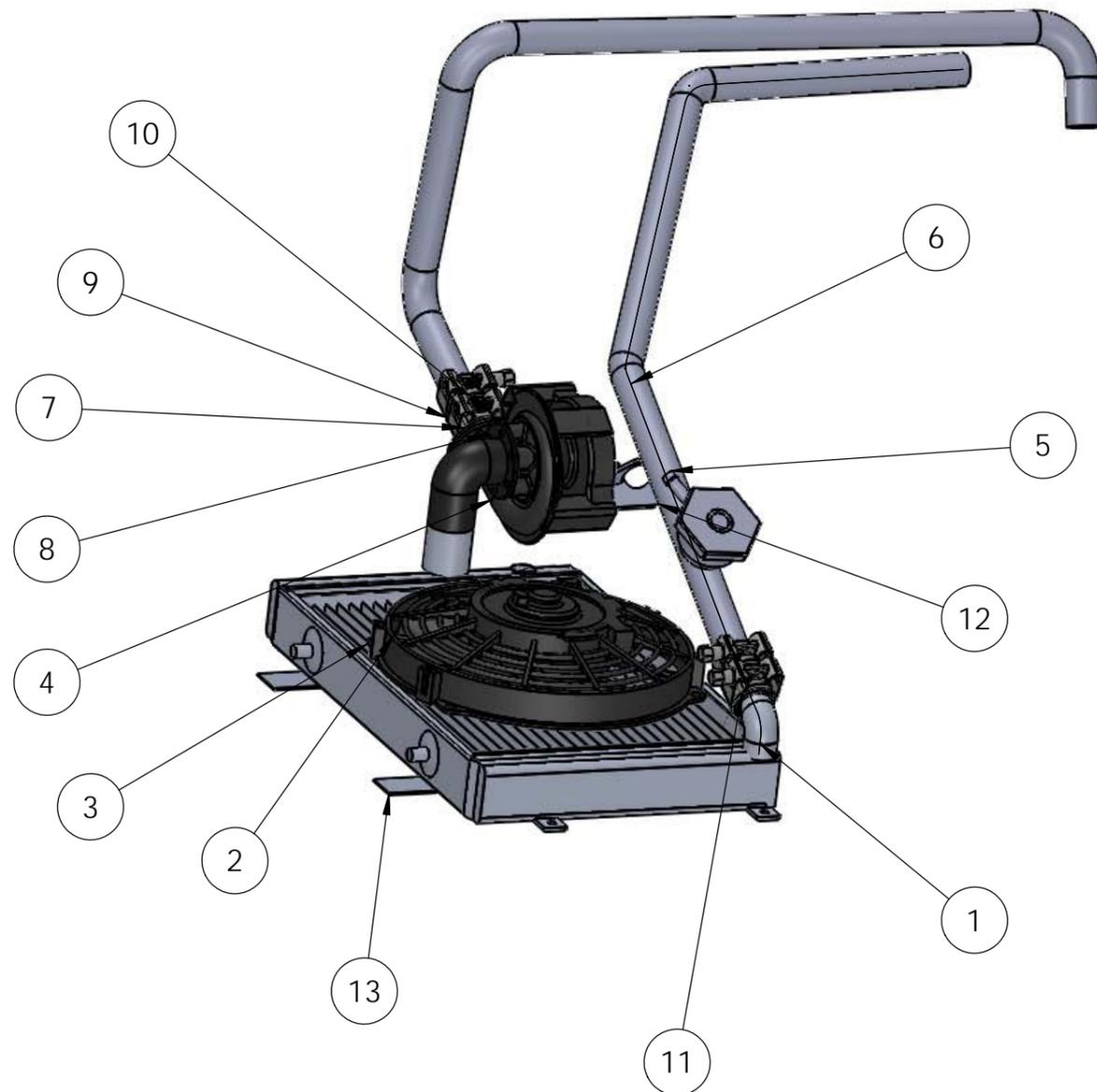
DESIGN	CARRALERO, ALBERTO	SIGNATURE	DATE	TITULO:
VERIF.	RODRÍGUEZ, RAFAEL		06/12/2018	<h1>Shifter Assembly</h1>
APROB.	SPITZER, DAVE			
FABR.				
Embry-Riddle Aeronautical University				
				SYSTEM: Miscellaneous, Finish & Assembly
				A3
				SCALE: 1:2
				PAGE 1 OF 1



N.º OF ELEMENT	N.º OF PART	DESCRIPTION	QUANTITY
1	17EN40025AA	oil tank	1
2	17EN40027AA	oil tank bottom	1
3	17EN40029AA	oil tank top	1
4	17EN40031AA	oil tank baffle	2
5	17EN40033AA	oil tank cap boss	1
6	17EN40035AA	oil tank cap	1
7	17EN40037AA	oil tank fitting boss	2
8	17EN40041AA -10	weld fitting	2
9	17ENA40015AA	oil catch can	1
10	91292A136		2
11	90965A170		4
12	94645A205		2
13	17EN40051AA -10	hose end 45	1
14	17EN40039AA	oil tank vent fitting boss	1

DESIGN	CARRALERO, ALBERTO	SIGNATURE	DATE	06/12/2018	Oil Tank
VERIF.	RODRÍGUEZ, RAFAEL				
APROB.	SPITZER, DAVE				
FABR.					
Embry-Riddle Aeronautical University					SYSTEM: Engine & Drivetrain
				SCALE: 1:5	PAGE 1 OF 1

A3



N.º OF ELEMENT	N.º OF PART	DESCRIPTION	QUANTITY
1	FSAEM16098EN06001AA	RADIATOR	1
2	FSAEM16098EN06050AA	FAN BLADE HUB	1
3	FSAEM16098EN06050AA	FAN CASING	1
4	FSAEM16098EN06070AA	WATER PUMP	1
5	FSAEM16098EN06072AA	RADIATOR PRESSURE CAP ASSY	1
6	Rad lines		1
7	Water Pump outlet		1
8	Water Pump outlet 2		1
9	silicone		2
10	5443K18		2
11	5443K18		2
12	waterpump mount		1
13	Radiator mount		1

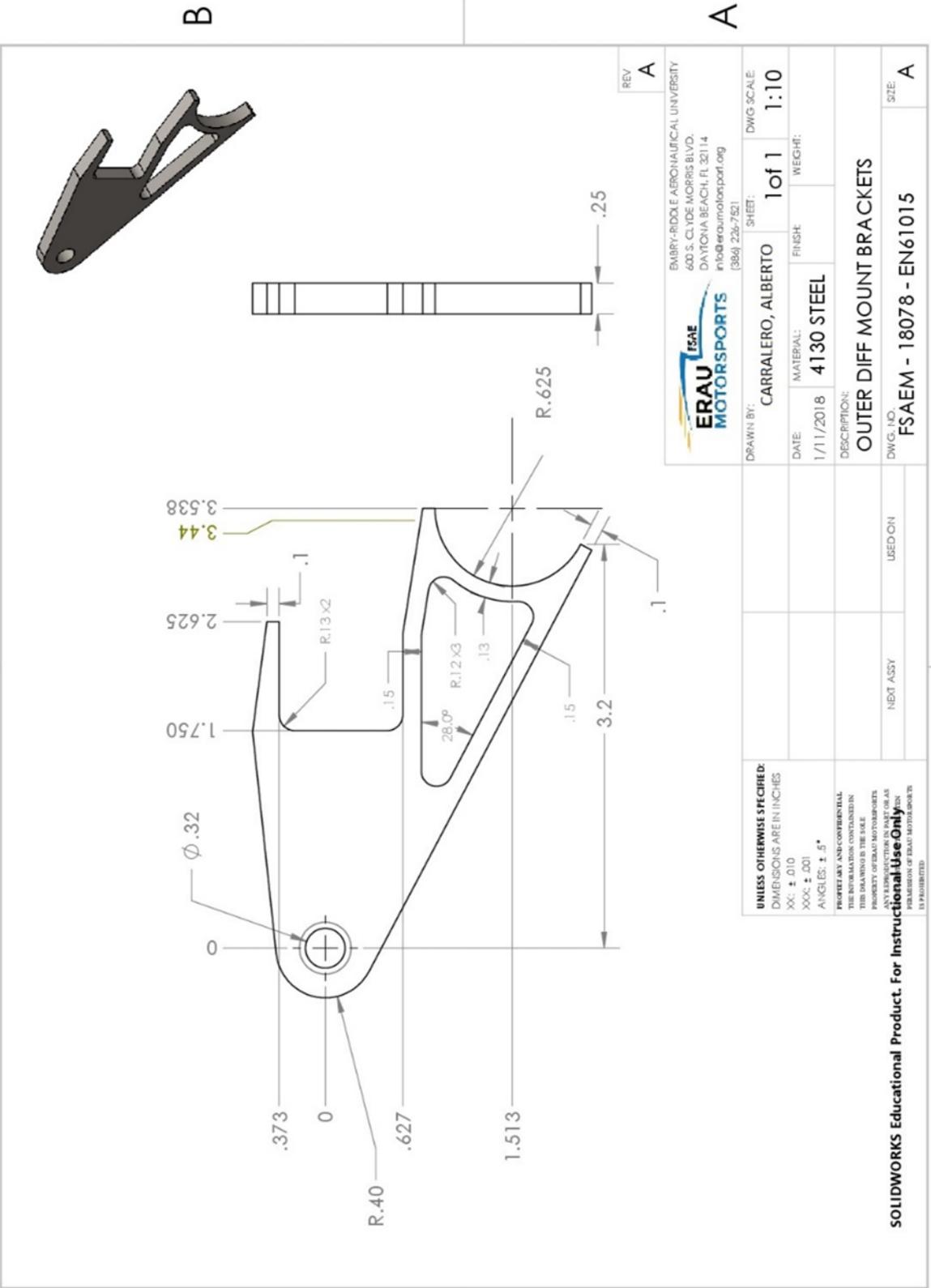
	NAME	SIGNATURE	DATE	TITULO:
DESIGN	CARRALERO, ALBERTO		06/12/2018	<h1>Cooling Assembly</h1>
VERIF.	RODRÍGUEZ, RAFAEL			
APROB.	SPITZER, DAVE			
FABR.				
Embry-Riddle Aeronautical University				SYSTEM: Engine & Drivetrain
				A3
			SCALE: 1:20	PAGE 1 OF 1

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UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN INCHES
 XX: ± .010
 XXX: ± .001
 ANGLES: ± 5°

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DATE	1/11/2018	MATERIAL	4130 STEEL	FINISH		WEIGHT	
DRAWN BY: CARRALERO, ALBERTO				SHEET: 1 of 1		DWG SCALE: 1:10	
NEXT ASSY		USED ON		DESCRIPTION: OUTER DIFF MOUNT BRACKETS			
DWG. NO. FSAEM - 18078 - EN61015				SIZE: A			

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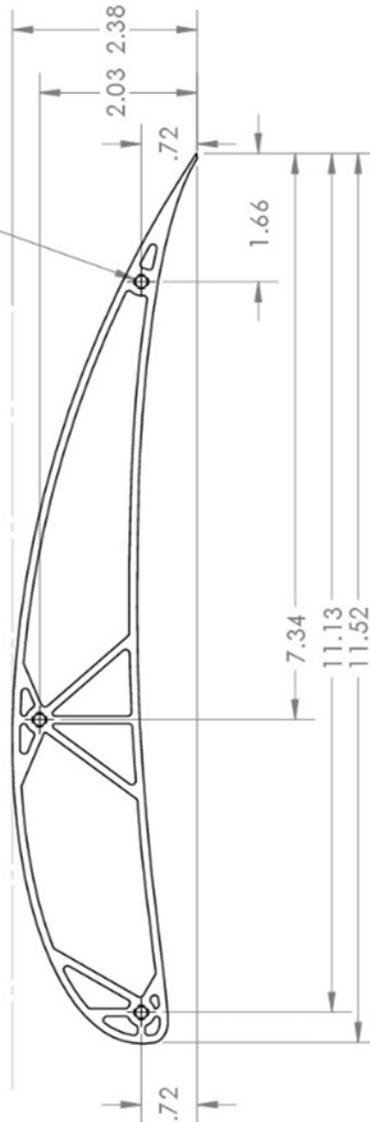
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B



UNF #10-32 THRU X3



REV A

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY
 600 S. CLYDE MORRIS BLVD.
 DAYTONA BEACH, FL 32114
 info@erau.edu
 (386) 225-7521



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UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES XX: ± .010 XXX: ± .005 ANGLES: ± .5°		DRAWN BY: Carralero, Alberto		SHEET: 1 of 1		DWG SCALE: 1:2	
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NEXT ASSY		USED ON		DESCRIPTION: Rear Wing Upper Primary Airfoil Insert			
DWG. NO.: FSAEM-18078-FR23007 RWME Fish		SIZE: A					

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