ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

MASTER EN INGENIERÍA INDUSTRIAL

PRODUCT LAUNCH DEVELOPMENT OF A FORMULA SAE VEHICLE

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Madrid

Junio 2018

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DISEÑO Y DESARROLLO DE UN VEHICULO FORMULA SAE

Autor: Serrano Gil, Luis.

Director: Dhainaut, Jean Michel.

Entidad Colaboradora: ICAI - Universidad Pontificia Comillas.

RESUMEN DEL PROYECTO

Introducción

La formula SAE es una competición de coches de carreras a nivel mundial entre universidades. La competición promueve el uso de la ingeniería aplicada al mundo de la automoción. El nombre de la competición viene dado por la Society of Automotive Engineers, ahora denominada SAE Internacional y es la responsable de la organización de los eventos.

Esta competición consiste en una serie de test estáticos y dinámicos donde participan 120 universidades de todo el mundo y compitiendo en el circuito de Michigan (EEUU). Cada test tiene una puntuación distinta.

El objetivo de este proyecto es por tanto, centrarse en uno de los test que consiste en el desarrollo de un plan de negocio y de fabricación para sacar el prototipo a la venta. El siguiente proyecto se basará en el desarrollo del prototipo ER 04.

Metodología

Para alcanzar el objetivo propuesto, este proyecto se ha divido en cinco grandes apartados que se describen a continuación:

- <u>Estado del arte</u>: en este apartado se describe la historia de la competición, así como las reglas y test a los que se debe de enfrentar el prototipo.
- <u>Plan de negocio</u>: este apartado se centrará en el desarrollo de la empresa, el producto y el análisis del mercado y competidores.
- <u>Plan de marketing</u>: el principal objetivo de este apartado es el análisis del potencial cliente y las maneras a llevar a cabo para atraerle.

- Plan financiero: este apartado se centrará en el análisis de las proyecciones financieras y de las inversiones necesarias para que el proyecto sea exitoso.
- Plan de manufactura: este es uno de los principales apartados del proyecto que se centrara en el diseño y desarrollo del prototipo y el sistema de producción idóneo para su fabricación.

Resultados y Conclusiones

Tras identificar y marcar unos objetivos claros, ambiciosos y alcanzables, y después de establecer una hoja de ruta clara, ordenada y efectiva se puede concluir lo siguiente del proyecto:

- El prototipo ER 04 es un vehículo de autocross que tiene un gran potencial, manejo, fácil de mantener y que ha pasado numerosos test satisfactoriamente.
- De este prototipo se harán dos modelos distintos para satisfacer a nuestros potenciales clientes.
- Los potenciales clientes podemos dividirlo en dos: uno es un piloto actual y el otro no es piloto pero tiene todas las características para serlo.
- Una de las estrategias principales para llegar a ello se basará en publicidad y en crear un programa de lealtad para poder satisfacer las necesidades del cliente junto con el programa de atención al cliente.
- El plan financiero se resume en la siguiente tabla:

Pro Forma Income Statement				
	Year 0	Year 1	Year 2	Year 3
Revenues		1,575,000	3,375,000	5,625,000
Price		23,000	23,000	23,000
Nº Vehicles Loaded		53	113	188
Price		21,000	21,000	21,000
Nº Vehicles Basic		18	38	63
Costs	477,500	1,599,338	3,079,438	4,880,563
Machinery	200,000			
Material	-	1,121,838	2,403,938	4,006,563
Labor	253,500	448,500	643,500	838,500
Other Costs	24,000	29,000	32,000	35,500
Net Income	- 477,500	- 24,338	295,563	744,438

Table 1. Resumen de las proyecciones financieras

- El vehículo se fabricará en Daytona Beach (EEUU) bajo la modalidad lean manufacturing, just-in-time.

- El prototipo de fabricará a partir de unos módulos que se resumen en la siguiente imagen:

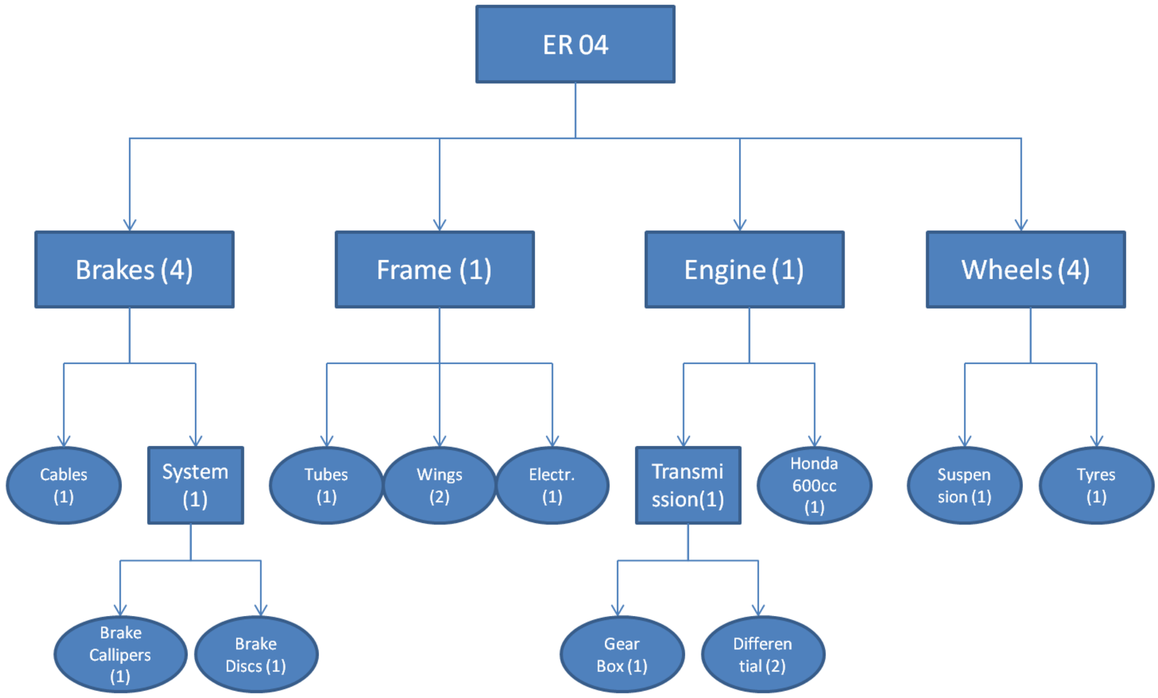

Figure 1. Estructura del producto

- Se hará una transición de tipo de producción de posición fija cuando las unidades a fabricar sea pequeñas a una modalidad de ensamblaje en línea cuando las unidades a producir sean mayores.

PRODUCT LAUNCH DEVELOPMENT OF A FORMULA SAE VEHICLE

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Director: Dhainaut, Jean Michel.

Collaborating Entity: ICAI - Universidad Pontificia Comillas.

SUMMARY OF THE PROJECT

Introduction

Formula SAE is a competition of racing cars worldwide among universities. The competition promotes the use of engineering applied to the automotive world. The name of the competition is given by the Society of Automotive Engineers, now called SAE International and is responsible for the organization of the events.

This competition consists on static and dynamic tests involving 120 universities around the world and competing in the Michigan circuit (US). Each test has a different score.

The objective of this project is therefore to focus on one of the tests that consists on the development of a business and manufacturing plan in order to launch the prototype to the market. This project will be based on the development of the ER 04 prototype.

Methodology

To achieve the objective, this project has been divided into five sections described below:

- State of art: This section describes the history of the competition, as well as the rules and tests that the prototype has to pass.
- Business plan: the business plan will consist of the following five elements: Executive Summary, brief Company Overview, Product and Service, Market Analysis and Competitors Analysis.
- Marketing plan: the marketing plan will be focused on reaching our target customer, company positioning and marketing goals.

- Financial Plan: the financial plan will be focused on the financial projections and company funding needs.

- Manufacturing Plan: the manufacturing plan will describe the specifications of the vehicles and how it will be processed in order to manufacture the vehicle.

Results and Conclusions

After identifying and setting clear, ambitious and achievable objectives, and after establishing a clear, orderly and effective roadmap, the following points can be concluded from the project:

- The new ER04 is an autocross vehicle with great potential, handling, is easy to maintain, and has been tested successfully.

- There will be two types of models, one basic and one fully loaded to meet the needs of our two types of potential customers.

- One of them is currently a driver and the other is a racing fan willing to drive a competition vehicle.

- To reach them, the company will develop a marketing strategy based on advertising and a loyalty service with a great customer service program.

- the finance statement is summarized in the following table:

Pro Forma Income Statement				
	Year 0	Year 1	Year 2	Year 3
Revenues		1,575,000	3,375,000	5,625,000
Price		23,000	23,000	23,000
Nº Vehicles Loaded		53	113	188
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Nº Vehicles Basic		18	38	63
Costs	477,500	1,599,338	3,079,438	4,880,563
Machinery	200,000			
Material	-	1,121,838	2,403,938	4,006,563
Labor	253,500	448,500	643,500	838,500
Other Costs	24,000	29,000	32,000	35,500
Net Income	- 477,500	- 24,338	295,563	744,438

Table 2. Financial Projections

- This vehicle will be manufactured in Daytona Beach, FL (USA) under the modality of just-in-time being.

- The prototype will be manufactured from modules that are summarized in the following figure:

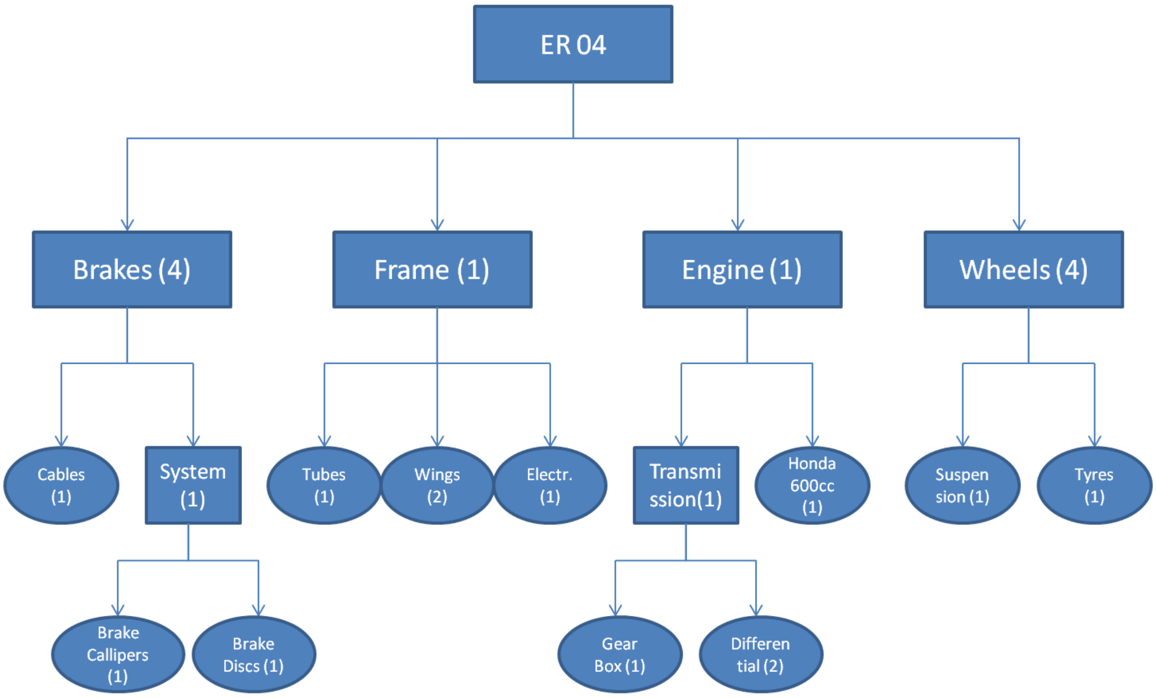

Figure 2. Product Structure

- The early years the vehicle will be manufactured in a fixed position with a transition to a line assembly when the capacity increases.

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Madrid

Junio 2018

Dedicatoria

A la memoria de mi madre.

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1. State of the Art.

1.1 Formula SAE.

The Formula SAE is a single-seat racing car competition between universities that promotes the development of engineering applied to the automotive industry. The participants in this competition are teams that represent their universities from all over the world. The name is given by the SAE (Society of Automotive Engineers) now called SAE International, which organizes the events.

Figure 3. SAE International logo **(1)**

SAE International was created in the US in 1905. The main objective was the development of the standards for all types of vehicles, including cars, trucks, ships, planes, etc. Today, according to data from its web page www.sae.org, the organization is composed of 128,000 members spread across more than 100 countries around the world.

SAE International organizes eight different competitions within its program Collegiate Design Series (CDS). The goal is to design, manufacture and evaluate the vehicle, which is then put to the test and final competition. Some of the competitions are: SAE Aero Design, Baja SAE, Clean Snowmobile Challenge, Formula SAE and Formula SAE Electric.

1.2 Formula SAE History

The Formula SAE has its origin in the United States. The first competition began to take shape in 1979 when Mark Marshek, a professor at the University of Houston, contacted the Educational Relations Department of SAE a year earlier.

The original concept of the Formula SAE was an evolution of the Baja SAE, an existing competition in which the type of vehicle to be built by the students. It is similar to a off road vehicle (Figure 4. **Baja SAE vehicle** . However, this competition limited the freedom (engine provided by the organization without the possibility of modifying it) and the new competition should give them more time to design the car.

Figure 4. Baja SAE vehicle **(2)**

In 1981, the University of Texas (Austin), organized the first edition of the Formula SAE where 6 teams participated but only 4 actually showed up.

This completion has been growing rapidly and in 1998 the first edition of the event was held outside the US. In this year, two American cars and two English cars competed in a demonstration in MIRA (Motor Industry Research Association) test area, in the city of Nuneaton, England. The initiative was considered very useful for the development of students, and learning practical skills, so, the "Institution of Mechanical Engineers" of England, accepted the management of this European event in an association with the SAE. This event was called Formula Student. The Formula Student is slightly different from the Formula SAE, since it is designed to be a progressive learning exercise throughout a three or four year academic course. However, the same rules are used for the Formula Student and the Formula SAE (with some minor changes) and this means that student teams can participate with their cars in both events.

Subsequently, events were created in other countries such as Germany, Japan, Brazil, Australia, etc. All of them use the same original base regulations of the Formula SAE and can hold up to 120 teams and more than 2,000 students.

1.3 Objectives of the competition

The challenge of the teams is to develop a vehicle that is capable of successfully passing each of the competitions' events and the team winner will be the one with the highest score based on those tests.

For the purpose of the competition, the teams have to assume the role of employees of a car company which designs, manufactures, tests and performs a demonstration of a prototype car that they want to sell to a hypothetical corporation or person that is considering buying a racing car.

In order to judge the excellence of the work carried out by each team, a series of events are made, which are punctuated in Table 3. Each test will be explained in the following section.

Static Events:		
	Presentation	75
	Engineering Design	150
	Cost Analysis	100
Dynamic Events		
	Acceleration	100
	Skid-Pad	75
	Autocross	125
	Efficiency	100
	Endurance	275
Total Points		1,000

Table 3. Points possible in each test

1.4 Events

The requirements regarding the vehicle and the participants, as well as everything related to the tests and rules of the event, are included in a document that SAE updates for each competition season. In the following lines, we will focus on briefly explaining how the tests that the teams must pass and what they consist of.

The largest competition in the United States takes place in Michigan International Speedway (MIS) during May 2018 in Brooklyn, Michigan. The Figure 5 shows the automotive tracks options available at MIS.

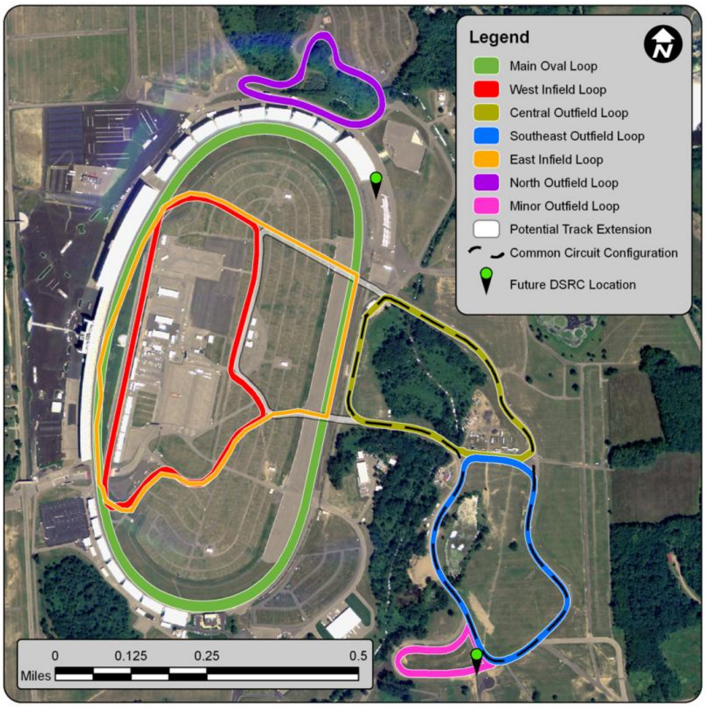

Figure 5. Michigan International Speedway Track Options

There are two types of tests: Statics Events and Dynamics Events.

1. Static Events: These events are carried out with the car stopped and turned off. The sum of points for this type of test is 325 maximum. Four events under this category are carried out, but one of them, the technical inspection test, does not score.
    a. Technical Inspection: The objective of technical inspection is to determine if the vehicle meets the FSAE Rules requirements and restrictions and if, considered as a whole, it satisfies the intent of the Rules. Vehicle inspection will consist of three separate parts: Electrical and Mechanical Technical Inspection, Tilt Table, Noise, Master Switch, Ready-To-Drive-Sound and Brake Tests.
    b. Business Presentation: The objective of this test is to evaluate the ability of each team to sell the product to a hypothetical corporation that wants to invest in the manufacturing of a racing vehicle. The presentation should try

to convince the representatives of the superiority of their design against other competitors. The judges evaluate both the organization and the content and award a score based on that. The maximum score possible in this test is 75 points.

c. Engineering Design: The objective is to evaluate the engineering work in the design of the car and how it meets the vehicle requirements and market demands. Thus, during this event, the design of the components of the vehicle is questioned by engineers and designers in the automobile industry. It is necessary to show all the elements of the car and defend the different technical solutions adopted. Likewise, the participants are required to give justifications to the solutions chosen and show the results of the different tests done in order to verify the validity of the design. The maximum score that can be obtained in this test is 150 points.

d. Cost Analysis: The objective of this test is to show participants that cost and budget are critical factors and that they should be taken into account in any engineering process. Team members are expected to learn the concept of a "trade-off" between content and cost based on the performance of each part and assembly. The maximum achievable score in this test is 100 points. The evaluation is based on two points:

    i. The elaboration and presentation of a written report that must be sent to the judges before the competition.

    ii. The defense of the cost of any part of the vehicle in an event that takes place during the competition days.

2. Dynamic Events: As its name suggests, in these events the dynamic capabilities of the vehicle are evaluated. In order to evaluate their aptitudes there are five different tests. It should be noted that due to the nature of the tests, the pilot or pilots involved in them, play an important role in the performance of the car during this event.

   To participate in this block of tests it is necessary to pass the technical inspection successfully. The sum of points of this block of tests is 675 maximum, which added to the 325 points of the static event gives us the maximum score distributed among the entire event that is 1000 points.

a. Acceleration: The acceleration of the car is measured in a straight line, starting from a standing position on a flat surface. The car has to travel 75 meters (246 feet). The foremost part of the car will be staged at 0.30 m (11.8 inches) behind the starting line. The time will begin to count once the vehicle crosses the starting mark. There are two rounds for this event, where each team is given two attempts per round to set their best time. Each round will be carried out by a different driver. The best time achieved in all attempts is the one that counts towards the score obtained. The maximum score that can be obtained in this test is 100 points.
b. Skid-Pad: The purpose of the test is to measure the ability of the vehicle to turn on a flat surface while performing a constant radius turn. Each car can make two rounds, with a different pilot in each round and with two attempts in each of them. The circuit consists of two circles of 15.25 m (50.03 feet) diameter arranged in an eight-form. The centers of the circles will be 18.25 m (59.88 feet) apart, with a lane with a width of 3 m (9.84 feet) that is marked by cones of different colors on each side. The start and stop line will be determined by the line joining the centers of the two circles. The cars enter perpendicular to the eight and should make two full laps to the right circle and then two more laps in the left one. The outline of the circuit can be seen in Figure 6. For each cone that is knocked "out or down", there will be a penalty of 0.25 seconds. The time that is computed in each of the attempts is the one corresponding to the second completed turn in the right circle plus the second completed turn in the left circle. The maximum score that can be obtained in this test is 75 points.

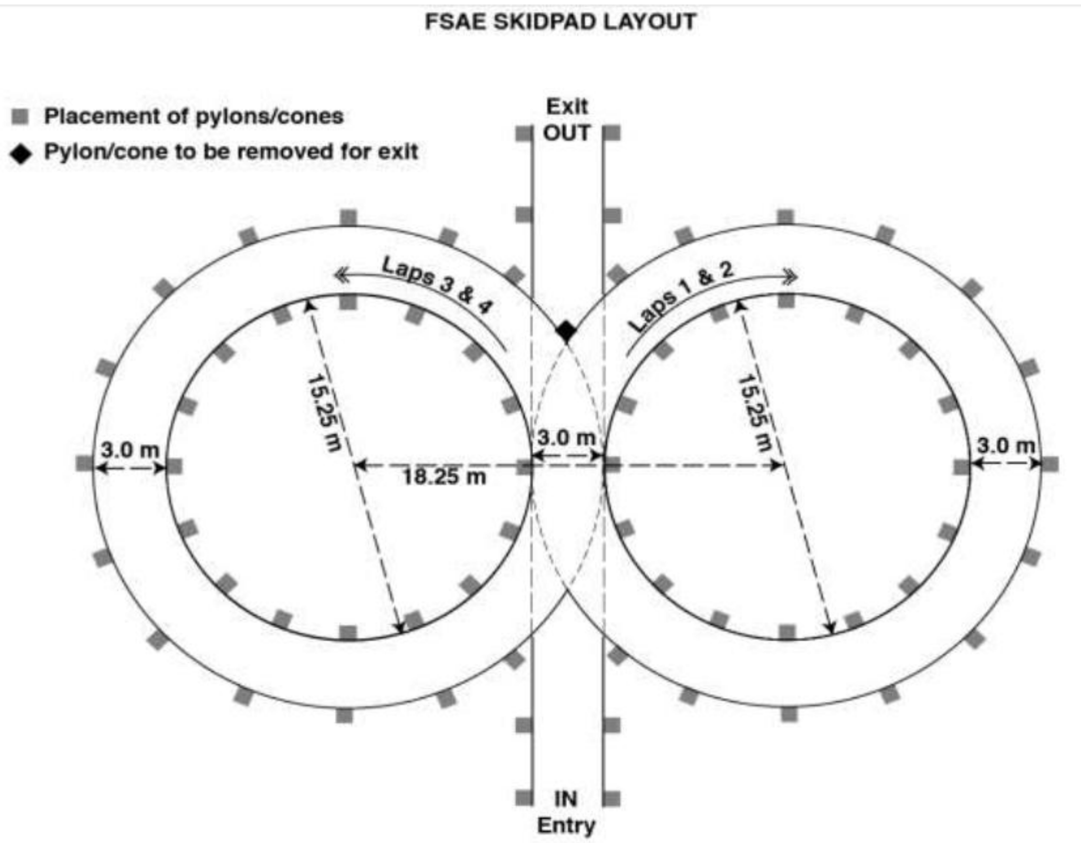

Figure 6. Formula SAE Skid-Pad layout

c. <u>Autocross:</u> The objective of this test is to evaluate the maneuverability of the vehicle on a tight circuit and in the absence of other competing vehicles. This test combines the ability of the car to accelerate, brake and take sharp turns. As in the previous tests, it is possible to carry out two rounds. Of the four laps given by the two pilots, the best of the four is counted as the time of the race. The average speed that will be reached in this test is between 40-48 km/h (25-30 mph). The straight lines are not longer than 60 m (200 feet). The turning radius ranges from 23 to 45 m (75 to 148 feet). The slalom zones will be formed by separated cones a distance that can vary between 7.62 m and 12.19 m (25 to 40 feet). The length of each lap is approximately 0.805 km (1/2 mile). Each cone knocked down during the race is penalized with two seconds over the total time. The maximum score that can be obtained in this event is 125 points.

d. Endurance and Efficiency: This test is designed to evaluate the overall performance of the car and thus to test its durability and reliability. The fuel economy efficiency of the car is measured in conjunction with endurance test. This test is carried out in a single round consisting of about 22 laps where the vehicle cannot be repaired. To evaluate the consumption of the car the tank is filled until the fuel level line before the beginning and once the vehicle completes the event, it is refilled in order to measure the consumption during the test. Therefore, refueling is not allowed during the test. The average speed reached in this event is between 48 and 57 km/h (29.8 to 35.4 mph), reaching maximums of about 105 km/h (65.2 mph). The straight lines are usually no larger than 77 m (252.7 feet). The turn radio is between 30 and 54 m (98.4 to 177.2 mph). In the slalom zone the cones have a separation of between 9 and 15 m (29.5 to 49.2 mph). It is possible to change the pilot one time during the race and the change should last for a maximum of three minutes. The maximum score obtained in this endurance test is 275 points according to the time spent on the 22 km in the circuit and 100 additional points that are awarded based on the lowest fuel consumption.

1.5 Formula SAE in Embry Riddle Aeronautical University (ERAU)

1.5.1 ER01

ER01 was the first vehicle designed and manufactured by the team for the Michigan competition in 2015. The final result was not as expected but it was a great start to develop the prototype of the following year.

1.5.2 ER02

The ER02 was designed for the Formula SAE Michigan competition in 2016. This year was the first year when Embry Riddle Aeronautical University attended the competition with a full car ready to compete. The prototype passed static events and almost every dynamics events except the endurance test, where the vehicle had a power-train failure. The results are shown in the next table:

Formula SAE Michigan 2016	
Test	points
Cost	53
Presentation	50.1
Design	60
Acceleration	56.5
Skip Pad	11
Autocross	57.4
Endurance	-
Efficiency	-
Total	288
Final Place	81/115

Table 4. Points in Formula SAE Michigan 2016

Figure 7. Picture of the prototype ER02

1.5.3 ER03

The ER03 was designed for the Formula SAE Michigan competition in 2017. The prototype passed statics events and almost every dynamics events except the endurance test, where the vehicle had a brakes system and engine failure. The results are shown in the next table:

Formula SAE Michigan 2017	
Test	points
Cost	61.5
Presentation	43.9
Design	70
Acceleration	39.9
Skip Pad	26.9
Autocross	67.4
Endurance	11
Efficiency	-
Total	320.6
Final Place	70/109

Table 5. Points in Formula SAE 2017

Figure 8. Picture of the prototype ER 03

In the 2017 edition, the team improved compared to last edition in the cost event (8.5 points), design event (10 points), skip pad event (15.9 points), autocross event (10 points) and finally the team got its first points in the endurance test (11 points) before the engine failure. Overall, the team improved by 11 positions.

2. Business Plan

2.1 Introduction

In this section we will analyze the steps necessary to develop the business plan of our company. The objective is to capture all ideas on the same paper in order to have a successful project.

Therefore, this Business Plan will consist of the following five elements: Executive Summary, brief Company Overview, Product and Service, Market Analysis and Competitors Analysis.

2.2 Executive Analysis

The objective is to capture the reader's interest, the idea is to convince them to read the entire plan.

- Concept Description: ERAU Motorsports is focused on the design, manufacturing and sales of an autocross vehicle whose potential customer is the racing fan that wants to drive a race car during his free time.
- Opportunity: the new ER04 satisfies the needs of the market with an autocross vehicle with good performance, great serviceability which gives the racing fan the possibility of obtaining the Fast Time of the Day (FTD) in each race.
- Product: the new ER04 is an autocross vehicle with a high engineering design which is made with high quality materials. As result of this, the new ER04 has the performance and reliability needed to satisfy the needs of the customer.
- Value Proposition: Our ER 04 autocross vehicle helps racing fans and drivers who want to go racing in their free time by reducing the time of preparation and travel with the same adrenaline feeling unlike regular racing cars which need more time for maintenance and travel for racing.
- Marketing Strategy: the marketing strategy will consist on solid brand awareness with advertising in social media and magazines offering loyalty and standout customer service.

- Management: The team is formed by people from diverse backgrounds with experience in companies of the highest level and in the Formula SAE competitions.
- Financial: The breakeven point of the investment will come at 72 units sold and the revenues in the third year of $740,000
- Funding: the company will require $500,000 in return for 40% equity in the company and a payback schedule of 3.1 years. The Return on the Investment (ROI) will be 50% in the 3rd year.

2.3 Company Overview

The Company Overview is a brief description of the company that a person funded or wants to fund.

ERAU Motorsports is a company located in Daytona Beach, FL belonging to Embry Riddle Aeronautical University.

ERAU Motorsports started in 2014 formed by the students of Embry Riddle. The objective of this company is to design, manufacture, build and test an open-wheel style Formula racecar marketed to the weekend racer and to develop a business plan in order to sell the vehicle.

2.4 Product and Service

This section will give a detailed description of the product and it will be focused on the features, benefits and stage of development.

2.4.1 Features

The differentiation is clear, racing cars require a lot of time for car preparation, travel to distant race tracks, and the race events itself. This keeps many people away that have commitments to family, business, or other interests and are forced to choose how to spend their weekends.

The ER04 platform provides exceptional sound, grip level (lateral, braking, acceleration g level), and close competition. Using autocross we bring the competition close to any home. Furthermore, our particular approach of proven components and standout customer service is the secret to our success.

2.4.2 Benefits

- Best quality: the appearance is similar to a Racing car with its features and the exhaust sound.
- Good service: ease to maintenance and 24/7 online support. Moreover, instructional videos for the car setup and car service will be available. This will be developed further in section 3.7.1 Marketing Strategy.
- Efficiency: the ER04 is characterized by its serviceability and its outstanding performance on the track. The time needed to set-up the car is a great advantage and key element in this new vehicle, for instance, the pilot pedal adjustment can be modified in seconds.

2.4.3 Stage of development

Currently, the prototype is in its final phase. The new ER04 is passing the appropriate tests in order to present it to the competition and its future introduction to the market. The objective is to take a chassis dyno test, attending an autocross race and taking an aerodynamic validation test before going to the competition. The following pictures show the dyno test and the endurance test. The vehicle has successfully performed two fully endurance events during testing.

Figure 9. Dyno Test on the 28th March

Figure 10. First endurance test on the 15th April

2.5 Market Analysis

This section will describe the market the company will enter and the industry in which the company will compete. In section 3.1 it will describe our target customer with two different personas.

2.5.1 Target Market

A market consists of a group of customers who are willing to buy products or services to satisfy a need in autocross racing.

ERAU Motorsports compete in the market of the autocross vehicles around the United States. One of the main markets is called SCCA (Sport Car Club America).

2.5.1.1 SCCA

The Sports Car Club of America (SCCA) is an American automobile club and sanctioning body supporting road racing, rallying, and autocross in the United States. Formed in 1944, it runs many programs for both amateur and professional racers.

Figure 11. SCCA Logo

The SCCA is formed by nine division and 115 regions around the United States. The divisions are Central Division, Great Lakes Division, Midwest Division, Northeast Division, Northern Pacific Division, Rocky Mountain Division, Southeast Division, Southern Pacific Division and Southwest Division. (4)

2.5.2 Market Size

According to the SCCA webpage, in 2017 there was around 900 autocross events around the United Stated. There is an average of 100 drivers per event of which 70% are returning members.

The market size is:

$$MS = 900 \times 100 \times (1 - 0.3) = 27.000\ people$$

2.5.3 Demographics

According to 2014 SCCA Membership Demographic Profile:

Table 6 shows the SCCA age ratio where the median age for SCCA members is 46.

AGE	
Under 18	7,2%
18-24	10,3%
25-29	8,5%
30-34	7,1%
35-39	6,4%
40-49	15,7%
50-59	20,7%
60 or older	24,2%

Table 6. SCCA Age Ratio

Table 7 shows the SCCA gender ratio.

Gender Ratio	
Male	81%
Female	19%

Table 7. SCCA Gender Ratio [8]

Table 8 shows the SCCA household income where 89.3% of the SCCA membership earns $50,000 or more per year. The Median Household Income is $112,000 and the Average Income is nearly $138,000.

HouseHold Income	
Under $20,000	1.6%
$20,000 to	9.1%
$50,000 to $79,999	18.5%
$80,000 to $99,999	13.6%
$100,000 to 124,999	14.8%
$125,000 to $149,999	11.9%
$150,000 to $299,999	21.5%
$300,000 or more	9.0%

Table 8. SCCA HouseHold Income [8]

Table 9 shows the number of times SSCA members attended to a solo autocross event. The average is 4.6.

Solo Autocross Times	
None	38,1%
1 to 2	14,9%
3 to 5	13,3%
6 to 10	14,4%
more than 10	19,3%

Table 9.Number of times attended to a Solo Autocross Event [8]

2.6 Competitor Analysis

The analysis of competitors will be carried out analyzing the racing vehicles according to their drivability and performance. The result is as Figure 12 shows:

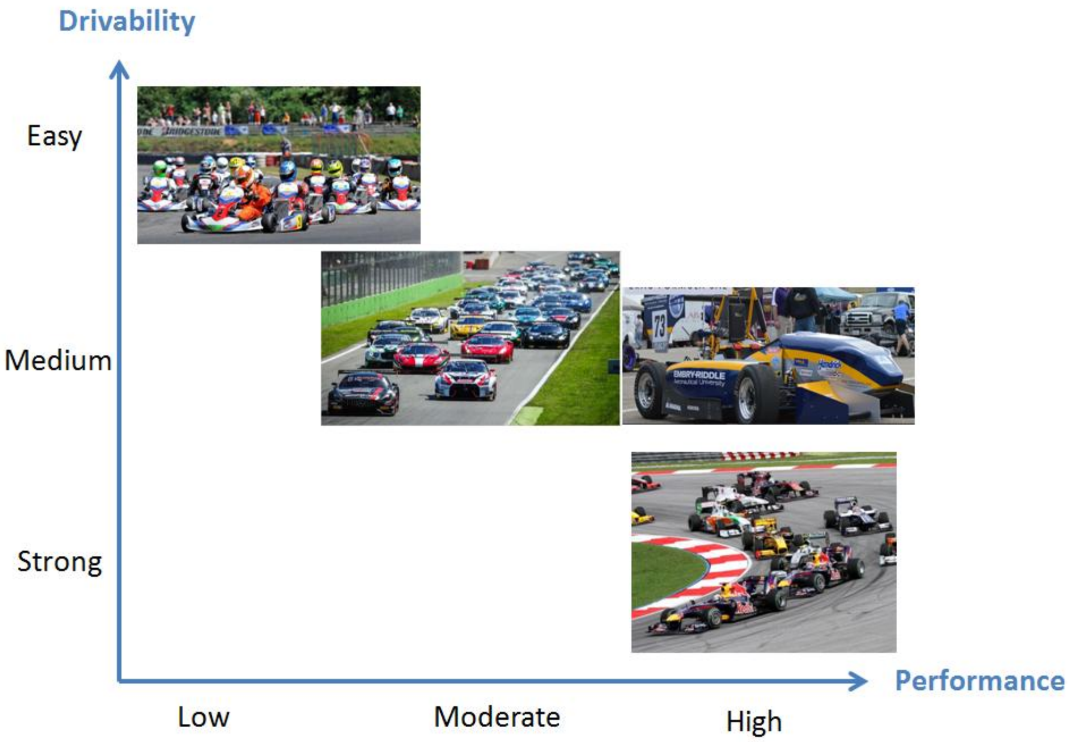

Figure 12. Vehicle comparison according to its drivability and performance

The different types of vehicles are:

- Karting: it is a vehicle designed for good handling at a good price but its performance is limited. We could say that this group is consider an indirect competition since its product and services are focused on a potential customer which attend a different type of competition.
- Modified street cars: It is a vehicle with a balanced performance and handling, however it is not that unique compared to an open-wheel race car. This group is consider a direct competition since its products and services compete in the same autocross competition as our product.
- Formula cars: its performance is very good but its little drivability makes it a car not suitable for any autocross circuit. Moreover, it requires time for preparation and

maintenance. This group is also considered a direct competition with our product, but its presence in many of autocross races is limited.

3. Marketing Plan

3.1 Introduction

The following section will describe the advertising and marketing efforts for the company. These activities will be focused on reaching our target customer, company positioning and marketing goals. (5)

3.2 Target customer.

A persona is a composite sketch of a target market based on personal information that informs content strategy to drive productive buyer engagement. A persona is the potential customer for the company.

Our company has two main personas: John and Sam. First, I will analyze the survey done at an Autocross event and then, two sections will explain how they are and what they want.

3.2.1 Survey

This survey was done in one Autocross event in Orlando (Florida) on the 1st of April 2018. The survey used is attached as an appendix 8.1 Surveyat the end of this report. The main objective of this survey is to understand the needs of our potential customer. Survey data was collected from 12 potential customers.

The results are:

- 85% know what a Formula SAE vehicle is.
- 70% will change their car in the next years.
- They want a car as a point of connection and extension between the vehicle and the driver.
- The most important feature is customization although they care about the customer service and the beauty and sound of their car. Figure 13 shows the percentage of features according to the respondents.

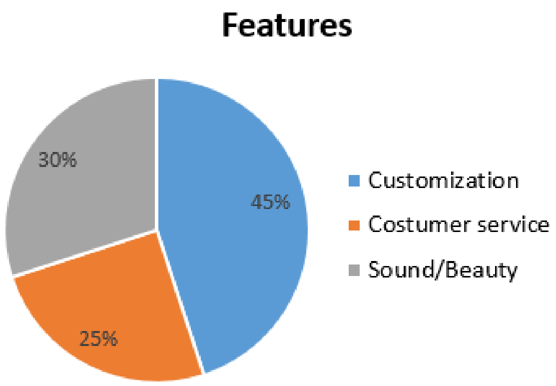

Figure 13. Chart with the ranking of features

- The most important specification is the performance without neglecting safety and serviceability of the vehicle. The Figure 14 shows the percentage of specifications according to the respondents.

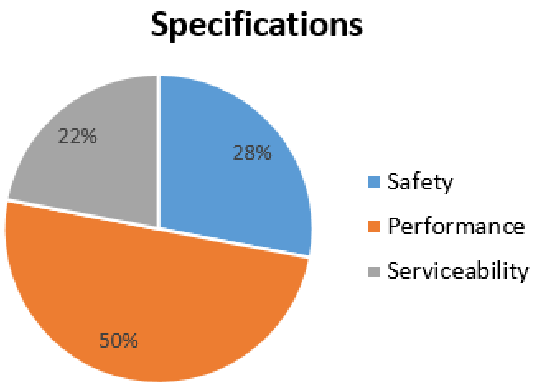

Figure 14. Chart with the ranking of specifications

3.2.2 John

He is an existing “autocrosser”, someone who is already in the sport and who has the ability to spend $25,000 on a racing car. John is between 30 and 50 years old who belongs to the middle class. He has experience on the track and he is a passionate about racing, He is very competitive when it comes to racing. Moreover, he has a family and a job. As a result of this, he cannot waste his time preparing the car and traveling to races. Furthermore, John is looking for a vehicle with beauty, fast, and with ease of maintenance and always ready to race and to be the best one in the competition. This type of persona corresponds with approximately 80% of the total customers.

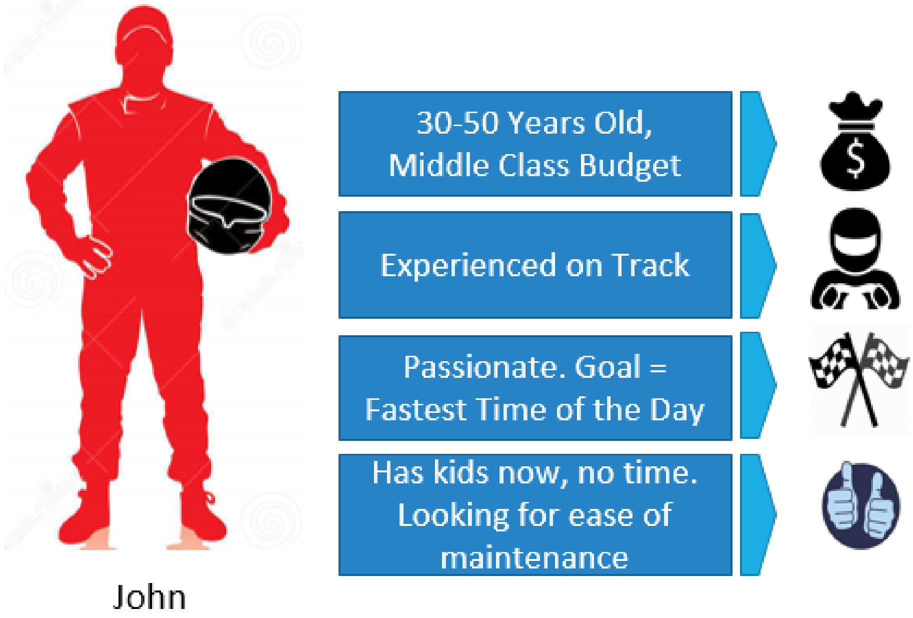

Figure 15. Sketch of our first persona, John

3.2.3 Sam

On the other hand, Sam is not currently an "autrocrosser" but he has the right ingredients. He has the money and the desire for adrenaline and competition, but he did not think autocross was for him. He cares what people think about him and he always wished he got into racing but he did not have the opportunity. He is also busy during the week and he has other commitments with family and other hobbies so the time of preparation and traveling is also important for him. This persona corresponds with approximately 20% of our total potential customers.

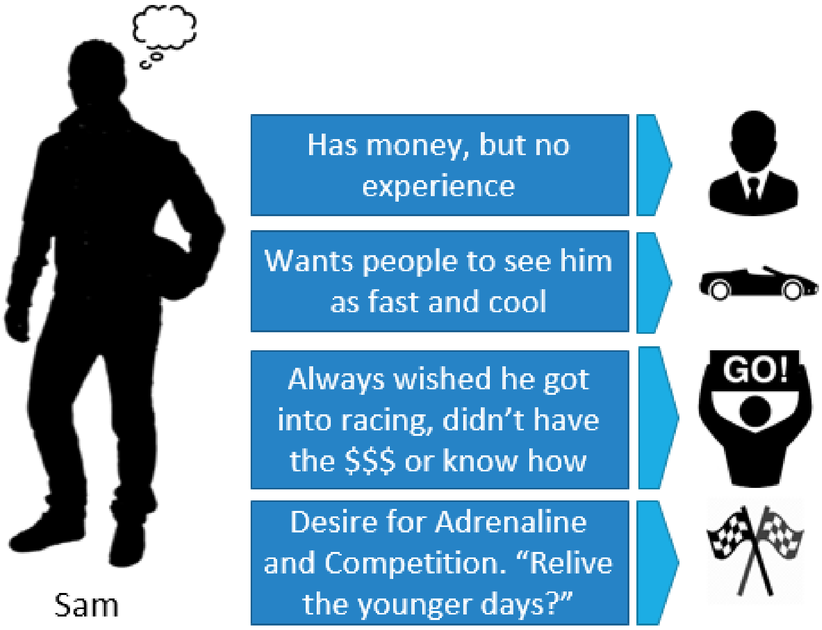

Figure 16. Sketch of our second persona, Sam

3.3 Goals

The goal of this company is to produce a simple and reliable autocross vehicle that can be easily mass produced, while providing customer care to make an excellent track car for the weekend racer. The company must deliver maximum value in terms of experience, achievements and instant visual appeal. Customers want to feel the quick linear acceleration and sharp turns that professional drivers experience without paying the professional car price. Through our team's customer care we can guide and inform our weekend racer through the process of how to revitalize and understand the racecar. With knowledge, experience, and a fast and visually appealing car people are bound to swarm in every time they open their garage. In order to achieve these goals it is necessary to have a target customer and to develop, brand awareness, distribution channels and a pricing strategy.

3.4 Unique Selling Proposition (USP)

The prototype presented in the competition is not a newly assembled vehicle. The ER04 is a vehicle that has passed different tests before its release to the market. The ER 04 has a great performance, easy to maintain and it is ready to be used on different types of tracks. Its high quality materials and aerodynamics are compared with high competition vehicles. In addition, customer service and instructional videos on how to maintain and set up the car is an advantage for our customer. Figure 17 shows the calendar of test during the 2018.

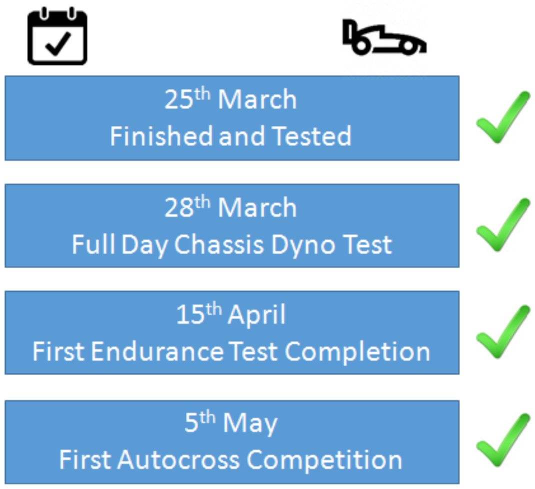

Figure 17. Tests done by the ER04 before the competition

3.5 Brand

ERAU Motorsports is a company that is focused in the design, manufacturing and test of the vehicle but it also has a very important aeronautical engineering background. This aeronautical engineering background provides precision, performance, quality and reliability to the vehicle and to the company.

The company has Facebook page (ERAU Motorsports), Instagram account (@eraumotorsports), YouTube channel and webpage (www.eraumotorsports.org). **Figure 18** shows the logo of the company.

Figure 18. ERAU Motorsports logo

3.6 SWOT Analysis

3.6.1 Strength

- High quality of product and services.
- Strong relationship with suppliers, low risk of non-delivery.
- Efficiency and effectiveness in supply chain.
- High technology and aerodynamic in an autocross car.

3.6.2 Weakness

- Sales only in the United States.
- Vulnerable to increase in material costs.
- Only one product although it is possible to customize it.

3.6.3 Opportunity

- Positive market growth.
- Collaborations with automotive industry.
- Implementing online customer services.

3.6.4 Threat

- Rising oil prices.
- Intense competition.

3.7 Distribution Channels

In the first years of the company, the distribution channel will consist of a Business-to-Customer (B2C) distribution and direct distribution. Our vehicles will go from our factory plant to the final customer. However, in the future we will implement indirect distribution selling also our vehicles to third companies and intermediaries.

3.7.1 Marketing Strategy

The marketing campaign that the company will carry out will be based on advertisements. These advertisements will be established in social media, magazines and television programs. Our customer is a person who takes care of his image and cares what others think of him. Therefore, we will do advertising campaigns in men's magazines such as "GQ", "Men's Health" and in automotive magazines such as "SportsCar". In addition, advertising campaigns will also be carried out on social networks such as "Autocross Buddies", "SCCA" and "DriveTribe" which also has a television program.

Figure 19. Advertising campaign

This company will offer a loyalty service to our customers with the objective of satisfying their needs during the sale and after the sale of the vehicle. To do this, we will have a monthly newsletter program with news about both vehicle updates and coming races adapted to each customer need. There will be a customer service with the aim of solving problems that may arise as quickly as possible. In addition to this customer service, our company will launch instructional videos where it shows how to set up the vehicle and doing maintenance changes so that our customer can do it wherever and whenever he/she wants. We will have the collaboration of Daytona International Speedway to offer the possibility to customers to test their vehicle in their facilities. In addition to this, we will also have the collaboration of the SCCA to be able to inform our customers of the latest events available in the United States.

3.8 Pricing Strategy

Two different versions of ER04 will be made. The first will consist of the car without the data acquisition package. This model will be the basic model and its cost is $ 14,800. This model has an original sale price of $ 22,000. However, a reduction of the original price will be made up to $ 21,000 so that our customer will accept easy our offer and feel that he has made a good purchase.

On the other hand, we have the ER04 model with all the features. We will call this model fully loaded model and it has the data acquisition package. The cost of this model is $16,435 and its original sale price is $ 24,999. In the same way, a reduction of the original price will be made up to $ 23,000.

A more detailed analysis of manufacturing costs will be made in section number four, financial plan.

4. Financial Plan

4.1 Introduction

The following section will describe the financial projections and funding that the company needs.

4.2 Forecast Vehicles Sold

According to the business case submitted to the competition in the beginning of this edition, our goal is to manufacture 250 vehicles. This goal will be fulfilled in the third year. ER04 has two different configurations, the basic model and the fully loaded model. The company expects to sell 25% of the basic configuration and 75 % of the fully loaded configuration.

Figure 20 shows the forecast for each model for the next 3 years.

	Year 1	Year 2	Year 3
Fully Loaded	53	113	188
Basic	18	38	63
Total	71	151	251

Figure 20. Forecast of vehicles sold for 3 years

4.3 Financial Projections

This section will analyze the pro forma income statement of the company and cash-flows projections for 3 years.

4.3.1 Revenues

The revenues will consist mainly on selling the ER 04, but there will be also others streams of revenues which consist on selling merchandising such as t-shirts or posters and the organization of events through the social media and webpage.

4.3.2 Costs

The company will have different costs which are part of the Cost of Goods Sold (COGS):

- Manufacturing costs: these costs include all the material needed for the manufacturing of the vehicles. There are two types: Basic Model manufacturing costs and Fully Loaded Model manufacturing cost.

  Figure 21 shows a cost summary for the Fully Loaded Model and the Appendix 8.2 Cost Breakdown for the Fully Loaded Modelincludes the cost breakdown with the cost of each part.

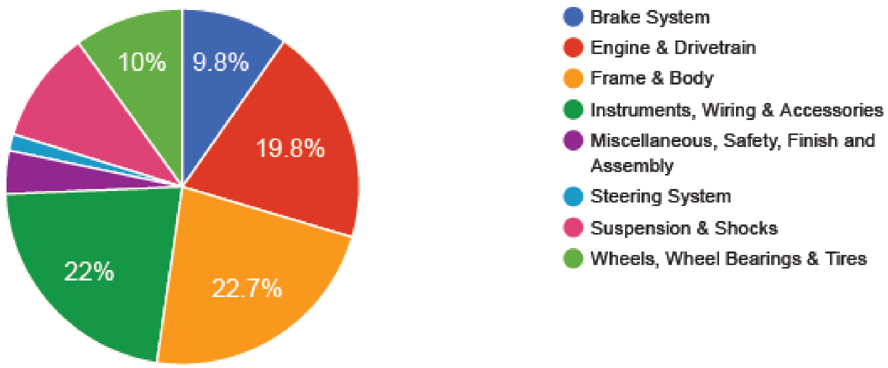

Figure 21. Cost summary for the Fully Loaded Model

- Machinery: these costs include all the tools, forklift, painting machinery and quality equipment needed for the manufacturing of the vehicles.
- Salaries: the company will have different types of employee.
  - Engineer: the function of this employee is to analyze the design and specifications of the vehicle and to choose the best suppliers for the different components of the vehicle. This employee also coordinates the customer service program.
  - Assembler: the function of this employee is to assemble the different parts of the vehicle and the final painting and quality analysis.
  - Worker: the function of this employee is to put the different pieces and tools in their right position; he is the one who move the parts from the warehouse to each working area and the one who prepare the delivery of the vehicle.
  - Sales: the function of this employee is to coordinate the advertising and marketing campaigns and the orders of vehicles.
  - Manager: the function of this employee is to control every process in the company and the financials.

- Other costs: this section include the benefits for the employees (30%), and the costs of utilities, supplies, insurance, rent and advertising campaign budget.

Table 10 shows the Pro Forma Financial Statement for 3 years.

Pro Forma Income Statement				
	Year 0	Year 1	Year 2	Year 3
Revenues		1.575.000	3.375.000	5.625.000
Price		23.000	23.000	23.000
Nº Vehicles Fully Loaded		53	113	188
Price		21.000	21.000	21.000
Nº Vehicles No data		18	38	63
Costs	477.500	1.599.338	3.079.438	4.880.563
Total COGS		1.121.838	2.403.938	4.006.563
COGS		16.435	16.435	16.435
Nº Vehicles Fully Loaded		53	113	188
COGS		14.800	14.800	14.800
Nº Vehicles No data		18	38	63
Machinery	200.000	-	-	-
Salaries	195.000	345.000	495.000	645.000
Nº Engineer	1	1	1	1
Engineer Salary	70.000	70.000	70.000	70.000
Nº Assemblers	-	2	4	5
Assembler Salary	50.000	50.000	50.000	50.000
Nº Workers	-	1	2	4
Worker Salary	50.000	50.000	50.000	50.000
Nº Sales	1	1	1	1
Sales Salary	45.000	45.000	45.000	45.000
Nº Managers	1	1	1	1
Production Manager	80.000	80.000	80.000	80.000
Benefits Overhead	58.500	103.500	148.500	193.500
Percentage	30%	30%	30%	30%
Other Costs	24.000	29.000	32.000	35.500
Rent	20.000	20.000	20.000	20.000
Insurance	1.000	1.000	1.000	1.000
Adv. Campaign	1.000	3.500	3.500	4.000
Supplies	1.000	1.500	2.000	2.000
Utilities	1.000	3.000	5.500	8.500
Net Income	- 477.500	- 24.338	295.563	744.438

Table 10. Pro Forma Income Statement for 3 years.

The Table 11 shows the cumulative cash-flow of the company for 3 years.

	Year 0	Year 1	Year 2	Year 3
Beggining of the year	0	- 477.500	- 501.838	- 206.275
End of the year	- 477.500	- 24.338	295.563	744.438
Acumulative cash-flow	- 477.500	- 501.838	- 206.275	538.163

Table 11. Cumulative cash-flow table for 3 years

Figure 22 shows the development of the net income and the cumulative cash-flows from year 0 to year 3.

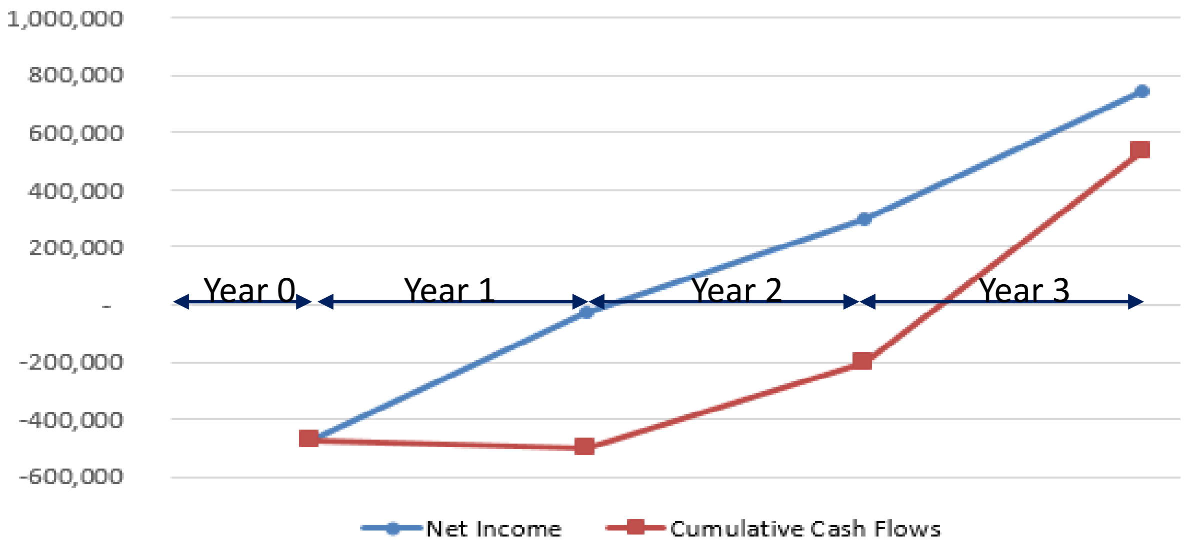

Figure 22. Net Income and Cumulative Cash Flows from year 0 to year 3

4.4 Funding

According to the competition rules, the judges will be potential investors and it is necessary to request an investment from them. The money needed to carry out this project is $500,000.

According to this data it is possible to analyze some financial ratios:

- Break Even Point in units: 72 units.
- Return on Investment for year 3: 29%
- Payback to investors: 3.1 years.

The investment breakdown is show in Figure 23.

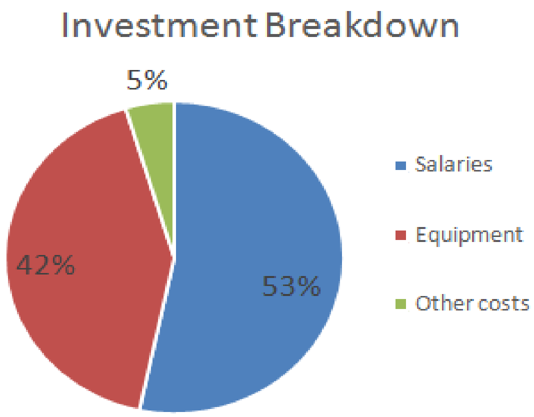

Figure 23. Investment breakdown graph

5. Manufacturing Plan

5.1 Introduction

The following section will describe how the vehicle will be manufactured and its specifications.

5.2 Design and Product Development

5.2.1 Product Strategy

The foundation of the existence of an organization lies in the product or service it provides to society. An effective product strategy takes into account: investments, market share and product life cycle.

The selection and design of the product affect the entire production system. In addition, the design of the products play a fundamental role in the competitiveness of the company where the cost, quality and service time are fully linked to the design. Less market share and technical problems usually appear when there are deficiencies in the design of the product.

Figure 24 shows the product life cycle. Our product is now in the introduction stage.

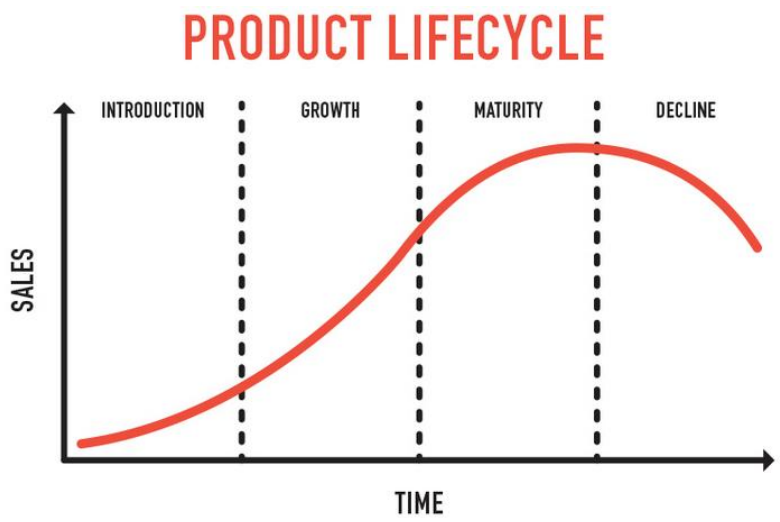

Figure 24. Product Life Cycle

5.2.2 Design Stages

The stages of design and development of the product are the following:

- Generation of the idea
- The company´s ability to execute the idea
- Customer needs
- Functional specifications
- Product specifications
- Design review
- Market test
- Market penetration
- Assessment

5.2.3 Specifications

The ER04 is a compact, lightweight chassis with a fully adjustable inboard suspension capable of a 2.0g lateral turn. The front and rear carbon fiber wings and under tray deliver 800 N (180 lbf) of down-force at 70 km/h (43.5 mhp) with adjustability for optimal vehicle balance based on the speed of the course. In addition, the ER04 was opted for a lighter structural design while maintaining structural integrity. With a MOTEC data logger, ECU, and driver display, the customer is provided with tools to optimize the balance between driver capabilities and the vehicles behavior to achieve the best results. Using a design that is desirable, and refining it over years, results in a product that is fined tuned with a combination of successful systems engineered to deliver record breaking performances. Having systems that have been proven and tested will give our customer the confidence to push the machine to its limits and still be dependable.

Table 12 and Table 13 show the key design features and the key performance targets for the ER04.

Key Design Features	
Chasis/Body Type	4130 Chromology Tubing
Power train type	IC Engine / Chain Drive
Power / engine	2008 CBR600RR 80bhp
Target weight Kg	215 kg
Downforce	800 N at 70 km/h (180lbf at 43,5 mph)

Table 12. ER04 Design Features

Key Performance Targets	
Accn. 0-75 Metres	4,2 seg.
Lateral Accn. (g)	2,0 g at 70 km/h (43,5mph)
Fuel Economy	3 km/liter (7,05 mpg)
Max Braking Decelerat.	2,1 g
Turn Radius	3,05 m (10 feet)

Table 13. ER04 Performance Targets

5.2.4 Design Methodology

5.2.4.1 Concurrent Engineering

The beginnings of Concurrent Engineering arose from the aerospace industry, in which all the processes are governed by two main ideas:

- All the components and elements of the final product must be taken into account from the earliest stages of the design.
- All the design activities that preceded the achievement of the product must be happening at the same time, that is, they must move forward simultaneously in the process.

Once contextualized the Concurrent Engineering, which is closely related at present with the development of new products, we can define it as the process of development of new products in which all departments should be involved, working in unison in the creation of the product. This involvement addresses from the contribution of ideas to the fit and readjustment of the information that allows achieving the agreed product.

Apart from being a mere philosophy of work, Concurrent Engineering involves a series of work techniques that allow to considerably reduce the development time of a product, allowing to reduce its quality costs and improve it.

The simultaneous development by the actors involved in each of the phases involves solving and making decisions together avoiding the loss of time and favoring the flow of information in the group.

Some of the advantages of applying Concurrent Engineering that companies value to use this approach in the design of products are:

- The most demanding markets demand well-finished products, based on the idea of doing things right the first time.
- The continuous evolutions of the market and the need to put solutions more and more quickly in the market to overtake the competitors.
- Maximize the quality of the final product, implying costs and time in the initial development that later avoid costs and reduce times in later phases.
- The unification of work groups and work in teams generate synergies and positive relationships.

5.2.4.2 Quality Function Deployment

Quality Function Deployment (QFD) is a structured approach to defining customer needs or requirements and translating them into specific plans to produce products to meet those needs. The “voice of the customer” is the term to describe these stated and unstated customer needs or requirements. The voice of the customer is captured in a variety of ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports, etc. This understanding of the customer needs is then summarized in a product planning matrix or “house of quality”.

Appendix 8.3 QFD Matrixshows the QFD house attending the customer needs and the product characteristics.

According to the solution of the QFD matrix, the elements that our customer will care more about are the use of composites and the wings of the vehicle. On the other hand, changes in the exhaust system or in the data acquisition package will not affect our customer perception seriously.

5.3 Design for manufacturing (DFM)

5.3.1 Introduction

The principles of this technique are to achieve compatibility between the design of the product and the manufacturing process to reduce manufacturing costs. Therefore, throughout the editions of the competition the cost of the vehicle has been declining when applying this technique.

Vehicle	Cost
ER 01	$ 20.387
ER 02	$ 19.750
ER 03	$ 18.128
ER 04	$ 16.435

Table 14. Cost reduction in the vehicle

5.3.2 Steps

The design for manufacturing has five steps which are shown in the Figure 25.

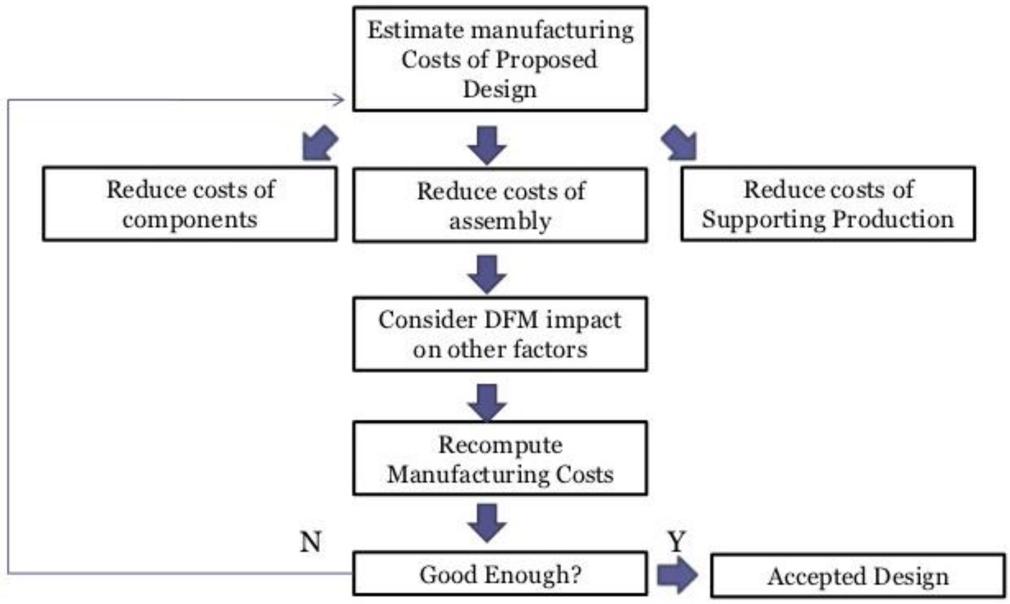

Figure 25. Steps for DFM

5.3.2.1 To Estimate the manufacturing costs

These costs include the cost of the components, the cost of the assembly and the indirect costs.

- Cost of components: here it is included the parts purchased from standard suppliers, for example, an engine, as well as custom parts that are outsourced.
- Cost of assembly: this includes the cost of labor and equipment and the tools used.
- Cost of supporting production: here it is included all the support and logistics costs necessary to take the product forward.

5.3.2.2 Reduce costs of components, assembly and supporting production

The second step is the analysis of all costs in order to reduce them, for this it is necessary to do the following steps:

- Cost of the components: to reduce these costs, a series of activities can be carried out, such as:
  - Redesign components to eliminate steps in their processing.
  - Select the appropriate economic scale to process the piece.
  - Standardize components and processes to avoid extra costs.
- Assembly Cost: The design for assembly, DFA, is a well-established subset of the design for manufacturing that encompasses the decrease in the assembly cost. For almost all products, the assembly constitutes a relatively small part of the total cost. However, concentrating attention on assembly costs gives great indirect advantages. Often, as a result of the importance given to DFA, the total number of parts, the complexity of manufacturing and the support costs are reduced along with the cost of the assembly. In this section there are some useful principles to guide design decisions for assembly. The great result of this technique is the saving of time in the assembly of the pieces.

  To reduce the assembly cost you can:
  - Integrate several pieces in one piece.
  - Maximize the ease of assembly.

Figure 26 shows an example of design for assembly.

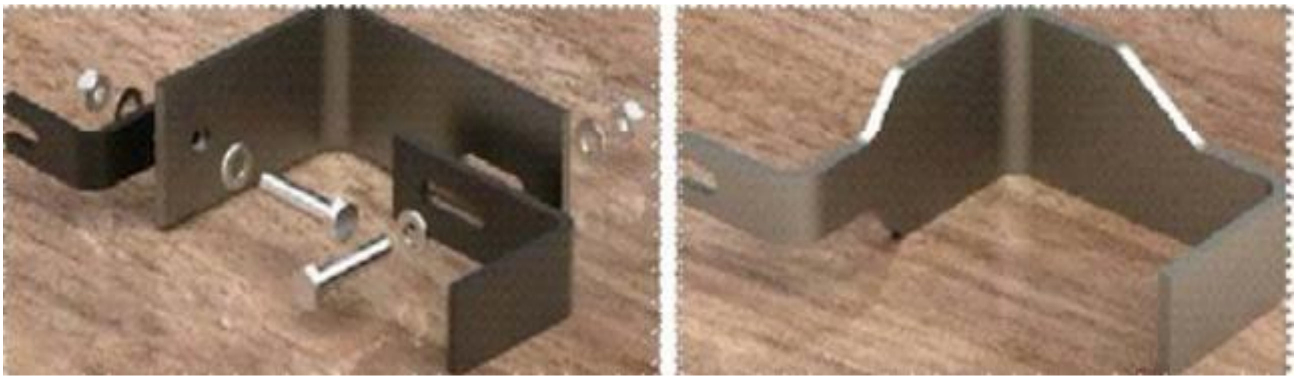

Figure 26. Example of Design for Assembly (DFA)

- Supporting production cost: By working to minimize component and assembly costs, the team can also achieve cost reductions in the production support functions. For example, a decrease in the number of pieces lowers the demands on inventory management. A reduction in the assembly content decreases the number of workers needed for production and therefore reduces the cost of supervising and managing human resources. The standardized components will reduce the demands in engineering support and quality control. Finally, minimizing the systematic complexity would reduce costs and time in the manufacture of the pieces.

5.3.2.3 Consider DFM impact on other factors

Minimizing the cost of manufacturing is not the only objective of the product development process. The economic success of a product also depends on its quality, the timing of its introduction and the cost of developing it.

- DFM in development time: Development time can be very valuable. For the project development of a car, the time can be worth several hundred thousand dollars per day. For this reason, design decisions for manufacturing should be evaluated for their importance in the time of development as well as their effect on the cost of manufacturing.
- DFM in the quality of the product: it is necessary to take into consideration the quality at the time of reducing costs, sometimes reducing cost and consequently, weight in the vehicle is favorable but in other cases not as much, because the quality may be affected. Therefore, we must know when to sacrifice quality for cost and when not.

- DFM in external factors: within this section it is possible to differentiate two:
    - Reuse of components.
    - Costs during the life cycle.

5.4 The prototype

This section will describe different parts of the ER 04 prototype that have been developed by the Formula SAE team. [14]

5.4.1 Frame

5.4.1.1 Introduction

The frame is nearly always the largest single component of any vehicle. The pupose of the frame is supporting the systems of the prototype in such a way to reduce weight and improve the handling characteristics in racing scenarios. The frame is designed attending criteria defined both by the rules of the competition and goals set by the team. The rules are primarily limited to properly triangulating tubes, and utilizing the appropriate size tubes. The criteria set by the team are much more specific and lengthy. First, attending the costs, the body and aero pack cannot change as the cost for tooling is expensive to justify a re-design. The previous vehicle exhibited a significant reduction of handling when experiencing roll conditions. It is possible that the frame was a factor if it was not torsionally rigid enough, as such a focus was placed on improving the rigidity of the frame. This prototype is for a racing application, as a result of this, the weight of the frame is always a consideration with the intent of reducing unnecessary mass. Lastly the suspension mounting points were triangulated to reduce tube bending which would compromise the suspension.

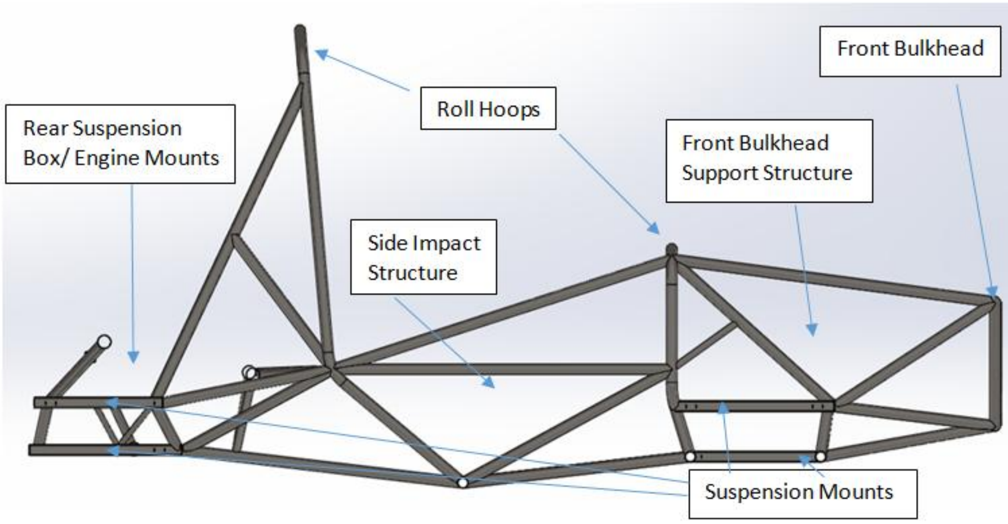

Figure 27. Frame structure with components location

5.4.1.2 Design Specifications

The frame has a number of requirements dictated by the team, the first requirement is that all primary structure shall be triangulated in order for the loads in the tubes to result in primarily tensions and compressionn to limit the effect of bending on round tubes. The part that makes the most significant effect on the performance of the prototype is the mass of the frame, so that, it is a requirement to reduce the weight of the vehicle as long as in the process the strength of the frame is not compromised. ER03's frame weighed 71.5lbs (32.4 Kg) the new frame shall weigh 65 lbs (29.5 kg).

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. Any bent tubes, or member consisting of multiple tubes that are not in a straight line, must have an additional tube attached to support it of the same diameter and wall thickness.

ITEM or APPLICATION	OUTSIDE DIMENSION X WALL THICKNESS
Main & Front Hoops, Shoulder Harness Mounting Bar	Round 1.0 inch (25.4 mm) x 0.095 inch (2.4 mm) or Round 25.0 mm x 2.50 mm metric
Side Impact Structure, Front Bulkhead, Roll Hoop Bracing, Driver's Restraint Harness Attachment (except as noted above) EV: Accumulator Protection Structure	Round 1.0 inch (25.4 mm) x 0.065 inch (1.65 mm) or Round 25.0 mm x 1.75 mm metric or Round 25.4 mm x 1.60 mm metric or Square 1.00 inch x 1.00 inch x 0.047 inch or Square 25.0 mm x 25.0 mm x 1.20 mm metric
Front Bulkhead Support, Main Hoop Bracing Supports, Shoulder Harness Mounting Bar Bracing EV: Tractive System Components Protection	Round 1.0 inch (25.4 mm) x 0.047 inch (1.20 mm) or Round 25.0 mm x 1.5 mm metric or Round 26.0 mm x 1.2 mm metric

Figure 28. Tube Outside Diameter and Wall Thickness

5.4.1.3 Frame Assembly

The top view showcases the removal of floor tubes forward of the driver cell creating "square" sections instead of triangular sections. This was done to save weight in an area that would not benefit from more tubes. The crossbar tube is also shown here with mounting points for both the suspension and the engine, improving torsional rigidity. The hip joints are shown here that were moved out along the Y-axis to improve torsional rigidity.

Figure 29 shows the top view of the frame.

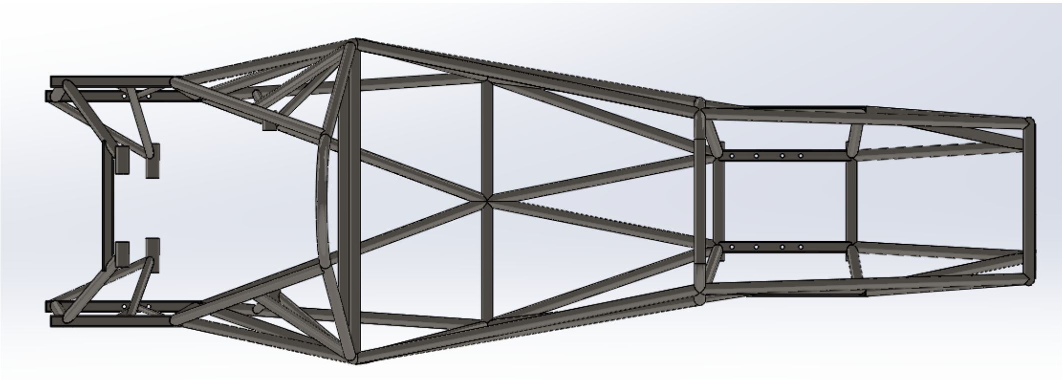

Figure 29. Top View of the Frame

Figure 30 shows the front view of the frame:

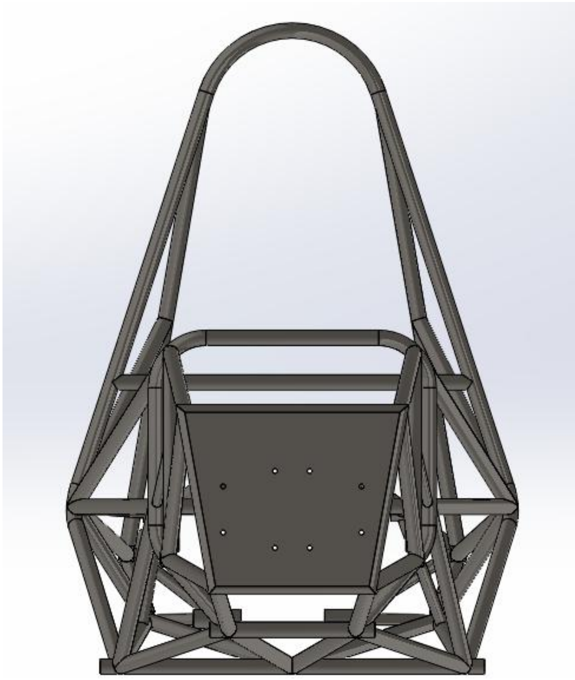

Figure 30. Front View of the Frame

The torsional rigidity was tested in Solidworks FEA by applying loads at the rear anti-roll bar mounts while fixing the front anti-roll bar mounts. This test was conducted both with and without an aluminum block modeling an engine. The reasoning behind modeling both is that the only model of the engine is a zero thickness surface.

The Appendix 8.4 Frame and Bill of Material Drawingshows the frame and bill of materials drawing.

5.4.2 Brake System

5.4.2.1 Introduction

The ER-04 braking system and pedal assembly design is a modification of the previous system (ER-03), and the brake fluid systems, a continuation of the system used on ER-02 prototype. There are improvements to be made over the previous iterations were as follows: a nearly linear pedal ratio, reduced compliance, correctly calculated master cylinders, nominal balance set as such it can be adjusted rearwards to function in wet conditions, and a functioning brake over travel switch.

Figure 31 shows the ER-03 brake system:

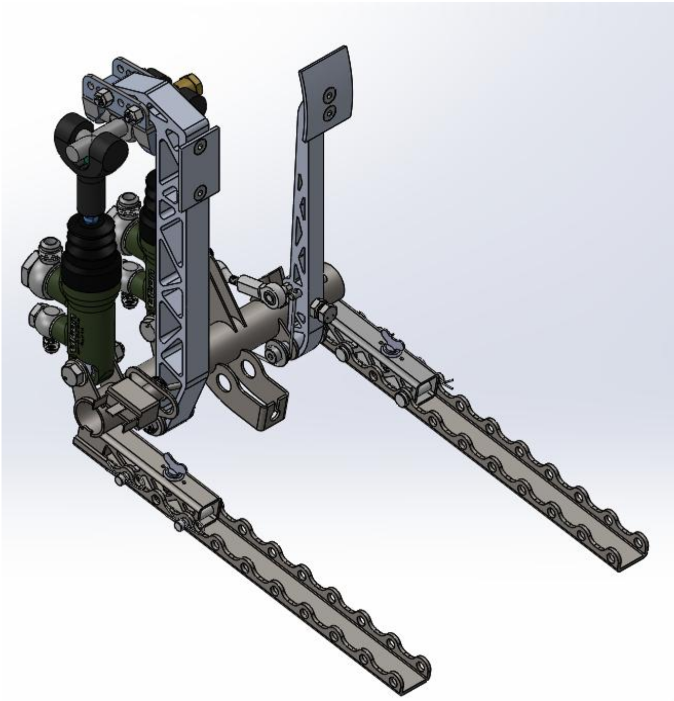

Figure 31. ER-03 Brake System

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 excel. The pedal ratio was simulated in a Matlab script written specifically for the task. With this program, the travel of the pedal, linearity of the pedal ratio, and the change in height of the pedal could be calculated.

The lateral play in the pedals of the pedal assembly and the compliance in the throttle linkage were reduced by changing the type of bearings used in the throttle pedal and throttle linkage bar. 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.

5.4.2.2 Design Specifications

The pedal assembly will have the following specifications or better:

- Weigh 2.48 lbs. (1.12 kg) dry including the pedal assembly and throttle pedal with linkage with heel plate and brackets. (Design for weight for ER-03 was 2.73 lbs. (1.24 kg))
- Have 8 inches (20.32 cm) of travel to accommodate a the 95th percentile male and 5th percentile female
- Trigger the brake over travel switch only when the system has a failed brake fluid system
- Use a design load of 2000 N applied parallel to the ground at the brake pedal face with less than .125 in (0.32 cm) of compliance
- Allow the pass through template to reach 3.5in (8.9 cm) from the brake pedal face in its forward most position
- Use Tilton 78 Series master cylinders with bores from .625in to .75 in (1.6 cm to 1.9 cm)
- Reduce the pedal travel at full braking to 1 inch (2.54 cm)
- Allow for a range of bias that includes both maximum grip in dry conditions and wet conditions with 25% adjustment fore and aft of these values respectively

5.4.2.3 Pedal Manufacturing

The design of many items of the pedal assembly stayed largely the same between ER-04's pedal assembly and its predecessor. Namely the largest components being the cross tube, the whole throttle linkage type and method, the mounting tab type, and the style of the throttle pedal.

The throttle pedal is a largely complex part, and has many important features built in. Many of these features have been developed due to issues with the performance of ER-02's pedal assembly. These features are the set screw to act as on adjustable forward stop for the pedal, the bolt onto the mounting tube as a pedal stop, and the integrated torsion springs to increase the pedal resistance. The set screws have a nylon section that serves as a locking mechanism. The main pedal stop saw a change from a bolt and nylock to the nylock set screw as ER-03's assembly had the potential for the bolt to cause issues by hitting the driver's foot. While this never proved to be an issue, it was taken care of regardless to avoid an unforeseen change in the system making it an issue. The pedal was manufactured using a waterjet tool and machined forward.

The brake pedal saw a drastic change is style. The previous pedal, seen compared to the new pedal, is seen in the Figure 32.

Figure 32. ER-03's Brake pedal (left) with ER-04's brake pedal (right)

The method used for the slider mechanism changed the mounting flanges to steel so that they could be welded to the assembly. This slightly increased the weight of the system, and in an effort to reduce the weight, the throttle pedal side, which sees less load, was outfitted with thinner, and optimized flanges. This move does increase the cost of the pedal assembly, but it remains in budget while reducing weight. The Figure 33 shows the slider mechanism used for the brake system

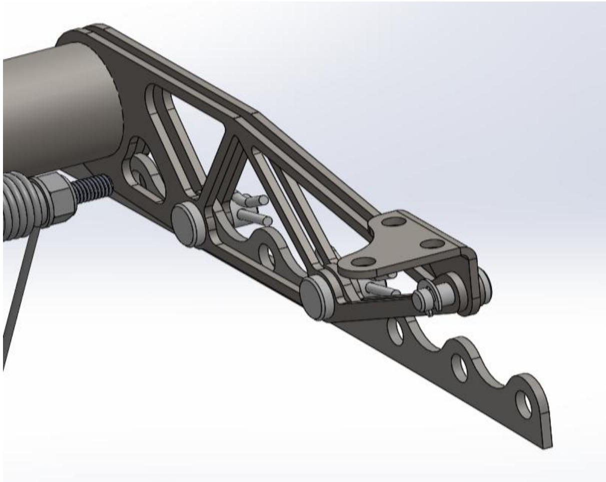

Figure 33. Slider Mechanism

Appendix 8.5 Brakes Designshows the CAD drawing of the brake system.

5.4.3 Steering System

5.4.3.1 Introduction

This system was not redesign for the ER-04. Instead, the goal was to refine and simplify the design from ER-03 in order to fix the problems found and to improve the functionality. There were 2 main problems with the design of the steering system in ER-03. 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 lead to some difficulties when getting the car to pass the competition rules.

5.4.3.2 Design Specifications and Assembly

The design for the new steering system started by replacing the currently used Sweet steering rack with the Zedaro Z-Rack 358 S+. This was done for a number of reasons. The primary benefit is that the Z-Rack is designed to be mounted using pillow block clamps along its length. This is more stable and less likely to fail than the current mount system of the rack center being bolted to a plate welded in the center of the chassis. Additionally, with the new chassis design, there are no tubes on the bottom of the front bulkhead, making the old system completely unfeasible. The S+ rack was chosen because it comes with a built in steering position sensor which can be wired directly into the MoTec system currently installed on the car.

Figure 34. Steering System

The Table 15 shows the specifications for the steering system.

Component	**Specification**
Zedaro Z-Rack S+ 358	500 lbs lateral load
Apex 300-12-S	100 ft-lbs torque
Tie Rod tubes	500 lbs Compression
Steering Column Tube	100 ft-lbs torque
Steering Rack Pillow Blocks	500 lbs lateral load
Torque Transfer Rod	100 ft-lbs torque

Table 15. Specifications for the Steering System

5.4.4 Shifter

5.4.4.1 Introduction

The main function of the shifter assembly for ERAU Motorsports' formula car is to allow the driver to change gears during operation. The sequential transmission is located behind the driver's seat- creating a design challenge of linking this system to a driver control inside the cockpit. This problem is solved by mounting a shift lever on the left side of the cockpit that is connected to a push-pull cable. The other rear end of the cable is connected to the shifter on the exterior of the transmission. A push forward on the shift lever results in a downshift while a pull backwards causes an upshift. Additionally, the shift lever is paired with a clutch lever that allows the driver to manipulate the clutch for accelerating in first gear from a standstill.

Figure 35 shows the shifter overview:

Figure 35. Shifter Overview

5.4.4.2 Design Specifications

The following are requirements of the shifter assembly design:

- System shall withstand repeated loading of 50 lb in both forward and rear directions order to shift gears
- Shall have an ergonomic, lightweight grip that will assist the driver in successfully completing the endurance race at FSAE Michigan 2017

According to *2017-18 Formula SAE Rules* require the following specifications:

- T.4.1: Vertical pass-through template must fit in cockpit without the shifter being removed
- T.4.2: Horizontal pass-through template must pass forward to four inches rear of the pedals in their most forward position without shifter being removed
- T.4.6: All vehicle controls (including shifter) must be operated from inside the cockpit without any part of the driver's body outside of the side impact structure of the chassis

5.4.4.3 Shifter Manufacturing and Assembly

Shift Lever

The shift lever is designed to withstand a 50 pound (22.68 Kg) force applied in the positive and negative x directions to simulate a maximum effort gear shift input from the driver. Material was added to the weight-reduction cut outs to increase the factor of safety and prevent stress concentrations. All holes were under-sized in the water jet order to account for the poor tolerance of that manufacturing process. Critical dimensions will be post-machined in house before installation. The bottom half of the lever includes holes mated to the sheet metal bracket that is used to link the push pull cable and clutch lever to the shift lever. The material used is 6061 Aluminum.

Appendix 8.6.2 Shift Levershows the CAD drawing of the shift lever

Shift Lever Bracket

The shift lever bracket is a sheet metal component plasma cut from 4130 chromoly steel and bent into position. This bracket allows the push pull cable and clutch lever to be connected to the shift lever. All bolts and locknuts used are low-profile variants to reduce the intrusion of the system into the cockpit to allow the inspection templates to pass through easily. The shift lever bracket also has a guide hole for the clutch cable.

Figure 36 shows the FEA of shift lever bracket for 50 lb Load:

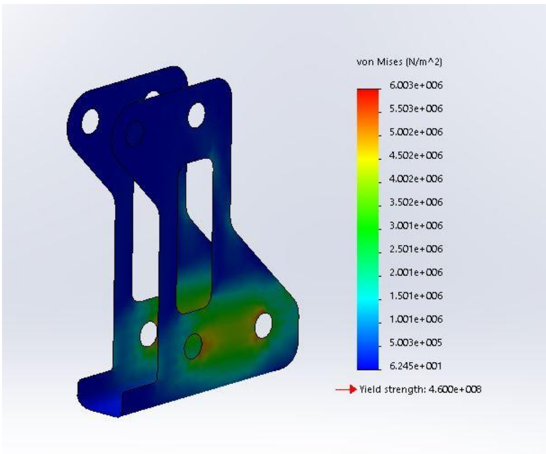

Figure 36. FEA of Shift Lever Bracket for 50 lb Load

Appendix 8.6.1 Bracketshows the CAD drawing of the shift lever bracket.

Bearing Sleeve

The bearing sleeve is the critical component that reduces the degree of rotation of the shift lever. The reduced width of the shift lever decreases the surface area of contact between the shift lever and the mounting shaft. Preliminary design used a single bearing centered in the shift lever. The bearing sleeve spaces two bearings laterally, greatly reducing the rotational freedom of the shift lever.

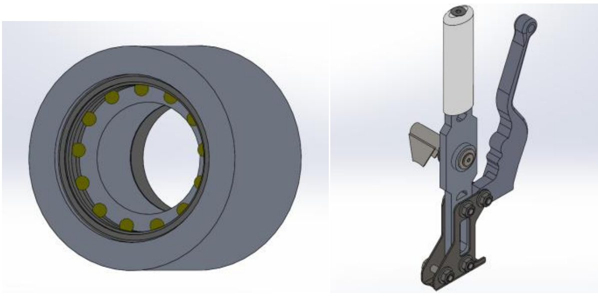

Figure 37. Bearing Sleeve Used and Location

5.4.5 Differential Mounting System

The current differential mounting system utilizes mounts to secure the differential to the frame while using adjusters (turnbuckles) to move the differential relative to the engine. These turnbuckles are what apply the correct tension to the drive chain. The goal of the setup for this system is to reduce complexity in securing the differential and applying correct chain tension. The differential mount frame is made with 6061 Aluminum while the Jackbar is made with mild steel.

Figure 38 shows the driveline system overview.

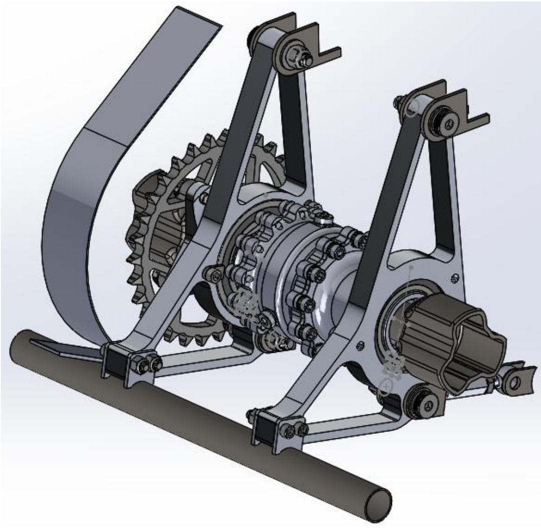

Figure 38. Driveline Systems Assembly

Appendix 8.7 Differential Mounting Systemshows the CAD drawings of the differential mounting system.

5.5 Production System

5.5.1 Production Processes

5.5.1.1 Introduction

The flow structure of the process used to make or deliver a product or service, impacts the facility layout, resources, technology decisions, and work methods. The process architecture may be an important component in the firm´s strategy for building a competitive advantage.

When designing a process, it is necessary to consider the following key aspects:

- Process structure: how the processes will be designed in relation to the necessary resources and how the resources will be distributed among the processes.
- Customer participation: how the customer participates and the quantity in a process.
- Resource flexibility: ease of handling a variety of products, production levels, tasks, and functions.
- Capital intensity: Relative weight of equipment and automation with respect to human skills.

The product process matrix shown in Figure 39 represents the relation between variety and volume of a product.

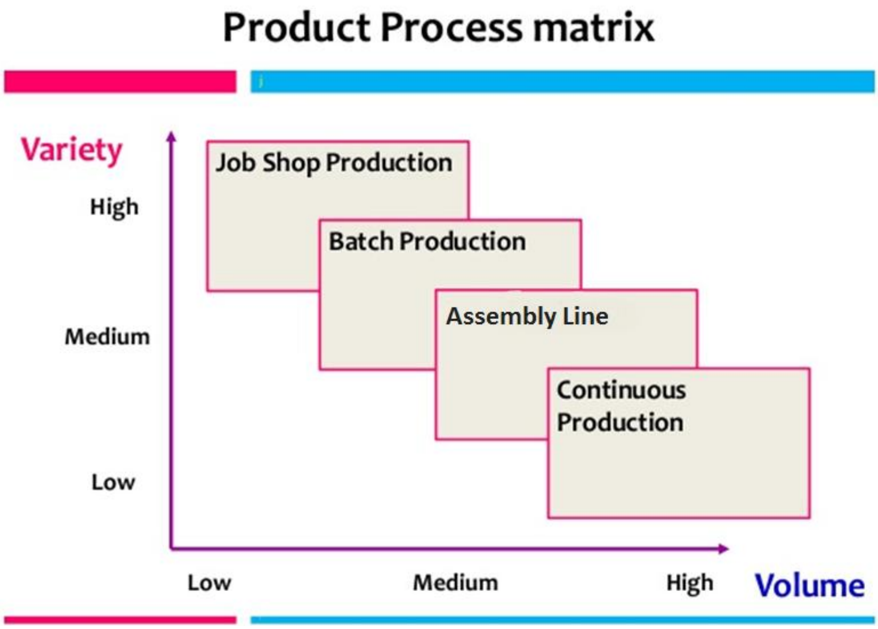

Figure 39. Product Process Matrix

5.5.1.2 Job Shop

Job shops are designed to manufacture a wide variety of products with small lot sizes in order to achieve maximum flexibility. Products usually have different operation sequences and operating time for each operation, which could vary significantly in job shop manufacturing. A job shop process is defined by:

- Production of small quantities and a wide variety of products.
- Highly qualified workers with high remuneration.
- Many specific operations instructions (each project is different).
- Inventories of raw materials / components relatively high for the value of the product.
- The units move slowly through the plant.
- It works make-to-order and no final product is stored.
- Low fixed costs and high variable costs.
- The cost is estimated before doing the work but only the real cost after work is known.

Advantages:

- Maximum flexibility in the characteristics of the product.
- Low initial investment

Disadvantages:

- Employees require training and higher remuneration.
- The planning and control of production is more difficult.
- Low equipment utilization (5% -25%).

Figure 40 Shows an example of job shop production, where 3 different products use different machines.

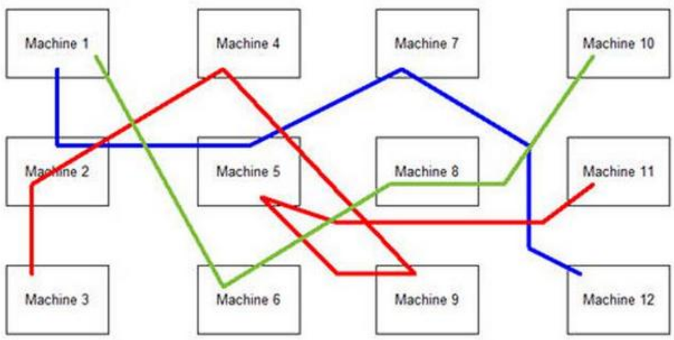

Figure 40. Job Shop Example

5.5.1.3 Batch Production

It is characterized because the manufactured quantity of the same product / component is superior to job-shop process. Each lot is constituted by a set of units to be produced that are equal to each other. This type of production is typically used to manufacture components or modules that are subsequently assembled in an online process (example: bumpers)

This process is defined by:

- The variety of product is broad although not as much as a job-shop process.
- From one batch to another it may be necessary to change manufacturing tools and also change part of the process (example: industrial bakery).
- The facilities can be expanded but require a certain level of investment expenditure.

- Fixed and variable costs are mid-level.
- The facilities are organized in a flexible way although operationally there are some routes that are used more frequently.

Advantages:

- High flexibility in the characteristics of the product.
- High use of the equipment (from 50 to 85 percent).
- Planning and production control is easier.
- Low variable cost.

Disadvantages:

- Equipment with less general utility.
- The employees require training but not as much as job-shop.
- Moderately increased of fixed cost.

5.5.1.4 Assembly Line

The assembly line is characterized by a high volume of a standardized product with different versions from modules. Therefore, combining modules allows different features of the product.

Figure 41 shows an assembly line example:

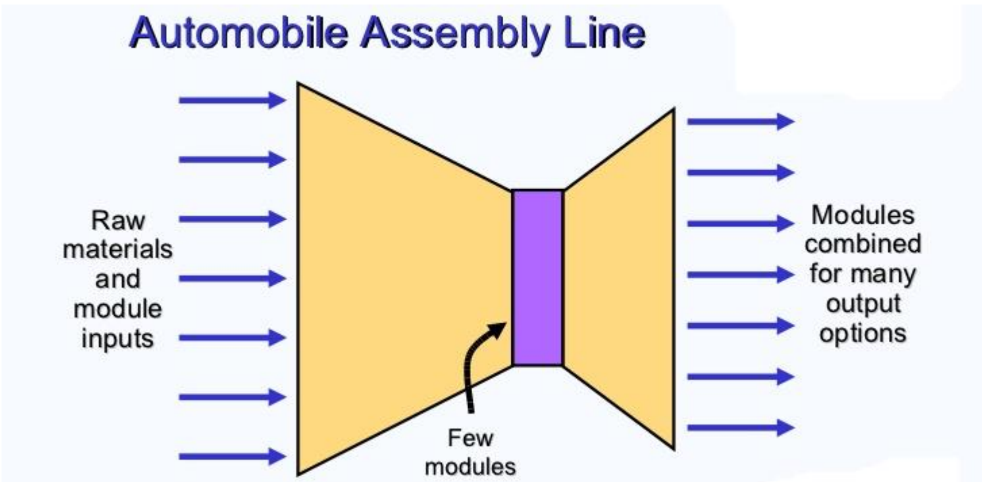

Figure 41. Assembly Line Example

Assembly line process is defined by:

- Specialized equipment (tools / robots in the assembly line).
- Well-trained and specialized employees.
- Repetitive operations reduce training and changes in work instructions.
- "Just in time" techniques in procurement and inventory management.
- Frequent forecasts to produce the final products.
- Work orders are not directly related to customer orders. Some orders can be ordered and others are kept in stock (make to stock) until they are ordered by the customer.
- They require larger facilities than the previous processes.
- The fixed costs are high.
- The level of inventory in progress is low compared to the volume of production.

Advantages:

- Flexibility in the characteristics of the product.
- High use of the equipment (from 70 to 85 percent).
- Planning and control of production is easy.
- The employees are specialized and their remuneration is lower.

Disadvantages:

- Specialized equipment.
- The facilities are larger.
- Rise of the fixed cost.

5.5.1.5 Continuous Production

This process is defined by:

- It produces a large quantity and little variety of products.
- Very specialized team.
- Very specialized workers.
- Orders and work instructions are few, because they are standardized.

- Inventories of raw materials and ongoing products relatively low compared to the volume of the product.
- Fast movement of the units through the installation.
- Final product made from a forecast and stored (make to stock).
- Very high fixed costs and low variable costs.
- The costs depend a lot on the utilization of capacity.

Advantages:

- The variable cost per unit is lower.
- Less labor skills but more specialized.
- Planning and control of production is easier.
- A greater use of the equipment (from 70 to 90 percent).

Disadvantages:

- The flexibility of the product is lower.
- The team is more specialized.
- Normally, the investment is higher.

Figure 42 shows an example of continuous process.

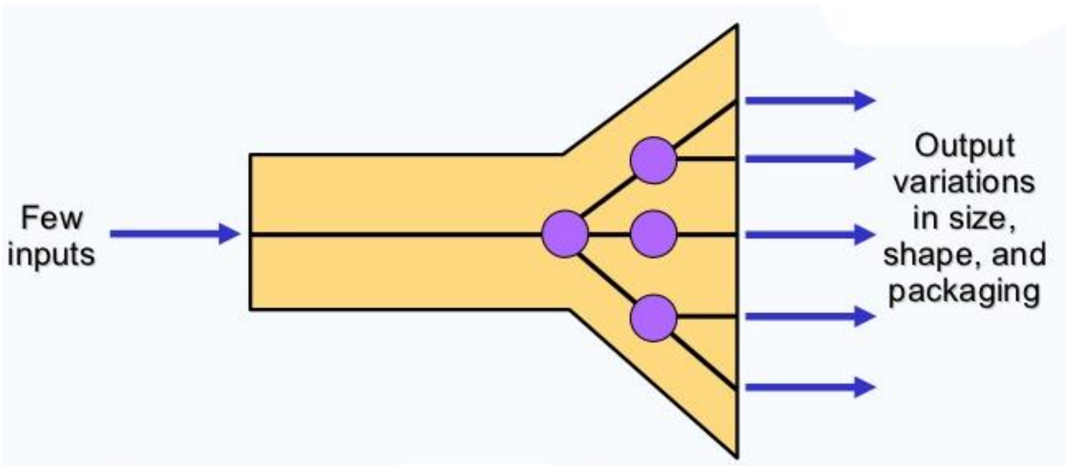

Figure 42. Continuous Process Example

Once analyzed the different types of processes for manufacturing a product, we have to choose the best strategy for the ER 04. As explained in previous sections, the ER 04 is a totally new vehicle whose market and number of customers will grow every year.

Therefore, the strategy that the company will follow, with the aim of being competitive in product and costs, will be to move from a type of batch production where it is characterized by great flexibility through modules to a line assembly production when the quantities to manufacture the vehicle will be superior. In addition, starting with a technique that allows us greater flexibility will help to promote the marketing of the vehicle itself.

In addition to this, the assembly of the new ER 04 will be made from modules with the aim that the assembly is quick and simple. As a result of this, the DFMA (Design for Manufacturing and Assembly) technique, already explained above, will be used. The majority of the modules will be outsourced for manufacturing, in order to save costs in manufacturing machinery and labor.

The agreement signed with Volusia Manufacturing Association (VMA) allows us to subcontract the pieces with very high quality. Volusia Manufacturing Association offers all types of products and manufacturing processes within its members.

Figure 43. Volusia Manufacturing Association Logo

5.5.2 Layout

There are four different types of layout: [7]

- Flexible-flow layout: this type organizes resources and equipment by function rather than by service or product.
- Line-flow layout: this is a layout in which workstations or departments are arranged in a linear path. This layout has a low cost per unit but it needs a high volume of production in order to be profitable.
- Hybrid layout: an arrangement in which some portions of the facility have a flexible-flow and others have a line-flow layout.
- Fixed-position layout: a layout in which service or manufacturing site is fixed in place; employees along with their equipment come to the site to do their work.

For the manufacture of the ER 04, the company will use in the early years a layout of fixed position where the car will be assembled in its entirety in a fixed station and will make a transition to a line-flow layout when the annual production is higher. The main reason for this is cost, to have a cost-effective line-flow layout it is necessary to have a high production capacity and a larger number of employees.

The line-flow layout organizes the workstations in sequence, where the product advances from one station to the next until it is completely finished. The main task of using this technique is the balancing of the line, which consists of assigning work to the stations until reaching the desired production rate with the lowest possible number of stations, in other words, maximizing efficiency. Finally, the station with the highest workload is the one that establishes the production rate (r) expressed in units produced per unit of time in order to avoid bottlenecks in the system.

Figure 44 shows the fixed-position layout in the early years. There will be an incoming inspection area, a warehouse, 3 areas for manufacturing, a painting room, an office and a quality and shipment facility.

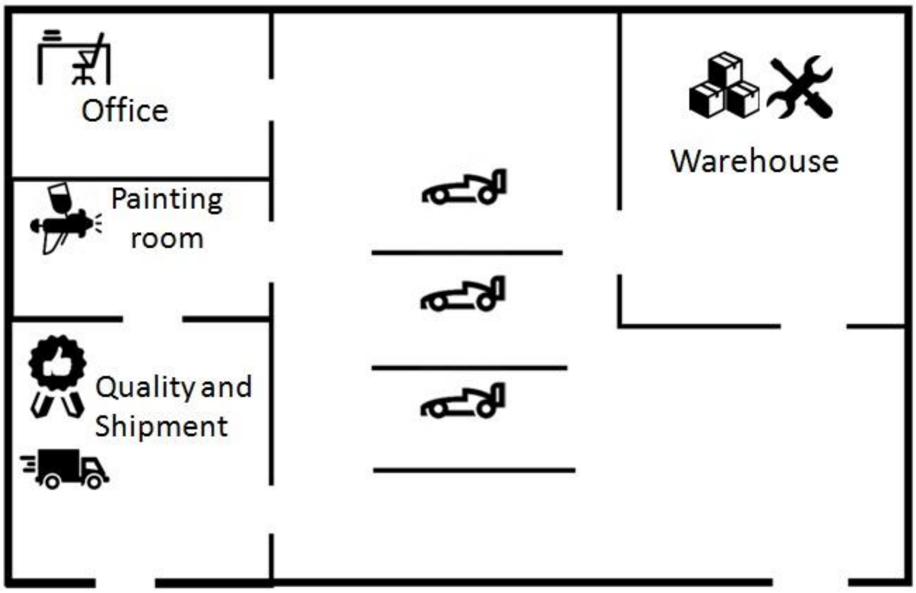

Figure 44. Fixed-Position Layout

Figure 45 shows the line-flow layout once the capacity of the company is bigger. There will be an incoming inspection area, a warehouse, an assembly line with five stations, a painting room, an office and a quality and shipment facility.

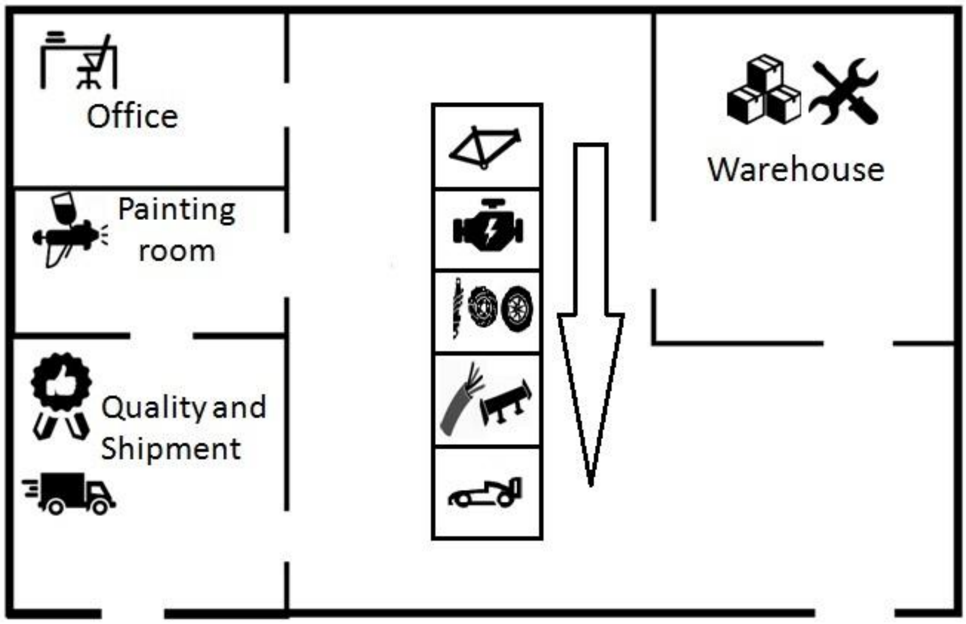

Figure 45. Line-Flow Layout

5.5.3 MRP System

5.5.3.1 Introduction

Material Requirements Planning (MRP) is a production planning and inventory control system. An MRP integrates data from production schedules with that from inventory and the bill of materials (BOM) to calculate purchasing and shipping schedules for the parts or components required to build a product.

5.5.3.2 Product Structure

Figure 46 shows the subassemblies necessary for the manufacturing of the ER 04.

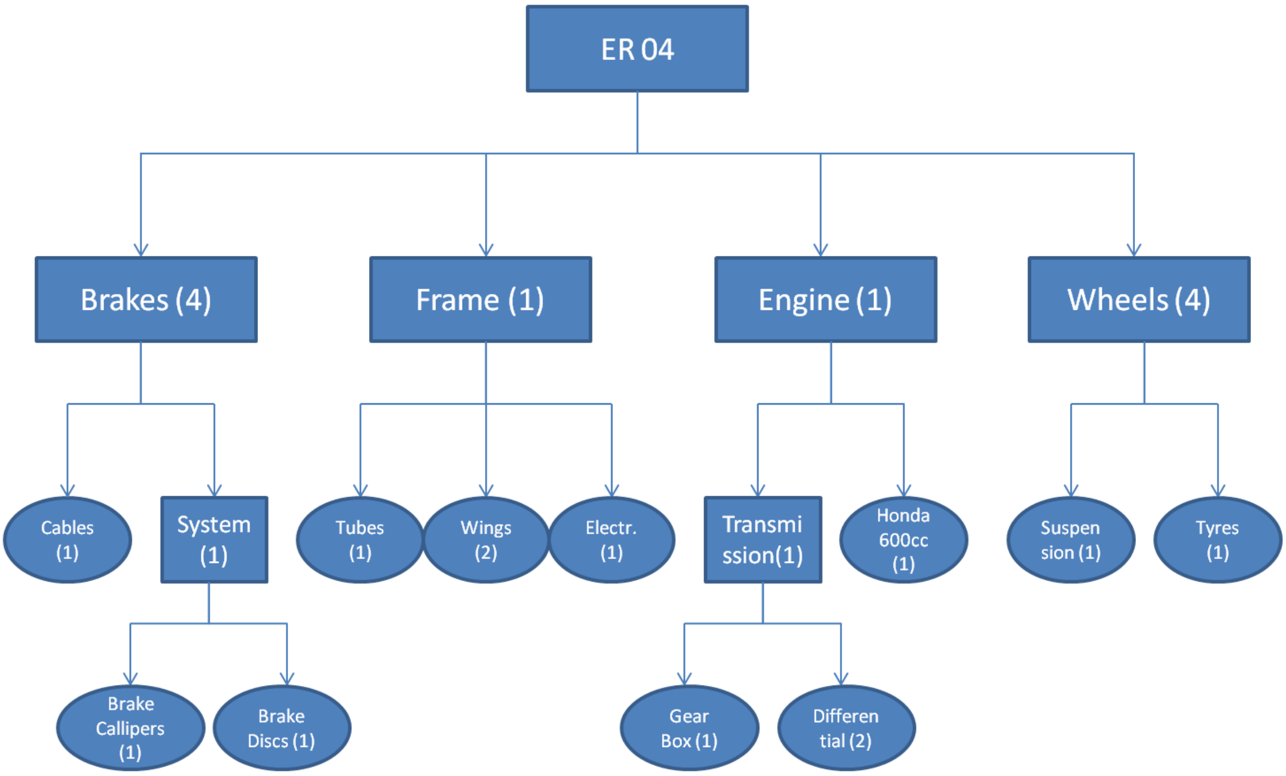

Figure 46. Product Structure for the ER 04

5.5.3.3 MRP for Brake System

Table 16 shows the MRP for the brake system.

Week	1	2	3	4	5	6	7	8
ER04 (units)				1	3	2	2	1

	S.I	I.I	LOT	Q	F.T	W.F			
Level 0	0	1	1X		1	0%			
Product ER04		1	2	3	4	5	6	7	8
Gross Requirements					1	3	2	2	1
Scheduled Receipts									
Projected Available Balance		1	1	1	0	0	0	0	0
Net Requirements						3	2	2	1
Planned Order Receipts						3	2	2	1
Planned Order Releases					3	2	2	1	

	S.I	I.I	LOT	Q	F.T	W.F			
Level 1	0	0	min	4	1	0%			
Product Brakes (4X)		1	2	3	4	5	6	7	8
Gross Requirements					12	8	8	4	
Scheduled Receipts									
Projected Available Balance		0	0	0	0	0	0	0	0
Net Requirements					12	8	8	4	
Planned Order Receipts					12	8	8	4	
Planned Order Releases				12	8	8	4		

	S.I	I.I	LOT	Q	F.T	W.F			
Level 2	0	3	Fix	10	2	5%			
Product Cables		1	2	3	4	5	6	7	8
Gross Requirements				13	9	9	5		
Scheduled Receipts									
Projected Available Balance		3	3	0	1	2	7	7	7
Net Requirements				10	9	8	3		
Planned Order Receipts				10	10	10	10		
Planned Order Releases		10	10	10	10				

	S.I	I.I	LOT	Q	F.T	W.F			
Level 2	0	0	min	5	1	0%			
Product System		1	2	3	4	5	6	7	8
Gross Requirements				12	8	8	4		
Scheduled Receipts									
Projected Available Balance		0	0	0	0	0	0	0	0
Net Requirements				12	8	8	4		
Planned Order Receipts									
Planned Order Releases			12	8	8	4			

	S.I	I.I	LOT	Q	F.T	W.F			
Level 3	0	2	X	6	1	0%			
Product Brake Callipers		1	2	3	4	5	6	7	8
Gross Requirements			12	8	8	4			
Scheduled Receipts									
Projected Available Balance		2	2	0	4	0	0	0	0
Net Requirements			10	3	8				
Planned Order Receipts			12	6	12				
Planned Order Releases		12	6	12					

	S.I	I.I	LOT	Q	F.T	W.F		
Level 3	0	3	X	4	1	0%		
Product Brake Discs		1	2	3	4	5	6	7	8
Gross Requirements			12	8	8	4			
Scheduled Receipts									
Projected Available Balance		3	3	3	3	3	3	3	3
Net Requirements			9	5	5	1			
Planned Order Receipts			12	8	8	4			
Planned Order Releases		12	8	8	4				

Table 16. MRP for Brake System

5.5.4 Lean Manufacturing

5.5.4.1 Introduction

A series of principles, concepts and techniques designed to eliminate waste and establish an efficient, just-in-time production system, which allows deliveries to customers of the required products, when required, in the required quantity, in the required sequence and without defects.

5.5.4.2 Lean Manufacturing in the Company

To apply the lean philosophy in the company we will focus on avoiding the seven wastes:

- Transportation: unnecessary movement of parts in the process.
- Inventory: All that raw material, product in progress or finished that is being stored.
- Movement: Unnecessary movement of people within a process.
- Waiting: people or parts waiting for the end of a work cycle.
- Overproduction: Produce before, faster or in greater quantity than what is demanded by the client.
- Overprocessing: processing beyond the standards required by the client.
- Defects: a defect represents a component considered unacceptable from the client's point of view because it does not comply with its quality standards.

The 5C rule for the organization of the job position will also be applied, which are: cleanup, configure, clean and check, conformity and custom.

In addition to this, the company will use the pull strategy. A pull system is a lean manufacturing strategy used to reduce waste in the production process. In this type of system, components used in the manufacturing process are only replaced once they have been consumed so companies only make enough products to meet customer demand. This means all of the company's resources are used for producing goods that will immediately be sold and return a profit.

5.5.4.3 Just in Time Production

Just-in-time (JIT) manufacturing is a production model in which items are created to meet demand, not created in surplus or in advance of need. The purpose of JIT production is to avoid the waste associated with overproduction, waiting and excess inventory.

The production rate will be one vehicle per assembler and week. In the first year 71 vehicles will be produced, which means a production capacity of 71%. In the second year there will be 151 vehicles produced which mean a production capacity of 76% and finally the third year there will be 251 vehicles manufactured with a full capacity. Full capacity requires manufacturing of 5 vehicles at the same time.

5.6 Lines for the Future

As previously mentioned, the way of manufacturing the ER 04 will change depending on the number of units to be produced. This transition will go from a production in a fixed position when the number of units is low to a line-flow layout as the number of units increase. In addition, as time goes by, the company will focus on reducing the cost of manufacturing for both material and assembly, but always maintaining the quality demanded by the customer.

On the other hand, the number of employees will be increased depending on the demand for vehicles and always under the philosophy of lean manufacturing.

6. Conclusion

In this project a rigorous work of analysis and understanding of the studied subject has been carried out. First, it has focused on the development of a business plan to achieve the success of a sales plan to the right customer and second, it has focused on the development on a manufacturing plan with the design and development of the product and processes needed.

Specifically:

- The new ER04 is an autocross vehicle with great potential, handling, is easy to maintain, and has been tested successfully.
- There will be two types of models, one basic and one fully loaded to meet the needs of our two types of potential customers, one of them is currently a driver and the other is a racing fan willing to drive a competition vehicle.
- To reach them, the company will develop a marketing strategy based on advertising and a loyalty service with a great customer service program.
- The ER04 has a tubular steel space frame with laser mitered tubes and full steel assembly fixtures. Laser cut A-arm tubes and ends. Billet machined CNC wheel centers, uprights and hubs. Simple carbon seat with foam inserts for any driver. Proven brand-name components including AP calipers, Ohlins dampers, Drexler differential, and Dailey oil pump to give the customer confidence in our quality. In order for these cars to be built in an efficient manner, while keeping quality high, many brackets and parts were designed for laser or water jet cutting and other inexpensive outsourced manufacturing processes minimizing internal labor and equipment costs.
- This vehicle will be manufactured in Daytona Beach, FL (USA) under the modality of just-in-time.
- The early years the vehicle will be manufactured in a fixed position with a transition to a line assembly when the capacity increases.
- Finally, the finance statement is summarized in the following table:

Pro Forma Income Statement				
	Year 0	Year 1	Year 2	Year 3
Revenues		1,575,000	3,375,000	5,625,000
Price		23,000	23,000	23,000
Nº Vehicles Loaded		53	113	188
Price		21,000	21,000	21,000
Nº Vehicles Basic		18	38	63
Costs	477,500	1,599,338	3,079,438	4,880,563
Machinery	200,000			
Material	-	1,121,838	2,403,938	4,006,563
Labor	253,500	448,500	643,500	838,500
Other Costs	24,000	29,000	32,000	35,500
Net Income	- 477,500	- 24,338	295,563	744,438

Table 17. Pro Forma Income Statement

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8. Appendix

8.1 Survey

1. What do you think that is important in an autocross car?

2. Would you consider buying a single seat, open wheel racecar in the next ten years – something that you would trailer to an autocross competition?

3. What would your likely budget for such a vehicle?

4. Have you ever thought about buying a formula SAE car?

5. Do you know anybody that have or want to have a vehicle like that?

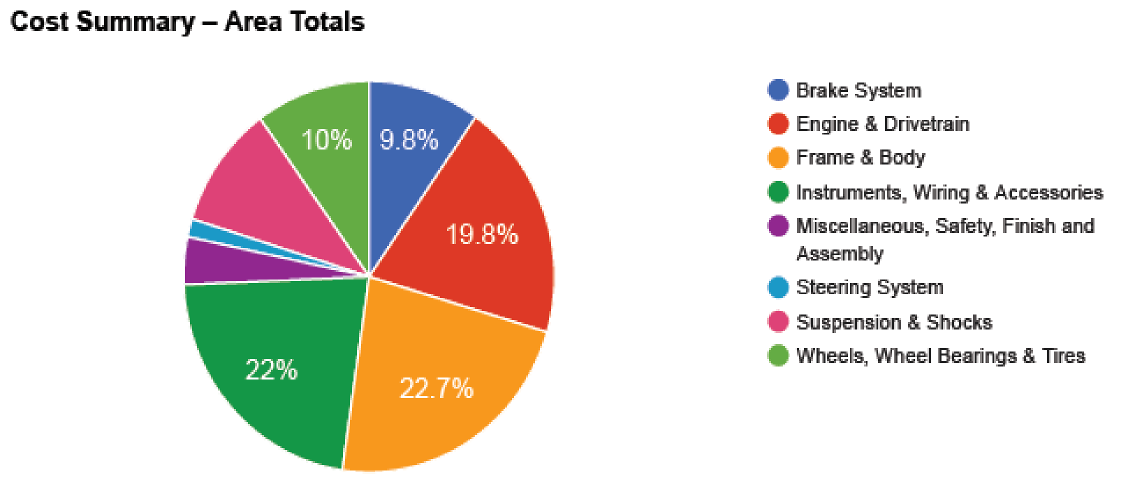
6. What are your most dissatisfied with about your current vehicle

7. What features are important for you:
    a. Customization
    b. Customer Service: Online support
    c. Data acquisition package
    d. Sound/beauty/Sex appeal
8. What specifications are more important for you:
    a. Safety
    b. Performance
    c. Reliability
    d. Efficiency
    e. Ease of repair/ serviceability
9. How important is Fastest Time of the Day (FTD) for you?

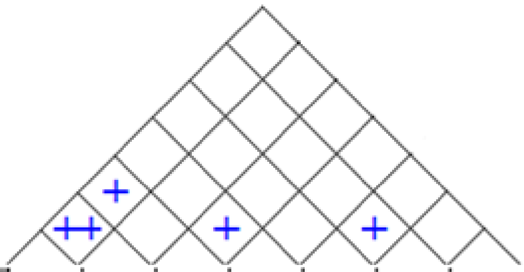
10. What should I have asked you that I didn't?

8.2 Cost Breakdown for the Fully Loaded Model

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



8.3 QFD Matrix

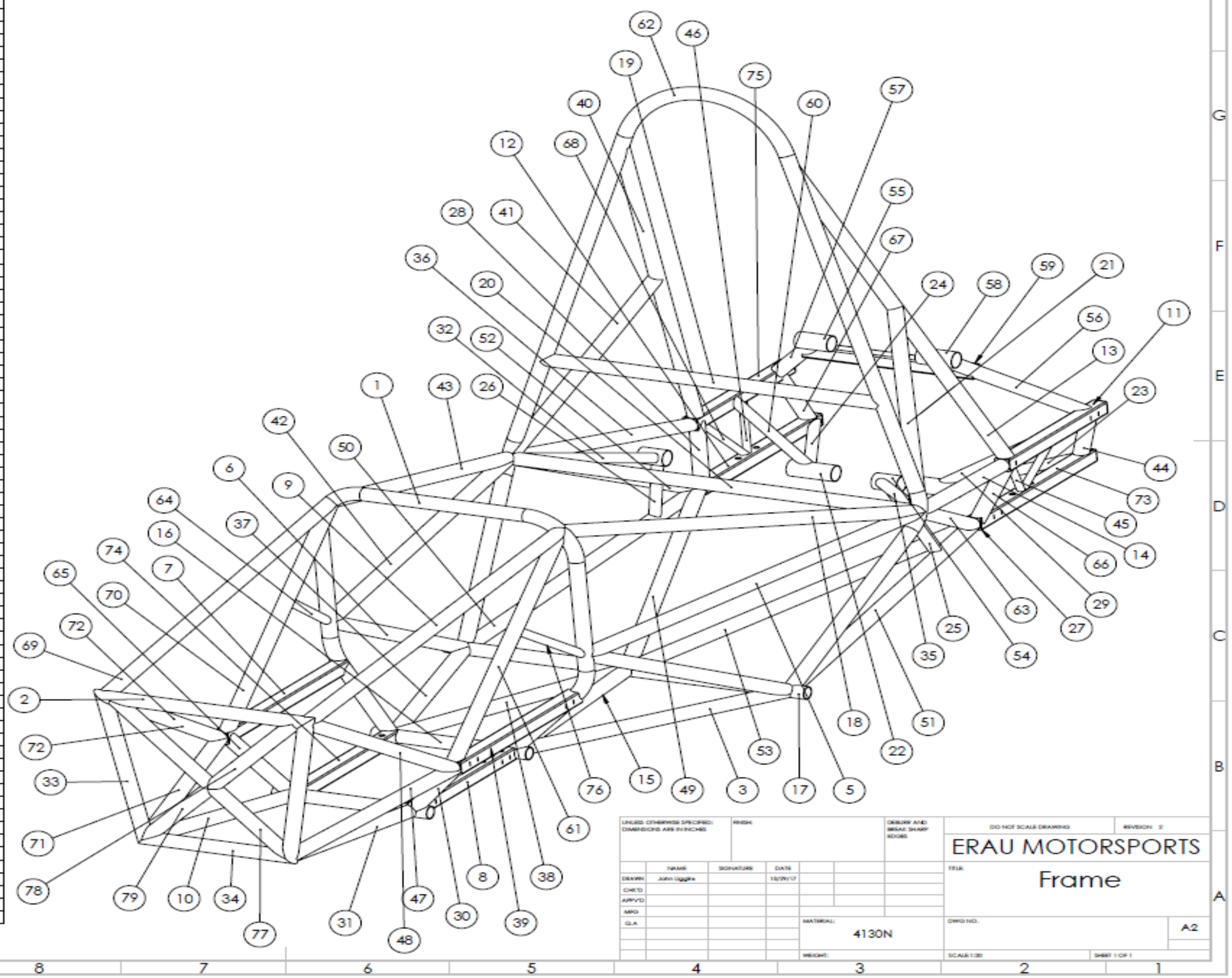


Max Relationship Value in Row	Relative Weight	Weight / Importance	Customer Requirements \ Design Requirements	Composites	Wings	600 CC Honda Engine	Exhaust System	Data Acquisition Package	Modular Design	Open Wheel Car
3	13,9	5,0	Safety	O						
9	13,9	5,0	Performance	Θ	O	Θ	O	▲		
9	11,1	4,0	Ease of Maintenance	O				▲	Θ	O
9	11,1	4,0	Handling	O	Θ	O				O
9	11,1	4,0	Customization	▲				Θ	Θ	
3	11,1	4,0	Customer Service						O	
3	8,3	3,0	Easy to transport	O						O
9	11,1	4,0	Aerodynamics	Θ	Θ					Θ
9	8,3	3,0	Sound and Beauty		Θ	O	Θ			Θ
			Importance Ratings	132	114	57	42	45	84	96

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	

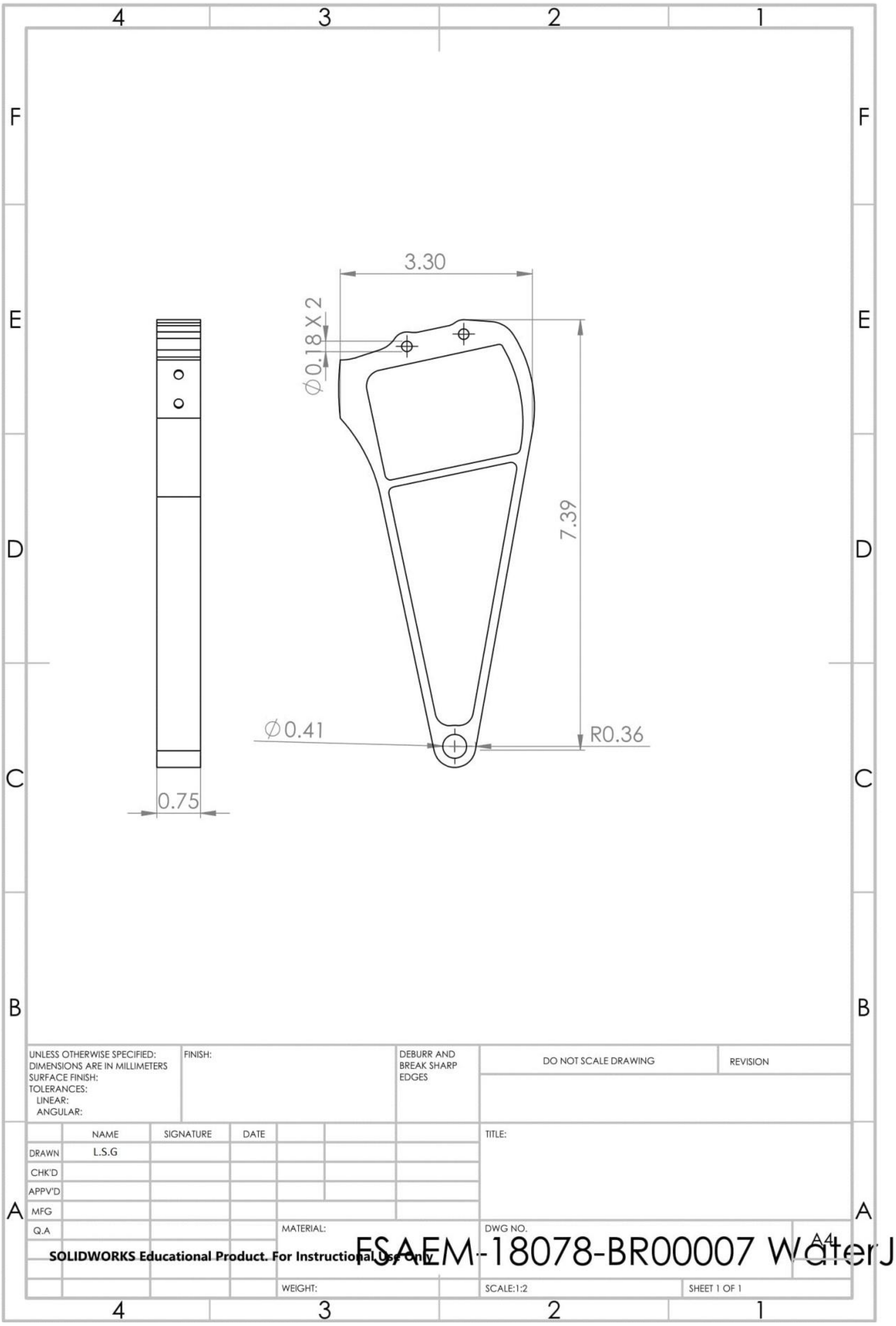
8.4 Frame and Bill of Material Drawing

ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	1	Tube 1.00 x 0.095	56.19
2	1	Tube 1.00 x 0.120	15.19
3	1	Tube 1.00 x 0.065	22.2
4	1	Tube 1.00 x 0.065	21.68
5	1	Tube 1.00 x 0.065	31.57
6	1	Tube 1.00 x 0.065	21.68
7	1	Tube SQ 1.000 x 1.000 x 0.049	14.62
8	1	Tube SQ 1.000 x 1.000 x 0.049	11.98
9	1	Tube 1.00 x 0.065	29.96
10	1	Tube 1.00 x 0.049	16.28
11	1	Tube SQ 1.000 x 1.000 x 0.049	11.74
12	1	Tube SQ 1.000 x 1.000 x 0.049	13.92
13	1	Tube 1.00 x 0.065	32.26
14	1	Tube 1.00 x 0.049	16.4
15	1	Tube 1.00 x 0.049	21.42
16	2	Tube 1.00 x 0.065	10.74
17	1	Tube 1.00 x 0.065	25
18	1	Tube 1.00 x 0.065	33.31
19	1	Tube 1.00 x 0.095	23.47
20	1	Tube 1.00 x 0.065	28.4
21	1	Tube 1.00 x 0.049	15.99
22	2	Tube 1.25 x 0.049	3.1
23	1	Tube 0.75 x 0.065	9.1
24	1	Tube 0.75 x 0.065	8.45
25	1	Tube 0.75 x 0.065	5.77
26	1	Tube 0.75 x 0.065	5.11
27	10	Tube Endplates - Provided by ERAU Motorsports	
28	1	Tube 1.00 x 0.049	4.92
29	1	Tube 0.75 x 0.065	7.77
30	1	Tube 1.00 x 0.049	5.7
31	1	Tube 1.00 x 0.049	16.28
32	1	Tube 0.75 x 0.065	9.06
33	2	Tube 1.00 x 0.120	12.52
34	1	Tube 1.00 x 0.120	10.84
35	1	Tube 0.75 x 0.065	10.23
36	1	Tube 1.00 x 0.049	16.38
37	1	Tube 1.00 x 0.065	22.2
38	1	Tube 1.00 x 0.049	21.42
39	1	Tube SQ 1.000 x 1.000 x 0.049	14.62
40	1	Tube 1.00 x 0.065	32.26
41	1	Tube 1.00 x 0.049	15.99
42	1	Tube 1.00 x 0.065	31.57
43	1	Tube 1.00 x 0.065	33.31
44	1	Tube 1.00 x 0.049	4.26
45	1	Tube 0.50 x 0.028	4.73
46	2	Tube 0.50 x 0.028	4.26
47	1	Tube 1.00 x 0.049	15.26
48	1	Tube 1.00 x 0.049	17.47
49	1	Tube 1.00 x 0.049	27.57
50	1	Tube 1.00 x 0.049	26.09
51	1	Tube 1.00 x 0.049	26.09
52	1	Tube 1.00 x 0.049	16.17
53	1	Tube 1.00 x 0.049	27.57
54	2	Tube 1.25 x 0.049	1.75
55	1	Tube 1.25 x 0.049	2.25
56	1	Tube 1.00 x 0.049	9.86
57	1	Tube 1.00 x 0.049	9.14
58	1	Tube 1.25 x 0.049	2.5
59	1	Tube SQ 1.00 x 0.065	11.79
60	1	Tube 0.75 x 0.065	6.89
61	1	Tube 1.00 x 0.049	19.77
62	1	Tube 1.00 x 0.095	103.51
63	1	Tube 1.00 x 0.049	16.05
64	1	Tube 0.625 x 0.049	6.92
65	1	Tube 1.00 x 0.049	5.7
66	1	Tube 1.00 x 0.049	4.92
67	1	Tube 1.00 x 0.049	4.26
68	1	Tube 0.50 x 0.028	4.73
69	1	Tube 1.00 x 0.065	29.96
70	1	Tube 1.00 x 0.049	19.77
71	1	Tube 1.00 x 0.049	15.27
72	1	Tube 1.00 x 0.049	17.52
73	1	Tube 1.000 x 1.000 x 0.049	13.92
74	1	Tube 1.000 x 1.000 x 0.049	11.98
75	1	Tube 1.000 x 1.000 x 0.049	11.74
76	1	Tube 0.625 x 0.049	6.92
77	1	1.00x0.065	16.02
78	1	1.00x0.065	8.94
79	1	1.00x0.065	7.07

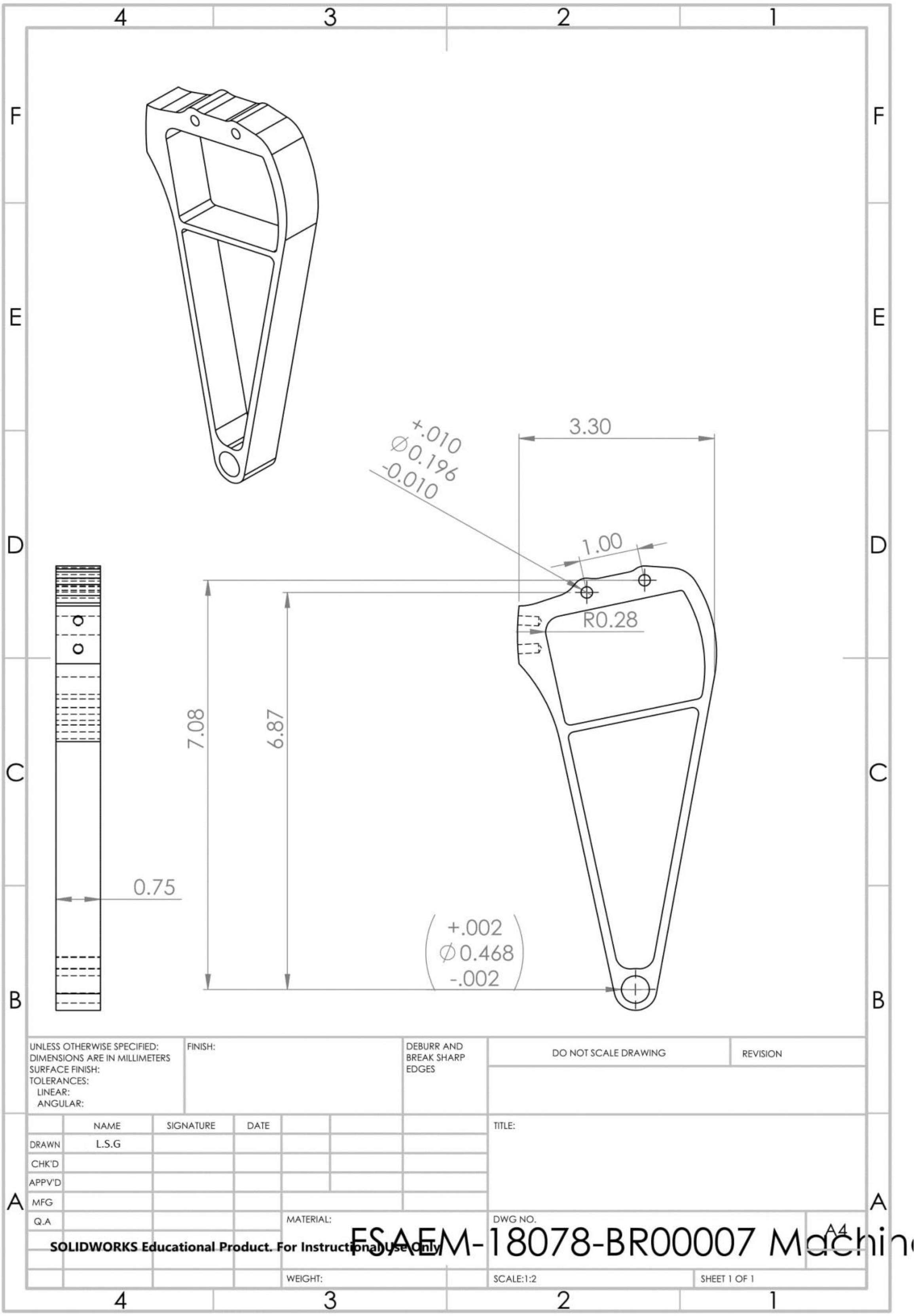


8.5 Brakes Design

8.5.1 WaterJet

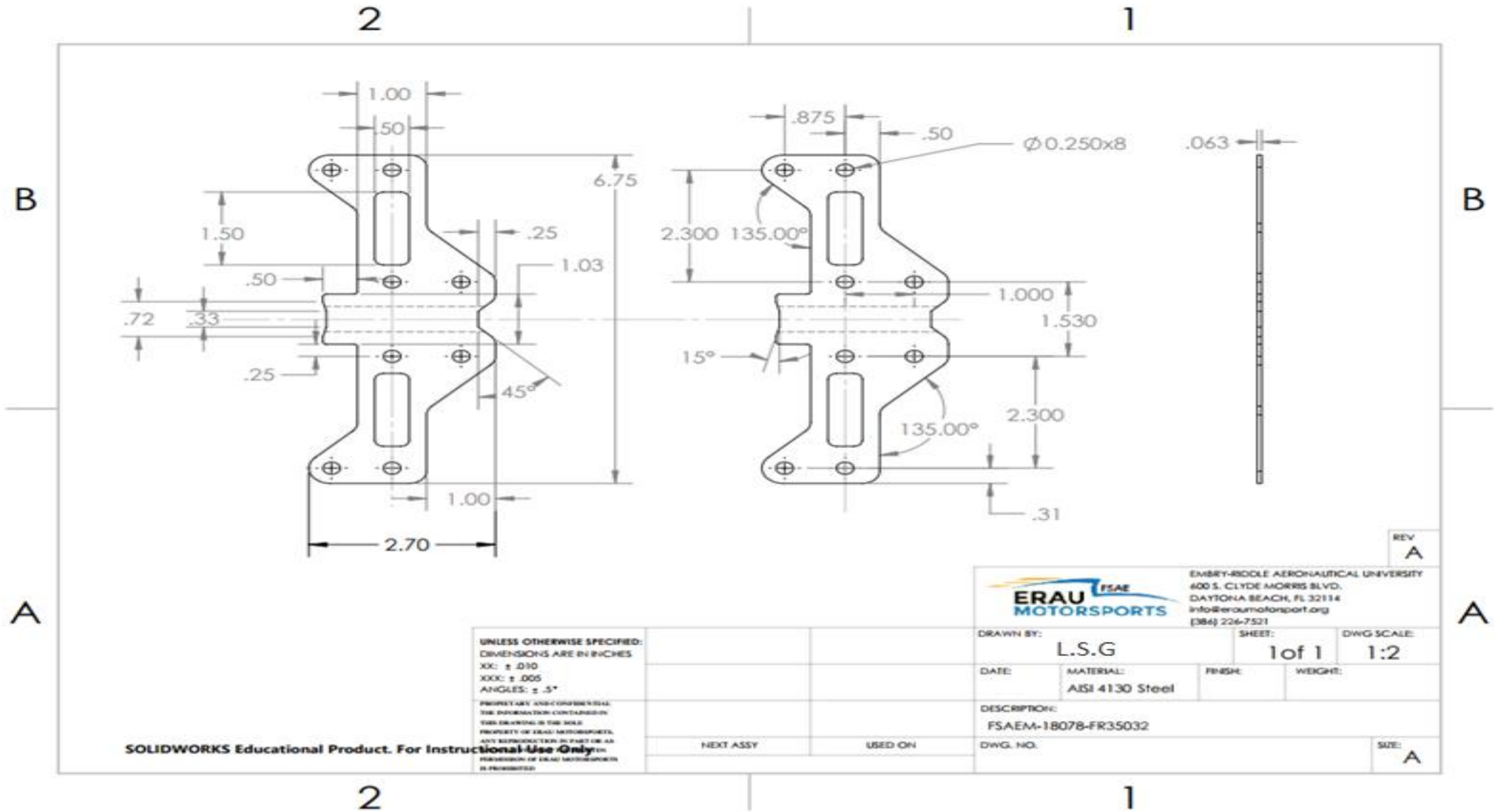


8.5.2 Machined

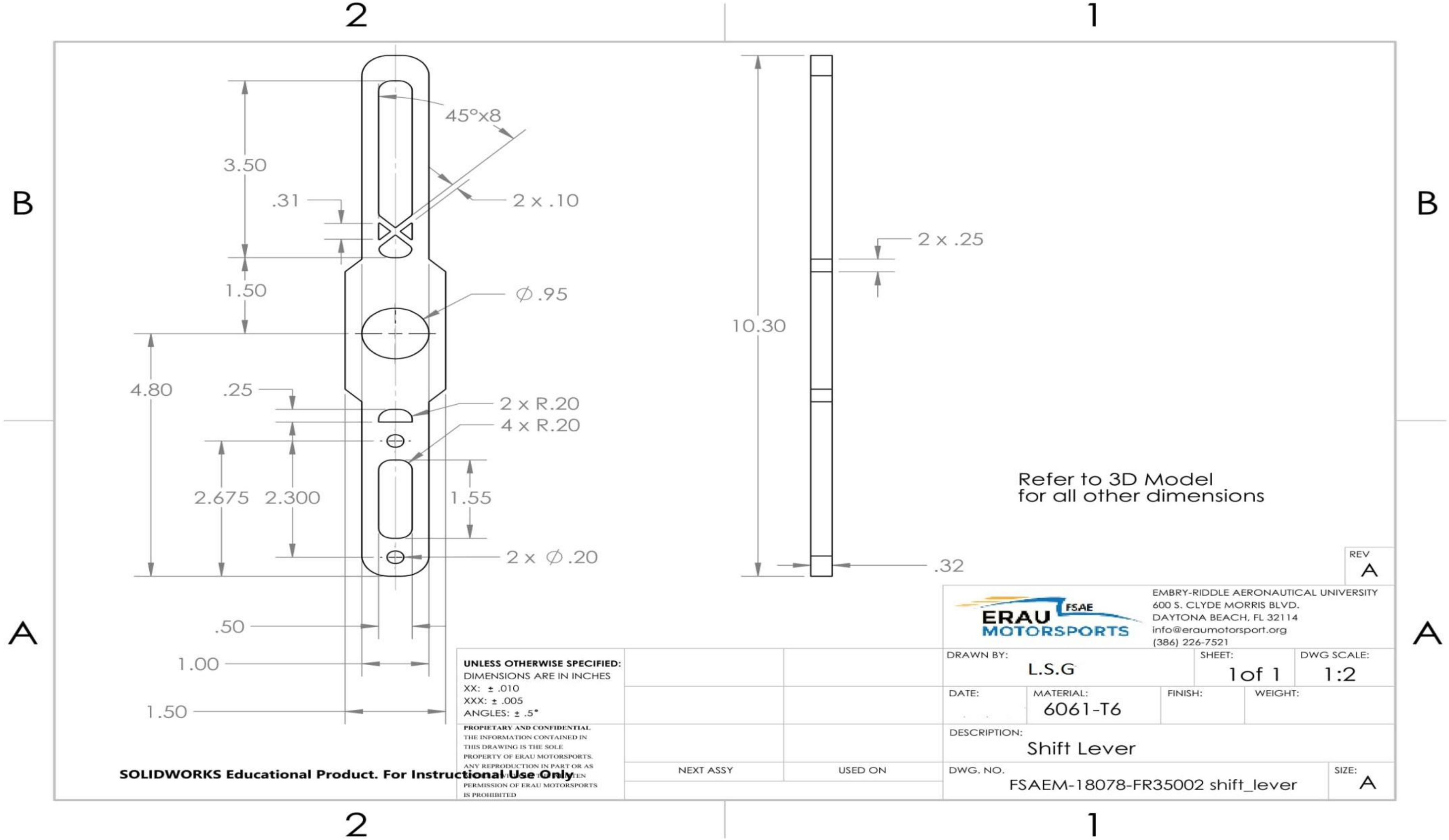


8.6 Shifter

8.6.1 Bracket

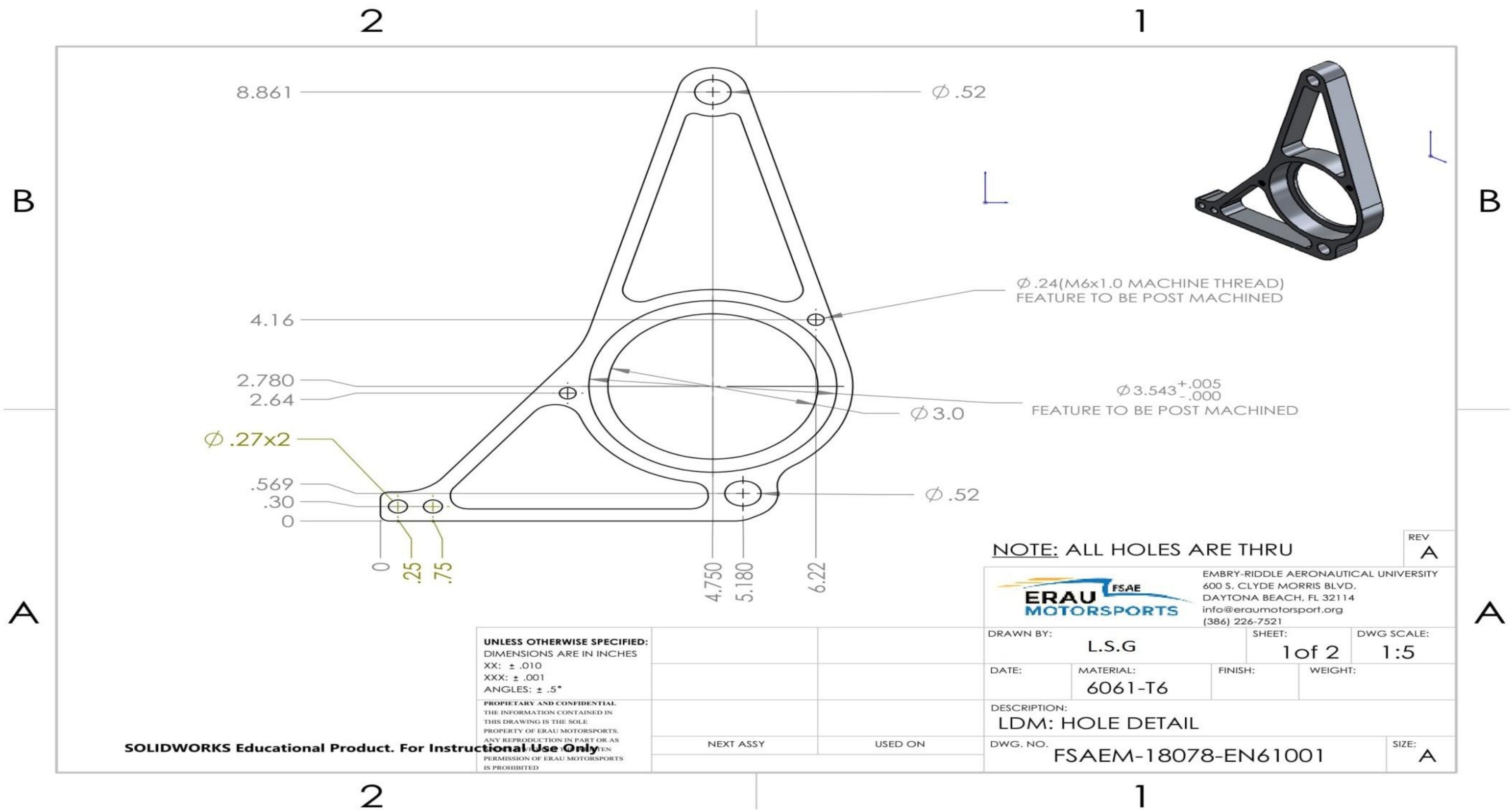


8.6.2 Shift Lever

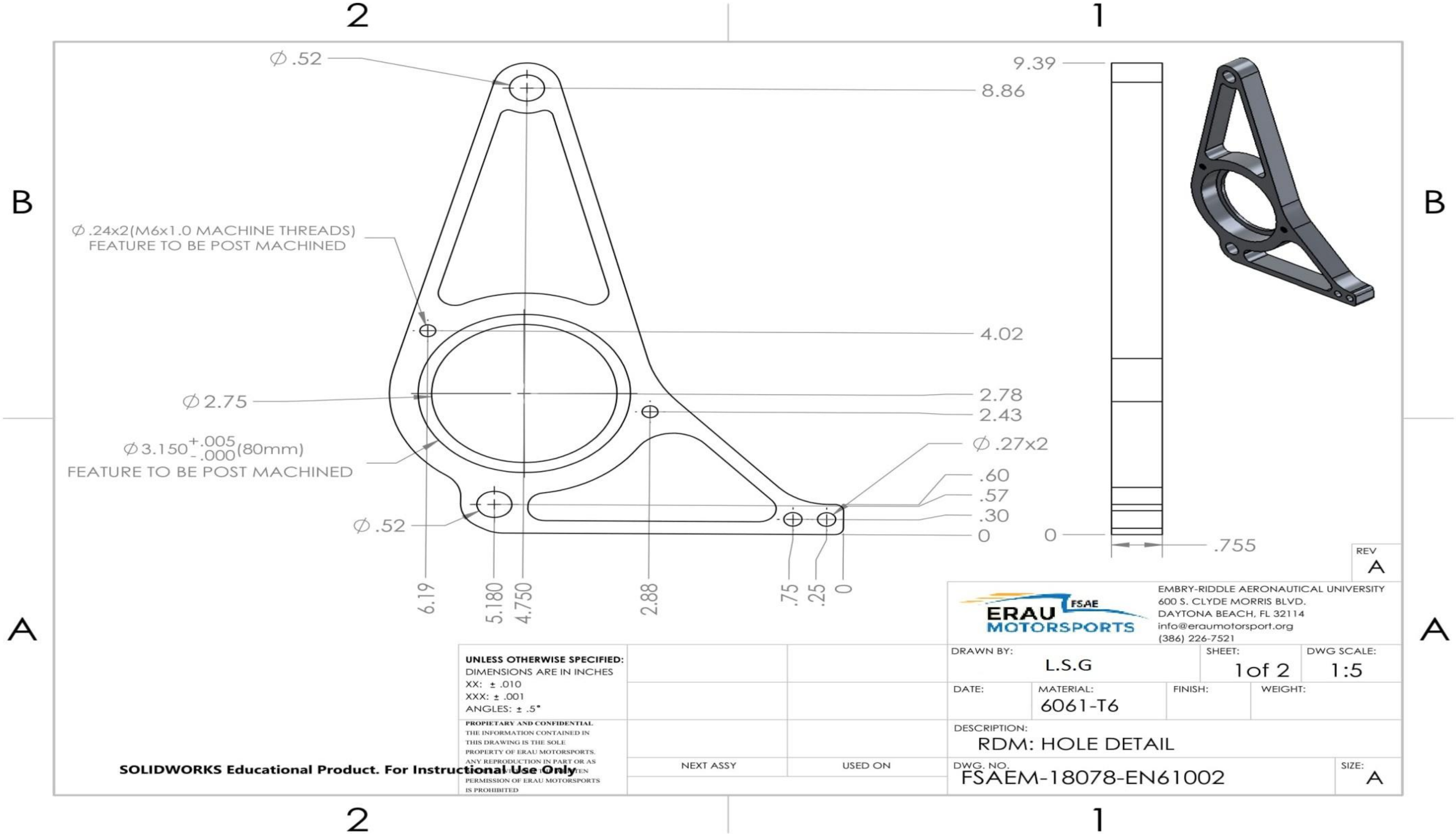


8.7 Differential Mounting System

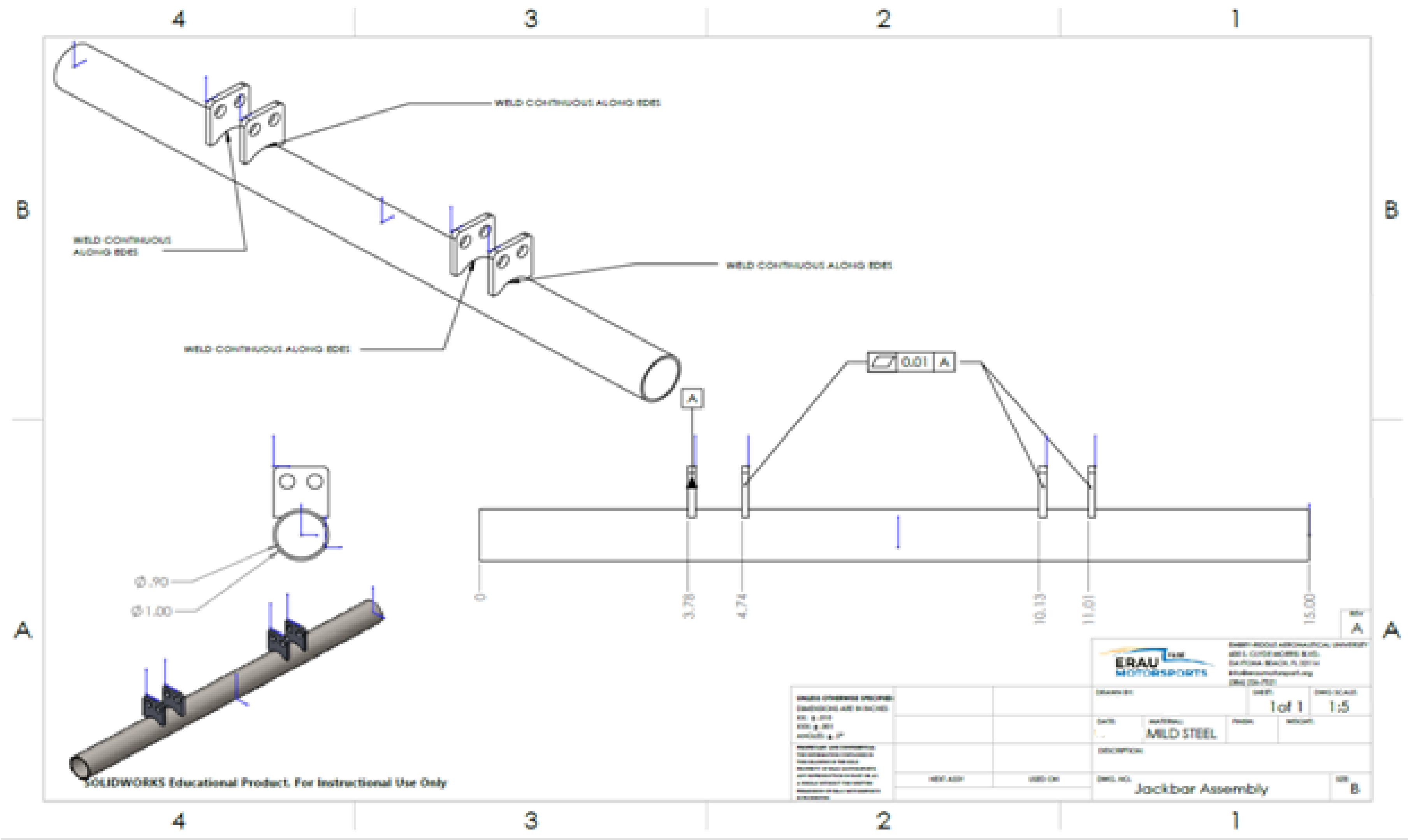
8.7.1 Left Part



8.7.2 Right Part



8.7.3 JackBar



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1:5
MILD STEEL
Jackbar Assembly
B
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