# Seat & Firewall Design for Cornell Racing FSAE

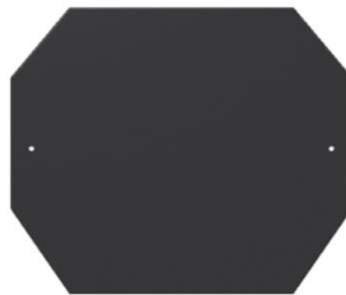By Bailey Herbstreit, Cornell University

0. Introduction

The purpose of the seat is to comfortably constrain the driver to the monocoque while allowing easy mobility of his/her arms while steering and shifting. By transferring the driver's weight and all consequential forces to the monocoque, the seat contributes to higher performance on events, especially acceleration. The comfort of a seat is vital in that a poorly designed seat can direct the driver's attention towards his/her discomfort rather than driving. The seat should be able to house a driver, providing safety and comfort.
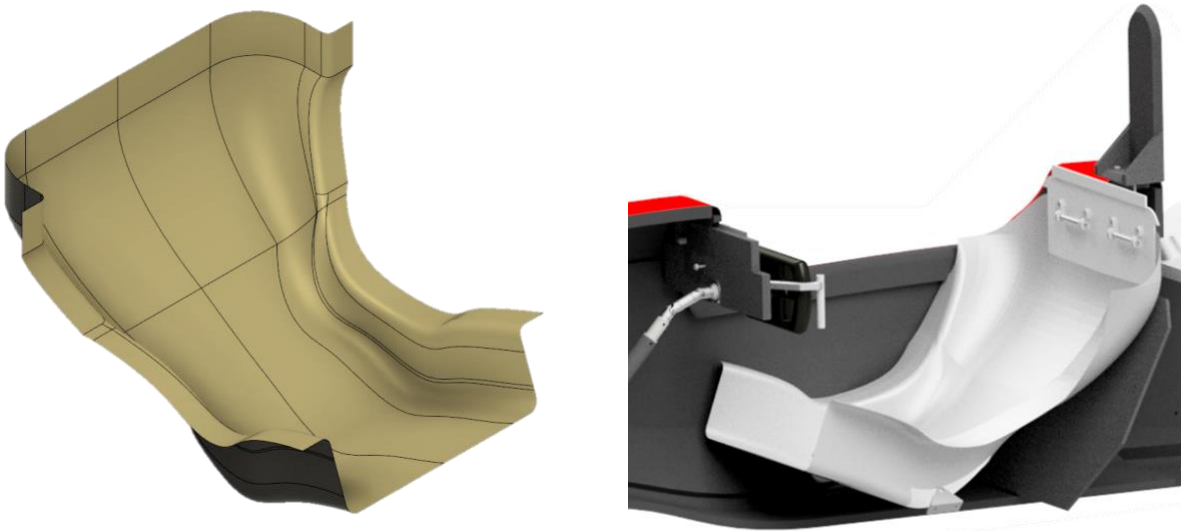
Figure 1.1. Driver (Graham) in ergonomic mockup with seat CAD

The firewall must be made of heat-resistant material because it acts as a shield between the driver and the engine's heat, fuel, oil, and cooling system. It is a barrier that ensures complete sealing from fluids and has no holes (unless a grommet is incorporated for wirings and cables. The firewall is to be no closer than an inch to the fuel tank, and should be high enough to shield the neck of the tallest driver. Most of the firewall design is dictated by FSAE rules 2017-2018 (T4.5).

Figure 1.2: Firewall

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1. Technical Overview

There were three main goals the seat had this semester: increase seat constraint in relation to the monocoque and the driver, maximize comfort, and lower driver angle in the car while maintaining operable visibility. Constraints in the monocoque changed from not just the side flanges near the thighs/hips, but also near the shoulders as a press fit along the monocoque edge. ARG17 proved that the side flanges and propped seat belt tabs have enough constraint. The formative CAD design process constantly evolved the choice of constraint location within the monocoque, height of sides, lumber support, etc. NASA and various ergonomic studies supported the neutral body position (128°) in high intensity environments [2]. The seat is designed to have padding in the lumbar, shoulder, and elbow region (located based on survey results) to support all kinds of drivers. Lastly, the neutral body posture from NASA, supported by Nissan Altima®, defined the driver angle in the seat [2, 3]. The driver mockup determined the seat angle in the monocoque.

Details of questionnaires and data sheets can be found in section 3. Data.

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2. History of Past Designs
In 2007 the team introduced the design of in-house carbon fiber seat manufacturing. Originally stemmed from expandable foam or a plan go-kart seat. However, since carbon fiber seats, the team has been able to customize the seats to our driver's. Therefore, measurements and other research/mockups have taken place to ensure that driver is constrained safely and still able to perform optimally.

ARG17
One method of determining comfort that was used for ARG17 and all previous cars was taking qualitative assessments of the driver's opinions. Subjective scales, as honest and easy as the data may seem, it does not achieve external validity (the extent to which the results of a study can be generalized to other situations and to other people). ARG17 recognized that **all** their **drivers are different**, which sparked the idea of foam inserts. Foam inserts provided personalized comfort and allow for one base to be used for multiple drivers. This design decision cuts down on manufacturing time and effort.

The lower seat belt clevis was cut larger than previous years to ease the seat in and out of the car in a quick, simple manner. In previous years, there was trouble getting the seat out of the car because the seat belt tabs would get stuck around the clevis holes on the seat, so by making them larger, it makes it quicker to get to the engine. ARG17's firewall was only a panel with no bolts, so it was a matter of pulling off the panel.

Firewall is made of carbon fiber with a layer of Nomex honeycomb core in between, which is a heat resistant material, and then is taped with a lightweight heat-resistant tape to ensure the safety of our drivers. The firewall is also cut so that it is flush to the floor and sides of the monocoque, sealing passage of any fluids.
NEEDS to Change
- Designing a composite part: think about the manufacturing process before as you design. Think about the mold process. It is very important to know how a part is manufactured before designing any part so that you know what geometries are possible. It can be easy to go crazy with the splines when CADing something like the seat, but do a mental check occasionally.
  - Top flanges need to be redesigned to prevent wear-and-tear over time, improve fit and reduce slop.
  - Improve firewall measurements to ensure precise fit.
- Padding: Shoulders and knees were most commonly bruised during ARG17. It is important to recognize these long-term injuries are a dangerous game to play with our drivers. With comfort, the seat can also increase constraint for our driver. San Jose had a great design for upper mounting and shoulder padding.
- Better manufacturing for female inserts.

Could Fix
- Simulating: Trying to simulate driver position was a struggle this year, especially with the unfamiliarity of RAMSIS (ergonomics software that allows you to

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simulate driver placement), but utilizing this software would help foresee interferences drivers could potential have with the seat design pre-manufacture.
- Press fit v. locking mechanism: how is the seat placed inside the monocoque. What are the overall goals of getting the seat in and out of the vehicle?
- FOR FUTURE YEARS: explore shaping the top of the seat to the edge of the monocoque
- Shape can be determined based on driver feedback

Should NOT Change
- ARG17 did a great job of reducing material that was unnecessary, and therefore reducing the weight when compared to previous seats. This also allowed for driver's own personal upper constraints via foam inserts. This was a success, as displayed by driver testimony, and should be explored once more.
- Carbon fiber has been deemed successful for a decade now on the team. The molds have been iterated to a point where the team is learning a lot about the quality and strength of carbon fiber. The best thing to do moving forward is to improve the overall execution.

ARG 2016
The goal for 2016 was to integrate the seat and firewall. It was intended to be a innovative way to integrate two structures. However, it posed consequential problems with quality. The final design was two separate structures.

The seat was made of ¼ inch Nomex core with 3 plies of carbon fiber on each side. The seat weighed 4.57lbs., which was heavier than previous years. More elbow room was needed. The seat did not meet the 95th percentile male. The team felt the seat could have gone under further quality and comfort investigation. One design note that was important to note: **not one size fits all**, aim to create the simplest base and focus on the upper constraints to fit with the driver's individual body and style of driving.

ARG 2015
The seat was made of carbon, and aimed to accommodate multiple drivers. They addressed the problem of having high "sidewalls" that would interfere with the clutch system (a problem ARG11 mostly had).

ARG 2011
This was the fourth year of manufacturing a carbon fiber seat. The layup schedule was almost the same as recent years: 3 plies of carbon, nomex core, another layer of carbon with vacuum bag, and then 2 more plies of carbon before going into the oven. ARG11 took ARG10's seat and readjusted the angle by using a lot of bondo on the mold. The main struggle in ARG11 was not enough understanding of the materials used to make the seat. A lot of time was spent cutting out/sanding down excess material off the seat, there was a failure to transfer knowledge about material behavior. This allowed the seat had high sidewalls that would interfere with the clutch system. The other issue was the curvature of the spine which caused bruising along the spine.

3. Data and Testing

Major design criteria for the seat is its shape, size, and material. These qualities should provide comfort and constraint for the driver to ensure their safety. Before designing the seat, measurements need to be taken of the drivers and interior of the monocoque. The measurements of the seat and monocoque need to account for significant sanding, therefore measurements are imperative. The following data was collected to support the design decisions:

A) Driver measurements
B) Driver position
C) Quantitative studies; post-manufacturing padding
D) Qualitative studies; future ergonomics tests

A. Driver measurements

Driver measurements (anthropometrics) were taken periodically throughout the semester to ensure valid records. Using a tape measure, sewing tape measure, and two straight edges the driver's measurements were taken in a seated position. **Four driver's measurements were taken; Graham, Harry, Joseph, and Balen. For competition evaluation, Balen and Harry's measurements were used because they represented the widest range of driver dimensions and still met within the 95th and 5th percentile.** Measurements were recorded below:

drivers	weight	ARG18 standing height (1)	hip height (5)	erect sitting height (8)	sitting shoulder height (10)	sitting shoulder width (17)	rib width	hip width (19)
Harry	145	69.75	41.5	35.75	24	15.5	13	14 (31)
Graham		69.6	41	38	25	18.5	12	13 (30)
95th male	225	73.4	39.4	38.2	25.4	19.9	-	15.9
5th female	108	59.6	29.1	31.3	19.9	14.8	-	12.2
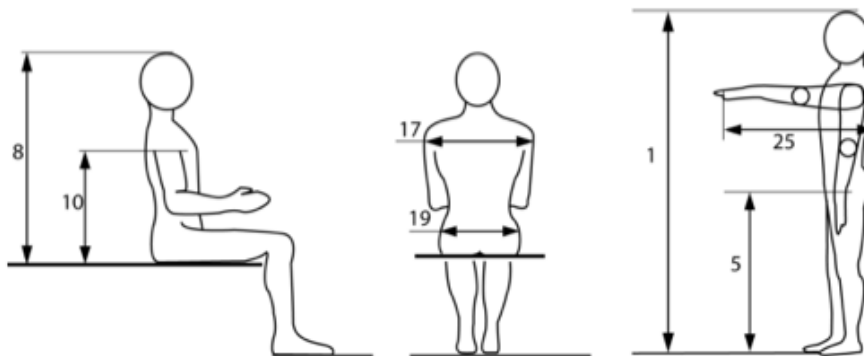
B. Riley, "FORMULA SAE ANTHROPOMETRIC REFERENCE DATA 5 TH PERCENTILE FEMALE & 95TH PERCENTILE MALE," November 23, 2015. Retrieved
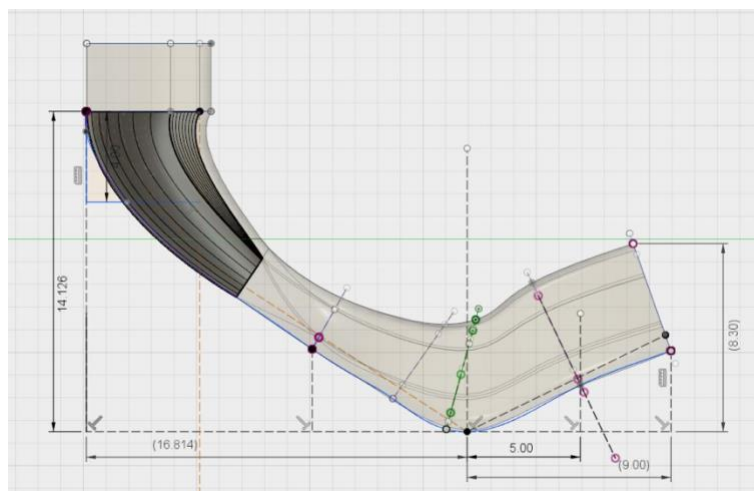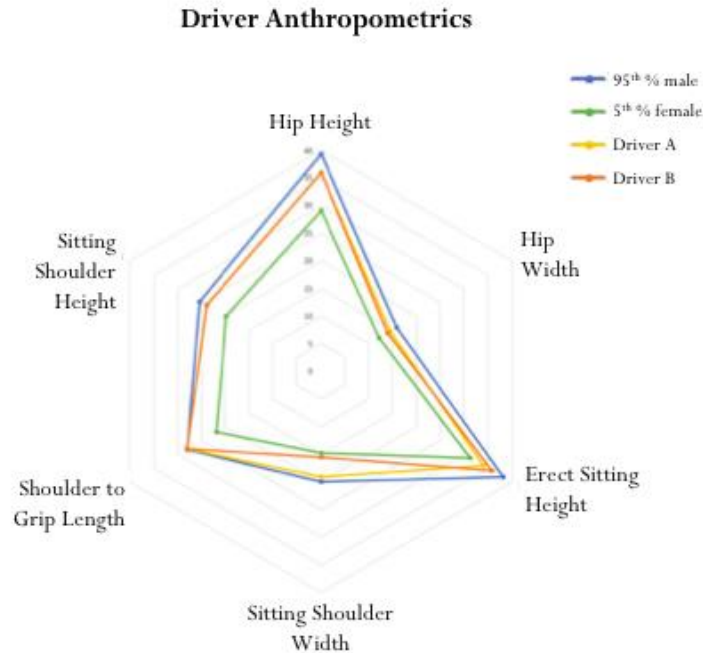
Table 2. Driver Measurements

Figure 2.0. FSAE Anthropometrics Chart

Driver anthropometrics were compared to the 95th percentile male and 5th percentile female. The above driver dimensions were the hallmarks for how we design the steering system, pedals, steering wheel, seat, head rest/pad, and firewall. The below figure was the data presented at competition.


Figure 2.1. Driver dimensions broken into major segments along curvature of body.

The seat was broken into 7 main sections to cover the major biometrics and also to accommodate CADing struggles. Figure 2.1 displays the major dimensions of the seat. The top and bottom dimensions were directly taken from the monocoque, which did account for carbon fiber thickness and variability of the monocoque (measurements were also taken on ARG17).

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a. **Driver Position**
   The position of the driver in the monocoque was determined based on our own ergonomic mockup and NASA's neutral body posture [2]. The mockup conducted evaluated Harry and Graham's driver preference. Figure 2.2 breaks down what was an independent variable and what was held constant.
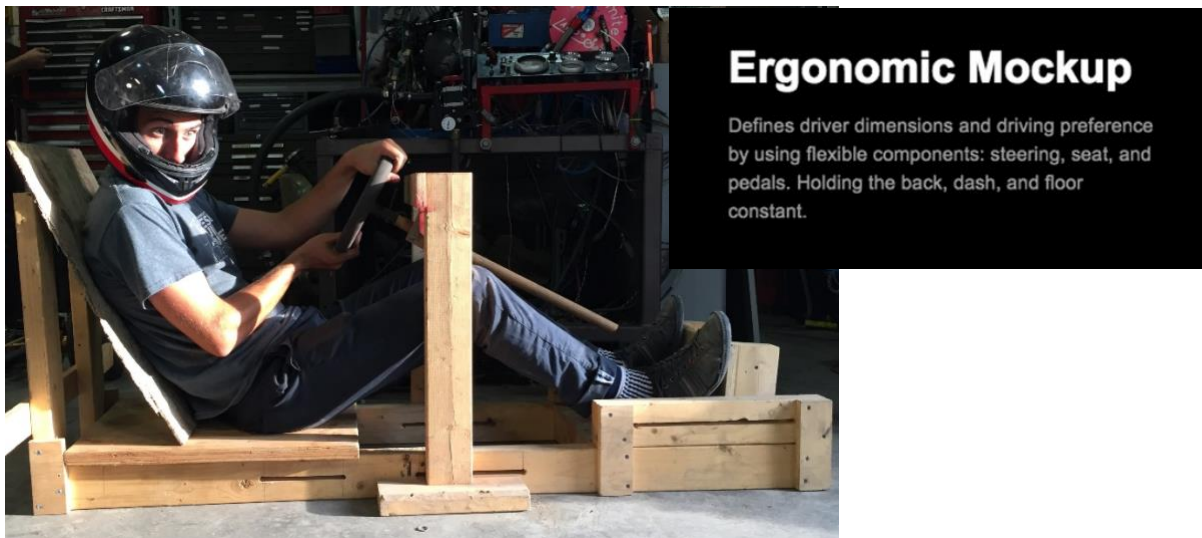
Figure 2.2 Ergonomics Mockup (Harry)

The driver position was inspired by NASA's neutral body posture which was discovered by looking at astronaut's resting position in space (figure 2.3). The position revealed the closest comfort position that maximizes physical productivity. The design of driver angle was also based on the maximum distant that the driver can be leaned back while maintaining a healthy leg position from the pedals. Additionally, the position of the driver was regulated by the monocoque being able to fit the width of the seat, which was discovered at 16.81 in (figure 2.3, 2.4). The driver position for the seat design, after triginometery was calculated, resulted in 121° (figure 2.5).
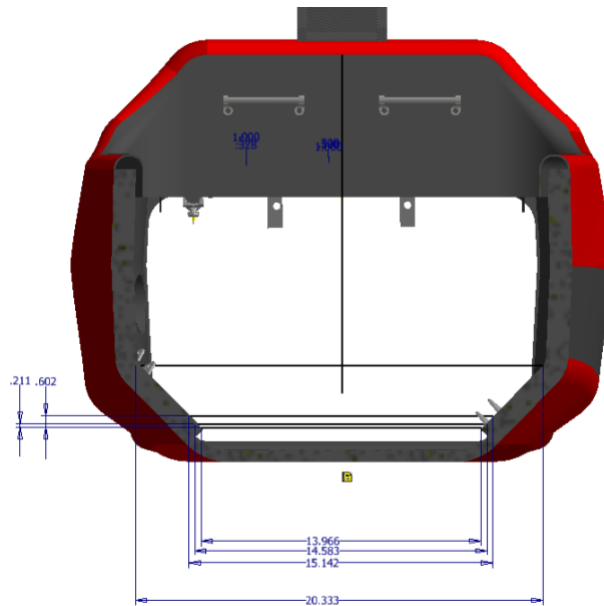
Figure 2.4 Monocoque strategy at point of contact with seat

Figure 3.3.4.3-1 Neutral Body Posture

Note: The segment angles shown are means. Values in parentheses are standard deviations about the mean. The data was developed in Skylab studies and is based on the measurement of 12 subjects.
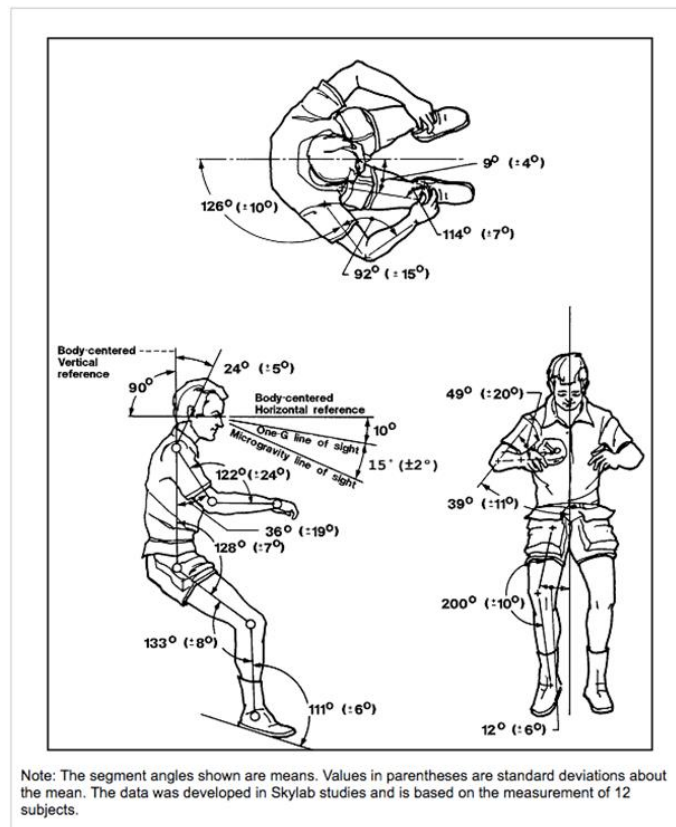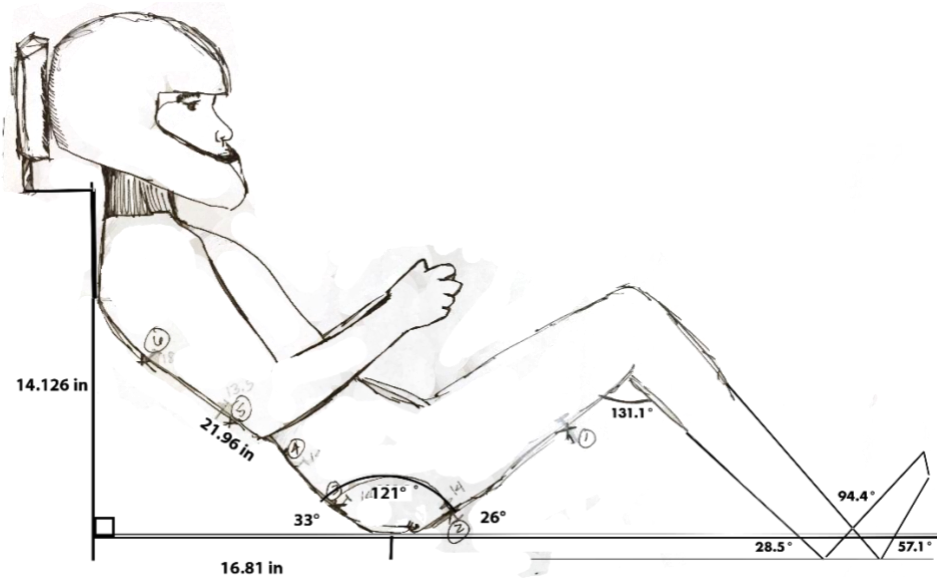
Figure 2.3 Neutral Body Posture

Figure 2.5. ARG18 driver position in seat and monocoque near neutral body posture

b. Quantitative Studies

Several observational and self-reported research methods (highly replicable) have been conducted on ARG17's drivers (found in ARG18's PDR report [9]); Rapid Upper Limb Assessment (RULA), reaction time, physical patterns from GoPro footage, Rapid Entire Body Assessment (REBA), and a modified Musculoskeletal Discomfort Questionnaire gather quantified data to show trends and correlations with multiple different aspects of the car and driver. With this data you are able to determine if changes to designs positively or negatively affect driver comfort and performance. This method allows for the most up to date set of data and not having to rely on sheer memory of the drivers.

     i. RULA
    ii. REBA
   iii. Musculoskeletal Discomfort Questionnaire
   iv. Driver Survey

RULA

The Rapid Upper Limb Assessment (RULA) was conducted to generate a single numerical score to identify high risks tasks with pre-post measures for intervention [4]. The RULA scoring ranges from 1 (acceptable risk) to 7 (investigate and change immediately) (Figure 3). The process of the RULA would to either interview or observe sections of the body to determine the highest risk tasks and subtasks and then calculate the total score.

For ARG17; Driver 1, Harry Galbraith, scored a 6 overall during a video recording at Groton race car lot. According to RULA, "6" looks for further investigation and some form of the task should change soon (Figure 3.1).

Additional notes: Fatigue was apparent when driver held for extended period and two hands were utilized at one point. The operation of the clutch lever observation posed possibilities of angling the handle on the lever to the same degree as the steering wheel to

maximize grip strength. Additionally, the driving observations quantified the length of time that the lever will be utilized (up to 3 minutes).

Driver 2, Graham Nickel, scored a 7 overall during a live observation at Groton race car lot. According to RULA, "7" calls for investigation and change immediately.

However, the RULA was later recognized as a measurement tool for sedentary seated work or standing without moving about. Both measuring some form of inactivity while conducting a task.

REBA
One solution is to conduct a Rapid Entire Body Assessment (REBA) which captures more detail on the torso, lower body, exertion, type of movement or action, repetition, and coupling (Figure 3.1) [5]. The entire assessment is designed to better capture active work, manual material handling, whole body movements, or risk to the back and legs.

Driver 3, Jonathan de la Fuente scored a 7 REBA score during recorded observation via GoPro at Groton race car lot. According to REBA, 7 is classified as a "medium risk, further investigation, and recommends change soon."

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REBA Employee Assessment Worksheet

Musculoskeletal Discomfort Questionnaire

The last ergonomic assessment given was an amended version of the Student Specific Cornell Musculoskeletal Discomfort Questionnaire (SS-CMDQ), an adaptation of the Cornell Musculoskeletal Discomfort Questionnaire developed by Dr. Oguzhan Erdinc, and Dr. Mahmut Eksioglu (BoğaziçiUniversity) in Turkey [2], it has been shown to have good validity. Below illustrate the results; areas of discomfort: forearm, wrist, hands/fingers, hips/buttocks, thigh, and knees (figure 2.6.a). **Figure 2.6.b shows an incredible change using the ergonomics assessments over the course of 200 hour driving period, with a total of 25 responses over 4 drivers.**

Figure 2.6.a. Musculoskeletal Results, before and after comfort changes [9]

Figure 2.6.b ARG18 Ergonomic Assessment compilation

Implications of Seat Padding
The back region of ARG18 will have a straight back to avoid issues with misplacement of lumbar support. Not everybody is made equal, which was clearly identified in ARG17. Therefore, permanent padding will be adding in post-manufacturing in the lumbar, rib, and shoulder region. KamiSpeed.com illustrates the quality and application that we are looking for [10].

Figure 3.1. KamiSpeed.com padding for racing seat

SURVEY RESULTS [9]
Key Takeaways
    a. Placement in monocoque; increase feeling of being constrained, focus on specific areas of discomfort, and design to fit with body
        v. Consider the process of taking seat in and out of monocoque
    b. Driver seat angle
    c. Seat + driver visibility
    d. Elbow range
        i. Relative to edge of monocoque and steering wheel
    e. Thickness of carbon fiber
    f. Emergency Access
    g. Foam inserts

Where did you feel the most pain on your body?

4 responses
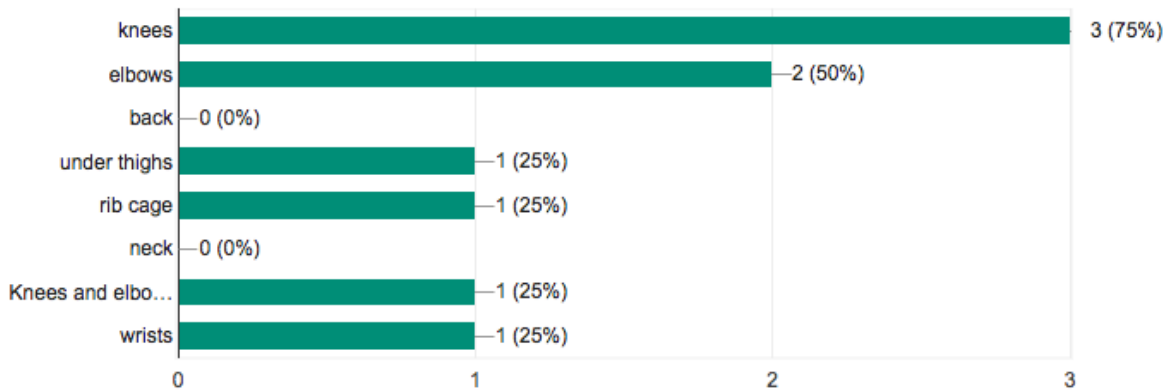
Chart 1.1. Number of responses to pain experienced in the car (n=5)

- *"Felt **a little upright** to be honest. Was **good for visibility**, but not as good for "feeling the car"*
- *"there was **some back pain** from the hardness of the seat if I was in the car too long"*
- *"main issue depended on seat placement, your **elbows would run into the seat or fuse box**"*

How constrained did you feel in the car?

4 responses
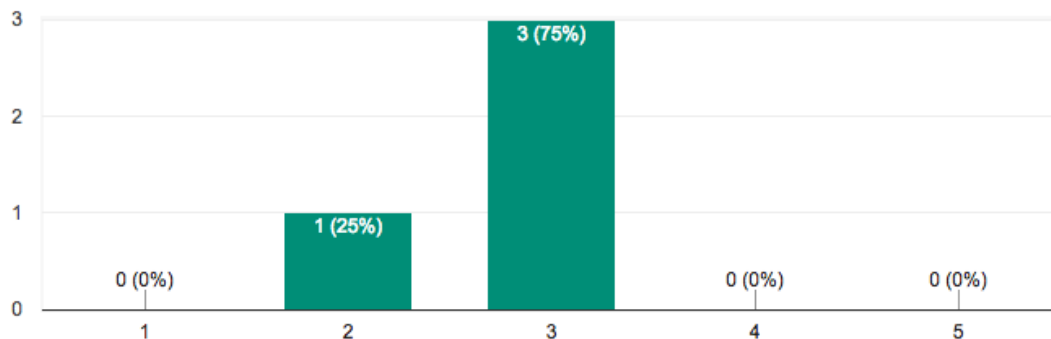
Chart 1.2. Likert Scale (1 = strongly disagree, 5 = strongly agree) vs. number of respondents (n=5)

Data Collection—Future Work

Previous data collected was for ARG17 via discomfort questionnaires. The more data collected and the larger the sample size, then the more valid our driver's testimony becomes.

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Testimony from Ergonomic Assessments of ARG18

> Yea the upper seat belt tabs were rather uncomfortable on the upper back. Eventually left bruises. Steering effort is a bit high but is comfortable.

> Would be nice to have only the ones chosen on the first page to show up on the following pages

> I couldnt steer the car without squichsin my finger between the wheel and my legs with the seat in the car. Without the seat i could steer easier however the battery caused discomfort in my side and lower back. I also moved around a bit.

> Had two spots on the lower back right near the butt, other two spots more mid back area

> Got a nice bump on my spine now

> fuck endurance

- due to angle of pedal, ankle is tensed backwards when off throttle. hurts after a while
- its more the middle back in one particular spot, would only prevent back to back long stints
- Adding my seat, which effectively gives me more room in the car, made driving worlds better. I was able to drive to the best of my ability because I no longer had to deal with taking my hands off the wheel and repositioning to make tight corners. Plus, the seat was very comfortable for me.

Material Used: carbon fiber and Nomex honeycomb core from ARG17 [6]

Properties of Material: Carbon
(Cytec—with MTM45 resin system)
- Tensile Strength: 124-131 ksi
- Compressional Strength: 86-93 ksi

    a.   Pros:
- High stiffness to weight ratio:
  - More stiffness is better because it is directly correlated to driver safety. When a driver makes a sharp turn, the seat should be stiff enough to prevent the driver from experiencing a strong impact due to high cornering.
  - Less weight is always better since it directly impacts how fast the car can go overall
- Familiarity of manufacture
  - Our team has a lot of experience with carbon fiber manufacture

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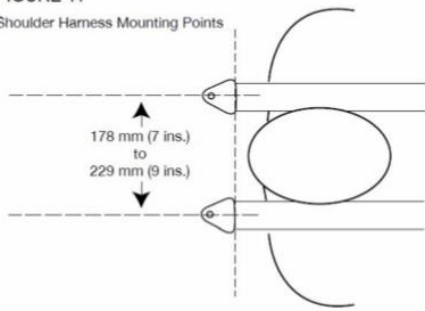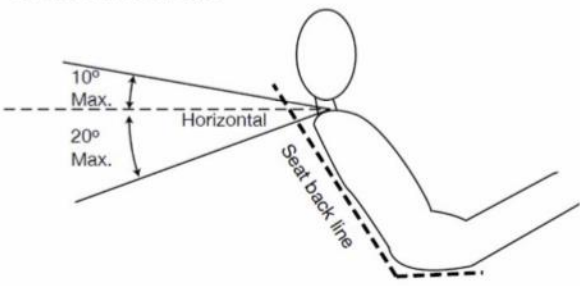
- o Less time spent learning/experimenting with a new method, more time spent improving a familiar process
  h. Cons:
    ▪ Expensive:
      • Carbon fiber has very appealing properties, which leads to high cost. It is difficult to make a lot of carbon fiber parts on a small budget.

Data Still Being Transcribed:
A VBA Code should be performed for Calculation of Driver Center of Gravity.

Systems Integration

The placement of the seat belts depends heavily on FSAE rules. Both the upper and lower seat belts will be mounted in a monocoque hardpoint. The rule section of this document breaks down the rule specifications and related justifications for ARG18 placement:

FSAE Rules	ARG18
T5.4.3 FIGURE 11 Shoulder Harness Mounting Points 178 mm (7 ins.) to 229 mm (9 ins.)	Distance = 7.5" (adjustable based on driver preference once they sit in the seat in ARG18)
T5.4.4 FIGURE 12 Shoulder Harness Angle 10° Max. Horizontal 20° Max. Seat back line	

	The position of driver shoulders was estimated by looking at the ARG18 seat in the CAD monocoque. Then, we had drivers sit in the ARG17 monocoque, without a seat and at the proper H-point position, to be able to understand where their shoulders will likely fall. Graham's shoulders were 2.75" from the top of the monocoque, Harry's shoulders were 3.75" from the top. Both of these methods generated similar shoulder positions, and confirmed the height of the seat. The seat belts were placed at 3.1" below in order to work for both drivers, with the knowledge that we have additional room for movement on the Hardpoint.
T5.3.5-6	

In order to make sure the seat belts are as comfortable as possible, we want them as far back as possible, where the monocoque is wider, and the seat belts can be further away from the seat and driver hips. I used 60 and 80 degrees for the range of the belts, because that is the requirements for the reclined driver position.
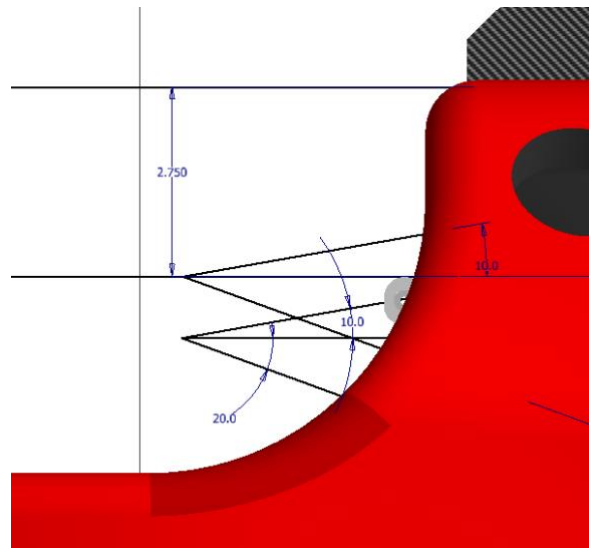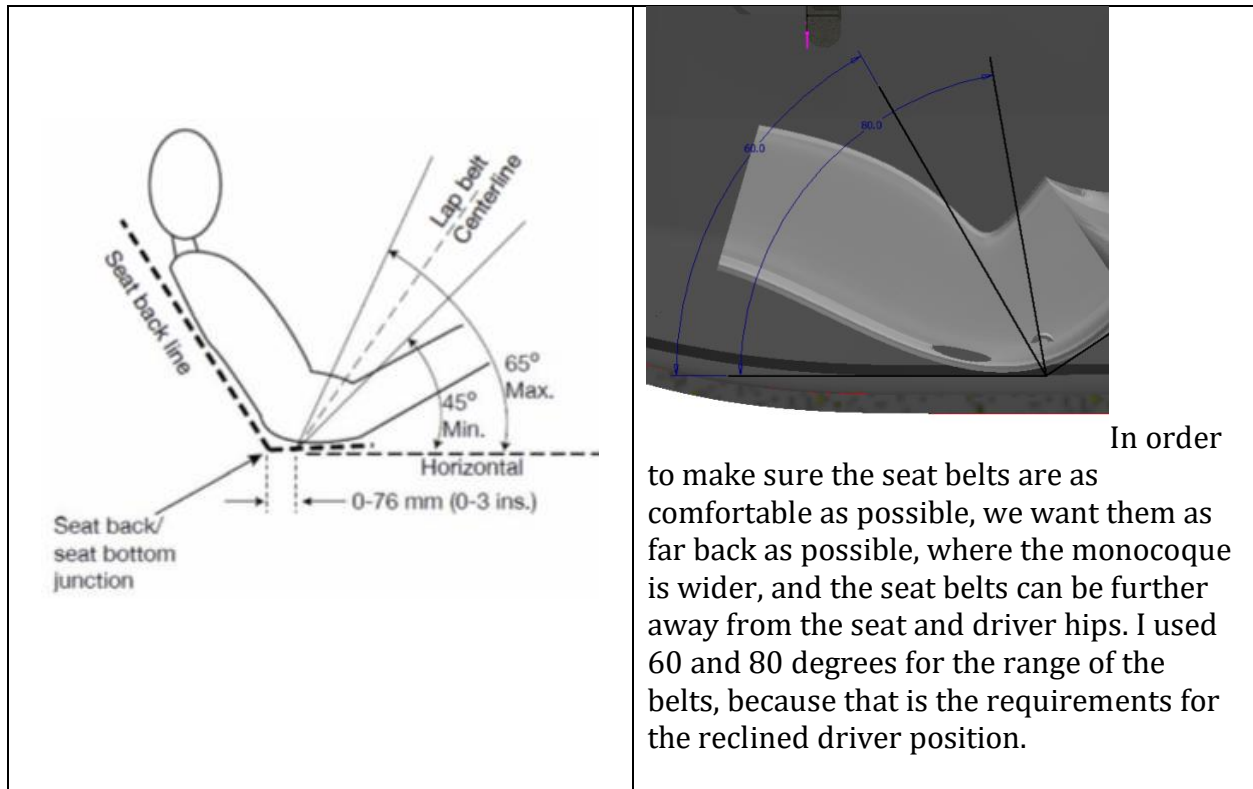
- Data from past years
  - Data for the seat will continuously change because it is completely contingent on the driver's and monocoque design.

ARG 2017
Driver Comfort and Fit

Driver Comfort is subjective data, so over the summer, I was able to send out a list of questions to ARG16's drivers, asking comments and ratings on different parts about the seat (See Appendix A for driver answers). Some of the questions asked were:

1. On a scale of 1-10 (with 10 being very satisfactory), how comfortable was the seat for ARG16?
2. If you have driven previous years, which year had the most comfortable seat, and why?
3. Were there any personal discomforts to the seat? (elbow room, more shoulder support, etc?)
4. What are your personal preferences to the seat that you'd like to see with this year's seat?
5. Was there anything that other teams did at competition that you liked in particular?
6. Any other suggestions/comments?

An attempt to visualize potential driver comfort was through a new ergonomics software we had access to this year: RAMSIS. This was only made available after the seat was made in CAD, so I was able to use it as a method of ensuring driver fit, but the software wasn't able to accurately portray how a driver would actually sit in the car, so it was difficult to see how comfortable the seat would be. However, for future years, it may be a good idea to learn more about the software before designing the part and incorporate it as a part of initial designing process rather than using it as a trial-and-error checking method. Here are pictures of RAMSIS, simulating driver position in the car:
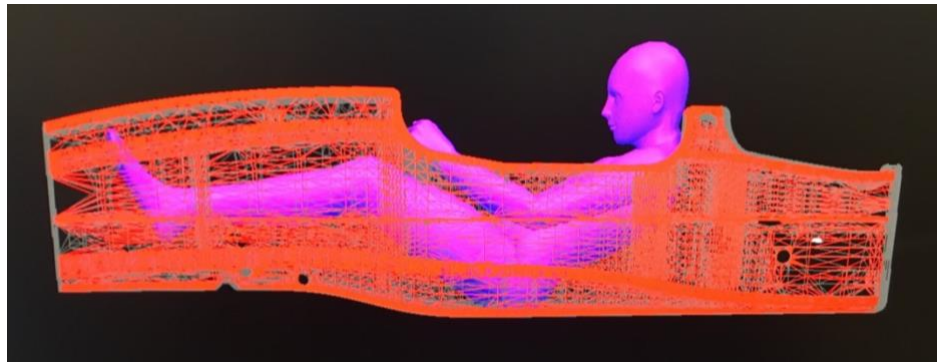
Figure 1.1: Driver (De la) in monocoque

Driver fit involves measurements of drivers, dimension of the cockpit, and FSAE rules on the 95th percentile male and 5th percentile female dimensions. Before designing the seat, I made a list of potential ARG17 drivers and measured the following:

- Rib width
- Shoulder width
- Hip width
- Hip to shoulder height

- Foam Beads
  - o Manufacturing:

- Beads that are put into a bag mixed in with epoxy, fit around a driver while being vacuum sealed, and then cured.
  - o Strength + Density:
    - slightly higher than expanding foam, but highly dependent on the amount of epoxy used.

Figure 1.4: Foam bead seat manufacture (Belardi Auto Racing) [4]

As the H-point largely drove the design of ARG17's seat, it was very important to determine the effect of moving the H point on the center of gravity of the driver. A stick figure was made in CAD. The center of gravity of each body segment was marked from the peripheral point of the body segment, as specified by multiple sources (University of Minnesota, Research Gate). After selecting the cover CG point of each body segment (as a work point), the coordinate points were exported into Excel and used to calculate total CG.
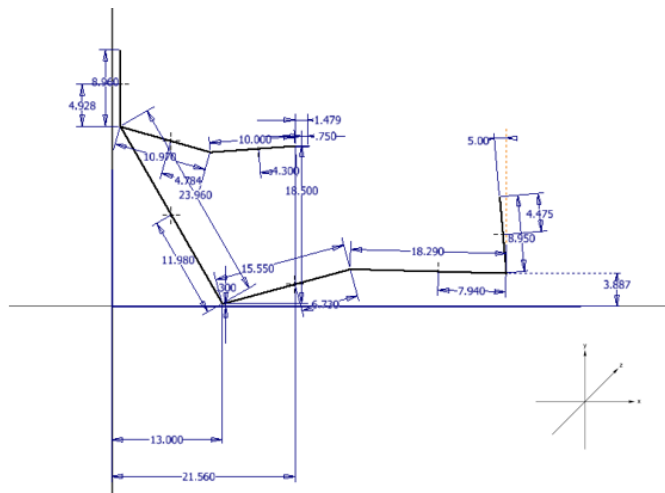
Figure 1.6 Sketch of Driver Position (To use to calculate CG)

The weights of each body segment (determined as a percentage of total driver weight) were used to determine the location of the CG of the driver in both vertical and horizontal directions.

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4. ARG18 Design

Figure 4. ARG18 Seat Design with Driver Comparison
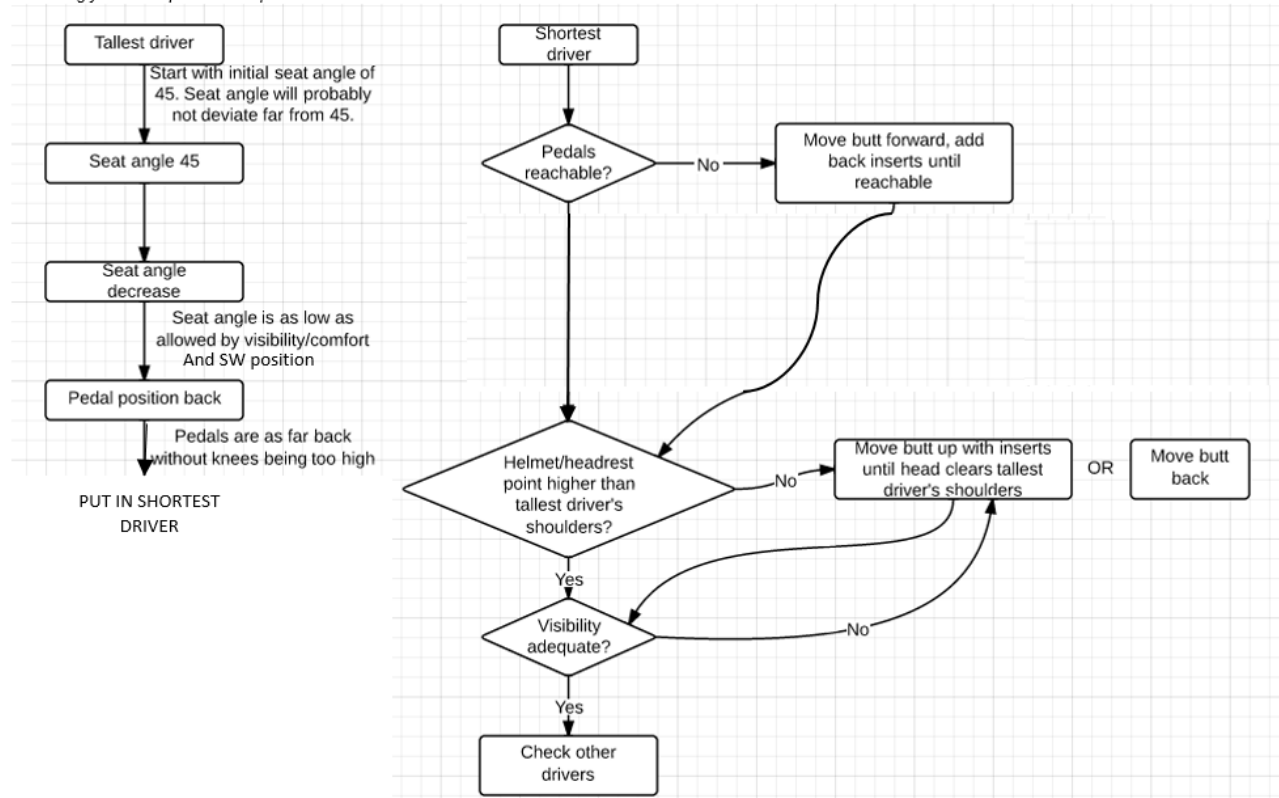
Figure 4.1 Process wireframe of conducting ergonomic mockup placement

The seat was designed using Autodesk Fusion 360 via t-splines and lofting. The design stemmed from ARG17; using ARG17's ergonomic assessments (i.e. Musculoskeletal Discomfort Questionnaire [1], observations, surveys) identified failures and achievements of the seat. Once driver dimensions were decided [based on the leadership], anthropometrics (driver position, anatomical references) were taken

periodically throughout the semester using a driver mockup to ensure validity of the drivers, researchers, and the final CAD.

There were three main goals the seat had this semester: increase seat constraint in relation to the monocoque and the driver, maximize comfort, and lower driver angle in the car while maintaining operable visibility. Constraints in the monocoque changed from not just the side flanges near the thighs/hips, but also near the shoulders as a press fit along the monocoque edge. ARG17 proved that the side flanges and propped seat belt tabs have enough constraint. The formative CAD design process constantly evolved the choice of constraint location within the monocoque, height of sides, lumber support, etc. NASA and various ergonomic studies supported the neutral body position (128°) in high intensity environments [2]. The seat is designed to have padding in the lumbar, shoulder, and elbow region (located based on survey results) to support all kinds of drivers. Lastly, the neutral body posture from NASA, supported by Nissan Altima®, defined the driver angle in the seat [2, 3]. The driver mockup determined the seat angle in the monocoque.

- **What aspects of your design is incomplete?**
  When manufacturing the seat, the design is taking a chance that it may not fit in the car. The monocoque can vary greatly in its sizes. That being said, the total weight and size of the final seat is incomplete.
- **What would you change if you had more time?**
  I would like to work on the upper shoulder region for driver fit. I am scared that the ribs may intersect the driver's arms and restrict their arm mobility. Additionally, I would have used a friendlier program that works with biometrics, in a perfect world this would exist.

5. Components Overview

Component	Mass	Quantity	Supplier	Cost
Carbon	-	-	Cytec	-
Adhesive	-	-	-	$0
Dolphin Glaze	-	Few tablespoons	-	$0
Bondo	-	Few tablespoons	-	$0
Hardener	-	1 teaspoon	-	$0
Steel Round Bar (for upper tabs) (ST 4130)	-	313" OD, .095" Wall Thickness	McMaster	$9.33
Nomex	-	One sheet	-	$0
Aluminum Tape	-	One roll	-	$0
AN5 bolts	-	8	In House	$0

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AN5 washers	-	8	In House	$0
Steel Tube (for lower clevis) (ST 4130)	-	1" x 2", wall thickness (at least 0.12 in)	Speedy Metals	$12.32 (x2)
Steel Square Stock (for seat belt tabs) (ST 4130)	-	1"x1.406" (5" length)	Speedy Metals	$3.08
Grommet	-	A few feet	-	-

Part Number	Quantity	CAD Weight [lb]	Description	Manufacturer
ER18 05C01	1	~3.40	Seat	In House
ER18 05C02	2	0.284	Seat Belt Clevises (lower) + washers and bolts	In House
ER18 05C03	2	0.39	Seat Belt Tabs (rod + clevises) + washers and bolts	In House
ER18 05C04	1	1.00	Firewall	In House

6. Failures and Design Complications
- Discrepancies are discussed in 8. Recommendations

7.Competition Research
- Common designs for other teams
  - Expandable foam
  - Carbon fiber

University of South Korea
  - Uses mesh on sides to catch driver elbow interference
  - Uses clay to mold seat plug, skips CAD entirely

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     o Matches to the car by mounting top region of seat on ledge in cockpit

8. Recommendations (current process + failures + complications)

SUMMARY
- Background
  - Design requirements
  - Basic process; CAD, plug, fiber glass mold, layup, shape, additional steps
- CAD: Software program breakdown
  - Rational
- Seat Plug Process
- Fiber Glass Mold
- Carbon Fiber Layup
- Shape/Miter to Monocoque dimensions
- Additional Steps

Seat Design and Manufacturing

Foam routing uses .STL to format a InVIsion file into code language for the CNC.

Design requirements

Rules/things to consider:	Interfaces with:	Type of constraint:	Part (s) affected:	Consequence:
95th male and 5th female Percentile Rule	--	Size	Seat	Seat must be large enough to fit the 95th percentile male, and accommodate for the 5th percentile female.
ARG18 drivers	Drivers	Size	Seat	The seat dimensions were based on Harry and Graham, who fit closer to the 50th percentile male [2].
Driver angle	Drivers	Design	Seat	Rules state that a reclined driving position is 30 degrees from the vertical, but driver preference should be taken into account when finalizing seat angle (see below).
Cockpit size	Monocoque	Size	Seat	The maximum width and furthest distance from the back of the monocoque at which define , which definitely takes

				priority since we're using the same monocoque molds this year.
CNCing the plug for the mold	Architecture school	Time	Seat	Molds must be created during JanMan by RPL (specifically 1/10/2018). ARG17 CNC'd seat molds during JanMan, which is ideal for the seat to done by the end of JanMan.
EE's battery box location	Electrical, Monocoque	Placement	Firewall	Unclear where ARG18 location will be, but will not be in a intersecting location for the seat.
Fuel tank	Fuel	Placement	Seat, Firewall	Full tank will determine firewall placement.

CAD Surface Geometries and Plugs

Program Breakdown

	Fusion 360	Inventor Professional	Rhinoceros 3D
Supports Windows operating system	✓	✓	✓
Supports OS X (Mac) operating system	✓		✓
T-Spline modeling	✓	✓	✓
Freeform surfaces (lofting, sweep)	✓	✓	✓
Exports .STL	✓	✓	
Sculpt mode (manipulate faces)	✓		✓
Functions in car assembly	/ (turns into mesh structure that can be constrained)	✓	
Swanson accessibility	✓	✓	

Fusion 360
The sculpt mode allows you to draw design pieces by pulling on surfaces to give them the desired shape.

Inventor
Inventor also uses a similar modeling process with the same terminology as Fusion 360, but does not have the sculpt mode that is forgiving in some lofting and sweep functions. Therefore, the geometries must be very controlled and account for exact precision. Seats in the past were made using Inventor.

Rhinoceros 3D
Rhinoceros 3D (Rhino3D) geometry is based on the NURBS mathematical model, which focuses on producing mathematically precise representation of curves and freeform surfaces in computer graphics (as opposed to polygon mesh-based applications). Rhino3D is used in processes of computer-aided design (CAD), computer-aided manufacturing (CAM), rapid prototyping, 3D printing and reverse engineering in industries including architecture, industrial design(e.g. automotive design, watercraft design), product design (e.g. jewelry design) as well as for multimedia and graphic design.

Rhino3D allows the export of the .STL and .OBJ file formats. Rhinoceros 5 SR10 can import and export DWG/DXF file formats.

Plug-ins available for Rhino3D
- Shape Modelling for Rhino by Autodesk. Creation, analysis and modification of freeform surfaces
- T-splines for Rhino by Autodesk: T-splines modelling

Carbon Fiber Breakdown

- Weights, densities, surface areas
- Plys
- Layup process
- Foam Router process
  Initial Problems
  Cutting Curved Geometries
  - **Reasoning:** The foam router is not able to cut sections that have concaved geometries on the top and bottom sections. The current router does not have a z-plane for the router to hit multiple angles on a y-axis.

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- **Solution:** When breaking the plug into sections for foam routers, via split-body, place the split-body plane into sections that only have one angled direction.

Foam Inventory v. Router Location
- **Foam Location:** HVL
- **Foam Size Used:** 4'x8'
- **Router location:** RPL

Foam Routing Problems
Confirming Routing Cuts
- **Current Process:** .STL files are sent to RPL, FSAE member that is approved to run router will convert files into Aspire CNC Router. Once the file has been uploaded, they place the file on to a virtual board with the dimensions of the foam stock placed in the machine.
- **Solution:** TO THE DESIGNER AND MEMBER RUNNING FOAM ROUTER: QUADRUPLE CHECK FILE IS CORRECT WITH ORIGINIAL CAD. Sometimes dimensions do not align, or the original CAD is slightly different when placed in Aspire. Therefore, quadruple check each cut with the designer and member running the foam router to avoid any unwanted cuts.

Seat Plug and layup Process
1. Send completed, ready-to-cut CAD files to CNC Foam Router.
2. Cut foam with Compact Reciprocating Saw to size, account for clearance by oversizing by 1-2"
3. Deliver foam to CNC Foam Router, member trained on CNC cuts foam, remember to graciously thank

Figure 2 Ensure that no offsets are predetermined in CNC cuts to account for misalignment

4. Collect foam and stack into two assemblies, based on the midsection.
5. Double check alignment and dimensions before bonding.

6. Bond foam together with Epoxy and Glad Bubbles, let sit for 8 hours before sanding.
   a. Check periodically for alignment and Epoxy runoff

7. Sand and apply four Duratec coatings. First layer of duratec is not considered an official layer because the foam will absorb some of it. **USE HIGH DENSITY FOAM ALWAYS.**
   a. Sand to 2,000 grit
   b. Once you pass 600 grit, start with wet sand
8. Apply fiberglass coating with epoxy mixture
   a. Carbon fiber, wet layup, can substitute

9. Drill holes at connecting seam and assemble.
   a. Sand until scratches and bumps are gone.
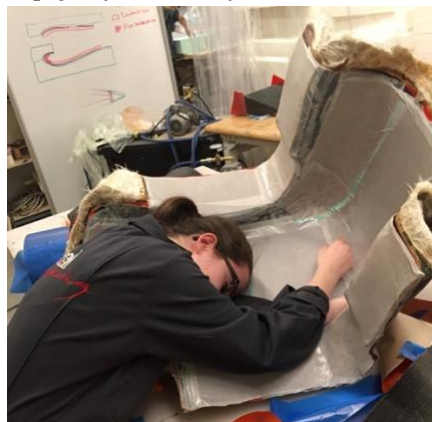   b. "Bondo" any large missing areas

c. "Dolphin glaze" any small cracks (this is a better product to use because it doesn't stick as much to carbon fiber during layup.

d. Trim any unnecessary geometries
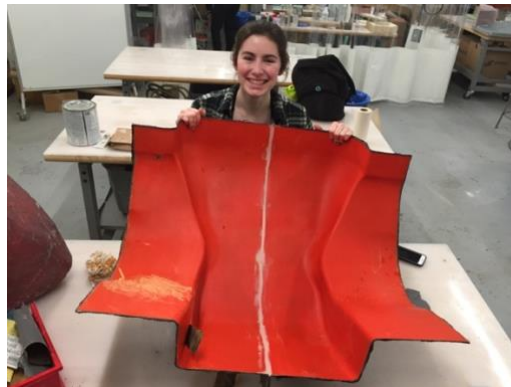
10. LAYUP
   a. 3 plys (0°,45°,0°)
   b. adhesive
   c. Nomex core
   d. adhesive
   e. 3 plys (0°,45°,0°)

11. Apply adhesive film layer (red)

    a.
12. Cover with breather (white)
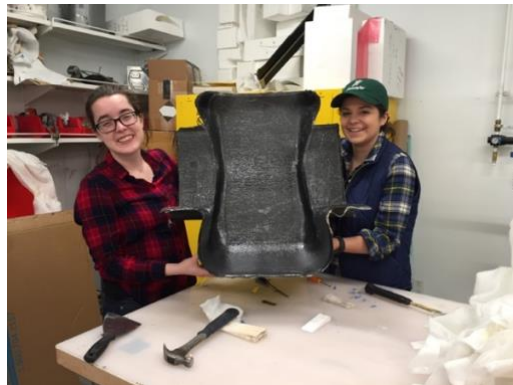13. Bag with plastic and mastic tape (clear + yellow)

    a.
    b. Cook (consult frame specialist for degrees of cooking and duration)
14. RELEASE

    a.
15. Cut to the car
        a. **Takes time and patience**. Measure over and over again to meet the width of
            the car.

9. Conclusion
- Three seats were made this semester.
  - Version 1: using Graham and Harry dimensions but ended up fitting Joseph
  - Version 2: ARG16 mold
  - Version 3: Expandable foam fit to Balen's body, used for the 95th percentile male
- What could have been done to ensure the issue is caught in the design phase?
  - Measurements are difficult, especially human measurements…therefore, treat your measurements as precise numbers. I was lenient when I took dimensions and added 1/2 " to each one when I see that it made the seat a lot bigger than it needed to be
  - Cutting afterwards, when the seat is layed up is way better than accounting for it in your design.
  - CAD is not always the best way to make a seat, consider other ways such as CLAY
- How is the new design an improvement?
  - It fit multiple drivers and could fit the smaller drivers better if there were inserts. Inserts were used in past seats, even when the seat was small. I am always an advocate for a seat that will fit the majority of your drivers rather than a select few because you know that you met the goal of the team and not just a niche market of sizes.
- How is the new design a loss?
  - I could've pushed for padding for the smaller drivers and I just did not get to it. Consider for future.

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