Steering Critical Design Review 2024

Brady Garrison

Rules

Draft Rules 2025

Source

V.3.2 Steering

V.3.2.1 The Steering Wheel must be mechanically connected to the front wheels

V.3.2.2 Electrically operated steering of the front wheels is prohibited

V.3.2.3 Steering systems must use a rigid mechanical linkage capable of tension and compression loads for operation

V.3.2.4 The steering system must have positive steering stops that prevent the steering linkages from locking up (the inversion of a four bar linkage at one of the pivots). The stops:

a. Must prevent the wheels and tires from contacting suspension, bodywork, or Chassis during the track events

b. May be put on the uprights or on the rack

I believe this is a part of suspension, but I want to be sure

Draft Rules 2025

Source

Chassis mount

V.3.2.6 The steering rack must be mechanically attached to the Chassis **F.5.14**

V.3.2.7 Joints between all components attaching the Steering Wheel to the steering rack must be mechanical and be visible at Technical Inspection. Bonded joints without a mechanical backup are not permitted.

V.3.2.8 Fasteners in the steering system are **Critical Fasteners**, see **T.8.2**

V.3.2.9 Spherical rod ends and spherical bearings in the steering must meet **V.3.1.5 above**

V.3.2.10 Rear wheel steering may be used.

a. Rear wheel steering must incorporate mechanical stops to limit the range of angular movement of the rear wheels to a maximum of six degrees (6°)

b. The team must provide the ability for the steering angle range to be verified at Technical Inspection with a driver in the vehicle

c. Rear wheel steering may be electrically operated

Draft Rules 2025

Source

V.3.3 Steering Wheel

V.3.3.1 In any angular position, the Steering Wheel must meet **T.1.4.4**

V.3.3.2 The Steering Wheel must be attached to the column with a quick disconnect.

V.3.3.3 The driver must be able to operate the quick disconnect while in the normal driving position with gloves on.

V.3.3.4 The Steering Wheel must have a continuous perimeter that is near circular or near oval.

The outer perimeter profile may have some straight sections, but no concave sections. “H”, “Figure 8”, or cutout wheels are not allowed.

Draft Rules 2025

Source

Autocross

c. Constant Turns: 23 m to 45 m diameter

d. Hairpin Turns: 9 m minimum outside diameter (of the turn)

Skidpad

- Inner circles 15.25 m in diameter
- Outer circles 21.25 m in diameter

Tech Guidelines 2024

(Source: FSAE Online>Tech Inspection Resources)

General Inspection - Chassis

☐ 57. STEERING - V.3.2 •All steerable wheels must have positive stops to prevent linkage lock-up or contact with other parts. •7° max freeplay at the steering wheel. •NO STEER-BY-WIRE on front wheels. •No cables or belts. •No bonded joints in column without metal backup. •Rear steer limited to 6° total, with mechanical stops.
☐ 58. CRITICAL FASTENERS, Steering - V.3.2.8 Steering wheel, column, rack mounting, tie rods.

Same as previous

Cockpit Templates

◯ S29. MAIN HOOP & FRONT HOOP HEIGHTS - F.5.6.5 Helmet of 95th percentile male (PERCY) to be 50 mm below the lines between top of front and main roll hoops and between top of main hoop to rear attachment point of main hoop bracing. Center of bottom circle placed minimum 915 mm from pedals.
◯ S30. COCKPIT OPENING - T.1.1 Template to pass from above cockpit to bottom of top SIS tube and less than 320mm from lowest point inside cockpit. Steering wheel & column, seat and padding can be removed; no removing firewall. Fore/aft translation of template OK.
◯ S31. COCKPIT INTERNAL CROSS SECTION - T.1.2 Template to pass from rearwards of the steering column to 100 mm rearwards of the pedals. Steering wheel may be removed; padding may be removed if removable with no tools & with driver in seat.

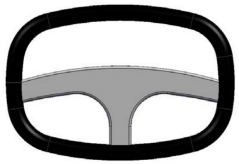
Steering wheel is removed for percy pass, steering column not considered.

Tech Guidelines 2024

(Source: FSAE Online>Tech Inspection Resources)

☐ 60. STEERING WHEEL - V.3.3
•Continuous perimeter, near round (no concave sections).
•Driver operable quick disconnect. •Not higher than top of Front Hoop, in any angular position. •250 mm max rearward of Front Hoop (F.5.7.5).

OK



OK

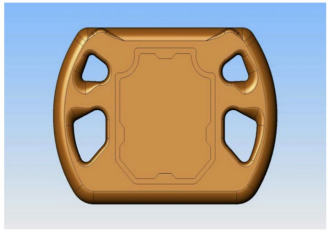
Not OK

Not OK

☐ 95. COCKPIT MASTER SWITCH - IC.9.4
•Pull-ON, Push-OFF type. •Alongside & unobstructed by steering wheel, easily reached by driver. •Must kill ignition & fuel pump(s). •Min dia 24 mm. •Marked with international symbol.

(Source: 2012 Tech Inspection Help Guide)

Not OK



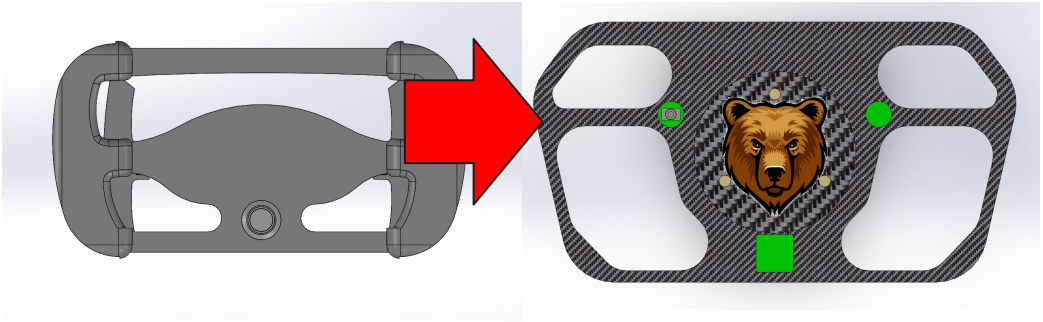
OK

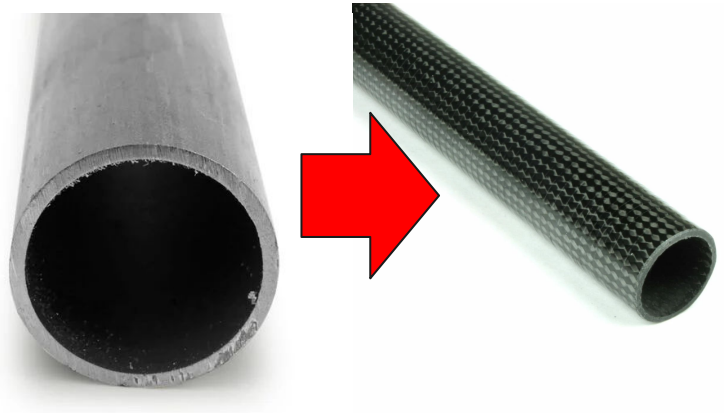
Car Goals

Weight Reduction

Three main sources of weight reduction:

- Transition from 4130 steel intermediate shafts to carbon fiber
- Transition from aluminum steering wheel to carbon fiber steering wheel





Weight Reduction (Cont.)

Goal of 23% weight reduction with these simple changes:

2023-2024 Weight Estimate

Component	Unit Weight (g)	Quantity	Total Weight
Steering Wheel	500	1	500
Borgeson U Joint	453.592	2	907.184
Chassis Mount	234.47	1	234.47
Narco Steering Rack	680	1	680
4130 Steel Tubing	266.5	2	533
Lifeline Quick Release	260	1	260
Total			3114.654

2024-2025 Weight Estimate

Component	Target Weight (g)	Quantity	Total Weight
Steering Wheel	400	1	400
Borgeson U Joint	453.592	2	907.184
Chassis Mount	200	1	200
Narco Steering Rack	680	1	680
Carbon Fiber Tubing	99.34	2	198.68
Lifeline Quick Release	260	1	260
Total			2645.864

Reliability

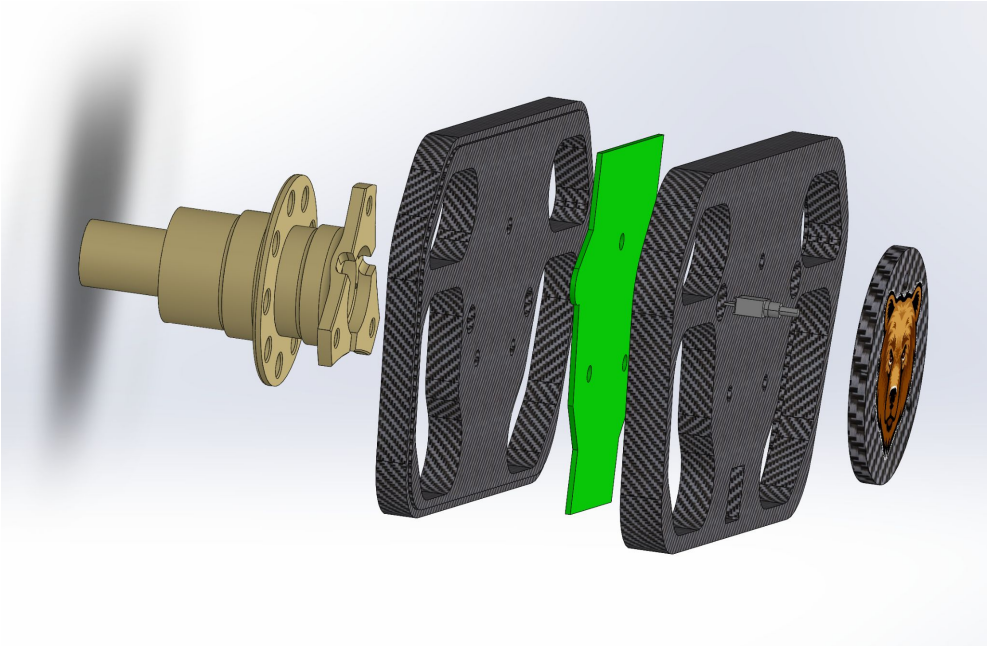
- Simplified steering chassis mount to reduce unnecessary waste of space/weight
- Reduced electronic components within the steering wheel via the use of an integrated PCB
- Improved steering ratio via selection of higher rack speed Narco rack

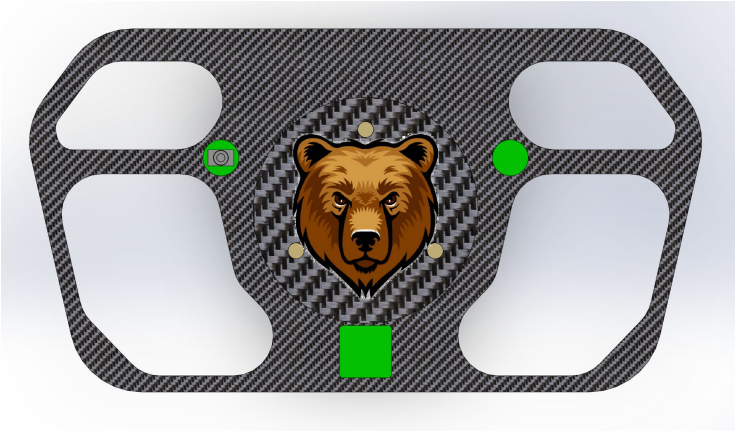
System Integration

- Chassis
  - Mounting of steering rack to carbon fiber floor
  - Upper column mounting to front bay
- Suspension
  - Ensure that steering rack placement is compatible with suspension geometry, work to optimize steering ratio
- Electronics / Dashboard
  - PCB Mounting in steering wheel, selection of buttons for steering wheel
  - Sensors
- Ergonomics
  - Sufficient Ergonomic testing to ensure that the steering wheel is optimized for user performance.

Design

Steering Wheel





- Double layer carbon fiber shell
- Integrated circuit board (pictured in green) for easy integration of buttons

Single Needle Bearing, 35° max angle

Steering Column

- Narco 4.0 in/revolution steering rack:

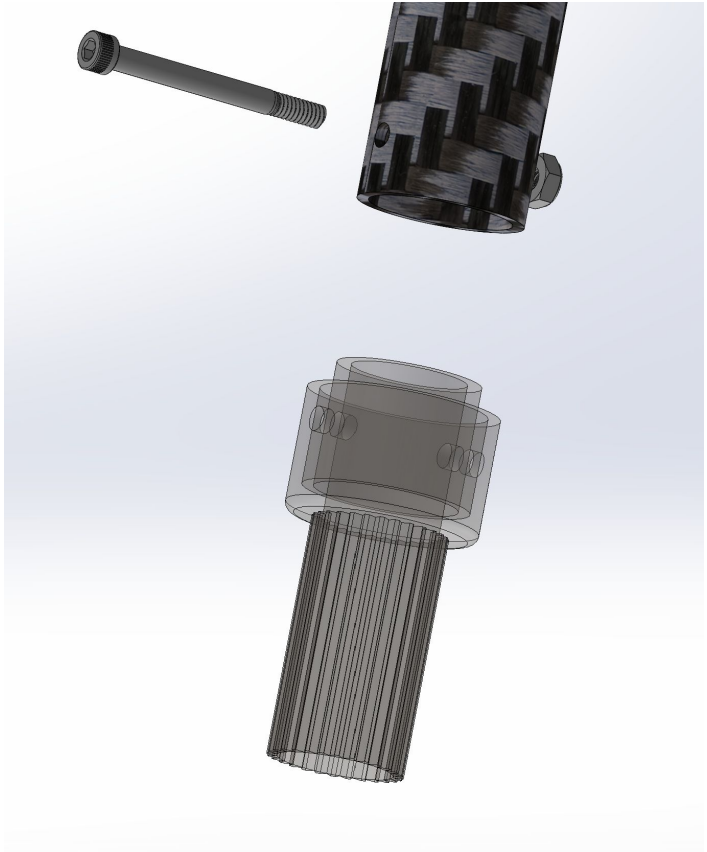
Steering Rack	Weight (g)	Price	Length	Rack Speed (in/rev)	Pinion Diameter	Steer Arm (in)	Steering Ratio
Narrco 4.0	680	600	17.4	4	0.637	2.93	4.60

- Borgeson aluminum U joints
  - Chosen to reduce complexity in mounting, no welding required to make female spline ends
  - No evidence of weight savings from other common options. If reduction is important, could consider custom U joints from: https://www.beldenuniversal.com/products/product-overview

Max Angle	Weight (g)	Price	Material	Length
35	453	90	Aluminum	1-⅝”

Carbon Fiber Tubing Assembly

- Welded outer sleeve on spline so that less stress is placed upon the carbon fiber tubing and to allow more surface area for carbon-fiber to steel bond
- Partially threaded screw to allow for pin that can take some torsional stress without damaging carbon fiber
- Assembly procedure:
    - Weld steel sleeve to ordered spline
    - Drill holes in carbon fiber tubing and spline
    - Use lock tight on inner and outer diameter to attach spline to carbon rod
    - Pin using partially threaded screw before lock tight is dry for extra security



New Member Projects

Chassis Mount (Top Left Image)

- Still work in progress with new members
- Planning on having simpler, lightweight design with tubes attached to the chassis

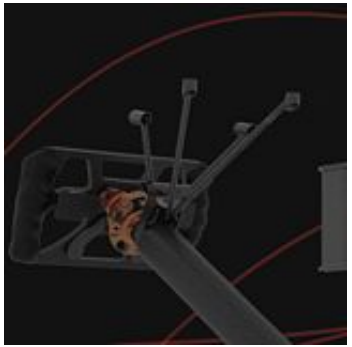
Steering Wheel Hand Grips (Bottom Left Image)

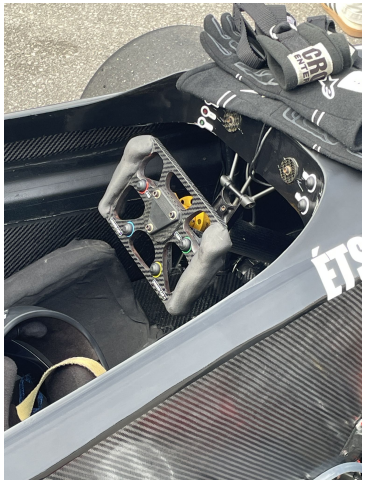
- Have begun work on molding hand grips using modeling clay
- Planning on having thumb channels to allow for maximum comfort
- Manufacturing Pipeline:
    - Clay Mold -> 3D Scan + 3D Printed Prototype -> Hard foam sleeves (possibly with leather cover)

Shifting Paddles (Right Image)

- Carbon fiber, flexible grip design

Inspiration images from other teams





Validation/Calculations - Carbon Fiber Tubing

Expected Shear Force: 130 ft.lb (from cockpit control forces)

Maximum shear stress at outer radius of steering column:

$$\tau_{max} = \frac{T * r}{J}$$

$$\tau_{max} = \frac{T * c_{outer}}{\frac{\pi}{2}(c_{outer}^4 - c_{inner}^4)}$$

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c_outer = 0.87
c_inner = 0.75
Torque = 130 %ft.lb
Shear_Max = (Torque * c_outer)/(pi/2 * c_outer^4 - c_inner^4)
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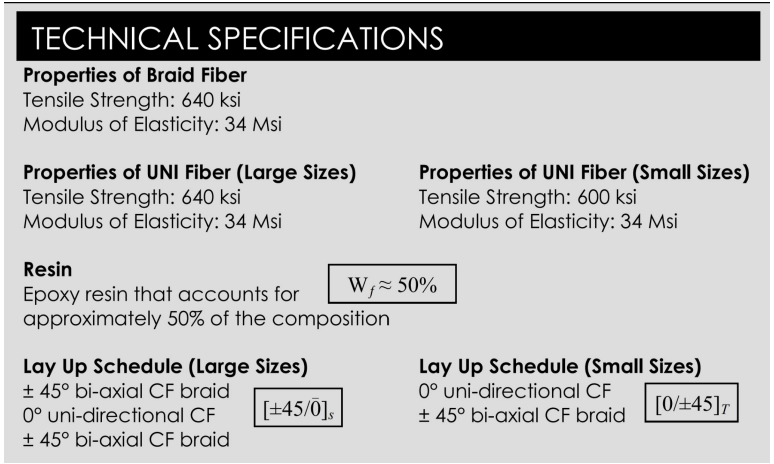
Shear_max = 193.83 lbf/ft^2



TECHNICAL SPECIFICATIONS

Properties of Braid Fiber
Tensile Strength: 640 ksi
Modulus of Elasticity: 34 Msi

Properties of UNI Fiber (Large Sizes)
Tensile Strength: 640 ksi
Modulus of Elasticity: 34 Msi

Properties of UNI Fiber (Small Sizes)
Tensile Strength: 600 ksi
Modulus of Elasticity: 34 Msi

Resin
Epoxy resin that accounts for approximately 50% of the composition
$W_f \approx 50\%$

Lay Up Schedule (Large Sizes)
± 45° bi-axial CF braid
0° uni-directional CF
± 45° bi-axial CF braid
$[\pm 45/\bar{0}]_s$

Lay Up Schedule (Small Sizes)
0° uni-directional CF
± 45° bi-axial CF braid
$[0/\pm 45]_T$

We can plug this data into Ansys and Perform FEA to validate the carbon fiber tubing

Important Design Calculations / FEA Plan

Static Steering Effort:

Weight of car: 75kg * 9.8 m/s/s = 735 N

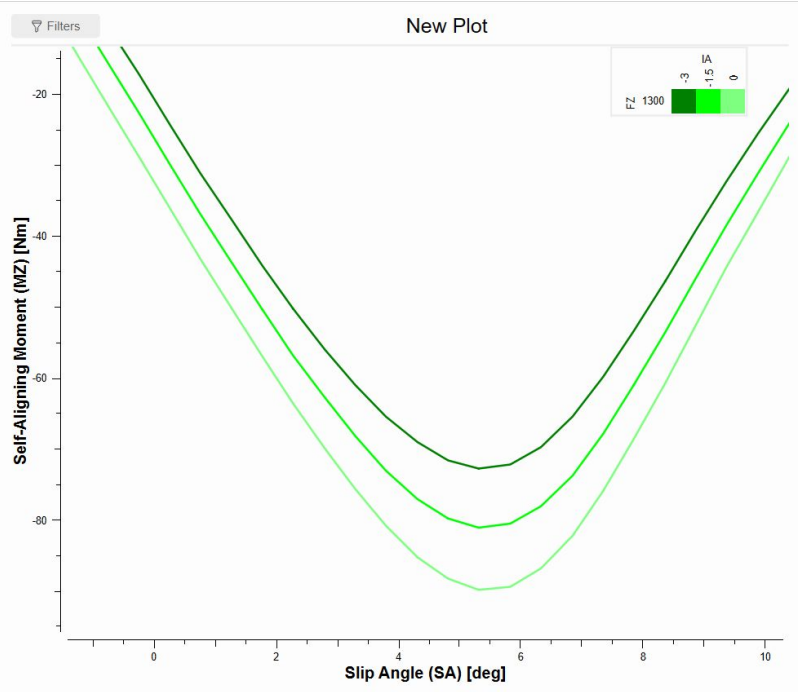
Friction Force: 0.7 & 735 N = 514.5 N

Effort to Steer: 514.5 N * 0.0140 = **7.203 Nm**

Dynamic Steering Effort

(90 Nm/4.6)/ 0.2159 m = **90.62 N**

Where 0.2159 is steering wheel diameter, 4.6 is steering ratio, and 90Nm is torque from tire data



Tire data from last year

FEA Plan:

- 200 N force on steering wheel
- 175Nm torque on carbon fiber steering column
- 400 N force on Chassis Mount

Testing Schedule

Ergonomic Rig Testing

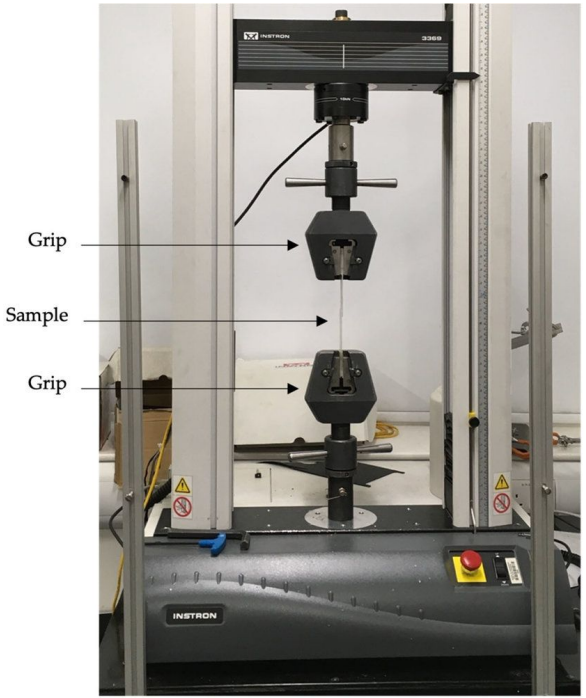
Planning on 3D printing more potential steering wheel designs with new members and testing them based on the following parameters:

Steering Wheel Width (in)	Steering Wheel Thickness (in)	Steering Wheel Angle (degrees)	Steering Wheel Shape
8.5	0.8	30	Rectangular
7.5	1.6	40	Semicircle
6.5	2.4	50	Rounded Pentagon

Conduct interviews with past drivers to determine additional features/feedback about the steering wheel

Steering Column Testing

- Will perform failure testing on manufactured steering columns
- Important for testing connection points between carbon fiber rods and splines
- Looking to find a tormach add-on at another engineering school in the new england area, or construct our own testing rig from scratch
- Full load validation testing of any components that will be placed onto the car



Validation

- Quantify steering effort vs angle using steering angle sensor
- Quantify slop/play in the system through user testing
- Measurement of maximum turning angle/skidpad performance

Timeline

Timeline

- October 14-21 - Complete ergonomic testing, finalize new member projects, finalize orders. FEA in Ansys
- October 28- November 4 - Manufacturing/testing of steering column + Chassis Mount
- November 4- November 18 - Begin manufacturing of final steering wheel design + Steering Columns
- Late November/Early December - Finalize Manufacturing
- Spring - Testing

Bill of Materials/Cost

Component	Price	Quantity	Total Price
Borgeson U Joint	89.55	2	180
Borgeson Spline Inserts	23.90	4	95.6
Narco Steering Rack	600	1	600
Carbon Fiber Tubing	68.78	2	137.56
Lifeline Quick Release	477.99	1	250
Katz Steering Sensor	150	1	150
1/2 Inch 4130 Stock (Rack Mount)	20	1	20
Laser Cut 4130 (Column Mount)	100	1	100
JB Weld	20	2	40
Critical Fasteners	20	1	20
Total Subsystem Price			1593.16

Thank You!