Team #2: Solar Car
Detailed Design Review and Test Plan

COE Advisors:
ECE Department
- Dr. Simon Foo
- Dr. Jim Zheng
- Dr. Mike Frank

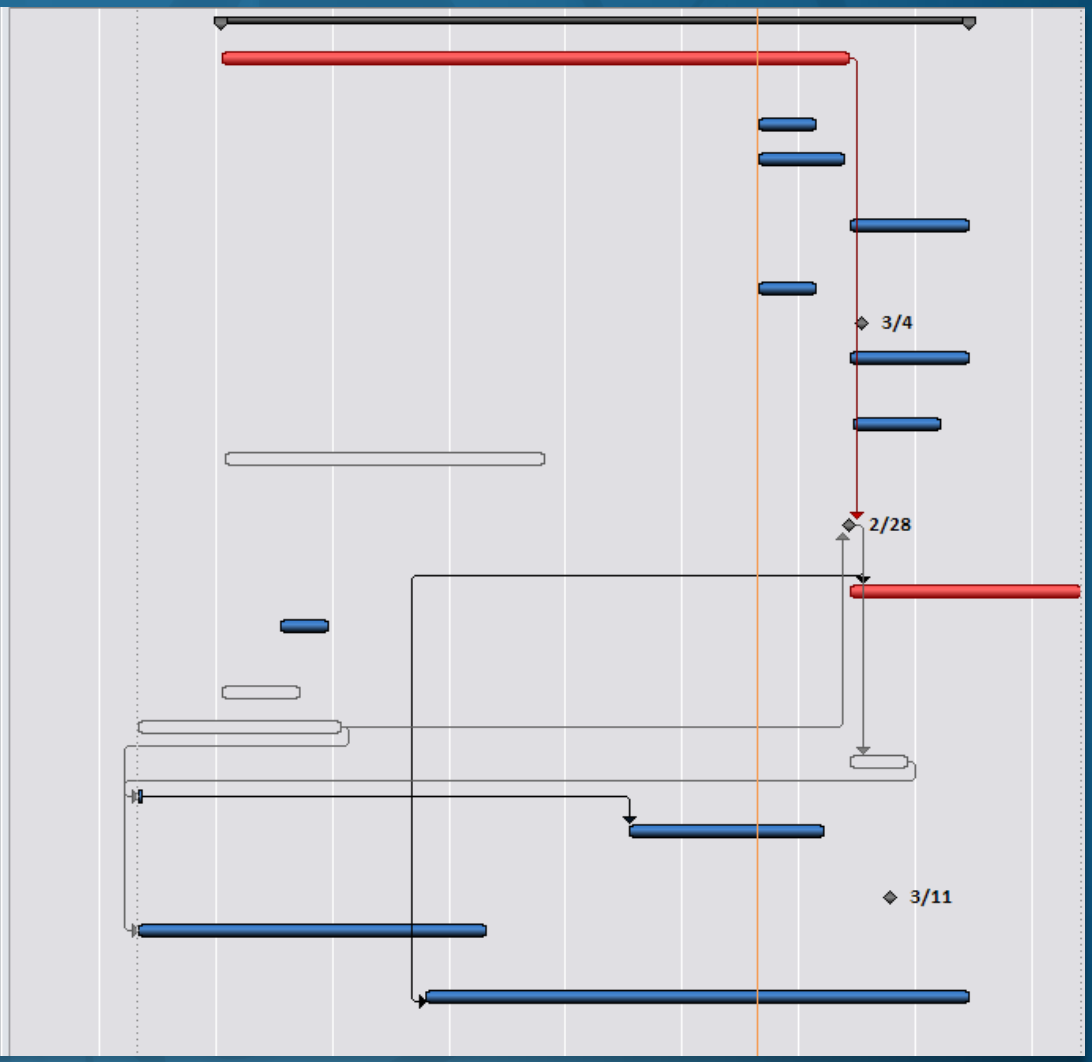
ME Department
- Dr. Pat Hollis
- Dr. Kamal Amin

Team Members:
Matthew Bosworth – EE
Christopher Dresner – EE
Ahmad Farhat – EE
Daniel Green – ME
Joseph Petit-Homme – ME
Thierry Kayiranga – EE
Clay Norrbin - ME

Matthew Bosworth

Schedule

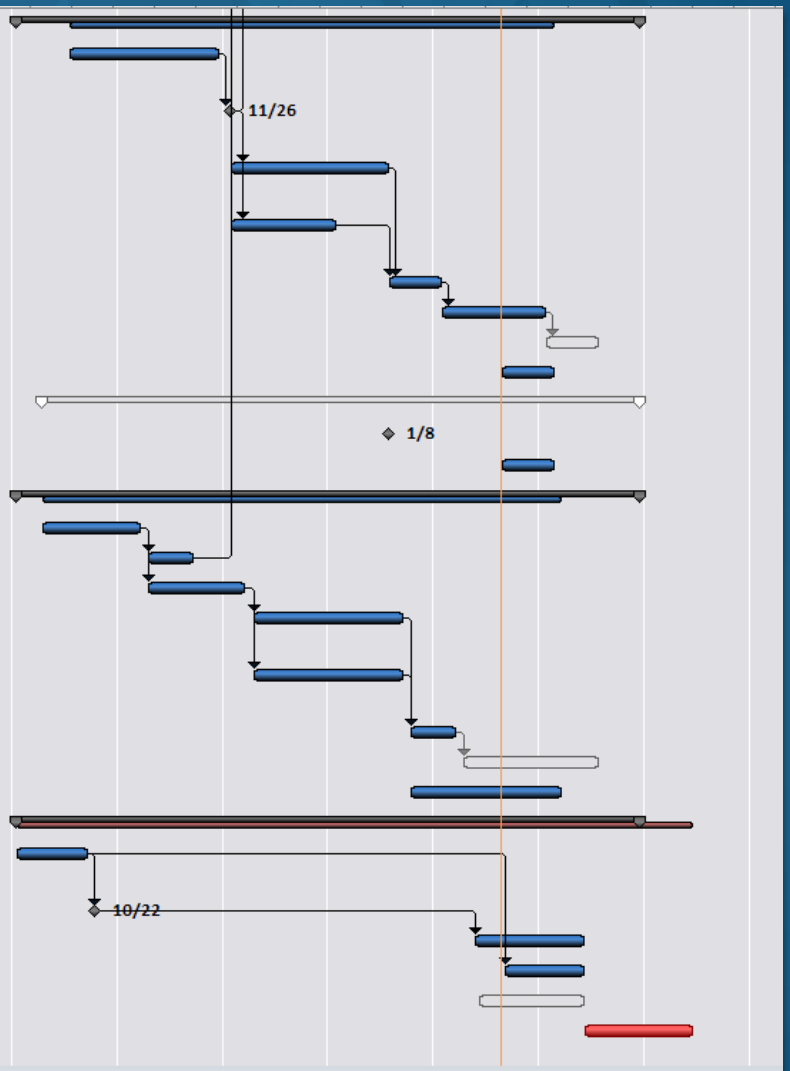
	Task Name	Duration	Start	Finish
	Chassis	**130 days**	**Mon 10/1/12**	**Fri 3/29/13**
	Development/Modeling Pro-Engineer	21.8 wks	Mon 10/1/12	Thu 2/28/13
	Chassis Material Decision	10 days	Thu 2/7/13	Wed 2/20/13
	Stress and aerodynamics testing	3 wks	Thu 2/7/13	Wed 2/27/13
	Start of Chassis Manufactoring	21 days	Fri 3/1/13	Fri 3/29/13
	Steering Simulation	2 wks	Thu 2/7/13	Wed 2/20/13
	Steering Wheel Selection	**0 days**	**Mon 3/4/13**	**Mon 3/4/13**
	Steering Ordering and Manufactoring	**21 days**	**Fri 3/1/13**	**Fri 3/29/13**
	Research on Brakes	**16 days**	**Sat 3/2/13**	**Fri 3/22/13**
	~~Suspension Research/Design~~	~~11 wks~~	~~Tue 10/2/12~~	~~Mon 12/17/12~~
	Final Prototype Design Chosen	0 days	Thu 2/28/13	Thu 2/28/13
	HPMI Design Development	8 wks	Fri 3/1/13	Thu 4/25/13
	Discuss w/ HPMI - Roll Bar Design	2 wks	Mon 10/15/12	Fri 10/26/12
	~~Research on Sheild/Cockpit~~	~~3 wks~~	~~Mon 10/1/12~~	~~Fri 10/19/12~~
	~~Hatch Design~~	~~7 wks~~	~~Tue 9/11/12~~	~~Mon 10/29/12~~
	~~Cockpit Design~~	~~2 wks~~	~~Fri 3/1/13~~	~~Thu 3/14/13~~
	Roll Bar Design	1 day?	Tue 9/11/12	Tue 9/11/12
	Roll Bar Simulation in PROe	35 days	Mon 1/7/13	Fri 2/22/13
	Integration of Roll Bar	**0 days**	**Mon 3/11/13**	**Mon 3/11/13**
	Car Chassis Open/Close/Locking	12 wks	Tue 9/11/12	Mon 12/3/12
	PRO-Engineer w/ Fully Articulated Model	19 wks	Mon 11/19/12	Fri 3/29/13



Matthew Bosworth

Schedule

	Task Name	Duration	Start	Finish
	Solar Panels	**120 days**	**Mon 10/1/12**	**Fri 3/15/13**
	Research into Manufactoring at COE	6 wks	Mon 10/15/12	Fri 11/23/12
	Manufactoring or Purchasing?	1 day	Mon 11/26/12	Mon 11/26/12
	Time needed to purchase or manufacture	6 wks	Tue 11/27/12	Mon 1/7/13
	Protection Design/Purchasing	4 wks	Tue 11/27/12	Mon 12/24/12
	Verification of Design	2 wks	Tue 1/8/13	Mon 1/21/13
	Build Array w/ Protection	4 wks	Tue 1/22/13	Mon 2/18/13
	~~Energy System Integration~~	~~2 wks~~	~~Tue 2/19/13~~	~~Mon 3/4/13~~
	Solar Panel Testing	2 wks	Thu 2/7/13	Wed 2/20/13
	~~HF Transformer~~	~~115 days~~	~~Mon 10/8/12~~	~~Fri 3/15/13~~
	Converter Selection	**0 days**	**Tue 1/8/13**	**Tue 1/8/13**
	Converter Testing	**2 wks**	**Thu 2/7/13**	**Wed 2/20/13**
	Battery System	**120 days**	**Mon 10/1/12**	**Fri 3/15/13**
	Company interactions	4 wks	Mon 10/8/12	Fri 11/2/12
	Model Development	2 wks	Mon 11/5/12	Fri 11/16/12
	Ordering and Shipping	4 wks	Mon 11/5/12	Fri 11/30/12
	BMS Testing with DC load bank	6 wks	Mon 12/3/12	Fri 1/11/13
	Battery Testing with DC load bank	6 wks	Mon 12/3/12	Fri 1/11/13
	Verification of Devices	2 wks	Mon 1/14/13	Fri 1/25/13
	~~Integration~~	~~26 days~~	~~Mon 1/28/13~~	~~Mon 3/4/13~~
	Battery Testing	30 days	Mon 1/14/13	Fri 2/22/13
	Motor	**120 days**	**Mon 10/1/12**	**Fri 3/15/13**
	Discussion with Different Companies	3 wks	Mon 10/1/12	Fri 10/19/12
	Motor Determination	0 days	Mon 10/22/12	Mon 10/22/12
	Purchasing and Shipping	4.2 wks	Thu 1/31/13	Thu 2/28/13
	Simulation Model of Motor	3 wks	Fri 2/8/13	Thu 2/28/13
	~~Integration~~	~~20 days~~	~~Fri 2/1/13~~	~~Thu 2/28/13~~
	Integration Testing	21 days	Fri 3/1/13	Fri 3/29/13



Matthew Bosworth

Budget

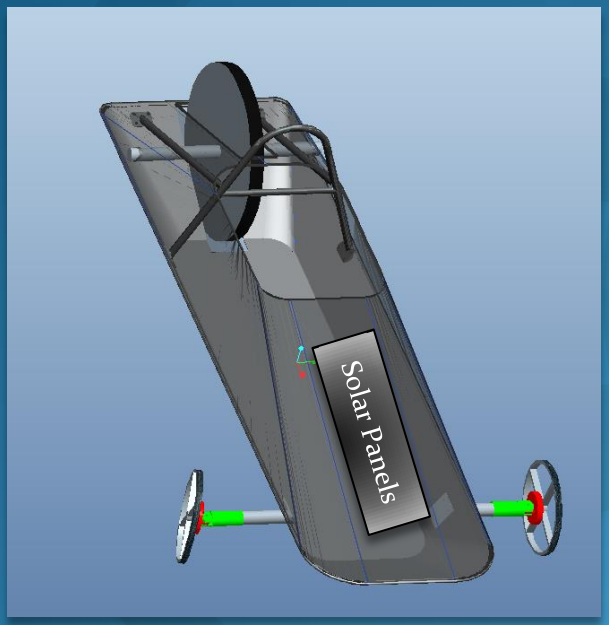
Part	Cost
Chassis Material and Manufacturing	$3000.00
Steering Materials	$400.00
Roll Bar Materials and Manufacturing	$500.00
Latching/Locking Mechanism	$50.00
Solar Cell Array	$0
Converter/MPPT	$0
Battery System	$480.00
Hub Motor plus Shipping	$265.00
BLDC Controller	$119.00

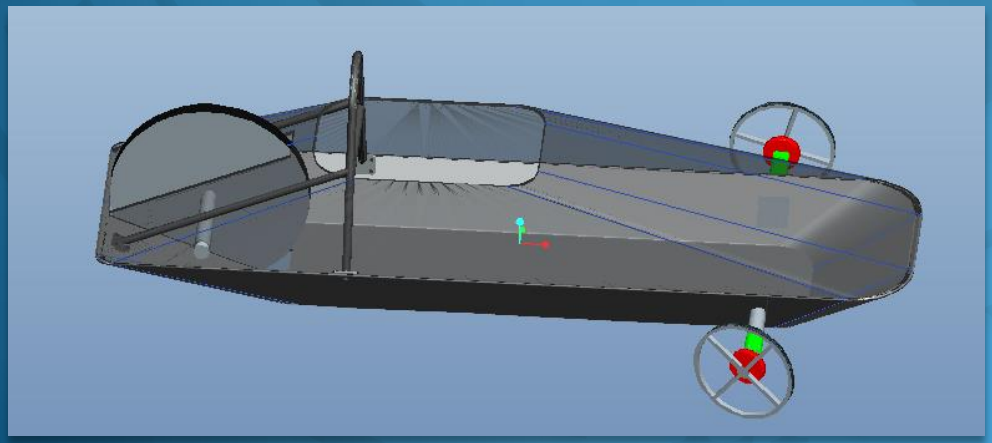
Part	Cost
Throttle/Brake Pedals	$138.00
State of Charge Meter	$19.00
Amperemeter	$29.00
Main Contactor	$29.00
Total	$5133.00

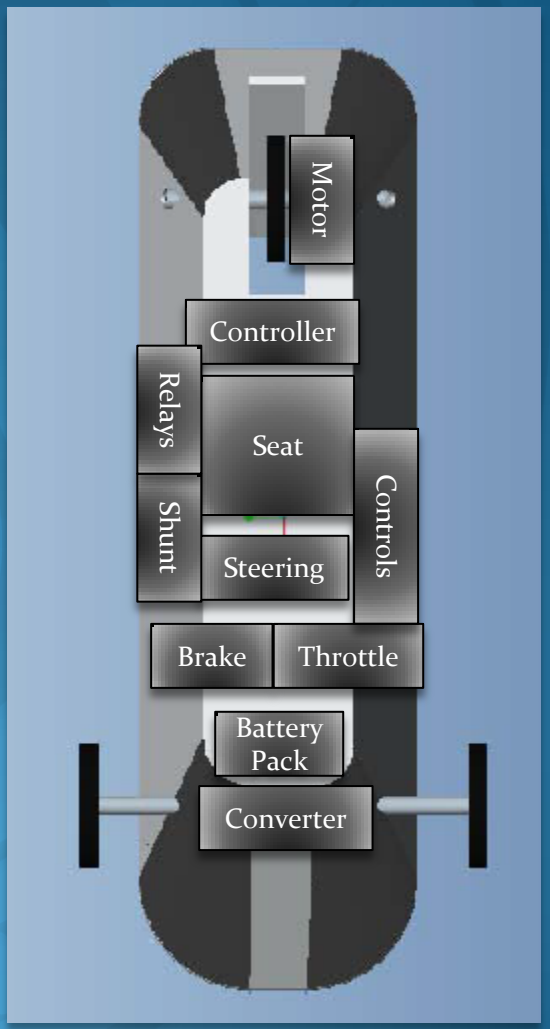
Total Funds Allotted: $6,000

Matthew Bosworth

Overall Design







Matthew Bosworth

Motor

Motor Testing

Determination of all wires and connections

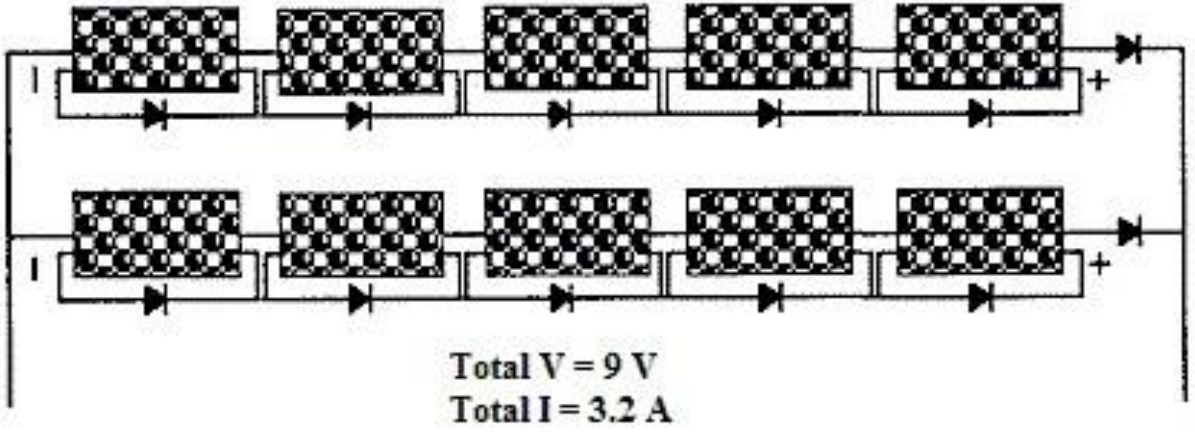
- **No datasheet was given**
- **No packing slip either**

For the simulation

- **Develop proper test of physical motor for necessary input parameters for the motor**

Solar Array Final Characteristics

Parameters	Rated Operation	Array Size: 0.156 m^2
Voltage (oc): 9V	Voltage: 8.2 V	Allowed Size: 0.17 m^2
Current (sc):3.2 A	Current:3 A	Available Size: 0.5 m^2

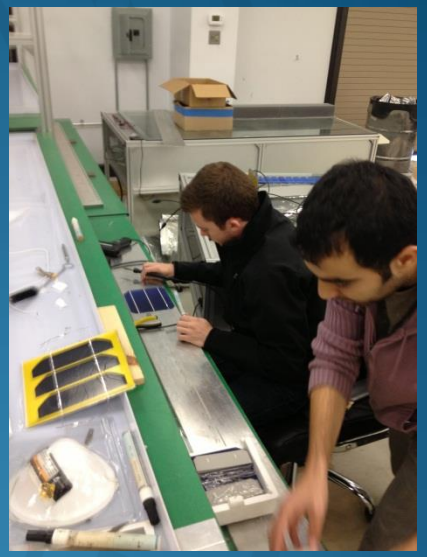


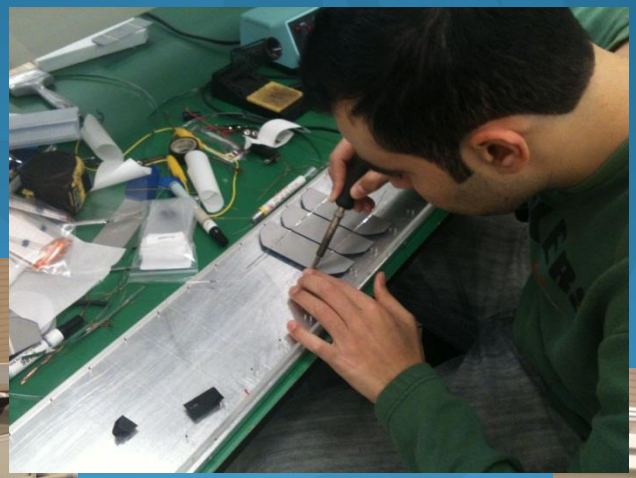
Ahmad Farhat

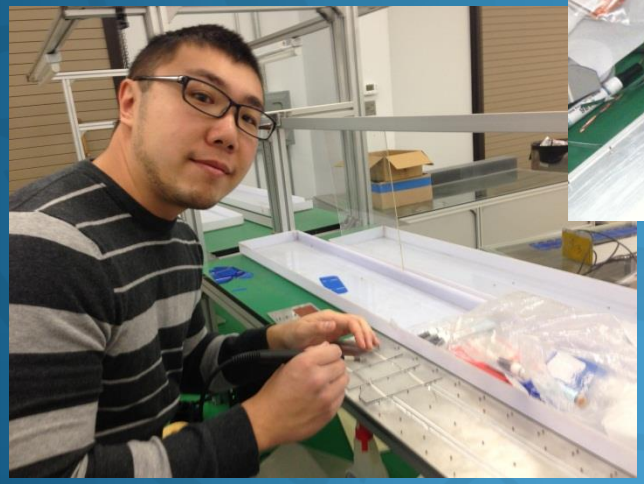
Cells Manufacturing & Encapsulation

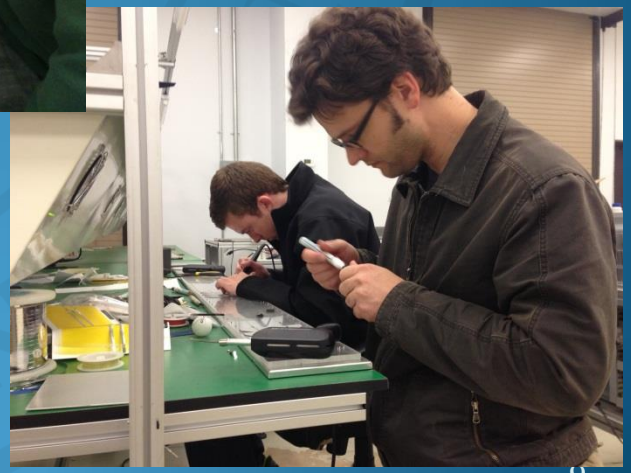
Single Cell Soldering

3 Cells Module Soldered Together







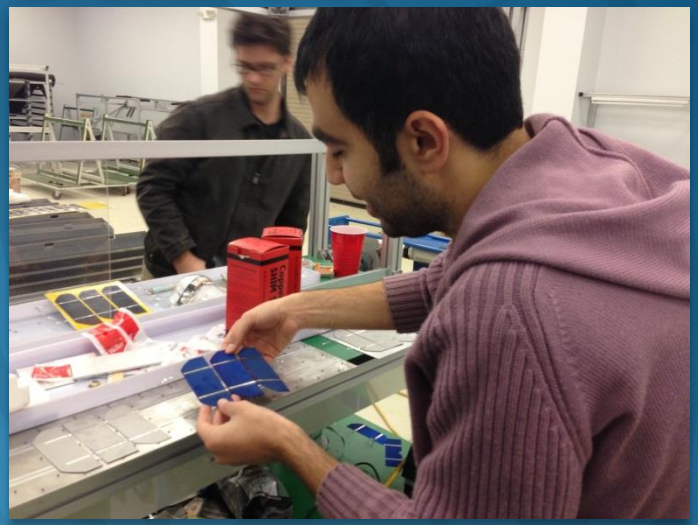


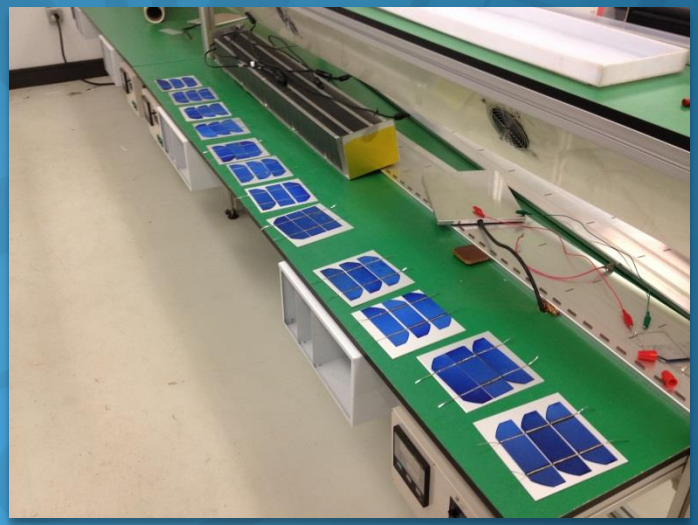
Ahmad Farhat

Final Product

Total number of single Cells 51

Total number of Modules 17



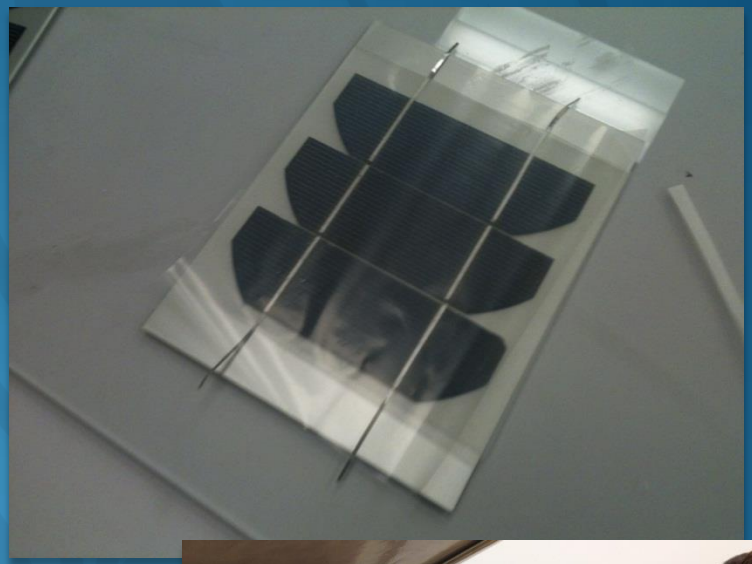


Ahmad Farhat

Encapsulation Process

4 Layers Protection Layers:

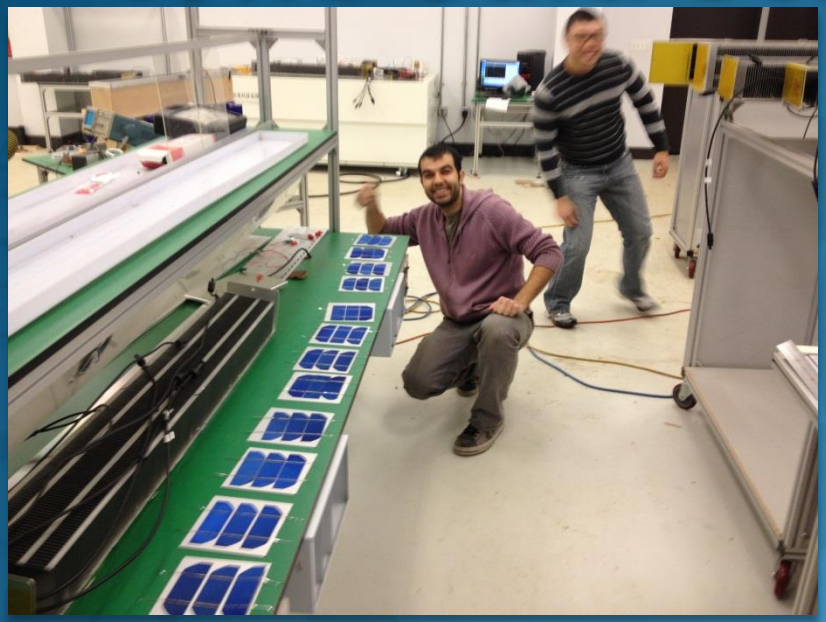
1. Aluminum Plate
2. EVA
3. Solar Cells
4. EVA
5. Clear Plastic Sheet

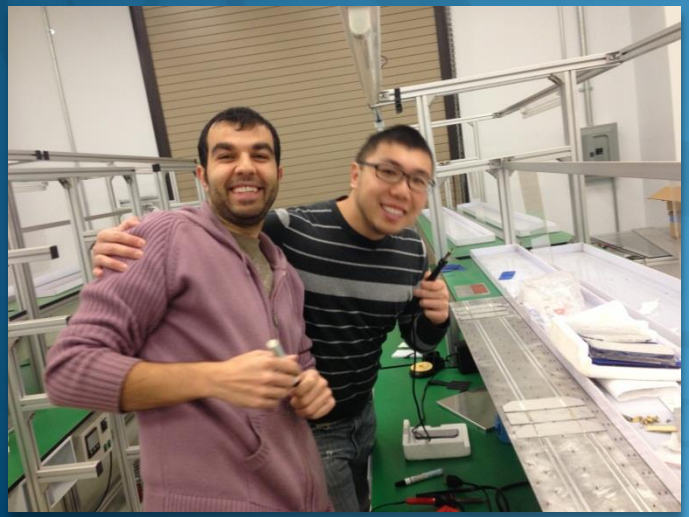


Solar Car Design Team 2012-2013

Ahmad Farhat

Who Said School is no Fun??





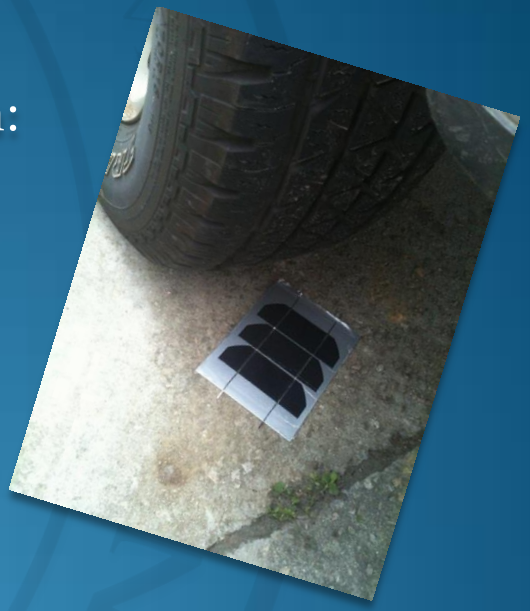
Ahmad Farhat

Completed Test Plans

Solar Module Test *(passed)*

Check solar modules for Voc and Isc to land within: 1.6 -1.8 V and 18-22 A respectively.

All Results matched expected



Solar Modules Physical Strength *(passed)*

1) Dropping the module from 5 feet high.
2) Driving over the module with a car.
3) Rubber hammer on the top of the solar module.

Passed 3 tests and no voltage or current Drop occurred

Ahmad Farhat

In Progress Test Plans

Protection Circuit Continuity Test

- Assure there are connections between the different nodes.

Protection Circuit Test on Single Solar Panel Set

- Test Current and Voltage with shading one of the solar modules each time

Solar Array Test

- Array Voltage should be between 7.9 V and 8.4 V.
- Array Current should be between 3.0A and 3.4A.

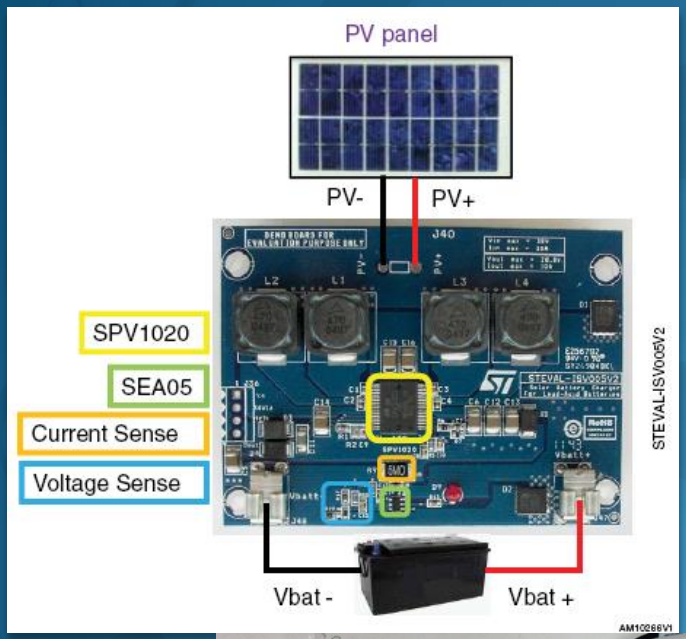
Solar Cells Computer Simulation

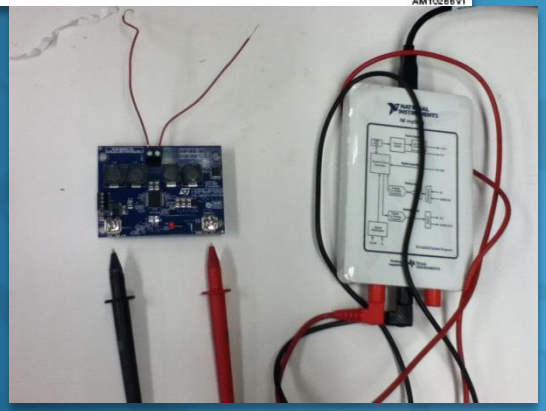
- Run manufacturing data for the solar cells from using PLECS

Solar Array - DC Electronic Load Simulation

- Connect solar cell to the BK Precision 2400W Programmable DC Electronic Load to simulate the voltage and current characteristics.

Energy Conversion





- PWM mode DC-DC boost converter
- Duty cycle controlled by MPPT algorithm with 0.2% accuracy
- Operating voltage range 6.5 - 40 V
- Overvoltage, overcurrent, overtemperature protection
- Interleaved 4-phase topology
- Built-in soft-start
- Up to 98% efficiency
- Power capability 320 W at 40 V output
- Automatic transition to burst mode for improved efficiency at low solar radiation
- SPI interface

Thierry Kayiranga

Test Plan

Test Item: Boost Converter Test

Test Date: 02/14/13
8:30AM, 10 AM, 12PM, 2PM, 4PM, 6:30PM

Test Description: This test will be done into multiples stages to simulate different weather conditions: Early in the morning at 9AM, midday at 12 PM, afternoon at 4PM and evening at 6PM. This test is to check that the voltage output of converter does not exceed 24V and the current is high enough to ensure that the battery is charging.

Expected Result: Output is boosted as expected at all times

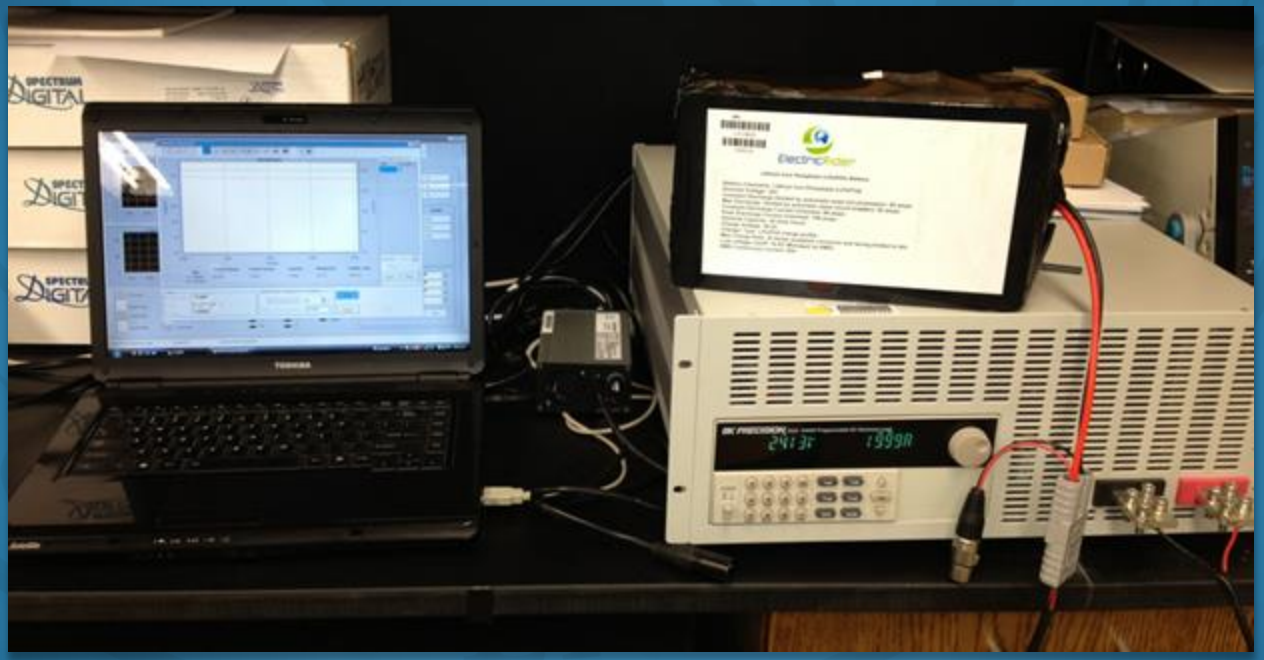
Status: Pass or Failed

BK Precision 8522 Programmable DC Electronic Load

- Operates between 0-500 VDC, 1 mA-120 A, 2400 W max
- Constant current (CC), resistance (CR), voltage (CV) and power (CP) operation
- Programmable via RS232 or USB interface. RS232 to TTL serial converter cable, USB to TTL serial converter cable, and application software included
- Battery testing mode to provide Ah rating of battery
- Low minimum operating voltage of <0.1 V and minimum input resistance of 5 mΩ allowing the load sink high current at low voltages, required for fuel and solar cell applications
- Over-Current/Over-Voltage/Over-Power/Over-Temperature Protection

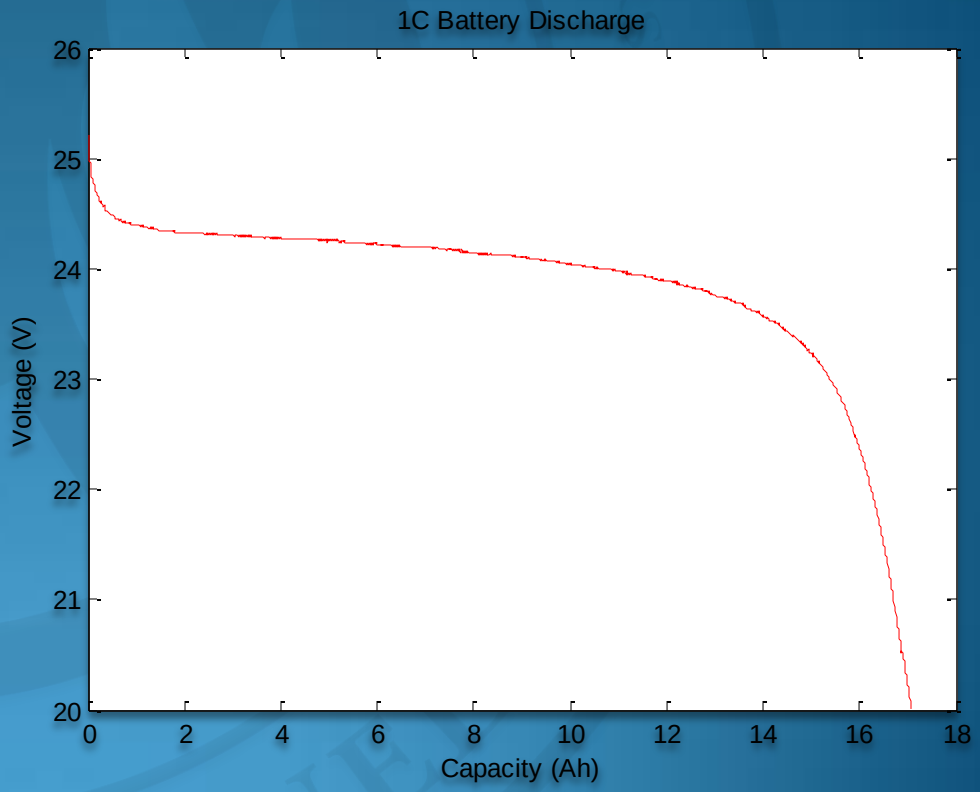
Battery Testing

- Battery Discharge – 1/2C, 1C, 2C
  - Description: Connect the fully charged battery to the electronic load and run the battery until the BMS voltage limit is tripped and ends the test. Record the time elapsed and the voltage cutoff.
  - Expected Results: 1/2C – 2hr, 1C – 1hr, 2C – 30min. Voltage cutoff at BMS limit of 16.8 V.



Battery Testing

- 1C Battery Discharge: Attempt #1
  - Results
    - Elapsed Time = 51:20
    - Capacity = 17.07 Ah
  - Errors
    - Battery not fully charged
    - Voltage limit set to 20V



Battery Testing

- Battery Charging Capabilities
  - Description: Connect the charger to the battery and time how long it takes until the charger LED turns green indicating that the battery is fully charged.
    - Battery Charger – 29.2V, 4A
  - Expected Results: Elapsed time = 5 hours
  - Actual Results: Elapsed time = 5 hours 29 minutes

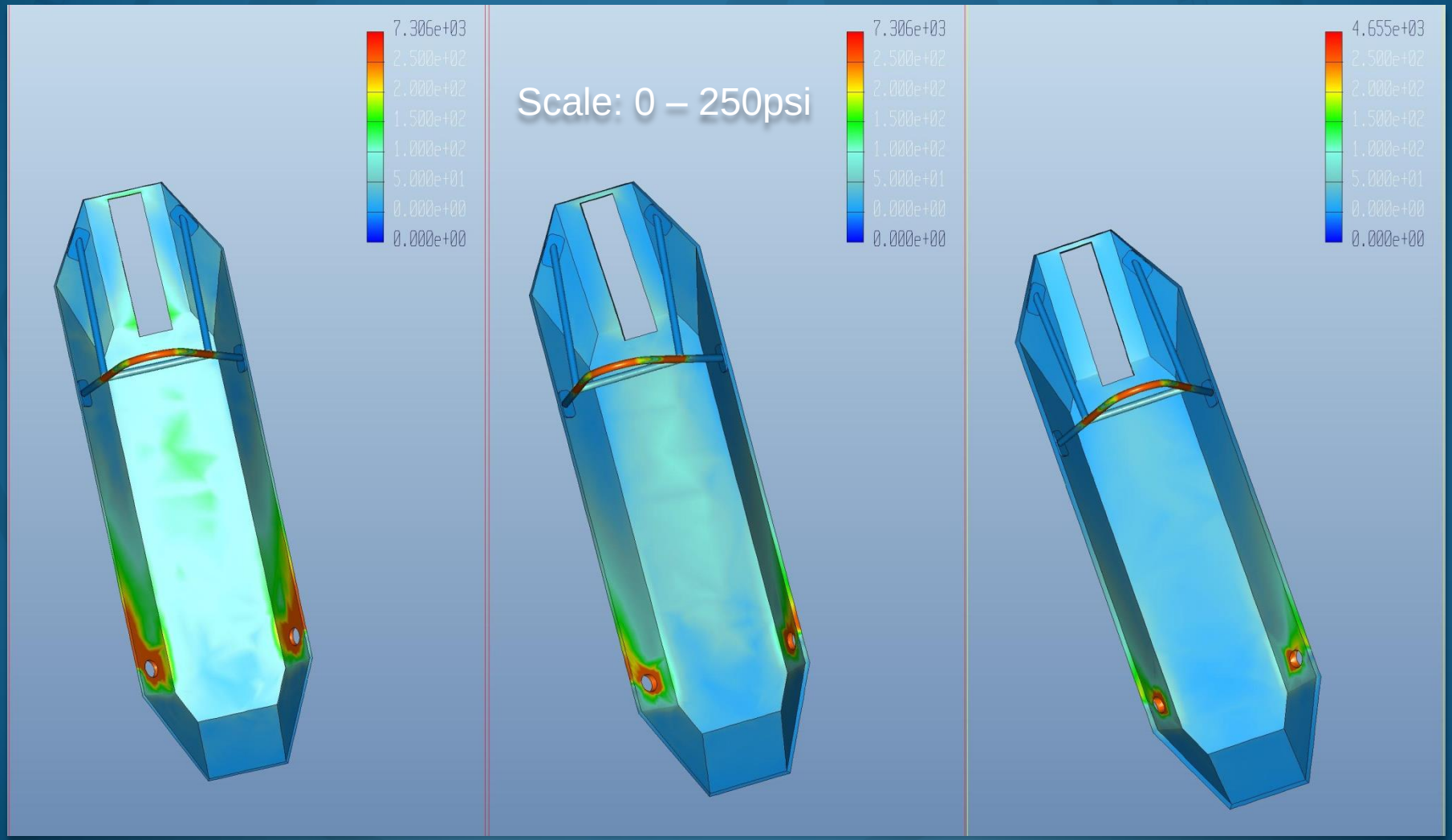
Clay Norrbin

Stress: Max Shear

0.5 Inch

0.75 Inch

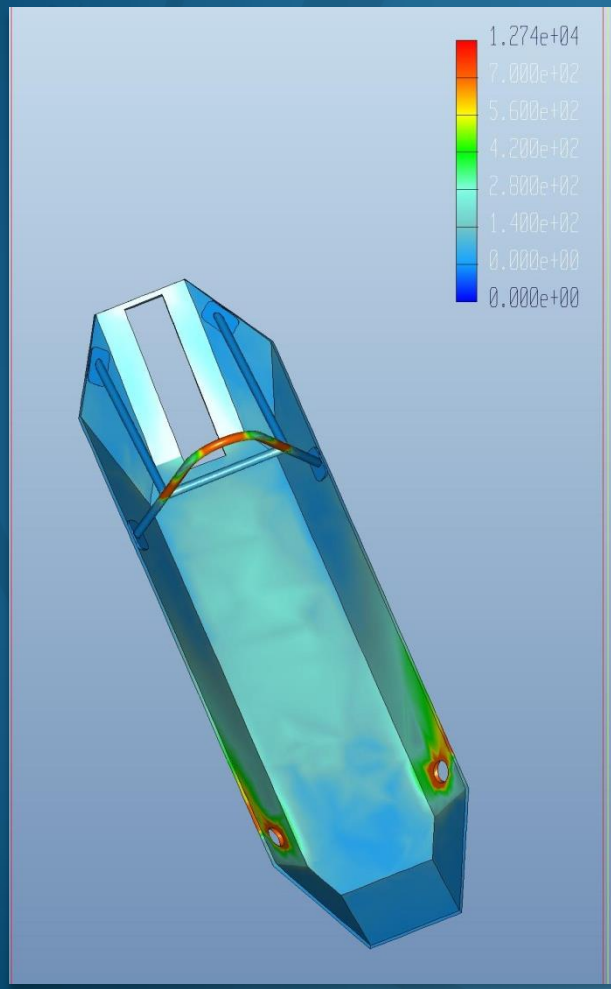
1 Inch



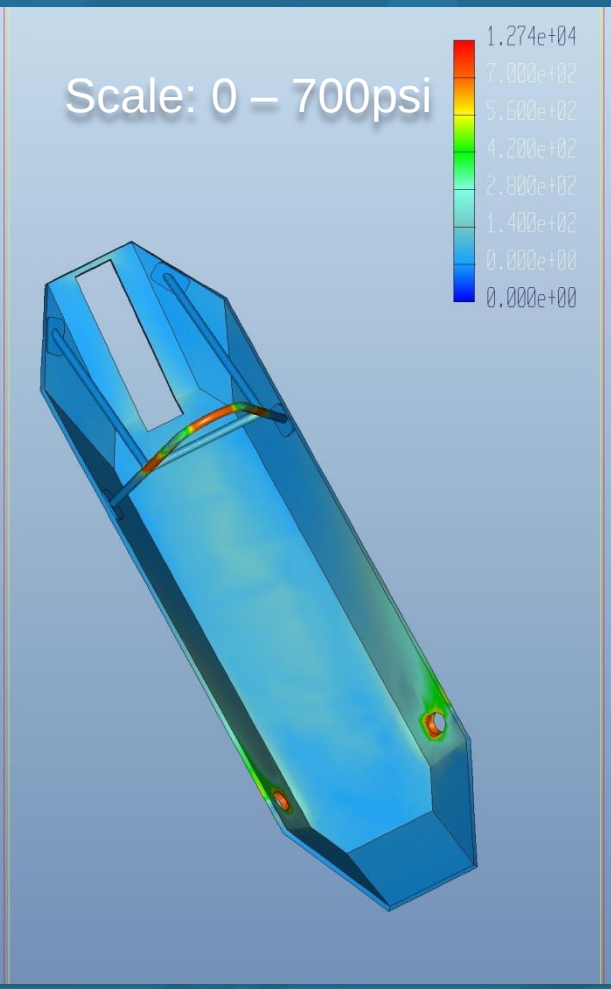
Clay Norrbin

Stress: Von Mises

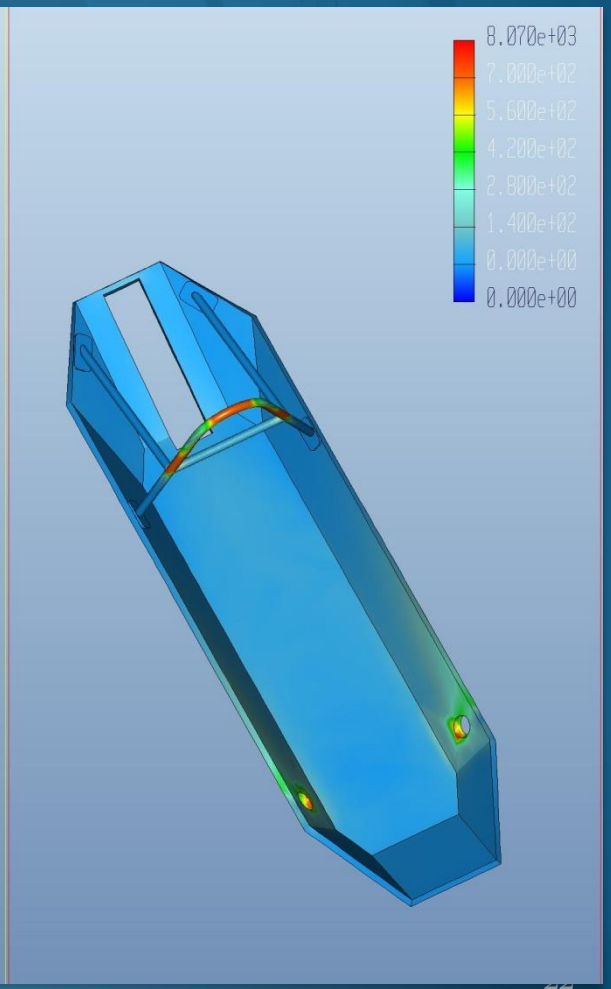
0.5 Inch



0.75 Inch



1 Inch



Clay Norrbin

Material Decision Matrix

	Price	Strength	Manufacturing	Total
Aluminum	8	2	8	5.3
Aluminum HoneyComb	5	6	6	5.8
Aluminum HoneyComb with Carbon Fiber	2	8	3	5.05
Weighting	X0.2	X0.45	X0.35	

Clay Norrbin

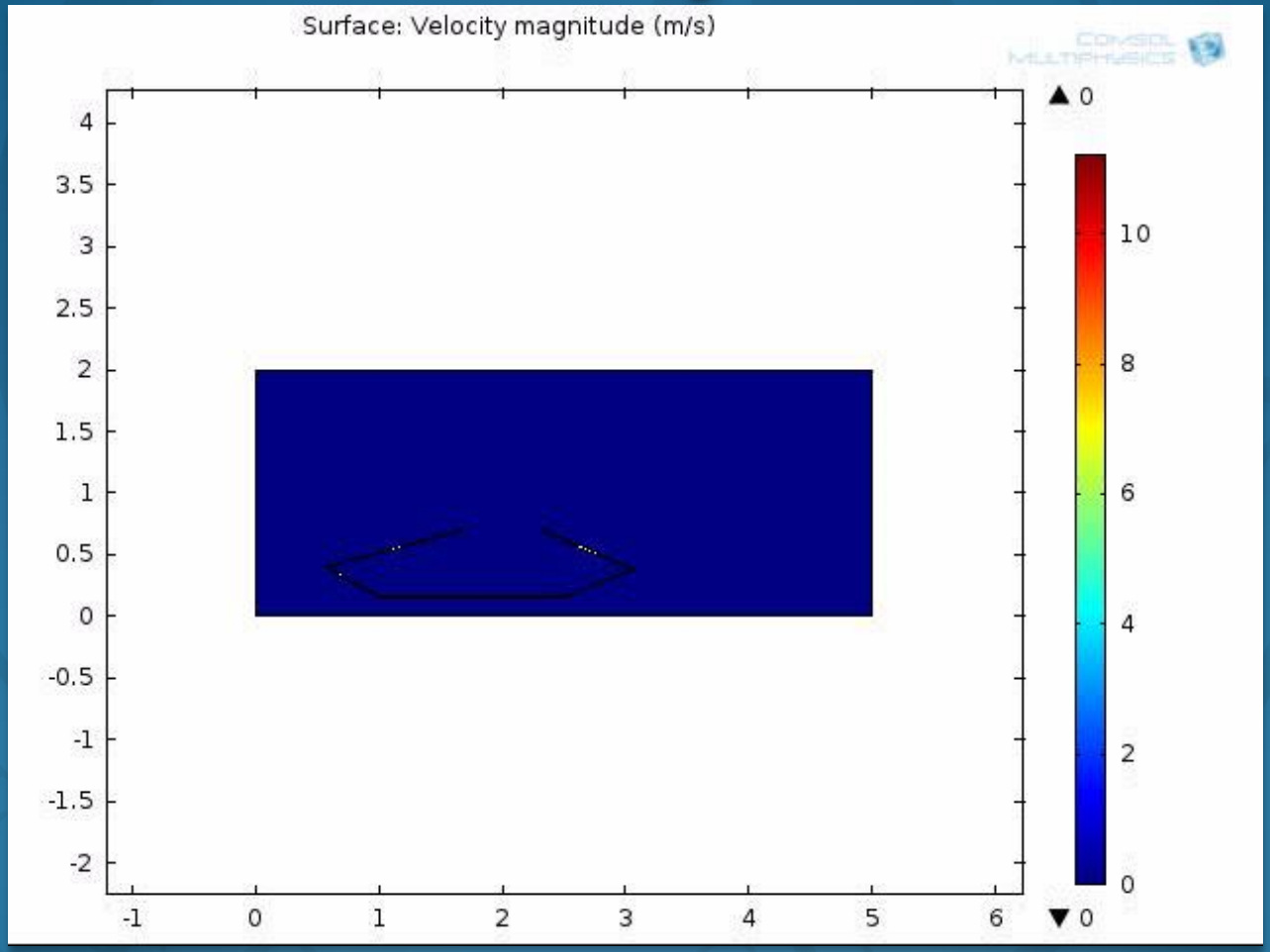
Material to Purchase

FlatIron Panel Products

- One 4’ by 8’ panel for 480 dollars with shipping
  - 0.5” thickness
  - 3/8” cell thickness
  - 0.032” panel thickness

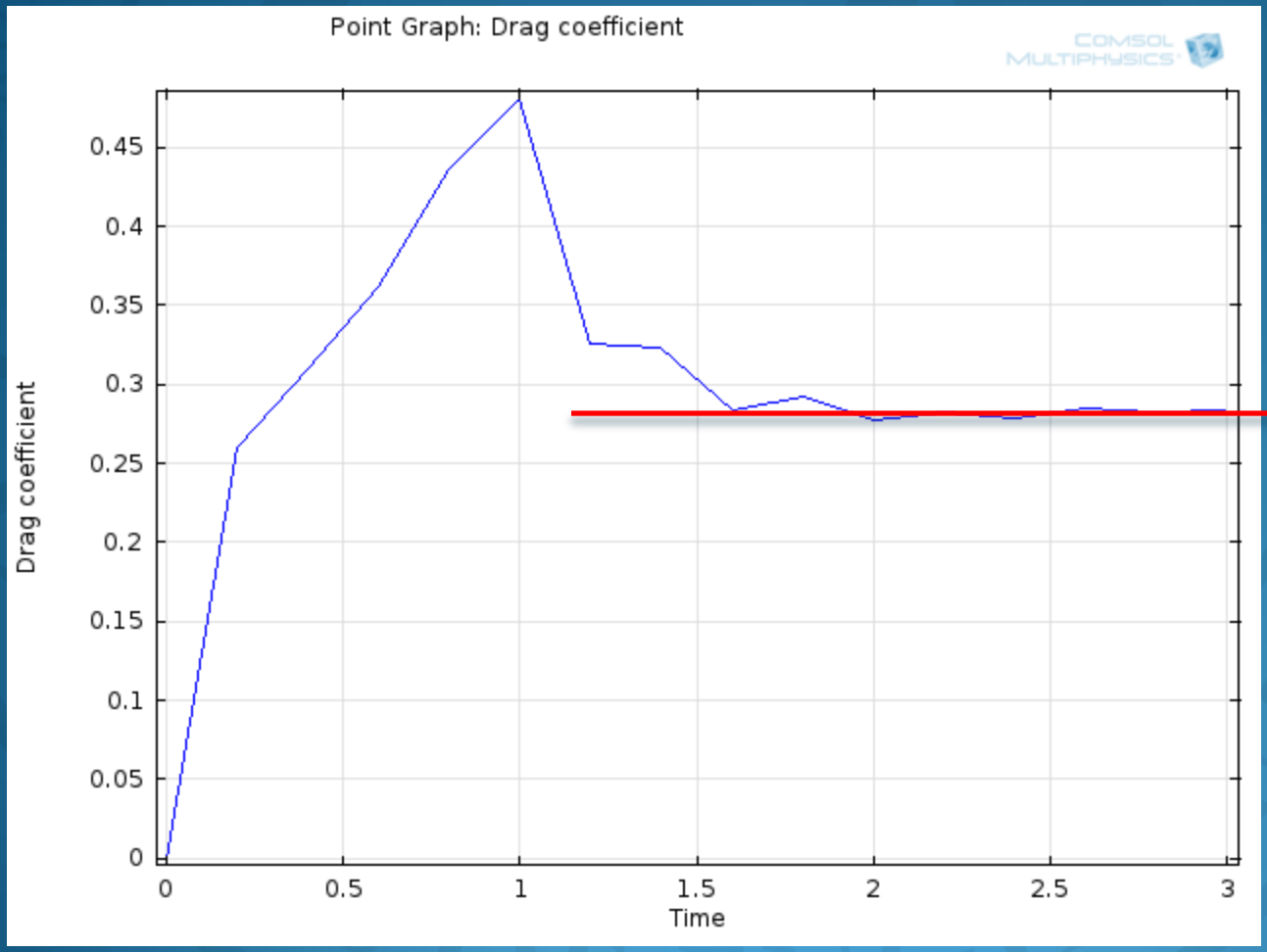
Clay Norrbin

2D Aerodynamics



Clay Norrbin

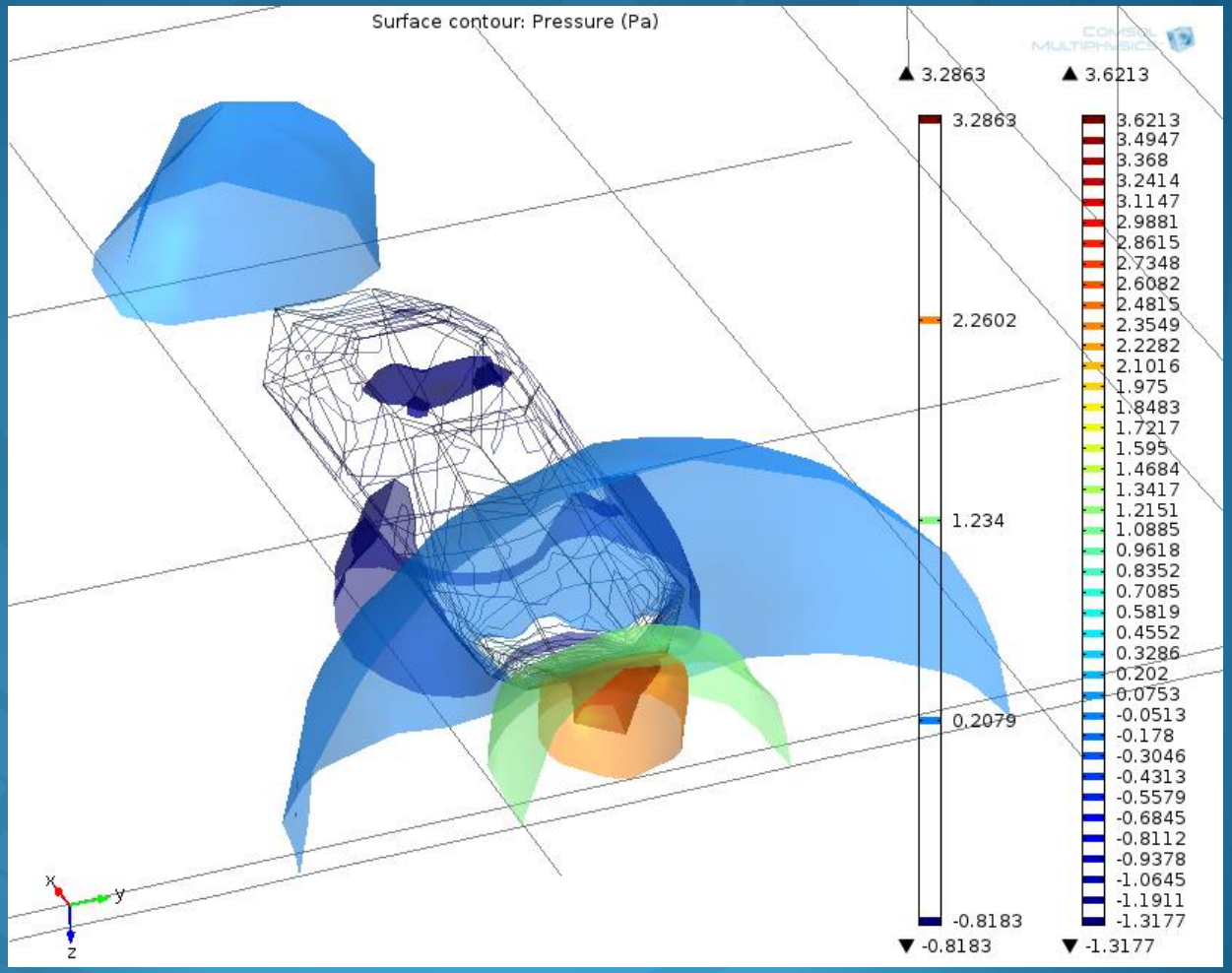
2D Aerodynamics: Drag Coefficient



Cd = 0.27

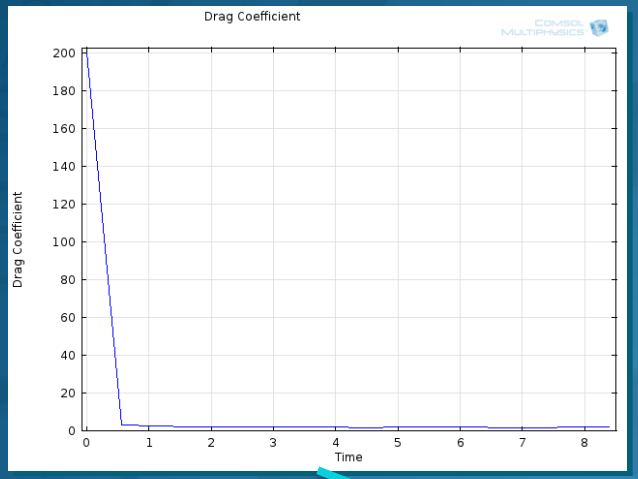
Clay Norrbin

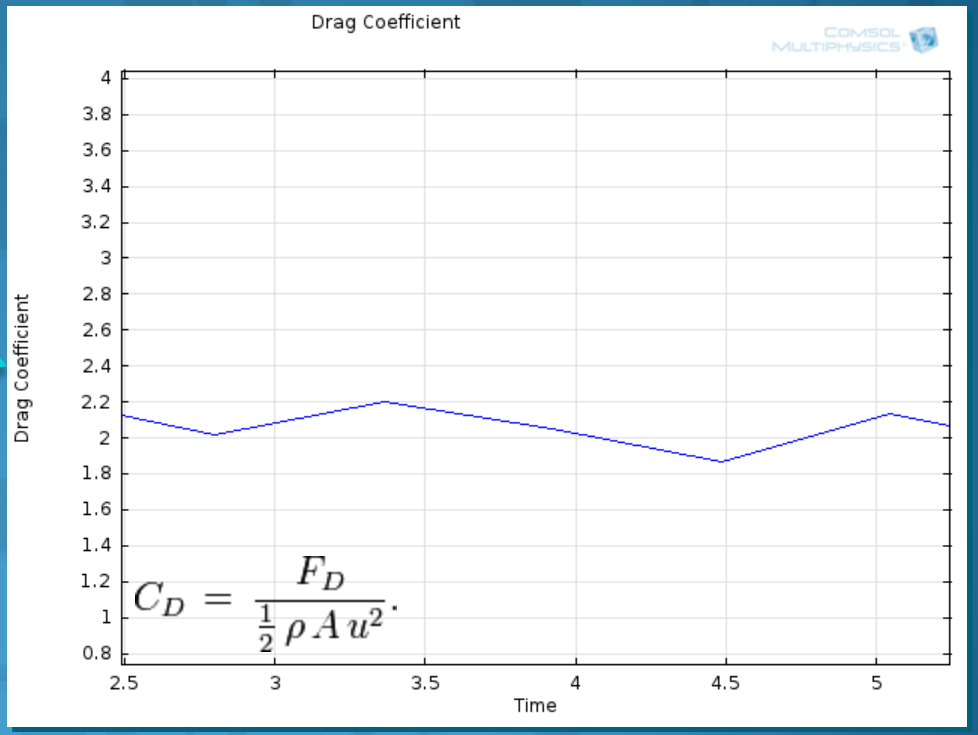
3D Aerodynamics: Something Wrong..



Clay Norrbin

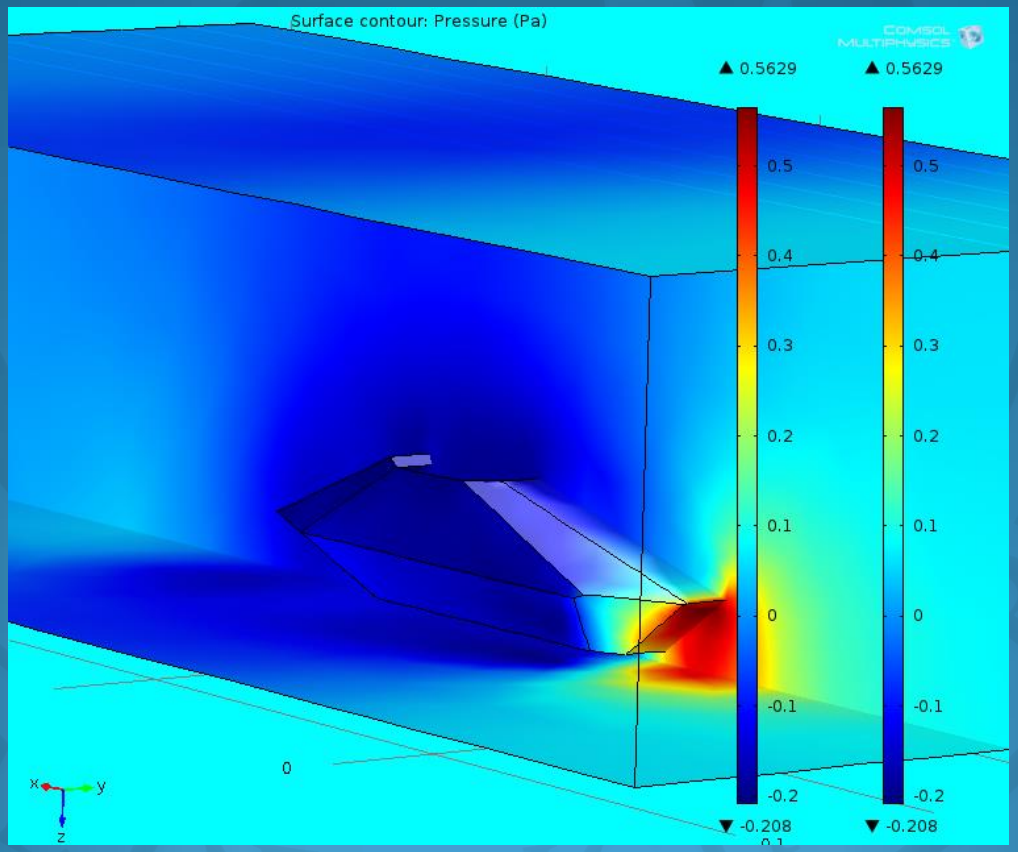
3D Aerodynamics Drag Coefficient





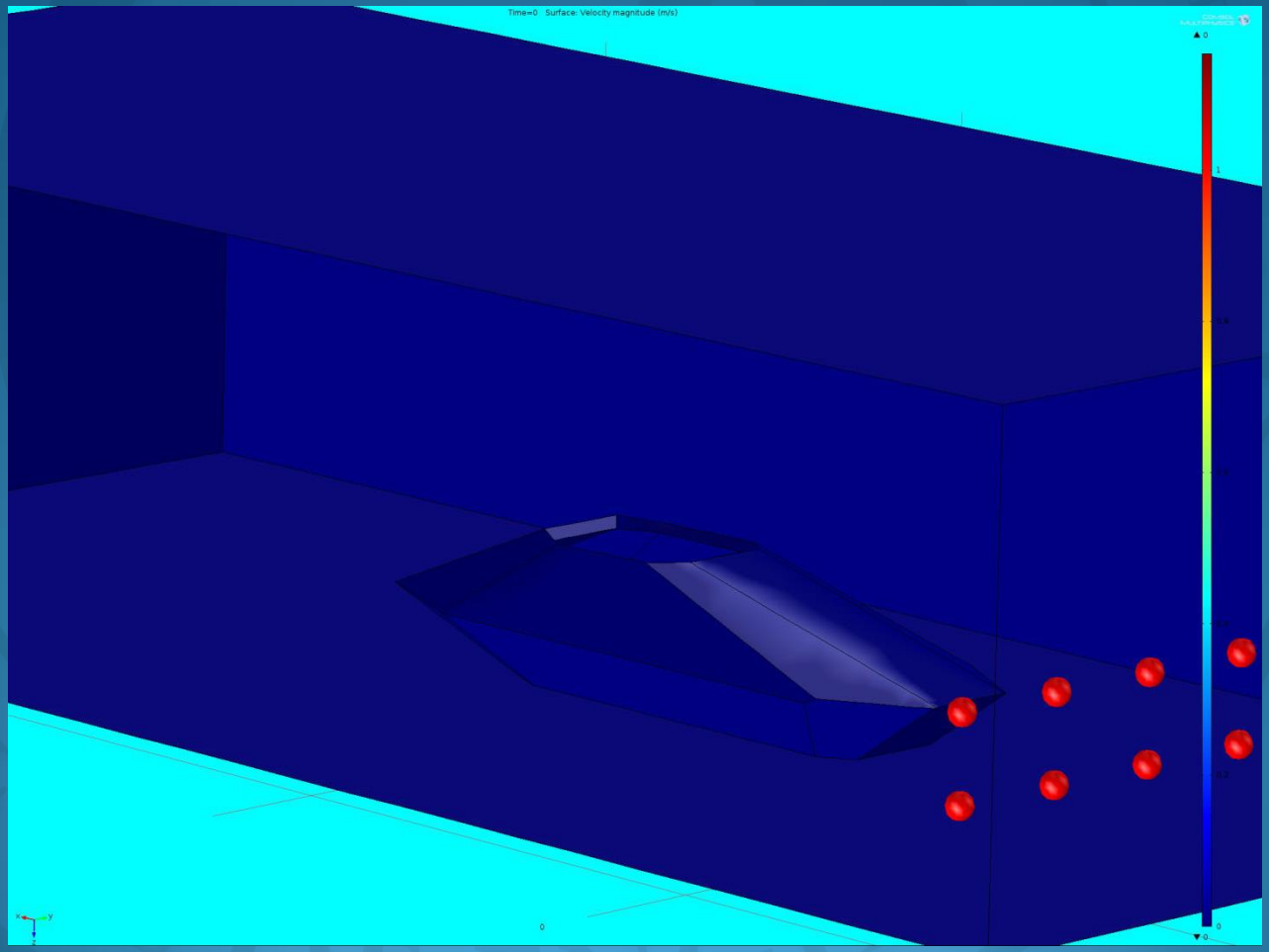
Clay Norrbin

3D Aerodynamics: Pressure



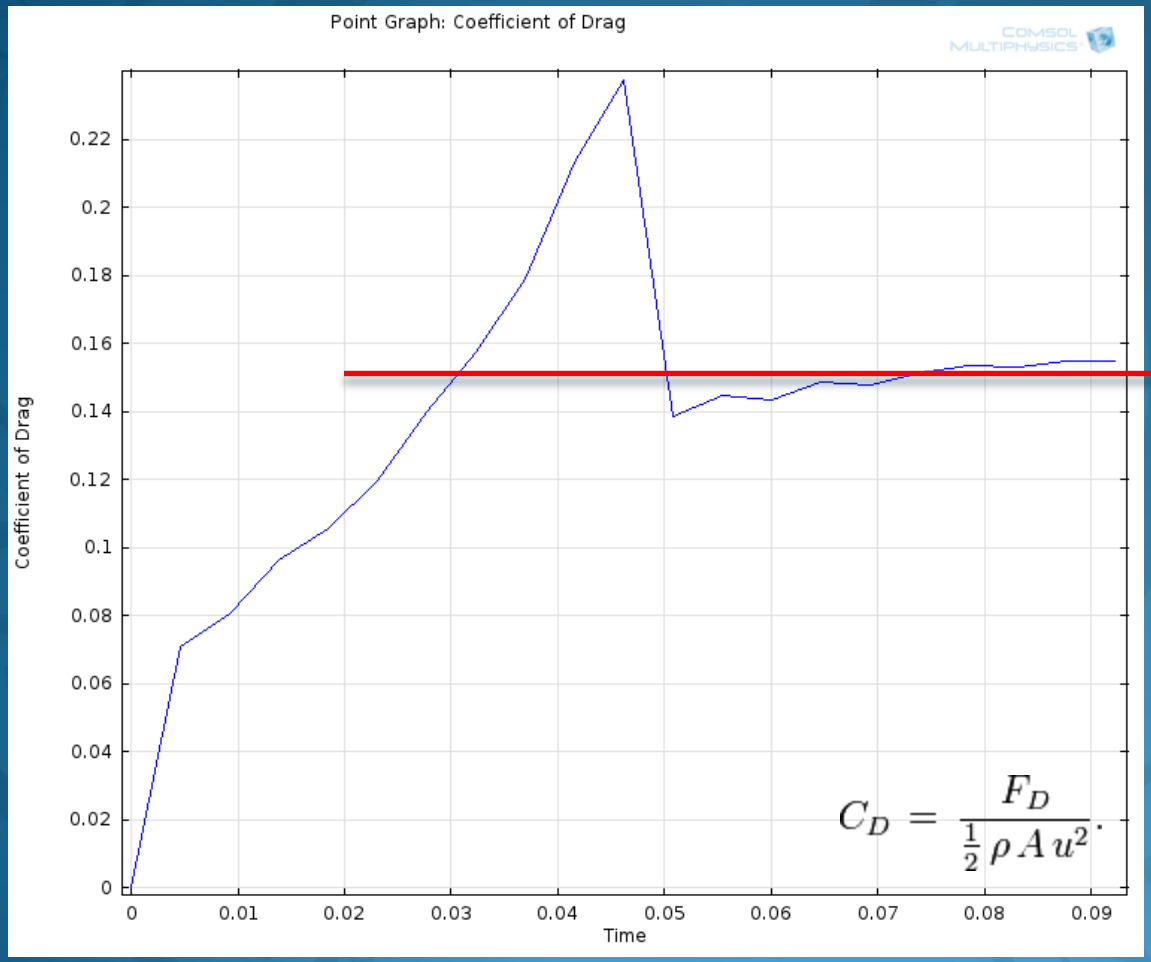
Clay Norrbin

3D Aerodynamics: Velocity



Clay Norrbin

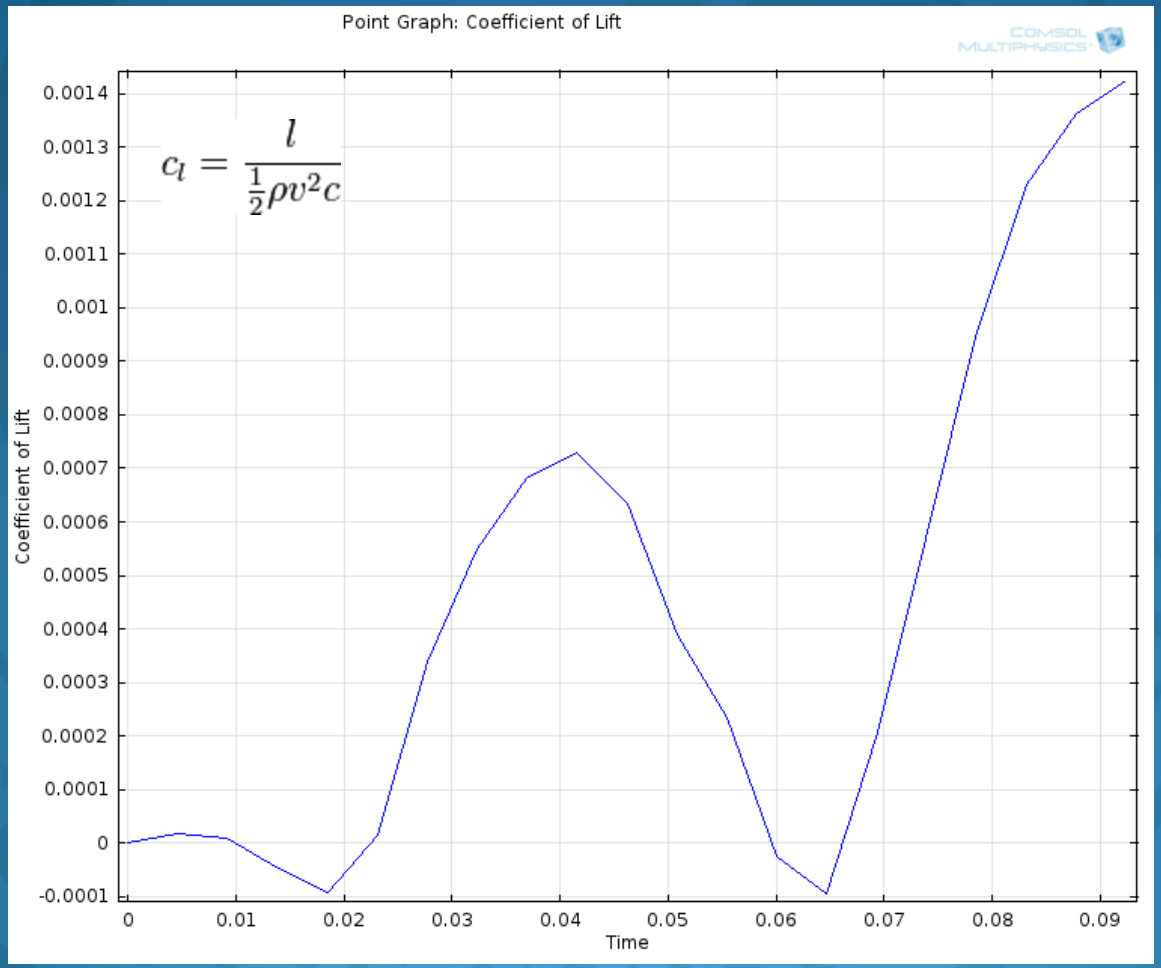
3D Aerodynamics Drag Coefficient



Cd = 0.155

Clay Norrbin

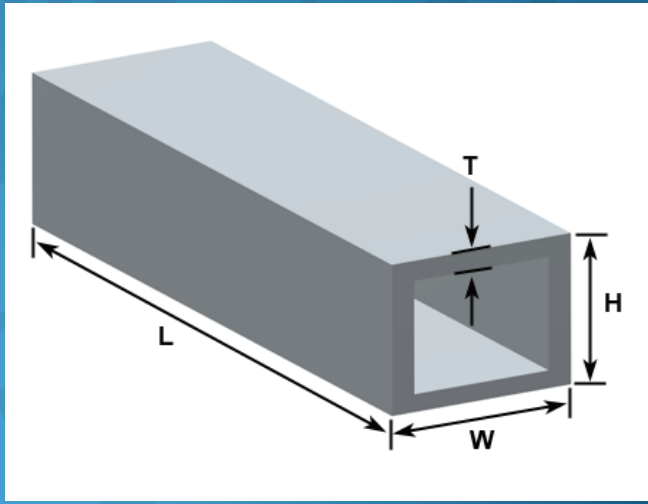
3D Aerodynamics Lift Coefficient



Joseph Petit-Homme, Jr.

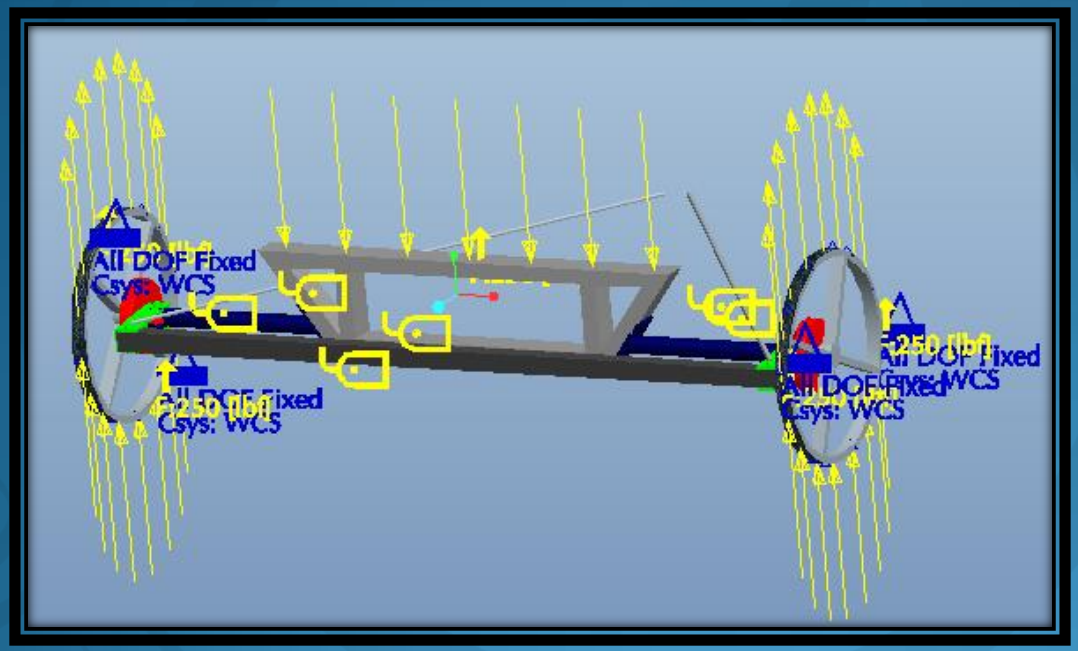
Steering

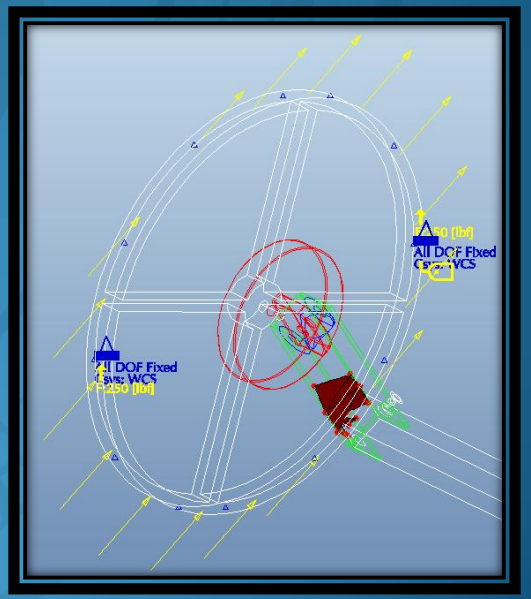
- Aluminum A6061 rectangular tubing T6 temper
- 2” x 2” with 1/8” thickness
- Yield Strength: 276 MPa(UTS: 310 MPa)
- Approx $8 per foot, Estimated Need: 6ft
- Internal Truss Structure
- Safety Factor of 2 implemented



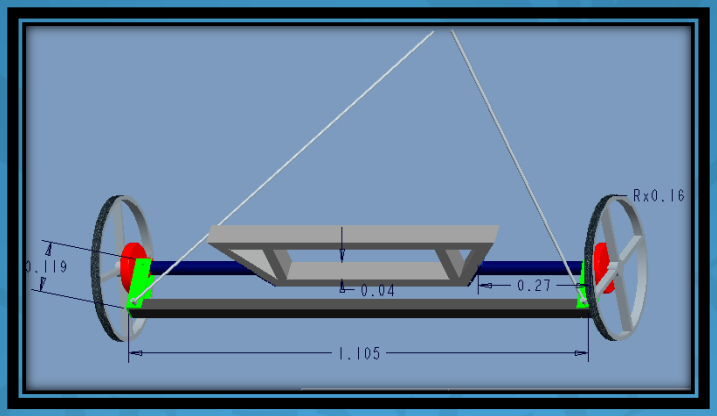
Joseph Petit-Homme, Jr.

Load Testing

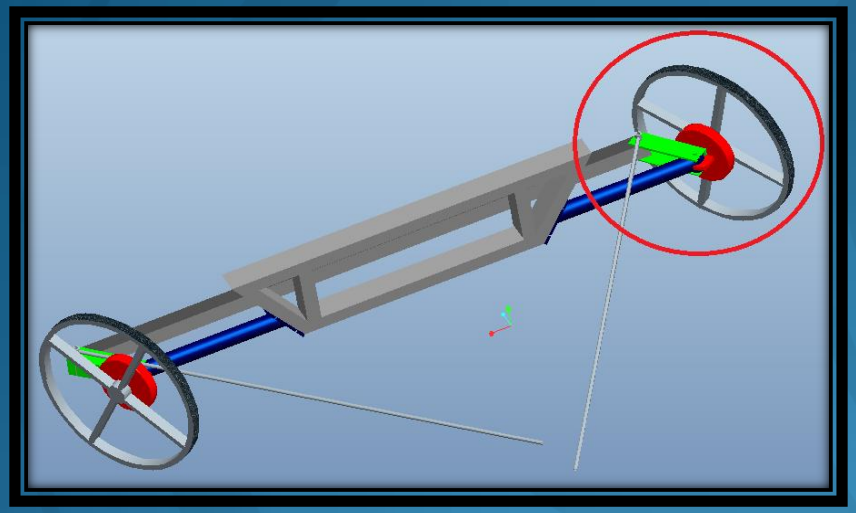


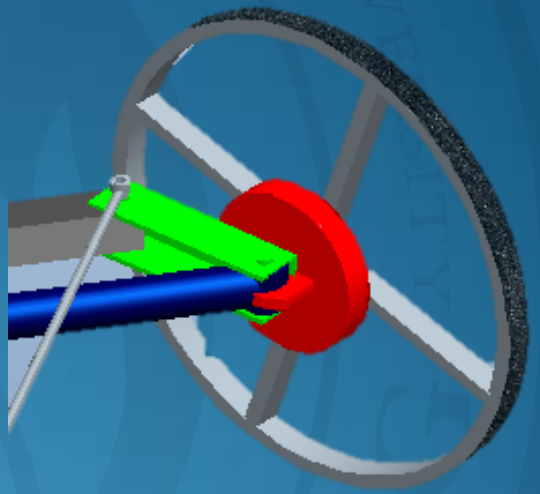


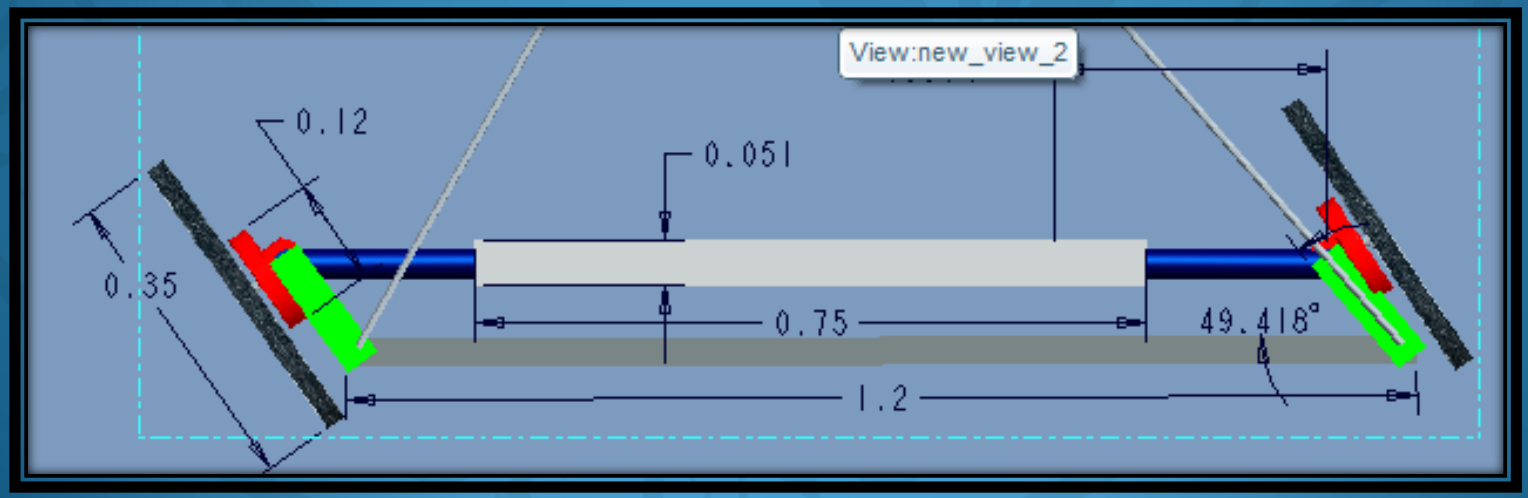
Joseph Petit-Homme, Jr.



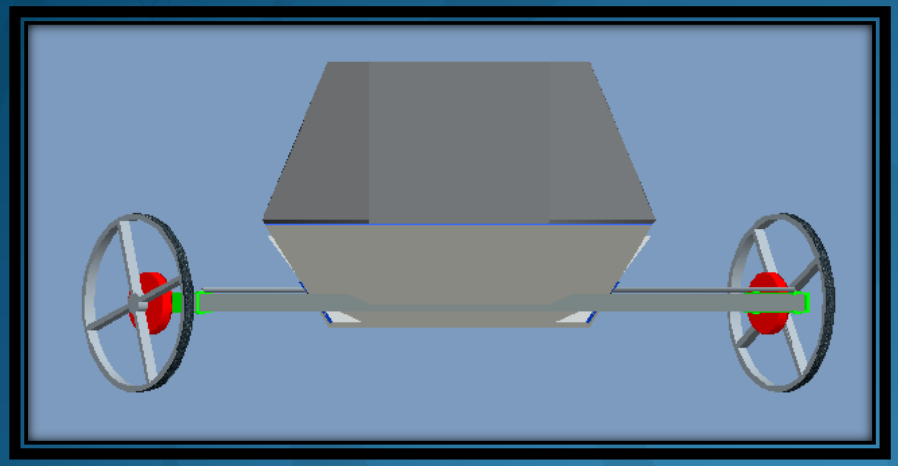
Joseph Petit-Homme, Jr.

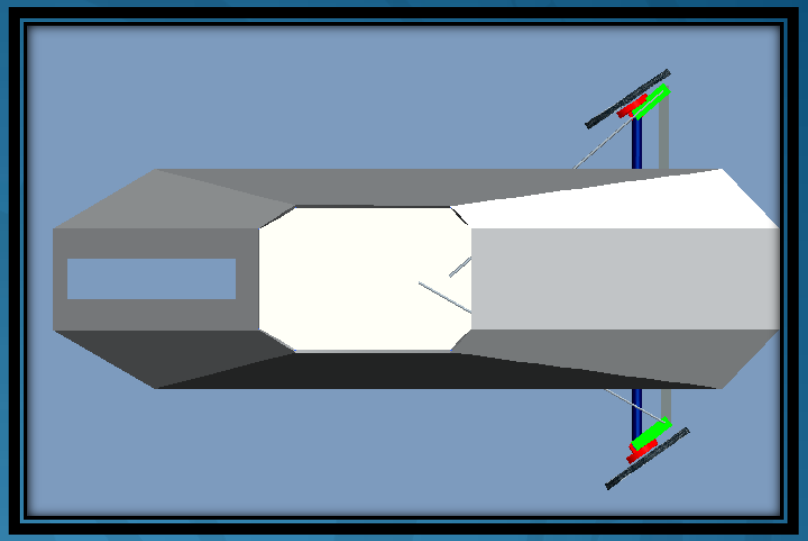






Joseph Petit-Homme, Jr.





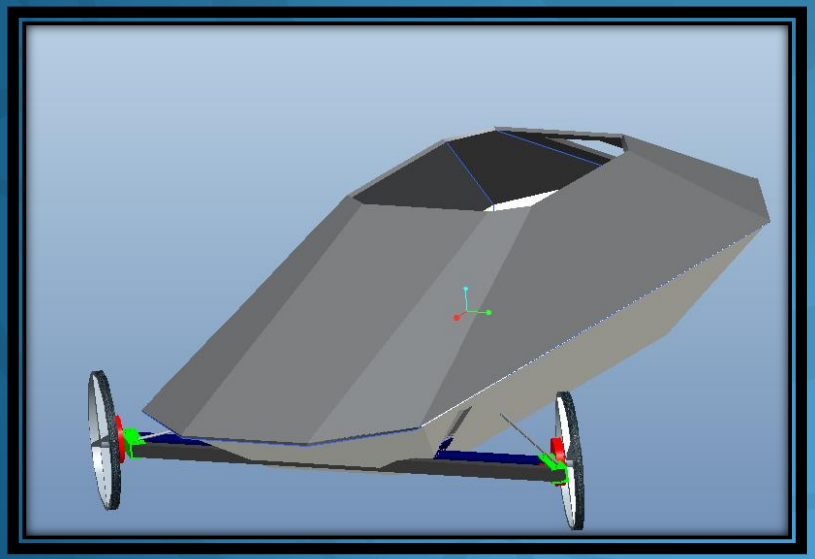
Turn Radius: 6ft
4 Link Style Steering
Mechanical Toggle

Joseph Petit-Homme, Jr.

Future Steering Tests…

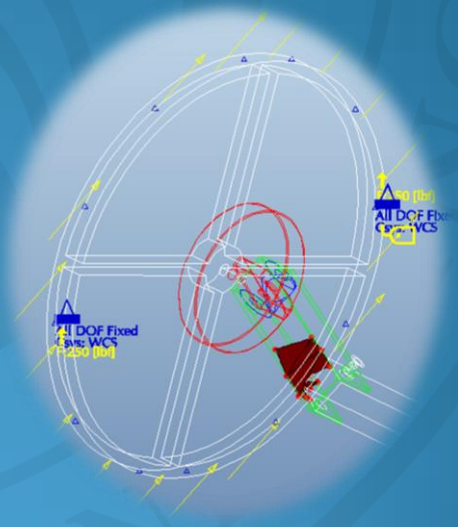
Design Simulation

- Integration into monoque
- Load testing at design conditions
- Re-run Stress Analysis



Physical Testing

- Fabricate and Check conditions

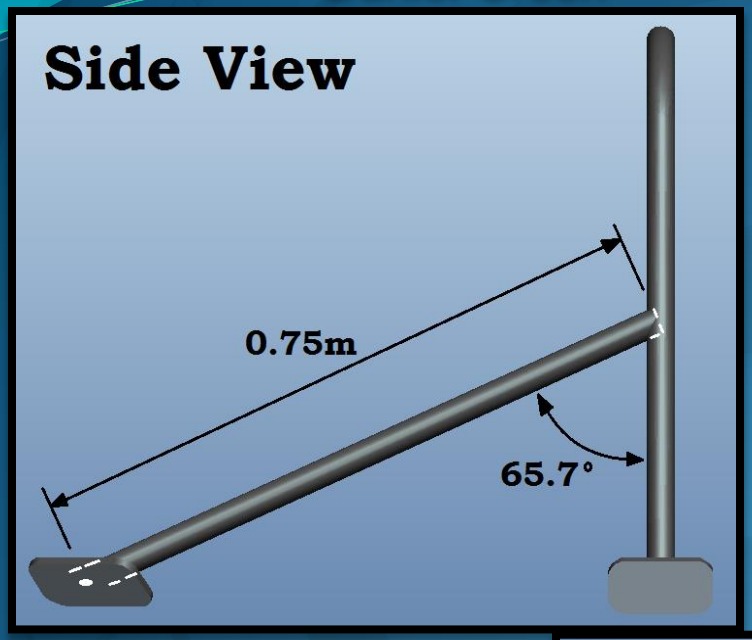


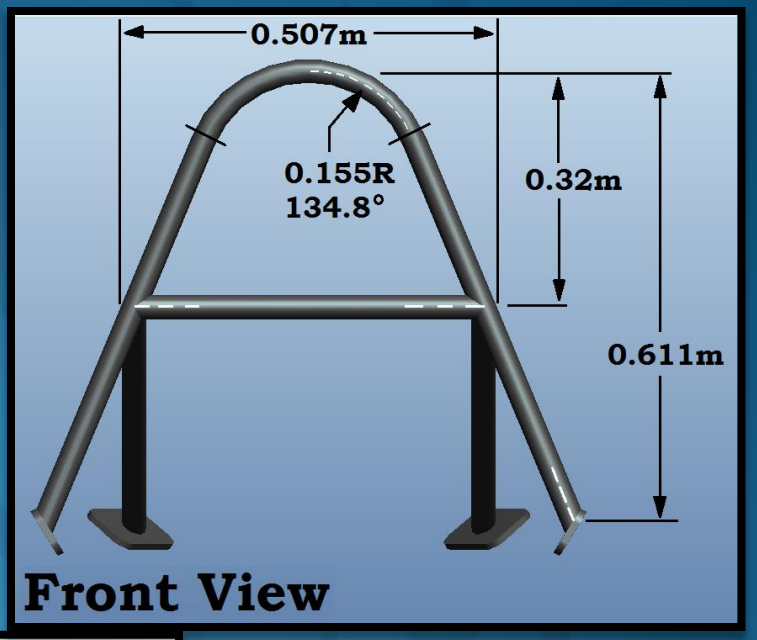
Daniel Green

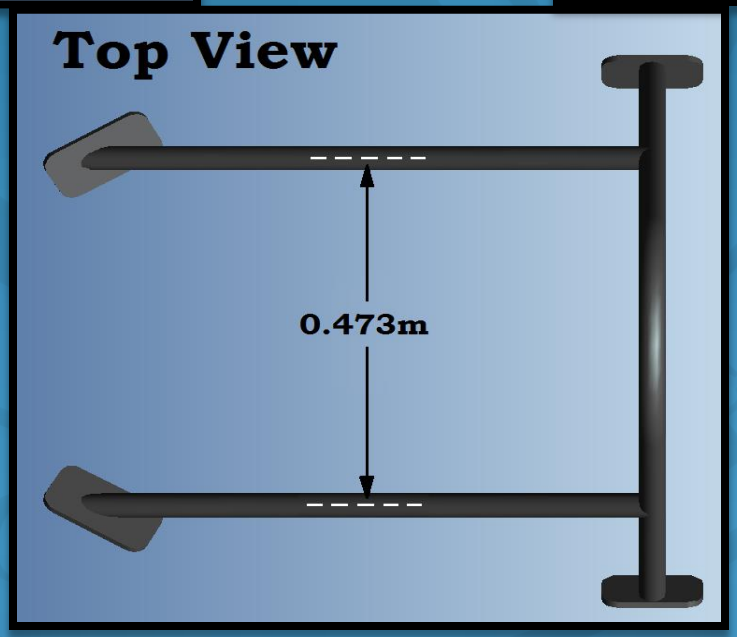
Roll Bar

- 4130N chromoly steel tubing, 1.25” x 0.049”
- Yield Strength: 435 MPa (UTS: 670 MPa)
- 0.6285 lbs. & $4.08 per foot
- Must withstand 70kg (~700N) without deformation
- Safety Factor of 2 implemented

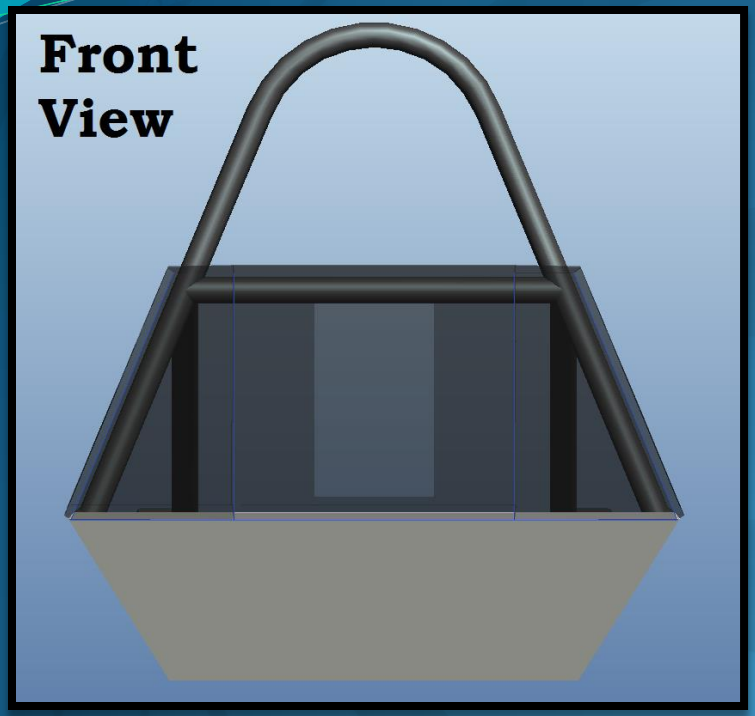
Daniel Green

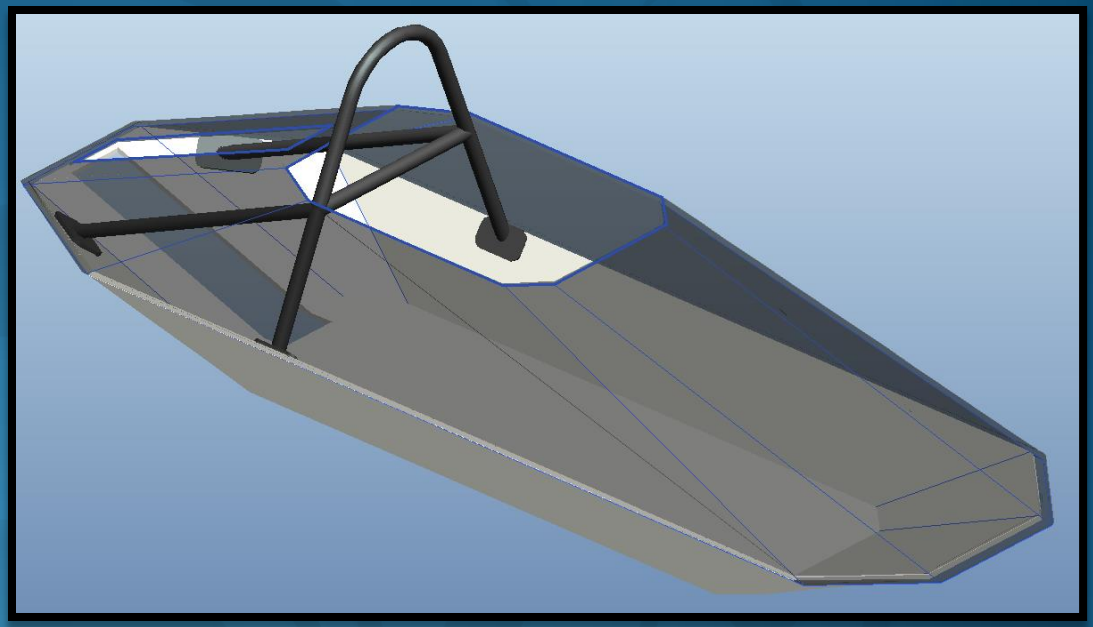






Daniel Green





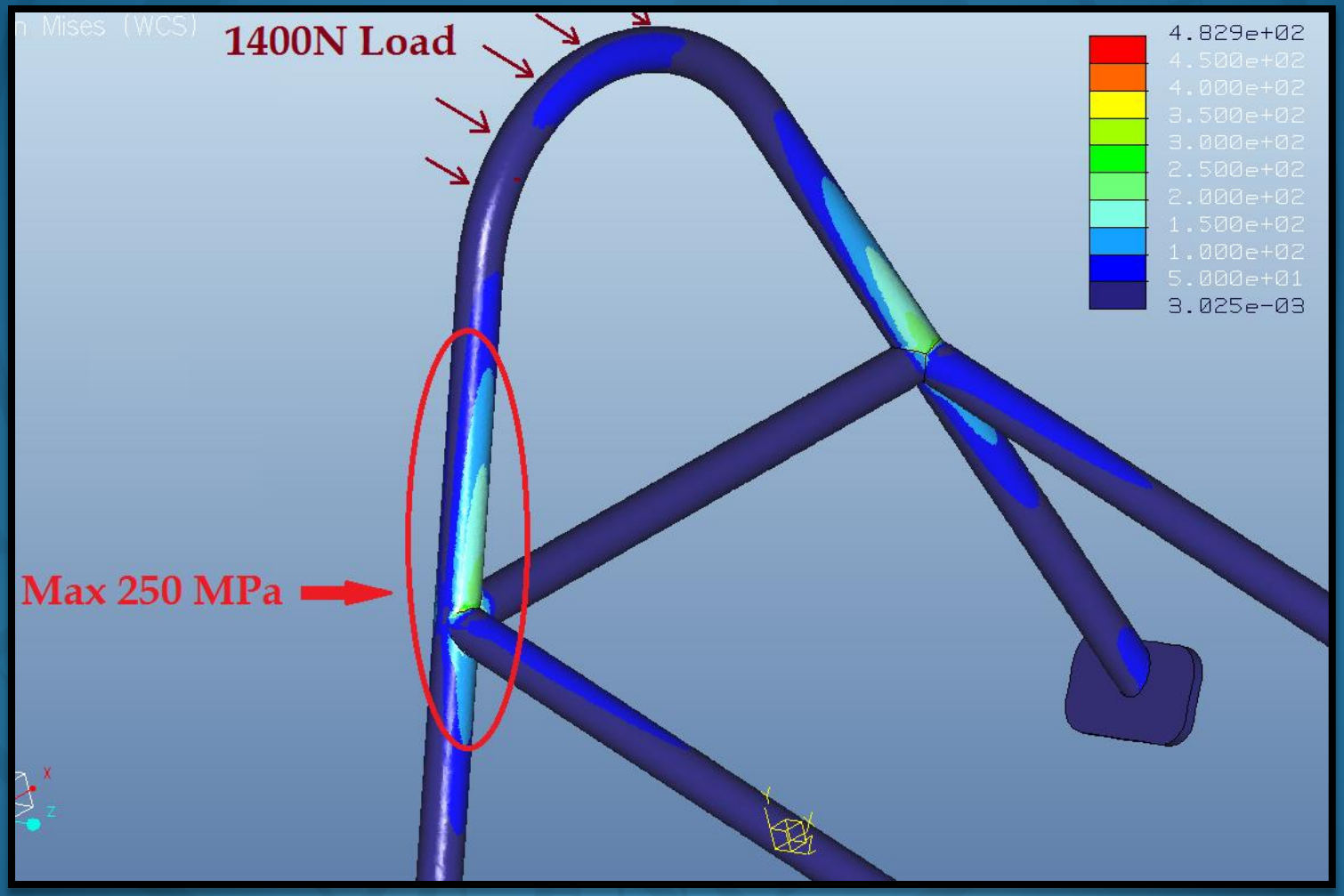
Total Tube Length: 11.5ft

Total Cost: $82.22

Total Weight: 11 lbs

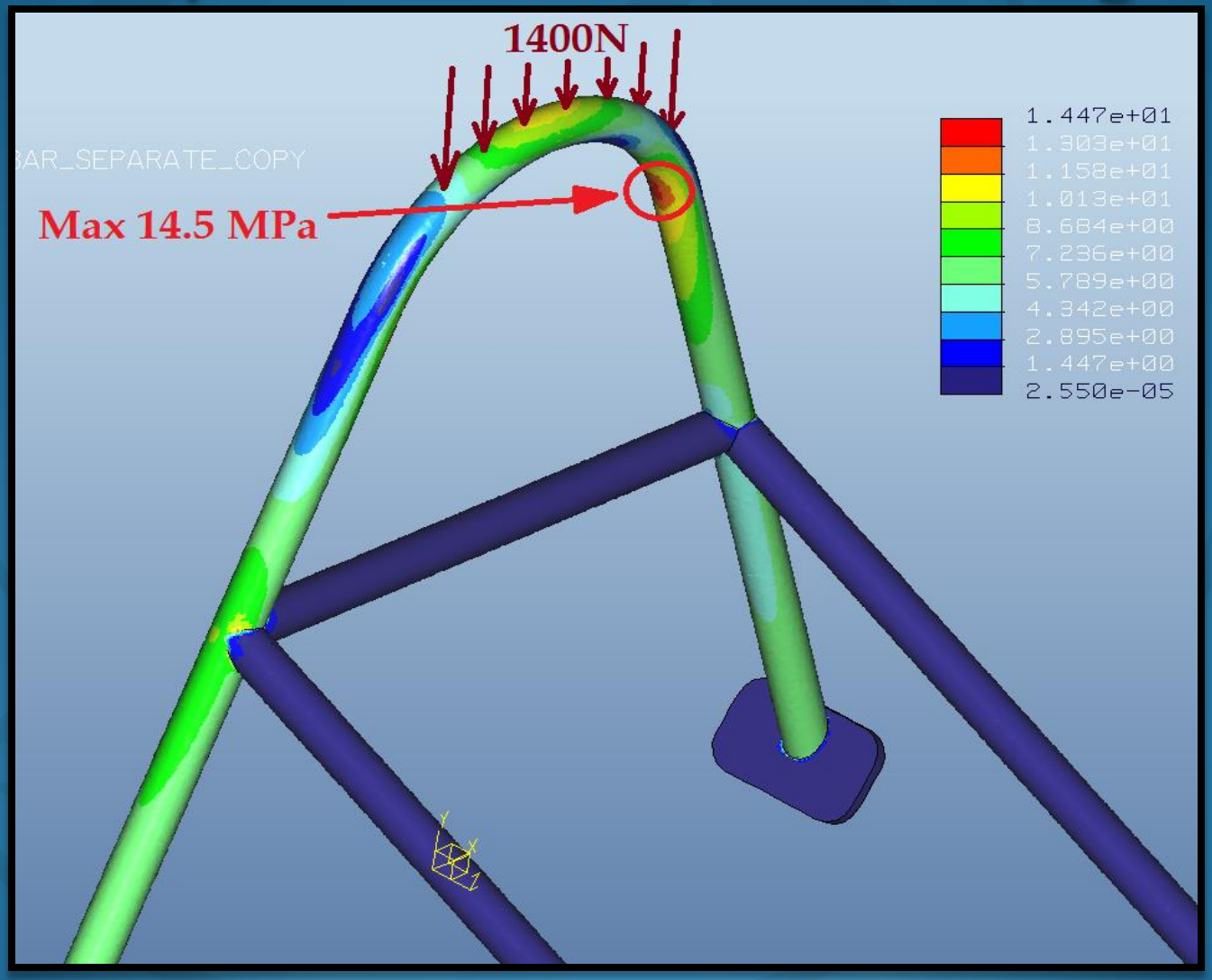
Daniel Green

Front Horizontal Load Testing



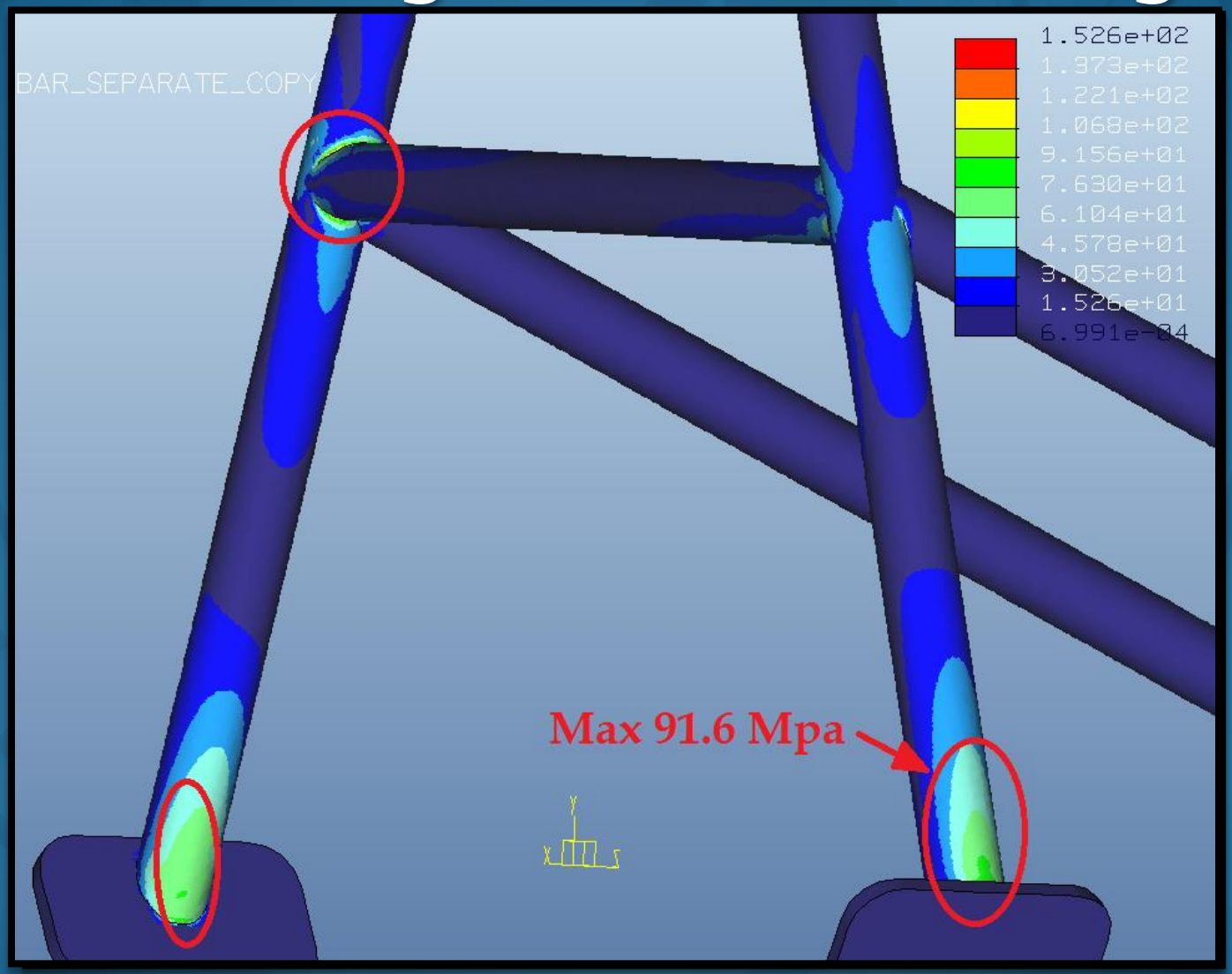
Daniel Green

Top Vertical Load Testing



Daniel Green

Side Diagonal Load Testing



Daniel Green

Future Roll Bar Tests…

Rear Wheel Attachment Stress Simulation

- Simulation of rear driving wheel attachment
- Stress and deflection test
- Impact of occupied vehicle's weight on roll bar
- Design flaw analysis

Physical Roll Bar Stress Testing

- Final fabricated roll bar completely restricted
- 160lb weight applied in different orientations
- Deformation???

Questions?