Team #2: Solar Car Project Proposal

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

The Team

Matthew Bosworth
Project Manager and EE Lead

Christopher Dresner
EE Business Admin.

Ahmad Farhat
EE Finance Manager

Thierry Kayiranga
Secretary

Clay Norrbin
ME Lead

Daniel Green
ME Business Admin

Joseph Petit-Homme
ME Finance Manager

Matthew Bosworth

Introduction

Problem Statement

- This 2 year project consists of redesigning, building and testing a car that is ready for the "Shell Eco-Marathon" competition in Summer 2014.
- The car will run completely on batteries and solar power with all necessary safety, chassis size, and weight requirements met.
- Year 1 efforts focus on the energy system and the design and build of the body of the car.

Matthew Bosworth

Operating Environment

- Able to drive a minimum of 6 miles on one battery charge
- Standard North American Climates
- Withstand normal wear with seasonal changes consistent with Tallahassee, FL
- The components will be protected electrically and physically.
- Able to handle up to a 12% grade and the ability to remain still at a 20% graded hill using brakes

Matthew Bosworth

Intended Use(s) and Intended User(s)

- Uses
  - Shell Eco-Marathon Solar-Battery Division in 2014
  - Outreach through SES and COE to local schools and businesses
  - Framework for new Solar Car Club within SES
- Users
  - Person under 150lbs
  - Person with legal driver's license
  - Person approved by Solar Car Team that is insured

Matthew Bosworth

Statement of Work

- Project Management
- Year 1
  - Chassis Design and Simulation
  - Roll Bar/Hatch/Latch
  - Battery System
  - Energy Conversion
  - Solar Panels
  - Motor
- Year 2 Projections

Matthew Bosworth

Schedule

8		Manually Sch	Professional Engineering Homework	0 days	Thu 11/1/12	Thu 11/1/12	
12		Manually Sch	Quiz on Engineering Ethics & Peer Eva	0 days	Thu 12/6/12	Thu 12/6/12	
14		Auto Schedul	Development/Modeling Pro-Engineer	5 wks	Mon 10/1/12	Fri 11/2/12	
15		Auto Schedul	1/10th Prototypes Build	2 wks	Mon 11/5/12	Fri 11/16/12	14
16		Auto Schedul	Simulation Testing of Prototype Desigr	4 wks	Mon 11/5/12	Fri 11/30/12	14
17		Auto Schedul	Aerodynamic Testing of 1/10th Ptotot	2 wks	Mon 11/19/12	Fri 11/30/12	15
18		Auto Schedul	Suspension Research	2 wks	Mon 11/19/12	Fri 11/30/12	15
19		Auto Schedul	Final Prototype Design Chosen	0 days	Fri 11/30/12	Fri 11/30/12	17,18
20		Auto Schedul	HPMI Design Development	8 wks	Mon 12/3/12	Fri 1/25/13	19
21		Auto Schedul	Discuss w/ HPMI - Roll Bar Design	2 wks	Mon 10/15/12	Fri 10/26/12	
22		Auto Schedul	Research on Sheild/Cockpit	3 wks	Mon 10/1/12	Fri 10/19/12	
23		Auto Schedul	Cockpit Design	2 wks	Mon 12/3/12	Fri 12/14/12	19
24		Auto Schedul	Car Chassis Open/Close/Locking	12 wks	Mon 12/17/12	Fri 3/8/13	23
25		Auto Schedul	PRO-Engineer w/ Fully Articulated Mo	12 wks	Mon 12/3/12	Fri 2/22/13	19
27		Auto Schedul	Energy System Simulation Model	75 days	Tue 11/27/12	Mon 3/11/13	31,39,46
30		Auto Schedul	Research into Manufactoring at COE	6 wks	Mon 10/15/12	Fri 11/23/12	
31		Manually Sch	Manufactoring or Purchasing?	1 day	Mon 11/26/12	Mon 11/26/12	30
32		Auto Schedul	Time needed to purchase or manufact	6 wks	Tue 11/27/12	Mon 1/7/13	31
33		Auto Schedul	Protection Design/Purchasing	4 wks	Tue 11/27/12	Mon 12/24/12	31
34		Auto Schedul	Verification of Design	2 wks	Tue 1/8/13	Mon 1/21/13	32,33
35		Auto Schedul	Build Array w/ Protection	4 wks	Tue 1/22/13	Mon 2/18/13	34
36		Auto Schedul	Energy System Integration	2 wks	Tue 2/19/13	Mon 3/4/13	35
38		Auto Schedul	Frequency Output Research	3 wks	Mon 10/15/12	Fri 11/2/12	
39		Auto Schedul	Model Development	2 wks	Mon 11/5/12	Fri 11/16/12	38
40		Auto Schedul	Ordering/Shipping	4 wks	Mon 11/5/12	Fri 11/30/12	38
41		Auto Schedul	Device Testing under Steady State Cor	2 wks	Mon 12/3/12	Fri 12/14/12	40
42		Auto Schedul	Verification of Device	2 wks	Mon 12/17/12	Fri 12/28/12	41

Matthew Bosworth

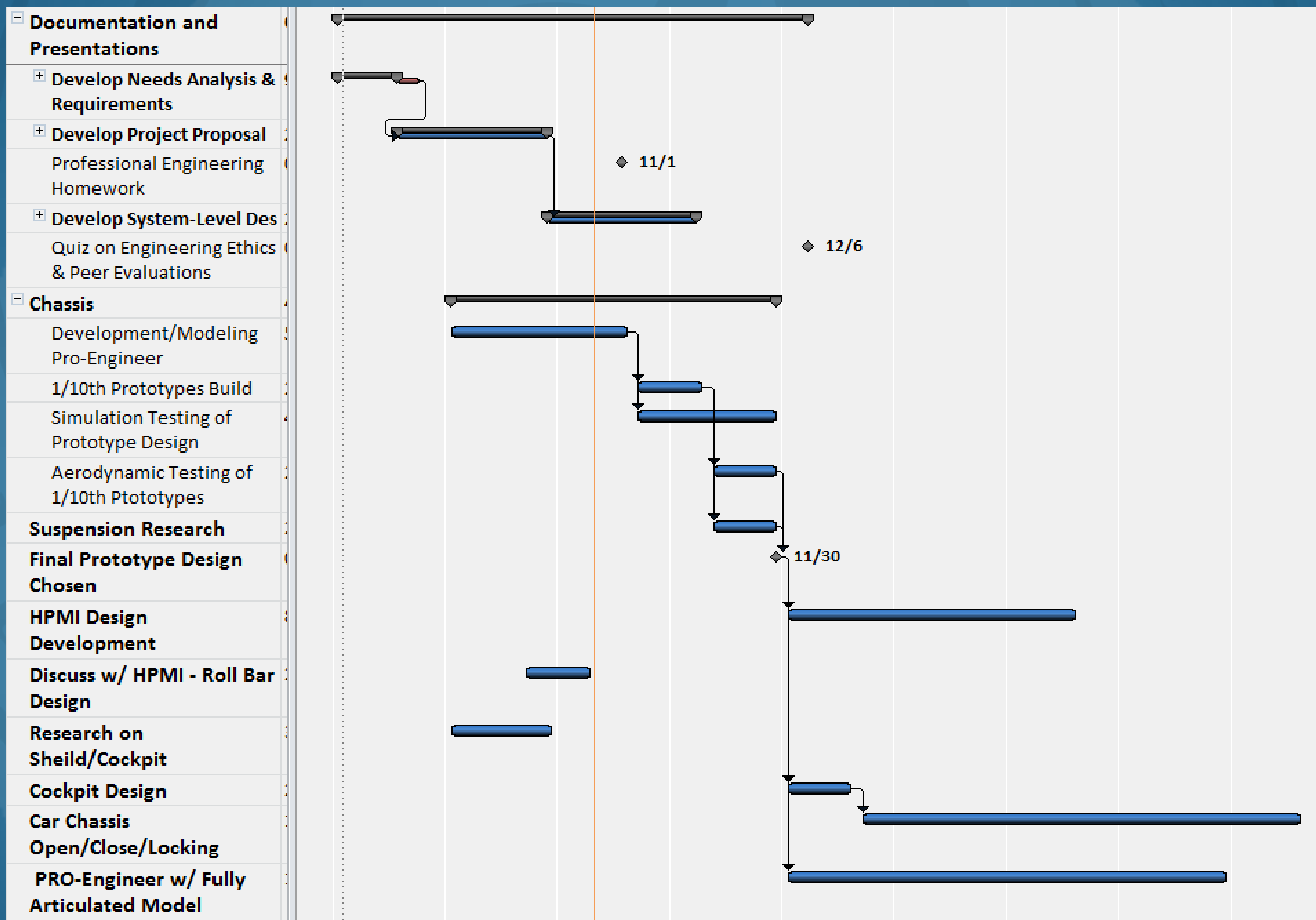
Schedule

43	Auto Schedul	Energy System Integration	36 days	Mon 12/31/12	Mon 2/18/13	42
45	Auto Schedul	Company interactions	4 wks	Mon 10/8/12	Fri 11/2/12	
46	Auto Schedul	Model Development	2 wks	Mon 11/5/12	Fri 11/16/12	45
47	Auto Schedul	Ordering and Shipping	4 wks	Mon 11/5/12	Fri 11/30/12	45
48	Auto Schedul	BMS Testing with DC load bank	6 wks	Mon 12/3/12	Fri 1/11/13	47
49	Auto Schedul	Battery Testing with DC load bank	6 wks	Mon 12/3/12	Fri 1/11/13	47
50	Auto Schedul	Verification of Devices	2 wks	Mon 1/14/13	Fri 1/25/13	48,49
51	Auto Schedul	Integration	26 days	Mon 1/28/13	Mon 3/4/13	50

53	Manually Sch	Discussion with Different Companies	3 wks	Mon 10/1/12	Fri 10/19/12	
54	Manually Sch	Motor Determination	0 days	Mon 10/22/12	Mon 10/22/12	53
55	Manually Sch	Purchasing and Shipping	6 wks	Mon 10/22/12	Fri 11/30/12	54
56	Manually Sch	Simulation Model of Motor	6 wks	Mon 10/22/12	Fri 11/30/12	53
57	Manually Sch	Integration	20 days	Fri 2/1/13	Thu 2/28/13	

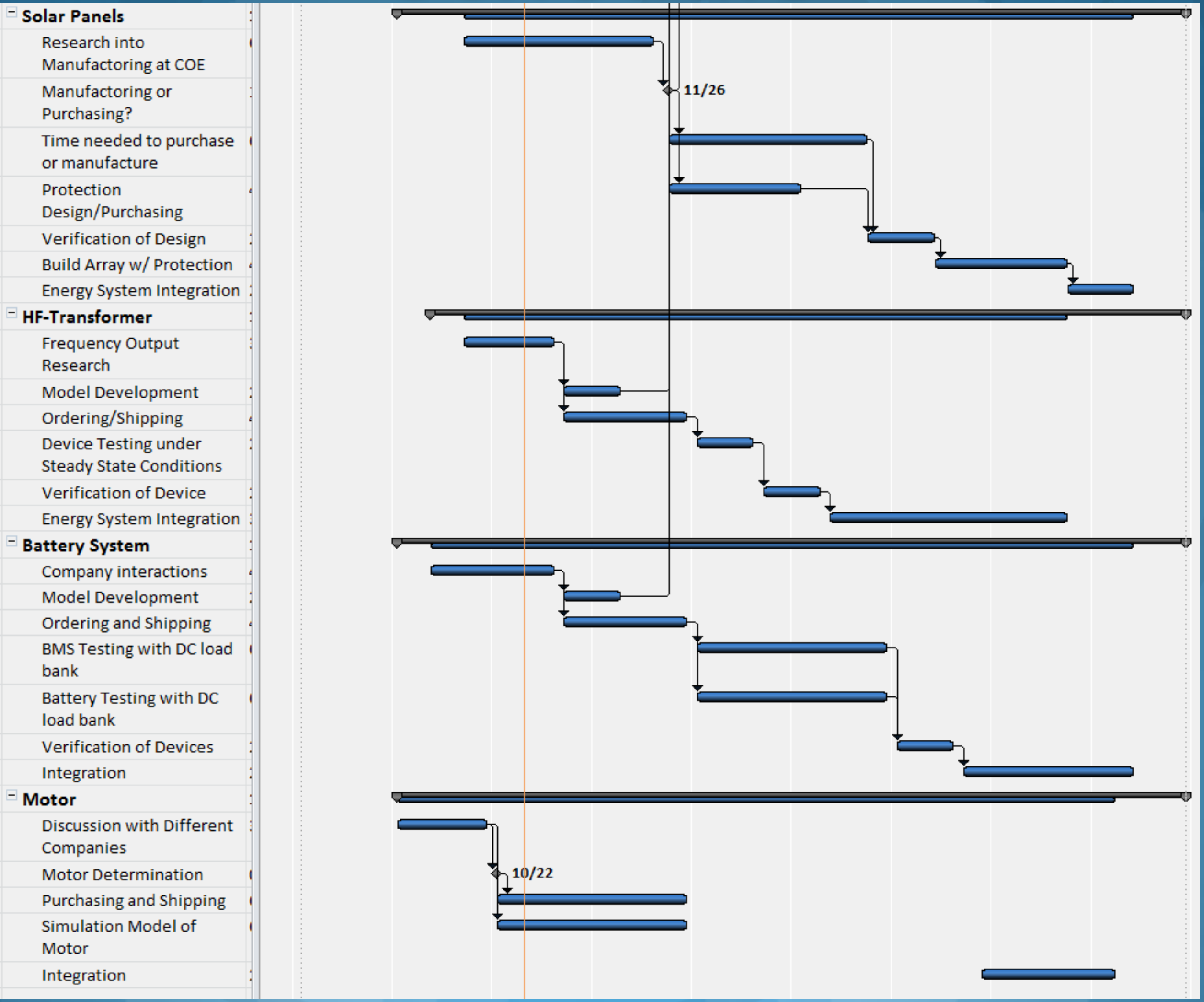
Matthew Bosworth

Schedule



Matthew Bosworth

Schedule



Year 1: Budget

Table 7.1: Personnel Expenses

Name	Effort(hr/wk)	Base Pay(per hr)	Total(per wk)	Total(per semester)	Entire Project Cost
Matthew Bosworth	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Clay Norrbin	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Chris Dresner	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Joseph Petit-Homme	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Ahmad Farhat	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Ryan Green	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
Thierry Kayiranga	12	$ 30.00	$ 360.00	$ 5,760.00	$ 11,520.00
				total:	$ 80,640.00

Table 7.2: Equipment Costs

Materials	$ 1,000.00
Motor Kit	$ 1,000.00
Chassis	$ 4,500.00
Brake	$ 800.00
Cockpit Design	$ 1,000.00
MPPT	$ 1,000.00
Battery System	$ 2,000.00
Seat	$ 200.00
Wheels	$ 400.00
Suspension	$ 1,000.00
Visor	$ 400.00
Steering	$ 300.00
total:	$ 13,600.00

Year 1: Budget

Table 7.3: Misc Expenses

Mechanical Expenses	Amount
Nuts, Bolts, Screws, Washers	$ 200.00
Hinges/Latches	$ 500.00
Labor for Machining	$ 2,000.00
Spare/Extra Parts	$ 600.00
subtotal:	$ 3,300.00
Electrical Expenses	**Amount**
Ribbon Wire	$ 100.00
Solder	$ 90.00
Solder Irons	$ 150.00
Solder Iron Tips	$ 40.00
Wire	$ 150.00
Connector	$ 40.00
PV cell protection parts	$ 800.00
subtotal:	$ 1,370.00
total:	$ 4,670.00

Table 7.4: Overall Costs

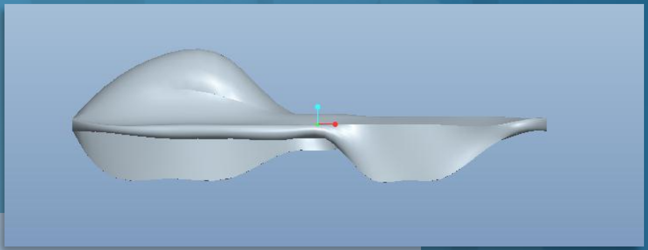
Total Parts/Equipment	$ 18,270.00
Total Personnel	$ 80,640.00
Total Estimated Cost w/ Overhead	$ 145,397.70

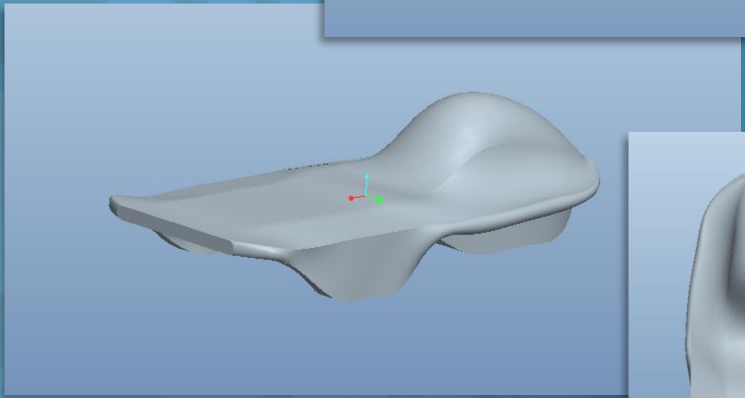
Clay Norbbin

Mechanical Team Progress

Last Year

New Prototype





Clay Norbbin

Mechanical Engineering Change

- Body shape change- smaller size due to less space for solar panels.

- Fully integrated one design instead of three designs- creates less chance of fitment problems

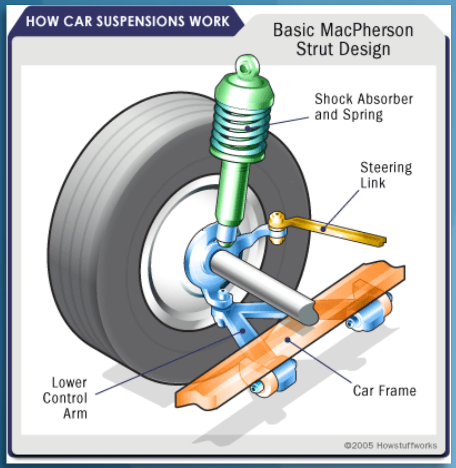
Clay Norbbin

Suspension

- No restrictions from Shell Eco-marathon.
- Solar cells must not have enough vibration to brake.

Designs:

Coil over



Rigid

Carbon Fiber

Clay Norbbin

Selection of Suspension

	Coil over	Rigid	Carbon Fiber	Weighting
Price	5	9	3	.2
Performance	8	1	7	.2
Complexity	4	8	5	.1
Weight	2	8	9	.3
Size	3	9	8	.2
Total	4.2	7	6.8	

Clay Norbbin

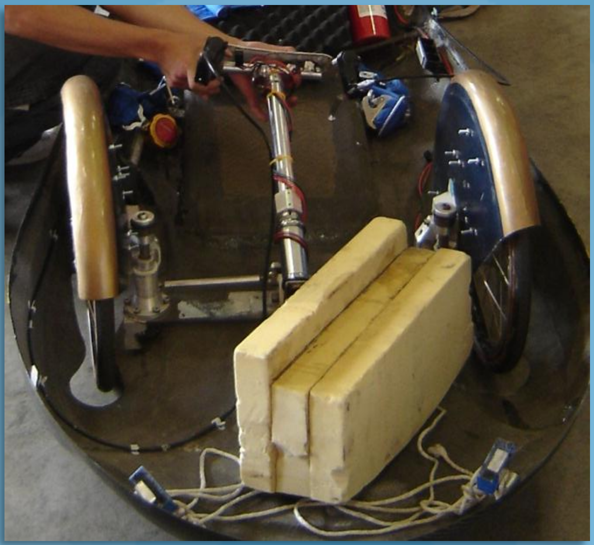
Steering

- Restrictions for turning radius from Shell Eco-marathon
  - Turning radius of 6m

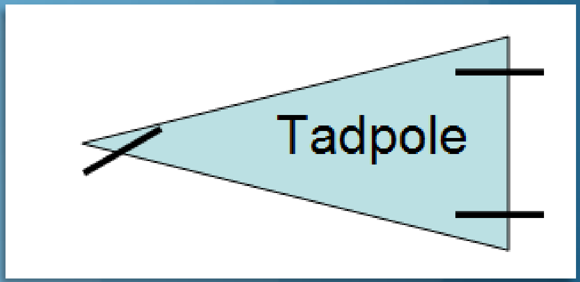
Designs:

Differenetially Driven

Front Steered



Rear Steered



Clay Norbbin

Selection of Steering

	Differential	Front	Rear	Weighting
Price	6	7	5	.2
Performance	8	6	4	.25
Complexity	3	7	6	.2
Weight	5	7	8	.25
Size	9	5	7	.1
Total	5.95	6.55	5.9	

Joseph Petit-Homme

Chassis – Monocoque

Decision Matrix

Chassis Structure	Price	Weight	Performance	Looks	Total
Aluminum - Carbon Fiber (CF)	3	2	4	4	3.1
Honeycomb CF Monocoque	3	4	5	4	3.85
Wood - Plastic	5	3	2	3	3.55
Weighting	0.4	0.25	0.25	0.1	Scale: 1-5

TECHNICAL SPECIFICATIONS

Properties of Carbon Fiber

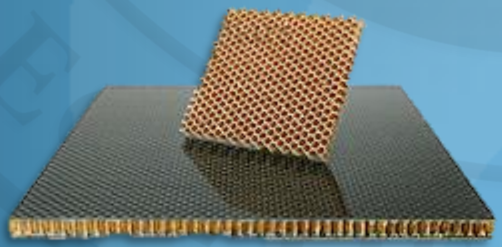
Tensile Strength:	512 ksi
Tensile Modulus:	33.4 Msi

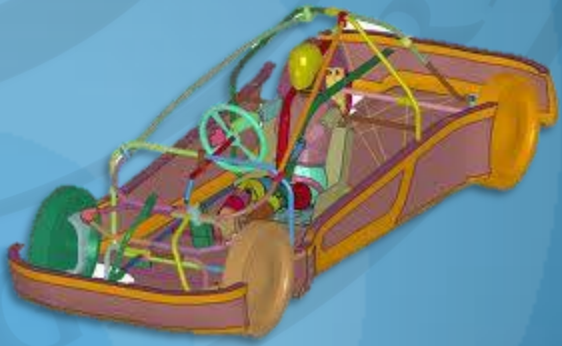
Properties of Honeycomb Core

Compressive Strength :	200 psi
Compressive Modulus:	2175 psi
Tensile Strength:	72.5 psi
Density:	4.8 lb/ft^3
Shear Strength:	70 psi
Shear Modulus:	725 psi

Lay Up Schedule

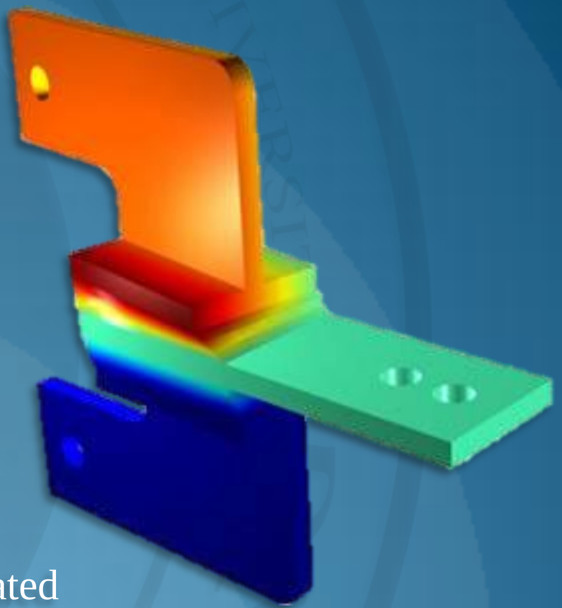
3 Layers Plain Weave Carbon Fiber (quasi-isotropic)
Polypropylene Structural Honeycomb
3 Layers Plain Weave Carbon Fiber (quasi-isotropic)



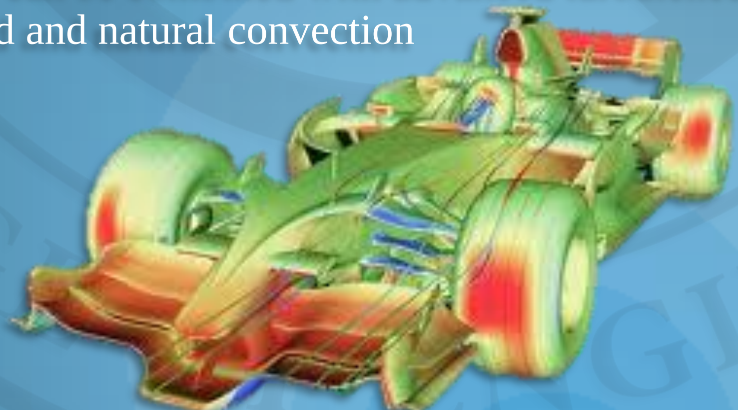


Joseph Petit-Homme

Comsol

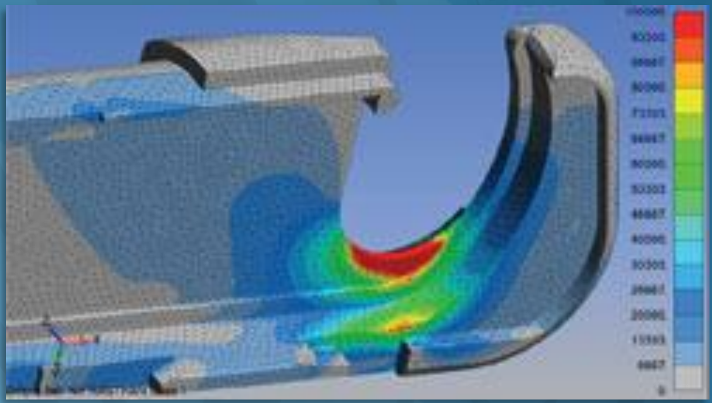


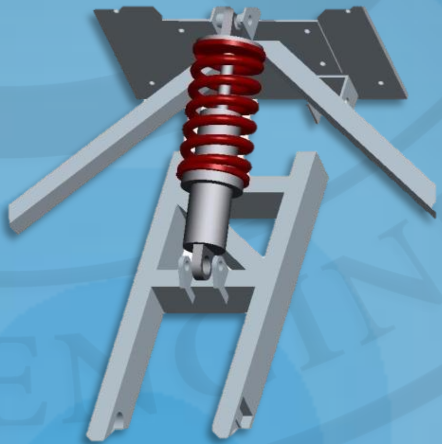
- Structural Mechanics Module
  - The Structural Mechanics Module is dedicated to the analysis of components and subsystems where it is necessary to evaluate deformations under loads
- Computational Fluid Mechanic Module
  - The Computational Fluid Dynamics (CFD) Module is the premier tool in the COMSOL product suite for sophisticated fluid flow simulations. Compressible as well as incompressible flows can be combined with advanced turbulence models and forced and natural convection



Comsol

- Perform Stress Tests
- Aerodynamic Simulation
- Decision matrix for optimization

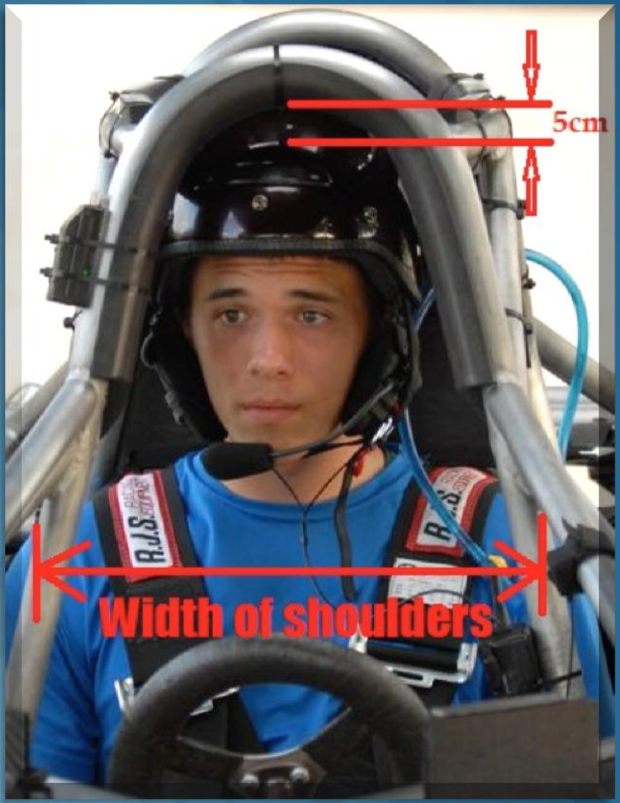




Daniel Green

Roll Bar

- Width extends beyond driver's shoulders
- 5 cm gap above helmet when seated
- Withstand minimum static load of 700 N (~ 70 kg) without deforming

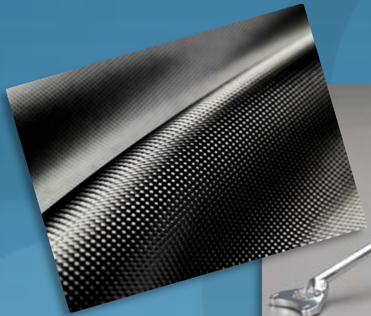


Material Choices

- Aluminum
- Chromoly Steel
- Carbon Fiber

Daniel Green

Material Decision Matrix



Scale: 1-5	Weight	Machinability	Cost	Safety	Total
Aluminum	Light weight, more material required (**3**)	Easy to machine, more difficult to form than steel (**4**)	Very cheap to purchase and machine (**4**)	Moderate danger of rapid failure, low strength (**2**)	**2.9**
Chromoly Steel	A lighter steel, heaviest material (**3**)	Simple to machine and form (**5**)	Expensive to purchase and machine (**2**)	Durable, resilient to impact, good strength (**4**)	**3.4**
Carbon Fiber	Extremely light, lightest material (**5**)	Very difficult and slow to machine and form (**1**)	Relatively inexpensive, machine cost varies with quality (**3**)	Durable, very resilient , highest strength (**5**)	**4.2**
Weighting	**0.3**	**0.1**	**0.2**	**0.4**	

Daniel Green

Hatch

- Required Capabilities
  - Must not hinder 10 second vehicle escape
  - Does not shatter into dangerous shards
  - Must have unassisted 180˚ line of sight
  - Must open from inside and outside vehicle

Daniel Green

Material Decision Matrix

Material must be lightweight, stiff, strong, with optical clarity

Polycarbonate

Or

Acrylic

Scale: 1-5	Impact Resistance	Machinability	Cost	Clarity	Total
Polycarb-onate (Lexan)	Very high, used in bulletproof glass (**5**)	Easy to work with and form (**5**)	Substantially more expensive (**2**)	Good clarity, risk of yellowing (**4**)	**4.05**
Acrylic (Plexiglas)	Weaker than Lexan by factor of three (**2**)	More fragile and likely to break while forming (**3**)	Cheaper than Lexan by factor of three (**5**)	Great clarity, can be polished (**5**)	**3.75**
Weighting	**0.35**	**0.1**	**0.2**	**0.35**	

Daniel Green

Latch System

Three existing preferences…

Spring-Loaded Slam Latch

Double-Point Cable Latch

Fixed-Rod Multi-Point Latch

Daniel Green

Final Latch Decision???

Being as there are many various latch types and ways to implement them, the team has yet to arrive at a final decision

Daniel Green

Hinge System

Simple Removable Pin Hinge

- Cheap if purchased
- Easy installation
- Allows complete removal of hatch
- Possible to make in machine shop

Christopher Dresner

Battery System

- Designed from motor specifications (48V, 800W)
- 24V vs. 48V
  - More efficient at 24V
- Testing
  - Battery Cells/ Pack performance
  - BMS
  - Charging abilities
  - Complete energy system
- Risks
  - Over Charging
  - Fire

Battery Options

- Li-ion 18650 Cylindrical

Company	Nominal Voltage	Nominal Capacity	Dimensions (H, D)	Weight
Tenergy	3.7 V	2.2 Ah	2.6 in, 0.7 in	0.1 lbs

- Lithium Iron Phosphate (LiFePo4)

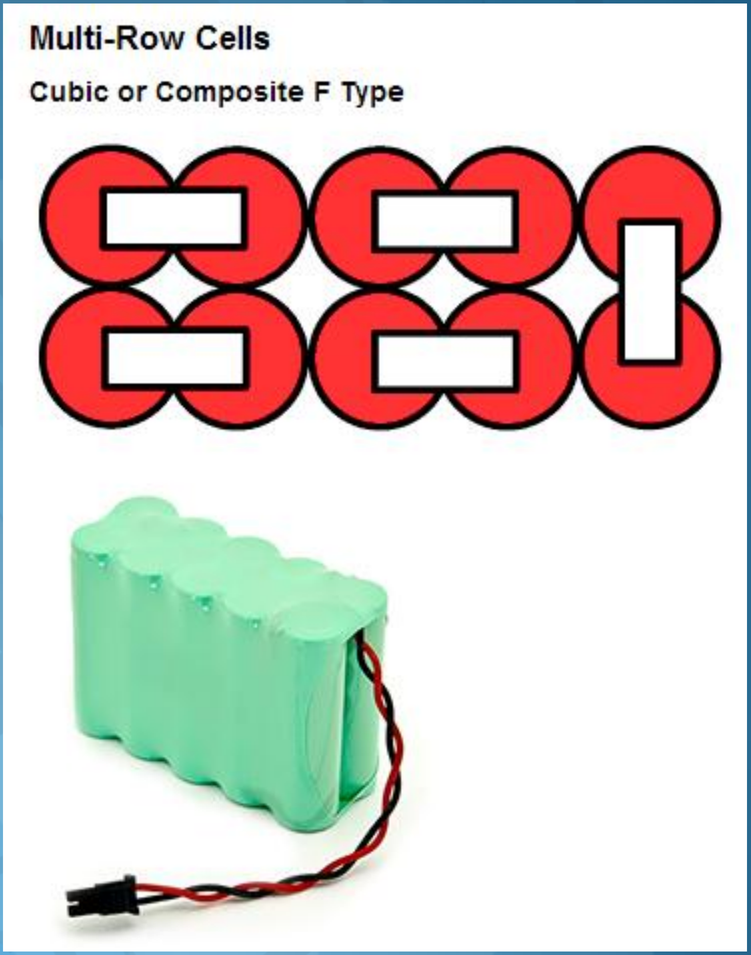
Company	Nominal Voltage	Nominal Capacity	Dimensions (L x W x H)	Weight
Tenergy	3.2 V	20 Ah	9.8 x 6.9 x 0.3 in	1.25 lbs
Elite Power Solutions	3.2 V	60 Ah	5 x 2.6 x 7.1 in	5.5 lbs

Christopher Dresner

Li-Ion 18650 Cylindrical

- 24V, 60Ah Battery Pack
  - 7 Series, 28 Parallel Combination
  - 196 Batteries - $1100
  - Weight: 20 lbs
  - Individual PCB protection

Pros	Cons
Lightweight	Long, tedious process to connect all the batteries
Small dimensions	Additional BMS needed to prevent against risk of fire



Christopher Dresner

Tenergy

- Custom made battery pack ($1500-$2000)
  - 24 - 3.2V, 20Ah Flat Cell Batteries
  - 8 Series, 3 Parallel Combination
    - Weight: 30.2 lbs
  - Battery Management System
    - LED gas gauge to show state of charge
  - Battery Charger
  - Battery pack NOT finalized

Christopher Dresner

Elite Power Solutions

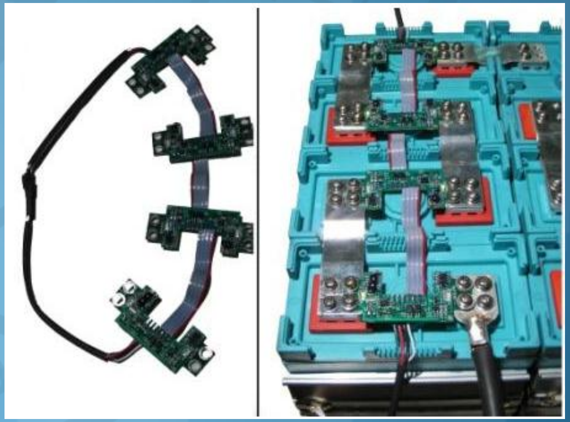
- Cost: $1300
- 8 GBS 60Ah Li-ion Cells
- Energy Management System
    - CPU
    - Sensor Boards
    - Shunt sensor
    - LCD Monitor
- Charger

Christopher Dresner

Elite Power Solutions

- 8 GBS 60Ah Li-Ion Cells
  - Voltage
    - Nominal: 24V, Range: 22.4-29.4V
  - Capacity
    - Cell: 60Ah, Pack: 1.54kWh
  - Dimensions
    - Weight: 40.6 lbs
    - 10 x 11 x 7.1 in

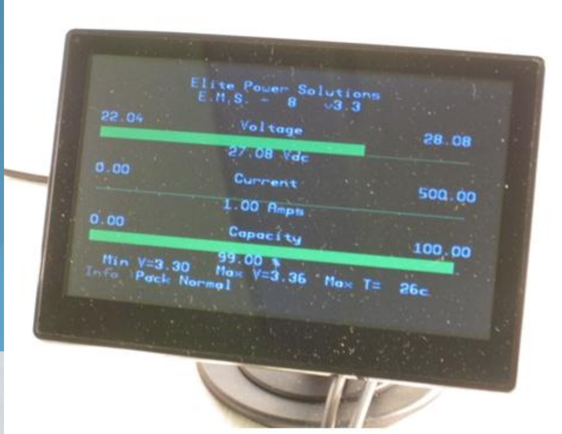
- Sensor Board Strings



Elite Power Solutions

- CPU
  - Provides alarm and video output

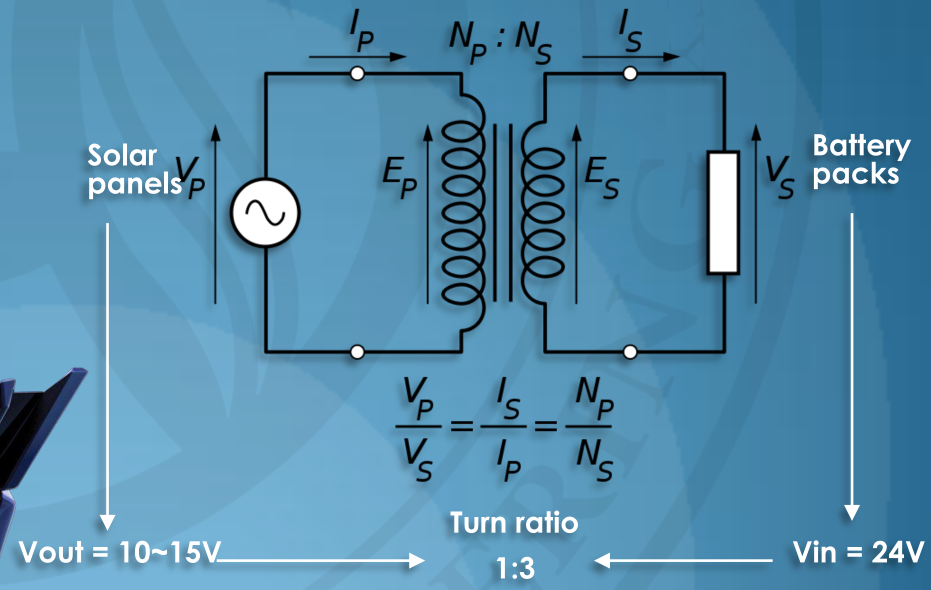
- LCD Monitor
  - Pack voltage, pack current, state of charge, individual cell voltage and temperature



- Li-Ion Battery Charger
  - Input: 110V AC single phase
  - Output: 29.4V, 15A DC
  - Interfaces with BMS

Thierry Kayiranga

Energy Conversion: High Frequency Transformer



Thierry Kayiranga

Energy Conversion: High Frequency Transformer

Model No.	Output Power	Secondary Volts.	Freq. Range	Price
AL-T250.1	250 Watts	150 V rms.	45Hz to 5000Hz	$350.00
AL-T250.2	250 Watts	150V rms.	5KHz to 50KHz	$375.00
AL-T250.3	250 Watts	150V rms.	50KHz to 250KHz	$400.00
AL-T250.4	250 Watts	150V rms.	250KHz to 800KHz	$450.00
AL-T350.1	350 Watts	300 V rms.	45Hz to 5000Hz	$450.00
AL-T350.2	350 Watts	300V rms.	5KHz to 50KHz	$475.00
AL-T350.3	350 Watts	300V rms.	50KHz to 250KHz	$500.00
AL-T350.4	350 Watts	300V rms.	250KHz to 800KHz	$550.00
AL-T500.1	500 Watts	1000V rms.	100Hz to 1000Hz	$550.00
AL-T500.2	500 Watts	1000V rms.	1000Hz to 7000Hz	$600.00
AL-T500.3	500 Watts	1000V rms.	7KHz to 30KHz	$650.00
AL-T500.4	500 Watts	1000V rms.	30KHz to 100KHz	$700.00
AL-T500.5	500 Watts	2500V rms.	100Hz to 800Hz	$800.00
AL-T500.6	500 Watts	2500V rms.	800Hz to 4000Hz	$850.00
AL-T500.7	500 Watts	2500V rms.	4KHz to 15KHz	$900.00
AL-T500.8	500 Watts	2500V rms.	15KHz to 60KHz	$950.00
AL-T750.1	750 Watts	3500V rms.	100Hz to 700Hz	$1000.00
AL-T750.2	750 Watts	3500V rms.	700Hz to 3000Hz	$1050.00
AL-T750.3	750 Watts	3500V rms.	3KHz to 10KHz	$1100.00
AL-T750.4	750 Watts	3500V rms.	10KHz to 40KHz	$1150.00
AL-T1000.1	1000 Watts	5000V rms.	100Hz to 600Hz	$1200.00
AL-T1000.2	1000 Watts	5000V rms.	600Hz to 2500Hz	$1300.00
AL-T1000.3	1000 Watts	5000V rms.	2.5KHz to 8KHz	$1400.00
AL-T1000.4	1000 Watts	5000V rms.	8KHz to 30KHz	$1500.00
AL-T1000.5	1000 Watts	7000V rms.	2KHz to 10KHz	$1700.00
AL-T1000.6	1000 Watts	7000V rms.	10KHz to 40KHz	$1800.00
AL-T1000.7	1000 Watts	10KV rms.	2KHz to 10KHz	$1800.00
AL-T1000.8	1000 Watts	10KV rms.	10KHz to 30KHz	$1950.00

Budget risk: Moderate

The transformer is rather expensive but is well within budget. However, a replacement is not an option and would be not in the budget

Technical risk: Moderate

The transformer can be made with the values of the turn ratio overestimated or underestimated causing either low or high voltage at the secondary terminal. However, no damage will be done to the batteries

Schedule risk: Low

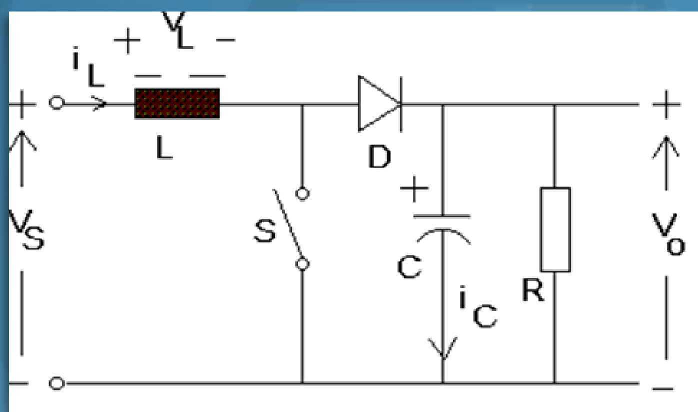
Custom-made transformers delivery could be delayed or lost.

Thierry Kayiranga

Energy Conversion: Boost Converter

Solar panels

Vout = 10~15V



Battery packs

Vin = 24V

$$D = 1 - \frac{V_i}{V_o}$$

Duty Cycle: 0.5

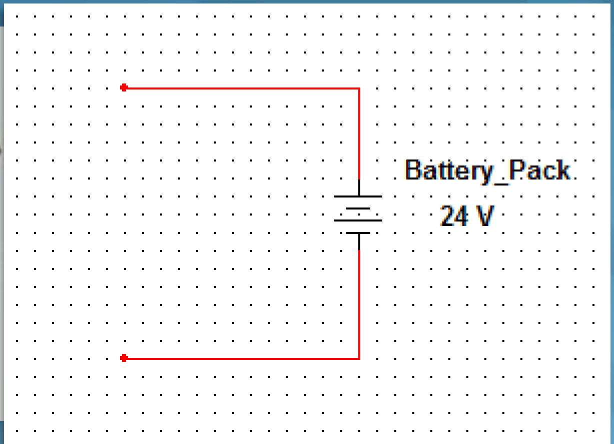
L = 0.5uH

C = 25uH

Schedule risk: Low
Custom-made converter delivery could be delayed or lost.
Technical Risk: Low
Passive elements could burn or explosive if driven over specified values

Thierry Kayiranga

Energy Conversion:
Direct Connection from Solar to Battery



Connecting the solar panels directly to the terminals of the battery packs. The design charges battery and provides a little current to motor

Solar panels

Vout = 10~15V

Battery Packs

Technical Risk: Low

Proposed design could not work as expected

Thierry Kayiranga

Energy Conversion:

	Pros	Cons
High Frequency Transformer	• Efficient	• Heavy • Dangerous to operate (overvoltage case) • Expensive
Boost converter	• Most efficiency • Cheap and safe	• Limit of output (Based on simulation)
Solar-Battery	• Efficiency • Less batteries	• Little knowledge of working mechanism (Need real life testing for proposed model)

Ahmad Farhat

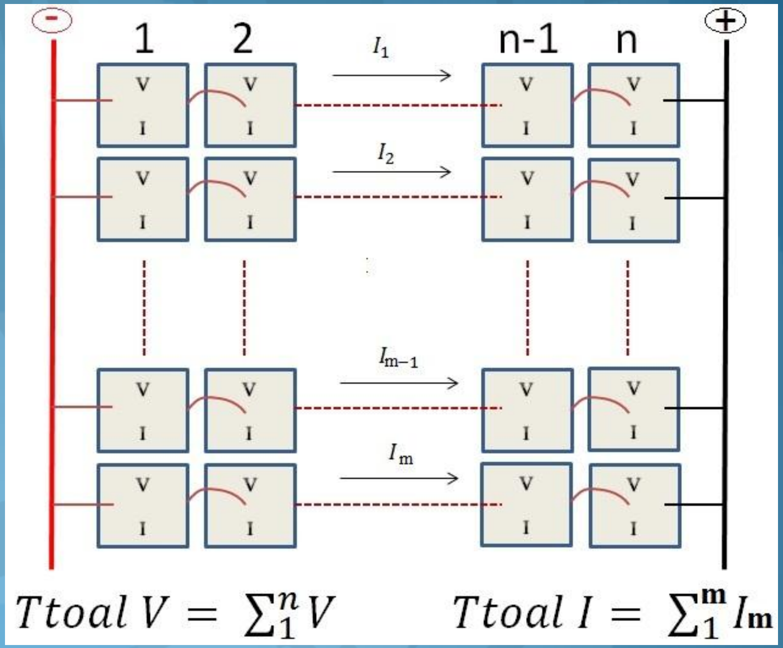
Solar Panels

General Solar Cells Aspects:

- To increase the Voltage the cells must be connected in series.
- To increase the Current the cells must be connected in parallel.

Solar Car Array Design:

- The right amount of voltage and current needed must be determined first.
- Solar cells will be only covering 0.17 m^2 of the whole surface area.
- Small modules will be build to easily install it at the preferred spots of the car body.



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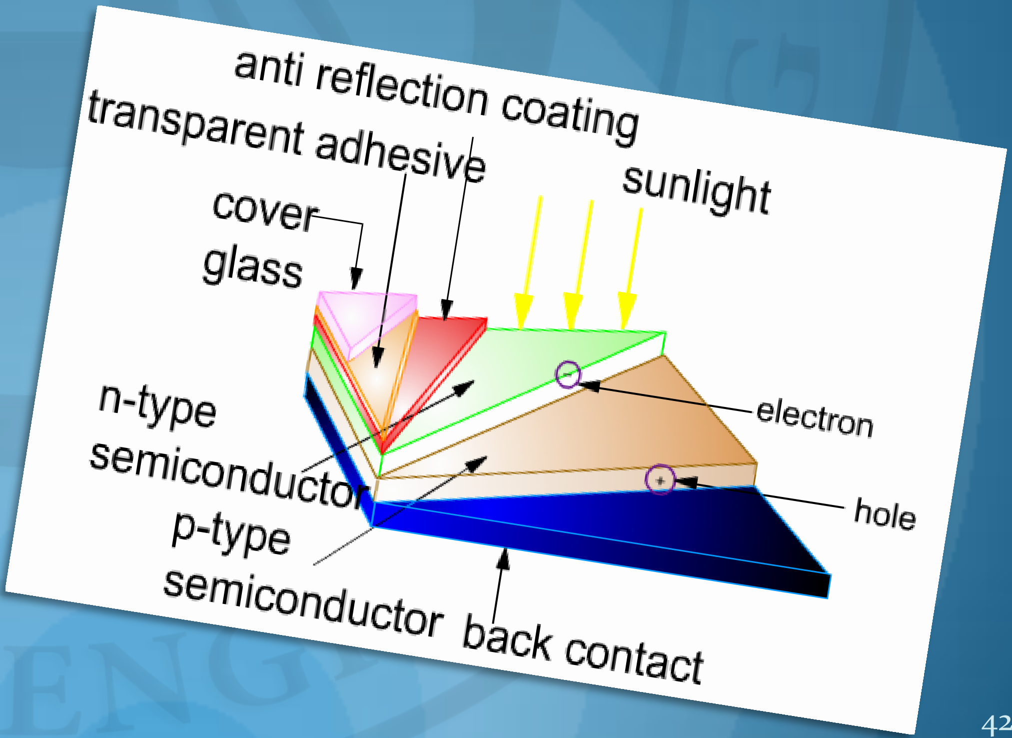
Solar Panels – Option 1

Manufacture Solar Cells

- To develop higher efficiency cells compared to market availability.
- One month will been dedicated to research into manufacturing solar panels.

Risks

- Time needed
- Manufacturing cost
- Access to equipment



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Solar Panels – Option 2

125x125 Mono-Crystalline Solar Cells

Voltage (OC) (V)	0.6
Current (sc) (mA)	6.8
Loaded Voltage (V)	0.53
Loaded Current (mA)	5.2
Ideal Power (W)	4.08
Loaded Power (W)	2.756
Efficiency	17.6
Panel Size (Inches)	5x5
Panel Size (mm)	125x125

- Not Flexible
- High current low voltage
- Cell Price $1.25
- Delivery time before the new year

- SunPower calls "C60 Bin J“

Voltage (OC) (V)	0.687
Current (sc) (mA)	6.28
Loaded Voltage (V)	0.582
Loaded Current (mA)	5.93
Ideal Power (W)	4.31
Loaded Power (W)	3.45
Efficiency	22.5
Panel Size (Inches)	5x5
Panel Size (mm)	125x125

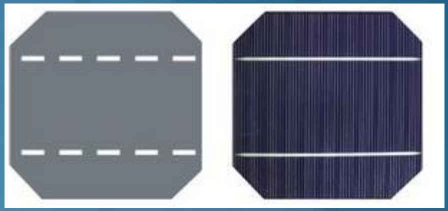
- Flexible
- High current low voltage
- Cell price $40
- Lead Time up to 9 month

Ahmad Farhat

Solar Panels – Option 2

125x125 Mono-Crystalline Solar Cells

- Can be purchased
- Max number of cells can be used 10
- Cutting the cells in half to double the Voltage and Current
  - Laser Cutting tool will be needed



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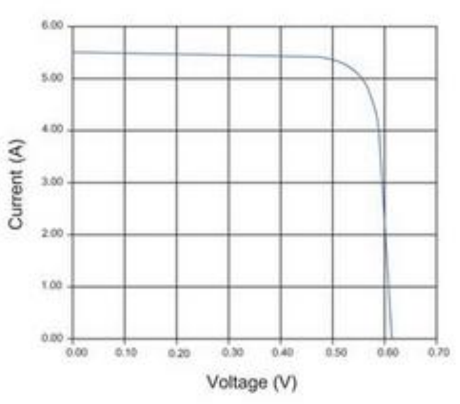

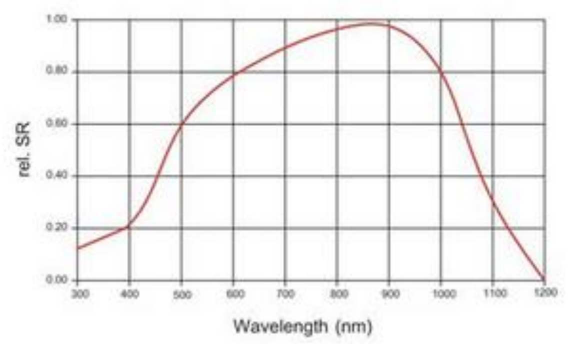

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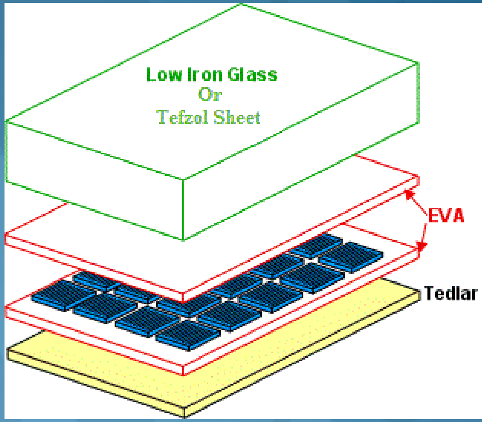
Solar Panels – Physical Protection

Tefzel/ Eva

- Multi-layer protection
- Mentor: Ian Winger inventor of ‘Solar Sausage’

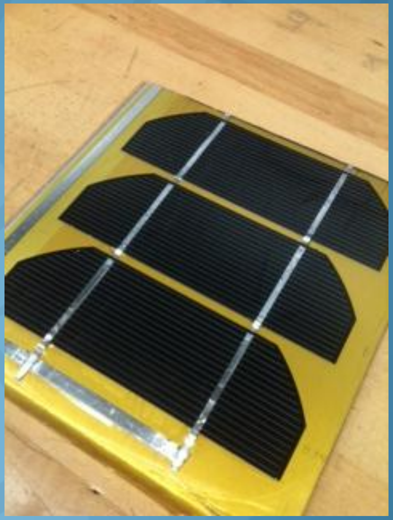


Risks

- Heat Oven will be needed
- Chance of Air bubbles

AeroMarine 300-21 Epoxy Resin

- Self Leveling
- Excellent gloss and clarity



Risks

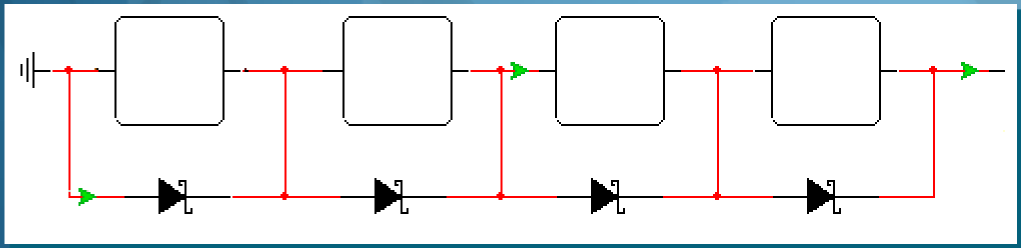
- Mixing Process is critical
- Chance of Air bubbles

Ahmad Farhat

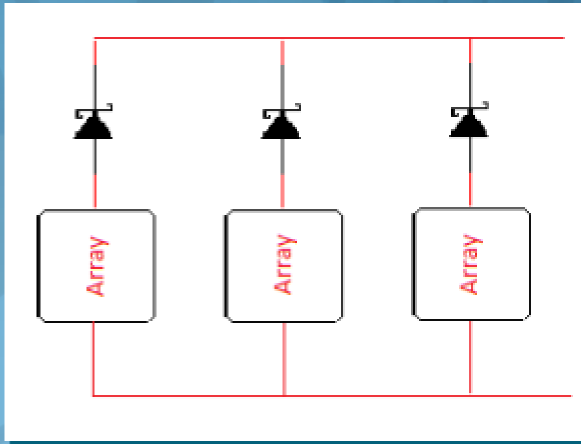
Solar Panels – Electrical Protection

The basic function of bypass diodes in solar cells is to protect against hot spot damage when the photovoltaic panel is partially shaded by snow, fallen leaves, or other obstructions

The basic function of blocking diodes in solar arrays is to prevent current flow into array.



bypass diodes



blocking diodes

Low voltage Schottky diode will be used
low break point voltage “0.2 v” cheap price “$0.25”

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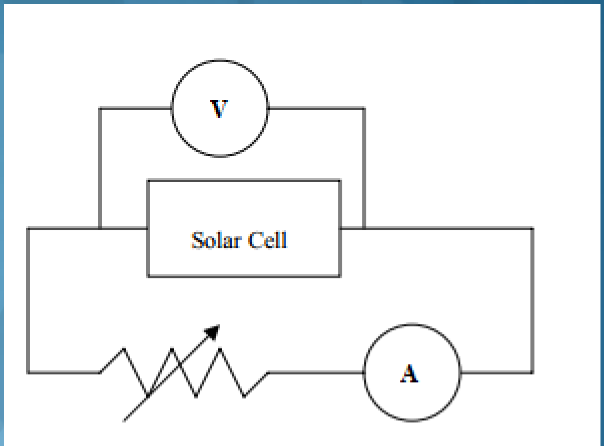
Solar Panels – Testing

Electrical Testing

- Software Simulation (Matlab,Multisim)
- Sample Cell will be tested to assure that data meet the factory specs
- Measure panel at different irradiation levels



Physical Testing

- Test Cells by dropping it from different heights

Solar Panel Risks

- Cells are fragile
- Exceed the allowed surface area
- Wrong encapsulation process
- No access to Heat Oven
- Wrong insulation

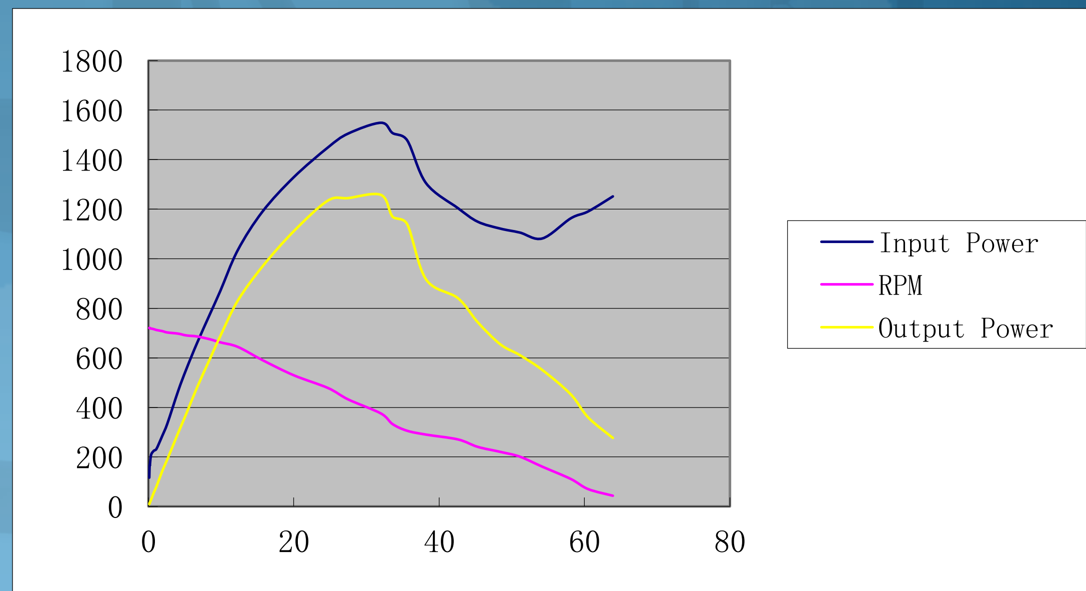
Matthew Bosworth

Motor

	Pros	Cons
LEMCO	• Moderately Priced • Powerful	• Mechanical Losses through gears • Lower Efficiency
Nu-Gen	• Most efficiency • In-wheel	• Made for 96V system • Very Expensive • 9 month lead time
Kelly Controls	• In-wheel, hub • 48V, 800W can run at 24V. • Comes in kit with controller and regen braking • <$1000	• Size of wheel

Matthew Bosworth

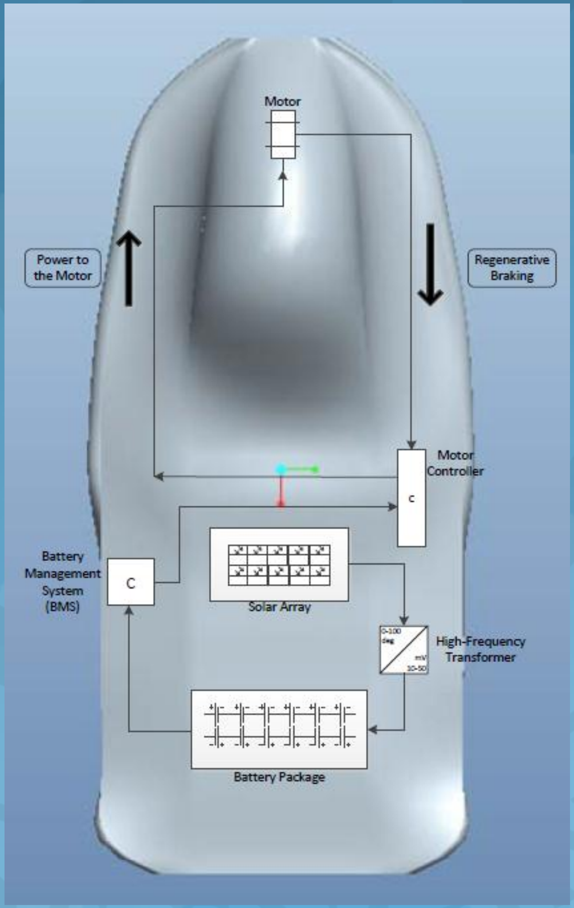
Motor



Torque (Nm)

Matthew Bosworth

Top Level Design



Matthew Bosworth

Projected Efforts for Year 2

- Braking, Horn, Fire Extingusiher
- Energy System Integration/Installation/Testing

Risk Assesment

General Uncertainties:

- Incompletely identified requirements or constraints:
  - Interpretation of goals
  - Communication

- Unidentified Solutions to Meet Requirements or Capabilities:
  - Monetary reasons
  - Physical limitations

- Technologies or Devices Not Completely Understood or Assessed:
  - Research
  - Overlooked features or limitations

- Critical Scheduling Issues:
  - Proper planning
  - Not enough work