Team #2: Solar Car Needs Analysis and Requirements

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

Outline

- Overview of Project
- Meet the Team
- What is the Shell Eco-Marathon?
- Year 1 ME Goals
  - Starting Over – Prototype Design
  - Prototype Testing
  - Suspension and Wheels
  - Safety – Bulkheads and Visibility
  - Exit Strategy
- Year 1 EE Goals
  - Energy Conversion System
  - Batteries
  - Solar Panels
- Preliminary Schedule and Budget

Overview of Project

- Complete redesign of Solar Car
  - Body, chassis, suspension, wheels, steering, energy system, and motor.
- This 2 year project consists of designing, building and testing a car that is ready for the "Shell Eco-Marathon" competition in Summer 2014.
- The car will run completely on batteries, a supercapacitor and solar power with all necessary safety, chassis size, and weight requirements met.
- This year's efforts focus on the energy system and the design and build of the body of the car.

Meet the Team

- **Matthew Bosworth**

Project Leader and EE Lead

  - Energy System(MCU, motor), overall design

- **Clay Norrbin**

ME Lead

  - Prototype #1, Bottom Half of Car body, Suspension

- **Ahmad Farhat**

EE Finance Manager

  - Energy System(Solar panels), Car shape

- **Joseph Petit-Homme**

ME Finance Manager

  - Prototype #3, Aerodynamics, Interior Design, Wheels

- **Christopher Dresner**

EE Business Admin.

  - Energy System(Batteries, Supercapacitor, motor), Simulations

- **Daniel Green**

ME Business Admin.

  - Prototype #2, Top half of Car body, Roll Bar, Exit Scheme

- **Thierry Kayiranga**

Secretary

  - Energy System(Power Electronics), Simulations

What is the Shell Eco-Marathon?

- The Shell Eco-Marathon challenges student teams to design, build and test ultra energy-efficient vehicles.
- The winners are the teams that go the furthest using the least amount of energy.

Shell Eco-Marathon Constraints

- New "Solar-Battery Electric Class" for 2013
- Safety First
  - Bulkheads, Fire retardant materials, exit strategy, roll bar, maximum voltage requirements, limitations on battery type, protection circuits, etc.
- Size and weight limitations
- Reference **Section 3** of our Needs Assessment and Requirements Specifications for a more detailed list of constraints and limitations.
- Shell's rules and regulations may change for next year's competition

Year 1 Goals

Mechanical Engineering

Clay Norrbin

New Challenge – New Beginning

- Current car designed around American Solar Car Challenge
- Shell Eco-marathon has different rules

Clay Norrbin

Starting Over – Prototype Design

- Smaller Body Size
  - 1650+ on unknown terrain vs. 6 miles on flat ground.
  - Need of the lowest Coefficient of Drag as possible.

Clay Norrbin

Prototype Comparison – Smaller Body Size

Old car

Competitor

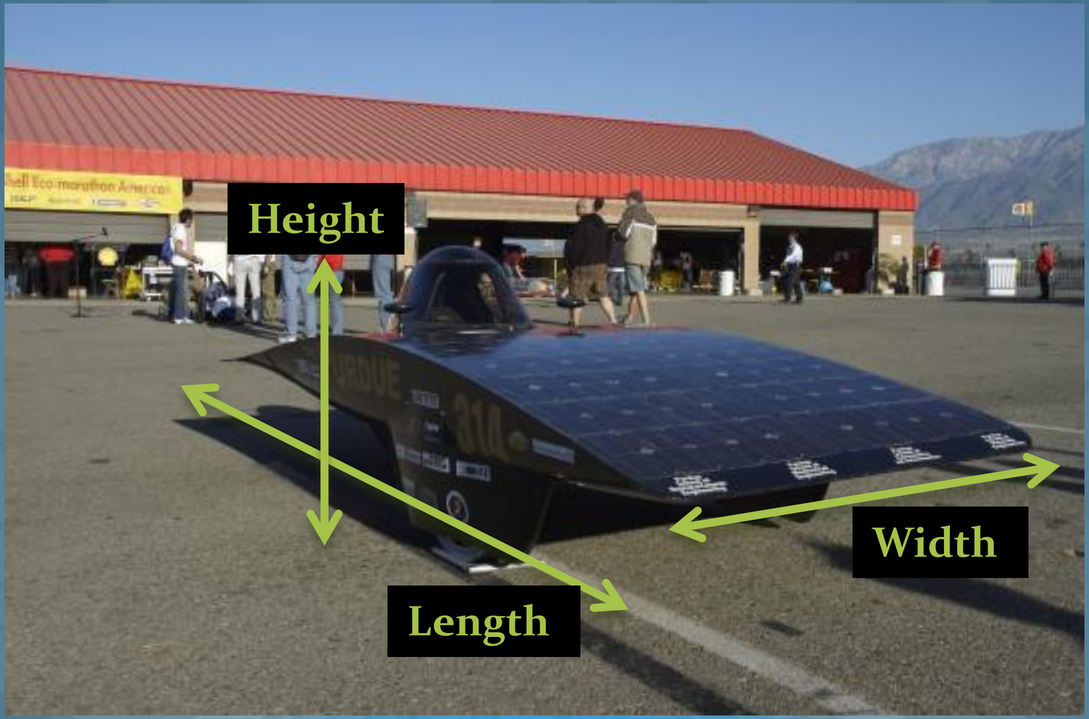
Clay Norrbin

New Prototype - Restrictions

Height <= 100cm Width <= 130cm Length <= 350cm

Test previous body vs. three prototypes

Vehicle weight <= 140kg(308lb)



Clay Norrbin

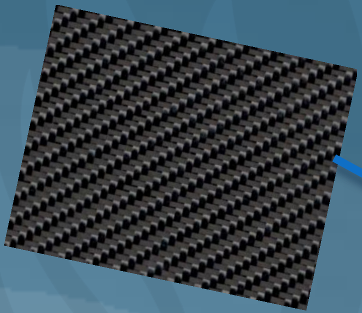
3 Prototypes

- Based on previous winners of solar car competitions
  - Purdue University
  - University of Michigan
  - Tokai University

Clay Norrbin

Body Fabrication - Price Estimate

- Carbon Fiber ~ $3,500
  - 5 layers
  - 78,000 sq. in.
- Resin ~ $1,000
  - 1:1 estimate
  - ~10 gallons needed



Joseph Petit-Homme

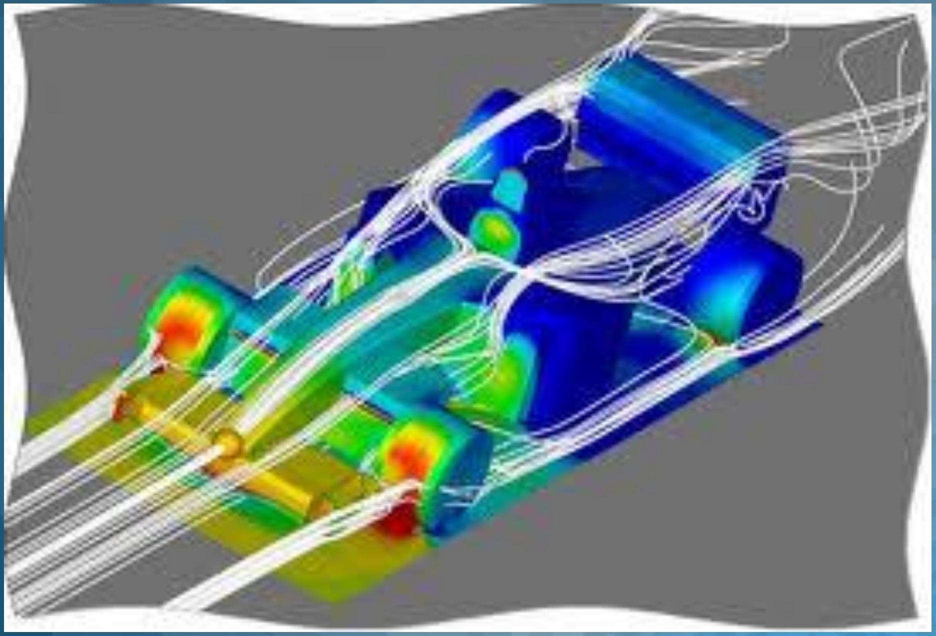
Prototype Testing

- 3D Printed Models 1/10 scale model

Joseph Petit-Homme

Prototype Testing

- Testing Tools
  - Computational Fluid Dynamics (CFD)
    - Subsonic flow – linearized Navier-Stokes equation



Drag and Lift Forces

$$C_D = \frac{F_D}{\frac{1}{2}\rho V^2}, \quad C_L = \frac{F_L}{\frac{1}{2}\rho V^2}$$

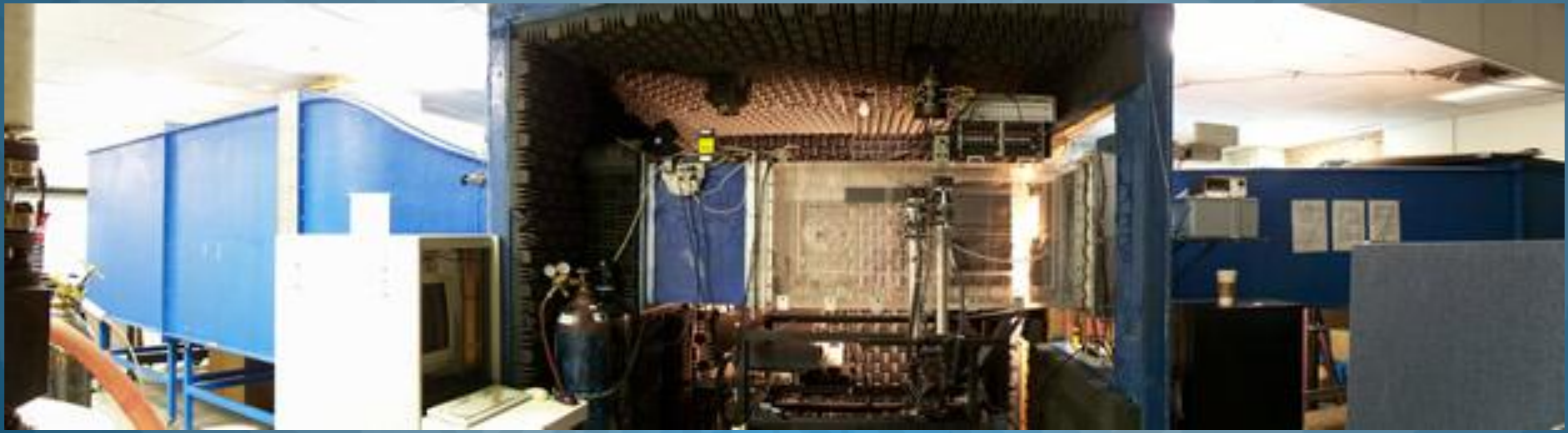
Navier-Stokes equation
(M<0.3, incompressible)

$$\rho\left(\frac{\partial \boldsymbol{v}}{\partial x} + \boldsymbol{v} \cdot \nabla \boldsymbol{v}\right) = -\nabla p + \mu \nabla^2 \boldsymbol{v} + \boldsymbol{f}$$

Joseph Petit-Homme

Prototype Testing

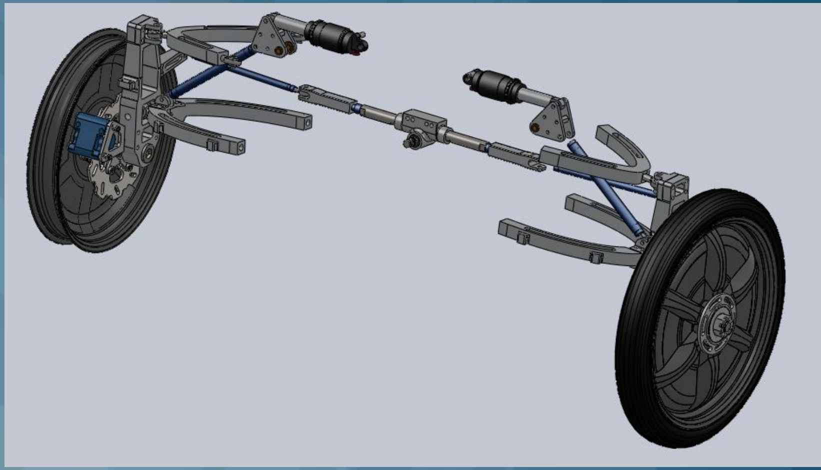
- Testing Tools
  - Wind Tunnel - M < 1
    - Subsonic flow – linearized Navier-Stokes equation
    - Assume fluid incompressible –> Vo_{max}= 90 m/s
  - Water Tunnel – for low Reynolds numbers



Joseph Petit-Homme

Suspension and Wheels

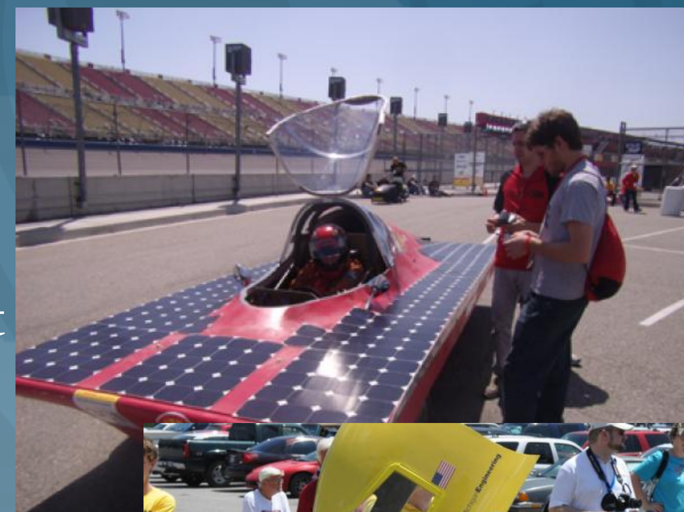
- Design around chassis to make integration easier
- Adequate suspension to prevent bottoming out
- Motorcycle or moped wheels
- Ecopia EP 80 for competiton
- Loose suspension can cause vehicle to flip



Daniel Green

Safety – Hatch and Visibility

- Required Capabilities
  - Escape the vehicle in 10 seconds without assistance.
  - Hatch must be made of a light-weight material with decent impact strength, stiffness and clarity.
  - In the event of an impact the hatch can not shatter into dangerous shards.
  - The driver must have a line of sight of 180˚ without aid.
  - A rear-view mirror must be placed on both sides of the vehicle.



Daniel Green

Safety – Hatch and Visibility

- Viable Material Option
  - Compression Molded Polycarbonate Plastic
    - Excellent dimensional stability
    - Good strength and stiffness over a wide range of temperatures
    - Low moisture absorption
    - Good insulating properties
    - Excellent flammability rating
    - Easy to fabricate, paint and glue

http://www.eplastics.com/Plastic/Sheet_Comparison_Molded_Window_Grade

Daniel Green

Interior Driver Safety – Roll Bar

- Required Capabilities
  - Vehicle chassis must be wide enough to protect the driver in the event of a frontal or lateral collision.
  - Vehicle chassis must be equipped with an effective roll bar that extends the width of the drivers shoulders and at least 5cm around the driver's helmet when seated.
  - The roll bar must withstand a static load of 700N (70kg)

- A strong light-weight metal is necessary
- A mild or chrome-molybdenum steel would be ideal

http://www.custoncages.co.uk/roll-cages/what-material

Daniel Green

10 second Exit Strategy

The batteries of Sikat II of Team Solar Philippines caught fire.
Car had to be evacuated.

Daniel Green

What can we do this year?

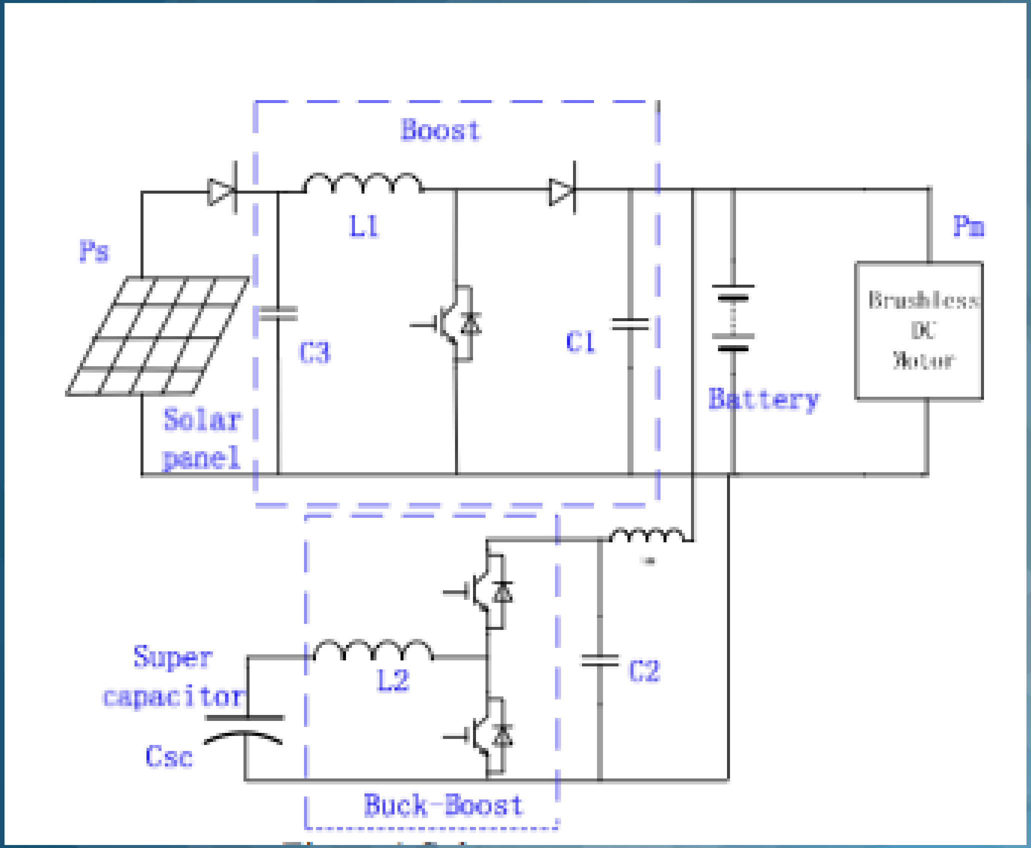
- Isolate the metal most befitting of the roll bar criteria, create the roll bar, test it's strength, and install it in the chassis.
- Choose a polycarbonate or similar material meeting all Shell standards that will serve as a car hatch, have it manufactured, installed, and tested for visibility.
- Measure the time it takes for the driver to escape the vehicle unassisted (once hatch has been installed).
- Ensure that as the car design progresses, the interior remains "collision-safe" for the driver.

Year 1 Goals

Electrical Engineering

Thierry Kayiranga

Energy Conversion System

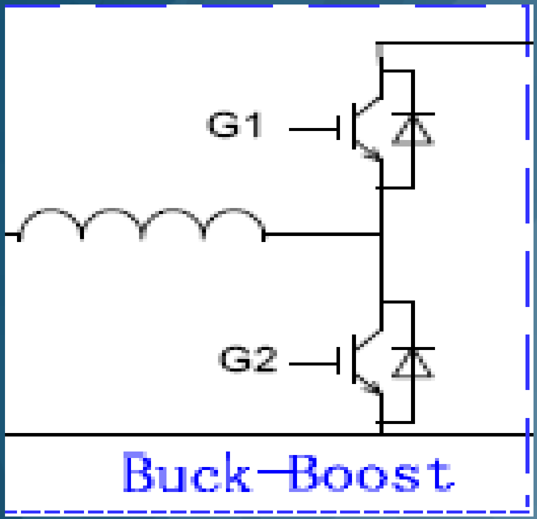


- Car runs on solar energy while cruising and the supercapacitor charges.
- During acceleration or when climbing slopes, the supercapacitor discharges and provides the necessary power to the motor.

Bin Wu et al, A management stategy for solar panel-battery-supercapacitor hybrid energy system in solar car.

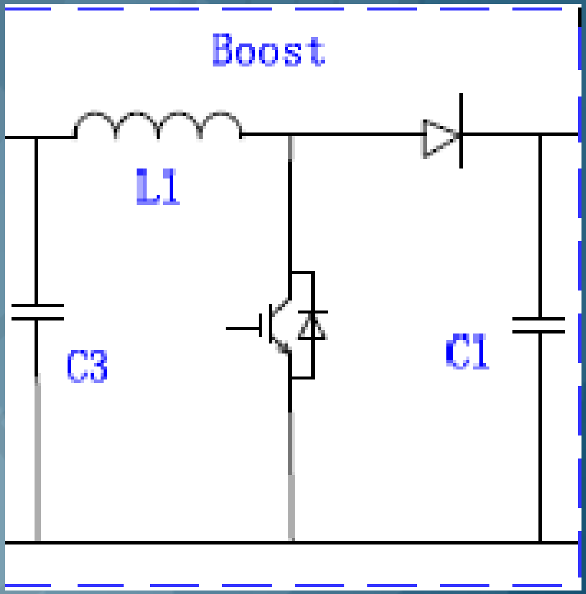
Thierry Kayiranga

Energy Conversion System



Buck Boost Converter
120F,2.3V
2000uF,2.5V
470uF,16V
285mH Inductor

Boost converter
NTE2394 Power MOSFET
10SQ080 Diode
1.8mH Inductor
1.5mF Capacitor



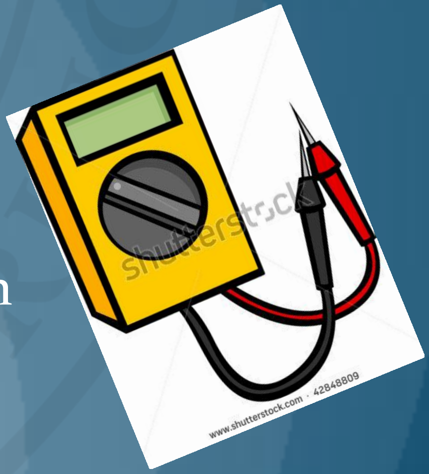
Bin Wu et al, A management stategy for solar panel-battery-supercapacitor hybrid energy system in solar car.

Thierry Kayiranga

Energy Conversion System

Testing Plan:

- Boost Converter: Can it provide power to batter as specified?
- Buck-Boost Converter: Does it switch to the supercapacitor when extra current is needed at the motor?



Limitations:

- Boost Converter
  - Component Value dependent on Solar Panels chosen
- Buck-Boost Converter
  - 120F, 2.3 V
  - Estimated Total Component Cost: ~$60.00

Christopher Dresner

Batteries

Requirements

- Lithium-Ion
  - Nominal voltage in car can not exceed 48V
- Battery Management System
  - Over/Under Voltage, Over Current, Temperature
- Auxiliary battery
  - Horn, Lights, Accessories, etc.

Constraints

- Voltage and Current ratings
- Size and Weight
- Cost

Testing

- Voltage and current measurements
- Charging abilities
- Battery management system

Christopher Dresner

Batteries

Outlook

- Thundersky Lithium Iron Phosphate (LiFePO4)

Nominal Voltage	Capacity	Dimensions	Weight	Cost
3.2 V	40 Ah	116 x 46 x 181 mm	1.5 kg	$60

- Tenergy Li-ion cylindrical battery

Nominal Voltage	Capacity	Dimensions	Weight	Cost
3.7 V	2.6 Ah	D=18.7, H=68 mm	50 g	$5.50

- Further consulting required with Dr. Zheng

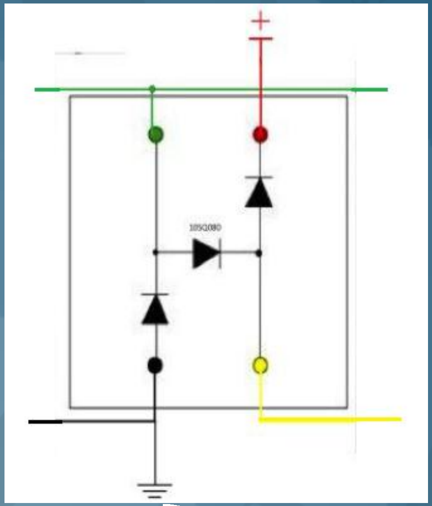
Ahmad Farhat

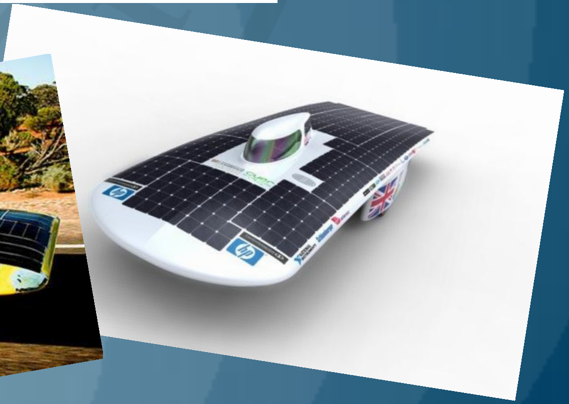
Solar Panels

Conversion of solar energy to electrical energy

- Only source for charging batteries and supercapacitor
- Works as a parallel source
- Panel Protection
  - By-pass and protection diode
  - Current protection diode
- Constraints
  - Weather, body shape, and limited surface area

Protection Circuit





Ahmad Farhat

Solar Panels

Types

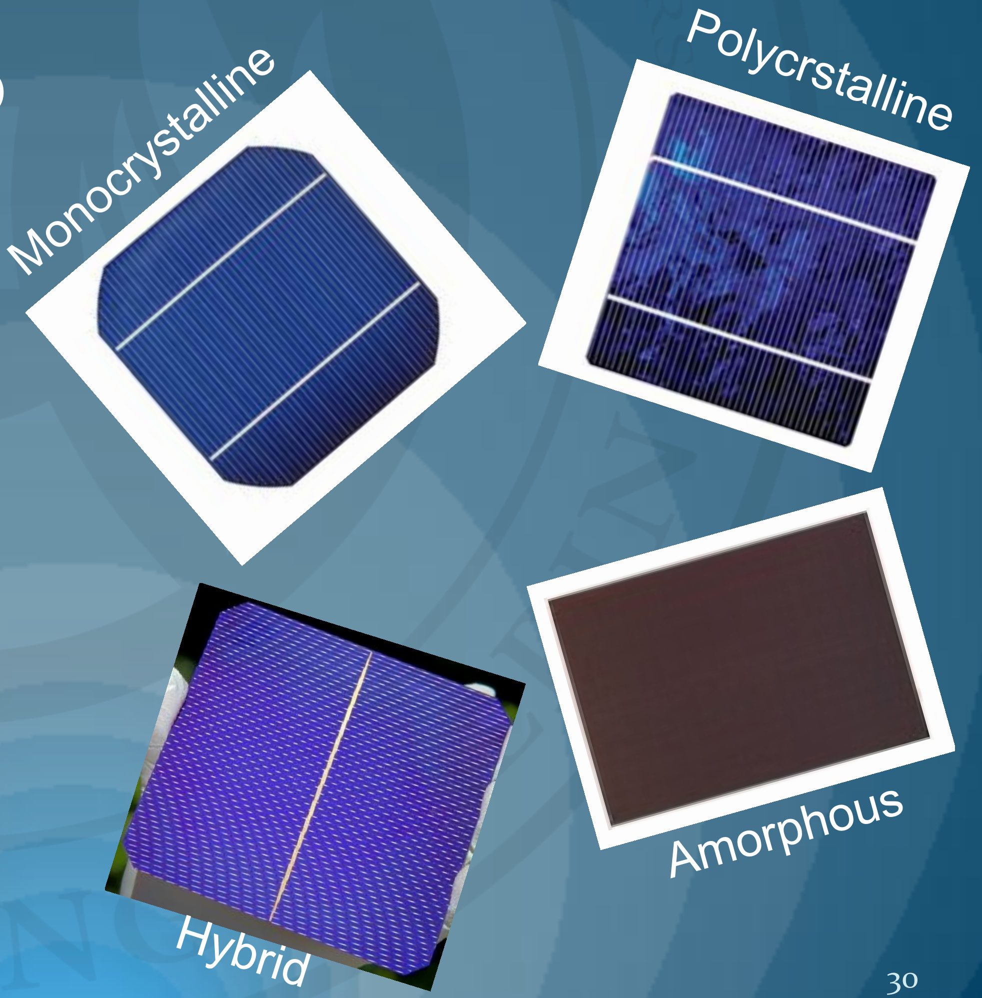
- Monocrystalline Silicon Cells (up to 24.2%)
- Polycrstalline Silicon Cells (up to 19.3%)
- Amorphous Silicon Cells (up to 10%)
- Hybrid Silicon Cells

Monocrystalline Advantages

- High Efficiency
- Acceptable Price
- Higher Current
- Longevity
- Greater Heat Resistance

Monocrystalline Disadvantages

- Fragile
- Not Flexible



Ahmad Farhat

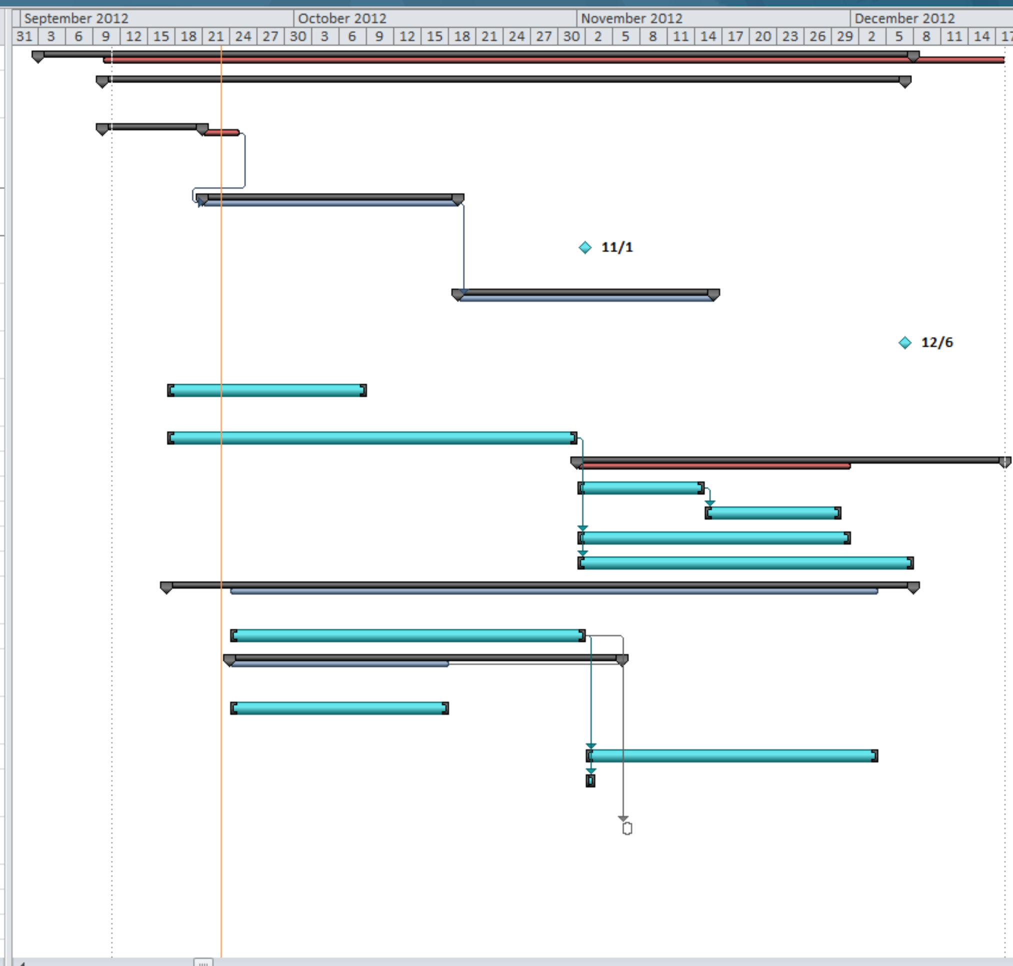
Solar Panels

Solar Cell Type	Dimensions (mm)	Surface Area (m^2)	V	I A	P	Effinciy	Cell Price $	Flexibility
monocrystalline Solar Cell	125 x 125	0.015625	0.53	5.2	2.756	17.6384	1.25	No
monocrystalline Solar Cell	156 x 156	0.024336	0.524	7.83	4.1	16.84746877	2.46 - 2.88	No
Grade B POLY Cell	52x78	0.004056	0.5	1.26	0.63	15.53254438	0.45	No
Grade B POLY Cell	156 x 156	0.024336	0.497	7.16	3.55	14.58744247	1.85	No
power film MPT15-75	253 x 75	0.018975	15.4	5.00E-02	7.70E-01	4.057971014	19.95	Yes
power film MPT15-150	253 x 150	0.03795	15.4	1.00E-01	1.54E+00	4.057971014	39.95	Yes
power film PT15-300	270 x 325	0.08775	15.4	2.00E-01	3.08E+00	3.50997151	99.95	Yes
power film MPT6-150	114 x 150	0.0171	6	1.00E-01	6.00E-01	3.50877193	19.95	Yes
power film MPT6-75	114 x 75	0.00855	6	5.00E-02	3.00E-01	3.50877193	12.95	Yes

Matthew Bosworth

Preliminary Schedule

	Task Mode	Task Name	Duration
1		Senior Design: Semester 1	70 days
2		Documentation and Presentations	64 days
3		Develop Needs Analysis & Requirements	9 days
6		Develop Project Proposal	20 days
9		Professional Engineering	0 days
10		Develop System-Level Design	20 days
13		Quiz on Engineering Ethics & Peer	0 days
14		Body and Chassis Prototyping	16 days
15		ProE Modeling	33 days
16		Car Interior	33 days
17		Cockpit Design	10 days
18		Roll Bar Design	11 days
19		Exit Strategy	22 days
20		Aerodynamic Testing	27 days
21		Energy System Development	60 days
22		Modeling Development	29 days
23		Solar Panel Determination	31 days
24		Modeling Solar Protection	18 days
25		Simulations	22 days
26		Purchasing of Power Electronics	1 day?
27		~~Motor Determination and Purchase~~	~~1 day?~~



Gantt Chart

Ready | New Tasks : Manually Scheduled

Matthew Bosworth

Budget

- Tentative: $6,000 starting.
- Gathering other funding sources.
  - Local Businesses
  - CAPS – Industry Advisory Board (IAB)
  - Contacting Chrysler and Fiat
- Sustainable Engineered Solutions (SES)
  - Support in contacting companies
  - Support in design and manufacturing

Matthew Bosworth

Next Steps

- Finish development of 3 different body prototypes.
- Determine metal for roll bar.
- Begin energy system simulation design.
- Calculate power requirements to determine motor specs
- Determine specs on supercapacitor and batteries.

Thank You

- Questions?