New Teams Workshop MECHANICAL

Solar Car Challenge

Design Criteria

- Design your car to be efficient from the beginning!
- Solar Power: 10% more power will give you a 4% increase in performance.
- Aerodynamics: 10% less drag will give you 3.1% increase in performance
- Rolling resistance: 10% less resistance will give you 1.3% increase in performance.
- Weight: 10% less weight will give you 0.9% increase in performance

What You Can Control

- The four things that you can realistically control:
  - Electrical efficiency
    - Losses due to electrical resistance
    - Losses due to poor gearing
  - Weight
  - Rolling friction
  - Aerodynamic drag

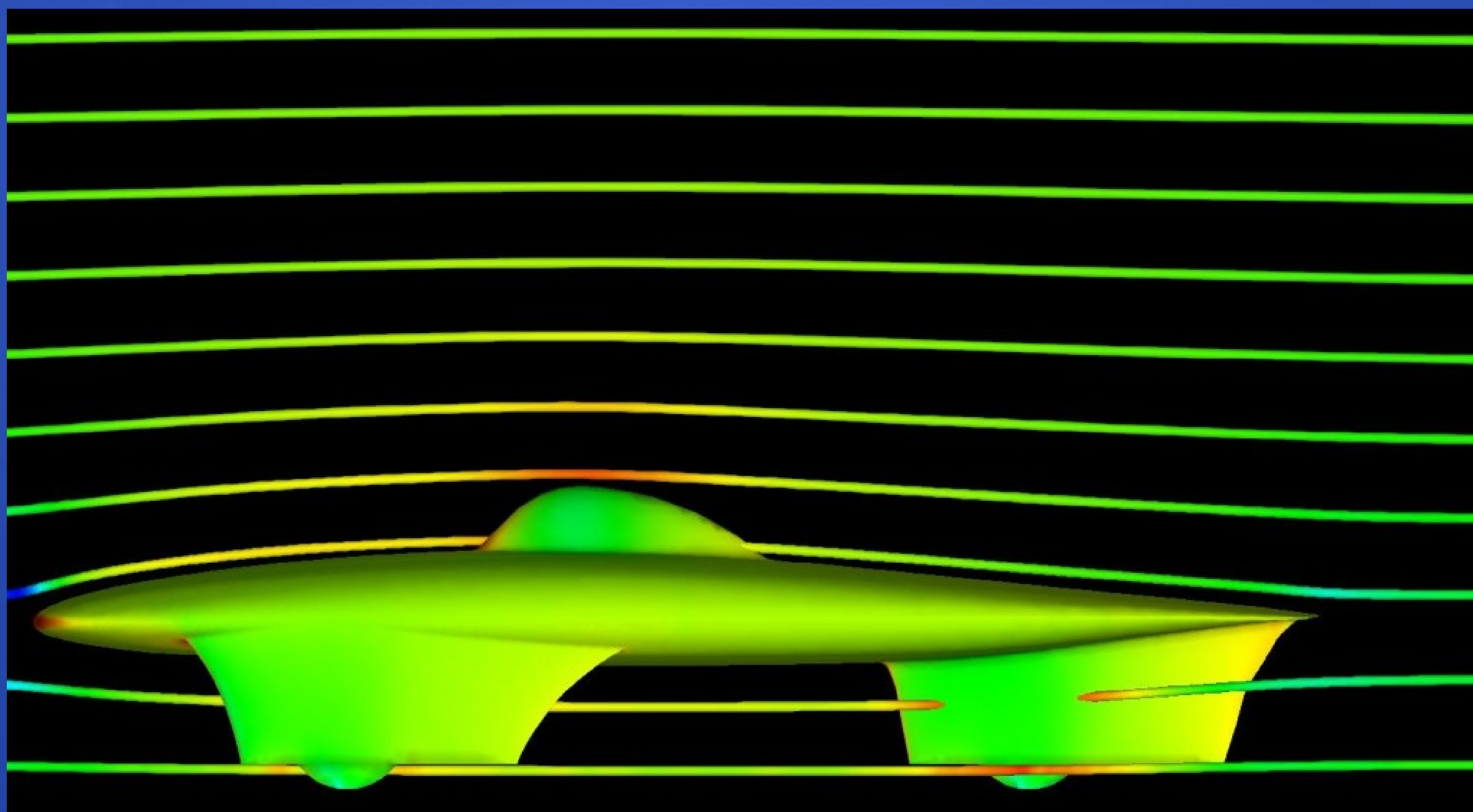
Weight

- Heavier cars have more rolling resistance and take more energy to accelerate. (Much bigger problem in a road race.)
- Do not reduce weight at the cost of safety.
- Making things too light will force you to find an expert welder because things WILL break.

Rolling Resistance

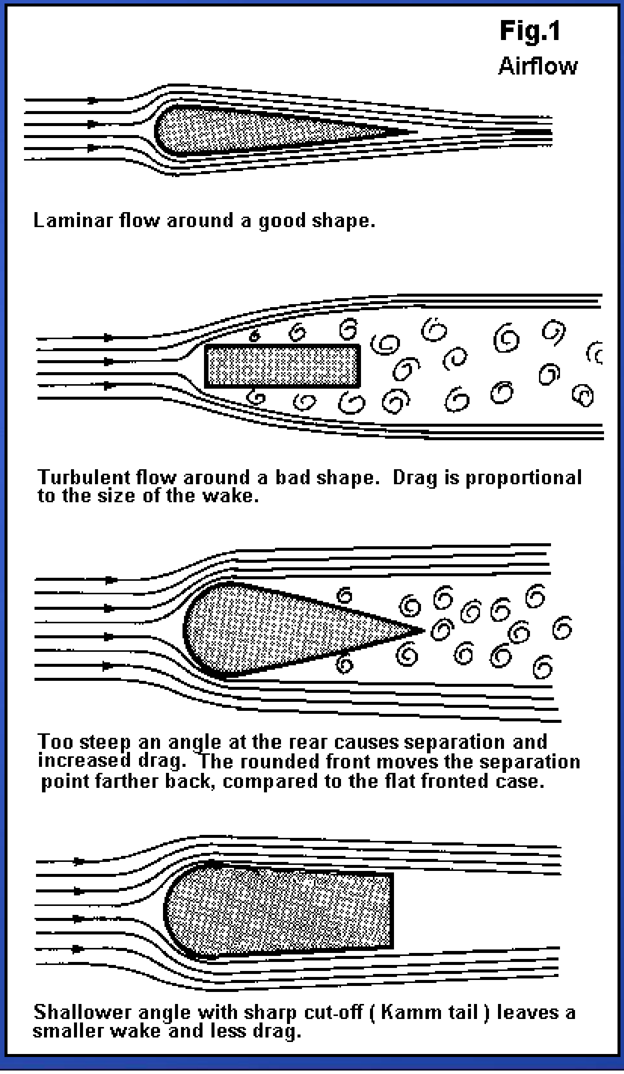
- Bearings can be opened, cleaned, and filled with a light oil.
- Tires with thin "supple" casings roll better than thick casings. (Higher risk of flats)
- Fat tires roll better than thin tires. (But weigh more.)
- If it rotates: lubricate!
- Wheel alignment is critical to reducing rolling resistance.

Aerodynamics



Aerodynamic Drag

- Drag starts at the back of the vehicle, not the front. Hence the name “drag”.
- Choose shapes that release airflow smoothly.
- Fairings can be made from many common and light weight materials.



Possible Order of Decisions

- Find your motor

  For example, an ETEK motor runs at 48 volts

- Plan for sufficient batteries to operate motor at the optimum efficiency

  A 48v motor will require four 12volt batteries, two 24 volt batteries, etc. [The number of batteries will coordinate with your frame]

- Plan your solar array so that it can efficiently charge your batteries

  A 48v motor will require at least 52 volts coming in from your solar array and producing approximately 2.5 amps. How many amps do you need to meet your power needs?

What kind of frame will carry you motor, batteries, and array

- Building the Vehicle Frame
  - Materials
  - Roll bar and Crush Zones
  - Suspension and Steering
  - Wheels and Brakes
  - Gears

Material for the frame

- Steel
  - Mild Steel
  - Chromoly Steel
    - Easy to work with
    - Relatively inexpensive ($4/foot)
    - Light weight
    - Can be easily changed/modified
    - Readily accessible
    - Comes in a large variety of sizes and wall thicknesses

Material for the frame

- Aluminum
  - Very stiff for its weight
  - Harder to weld
  - Needs more material to resist fatigue
  - Can be difficult to repair

Material for the frame

- Titanium
  - Light
  - Strong (but not stiff)
  - Absorbs shock
  - Hard to weld
  - Expensive
  - Limited sizes

Material for the frame

- Carbon Fiber (composites)
  - Lightest and stiffest
  - Can be formed to any shape
  - Expensive
  - Needs careful planning
  - Learning curve is steep
  - Very hard to repair on the side of the road

Roll Bar and Roll Cage

- Roll cage must:
  - encompass the entire driver
  - be integral part of the structure
  - be designed to deflect body/array panels away from the driver
  - allow 5 cm of clearance between the driver and the roll cage
  - meet minimum diameter and wall thickness rules

Roll Bar

Crush Zone

- Crush zone must:
  - be designed to absorb impact from a collision
  - protect the driver from front, side, and rear collisions
  - have a minimum of 15 cm of horizontal distance from all parts of the driver's body
  - new crush zone height and location requirements

  - Teams must be able to demonstrate a specific, adequate crush zone in order to compete. Insufficient regard for structural safety will result in disqualification.

Crush Zone

Crush Zone

Wheels

One of the most difficult parts to source

Choices need to be made very early in the design process

- Three wheel designs:
  - Lighter
  - Easier to align
  - Less expensive
  - Not as safe

Wheels

- Four wheel designs
  - More parts means higher cost
  - Harder to get alignment correct
  - Weight distribution less critical
  - Much safer in the event of a flat
  - Can "straddle" dead animals on the road

Wheels

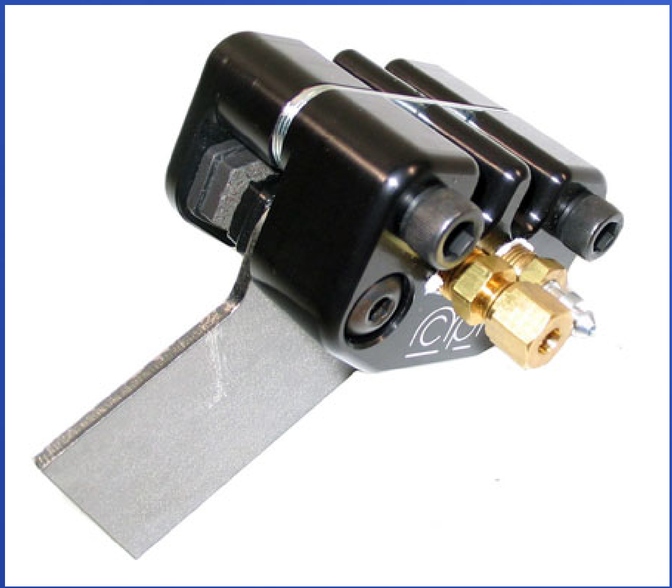
- Wheel choices (must be able to handle the weight of the car and lateral forces from turning)
  - NGM wheels and tires
  - Motorcycle
  - Junior Dragster
  - Bicycle

Choose the Correct Gears

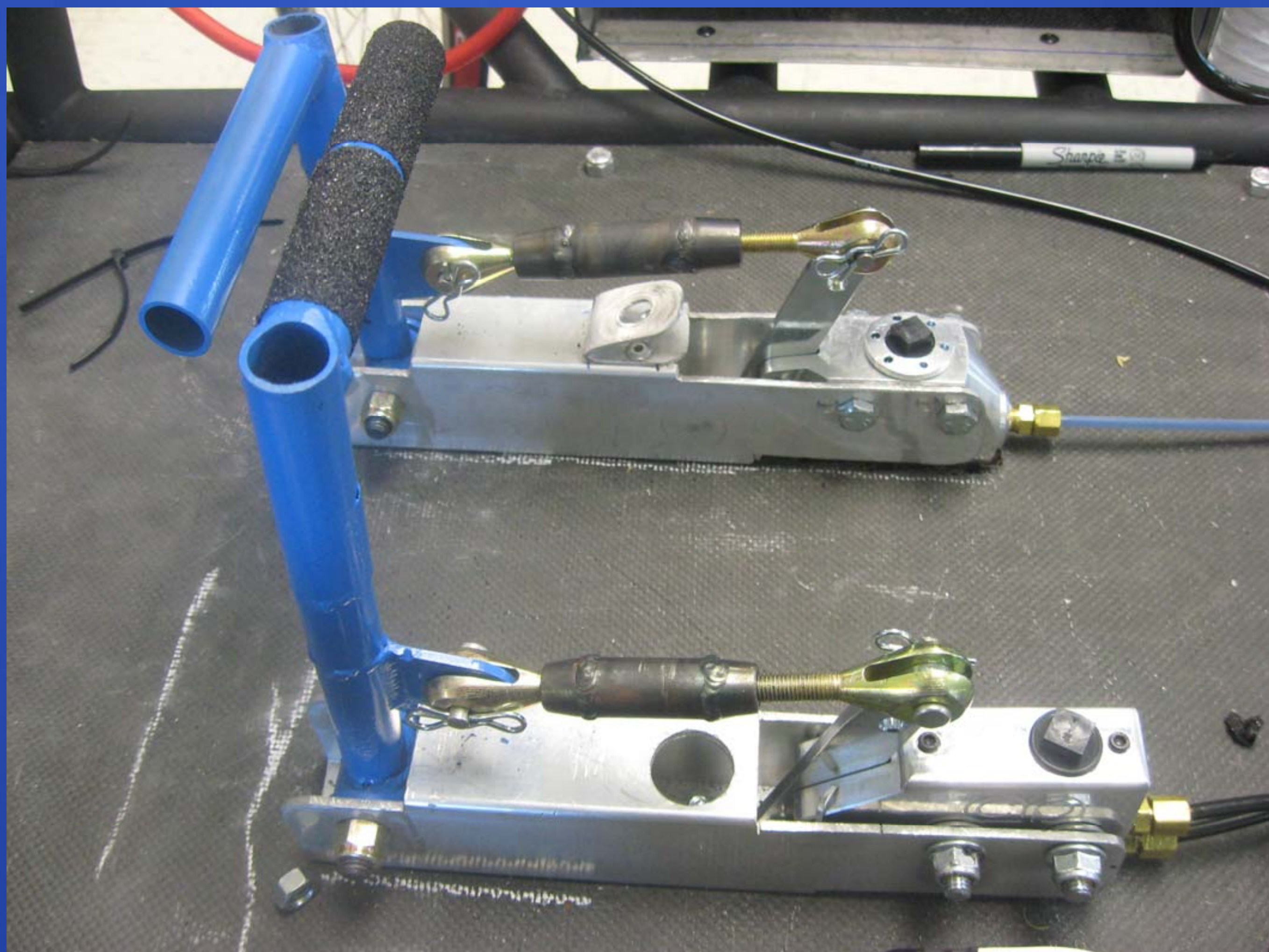
- Don't gear a car for 50 mph if you are going to drive it at 25 mph. Be realistic about your cars speed!
- Chain drive systems can be very efficient if gears are aligned and lubricated.
- Pictured: 48V system, 15 tooth front, 70 tooth rear. Max speed = 36 mph

Brakes

- Solar car must have two, independent, braking systems that allow the driver to stop the vehicle safely and quickly.
  - Most cars use hydraulic disk brakes
    - MCP single caliper brakes are easy to install and relatively inexpensive.



Brakes



Suspension

- Suspension systems
  - More important on the road than on the track
  - Adds weight and complexity to the vehicle
  - Protects sensitive and expensive solar and electric parts

Suspension

Powering the solar car

- How do you get the car moving?
  - Photovoltaic array choices
  - Power trackers and DC-DC converters
  - Electric motors and controllers

Shape of Array

- Flat Solar Arrays
  - Easier to execute
  - Angle to sun *less* of a concern
- Curved Solar Arrays
  - Higher the angle the greater chance for breaks without ideal support.
  - Angle to sun *more* of a concern

The Solar Array

- Pre-made panels
  - Reliable
  - Easily purchased
  - HEAVY (glass front adds weight)

The Solar Array

- Raw cells and lamination
  - Planning has to start FAR in advance (you are probably too late already!)
  - Process is expensive
  - Panels are very light and can be built to fit your car
  - Easy to maximize power and reduce aerodynamic drag

Laminated Cells

The Solar Array

- Do-it-yourself solar array
  - Amazing learning experience
  - Learning curve is steep
  - Hard to find raw cells
  - Takes a lot of man power
  - Hard to watch when cells are continually breaking
  - Can fit exactly to your car

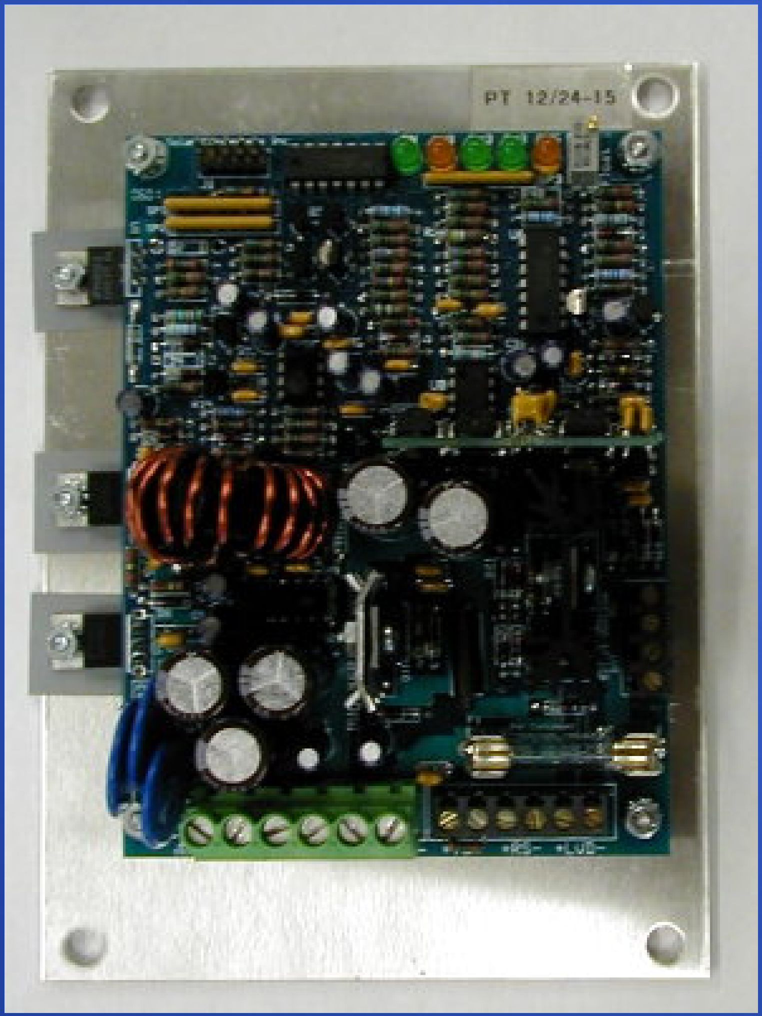
Do-it-yourself

Do-it-yourself

MPPTs and DC-DC Converters

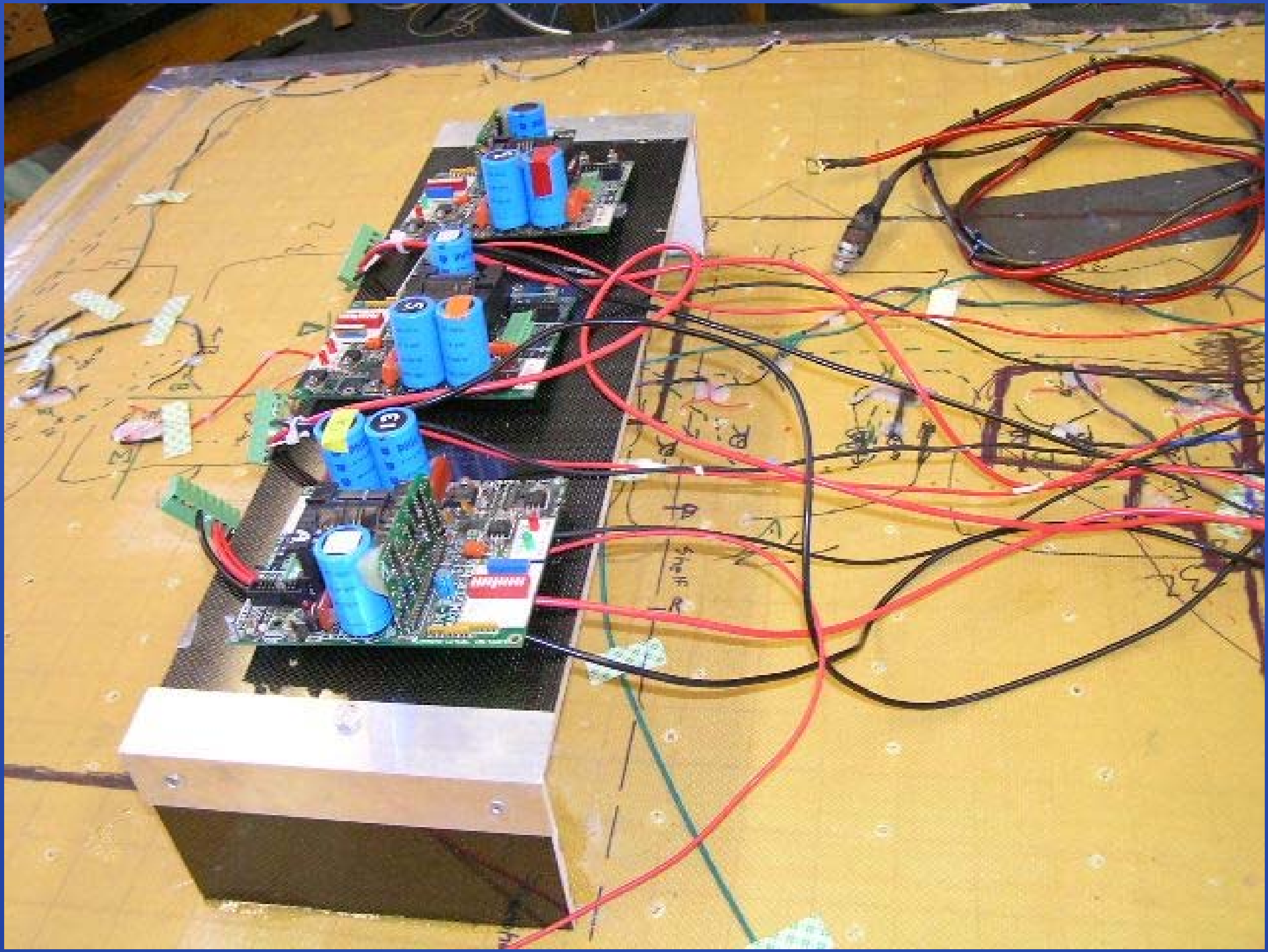
- Moving power from the solar array to the batteries is not as easy as hooking up a couple of wires!
- Voltage from your solar array needs to match the voltage of the battery pack.
- Maximum Power Point Trackers adjust voltage and current from your array to give you the most possible power to your vehicle.

MPPT and DC-DC Choices



- AERL (Australian Energy Research Laboratories)
- Solar Converters Inc
- Outback (and other grid type MPPTs)
- DC-DC Converters

AERL MPPTs



Electric Motors

- Brushed Electric Motors
  - Inexpensive
  - Lower overall efficiency
  - Controller is inexpensive and easy to wire
- Brushless Electric Motors
  - Very efficient
  - More expensive
  - Controller is more difficult to wire

Brushed Motor Examples

- Perm-Motor PMG-132 12-72 VDC
  - 90% efficient
  - Wide voltage range (12-72 volts)
  - Light weight (24 pounds)
  - $1400

Brushed Motor Examples

- Motenergy ME0909 Permanent Magnet DC
  - Best replacement for original Briggs and Stratton E-tek
  - 12-48 volt
  - Light weight (24 pounds)
  - Inexpensive ($450)

Brushed Motor Examples

- Advanced DC K91-4003 motor, 48-96VDC
  - Higher voltage motor (48-96 volts)
  - Strong motor for heavier cars
  - Low cost ($800)

Brushed PWM Controller

- Alltrax AXE
- Easy to wire
- 0-5k Pot control
- Programmable
- Durable

Brushless Motor Example

- Motenergy ME0907 Brushless PMSM/BLDC
  - No brushes=no maintenance
  - 24-72 volts
  - Very efficient (over 90%)
  - High current (up to 100 amps continuous)
  - Motor is inexpensive ($460)
  - Special controller needed

Sevcon controller (Brushless)

Hub Motor

- NGM 'Direct Drive' high efficiency in-hub motor with variable air gap adjustment.
  - Super efficient over a broad range of speeds
  - No need for gears or chain
  - Very expensive (Motor + controller > $25,000)

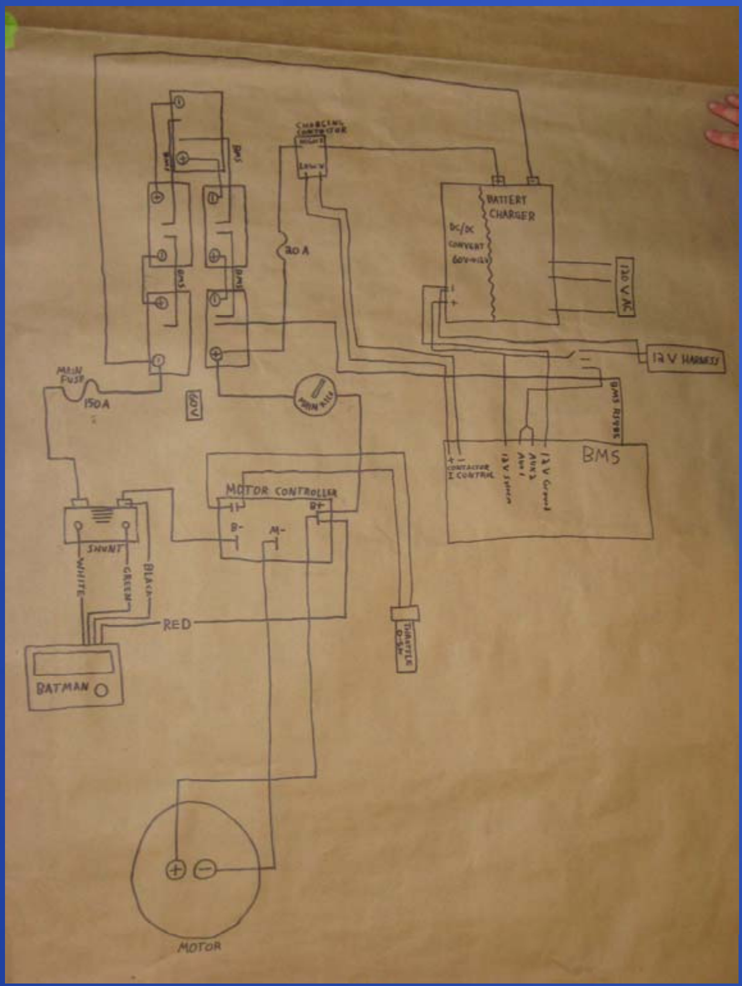
New Teams Workshop ELECTRICAL

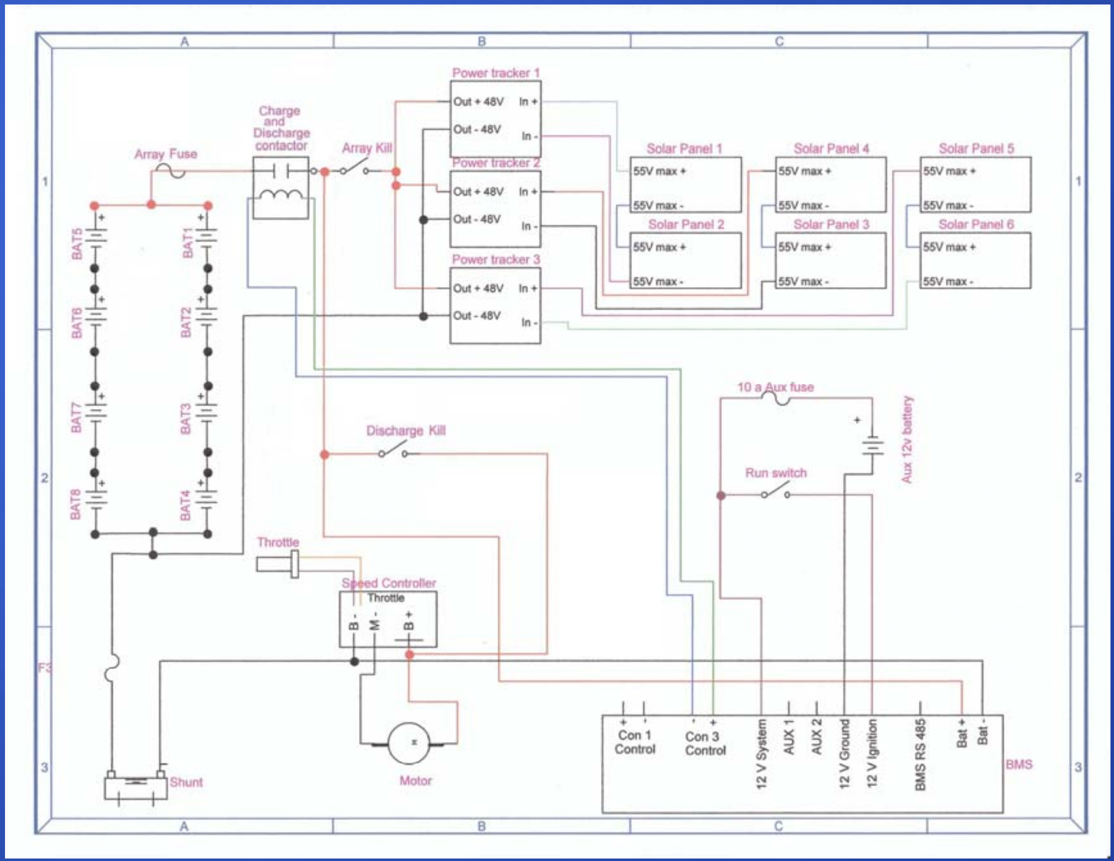
Solar Car Challenge

Electrical System

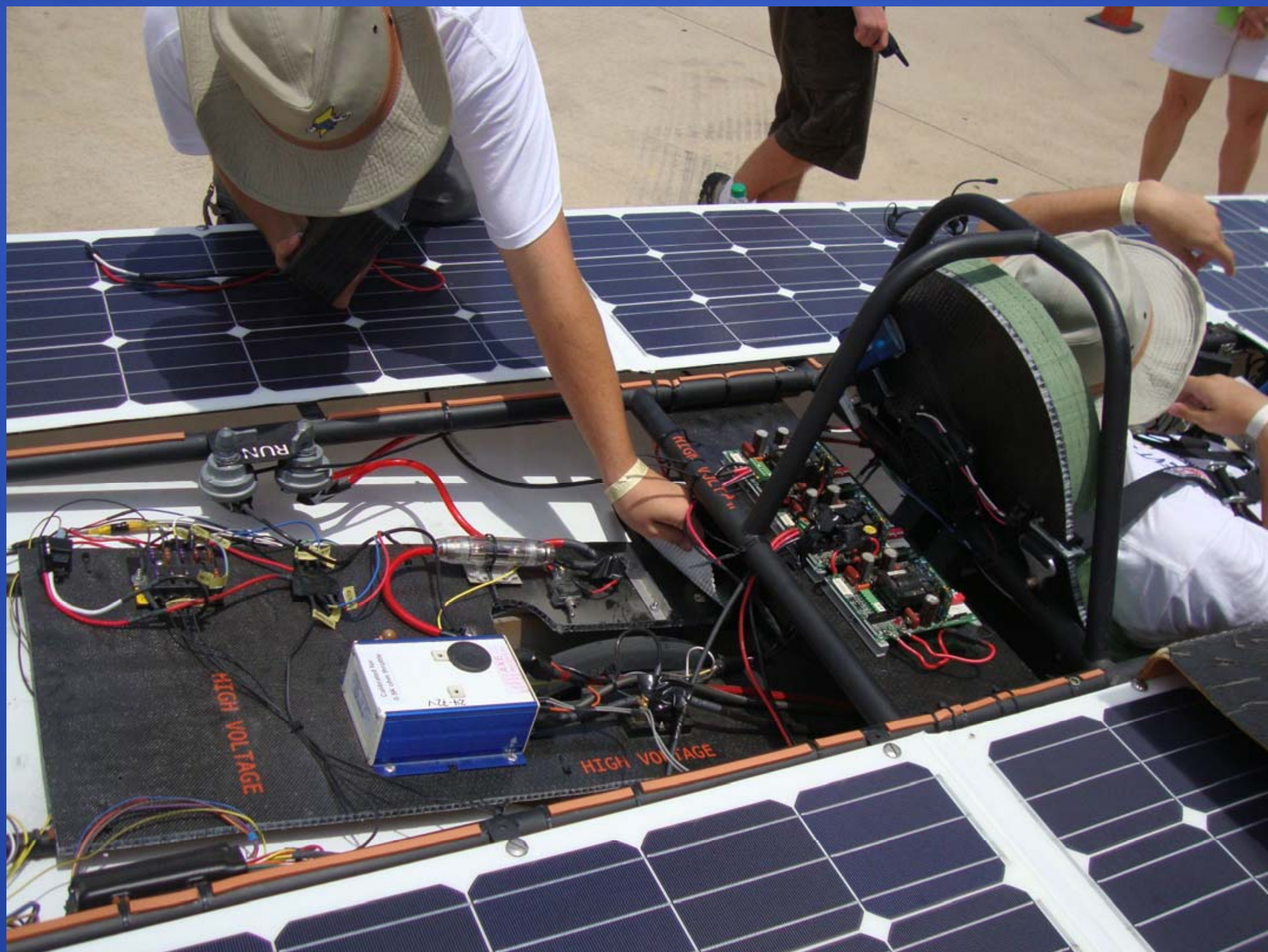
- Main electrical system (the one that makes your car move)
  - Use the correct gauge wire for the job
  - Disconnect switches should be designed for DC
  - Fuses
- Secondary electrical system (everything else on your car)
  - Lights
  - Fans
  - Horn

Electrical System Layout





Electrical System



Electrical Efficiency

- Choose the correct gauge wire for the current you expect to draw.
  - Most cars use 4 gauge or lower for the drive system in the car.
  - Soldered connections are more efficient than crimped connections.
  - Connections can be checked with an infrared thermometer.
    - Heat = energy loss!

Batteries

- Choose carefully
- Batteries are one of the areas where you get what you pay for.
  - Decisions to make:
    - What voltage does your car run at?
      - Higher voltage means lower current .
    - How much weight can you carry?
    - How much energy can you get at that weight?
    - Can your solar panels recharge the battery pack?
    - Is it a road race or a track race?

Batteries

- The 5 kilowatt-hour rule

  kw-h = Amp-hours x Voltage

  (at the 20 hour discharge rate)

  Example:

  Four, 12 volt, 84 amp-hour batteries in series

  84ah x 48 v = 4032 watt-hours or 4.032 kilowatt-hours

  (this battery pack would weigh around 230 pounds)

Batteries

- Testing batteries:
  - Understanding how your batteries perform is one of the most important things you can know BEFORE the race starts.
  - Carefully recording voltage, current, and amp-hours will help your team make good decisions during the race

Batteries

- Some of our favorites:
  - Concorde Sun Xtender series
    - 84 Ah $245/battery
  - EnerSys Odyssey Marine series
    - 68 Ah $250/battery

Power Management

- How much power does it take to make your car go down the road?
  - The amount you will use depends on:
    - Aerodynamic drag
    - Rolling friction
    - Weight
    - Electrical system resistance

Power Management

- A typical Solar Car Challenge vehicle array produces 800-1000 watts of power.
- There is approximately 12 hours of usable sunlight during a race day.
- 800 watts x 12 hours = 9600 watt-hours of energy/day. (Assuming clear skies and good sun.)
- A full-size, fully-charged battery pack has approximately 4000 watt-hours of energy.
- It will take approximately 5000 watt-hours of energy to completely recharge the battery pack.

Power Management

- Dead Batteries are dead weight
  - A 48 volt battery pack is "dead" at 42 volts.
- It will take (at least) 5 hours of full sun to completely recharge a dead battery pack.
- Hills, clouds, trees, wind, and children with sticky fingers all reduce your array efficiency.
- The only way you will know how much energy your car will use is to test it.
- Keep a record of current draw vs. mph   (It is not linear!)

Collecting Data

- How to measure what your car is doing:
  - Voltmeter and/or ammeter
  - Batman measurement system (Bruce Sherry Design)
  - Link (e-meter)

What Data is Important?

- Different teams have different answers to this!
- Typical measurements include:
  - Battery Voltage (measured under load)
  - Motor current draw (the rate that you are taking energy out)
  - Array current (the rate that you are putting energy back in)
  - Amp-hours or Watt-hours (how much total energy you have taken out or put back in)

Making Decisions

Getting Data to the Right People

- Driver should not need to make decisions other than driving.
- Pit crew should inform driver about “speeding up” or “slowing down”.
- One person should be responsible for communicating with the driver.
- Telemetry systems

GOOD LUCK!

Solar Car Challenge