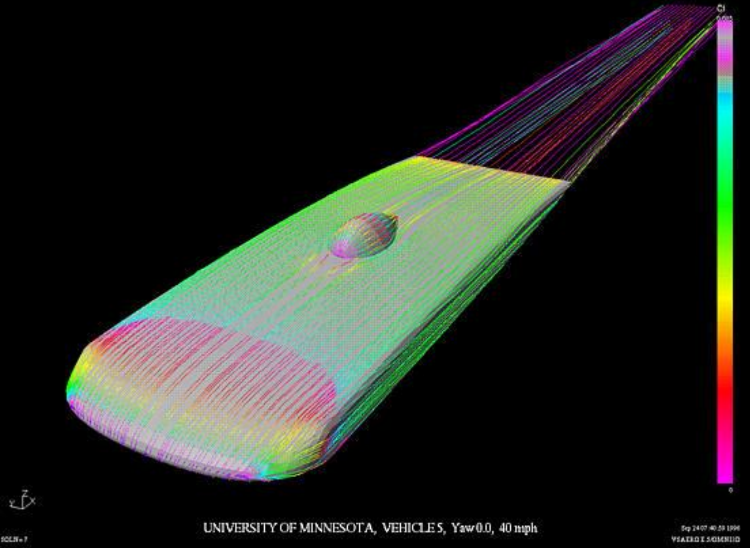
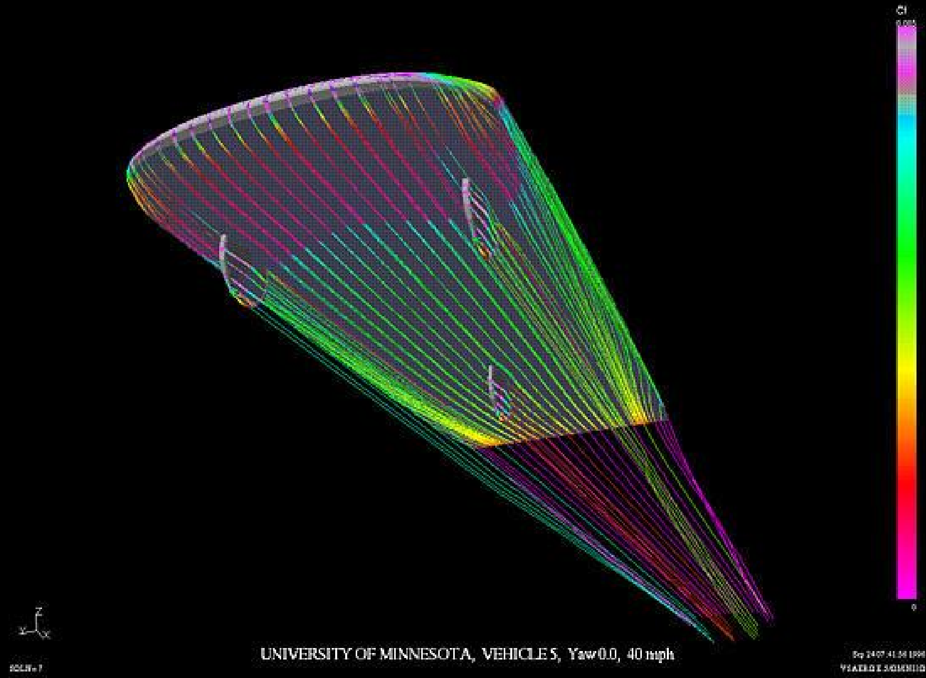
Solar Car Aerodynamics & Body Design





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ASC Conference, Ann Arbor MI

Why is the aerobody important?

Arguably the single most important part

- Touches every other part of the car: Array, chassis, suspension, etc
- Large majority of power is expended pushing the car through the air
- Determines shape of the array/amount of power available
- May be a major structural component

Basic Performance

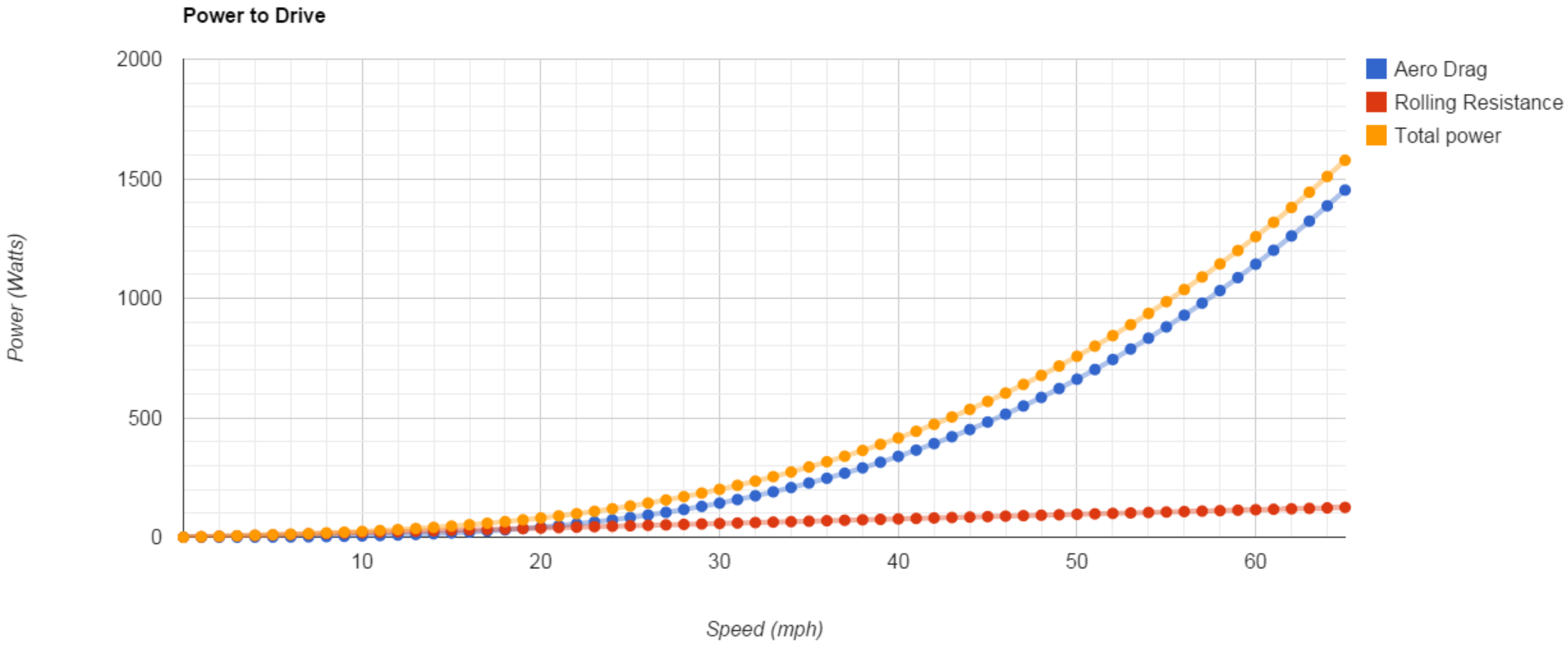
Critical equations:

$$P_{Aero} = (½)\rho V_a^{2} V C_d A$$

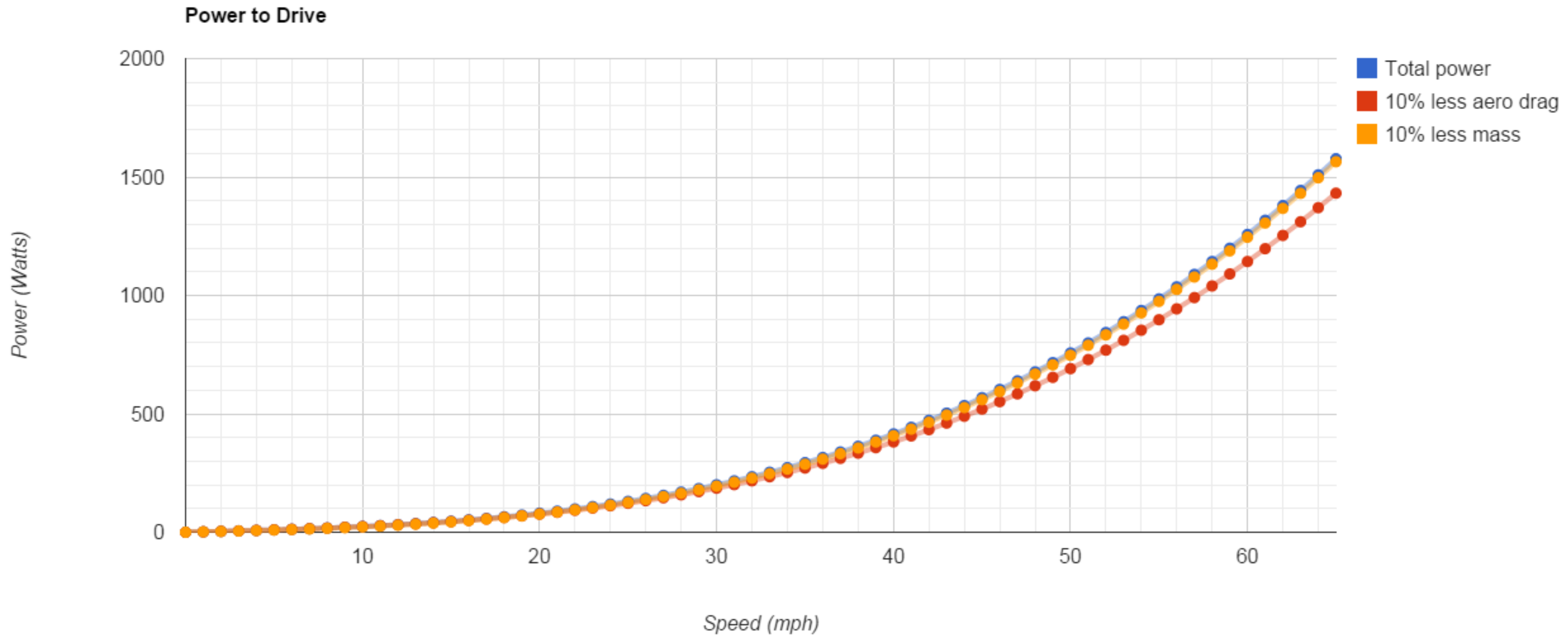
$$P_{RR} = C_{RR1} mgV + C_{RR2} N V^2$$

Other important factors: Power system efficiency (motor, battery, etc), constant quiescent draw of electrical system, etc.

Basic Performance



Basic Performance



Basic Solar Car Aerodynamics

Low speed aerodynamics!

- Skin friction dominates pressure drag
- Minimize pressure gradients
- Smooth blends between main body and protrusions (wheel fairings, driver canopy, etc) to minimize junction drag
- Interactions between wheel fairings are critical

System Design

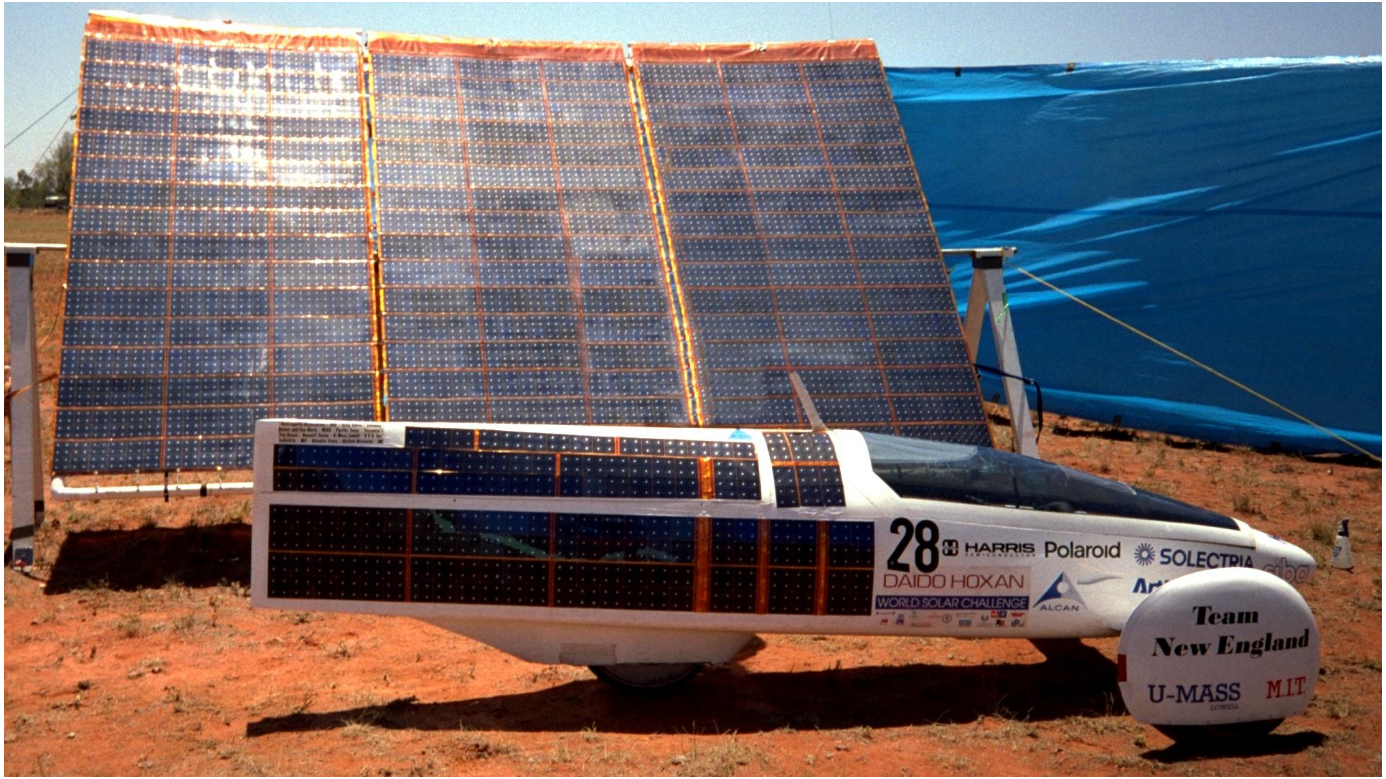
Aerodynamics do not exist in a vacuum - the design of the aerobody touches all other parts of the car.

- Array concerns
- Fitting mechanical systems
- Perfect physics world vs. real world

System Design - Array

- Aerodynamics vs. Solar Array: Maximize **system** performance.
- Careful analysis and simulation required
- Balance between the two may change race-to-race

System Design - Array



System Design - Array

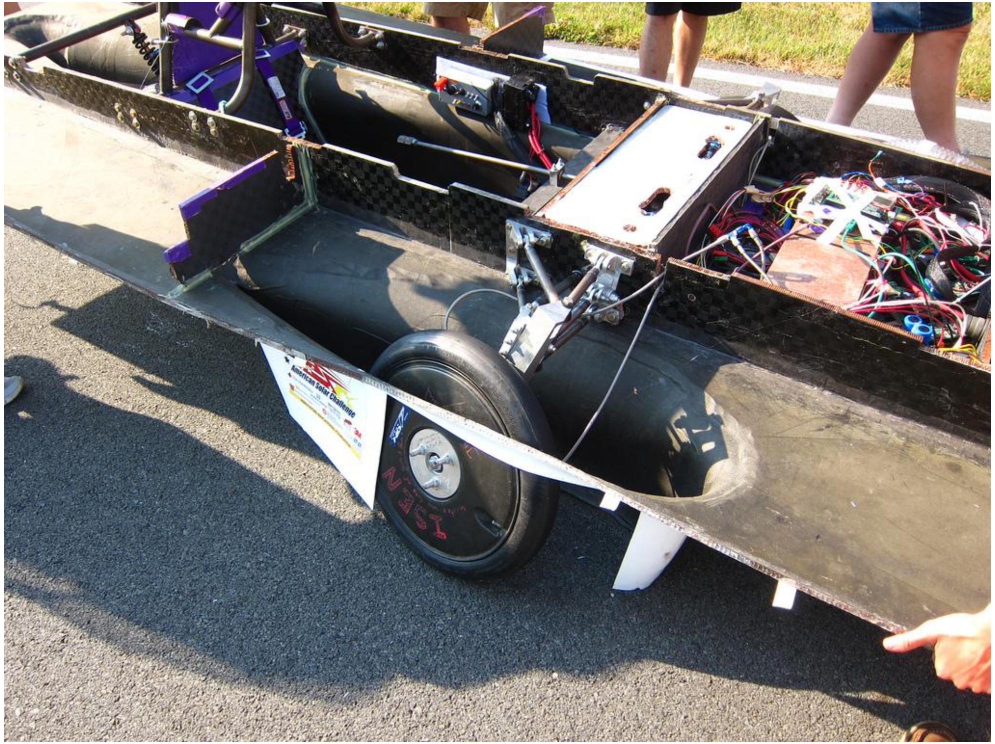
System Design - Array

System design - Mechanical

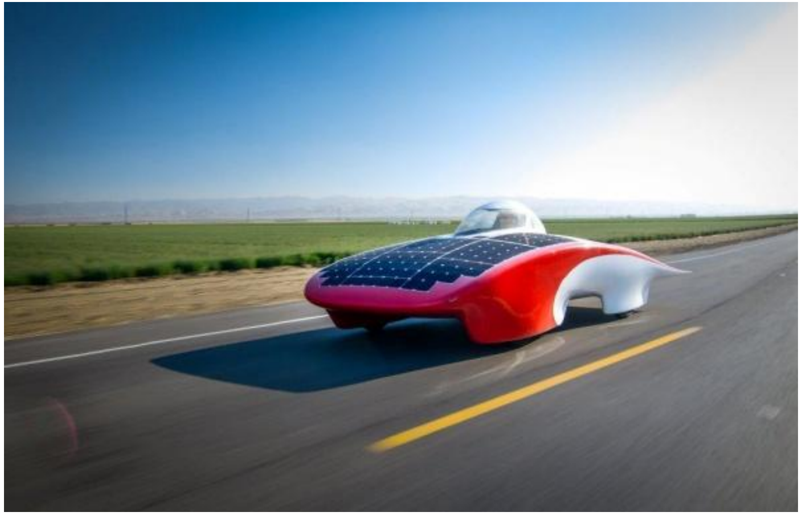
“Theoretically ‘better than the competition’ is only relevant if your car is not in pieces in the ditch.” - Laurie Miller, former Minnesota team lead, on "over optimized" designs.

No matter how good on paper, the design is no good if you can’t race it.

System design - Mechanical



System Design - Theory vs Reality



Wheel Fairings

Wheel Fairings

- Aero drag force of a spinning wheel in an airstream goes up with V^3 rather than V^2
- Many un-aerodynamic things attached to wheels - suspension member, brakes, brake lines, etc
- Complex flow interactions between different fairings under the car

Wheel Fairings

- Must be designed in concert with the aeroshell, not as an afterthought
- “Little baby solar cars” - wheel fairings will take almost as much design and manufacturing effort as the rest of the aeroshell combined.

Dynamic Wheel Fairings

Actuate in some way to allow the wheels to steer

- Pros: Narrower and not as long; less frontal and whetted area
- Cons: Mechanically complex. Panel gaps. Fit&finish issues may negate theoretical aero advantages

Dynamic Wheel Fairings

Wheel Fairings - other features

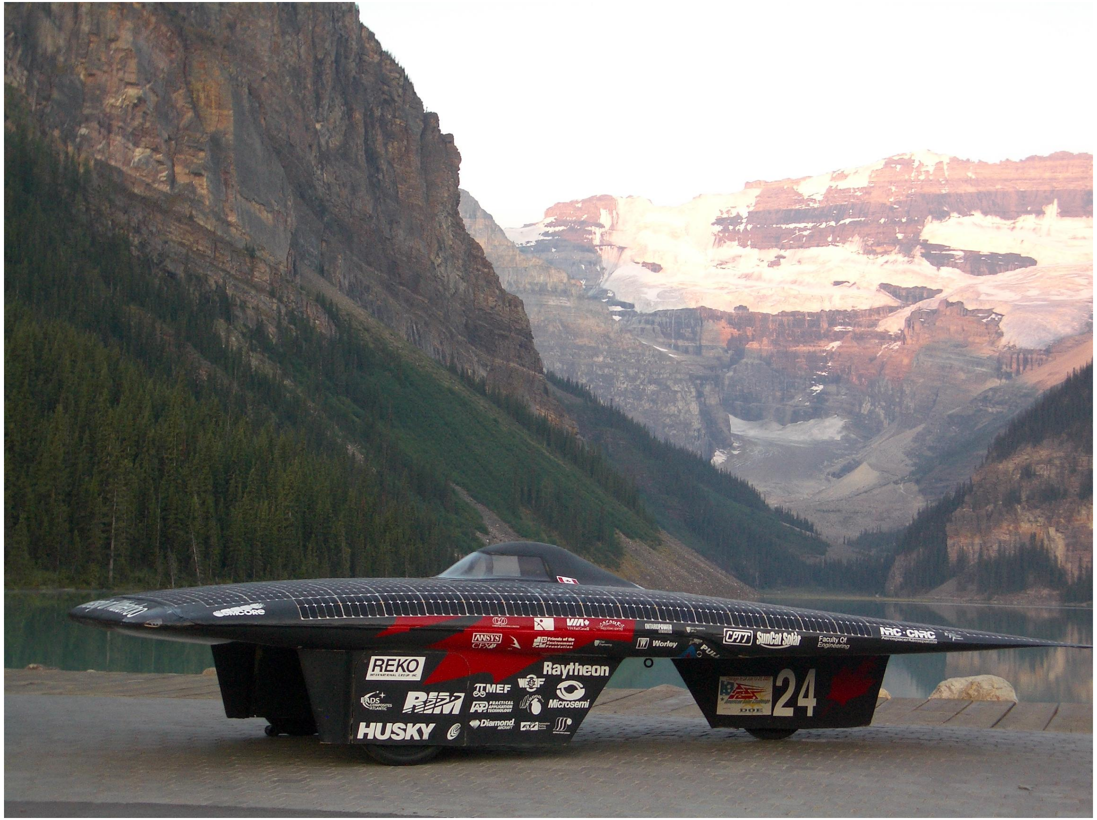
- Sealed wheel wells and tight fenders to minimize air circulation inside the car
- Sacrificial fairing bottoms to get as close to the ground as possible
- Spoke covers on wheels - claimed up to 100W PTD savings at highway speed by some teams

Crosswind Sailing

Generate thrust via crosswinds to reduce drag

Crosswind Sailing

Crosswind Sailing



Body Structure Design

Many different levels of structure required in aerobody

- Aerodynamic shell around welded tube spaceframe?
- Composite chassis bonded to aeroshell?
- Monocoque without removable topshell?

Regardless, care and precision required at all steps to maintain good aerodynamics

Molds

As many features in the mold as possible. The more detail is in the mold now, the less work there is to do later. PLAN AHEAD.

- Scribe lines for trimming egress hatch, windshield, fairing cutouts, chassis alignment, etc
- Joggles for access panels, fairing attachment
- Array inset and wiring channels

Surface Finish

- Array edges
- Driver egress hatch
- Fairing attachment
- Wheel access doors
- Top/bottom shell junction

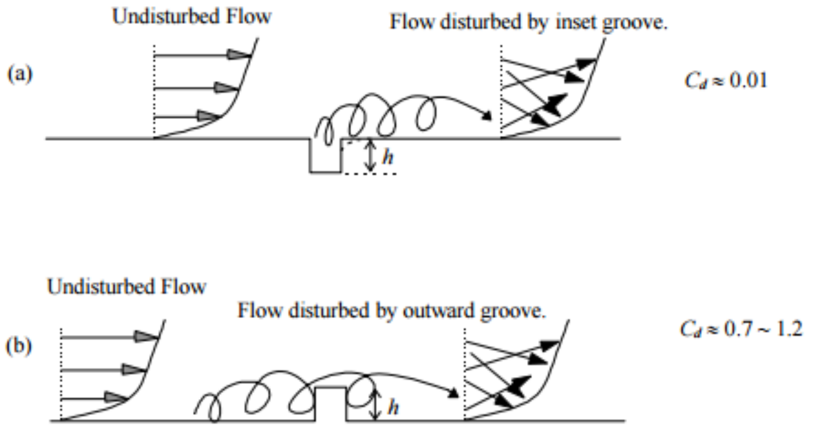


Figure 4.6.1: Side view geometry of 2-D (a) inset and (b) outward surface grooves oriented perpendicular to the flow direction. The grooves are approximately square. Examples of such a defect include body seams, and the gap between solar-cell subarrays. The C_d's are based on *h* per unit width.

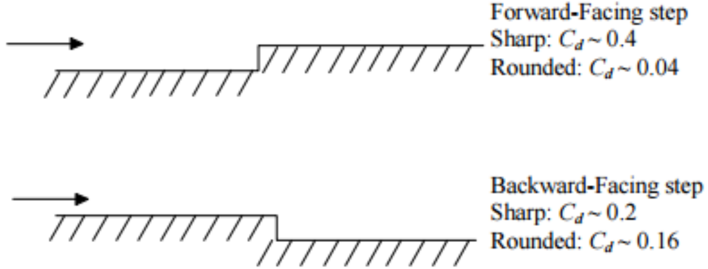
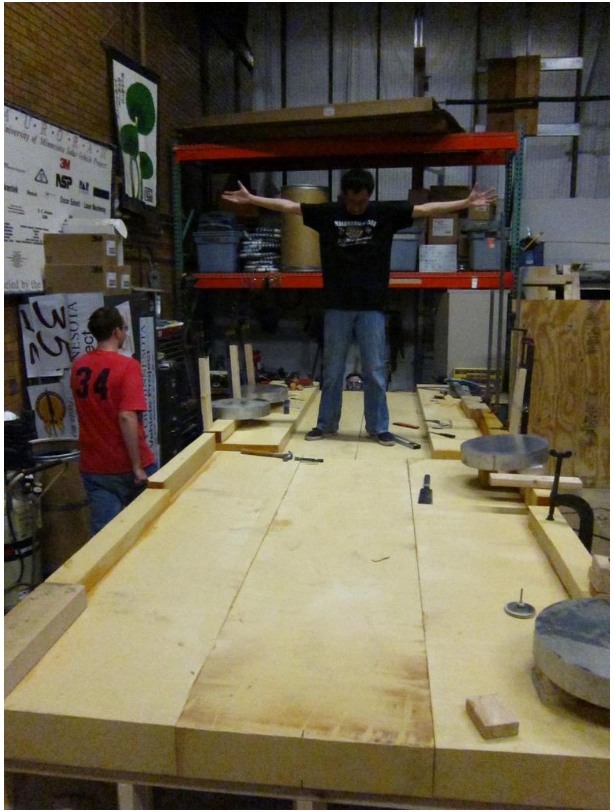


Figure 4.6.7: Illustration of a forward and backwards-facing step, and their approximate C_d values based on step height per unit step width (perpendicular to flow). Note that a rounded forward-facing step has about a quarter of the drag of its backward-facing counterpart, and that the backwards-facing step's drag is less sensitive to step sharpness. [Ref. Hoerner]

Molds

Build or Buy?

Molds - Build



Molds - Build

Molds - Build

Molds - Build

Molds - Buy

Layups

Plan, plan, plan.

- Know your materials, resins, cure times and temperatures
- Write up a complete procedure.
- Cut all material ahead of time and store in labeled containers
- Do a practice layup on the full mold with some cheapo fiberglass
- PPE: For your sake AND the car’s

Layups

Surface Finish

Body Structure

- Add extra support to keep array surface from flexing while driving
- Provide features to register location of the top shell and attach it to the chassis

Body Structure