Solar Car Team
Principia College
Elsah, IL 62028
www.prin.edu/solar
solar@prin.edu

Adopt-A-Sun
$5,000 +

You receive:

Subscription to *The Solar Flare*
Name on Car
2 Limited Edition Race Polos
RA VII Commemorative Crystal

Crystal Club
$2,000 +

You receive:

Subscription to *The Solar Flare*
Name on Trailer
2 Limited Edition Race Polos
RA VII Commemorative Crystal

Ra 32 Club
$1,000

You receive:

Subscription to *The Solar Flare*
1 Limited Edition Race Polo
Name on Trailer

Adopt-A-Cell
$500

You receive:

Subscription to *The Solar Flare*
2 Race T-Shirts

Adopt-A-Battery
$100

You receive:

Subscription to *The Solar Flare*
1 Race T-Shirt

Please address contributions to:

Fundraising Chairman
Principia Solar Car Project
Elsah, IL 62028

Checks payable to: Principia Solar Car Team

All contributions are gratefully accepted and tax-deductible to our 501(c)(3) educational organization. Please include a corporate matching form if your employer has such a program.

ONE MIND • ONE LIGHT • INFINITE RAYS

THE SOLAR FLARE

June 2008

Scrutineering Success

by Sten Palmer

On Saturday May 17th, the familiar clicking of a solar car motor could be heard whizzing down the Crafton parking lot. Although only one of teams (Minnesota) had a functioning car at that point, a total of seven schools participated in Principia's Pre-Scrutineering event (University of Minnesota; Southern Illinois University, Edwardsville; Illinois State University; Missouri S&T; FH Bochum, Germany; Northwestern; and Principia), making our Pre-Scrutineering event the best attended of the three in North America (the other two were in Alberta and Ontario, Canada).

Top: *While inspection took place inside the tent at Crafton Center, crowds gathered to look at Minnesota's new car as well as as Ra 6 (which was on display only, not to be scrutineered).*
Bottom: *Inspector Paul Hirtz meets with Minnesota team members to inspect the driver's roll cage.*

The teams met with North American Solar Challenge (NASC) inspectors Steve McMullen, Paul Hirtz, and Gail Lueck, who inspected the teams' cars, components, and/or plans for their mechanical and electrical integrity against the new NASC regulations.

Although Principia's solar car is still in production, the team learned several key ideas to improve the safety and integrity of our vehicle. Areas of the car that sparked discussion with the inspectors include the welds of our aluminum frame, the rear foam-filled tire, and the battery box. The common consensus among the teams was a sense of gratitude for the event and forward progress toward having their cars ready for the July race.

The abounding success of the event directly relates to the solid spiritual preparation by all. We'd like to extend special thanks to Principia's Facilities, Dining Services and Athletic Departments. Principia's Solar Car Team expressed solid teamwork throughout the day, and our

continued on page 2

Don't Forget!

The North American Solar Challenge begins July 13 from Plano, TX! If you're near the race route (check www.americansolarchallenge.org), come out and see us! Otherwise, you can track our progress through daily email updates during the race. If you'd like to receive these updates, please email solar@prin.edu. Also periodically check out our website at www.prin.edu/solar during the race for pictures and news. We appreciate your support, and we'll keep you posted.

Principia Hosted
NASC Pre-scrutineering May 17th-18th

by Sten Palmer
continued from page 1

team metaphysical work really paid off. Every need was supplied, from finding the exact tools we needed to having just the right number of bag lunches for our guests. Even the weather cooperated.

This spring's torrential downpours gave way to reveal a cloudless sky and temperatures in the 70s on Saturday. It was easily the most beautiful weekend of the quarter, and our visitors certainly noticed Principia's picturesque beauty. Due to our campus's wooden signs and stunning hardwood forests, visiting teams even started referring to us as "Principia National Park." Northwestern and FH Bochum joined our camping ala Crafton track experience on Friday night. On Saturday, it was only the Germans left, so another teammate and I took the two young men as our "dates" to the Spring Formal. (I had convinced them in emails prior to their arrival in the States that it would be a "cultural experience.") They were proper gents, and we all had fun. Before they left, they gave our team the biggest bag of gummy bears I have ever seen. I have really valued being a part of Pre-Scrutineering and have never felt so appreciated! Thank you all for your support as we continue to be fuelled with fresh inspiration to finish our car.

Solar Car Team Member Profile: David Crabill *by Matt Shaw*

A team member that has a drive to work on many aspects of the solar car is always good to have around. David Crabill is one of those team members. David will be a senior next year and has been on the solar car team since he started here at Principia. When David is not calling the electronics lab, machine shop, or solar car shop home, he calls Woodbridge, CA home. David is a Computer Science major, but his knowledge and skills branch out well beyond computers. David has been a big help with the mechanical, body, some electrical, and website divisions of our team. David has not been on a race yet, but is excited about the opportunity to race this summer. I asked David a few questions about himself and solar car:

Q: Why did you join the solar car team?
A: I enjoy engineering and like to work on hands-on projects, especially related to science. I am also interested in the progression of technologies like solar, nuclear, and electrical power.

Q: What is your favorite part about being on the solar car team?
A: I love getting to work with all of the other students in different majors which share a common interest in this science project. Also, learning things I would never learn anywhere else, like how to machine metal parts, is amazing.

Q: What is the most interesting part of the solar car you have worked on?
A: For me, that would be designing the logic for the lights on the car (turn signals, brake, and strobe light) and seeing how it is implemented on a circuit board.

Q: What do you hope the team can accomplish in the future?
A: I hope the team can adapt their project as technology changes and new opportunities arise. I hope we will still work on engineering projects, since they fill a void in our curriculum.

Q: And what is your favorite flavor of ice cream?
A: Homemade chocolate.

Solar Car Team Member Profile: Pathik Bollaidlaw

by Daniel Hensey

Pathik Bollaidlaw is a sophomore Physics major from Bethesda, Maryland, and is working hard on his second year of Solar Car. Besides his obsession with Physics and all of its principles, Pathik has a genuine love for Engineering, so much so that he joined the Solar Car team because it was the only program at Principia College that offered some sort of Engineering. So far, he's loving it. Pathik has the unique opportunity to be on the race team this summer, traveling with the car from Texas to Canada. His outlook for the team, and the race, is certainly positive. "I want a successful race, and by successful I mean that we've arrived at an outcome that we are happy with, and that we feel we have successfully expressed God through the designing, fabrication, and racing of the solar car – a group project." One of Pathik's favorite parts about Solar Car is working with tools, including the engineering software that our team uses. When I asked Pathik what his personal goals were for the race this summer, he replied, "I'd like to learn how the team interacts with each other to produce a successful race. Personally, I'd like to rely on God to be a creative problem solver if any issues come up on the race." Pathik is planning on attending Grad School, most likely for Engineering, after he graduates.

Designing the Solar Array

by Justin Sinichko

In our last newsletter, we briefly went over the mechanics of solar cells and how they convert sunlight into energy. Ra 7 will utilize 6 square meters of individual cells to produce the power we'll need to race from Dallas to Calgary. To do this, we needed to hurdle a few obstacles. Our primary goal was to arrange the cells onto the upper body in a way which could fit all the cells we were allowed. (This was a tight squeeze for such a small body.) Unlike all of our past cars, Ra 7 will use two different types of solar cells. We decided to place the cells we had less of, but which were more efficient, onto the front "hood" of the car, where the surface is mostly very flat. During the normal racing day, this area of the car will receive the greatest amount of sunlight.

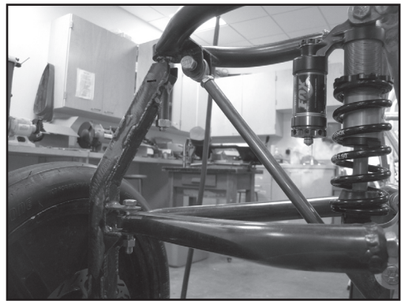
Once the cell placement was designed, we needed to arrange them into groups. This takes some finagling because ideally on a solar car you would prefer to have fewer different-sized modules. Unfortunately, our car lacks a simple shape, and trying to match rectangular cells to a more organically shaped body left much to be desired. Eventually, the plan was completed, and we were able to make all the cells fit using 8 different module types.

Producing these modules in an accurate manner is critical to the success of the car. Principia uses SunCat Solar, a Phoenix- based company who has helped produce the modules for our last few cars. They arrange the cells into our specified configurations and encapsulate them into modules. Simplified, the encapsulating process is a way of laminating the cells between a clear medium, which offers an added layer of protection to the cell. It also acts as the backbone for multiple cells to connect with one another. These encapsulated modules are literally glued onto the car's upper body and wired together. The power drawn from these cells passes through trackers (power balancing devices) and into the battery pack. When the driver presses the pedal, power is drawn from the pack and scrupulously given to the motor. Hopefully, clear skies permitting, we'll do this for the entire race.

Suspension System *by Pathik Bollaidlaw*

One of the critical systems of any solar car is the suspension system. The suspension, while providing some comfort to the driver, is critical in absorbing impacts and reducing vibrations that can be harmful to the car. By reducing such vibrations, the wear and tear on components diminishes, resulting in part life expectancies increasing, reducing the chance of parts vibrating loose.

Ra 6's front suspension shocks were in a normal unequal length a-arm position. This design had the shock mounted to the frame between the upper a-arm and the opposite end of the lower a-arm. For Ra 7, we redesigned the front suspension to use a cam position for our Fox Shocks DHX 5.0 shocks. The cam position has the new shocks mounted to the frame vertically (instead of at an angle, as before) between the two a-arms. Connecting the shocks and suspension is a pull rod mounting from the bottom of the shock to the opposite end of the upper a-arm. This pull rod is positioned somewhat similarly to the original shock but flipped about the horizontal axis.



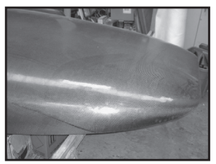
Ra 7's newly designed front suspension.

With the new requirement of having the driver positioned more vertically, we were forced to redesign the car to have room for the driver to sit. To accomplish this task, we sank the driver into the rear fairing, which forced us to compact the rear suspension (so that both the driver and the suspension fits in a single fairing). This design change was accomplished by using a four-link suspension that consists of an a-arm, shock loop, and rear swing arm. The shock is mounted vertically near the top of the car's frame (behind the driver's head) to the end of the a-arm. The shock loop (similar in shape to the a-arm) is mounted at this same junction to transfer the movement of the rear swing arm to the shock. (The a-arm keeps the shock loop in a vertical position as it travels and compresses the shock.)

While the suspension system does extend the life of our components and reduce the potential detachment of parts due to vibration, it still is not as smooth of a ride as a normal car. You're still situated in a tiny space with no sound dampening built into the car and no air conditioning during the summer on the roads in Texas. But will that stop our drivers? No way.

Why Carbon Fiber? *by Laura Warsinskey*

While building the body of our new car, everyone working with the body team has begun to have a close relationship with the material carbon fiber. At times, it is referred to as the "black itchy stuff" that stays in your clothes, but later in the process it is seen as the "strong shiny material" that glistens in the sun. So what is it about carbon fiber that makes it so spectacular, and why are we using this expensive material to build our car?



Left: *Carbon fiber in its original form, basically a weaved fabric.* ***Right:*** *Carbon fiber reinforced plastic creates the shell of our body.*

Carbon fiber is a material made up of many tiny fibers which are woven together into a fabric. These fibers are made up of tiny carbon crystals that align themselves with the length of the fiber. When this material is put together with an epoxy resin under pressure by a vacuum bag, it turns into a carbon fiber reinforced plastic (CFRP). Instead of a thin flexible fabric, the shape pulled from the mold is extremely rigid with a shiny look. The weaves from the carbon fiber material make the CFRP very strong and stiff.

Another critical advantage is its high strength-to-weight ratio. Making our body out of this material makes our car very strong but at the same time relatively light, making it easier to travel faster on the roads. CFRP materials are also known for their low density, corrosion resistance, vibration resistance, and low thermal expansion. All of these factors help contribute to an energy efficient car. CFRP is often used in the race car industry. They have developed ways to align the fibers in a certain direction in order to add strength in a load-bearing direction.

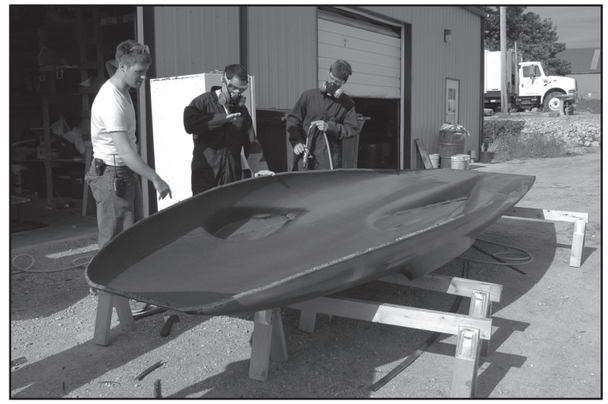
Due to the expense of the material, it has not been used in mass production for vehicles until recently. Car companies such as General Motors and BMW have now started to use it in everyday cars. The body of our car is made completely of carbon fiber along with a Nomex (honeycomb) core. We are excited to see this strong but lightweight car move efficiently on the road for the race this summer.

Major Developments for the Body Team

by Peter Chaney & Brian Kamusinga

Over the past several months, the body team has been working hard to finish the body of the car in time for testing in June. We have completed making the lower body and one of the two upper bodies of the car that we were planning to construct. (The second upper body will be used for testing and egress practice while the first body will be covered with solar cells and used in the race.)

The lower and upper body are made from a composite of carbon fiber with a honeycomb core fortified with epoxy resin. So currently we have the entire outer shell of the car. For all of us, this is an important achievement that brings us closer to the race in July. We still need to apply a protective clear coat of paint on the parts we just made to protect the car from UV rays from the sun (which may damage parts), to seal any imperfections that may have arisen during the lay-up, and also to give the car that extra shine. Next, we'll have to join the upper and lower bodies together and then attach the outer shell to the chassis. Cells for the car have finally arrived, and so we have started laying templates for the solar cells on the upper body. Soon we'll attach the cells themselves to the surface of the upper body one module at a time with silicon adhesive.



Ra 7's completed lower body (minus trimming and fairings) after 3 layups.

The upper and lower bodies for Ra7 have been the biggest parts that we have made using our new method of construction. Doing carbon lay-ups of this magnitude required us to adjust our whole lay-up process, particularly our strategy for mixing epoxy. Epoxy is a two-component polymer adhesive, composed of resin and hardener. The pot life, or the length of time epoxy is usable before it sets, is determined mostly by the type of hardener you use and the temperature of the surroundings. During previous lay-ups, we used a typical resin-to-hardener ratio and simply mixed epoxy continuously as we needed it. During this lay-up, though, we are using a different epoxy system. We want to use as little epoxy as possible to keep the car lighter, so we've rationed a specific amount of epoxy for each piece and are more precise in our ratios. In addition, we are now using a hybrid mixture of two hardeners with the usual epoxy resin. This new hybrid mixture was developed through substantial research and testing of different epoxy mix ratios. The current formula that we have gives us enough pot life to be able to carry out the large-scale lay-ups and provides the optimum resin that we require for the car body.

Previous lay-ups have just consisted of just one gigantic step. Our current lay-up system is a four-step process. First, we cut the paper honeycomb core into the shape of the part and epoxy it together into one piece. Then we do a lay-up of just the outer carbon skin, composed of two layers of carbon fiber. The outermost layer of carbon fiber has the weave running the length of the part, and the inner layer runs at a 45° angle to the part, giving the part strength in all directions. The honeycomb that was made to fit the part earlier is then epoxied to the carbon skin. The final step is to lay-up the inner carbon skin with two more layers of carbon fiber.

The process of making the two halves of the body was relatively complex. There were different approaches to all the processes involved, but when we actually did the lay-ups, we all had one vision of what we wanted the parts to be. There were many things that could have gone wrong but didn't. We all helped each other to stay focused and productive. One of the statements we were working with while making the lower and upper body was from Mary Baker Eddy's Miscellaneous Writings 113:25, which states, "We have nothing to fear when Love is at the helm of thought, but everything to enjoy on earth and in heaven."

The team learned a lot from the experience of working on the lower and upper body lay-ups, ranging from how to do a better honeycomb lay-up to how to concoct the optimum epoxy recipe for doing any kind of lay-up. But most importantly, we got to work together not as individuals trying to chip in but as a team members. We all had diverse points of view but one Mind and one vision: a vision to see the solar car not as a material object that can just be made and just as easily destroyed, but as an expression of the love and care that has gone into making it a possibility.

Responses to Reader's Questions

by Tom Brownell

1) How hot does it get inside the car for the driver?
Considering that most driving occurs during the summer (when the sun is shining the most), temperatures inside of the solar car are generally 10-15 degrees warmer than the ambient air temperature. While past cars have had bodies that were built using foam, which helps insulate against outside heat, Ra 7 will just have a carbon fiber and cardboard honeycomb body; therefore, we expect slightly higher driver temperatures in the new car.

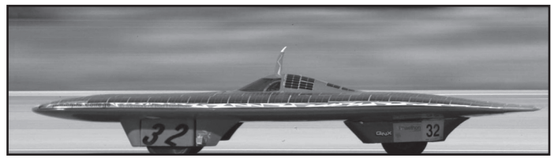
2) How long does it take to build a solar car?
It takes us about 2-3 years to build a car, from conception to operation. This includes everything from designing, reviewing, and modifying each part to actually building, fabricating, contracting, and assembling them. If all processes could be streamlined and coordinated perfectly (and if we weren't full-time students!), actually building the car would probably take about a month. We will usually spend about two quarters (10 weeks each) building the bulk of the car.

3) Where do you get engineering information without an engineering program on campus?
Our team relies heavily on professionals in the different fields related to the concepts and practices used in building the car. To understand the terms and processes used by professionals, we rely on highly motivated students who are

Steve Wright is a professional who has opened up his shop and freely given us all sorts of knowledge in the realm of body construction.

self-taught in the different areas of the car. The Internet is also a very helpful tool, both for gaining knowledge and for connecting with professionals who we can interface with.

4) What is the range of a solar car?
The record for farthest distance traveled by a Principia car currently stands at 409.5 miles by Ra 5 during the 2005 World Solar Rally in Australia. Technical and mechanical failures aside, the car



Ra 5 during the 2004 track race in Greece.

is only limited by the amount of sun, the size of the solar array, and the capacity of the battery pack. Generally, our cars can run all day long at about 50 miles per hour, given it is a sunny day and there are not very many hills. If the array were to be removed, a full battery pack should be able to power the car at similar speeds for 2-3 hours. The main factors that affect the range of the car are aerodynamics and the weight of the car.

5) How fast can the solar car go?
For the most part, our speed during a race is limited by the speed limit of the road we are traveling on. During a track race in Greece, Ra 5 exceeded 80 miles per hour; since then, our cars have only gotten lighter and more aerodynamic (top speed remains untested).

6) How many solar cells/batteries are there on the car.?
There are about 2,500 solar cells and 186 battery cells in Ra 7. The solar cells are connected in groups (called strings) based on size and position on the car. We use Gallium Arsenide solar cells, which are the same chemistry as the cells used in outer space to power satellites; in fact, the cells we use are cells that were designed for space use, but were found to have minor imperfections that would render them useless in a zero-atmosphere environment. The battery cells we use are Lithium Polymer, similar in chemistry to the battery found in a cell phone. Six battery cells are connected in parallel to form a module, and 31 modules are connected in series to create the final voltage (about 130 volts DC) for the battery pack.

7) How long does it take to recharge empty batteries?
It takes about 5 hours to completely charge the batteries from a fully discharged state, using the solar array in direct sun. We are allowed to start the race with a full battery pack, and then try to make sure the batteries are as fully charged as possible at the start of each day so that we can keep driving even if we lose exposure to the sun.

8) How much energy do the solar panels generate?
The peak rating for our particular solar array is approximately 1400 watts. This is similar to the amount of energy used by a hair dryer.

9) How long do drivers go on shift?
The North American Solar Challenge Regulations state that a driver may not drive for more than six hours during one race day; so to be able to race for the full 10 hour race day, we

Justin (a biology major) and Sten (a studio art major) enjoy the hands-on and messy activity of mixing epoxy in preparation for a layup.

need a minimum of two drivers. Our team will register four drivers, the NASC maximum. Driver selection is based on factors like car handling, driving performance, and dedication to the team. Finding the lightest driver is not necessarily an advantage since there is a regulation stating that drivers must weigh at least 80 kilograms (176 pounds), and that if a driver weighs less than that, ballast must be added so that the driver plus ballast equal 80 kg.

10) What is the total weight of the solar car? Is this the same for every car?
Ra 7 will weigh about 550 pounds, including the driver. This figure is not the same for every car, as each team uses different designs, materials, and hardware. This will be the lightest car that the Principia College team has built and raced.

11) Does the car have to be street legal?
No; for the race, organizers have coordinated with local and state officials in each of the states and provinces included in the route to allow for road-use by the solar cars. Each car will be required to have two support vehicles with it at all times, one in front of it and one behind it. Occasionally, teams will register their solar cars to be street legal; regardless of registration, the solar cars and support vehicles will be subject to traffic laws during the race and can receive tickets from the highway patrol.

12) What is the environmental impact of building this car?
The immediate environmental impact of building and racing this car is not as pretty as some may hope; from fuel used for transporting people and parts while building the car and fuel used in our support vehicles during the 2400 mile race, to chemicals used in the solar cells, battery cells, and composite materials that give the car its shape, it is definitely not a "green" project. What this project does do, though, is help to reduce the long-term environmental impact of transportation and energy sources through hands-on, visual demonstrations of alternative energy education and awareness. While solar cars themselves are not practical for transportation, electric vehicles and solar-electric generation is very viable and beneficial. Even by using electricity from a coal-fired power plant to charge the batteries of an electric vehicle, the net carbon footprint is significantly less than that of a petroleum-fueled vehicle. With the installation of solar panels on residential homes, the act of charging an electric vehicle becomes nearly carbon-free, and additional energy can be used to reduce demand for grid-electricity and reduce the peak load on the local electric grid (not to mention reducing your power bill). To see dozens of vehicles, built by students, complete a 2400 mile race at highway speeds without using any energy other than that captured from the sun is a spectacle that should make everyone stop and see the potential for an effective alternative to today's energy crisis.

Please feel free to call or email us with any other questions you might have; we like hearing from you, and we really like talking about the solar car!

Email: solar@prin.edu
Phone: 618-374-5290

John Broere, Car Leader:
john.broere@principia.edu
Andy Berner, Aerodynamics:
andy.berner@principia.edu
Makenna Reeves, Body:
makenna.reeves@principia.edu
Tom Brownell, Electrical:
tom.brownell@principia.edu
Asa Williams, Telemetry:
asa.williams@principia.edu
Katie Farquhar, Business Manager:
katie.farquhar@principia.edu
Joe Ritter, Faculty Advisor:
joe.ritter@principia.edu