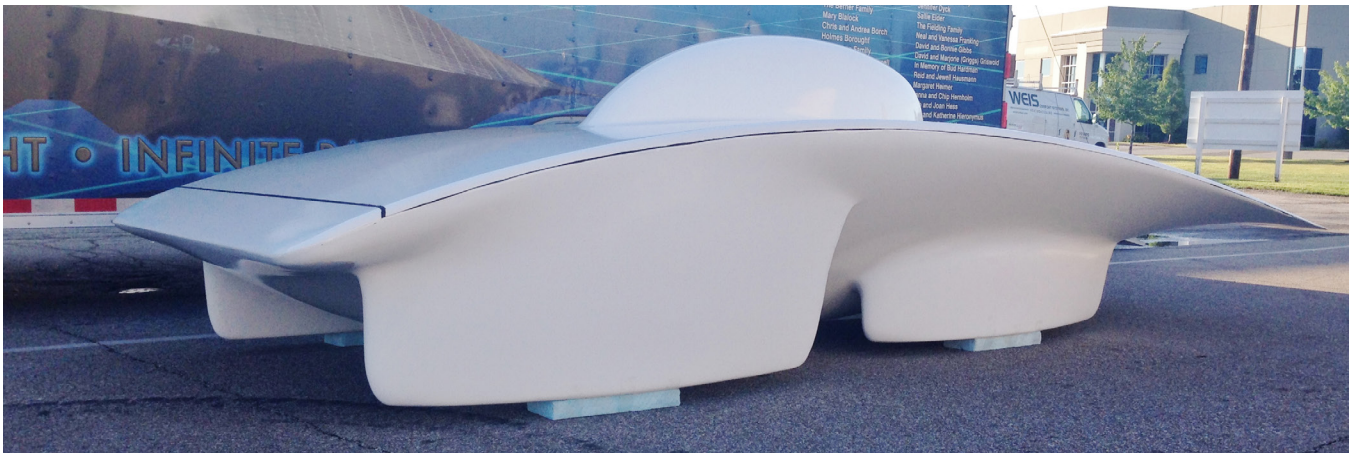
THE SOLAR FLARE

June 2014



Acting as a Competitive Team

By Kali McKee

At this point, you are probably wondering why you haven't heard much from the team or seen many "fulfilling" pictures of the progress on the design and construction of Ra 9. After driving manta-style cars, Ra 7 and Ra 7s, for six consecutive years, there have been a wide range of major regulation changes since 2008.

When the team was presented with the task of designing a brand new vehicle in the beginning of 2013, they couldn't design a competitive solar car that fit just one set of regulations. Since Principia Solar Car has a limited budget compared to most top solar car teams, an average of fifteen team members, and participates in a range of solar car races depending on the year, each new design is developed with the goal of competing in as many races as possible over the car's two year lifetime, with minimal changes.

As you may have heard, one of the major changes between Ra 7 and Ra 9 will be the addition of a fourth wheel. The last four wheeled vehicle the Principia Solar Car team designed was Ra 4, and this was before regulations required the driver to sit upright and the tires to meet a minimal level of tread. These regulation changes, if not researched and implemented correctly, could significantly affect overall aerodynamics and energy consumption levels.

This has put teams who race in both the American Solar Challenge (ASC) and World Solar Challenge (WSC) using a single design in an interesting position. WSC regulations require the most drastic of changes, and for teams racing in the 2014 ASC using the same car that has been built to meet WSC regulations, their multi-race car is more likely to be less energy efficient than vehicles designed only for ASC. In order to compete as a top team this summer, more effort must be dedicated to designing Ra 9 than a single race vehicle.

Although the Principia Solar Car Team is characteristically open about the design and structure of our cars, team leaders made a strategic decision to keep most of Ra 9's design under wraps until final decisions were made and it was closer to race time. Now, just under a month before the team sets out to race in Texan heat, this newsletter has been composed to illuminate our building process so that you are up to speed and ready for upcoming email updates as the team finishes Ra 9 and completes final preparations for racing in the 2014 ASC.

A Solar Car Race: What to Expect

By Ricardo Barrionuevo

There you are, standing in the middle of the crowd on a hot summer day in the heart of Texas. People are running back and forth making sure that the road is safe and that the whole track has been inspected and is ready for racing. Crew teams are going over their vehicles a final time to make sure everything is prepared for the race. Team managers and drivers are going over their strategies to make sure everything goes according to the day's plan. The 100 degree heat raises the tension and excitement of the crowd, and everyone taking part in the event is ready to start the race.

All this excitement for solar car races like the World Solar Challenge, American Solar Challenge, and the Formula Sun Grand Prix does not start the first day of the race—teams spend months, even years preparing for a race day. Teams like the Principia Solar Car Team spend countless, grueling hours designing and building the solar car to meet race regulations. For all competing teams, events begin about a week before the race, when team members perform final preparations and inspect all necessary racing equipment and tools.

This July, twenty-six teams will travel from all over the United States and the world to participate in the 2014 American Solar Challenge. Scrutineering and the qualifying track race, the 2014 Formula Sun Grand Prix, will be held at the 3.426 mile Circuit of the Americas in Austin, Texas. Each garage will be shared by two teams. Prior to qualifying for the road race, teams will have three days for registration and scrutineering, during which the car and drivers will go through a series of tests to make sure the car and team meets all regulations.

Scrutineering, Qualifying, and COTA

by Brian Ritter

Before the solar cars are allowed to run on public roads for the American Solar Challenge (ASC), they are put through rigorous static and dynamic testing (known as Scrutineering), followed by a track race (Formula Sun Grand Prix) that also serves as the qualifier for the race.

Scrutineering this year goes for three days, starting on Monday, July 14th. There are stations for driver registration, electrical, batteries, mechanical, body and sizing, array, and dynamic testing. Every station has a designated race official that meticulously checks that aspect of each team's solar car to make sure it meets the race regulations and safety standards.

Once a team receives at least a yellow status at each Scrutineering station, they can proceed to dynamic testing, which includes the figure eight, braking, slalom, and U-turn tests. The statuses a team can receive are: red – does not meet requirements; yellow – cleared for dynamic, not cleared for qualifier; blue – cleared for qualifier, modifications needed before ASC; green – cleared for ASC. Our goal is to pass inspection at every station in the first two days in order to use the third day to prepare for the qualifying race, Formula Sun Grand Prix (FSGP).

The qualifying track race will take place at the Circuit of the Americas (COTA), the first and only Formula 1 Grand Prix track in the United States. Teams must complete a minimum number of laps during the three-day race in order to qualify for ASC. The track itself is roughly 3.4 miles long with 20 turns and 133 feet of elevation change. Coming out of the pits, the cars face a steep incline followed by a hairpin corner at turn one. Many teams at the 2013 FSGP struggled up this hill, and cars leaving the pit for the first time were often cheered on by members of every team.

Lap times for the solar cars ranged from 4:42:000 to 8 minutes or more; to put this in context, the lap record for Formula 1 is 1:39:347. For our previous car, Ra 7s, targeting 6 minute laps proved to be the best trade-off between efficiency and speed. The track is demanding and puts more stress on our tires than driving on public roads, which makes it the perfect test of our car's roadworthiness, and we look forward to racing on this track again this July with Ra 9.

2014 American Solar Challenge

by Kenneth Stack

The 2014 American Solar Challenge (ASC) is a competition between academic institutions that will take place from July 21st to July 28th on public roads from Austin, Texas, to St. Paul, Minnesota. The objective is to travel the 1,700+ mile distance in the shortest time using only energy from the sun. There are currently twenty-six teams (including several from abroad) that have entered to compete.

The route itself has very specific directions along public roads that all the solar cars follow. There are nine locations during the race where the cars will stop and be on display. The first day begins in Austin, TX and cars will stop in Weatherford, TX for a short while on their way to Norman, OK. The cars will all leave from Norman the following day and pause in Wichita, KS for a media stop. Continuing from there, cars will stop in Overland Park, KS, and leave together the following day. The next stop is in Omaha, NE with a media stop in Ames, IA on the way to Lacrosse, WI. The final leg of the race leaves from Lacrosse and is just a few hours from the finish line in St. Paul, MN.

In addition to the solar cars, there are several support vehicles that travel along the route. A "lead vehicle" drives ahead of the solar car and a "chase vehicle" follows it. These serve to alert traffic to the presence of the solar car and to protect the solar car. In the chase vehicle, an observer monitors a team's progress and reports back to other race officials. Another important part of the team is the "scout vehicle" that investigates road and traffic conditions about an hour ahead of the solar car. Large truck and trailer units are also common among teams and help transport materials, tools, and other equipment for the race.

Each morning before racing, teams are able to charge their batteries from the sun for an hour. During the eight hours of driving time each day, teams will aim for a speed that optimizes both energy consumption and the distance traveled. Teams will often need to use this time to change drivers or tires and make any necessary repairs. After a day of driving, teams are allowed an additional hour to charge in the evening. Later that night, teams typically clean their car and perform any necessary maintenance.

We are all looking forward to this summer's events and are enthusiastic about the challenges and opportunities it will bring. Thank you for following along. To find out more about this summer's solar competition, check out ASC's official website: www.AmericanSolarChallenge.org.

What Spins and Why?

by Gage Edgar

There are lots of parts on the solar car that spin. The most significant of these are the wheels and the motor. We are using different types of wheels and a different motor, as well as a new hub and a new rotor, and you are entitled to know why.

First, an explanation of the brake system is necessary to understand the importance of the hub and the rotor, which are essential mechanical components. When a person pushes on a brake pedal, the brake system sends brake fluid to the brake calipers. The calipers cause brake pads to clamp down on the brake disc, also known as the rotor. The rotor is attached to the hub, and the hub is attached to the wheel. Finally, the ball bearings in the hub allow the wheels to spin, with the spindle sitting inside the hub, attaching the hub to the rest of the suspension. This entire process slows the car by stopping the wheels.

The brake discs we chose are a unique design, combining elements of standard production disc brakes with our own design. They are made from stainless steel, while the hub is composed of aluminum. Choosing whether a piece should be made of stainless steel or aluminum depends on the level of strength required for the part. The strength of the brake is crucial, as it determines whether or not the car can stop safely, while the strength requirement of the hub can be easily met with aluminum. Also, the ball bearings are made from ceramic to prevent them from denting.

The hub design has changed from Ra 7s to Ra 9. The new design is unique to our team; no other team has the exact same hub. Because our new tires are wider, the center of mass of the tire has shifted, which forced the team to create a new design in order to compensate. The new hub design accounts for this shift and readjusts the center of mass to the most stable position. This minimizes unequal wear on the tires.

The tires we are planning to use for Ra 9, MICHELIN radial 95/80 R16, are one of the best Department of Transportation (DOT) approved tires for solar car racing and offer incredibly low rolling resistance. Their tread is designed so that any water that comes in contact with the wheel is directed away from the tire, minimizing hydroplaning. The regulations for the World Solar Challenge require that tires be Department of Transportation (DOT) approved, but this is not the case for American races. In order to effectively race the same car under both race regulations, the team's strategy is to minimalize necessary changes.

Ra 9's motor is made by Mitsuba and is manufactured in Japan. DC brushless electric motors, like the Mitsuba motor, spin due to the interaction between magnetic fields generated by fixed electromagnets and a rotating permanent magnet. This motor is lighter and more efficient than our previous motor, weighing less than 11kg (about 25 lbs.) and performing at greater than 95% efficiency. This means that 95% of the electricity we send to the motor is converted into motion.

As you can see, many factors are involved in choosing our spinning vehicle components. A recurring theme is the desired reduction of rolling resistance. Such is the beauty of project-based learning at Principia. Each design team gets the opportunity to analyze past designs, think critically about current factors, and make educated decisions in order to build a world-competing solar car.

Constructing a Plug

by Gabe Korinek

Like many aspects of building a solar car, the process of constructing the upper and lower body is complicated and labor intensive. One process involves six different stages, which go as follows: designing the body, making a life size model of the upper and lower body with foam, creating a smooth plug by covering the foam model with Bondo, covering the plug in fiberglass to create a mold, prepping the fiberglass mold, and finally, using the mold to perform carbon fiber layups of the upper and lower body. This article focuses on the process of creating a life size model of the upper and lower body from foam blocks.

We started making the foam blocks by gluing sheets of regular household foam insulation together and weighing them down until they dried. Once ready, we stacked and glued the blocks together until we had two blocks of roughly 95 sheets of four by eight foot insulation. The blocks weighed over 800 lbs each and had to be moved around the shop by ten or more people until they were placed on rolling plywood platforms.

The blocks were then taken over to Elite Composites to have the exact shape of the upper and lower body cut out of the foam. This process is known as CNC (computerized numerical control) milling. It's a common phrase in the metal and prototyping industries and can be conceptualized as an automatic drill press whose cutting bit can move left and right, back and forth, and up and down. The drill bit cuts away a little material each time it goes around the part using a process that is known as stepping.

This process involves dividing the foam block into increasingly finer segments and cutting away the material. It's easier to think about this as a picture where we start out with very few and very large pixels and the image looks very pixelated. Then with each step the pixels get smaller, more numerous, and eventually we're left with a sharp image, or in this case, a continuous and smooth 3D shape which resembles the body of Ra 9.

However, since our foam blocks are so big, we can't do this with just any CNC mill. Thankfully, Elite Composites has a CNC mill that can cut out material from a block that is 50 feet long, 20 feet wide, and 12 feet high. This enormous contraption does not resemble the typical three axis CNC mill the Solar Car team is used to. Movement in the X-axis (back and forth) is provided by a set of rails on the ground spaced 20 feet apart.

A large n-shaped part with its legs connected to wheels on the X-axis and extends in the Z-axis (up and down). The top part of the n-shaped component is a rail which allows for movement in the Y-axis (left and right). The drill hangs down from the Y-axis rail and is controlled by a piston so it can change height. The process takes quite a long time (around 24 hours) and generates lots of foam shavings. But once it was completed, we had our first physical, life-size model of our car.

We used the foam models as a form to shape the upper and lower fiberglass molds. At the end of the construction of the car, the foam plugs will likely be thrown away. Their only purpose is to provide a shape for the fiberglass molds, and they usually can only be used once. However, we will keep the fiberglass molds as long as Ra 9 is in commission.

More on the Building Process

By Michael Rohrer

One major part of a winning race strategy is how efficiently your team uses the energy that the sun provides to the car. One of the best ways to improve efficiency is to improve the aerodynamics of the car. You may ask, what does this have to do with a plug? The answer is, your aerodynamic design will only apply if the plug is made properly.

What is a plug?

The plug is the initial process for creating the mold. There are two plugs, one for the top half of the car and one for the bottom half of the car. You can think of the plugs as the molds for the molds.

How do you make a plug?

The first part of creating a plug is gluing about 100 sheets of insulation foam, from our local hardware store, together into a 16'x7'x4' block. In order to do this we had to find a method to glue them together. We first attempted to use an air cured caulk. This failed because there is little to no space between the two sheets of foam, and therefore there is not enough air to cure the glue. Our next trial involved Gorilla Glue, which is chemically cured. This allowed it to bond without the presence of air. Although Gorilla glue successfully stuck to the foam, it expands and pushes the two surfaces being glued apart. In order to compensate for this, we had to apply a large enough force to keep the glue from creating detrimental gaps between layers of foam. We decided that if we could glue the pieces together while they were parallel to the floor, we could stack heavy objects on top of the foam to compress the pieces together during cure time. Using this method, we successfully created the foam blocks for the upper and lower body.

Once these blocks were milled into the shape of Ra 9 by a CNC mill, they were transported back to the shop for a fiberglass layup. This step protects the foam blocks from the Bondo Body Filler, which can dissolve foam. The fiberglass sheets had to be tailored to fit the shape of the car and leave no spot unprotected. Once the fiberglass sheets were in place and cut to size, resin was added to create a hard protective layer that conformed to the shape of the foam. When cured, rough spots were sanded off and the Bondo was added. Bondo is a body filler used to repair rust spots and other aesthetic issues on cars. We used the Bondo to provide a smooth surface for the mold to be assembled on.

The Bondo is a two part chemically cured body filler that consists of the hardener and the Bondo itself. Once the Bondo is mixed with the hardener, the spreader has about 5 minutes before the Bondo cures. The first step of applying Bondo is to spread a layer about 1/16" thick in an area approximately 2-3 square feet. Once the Bondo is tacky, a process that we call "cheese grating" is performed in order to flatten out high spots and conform to the shape of the car. We call this cheese grating because the grater looks like a cheese grater from your kitchen. After the cheese grating is completed, there are still high spots that are then sanded with 36-grit sandpaper while the Bondo is mostly dry. The process is repeated until the entire car has a layer of Bondo on it.

After sanding with 36-grit, 80-grit sandpaper is used to smooth the Bondo surface even more. Once the surface is smooth enough, it is then brought back to the fiberglass shop where six coats of primer are added to the surface. After three layers of primer have been added, the surface is sanded first with 180-grit sandpaper, then 220-grit sandpaper. The next three coats are applied and sanded with 220-grit sandpaper, followed by 320-grit sandpaper until the surface is as smooth as glass. After a final approval by all team members and our fiberglass expert, Steve Wright, you can celebrate because you have finished your plug! However, there is still much more work to be done before the solar car is race ready.

Fiberglass Molds

by Evan Sperr

There are many steps in the process of creating a fiberglass mold. First we sprayed the plug with a mold release agent. The mold release agent is called Polyvinyl Alcohol (PVA). PVA allows the mold to be separated from the plug once it is finished.

Once the PVA dried, we applied a gel coat with an air sprayer. The gel coat is a pigmented resin, which gives the mold surface a harder, more durable finish. The next step was to measure the sheets of fiberglass we would need for the mold. Everyone wore gloves and a respirator to protect them from fiberglass particles and chemical fumes from the materials we were using. Now we were ready to perform a fiberglass layup.

First we laid the fiberglass material on the plug and impregnated the piece with resin. A special roller is then used to remove air bubbles. Air bubbles, if left in the curing resin, reduce the strength of the finished mold and increase time put into fixing the mold after it is pulled from the plug. When laying the sheets of fiberglass down, we would cover 2/3 of the previous sheet to provide us with an efficient laying process, because we only had a small period of time before the resign hardened. This process was repeated two times. Once the final layers of fiberglass are applied to the mold, the mold is left to set and cure.

Once the plugs are pulled from the molds, the team must repair and prepare the molds for carbon fiber layups. The best results from carbon fiber layups will only result from precise, thorough work done on the molds. Therefore, it is important to make sure the molds are completed with as few imperfections as possible.

Mechanical Report

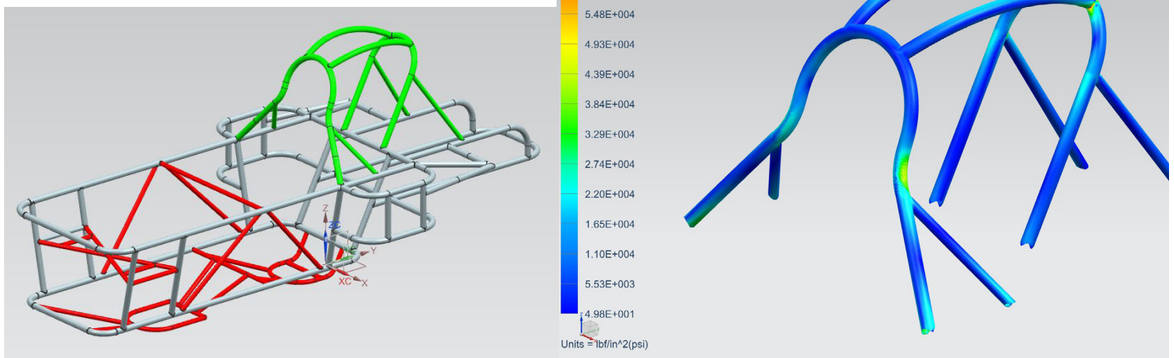
by Garrett Fielding

In a project as futuristic and complex as building a solar car, it is easy to forget that the final product is still a car. Like standard production vehicles, the solar car has mechanical components that allow basic automotive functions. Mechanical systems are one of the primary design considerations when building a solar car, along with aerodynamic design and the electrical systems. For Ra 9, our mechanical design began with the frame of the car. Our objective was to fit a structurally sound frame inside our proposed body shape. The frame will be fabricated from aluminum tubing and is designed to provide driver protection and hold the body of the car together.

Once the sizing of the frame is determined, it is continually altered to provide more protection for the driver, accommodate regulations, and provide locations for the suspension and wheels to attach. From here, suspension components are created based on sizing and spacing needs. For example, we know that on the rear wheels we need to fit a tire, shocks, a parking brake system, and a motor into a very tight space. Suspension components are designed to absorb some of the force from bumpy roads while holding together essential components in confined spaces. Once the structural integrity of these systems has been tested using computer stress modeling, other systems can be designed such as steering and braking.

The mechanical design process functions as a cascading chain of events, starting with the largest mechanical part – the frame – and progressively moving on to lower systems that interact with the component above them. The organizing body of each race dictates how much stress all of these components must be able to absorb before failing. For example, regulations for the American Solar Challenge state that the frame must be able to withstand a 5G impact from all directions, meaning that five times the weight of the car must be able to press against any location and the driver still remain safe. Suspension components must withstand a 2G bump, 1G turn, and 1G brake, again meaning that these components must withstand one to two times the weight of the car pressed against them without failing.

A delicate balance exists between creating a part that is structurally sound and creating a part that does not add excess weight to the car. Tweaks and fixes are made throughout the design process to ensure that parts are safe, light, fit, and interact with one another properly.



New Students: Gage Edgar

Hi! My name is Gage Edgar, and I'm a freshman on the solar car team. I am a declared physics major, and I might possibly minor or second major in mathematics. I was able to visit the Principia College campus last May for two weeks for my Principia Upper School senior project. This was my first time working with the team and using the team's 3D design software, Siemens CAD Software, NX.

Since then, I have worked in the machine shop to prepare myself for the construction of mechanical parts. For the most part, however, my time in solar car has been devoted to cleaning the construction tools that other team members get dirty in the construction of our molds.

I am quite excited to be on the race team this summer! It's my first time on a solar car race, and as a new race team member, I have yet to know what I will be doing on the race, though part of my job may involve cleaning the array. In the future, I would like to be involved in the design of Ra 10, either with the aerodynamic or mechanical design.

Michael Rohrer

My name is Michael Rohrer and I grew up on a small lake in Grayslake, Illinois. Throughout my childhood, my dad would usually be working on some sort of remodeling project around the house. As I became interested in what he was doing, he began teaching me how to use the different tools. From there, I started building things out of old plywood and 2x4s that I found in our garage.

I discovered how much I loved building and designing furniture. Eventually, I started making furniture for people. Due to my love of building, I knew that I would enjoy the Principia Solar Car team. I promptly signed up after my first semester and now have the privilege of going on the race this summer!

Jackson Walker

Hello! My name is Jackson Walker and I just finished my freshmen year at Principia College. I am involved in Principia's solar car program and intend to major in Computer Science, with a minor in either Economics or Business Administration (or both!). I am 19 years old and come from South Kansas City, Kansas. I have always been interested in reading, and I'm currently trying to read George R.R. Martin's A Song of Ice and Fire series before the TV version, "Game of Thrones," catches up to where I am. I really enjoy music and was in my school's marching band, but unfortunately couldn't continue that when I came to Principia. I play both the piano and clarinet.

Principia College was not originally my first choice for college. I wanted to go to a science-focused college and not a liberal arts school. However, the solar car team added a lot of appeal to Principia. After seeing that I could join the solar car program while studying in a potentially unrelated field of study, I was intrigued and did research on other comparable teams. I was drawn to the Principia team because I could participate instead of being relegated to the sidelines like I saw rival teams doing with their freshman.

When I got to Principia, I realized that I made an excellent decision, as I was warmly welcomed onto the team and am treated as an equal, even with people who have many more years of experience in their fields than I have.

Within the solar car program, I am an electrical engineering apprentice (also known as a junior sparky). I am learning how the solar array interacts with the batteries, how the batteries interact with the motor controller, and how the motor controller interacts with the motor. I'm really excited continue studying this fascinating side of solar car racing. Just a few weeks ago, the sparky team took apart an old battery module in an attempt to charge up old cells to their previous operating capacity.

While I don't know the first thing about electrical engineering, I look forward to learning and presenting my skills to my peers in a way that is useful and fun!

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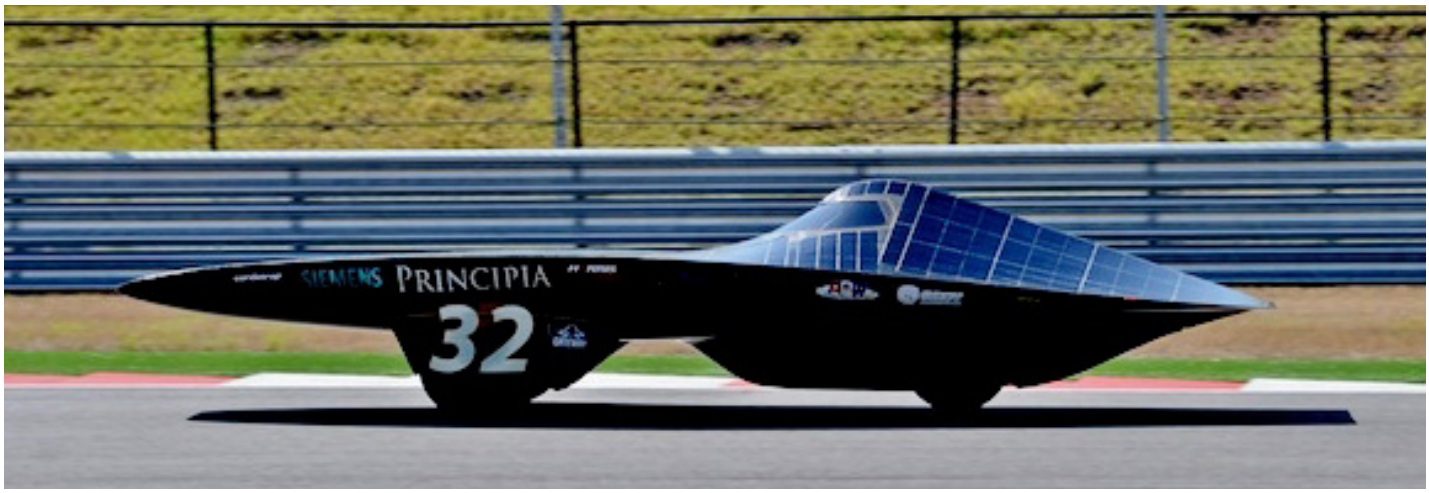

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