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## Borealis II Triumphs!

**B**orealis II (far right), the creation of the 2003 University of Minnesota Solar Vehicle Project, victoriously takes its place at the finish line of the American Solar Challenge 2003. Borealis II outstripped more than 30 competitors and 20 starters in the race from Chicago, IL to Los Angeles, CA for a second place victory. The team traversed 2,233 miles in 56 hours and 36 minutes.

## Borealis II Takes 2nd Place in American Solar Challenge 2003

**O**ur team traversed the Land of Lincoln, crossed the Mississippi River, navigated the Great Plains, climbed the Great Divide, and ran through the heart of the Mojave. The University of Minnesota Solar Vehicle Team and our car, Borealis II, raced the sun across 2,233 miles of Route 66, America's Mother Road.

### July 13, 2003 – Day 1

The race began 9:00 AM in downtown Chicago at the Museum of Science and Industry. Our team was second in the starting order, thanks to a strong performance at the Formula Sun qualifier. The Windy City's urban sophisticates looked on in amazement as a pack of twenty cars barreled through town and out into the country. The close spacing of cars made the first day of racing an exciting one. We were aiming to set an ASC record and reach the St. Louis checkpoint in a single day, a distance of 328.57 miles. Borealis II rolled into St. Louis 8 hrs and 14 min after departing Chicago, just 5 minutes behind the race leader University of Waterloo. Borealis II ran flawlessly during the first day of racing with no unplanned stops. Still, many team members found reason to work late into the night tweaking systems for even better performance.

### July 14, 2003 – Day 2

A sunny morning met the ASC race leaders and the cars blasted out towards the first staged stop in Rolla, MO. Borealis II was pushed to the limit as the team drove at the speed limit for 107.26 miles through the rolling hills of eastern Missouri. Although a short race day, it proved a treacherous one during a passing maneuver with the University of Missouri – Rolla when one of our lead van drivers earned the nickname "Ditch Witch." Still the team persevered and arrived in Rolla just before 11AM. The team spent the remainder of the day charging the batteries in the intense heat content with our 2<sup>nd</sup> place position overall, but plotting our strategy to close the 14 second gap to Waterloo and take the

lead. The remainder of the teams filtered into the Rolla stage as the day continued and the team enjoyed trading tales from Route 66.

### July 15, 2003 – Day 3

This July morning brought sweltering heat and bright sun. All the teams set out towards the next stage in Albuquerque, NM – some 984.7 miles distant. The Minnesota team made a strong push overtaking leader Waterloo and stopping in Tulsa, OK. Official standings put the University of Minnesota in the lead. Borealis II continued operating without incident and made no unplanned stops during the day.



### July 16, 2003 – Day 4

Borealis II started strong out of Tulsa, OK, but the day turned grim when the brutal condition of Route 66 through Oklahoma proved too much for the rear suspension shock absorber. When the team pulled into the Sayre, OK press stop they were horrified to discover the bottoming of the rear suspension had torn a bracket loose on the chassis. The mechanical team immediately began a field repair and only an hour of race time was lost. The array continued to charge the batteries during the repair, so the strategy team approved an increased pace for the remainder of the day. The team stopped in McLean, TX for the evening. The residents of McLean proved very welcoming and much of the team was given the opportunity for a monster truck ride in the local gravel pit – a perfect release after a trying day.

### July 17, 2003 – Day 5

Borealis II finished the stage into Albuquerque, NM at 6:06 PM, having completed the 984.7 miles from Rolla, MO in 26 hrs and 39 min. Despite the emergency repair on the previous day, Borealis II's rapid progress over the past 3 days left our team in 2<sup>nd</sup> place, just 2 hrs and 50 min behind race leader Missouri-Rolla. The team turned in early to prepare for repairs and charging the following day.

### July 18 - 19, 2003 – Day 6 & 7

Having arrived a day early, the Minnesota team remained in Albuquerque charging and making repairs to the car while the trailing teams closed in on Albuquerque for the staged start on the 20th. Despite triple digit temperatures, spirits remained high as team members took a day to relax away from racing.

### July 20, 2003 – Day 8

Early in the morning the teams left Albuquerque with Barstow, CA, 721.55 miles distant, dead in their sights. In their way was a stretch of barren earth known as the Mojave Desert. Sand as far as the eye could see, 110° degree heat in the shade, and miles of black, beaten road proved to be a test for solar cars and team members alike. Borealis II pushed up in elevation to the Flagstaff, AZ checkpoint and then onward to Williams, AZ for the night. Borealis II was again operating beautifully and without incident.

### July 21, 2003 – Day 9

The team departed Williams, AZ at the south rim of the Grand Canyon determined to make



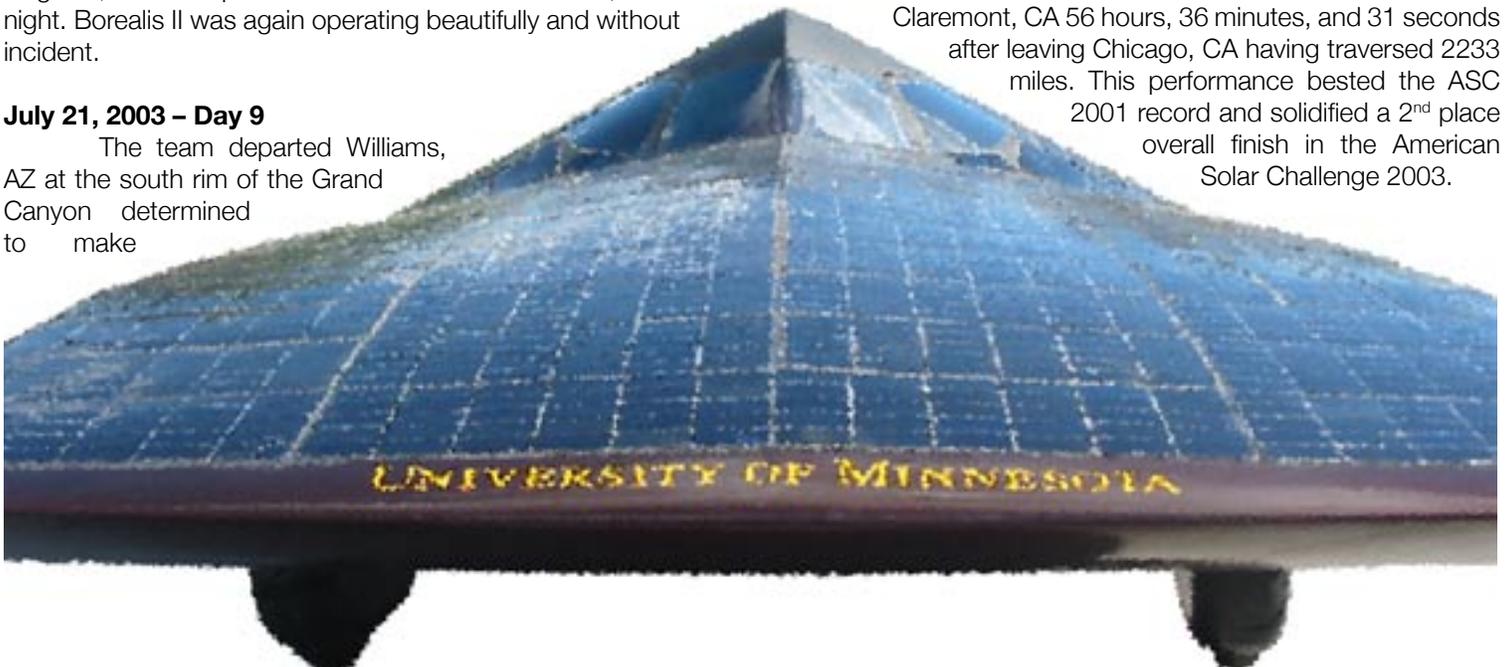
Barstow, CA before the end of the race day. Borealis II finished the 721.55 mile stage into Barstow at 4:30PM. The official standings had Minnesota in a solid 2<sup>nd</sup> place, 5 hrs and 6 min behind the leader Missouri-Rolla. Although we were unable to catch Rolla, we maintained a very solid second with nearly 1.5 hrs separating us from the third place Waterloo team.

### July 22, 2003 – Day 10

Again, having arrived more than a day early in Barstow the team performed routine maintenance on the car and topped off the battery pack for the sprint to the Claremont finish line.

### July 23, 2003 – Day 11

The starting line in Barstow met a team both relieved and excited – with just 91.55 miles to the finish line the race would be over in just a couple hours. Borealis II sped away from the starting line towards Claremont at the maximum allowable speed. The remaining distance was rapidly closed in just 2 hours and 42 minutes – the fastest of any team. Borealis II rolled into Claremont, CA 56 hours, 36 minutes, and 31 seconds after leaving Chicago, CA having traversed 2233 miles. This performance bested the ASC 2001 record and solidified a 2<sup>nd</sup> place overall finish in the American Solar Challenge 2003.



# Formula Sun Grand Prix 2003: The Making of a National Champion

After 564.9 miles, 269 laps and 3 days of competition, Borealis II edged out all competition for a 1<sup>st</sup> place finish in the Formula Sun Grand Prix 2003 event in Topeka, Kansas. The victory did not come easily, however, as the field encompassed other quality teams including the University of Missouri-Rolla and Kansas State University. In the end Borealis II powered through the rainy weather of the final day of the competition and claimed victory, just one lap ahead of rival Kansas State.

## May 14, 2003 - Day 1

The team and car overcame numerous challenges during the race, any of which could have spelled disaster instead of success. Entering Formula Sun, Borealis II lacked some critical testing needed to understand how it would perform under the stressful race conditions. Every team member knew it would be a trial by fire, but we maintained confidence in our design. The team's worst fears were realized only part way through the first day of racing when the team was alerted that the car was stopped on the track with "serious damage". Borealis II had lost her left front wheel! The team rapidly diagnosed the problem as inadequate wheel nut safety wire and replaced the damaged brake disc and installed a new wheel and tire. Day one continued uneventfully despite the car pitting periodically to be checked over. Finishing the first day of competition we completed 114 laps, trailing leader Kansas State by only 12 laps.

## May 15, 2003 - Day 2

Day Two commenced with Kansas State running laps at a slightly faster pace than us, but in the afternoon Missouri-Rolla experienced battery trouble that sidelined them for the remainder of the day. Our strategy team adjusted our pace and we began lapping Kansas State and by mid-afternoon we had closed the 12 lap difference to take first place. As we were breathing a sigh of relief, however, our driver reported to us that Borealis II's batteries were abnormally cutting power and Borealis II limped in to be checked out. After an inspection, we determined connections in the battery pack were tearing loose due to the vibration and the strong cornering forces on-track. A few minutes of careful deliberation later, the team decided to fix the problem and forfeit the remainder of the day rather than continue driving and risk further damage to the battery pack. Meanwhile, the competition

continued to race and the day ended with Kansas State 14 laps ahead.

## May 16, 2003 - Day 3

The final day greeted the team with a very dark sky and intermittent rain. Being an electric car packed with custom electronics and untested waterproofing techniques, the team worked furiously to prepare for what was promising to be a soggy day. The day began slowly as Borealis II crawled around the track due to lack of sun. As hours passed, however, it became apparent that race leader, Kansas State, had nearly exhausted their battery pack the previous day keeping pace with Borealis II. They were now stuck in the pits trying to charge their batteries from what little solar energy they could get. As a rainy 1 o'clock passed Borealis II made up a 14-lap difference to pass the leader and move into first place. Kansas State wasn't finished yet, however, and put their car back onto the track. The final three hours passed with both cars racing neck and neck. By this time all other teams had stopped racing due to the poor weather and rain. Information was unclear from race officials about exact lap totals and both teams crawled on through the rain not knowing how they placed. We were also continually worried about moisture reaching internal electronics. With 15 minutes left in the event it became clear that Borealis II was just a single lap ahead. Kansas State pulled the last Watt-hours from their pack determined to finish their current lap to bring the race total to a tie. Meanwhile, Borealis II was running low on power and was struggling to climb the last large hill on the track to coast down and over the finish line. Driver Al Majkrzak stopped the car on-track and after five minutes passed, officials were concerned that the car had broken down. In actuality, Borealis II was grabbing as much solar energy through the clouds as it could to build up enough power to climb the final hill. With fewer than five minutes left, the throttle re-engaged and Borealis II climbed the hill and came rolling toward the finish line to ecstatic team members and cheering fans.

The final trip around the track preserved the single lap lead over Kansas State. Despite strong competition and technical gremlins all of which could have spelled disaster, planning and teamwork prevailed and Borealis II became, in its first race, the Formula Sun Grand Prix 2003 national champion.



# A Day at the American Solar Challenge

No day was ever the same during this race, but the basic daily structure was similar. This account covers the 4<sup>th</sup> day of our experience in the American Solar Challenge. To give a bit of background; the "race caravan" includes the solar car, a lead van and chase van. The vans are always in front of and behind the solar car in order to protect it from on-road hazards. The solar car is street legal, but because of its size, shape and appearance, people tend to drive and react differently around it. We observed reactions ranging from jaw dropping shock, wild gesturing and attempts at amateur film-making from the driver's seat. In order to ensure compliance with rules and safety procedures, every team carried an official volunteer observer in the chase vehicle.



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## Race Day 4

Alarm clocks buzz at 5:00 AM in a hotel on the outskirts of Tulsa, OK. After a late night of working on the car, the team crawled out of bed, packed the trailers and drove a short distance to begin our morning battery charging. We were allowed to charge our battery pack using the solar array from 6:00 AM until our 8:00 AM departure. The morning light is not the best, but we take every watt available.

The charging location had been scouted out and decided upon last night. This day it was the parking lot of a thrift store that would open in a few hours, along with the rest of the town. Our Crew Chef served a breakfast of bagels, cereal and orange juice to get us ready for the day. The Strategy Team gave the rest of the team a brief overview of the current strategy for the day. We were in the middle of the second stage of the race; Rolla, MO to Albuquerque, NM - the longest stage at 984.7 miles, a distance that would take about 3 days of raying. Power conservation is extremely important during such an extended stage; a mistake in strategy could easily cost many race positions.

At 8:00AM the caravan got on the road, the day's



goal was to get to Amarillo, TX. There is not much freeway driving, mostly classic two-lane Route 66, which in Oklahoma is particularly rough. We drove straight to Edmond, OK our first media stop for the day and arrived in the late morning. Media stops are places where all teams stop for 30 minutes along the route to allow spectators to look at the cars. For the teams however these are times for frenzied activity in checking over the car, changing drivers, changing tires and talking with curious bystanders about the cars and race. It was a scorching day, so we were busily spraying the solar array and ourselves with water to keep cool.

Once back on the road, the drive was uneventful. Throughout the race, a good rule of thumb was that if you are bored then things are going well, as it indicates your car is running reliably and according to strategy. As the afternoon rolled on, we were pretty bored; the only thing that helped us keep our minds on the race was the road itself. The road quality went from bad to worse, it was like driving 50 miles per hour across 100 miles of speed bumps spaced about twenty feet apart. The team vowed that they would never look at Minnesota potholes the same way again.

Around 1:00 in the afternoon we arrived at our second media stop of the day in Sayre, OK. It started as a typical media stop with the team changing tires and driver, using the restrooms and stretching in the sun. As we were readying ourselves to leave, a crew member noticed a problem in the rear suspension. The Oklahoma bumps had done their worst, carbon fiber paneling under a bracket for the suspension had cracked, and it would not hold for up long. After a moment of shock the team was galvanized into action, closely analyzing the problem, deciding how to fix it and making an effective field repair.

It took some aluminum plate, inventive use of a grinder and drill, and an hour of race time before we were back on the road. With only an hour left in the race day we could not reach Amarillo as planned. However, while making the repairs, we had been charging the battery pack, which left us with power we hadn't planned on receiving. The strategy team ordered maximum velocity and we traveled at the speed limit for the remaining hour of raying. We used each extra watt to its full potential, passing two teams and making up some distance. We stopped at a little after 6:00 PM, within our half hour window in which we have to find a suitable place to charge.

After marking our stopping point on the road, the car was driven onto the highway median where we set up to charge until 9:00pm. Once the charging had started the team looked back at their rear suspension fix and another piece of aluminum was installed to help support the field repair. This repair would last us the rest of the race, as would the memories of the town in which we stopped.

We had stopped on the median in the town of McLean, TX. It was a very small town where everyone knew everyone else. Over the three hours we spent charging, we had a good portion of the town's population stop by to see what that weird

A Day . . . (cont.)

looking car was all about. The one thing we like as much as building a solar car is talking about it. Everyone was extremely friendly; one person gave team members rides in his monster truck and offered to open his auto parts store if need be.

At 9:00pm our charging was over, and our observer impounded the battery pack. The batteries are the only part of the car we were not allowed to work on outside of the race day. We continued working on the rest of the car and had some dinner. As some people worked on the car, others scouted the next days route, filled up the vans with gas, and the rest fell asleep. Long after the sun set, the car was put in the trailer and the team went off to bed for a few hours of sleep before repeating everything again the next day.



## In the Year 2005: A Look Into the Future

In 2001, a new team set out to create Borealis II, a refined design embracing sweeping improvements in quality and reliability over its predecessor. After two years, three very successful races, and countless hours of study and labor, the Borealis II team accomplished extraordinary goals.

Now, looking forward, returning team members and numerous new recruits are setting out to create the University of Minnesota's seventh generation vehicle. Senior team members from the Borealis II team have stepped down from leadership positions and moved on to graduate studies or their post-college careers, while new leaders are being mentored and developed. The new project leaders Trevre Andrews, Al Majkrzak, and Chris Olson, already accomplished contributors to the Solar Vehicle Project are making preparations for the 2005 car. Recruitment for the new 2003-2005 team is underway via recruitment seminars lead by former team members and faculty advisor Dr. Patrick Starr. The seminars introduce all facets of solar car racing and design and outline the foundations for the Product Development Process to be undertaken over the next two years.

Already, several new technical innovations are being pursued based on experience gained during the design, construction, and testing of Borealis II. The culmination of several years of development, the team will be fabricating and testing its own custom designed motor – a rare feat among collegiate teams most of whom continue to use prefabricated drive systems. Work has already begun to develop an array encapsulation method using a purpose built vacuum laminator that surpasses the team's prior attempts and many of the commercial options as well. The plan is to continue to fabricate the solar array in-house – something done almost exclusively by the Minnesota team and a key source of pride. Even the composite construction of the aerodynamic body is being reconsidered with weight and conductivity chief considerations in the choice of Kevlar fabric

instead of the carbon fiber used previously. Plans for further reducing weight and increasing efficiency in the mechanical systems are being formulated.

The new team is also starting proactively by conducting extensive tests on Borealis II to gather energy usage data at a range of speeds in various configurations and conditions. The test plans executed thus far are the most comprehensive ever undertaken by a solar vehicle team at the U of M. The team will take the data and use it to refine the next generation car designs as well as enhance racing strategy. The 2004-2005 team is already showing great enthusiasm and the 2005 solar vehicle should prove to be the best ever for the University of Minnesota.



## A Note from the Advisor

### **History**

Our first Solarcar, the Aurora I was created for the Sunrayce '93 event, 10 years ago. Since then, teams have created five more vehicles for the biennial cross country races in the USA, culminating with Borealis II in ASC 2003. We have also competed in three Formula Sun events and three international events in Japan and Australia for a total of 12 competitions. In six of these events, University of Minnesota teams finished first or second, and in only three events, did we finish lower than fourth! Quite a record of accomplishment by the young men and women on our Solar Vehicle Project teams as they represented the University of Minnesota and our sponsors.

### **Praise for the Borealis II Team**

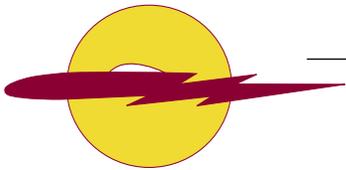
Second place overall out of 21 qualifiers in the 2233 mile ASC on Route 66 in July, and a "come from behind on the final day" victory in the Formula Sun event in May, which also served as a qualifier for the ASC event. If the basketball team had made the final four, the fans and sports press would go crazy. The Borealis II team made the "final two" in two national intercollegiate competitions. Remarkable accomplishments for a remarkable group of University of Minnesota undergraduates. Two years ago they were strangers to each other, attending the weekly recruiting seminars, and only shared a common interest in solar vehicles. As Design Teams were formed, each member willingly embraced the unknown and agreed to deliver results without fully understanding what was ahead. They exhibited the detective's ability to discover what needs to be known, the confidence



and intelligence to gain the knowledge needed, the ability to transform it into skills, and the perseverance to produce quality results. Thus they continued in the tradition of previous teams by exhibiting the qualities of curiosity, dedication and teamwork as they took responsibility for most of the design and manufacturing decisions, managed race operations, and ultimately created the world-class Borealis II vehicle.

We offer the vehicle projects to provide students the opportunity to gain hands-on experience with the Product Development Process in a team environment. When the vehicle is finished on time, qualifies for the competition and starts the race, we have successfully completed the development process. When we finish at or near the top, its frosting on the cake. The 2003 Borealis II team created much frosting!

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### Thank You Sponsors!

A sincere thank you to the Corporate, University and private individuals who provided the financial and in-kind donations that supported the Borealis II effort in these economically challenging times. Your support is an endorsement of the value of this hands-on design education.