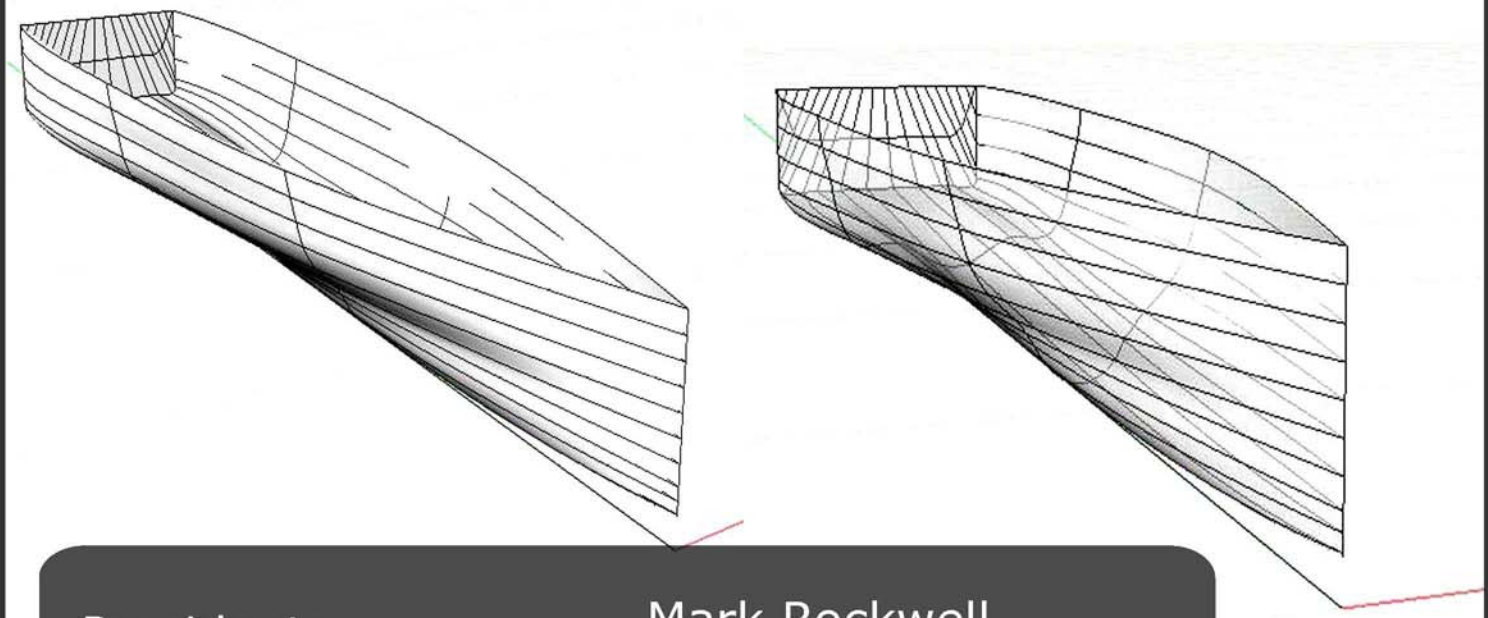
Carnegie Mellon
Solar Splash

2007 Business Plan



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Vice President:	Joshua Sztul
Hull Design:	Lluis Penalver-Aguila
Hull Build:	Joshua Sztul
Power Management:	Michael Kaufman
Propulsion:	Mark Rockwell
Treasurer:	Guido Bernardo Perez
Secretary:	William Wedler
Rules Chair:	Andrew Choate
Advisor:	Dr. Susan Finger

TABLE OF CONTENTS

INTRODUCTION

In June 2006, Carnegie Mellon competed for the first time in Solar Splash, the world championship of intercollegiate solar/electric boating. This is the 2007 business plan for Carnegie Mellon Solar Splash (CMSS). CMSS is a multi-disciplinary team of students working towards creating a solar/electric boat for the ASME sponsored competition, Solar Splash. The following pages document the goals and forecasts for our sophomore season.

MISSION STATEMENT

The Carnegie Mellon Solar Splash mission is to assemble and lead a multi-disciplinary team of Carnegie Mellon University students to compete in Solar Splash, the World Championship of Intercollegiate Solar Boating. Our mission is consistent with that of Solar Splash as stated by in the Solar Splash official rules:

> "Solar Splash has been established to promote interest in Science and Technology, Education, and Personal Interactive Skills. Established for collegians, it gives students an opportunity to apply theory to a practical project in a team environment. The Solar Splash itself serves as an opportunity for students to compete and showcase their accomplishments." (www.solarsplash.com)

CMSS will uphold this same purpose; extending this opportunity to the Carnegie Mellon community.

Moreover, through expositions on campus and in the Pittsburgh area, CMSS will use this project to raise awareness concerning green technologies. Our project is an example of one of the more exciting applications of alternative fuels and renewable resources; therefore we intend to use it to demonstrate the opportunities green technologies present.

CMSS 2006 TEAM RESULTS

In 2006, we successfully completed our solar boat and competed at Solar Splash for the first time in Carnegie Mellon's history. The 2006 season culminated with a week long journey in mid summer that took us from Pittsburgh, PA to Fayetteville, AR and back. We placed 14th overall and earned the distinction of "Notable Performance by a Rookie Team." Our goal for the 2006 season was to assemble a team of students and create a foundation for future CMSS teams. In addition, we set out to build relationships with the university and businesses in the area for the purpose of ensuring sustainability in the Solar Splash program at Carnegie Mellon.

By keeping everyone focused and staying true to our original goal of implementing a simple design (with the intent of expansion in future years), we were successful in reaching our goals. Not only did we create a solar/electric boat that competed at Solar Splash, but we were able to receive the aforementioned awards. We gained valuable experience that will be instrumental in expanding CMSS in future years. Moreover, we developed relationships with many key people and businesses that will help with future CMSS teams. We were also fortunate enough to have our accomplishments noted in several Pittsburgh area media outlets. These articles can be found in Appendix I.

CMSS 2007 TEAM GOALS

CMSS's primary goal is to develop into a sustainable organization. As mentioned in the introduction, 2006 was our first year competing in Solar Splash, and fortunately it proved extremely fruitful. One of our most exciting accomplishments last year was gathering enough funds, support, and knowledge to design and build a functional system out of nothing. We were able to build a hull, design and manufacture an outboard motor mount, and orchestrate a solar array and power management system.

This year presents our team with the unique opportunity of turning a year of work and design into a sustainable organization that will last for generations. Starting late in the summer of 2006, CMSS began redesigning a new hull and propulsion system as well as arranging tests for the optimization of our electrical systems. With these new additions to the project, we intend to continue building and contributing to CMSS's foundation in order to ensure it becomes a campus staple at Carnegie Mellon University. With consistent dedication, careful, we hope to gather enough experience, knowledge, and support to allow Carnegie Mellon to reach the pinnacle of competition.

To accommodate this goal, we will decide on one or two key design problems that we will focus the majority of our efforts towards. This will be our approach each year to ensure continual progress. This is in contrast to attempting to redesign and recreate every particular aspect of the project each competition year. Attempting this would only spread out our resources and potentially hurt our organizations long term goals. Staying focused on key areas of improvement allows us to optimize one or two aspects of the boat each year. In addition to the two major goals, we will gather computational and experimental data on the other parts of the boat (those deemed non-critical for that design year) with the intent to collect this data for future years and to gain a better understanding of those systems. The two goals for 2007 are to design an efficient and versatile hull and to redesign the drive-train to increase our maximum power.

With these goals in mind and this design pattern in place, we hope to set CMSS on a path to reach the top of the competition within the next five years. Through making CMSS a top competitor in the world of solar/electric boat racing, we hope not only to enhance and validate the prestige of the university, but also further raise awareness of the opportunities alternative energies offer.

CARNEGIE MELLON SOLAR SPLASH FUNDING STRATEGY

As with most large projects, raising funds and support from outside of our organization is a major obstacle. The CMSS 2006 project was funded primarily through the Carnegie Mellon University Undergraduate Research Office, businesses we contacted and the team members. Unfortunately, as we delve into our sophomore season and our experience, membership, and ideas increases so does our budget. Again, we are seeking funding and building relationships with corporations to secure funding for the CMSS project not only in 2007 but for future teams as well. Because approximately 70% of our funding comes from sponsors we are constantly looking for new people and corporations that can help out with our project. In accordance, CMSS has devised a series of different sponsorship levels: Platinum, Gold, Silver, and Bronze.

Title (Platinum): Sponsor donation total greater than $7500. Platinum sponsors are invited to team design reviews and will have an Extra Large Logo in a prominent location on our Boat. Moreover, if a color is commonly associated with a platinum sponsor then our boat's primary color will be consistent with the sponsor's. A platinum sponsor also receives the benefits of a Gold sponsor as listed below.

Gold: Sponsor donation total between $2500 and $7499. Gold sponsors will have their logos on the team memorabilia and documentation as well as a large logo displayed on our boat. Gold Sponsors are entitled to a select amount of team memorabilia. A Gold sponsor also receives the benefits of a Silver sponsor as listed below.

Silver: Sponsor donation total between $500 and $2500. We will place Silver sponsor's logos on our boat in medium format in addition to our team shirt. A Silver sponsor also receives the benefits of a Bronze sponsor as listed below

Bronze: Sponsor donations total less than $500. All Bronze sponsors will receive recognition on our webpage, an invitation to our project unveiling Barbeque, and the opportunity to purchase team memorabilia at team prices

We are a non-profit organization; therefore, any donation made to us is tax deductible. Our budget is available for perusal at the end of this document. Moreover, this business plan includes a detailed explanation of the goals and deadlines for the CMSS 2007 project, as well as various newspaper articles that have featured our project.

Through our fundraising efforts and your help we hope to raise enough funding, materials and tools to create a solar boat that will represent Carnegie Mellon, the team members and all supporters in the best possible way. It is the Carnegie Mellon Solar Splash mission to represent itself, the University, and its sponsors with the utmost honor, integrity, and excellence.

HULL

As CMSS begins its second year, the goals for the hull committee become more ambitious. As mentioned in our overall goals for 2007, the major goal of the hull committee is to design the optimal hull for the Solar Splash competition. The purpose of creating our own hull design is to surpass the performance of last year's hull while maintaining the previous design's stability and structural integrity. Because the hull shape ultimately dictates the overall performance of our solar boat, we hope that taking careful steps to find the optimal hull design will allow CMSS to be more competitive at Solar Splash 2007 and provide a platform for future teams to compete with as well. In order to accomplish this goal, we will conduct research exploring the advantages and disadvantages of planing and displacement hulls. Our main challenge is balancing hull performance versus the stability requirements mandated by Solar Splash rules.

After conducting extensive research concerning hull theory, our first step is to design several potential hull forms using the computational modeling program Rhino3D. Using the computational models, we will create physical models with proper scaling for experimental data collection. With this information we will be able to make modifications to the computational model and iteratively work towards an optimal design. To validate our designs we will use computational fluid dynamics (CFD) software such as FLUENT and ANSYS. With this information we will be able to optimize the hull's drag coefficient, wave drag effects, and planing velocity.

At this stage, only the outer shape of the hull form will have been completed. Further significant analysis will be conducted on the internal structure of the hull to ensure that the boat will be able to withstand operational loads. These loads include the force of waves on the hull, as well as all other boat systems, including solar array and motor assembly. At all times throughout the design process, there will be constant communication between the hull committee and other committees of the project to ensure proper integration and overall success of the project.

Ultimately, we have two major goals within the hull committee: to create a hull that maximizes our limited power source and will perform well in both displacement and planing situations. Moreover, this design should be strong and efficient enough for future CMSS teams to use. This will ensure that future teams will be able to concentrate and optimize other aspects of the CMSS project.

HULL COMMITTEE CALENDAR and DEADLINES

September 20, 2006 – Introduce problem
- Define the design challenge
- Figure out what to research and how to implement research tasks

October 9, 2006 – Create Hull committee budget

October 23, 2006 – Brainstorm
- Ideas, ideas, ideas
- Evaluate the pros and con of the conceptual ideas
- Define the ideas and group characteristics

October 30, 2006 – Computer Modeling
- Use Rhino3D to create preliminary computer models
- Evaluate preliminary designs from computer models

November 6, 2006 – Modeling and Simulation
- Continue creating concept designs
- Perform CFD simulations on refined designs

November 13, 2006 – Manufacturing Considerations
- Discuss method to transfer CAD model to physical mold
- Discuss method of designing tow tank models using Zcorp

November 20, 2006 – Manufacturing Considerations
- Organize transfer of CAD model to physical mold
- Begin making tow tank models using Zcorp

November 27, 2006 – Itemize bill of materials for hull construction and continue FLUENT simulations for optimizing hull shape.

December 8, 2006 – Choose and refine final design

January 4, 2007 – Order materials, create plans for manufacture

January 15, 2007 – Finalize Method of Mold Creation
Begin Design of Decking
Begin Acquiring Materials

January 23, 2007 – Model Mold Construction

January 29, 2007 – Begin Construction of Hull Mold
Fiberglass Hull models

February 9, 2007 – Mold Completion

February 12, 2007 – Prep and Begin Fiberglassing

February 19, 2007 – Surfacing of Hull

March 8, 2007 – Hull Form Completed

March 19-22, 2007 – Begin Structure and Decking/Panel Support Construction

March 30, 2007 – **DESIGN REVIEW VI:** Hull Completed

PROPULSION

The propulsion committee is in charge of designing, creating, and implementing all the mechanical components that make the boat move. Primarily, this involves configuring electric motors, propellers and a configuration for mounting these to the hull. Electric motors are inherently less powerful than their fossil fuel powered counterparts; therefore, our committee must find a way to optimize our electric motors through techniques such as weight reduction and propeller optimization.

During our Solar Splash 2006 season, we had a very simple design for the boat's propulsion. We implemented a single electric motor in an outboard motor mount that was constructed out of aluminum square tubing. This system was extremely durable and reliable, but major limitations from our propeller and gear ratios limited the system's maximum power and speed. This year we plan to expand on last year's idea with a variety of new ideas.

The overhaul of our propulsion systems is a major goal in 2007. Solar Splash rules allow for multiple configurations during different events, meaning we can tailor separate propulsion arrangements to different events. To accommodate this aspect we will be designing an outboard motor mount that can transform between different configurations, with the major difference being the implementation of a single motor during Solar Endurance and two motors for Sprint and Solar Slalom. This decision was made because Sprint and Solar Slalom our shorter events that require a lot of power over a short period of time. Paying attention to Solar Splash restraints is the best way to make use of all the power available to us. Meanwhile, Solar Endurance is a longer race that focuses more on system stamina, efficiency, and energy conservation. Moreover, hull theory actually limits the maximum speed of a boat at lower speeds (like those during Solar Endurance) having an additional motor would just waste our limited energy.

The CMSS 2007 drive-train will be able to transition between different configurations for the different Solar Splash events in order to maximize overall system performance. We will conduct research on propeller theory and design flow tank tests to determine the optimal propeller size for our boat. We will also be looking for ways to lighten the system because more weight will require a larger power drain by the motors. Keeping this in mind, it is extremely important that we create a realizable and durable final product because Solar Splash is a long and grueling competition and it would be catastrophic to have a fragile but extremely light design break during competition and render our boat immobile. Moreover, we are designing computational and experimental tests that will allow us to determine the performance of our system and find ways to make modifications and optimize our design.

PROPULSION COMMITTEE CALENDAR and DEADLINES (post 11-10-2006)

Prior to this point we have conducted research and brainstormed different ideas for creating a motor mount that can transform between a single and dual motor unit. There are two different ideas which we are currently in the process of finalizing computational designs and about to move into computational testing and optimization. We plan to use this data to make an educated decision in choosing our design for manufacture.

November 14, 2006 – Complete Solidworks Models of different Motor Mount designs

November 16, 2006 – Identify key parts of each design for computational testing and move into computational testing phase

November 17, 2006 – **DESIGN REVIEW I**: the propulsion committee will present their two ideas and explain the pros and cons of each. We will then take feedback from the entire team both concerning design choice and methods for determining proper design choice.

November 20, 2006 – Beginning computational analysis

December 7, 2006 – Complete computational testing, discuss results, and finalize design.

December 8, 2006 – **DESIGN REVIEW II**: the propulsion group will present their results and final design decision. After this meeting the Propulsion committee will begin using computational tools to optimize the chosen design

January 15, 2007 – Branch propulsion committee into subgroups: Propeller and Drive-train

- Propeller – Will begin to research propeller theory and determine how we can use information from the Hull committee to determine propeller selection
- Drive-train – Continue computational optimization of chosen design

January 26, 2007 – **DESIGN REVIEW III:**

- Propeller – present research about determining propeller and plan for experimental approach to propeller selection.
- Drive-train – Present finalized design

January 29, 2007 – Divide drive-train into two subcommittees: motors and manufacturing

- Propeller – Determine analytically what propellers we need
- Motors – Research motors and brainstorm testing ideas
- Manufacturing – modify finalized design for manufacture

February 05, 2007 –

- Propeller – Research manufacturers and pricing of analytically selected propellers
- Motors – Continue research and begin to design tests for motors.
- Manufacturing – Continue modifying model and create engineering drawings

February 12, 2007 –

- Propeller – Obtain propellers and brainstorm ideas for testing propeller performance
- Motors – Work towards finalizing motor performance test.
- Manufacturing – Develop Bill of Material and detailed plan for manufacture

February 16, 2007 – **DESIGN REVIEW IV:**

- Propeller – Information on selected propellers and suggested techniques for experimental validation/decision finalization.
- Motors – Explain what test will be conducted and what we hope to learn from these tests. (Obtain Motors)
- Manufacturing – Discuss manufacturing plan

February 19, 2007 –

- Propeller – Finalize construction plan, devise Bill of Material and detailed plan for manufacture.
- Motors – Devise Bill of Material and detailed plan for manufacture of testing arrangement.
- Manufacturing – Begin manufacture

March 12, 2007 – **DESIGN REVIEW V:** After this meeting the propulsion committee will divide into two groups Testing and Steering.

- Propeller – Testing design completed and ready to implement with newly completed
- Motors –Motor testing completed and Results displayed
- Manufacturing – Mount construction completed.
- Steering – begin to brainstorm and design simple steering mechanism

March 30, 2007 – **DESIGN REVIEW VI:** All testing will be complete and steering implemented in the system. Take information learned through testing and apply it to optimizing our system.

April 10, 2007 – **DESIGN REVIEW VII:** Complete all modifications and discuss any polishing that needs to be done for the system

April 15, 2007 – OVERALL DESIGN COMPLETION

POWER MANAGEMENT

The Power Management committee's goals for this year are based around data collection, analysis, and using these results to improve system efficiency. We have found that discharging and recharging batteries will lead to improved performance. Therefore, we plan to design a way to both "condition" our batteries and gather data concerning discharging and recharging rates. We will repeat the discharge/charge cycle of the batteries 8-12 times with controlled currents and voltages. We also plan to analyze the data collected from our solar charger when connected to the solar array with typical sun hours. With this data we hope to understand how to maximize the output from the Max Power Point Tracker (MPPT) and other solar conversion tools used in the solar charger. The motor controller will also be optimized with a derived algorithm in order to make its use more efficient and properly collect data for future analysis.

POWER MANAGEMENT CALENDAR and DEADLINES (post 11-10-2006)

November 17, 2006 – Finish design and cost analysis of the battery conditioning
– Order necessary equipment
December 19, 2006 – Finalize design and cost analysis for testing of solar charge controller
January 29, 2007 – Complete construction of battery testing/cycling device
February 05, 2007 – Begin testing/cycling of batteries
February 26, 2007 – Begin data collection and analysis for testing of solar charge controller
– Finish design and cost analysis of tester for motor controller
March 12, 2007 – Begin data collection and analysis with motor controller tester
April thru May – Implement tests during on water boat tests and optimize accordingly

CMSS OVERALL PROJECT CALENDAR

November 17, 2006 – **DESIGN REVIEW I**
December 8, 2006 – **DESIGN REVIEW II**
January 26, 2007 – **DESIGN REVIEW III**
February 16, 2007 – **DESIGN REVIEW IV**
March 12, 2007 – **DESIGN REVIEW V**
March 30, 2007 – **DESIGN REVIEW VI**
April 10, 2007 – **DESIGN REVIEW VII**
April 15, 2007 – OVERALL DESIGN AND CONSTRUCTION COMPLETION
April 28, 2007 – On-Water Test I
May 9, 2007 – MEETING OF THE MINDS: exposition at Carnegie Mellon where we will demo the performance and capabilities of the propulsion system along with the rest of the project
May 02, 2007 – Technical Report rough draft completed
May 05, 2007 – Technical Report due to Solar Splash Headquarters
May 16, 2007 – On-Water Test II
May 27, 2007 – Design unveiling and BBQ with sponsors and team members
June 13-17, 2007 – Solar Splash 2007 competition

MEMBERSHIP

Participant	Major	Year	Committees
Mark Rockwell	Mech E	Senior	Propulsion, Power Mgmt
Joshua Sztul	Mech E/IR	Senior	Hull, Power Mgmt, Propulsion
Lluis Penalver Aguila	Mech E	Senior	Hull
Michael Kaufman	ECE	Senior	Power Mgmt
William Wedler	Mech E	Junior	Propulsion
Anderw Choate	Mech E	Junior	Propulsion, Hull
Ming Huo	Mech E	Senior	Hull
Brian Hirsch	Mech E	Senior	Hull
Myles Cornwall	Civ E	Senior	Hull
Andrew Moore	Mech E	Sophomore	Hull
Mark Fuge	Mech E	Sophomore	Propulsion
David Pardo	Mech E	Freshman	Propulsion, Power Mgmt
Kevin Tian	Physics	Freshman	Power Mgmt
Alex May	Mech E	Sophomore	Hull
David Tuzman	ECE	Sophomore	Power Mgmt
Elizabeth Hohenstien	Mech E	Freshman	Propulsion
Andrew Gordon	ECE	Junior	Power Mgmt
Marco Dyer	MSE	Freshman	Propulsion
Alan Gerber	ECE	Freshman	Power Mgmt
Ottoleo Kuter-Arnebeck	Mech E	Sophomore	Hull
Nathaniel Zaharia	Mech E	Sophomore	Hull
Vishesh Nandekar	Mech E	Senior	Hull
T.C. Schwindling	Design	Senior	Hull
Guido Bernardo Perez	Business	Senior	Hull

Carnegie Mellon Solar Splash Budget

Overview of Budget

Project Budget

Item	Debit	Credit
Hull Design	$ 2,691.00	
Hull Construction	1,840.00	
Power System	4,190.00	
Propulsion	2,928.40	
Competition	2,507.60	
SURG Grant Drive Train		$ 1,000.00
SURG Grant Solar Array		2,500.00
Total	**$ 10,657.00**	

Detailed Budget

Hull Design

Item	Cost	Units	Total
Rhino w/ Rhinomarine Bundle	$ 500.00	1	$ 500.00
Monitor	400.00	1	400.00
Hard Drive	100.00	1	100.00
Fiberglass	526.00	-	526.00
Resin	330.00	-	330.00
Hardeners	235.00	-	235.00
Foam	600.00	-	600.00
Total			**$ 2,691.00**

Hull Construction

Item	Cost	Units	Total
Fiberglass Respirators	$ 90.00	4	$ 360.00
Vacuum pump	50.00	2	100.00
Fiberglass (internal structure)	175.00	-	175.00
Carbon Fiber	175.00	-	175.00
Nylon	175.00	-	175.00
Kevlar	175.00	-	175.00
Plywood (internal ribs + stringers)	80.00	-	80.00
Foam	600.00	-	600.00
Total			**$ 1,840.00**

Propulsion

Item		Cost	Units	Total
ETEK electric motor		$ 450.00	1	$ 450.00
L Series Timing Belt		15.00	5	75.00
H Series Timing Belt		20.00	5	100.00
L Series Timing Belt Pulleys				
By Teeth Size:	10	12.47	1	12.47
	20	27.56	1	27.56
	60	68.86	1	68.86
H Series Timing Belt Pulleys				
By Teeth Size:	14	29.00	1	29.00
	24	48.00	1	48.00
	36	69.52	1	69.52
	48	90.00	1	90.00
	60	93.00	1	93.00
Outboard Motors Steering		180.00	1	180.00
Teleflex Push-Pull Steering Cable		210.00	1	210.00
Steering Wheel		25.00	1	25.00
Bench Drill Press		169.99	1	169.99
Aluminum Stock Metal		80.00	-	80.00
Miscellaneous Cables and Hardware		100.00	various	100.00
Propellers		100.00	5	500.00
Strobe Light		250.00	1	250.00
Propeller Wrench		10.00	1	10.00
Grinder		145.00	1	145.00
Fiberglass/Resin		25.00	-	25.00
Speedometer		70.00	1	70.00
Tachometer		100.00	1	100.00
Total				**$ 2,928.40**

Power System

Item		Cost	Units		Total
Red Top Starter Batteries	$	150.00	3	$	450.00
Workaholic Batteries		150.00	2		300.00
Motor Controller		600.00	2		1,200.00
0 Gauge Wire		400.00	2		800.00
10 Gauge Wire		50.00	2		100.00
Relay		150.00	2		300.00
Ampmeter		130.00	1		130.00
Voltmeter		100.00	1		100.00
Fuse		60.00	2		120.00
Wire Connectors		30.00	1		30.00
Boots (Wire Covers)		30.00	1		30.00
Electrical Tape		30.00	1		30.00
Tools		100.00	various		100.00
120W Solar Panel		500.00	1		500.00
Total				**$**	**4,190.00**

Competition

Item		Cost	Units		Total
Gasoline expense / mile (2 cars)	$	0.44	3,840	$	1,689.60
Accommodations (8 people / 2 rooms)		70.00	2		140.00
Registration		400.00	1		400.00
Trailer Rental		200.00	1		278.00
Total				**$**	**2,507.60**

Appendix I

Carnegie Mellon Solar Splash
Media Exposure

Fired up: Sun's energy fuels motor for solar boat competitors
Wednesday, June 21, 2006
By David Templeton, *Pittsburgh Post-Gazette*

At first glance, the humble gray boat looks like the typical flat-bottomed variety used for fishing or duck hunting.

But once four solar panels are placed across its bow and wired to an electric motor mounted on the stern it's clear this one is powered by something other than a boater with oars.

This boat's fuel source is the sun and Carnegie Mellon University students have spent a year raising money and designing and building the solar-powered boat for competition this week.

Known as "The Carnivore" -- which demands explanation later -- the boat will be CMU's first-time entry in the Solar Splash World Championship, an annual collegiate competition of solar-powered boats built to meet strict contest rules.

Bill Wade, Post-Gazette
Carnegie Mellon University mechanical engineering students, from left, William Wedler, 20, a junior, of Ballwin, Mo.; Mark Rockwell, 20, a senior, of Farmington Hills, Mich., and Ming Huo, 21, a junior, of New York City, put solar panels on the boat they built for the Solar Splash Competition.
Click photo for larger image.

The competition starts today on Fayetteville Lake near the University of Arkansas campus in Fayetteville, and runs through Sunday when a world champion in speed and endurance will be crowned.

"The electronic technology is what has changed a lot," said Dr. Jeffrey H. Morehouse, a mechanical engineering professor at the University of South Carolina who organizes the event.

"What really is interesting is, since we sell technical reports [about the solar boats], we have requests from electrical boat companies, who buy the reports. They want to know how we're getting such high speeds and keeping batteries charged with solar panels."

Several CMU students, most of them mechanical engineering students, started the university's team a year ago with simple goals.

"We just wanted to get a team together, put a boat in the water and compete," said project leader, Mark Rockwell, 20, of Farmington Hills, Mich., noting that 10 students with various skills participated in the year-long project. "Next year we hope to have double or triple the number of people involved."

Mr. Rockwell and his teammates said they know they won't win the competition this year. But they entertain hopes of being rookie team of the year. Five rookie teams are scheduled to compete.

Dr. Morehouse said a rookie team placing in the top five "is possible, but not probable."

Still in need of design and mechanical improvements, The Carnivore can travel 4 knots an hour, equivalent to a brisk walk. Its student designers expressed confidence it can compete in the endurance competition by doing nonstop laps around the lake for two hours.

Mr. Rockwell and his teammates said they expect the best boats to reach 7 knots an hour in the endurance phase. "In comparison, we're not that much slower," Mr. Rockwell said.

The project required students to raise $6,500; line up donations of supplies, equipment and tools; do research and design the boat according to contest rules; then build and test it.

The team floated the boat in Schenley Pond near campus before doing a successful test run in Lake Arthur at Moraine State Park in Butler County, but only after they were forced to buy a boat license.

The only problem was, the engine does not drain the battery, which is a technical flaw. Ideally, the engine should gradually drain the battery so it runs at top power for the two-hour endurance test.

Mr. Rockwell said he attended Solar Splash last year in Buffalo to scope out the competition, get advice from other universities and do advance research.

Last year's overall champion was Cedarville University of Ohio, with the University of New Orleans winning the sprint championship.

To launch its project, the CMU team landed a $3,500 grant for environmental research from Ford, bought four solar panels for at a discount price of $1,640, borrowed tools from a boat company and received donated equipment and supplies.

Many hours were devoted to designing the boat to increase power, minimize weight and enhance the electrical system.

The four solar panels, which produce 480 watts of electrical power, are connected to a charge controller, which energizes a lead-acid battery that powers the boat. The controller has been the focus of many technological advancements over the years, Dr. Morehouse said.

The CMU team acquired a motor mount and propeller from a gasoline engine, but replaced the gas motor with an electric golf-cart motor, using a belt drive to spin the propeller.

Rather than build a hull for the boat, they opted for a duck-boat design with a flat bottom. Glen L Marine, a well-known boat design company in California, advised students on boat construction. Hull design to increase endurance and speed represents another area of focus for winning teams, Dr. Morehouse said.

There are no weight restrictions, but a boat cannot be longer than 20 feet, 7 feet wide or more than 4 feet out of the water. The Carnivore complies with those specifications, Mr. Rockwell said.

The boat's one passenger must weigh 150 pounds. If the boater weighs less, ballast is added.

"This is an excellent start, considering a year ago we had no money, no participants and no school involvement," Mr. Rockwell said, calling the project "a real world engineering experience.

"It's been a lot of work and at times painful. But we are using our engineering knowledge rather than earning a grade.

"We're creating a buzz."

Next year, he said, the team will design a fiberglass hull, with issues involving electrical power, engine size, gear ratio and propeller size better resolved.

Oh, and that name, "The Carnivore"?

Starting from scratch last year, the team suffered many setbacks and frustrations all year long. But when frustration set in, team members had a meat-eating retort for everyone to chew on:

"You're a carnivore," they would tell each other. "You're going to get it done."

Templeton, David. “Fired up: Sun's energy fuels motor for solar boat competitors.” *Pittsburgh Post Gazette* 21 JUNE 2006: G1+

CMU student crew engineers a splash
By **Jennifer Bails**
TRIBUNE-REVIEW
Thursday, June 15, 2006

Mark Rockwell drew a lot of stares driving through downtown Pittsburgh with a hand-built, solar-powered motor boat strapped to the roof of a 1981 Mercedes.

One rubbernecking motorist even pulled out a camera to get a picture of the unusual vessel on its way to a test run in a Butler County lake.

This weekend Rockwell and an enterprising band of fellow students from Carnegie Mellon University will embark on an even longer journey with the boat they designed and built from scratch in a Squirrel Hill garage.

They will drive almost 1,000 miles to Fayetteville, Ark., to become the first team from CMU to compete in the 13th annual Solar Splash 2006 World Championship of Solar/Electric Boating.

The intercollegiate regatta run by the American Society of Mechanical Engineers promotes the use of alternative energy sources while giving students hands-on engineering experience in a competitive setting.

Rockwell, 20, of Farmington Hills, Mich., is an aspiring roller-coaster designer who assembled the group of more than 10 engineering, business and design students to enter the Solar Splash competition with a red-and-black boat they named "The Carnivore."

"Our whole mentality was that we are the carnivore, that we are going to do whatever we need to do to get the boat done," said Rockwell, a Carnegie Mellon senior. "The project was not very easy. We had a lot of complications."

The students raised about $6,500 from corporate and individual sponsors, developed relationships with local boat experts, found space to build the boat and undertook the large-scale design project.

They crafted a plywood hull and outfitted it with four solar panels that charge the battery needed to drive the boat's motor.

Trial runs on Lake Arthur in Moraine State Park proved the boat seaworthy. On a clear day, it can cover distances of more than a mile and move at speeds up to four knots.

This week, Rockwell and teammates Ming Huo, 21, of New York City, and Will Wedler, 20, of St. Louis, are fine-tuning "The Carnivore" to make sure it complies with the strict rules for the five-day competition, which features slalom, sprint and endurance races.

As first-time participants, the students do not expect to win, but they hope to establish a foundation for future Solar Splash teams at Carnegie Mellon.

Solar boats aren't likely to become a practical alternative to gas-powered boats any time soon, but the students developed valuable knowledge about renewable energy and the mechanics of boat-building, they said.

"We put the things we've been learning all along in the classroom to good use," Huo said.

Bails, Jennifer. “Fired up: Sun's energy fuels motor for solar boat competitors.” *Pittsburgh Tribune Review* 15 JUNE 2006: C3

New Club Makes a Splash at Solar-Boating Competition

William Wedler (E'08) drives The Carnivore during the Solar Slalom event at the 2006 Solar Splash on Lake Fayetteville near the University of Arkansas. The Solar Slalom is a test of speed and maneuverability.

Mark Rockwell and his crew of fellow engineering students had modest and somewhat contradictory goals in mind when they set sail for their first Solar Splash, an intercollegiate solar-powered boating competition on Lake Fayetteville near the University of Arkansas this summer. They simply wanted the solar-powered boat they built to move across the water. And they also wanted to get their feet wet.

"Our goal [for this first competition] was to make a reliable boat, not a fast one. And we wanted to gain a familiarity with the competition," said Rockwell, founder and president of the new student club Carnegie Mellon Solar Splash.

They succeeded on both counts. Although their 14-foot-long boat, which traveled at a top speed of about 5 miles per hour, placed 14th overall in the field of 15, they earned a citation for "Notable Performance by a Rookie Team." The crew also learned a great deal at the competition, gaining insight into the many nuances of solar-powered boating.

A rising senior, Rockwell began organizing the club two years ago as Carnegie Mellon's sophomore representative to the American Society of Mechanical Engineers (ASME). He was looking for a new large-scale design project that would pique student interest and came across the Solar Splash, an ASME-sponsored event.

Mark Rockwell (E'07) looks on as Solar Splash judges examine The Carnivore's hull.

"It's a good fit for Carnegie Mellon. It's an interdisciplinary project that combines engineering and environmental principles. It gives you an awareness of how solar panels work and gives you exposure to solar power," Rockwell said.

"There was no other marine type of project on campus and it appeals to students interested in the environment and alternate fuel sources," he added. "It's a project that puts to good use the problem-solving skills you learn in the classroom."

During the second semester of his sophomore year, Rockwell began recruiting and organizing a team. He created posters that he displayed on campus, sent emails to his classmates and spoke about the new initiative to as many folks as possible. That summer he attended the Solar Splash to see what it was all about.

"I wanted to learn how the event was run and to understand what goes on. I wanted to be exposed to the atmosphere and to talk to other teams to see how they got started. It was an inspiration to me. I saw how rewarding and how much fun it could be," Rockwell said.

Carnegie Mellon Solar Splash team members include (left to right) Mark Rockwell (E'07), Luis Penalver-Aguila (E'07), Brian Hirsch (E'07), Andrew Choate (E'08), Siva Srinivasen (E'07), Mike Kaufman (E'07), Joshua Sztul (E'07) and William Wedler (E'08).

In September 2005, Rockwell and his newly established club began to meet once a week. They wrote a proposal for a Small Undergraduate Research Grant and started reaching out to marine supply and solar panel companies for donations and equipment, as well as knowledge and expertise. In January they started to build "The Carnivore."

The team purchased boat design plans from Glen-L. Marine in California for $40 and went to work. First, they built the hull using three 4' x 8' sheets of 3/16" okoume marine-grade plywood and one 4' x 8' sheet of 3/4" plywood. Bridgewater Marine donated the outboard motor, and the four 120-watt solar panels — which convert sunlight into electricity to power the battery and ultimately the motor — were acquired from Go Solar of Long Island, N.Y., for $1,600. Five car batteries were purchased for $600. The total cost of the project, including the trip to the competition, was about $6,500, which was largely funded by three Small Undergraduate Research grants totaling $5,500.

Rockwell and his crew took three months of Saturdays and Sundays plus spring break week to finish the hull. Once the hull was completed the team successfully put it to the test in Lake Arthur, north of Pittsburgh.

"It's a good fit for Carnegie Mellon. It's an interdisciplinary project that combines engineering and environmental principles. It gives you an awareness of how solar panels work and gives you exposure to solar power."
—Mark Rockwell

At the Solar Splash competition, "The Carnivore" was judged in seven different categories, including technical reports, visual displays, workmanship and maneuverability. On-the-water events included a Solar Slalom, which test speed and maneuverability, a 300-meter sprint and an endurance race.

Overall, Rockwell and his colleagues — Joshua Sztul, Ming Huo, William Wedler, Andrew Choate and his sister Sara Rockwell (E'06) — were pleased with their performance, but they know they can do better.

"Our propeller was too small. That's the reason our boat didn't go as fast as it could have," Rockwell explained. "We got our feet wet this year, but next year we hope to move up in the standings."

For more on Carnegie Mellon Solar Splash, visit http://www.andrew.cmu.edu/org/solar-splash/

For more on Solar Splash, visit http://www.solarsplash.com

Bruce Gerson
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