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Discussion

Educational Aspects of the Solar Splash Regatta

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The rationale behind and the educational goals of the Solar Splash intercollegiate solar/electric boat competition are examined. An assessment is made as to how well these educational goals are being met, including a brief discussion of competition participant problems. An apparent ''mismatch'' is identified between the Solar Splash rules and resultant boat designs and the goals for most collegiate engineering design courses, and possible methods of correction are discussed. [DOI: 10.1115/1.1345845]

Background on the Solar Splash

The ASME-sponsored Solar Splash, the intercollegiate solar/electric boat regatta, has been held for seven consecutive years and has been growing steadily in participation. The objective of the Solar Splash is to promote the construction and competition of a solar-powered boat which can be built within a school year at a reasonable cost. Over the past seven years, well over a thousand students have participated, many for multiple years and several from foreign countries. The competition is designed to provide practical educational experiences, encourage teamwork, and be fun—all achieved without a major disruption to the student's schedule and at minimal cost. To keep time and cost low, the boat size is limited to 6 meters in length and the solar panels are restricted to 480 Watts maximum. A history of the early organization and background of the Solar Splash is found in [1]. Current rules, a photo library, and previous years' competition results may be viewed on the Internet at www.solarsplash.com.

Competition Format. A month prior to the competition, teams are required to submit a Design Report. This engineering report describing their design approach and decisions, which counts as the first ''event'' of the competition, is evaluated and scored by ASME Solar Energy Division members. The Solar Splash on-site competition takes place over a period of five days. The first two days are devoted to Technical Inspections to verify that the craft and skippers meet all of the design and safety rules. The time is also used for Qualifying, a scored event which includes the performance of the craft on the water. Also during these two days, a Poster Presentation event, consisting of a public-level technical poster display constructed by each team, is evaluated and scored. Once the entries and their skippers have passed all of the required tests, the remaining three days are devoted to three types of on-water events. The first format involves a Slalom event, which tests the boat's maneuverability and handling at speed around buoys over a closed course. The second event is the Sprint which shows, using stored solar energy (battery energy), a boat can have practical speed for a limited distance (nominally 300 meters). The third event, the Endurance event (see Fig. 1), is worth the most points and is patterned after similar events which have been held in Japan since 1989 [2]. The goal of the Endurance event is to go the farthest in four hours (divided into 2 two-hour sessions).

Solar Splash Educational Goals

Solar Splash was created to promote student interest in solar energy, both as an energy source and in its engineering applications. As mentioned, the competition is designed to provide ''hands-on'' engineering experiences involving teamwork, while remaining a fun project. Specifically, the Solar Splash strives to:

Fig. 1 Three of the 1999 boats line up for the Endurance race. Note the variation in design, with the top boat optimized for the Sprint race and the bottom boat for the Endurance race. However, all boats must compete in all events, thus the ''compromise'' hull of the middle boat.

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- develop students' project and program management skills,
- serve as a tool to expose students to a multitude of technical disciplines,
- represent a valuable lesson in the effective use of energy–especially solar energy, and
- require systems and people integration into a successful craft and competitive team.

Each of the above four specific goals is discussed vis-a-vis the Solar Splash competition format and/or rules in the sections below, primarily to illustrate how these goals are being approached.

Project Management Goal. It appears that most of the colleges which have competed in Solar Splash have organized their teams under a Capstone or Senior Design Course [2–5]. The organization of the team via a for-credit course lends immediate structure and guidance to the overall project management, even if the team is ''learning while doing.'' As described in [3], such senior-level design courses generally have formal lectures on topics such as project planning methods, Gantt and critical path charts, progress reporting, team communications and dynamics, etc. On some teams, the student team members are rotated (monthly or every six weeks) into the Project Manager position, allowing all team members to experience the leadership role. Solar Splash emphasizes this project manager leadership role by requiring all communications between the Splash Headquarters (Advanced Energy Systems, Inc.) and the teams be via a designated team leader, both before the competition and during the competition itself [6]. In addition, the monthly Solar Splash newsletter produced by Splash Headquarters includes several articles on effective team organization and management ''tips'' during the pre-competition period.

The development of the students' non-technical project and management skills, such as oral and written presentations, peer, staff and shop personnel interactions, selling the project to management and sponsors, and handling the administrative paperwork, are considered to be as important as the technical elements of the design [3]. The Solar Splash helps foster the development of these non-technical skills directly through the Poster Presentation event, which features posters made by each team for the general public and displayed at the competition site. As mentioned, written communication skills are supported through the Design Report event. Additionally, the Solar Splash newsletter periodically contains articles on effective methods of getting sponsorship to aid in the project funding effort. Plus, a large number of the commercially prepared annual Solar Splash posters are sent to each school to help in fund-raising.

Multi-Disciplinary Goal. The Solar Splash rules are written assuming that multi-disciplinary teams, specifically electrical and mechanical engineering students, are involved in this project. Thus, the terminology in the electrical/battery section and in the boat/mechanical section of the rules is written for and best ''interpreted'' by students in those disciplines. It is obviously advantageous for a team to include marine engineering/design students for the hull and propeller design and/or specification, and several teams have been from marine engineering schools and programs [2,7]. Additionally, the Solar Splash newsletter discusses the advisability of getting non-engineering students (business, media relations, etc.) involved with the team, especially for fund-raising efforts.

However, historically, several of the teams are composed of only mechanical engineering students. In these cases, usually one or two team members will ''specialize'' in the electrical and solar systems, with lots of consulting with electrically and boat-design knowledgeable people. These ''mechanical engineering'' teams have competed quite successfully in several instances, and seem to illustrate the generalized knowledge breadth of the mechanical engineering curriculum.

Energy Use Goal. The basis of the Solar Splash competition is to promote ''wise'' use of energy, focusing on the application of the solar and electrical energy combination through solar cells and battery storage. Most students have not been exposed to solar energy resource assessment, solar cell operation, or even battery energy/power delivery characteristics. Thus, these technical areas usually require a team to become knowledgeable in several new technical areas–an introduction to the life-long learning skills required of today's engineers.

The overall competition is structured to require both the efficient use of energy (the Endurance event) and the effective use of power (the Sprint event). Since the rules allow the change-out of motor, batteries, and drive systems between these two events, to some extent the two events can be ''optimized'' independently–only the hull is required to stay the same for both events. Therefore, a system design to produce maximum power for propulsion is sought during the Sprint (without destroying the batteries), while the most efficient system design is sought to use the limited energy available from batteries and solar cells during the Endurance event. Also, an energy management scheme is required in the Endurance event to handle the battery-and-solar cells usage balance for cloudy and/or sunshine conditions. Thus, the Solar Splash competition format requires that the design teams deal directly with the two basic issues of energy use: power production and energy efficiency.

Systems Integration Goal. The overall Solar Splash competition is a program systems integration educational problem itself, since the design, construction, testing, funding, and logistics of getting to the competition require the planning and organizing of so many differing elements. Similarly, the hull design effort can be considered a systems integration problem both from the mechanical/electrical subsystems weight and physical placement design problem and from the trade-off required between the high speed Sprint event and slow speed Endurance event.

Examining the electro-mechanical power system technical design project systems integration effort alone, the different events require that the chosen single hull design be used with changeable electrical and mechanical subsystems. If a team ignores overall systems integration, then the boat's electro-mechanical systems have historically been either overly complicated and unreliable or difficult to change from Sprint to Endurance configuration, or both of the aforementioned.

Successes and Failures

The success of the Solar Splash as a viable student competition has been demonstrated through its steady growth in participation and its success in gaining sponsorship over its seven year life. However, success or failure in reaching its educational goals is harder to determine. It can be stated that the general goal of ''providing a hands-on, fun engineering experience involving teamwork'' is being met since:

- the number of participants is growing with new colleges entering and several others returning year-after-year;
- performance of the boats and the technology involved is becoming more sophisticated (see Fig. 2);
- inter-team co-operation is extremely high (little or no ''cut-throating''), even as the competition performance has intensified; and
- teams are becoming more capable of making major ''hands-on'' repairs and modifications during the competition to keep their boats competing.

With very few exceptions, the students appear to enjoy the competition and the chance to mix with students from other colleges and cultures. (The differences between how the Japanese, Puerto Rican and US teams act/react to various competition ''happenings'' is a basis for study itself!) There is no doubt that the Solar Splash competition requires an exceptional amount of hands-on engineering to get a craft operational and to keep it

Fig. 2 The highest technology and performance has been demonstrated in Japan's Kanazawa Institute of Technology (KIT) boat, shown here in 1999 ''flying'' on the hydrofoils it used in both Sprint and Endurance races. KIT has won the World Championship all 3 times it has attended ('94,'97,'99); however, other boats are approaching and beating KIT performance in several events.

operating. Nor is there doubt that teamwork is required to handle the multi-discipline design and construction, as well as the actual competing of the craft at Solar Splash. With all of the above in mind, it appears that the Solar Splash is meeting the general goal of ''hands-on engineering, fun, and teamwork.''

In determining whether the Solar Splash has been or is successful in meeting the specific goals focused on fostering education in the ''project management,'' ''multi-disciplinary,'' ''energy use,'' and ''systems integration'' areas, it would be necessary to examine what takes place, educationally, with each of the team members for a given college. Ideally, a before-and-after test would be administered to determine if the student had or had not gained knowledge/skills in these areas. Since many of the teams are working on their boat as part of a Senior/Capstone design course project, these students most likely are taking tests to determine if they have ''learned these lessons.'' One college has reported on this design course process [3], and the Solar Splash rules and competition requirements do tend to promote education in the specific goal areas. This finding is bolstered by many anecdotal stories from various team faculty advisors concerning how their teams learn and acquire the skills in the ''four goals'' areas. Many of the faculty advisors relate that their teams really learned what was necessary after the team had failed to perform as they had wanted to at the competition–hindsight does teach lessons!

Problems. There are two major problems associated with Solar Splash as reported by the participants. While neither problem is directly related with educational aspects, both have to do with time and money. The first problem arises because the competition is held during the summer (~June 21st) after school is over; thus, seniors have graduated and others have summer jobs–it's difficult for all team members to be able to go to the competition. Along with this goes the money given up if the student does go to the competition and leaves work for that week. However, there does not appear to be an alternative time for Solar Splash to be held which would solve this problem, mainly because the SAE competitions are held each week from the end of April to mid-June.

The second problem is associated with the time and money required to construct the boat and to go to and attend the competition. For most teams, the students themselves are required to raise the funds during the school year to support the solar boat construction and the travel expenses to the competition. This raising of funds is generally a time-consuming effort which can put severe time-pressure on the construction and testing of the boat itself. Thus, while fund-raising is seen as a valuable skill to be learned, this fund-raising activity can often impact the overall effort and cause schedule slips which result in inadequate time for testing the boat and systems–and lack of proper testing is the most often cited reason for poor competition performance [1]. On the other hand, several teams are either well-funded and do not need to engage in fund-raising efforts or the faculty advisor takes on the responsibility for securing funds. In either case, the students have a greater time for the actual design, construction and testing of the boat—and this is reflected in the generally higher competition standings of teams whose students do not need to do major fund-raising.

Associated with this fund-raising problem is the ''too well-funded'' team problem. Currently, some teams are going to and using systems costing in the tens of thousands of dollars, which does not fall within the Solar Splash's objective of having this competition be a ''minimal cost'' project. A mechanism for controlling boat cost is needed, both to keep the competition from being dominated by ''rich teams'' and to allow rookie teams to enter and be competitive at modest start-up cost.

A Competition Flaw? The original impetus behind the development of a solar-powered boat was to develop a practical non-polluting and fuel-free vehicle. This type of boat was seen to have application both as people and goods transportation on waters in developing nations (the fuel-free criterion) and as a recreational craft in developed nations (the non-polluting criterion) [1,4]. With reference to this latter application, the concept of having both a high-speed (Sprint) and a long-range (Endurance) capability in the same boat came from observing the US bass fishing competition boats, which dash to a fishing spot and then troll slowly while fishing. However, the current Solar Splash rules do not promote the design of a practical solar/electric boat for either the developed or developing nation applications described above.

Current rules allow the change-out of all power and drive-train systems between the three major competition events (Slalom, Sprint, Endurance) including battery size, electric motors, control systems, gears, drive shaft, and propellers–and all the major competitor schools install completely different systems for the different events. From an educational viewpoint, these differing systems require the students to ''learn and design more'' since they are making three systems, which is desirable. Also, the three separate systems require lots of ''hands-on experience,'' which is again desirable, since the team must remove and install the systems several times during the overall competition. However, from the ''practical engineering'' educational viewpoint, the current rules and boat designs do not address practicality or economics in their design, two elements which are fundamental to almost all the other collegiate Senior/Capstone course design projects (whether SAE projects or industrial projects). This lack of engineering design practicality and economy appears to represent a major discrepancy between the Solar Splash competition and the way engineering design project courses are focused.

Future Considerations

Overall, the Solar Splash competition appears to be meeting its stated educational goals. The ''problems'' discussed above have not seriously impacted the educational aspects of the teams' participation in the competition, nor do they appear to be a major issue in the future. However, the Solar Splash's lack of ''practical engineering design'' does seem to be something that needs to be addressed in the near future.

To bring ''practical engineering design'' into the Solar Splash competition would be fairly easy, since the rules could be changed to require a single system be used throughout the competition. Economic considerations could be handled similar to the SAE Formula and Baja competitions by establishing a cost goal for the boat and requiring a Cost Report detailing costs. This not only brings economics back into the design process, but can also keep

the teams' construction costs within reasonable dollar limits by having to meet the cost goals, and this will help address the ''too well-funded'' team problem.

Referring back to the original concept of a transportation craft for developing countries, a special class or an event of the competition could involve determining which team can design a craft to carry the greatest ''load/boat cost'' meeting some minimum speed and distance requirements (similar to SAE AeroDesign goals). A ''minimalist'' design class or event could be established, which uses little or no storage and only one panel (120W), and represent a low-cost design approach appropriate to developing countries.

On another topic, the Solar Splash competition geographical location for the first six years was in Wisconsin. This year (2000) the competition was held in New Orleans. Current plans are to move the competition around the country, both to allow travel costs to be spread more evenly among the schools over the years and to get more schools involved when the competition is closer, and more visible, to them. The 2001 Solar Splash will be hosted by and in Buffalo, NY during the centennial celebration of the Pan-American Exposition.

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