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Experimental Vehicles Program Provides Engineering Technology Education Through Interactive Experiences

Dr. Saeed Froudastan
Associate Dean of College of Basic and Applied Sciences
Middle Tennessee State University
Murfreesboro, Tennessee, USA

***Abstract*— The Experimental Vehicles Program (EVP) is an undergraduate research program consisting of five experiment vehicle projects. The objective of the EVP is to encourage the professional development of undergraduate students by enhancing the students' opportunities to engage in hands-on learning experiences. The EVP provides a forgiving environment where students are able to engage with others, test their abilities, and learn invaluable skills such as teamwork, communication, and leadership. Students work to design, construct, and test novel vehicle designs for participation in national and international competitions. Due to the competitive nature of each event, students must use cutting-edge technology and methods to create the best entries. Each year EVP sponsors approximately seventy interdisciplinary students to collaborate and to expand upon their classroom knowledge by building innovative vehicles. The EVP has been recognized by becoming the national model for hands-on engineering education.**

Keywords—Experminetal Vehicles Program; Solar Boat; Lunar Rover; engineering education; interactive learning

I. INTRODUCTION

With technology constantly changing and advancing, the curricula for national and international engineers is continuously being improved and updated. Experienced and innovative engineers are needed to help solve some of the most complicated problems that occur in the engineering industry. Classroom learning alone may not provide students with the necessary challenges and interactive experiences they need to expand their creative minds. Thus, the projects provided by the EVP allow students to explore original ideas outside the classroom. The EVP is an umbrella program that includes the Solar Boat, the NASA Lunar Rover, Formula Hybrid, the Formula SAE, and the SAE Baja. Projects such as the Solar Boat and the NASA Lunar Rover supply a creative environment to nurture and inspire innovative thinking, which allows students to be exposed to groundbreaking technologies like the aluminum structure used in the NASA Lunar Rover and the award winning drivetrain utilized in the Solar Boat.

Each year, the EVP students create new, increasingly efficient, and well-designed vehicles for each project. These unique research projects provide great benefits for the professional development of engineering and engineering technology students because hands-on learning is a direct application of classroom concepts. In addition, these particular projects help students learn to think inventively, communicate professionally, manage projects efficiently, and work cooperatively in a team environment [1].

The program provides a diverse range of students with a large collection of projects to facilitate excellence in engineering technology education and to encourage undergraduate participation through innovative, competitive research. Students work diligently on these projects and incorporate skills needed in the workforce such as: project management, decision-making, leadership, critical analysis, and problem solving. Participants learn the value of research, teamwork, and effective communication. They learn to incorporate innovative ideas into a single goal, complete projects, and excel at competitions. In addition, the national and international design competitions provide valuable exposure for the university and EVP partners [3]. Because of the competitive nature of each event in which the EVP participates, students must use cutting edge technology to field the best entry possible. Often, these projects serve as rolling test beds for the latest innovations in various technical fields and are accompanied by a great deal of student research.

II. SOLAR BOAT

The university offers five nationally and internationally competitive experimental vehicle projects as extracurricular activities for undergraduate students [6]. One of the five projects is the Solar Boat project. The Solar Boat project was founded following the inception of the Institute of Electrical and Electronics Engineers Power Electronics Society's Solar Splash Competition, an international collegiate competition showcasing solar/electric boating [7]. The EVP has been involved in the Solar Splash Competition since its inception. The Solar Boat project allows students to focus their research on current social topics. The competition asks the vehicle to have the ability to utilize and store solar energy. The boat

design must follow a set of regulations to accomplish numerous pre-determined outcomes set out by the competition guidelines [8]. As the students design their

Figure 1: 2015 Solar Boat Innovative Dash System

vehicles they must consider all the stipulations set out by the competition rules. However the students are given large amounts of creative freedom when designing their vehicles. Once the Solar Boat Projects are complete, the students are able to showcase their designs during a five day competition [7].

The EVP Solar Boat team members collaborate on all decisions throughout the lifetime of their project. Together the students decide how they want to build their boat, conduct all the necessary research, construction, and testing in preparation for the annual competition. When designing the ideal boat for the competition parameters, the students are faced with challenging dilemmas. To combat these dilemmas, the 2013 team incorporated an innovative drivetrain system. The addition helps with rudderless steering and provides adjustable trim. The Arneson-type surface drive features an electric actuator to allow trimming of the drive during operation. The 2013 addition has been modified slightly from the 2012 by adding a “string pot” to the actuator which is used to control an actual trim gauge on the dash pictured below. This helped the pilot from over or under trimming the drive. This groundbreaking steering integrates interchangeable motors, transom-mounted surface drive, interchangeable sprockets for variable gear ratios that allow for a wide variety of torque and horsepower combinations, and therefore a high degree of adjustability. The drive system is also outfitted with surface-piercing propellers, which dramatically increasing propeller efficiencies by decreasing overall propeller slip.

Furthermore, the 2013 team constructed the hull completely of carbon fiber paired with a special core material known as Lantor® Soric XF3.This core material, while serving as an inter-laminar breather material, also serves as a buoyant foam-core material similar to Nomex® honeycomb but at a fraction of the cost. By utilizing this low-cost option, the team was able to construct a lightweight, structurally rigid hull with a finished weight of approximately 90 pounds. The 2013 team used the basic design of past boats; however, they were able to reduce the hydrodynamic drag by slightly modifying the hull. They removed the skew that pulled the 2 2 boat dramatically to the left, leaving it with a true centerline. Additionally, they were able to reduce the aerodynamic drag of the boat by amending the open-topped design originally featured to highlight a top surface that was designed to smooth the flow of air over the top of the boat as well as the pilot. The top surface was fabricated from 2 inch thick foam insulating board and laminated with a single layer of fiberglass in order to minimize the contributing weight. Moreover, careful planning was taken to balance the Solar Boat more efficiently. The 2013 team moved the Boat’s center of gravity slightly toward the back in attempts to lift the hull slightly for the sprint portion of the competition. However, the team was diligent in this balancing act, shifting the center of gravity too far would mean lifting the hull’s displacement features out of the water and a poor performance in the endurance component of the competition. The 2013 Solar Boat pictured below was extremely streamlined and proficient.

The 2015 telemetry system has vastly improved over the last years. The system is achieved through the implementation of a long range WIFI system that features a maximum range of 20 miles. The telemetry system consists of a 1-Watt wireless access point on shore and a 0.5-Watt wireless access point aboard the boat. Remote telemetry will be utilized to provide onshore real-time monitoring and adjustment of the configuration settings of both onboard motor controllers. In addition, the telemetry system will allow for onshore monitoring of system voltage, current draw, throttle position, speed, distance traveled, and GPS position. The IP connectivity scheme eliminates the connectivity errors associated with the RS232 radio modems incorporated into last year’s telemetry system. Attempts are being made to improve the efficiency and achieve a more reliable data link between the Solar Boat and our onshore telemetry station. The new telemetry system has exceeded expectations and is considered to be fully operational and race ready.

In addition, a new Wireless Data Acquisition System was developed to allow an onshore pit crew to collect and analyze data while simultaneously adjusting motor controller parameters to carefully regulate the power consumption of the electrical system, especially during the endurance races. For ease and simplicity, this system utilizes parameter monitoring functions of the motor controllers paired with an over-the-counter microcontroller and simple transducers to provide a complete analysis of the system without an overpriced data acquisition unit and software.

Figure 1: 2015 Solar Boat Innovative Dash System

The modifications and innovations made by the 2013 Solar Boat team were aptly recognized during the 2013 Solar Splash competition. As mentioned before the team was awarded with 2nd place in the sprint portion of the competition. The sprint competition was designed to test the ability of the boat to maneuver with agility through the water, receiving second place gives praise to the advanced engineering mechanics of the boat. Aside from speed the Solar Boat was also honored for outstanding design, receiving the Design Achievement Award. This particular award was sponsored by the Institute of Electrical and Electronics Engineers Power Electronics Society (IEEE-PELS) and honors the flawless engineering technic used to manufacture the Solar Boat. The Solar Boat was graced with this award because it was able to pass inspection without requiring modifications while other boats, in some cases, needed two days to repair their boats. The Solar Boat was also rewarded with the Outstanding Workmanship Award due to the fact that it was highly regarded as the most attractive boat in the entire competition. This award not only applauds that boat itself but the craftsmanship required to build an engineering marvel. Impressed by their abilities both to successfully compete in every event and to confidently navigate the Solar Splash challenges, judges awarded the university's team the 2013 Participation Award. This award highlights not only the academic abilities of the students but also their technical capacities and skills as well. Additionally, the Solar Boat secured a spot in the coveted top-ten list of the Solar Splash competition and received an award for 7th Place Overall. In 2013 the Solar Boat won the Outstanding Workmanship Award. The 2015 Solar Boat team won 2nd place nationally at the Solar Splash Competition. They also won Sprint Award, Qualifying Award, Solar Slalom Award, Visual Presentation Award, Design Achievement Award, Outstanding Workmanship Award, and the Sportsmanship Award.

III. NASA LUNAR ROVER

The NASA Lunar Rover project is one of the most popular in the EVP. It has inspired several innovative inventions from undergraduate students. The vehicle is required to handle all terrains while at the same time being light weight and flexible. The Great NASA Lunar Rover Race sponsored by NASA stipulates several general rules for each vehicle to follow. First, each vehicle must be able to traverse a half-mile course of simulated lunar terrain. Each year the course designers make the competition more difficult by including obstacles to replicate craters, inclines, and lava ridges. Additionally, to make the students use their critical thinking skills during the design the vehicle must be powered by one female and one male student and be carried and assembled at the starting line. During the overall race each vehicle is judge on both design and performance. Every year the NASA Lunar Rover teams work to improve upon the efforts and knowledge passed down by previous participants of the EVP. This year's NASA Lunar Rover is displayed in action fig. 3.

Brainstorming as a team prior to the fabrication of the vehicle has led to exciting inventive breakthroughs in the past such as the carbon fiber frame and groundbreaking wheel design. Eighty to ninety percent of all vehicle fabrication and assembly is carried out in the Industrial Studies Complex in dedicated workspaces by EVP students. The laboratory space is stock plied with the materials needed to create and manufacture everything to assemble a highly function cross-terrain vehicle. One of the most useful tools is the Inventor program which allows students to input vehicle designs and tweak them through the process of trial and error. The program provides the students with the information needed to create the most proficient vehicle possible. The program inspires modifications on odd ideas, and at the same time stimulates ingenuity to spark new designs.

Every year students have paid close attention to the wheels of the vehicle; fabricating them entirely in the engineering laboratories. The 2010 EVP team constructed their NASA Lunar Rover wheels completely in house. The new wheel design was constructed from 1/2" aluminum and 21 inches in diameter. The team opted to use a six spoke design. The six identical sections were made on a CNC machine. The overall design helps to eliminate weak points in the wheel. Additionally the separate sections allow for replacement of only the damaged portion of the wheel during competition. These particular wheels have been so successful in their design that since their conception each new NASA Lunar Rover team has been able to use them without modification.

Recent teams have been able to utilize portions of past NASA Lunar Rover innovations and incorporate them into versatile and more proficient cross-terrain vehicles. For example, this year students have

Figure 3: NASA Lunar Rover during competition

expanded on the revolutionary component of aluminum to increase the functionality of the NASA Lunar Rover. They have created the framework and main mechanisms from schedule 6063 aluminum tubing with a 0.133 wall thickness. The elastic and ductile properties of the material allow it to perform under stress, making it good for absorbing shock when the NASA Lunar Rover is driven over rough terrain or is subjected to sudden and intense forces. This material is ideal for a lunar vehicle due to its exceptional strength to weight ratio allowing easy maneuverability in a low gravity atmosphere.

The steering system, also constructed from aluminum, was originally designed to be a radial system. However, extensive test-driving showed this to be unsatisfactory with respect to the vehicles turning radius. The existing hardware was modified to more closely resemble a rack and pinion system which proved to be much more effective. Instead of a hindering steering wheel the vehicle is steered with left and right hand controls. This modified structure allows for easier maneuverability around complicated obstacles during the race. The team also discovered that without the correct alignment of the frame and the tire A-frames, the vehicle would run into an issue known as “bump steering”. Bump steering happens when the framework of the vehicle is not built exactly parallel and with complementary angles and measurements. For example, the uprights fashioned to the wheels measure 4 inches in height and are attach to the vehicles advanced suspension. They were built in house and made to be comparable to the vehicle’s 4 inch steering mechanism. These exact measures are in order to insure that the wheels do not tilt due to torque during the steering process preventing the wheels buckling during a turn. The pictures below show the advanced design in an upward and down position while the wheel remains in a 90^{o} angle. The innovative design feature allows the NASA Lunar Rover to remain stable throughout the landscape of the race.

In order to make the vehicle as fluid on the course as possible the designers had to also incorporate the proper suspension mechanisms. The specifications set by the competition rules indicate that the players must originally sit 15 inches above the ground. In the past, NASA Lunar Rover teams have opted to use little or no suspension in order to comply with the rigid competition rules. The current NASA Lunar Rover uses rock shocks that can be customized to fit the needs of the vehicle. This allows the suspension to have a 15 inch diameter meaning that the riders easily sail over the rough terrain without being thrown and jarred during the course.

Furthermore, the propulsion system was also modified. The propulsion of the NASA Lunar Rover is supplied by two complete systems, each consisting of: pedal crank assemblies, gears, chains, tensioners, and hand brakes. While this configuration requires an increased level of communication and coordination between drivers, the potential for failure in this system benefits from the built-in redundancy. This would allow

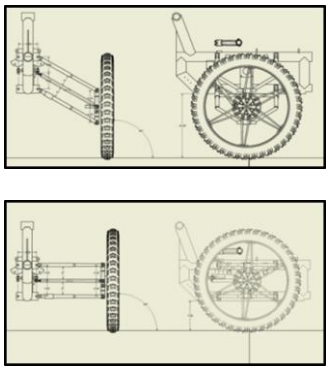

Figure 4: Innovative steering/suspension alignment to prevent bump steering

the vehicle to continue operation if one system fails. In the event of failure, the sprocket assembles can be removed and replaced in a matter of minutes due to the modular design of the mounts and housing. Previously, the team designed a device known as telemetry which allowed them to record real time video feed, velocity, distance driven, compass direction, and gravitational measurements. After a year of continual efforts experimenting with the device, they were able to improve its functions and efficiency for this year’s competition. The team built a telemetry system using Arduino Uno, Xbee, and other hobby parts. The Arduino communicates to the different modules connected by wire. The GPS module transmits real time global position readings to the Arduino, and then transfers the information through radio frequency communications to a laptop for processing. This will allow the team to track the NASA Lunar Rover while it runs the course. Along with the telemetry, the team used a GoPro camera and a wireless camera to see and record live action video and sound during the race. With an upgraded microprocessor, the team was able to manage more code for the sensors used in the new telemetry device. The new and improved telemetry device and video systems are now light weight, compact, and modular between multiple rovers constructed in house, gathered data during the course route and reported back to home base in real time.

The telemetry, pictured below, collected results such as coordinates and speed which in the event of failure would give clues to its location for the repair of the vehicle. Also the constant flow of data derived from the device would be invaluable in a real-world NASA Lunar Rover situation.

Figure 5: The new and improved telemetry created for the 2015 NASA Lunar Rover

IV. Retention and Graduation

The Experimental Vehicles Program was created as an outlet for bright students searching for more than the standard classroom experience. The program targets and engages freshman and sophomore students from a wide range of academic backgrounds. Once enlisted into the program, students are guided through the process of designing, manufacturing and developing innovative vehicles by mentors of upper classmen still involved in the program and highly skilled faculty advisors. Throughout the process the students learn much more than innovative hands on problem solving, they learn the ability to work in collaboration with others and in turn build strong relationships through teamwork. The bonds they form throughout the duration of their participation with the EVP has proven not only to help their grades but also increase the likely hood of the students continuing their secondary education especially within a STEM discipline. Studies have indicated that students that work within small groups tend to retain more information than students that tend to work individually [2]. The EVP setup is organized to facilitate this small group framework. Each year the students recruited are partitioned in to smaller teams of 10-15 in order to help each individual student's talents be utilized and displayed in the best way possible. The teams are designated the task of designing and fabricating a vehicle. During the vehicle creation the students form close relationships with their team members which keeps them focused and engaged in a highly academic extracurricular activity. The EVP provides an environment that is meant to supplement classroom lectures by introducing the students to active learning. This alternative to the traditional classroom setting is in some ways considered more conducive to learning and retention especially when coupled with a comfortable group environment. Groups provide a safe place for students to nurture their talents. They also provide as place for students to belong in which they feel valued and much more willing to share their own ideas The supportive group setting created by the EVP is meant to counteract the limited attention and pressure sometimes felt by students in college courses. In the classroom it is often the case that value is placed on standardized correct answers [6]. Often students are discouraged by this, and many may leave the STEM disciplines, but the EVP projects seek to encourage students to put their hands on an actual project and gain experience regardless of their opinion or of their previous engineering skills. The learning objective of the projects is to test out a variety of theories and methods and to investigate the consequences of each decision. Mistakes are seen as learning opportunities for the future and often spark a flame in the students for more knowledge. The opportunities created by the EVP prepare students for the future and are valued in the workplace as seen in Table 1.

TABLE I. Engineering Exit Survey [4].

Exit Survey and 5 Year Program Review Questions	EVP Alumni Responses
Did the technical skills learned help prepare you for work in the industry?	100%
Do you feel like the interpersonal/teamwork skills learned prepared you for the workplace?	87%
Was the EVP a talking point in your interview process to be hired? If so, do you feel like being a part of the EVP helped you in acquiring your job?	100%

In the past the EVP experience has not only provided a valuable way for students to gain essential hands on experience but also had led to higher retention and graduation rates. In addition out of the multiple students that participate in EVP projects 95% receive highly desired jobs upon graduation both at the national and international level. As further testament to the fortitude of this program, the Tennessee Board Regents awarded the program the Academic Excellence Award in 2012.

V. Conclusion

The Experimental Vehicles Program provides an alternative outlet for young students to engage in active learning. Each of the EVP projects supplies the students with unique opportunities to build upon their traditional classroom knowledge. The challenges presented by the five vehicle projects allow students to engage in hand-on research which helps them walk away with a better base of knowledge and enthusiasm for the STEM disciplines. The on campus engineering laboratories help to facilitate the complete working experience for the students. The labs allow the

students to design, create, and enhance their vehicles. Each student has the ability to work on every aspect of the vehicle they are creating and hone their skills. The machine shop allows the students to test their designs as well as gain invaluable experience working on machines such as laser cutters that they will be using during their future careers. These projects help students to sharpen their skills for future workmanship, such as team work, understanding responsibility, and making use of techniques learned in class. As the students learn to cooperate together to solve current social economic issues they begin to understand the importance of collaborative research in complex problem solving. Moreover the students gain confidence in their work through displaying their research at national and international competitions. Many times the vehicles are recognized for their innovation.

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