The Evolution of a Senior Capstone Course in the Context of a Research-Based University Quality Enhancement Plan

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Abstract

The process of reaffirming accreditation at the University of Houston has identified research-based instruction as a critical component of the campus learning environment for the foreseeable future. This assertion is consistent with broader trends in higher education that tout the benefits of this approach especially with regard to enhancing undergraduate instruction. This paper demonstrates how the Senior Capstone course (ELET 4308) in Computer Engineering Technology paralleled historical efforts to incorporate research-based learning in the undergraduate curriculum, thus anticipating University efforts in this area. The paper also examines the current state of the Senior Capstone course and relation to the University Quality Enhancement Plan.

Introduction

The current emphasis on undergraduate research as an instructional tool can be traced to the landmark Boyer Commission Report, Reinventing Undergraduate Education: A Blueprint for America's Research Universities. A follow up report three years later confirmed that some of the report's recommendations had begun to infiltrate the undergraduate curricula [1]. This pedagogical movement to incorporate research into the undergraduate curriculum has been the primary impetus for the focus of University of Houston's Quality Enhancement Plan.

The Quality Enhancement Plan (QEP) is a critical component of the reaffirmation of accreditation by the Southern Association of Colleges and Schools. The purpose of the QEP is articulated in the SACS handbook.

> "The QEP describes a carefully designed and focused course of action that addresses a well-defined topic or issue(s) related to enhancing student learning. The QEP should complement the institution's ongoing integrated institution-wide planning and evaluation process." [2]

A representative committee composed of administrators, faculty, staff, and students selected the topic of "undergraduate research" for the QEP after a lengthy data gathering and discussion process regarding how the University could most effectively enhance

learning. Ultimately, the QEP Planning Committee adopted a broad definition of research that would guide University activities.

> Research is a diligent and systematic inquiry or investigation into a subject in order to discover facts or principles, and increase the sum of knowledge, enhance design, or enrich artistic ability.

As the QEP was discussed and disseminated for review it became apparent that many of the best practices intrinsic to research-based learning were already being utilized and refined in many of the Computer Engineering Technology courses in the Engineering Technology Department in the College of Technology, especially the Senior Project course.

Senior project courses across engineering and engineering technology departments are considered an important component of these programs. There exists a range of capstone course implementations but often students do not disseminate the experience and the results of their projects. Most papers published in journals, conference proceedings and presentations at the conferences appear to be the effort of the faculty leading capstone courses. The good news is that capstone courses continue to be scrutinized, reviewed and improved. In the past, most publications centered around general report on capstone course development, implementation and improvement [3, 4] and adding industry collaboration component to the capstone courses [5, 6]. After ABET 2K [7] release, established capstone courses added systematic assessment component [8, 9]. Recently, an interest to introduce entrepreneurship and commercialization into capstone courses were reported and they are on the rise [10, 11, 12, 13, 14, 15, 16, 17, 18].

The course was originally taught under the title of *Microcomputer Interfacing*. The course consisted of three hours lecture and one hour lab. In its old format, the course covered topics such as Op-Amps, ADC/DAC, interfacing, signal conditioning, microprocessor I/O, bus structure, and some machine language. The course was more hardware intensive with very limited software component present and did not have any laboratory assistants. During the revision phase, the author identified that most of these topics were covered in earlier CETE curriculum. The lab component consisted of several small experiments during the first half of the semester and the second half of the semester was devoted to a term project (certainly not enough time for a meaningful team project experience). Students grouped in teams of two and proposed their idea to the lab instructor and the course instructor for approval. The students had to purchase their own parts and most often work outside of the lab, due to a limited lab space availability, to construct their projects. Most often, the course and lab instructors were different with very little interactions between them. Part-time faculty often taught the laboratory component. The instructor attended several of the earlier lectures and observed student projects while noting the deficiencies and changes that had to be implemented to make the success in the course a true measure of student mastery of the major.

Deficiencies observed in the senior course were traced back to the fundamental courses and gave rise to the CLABS (read as C- LABS) Project [19, 20, 21] in summer 2004. The

CLABS Project was made possible with a change in administration of the college and department, hiring a new generation of energetic faculty and strong desire to change at all levels. The rationale behind the CLABS Project is reported in several publications [22, 23, 24, 25]. Recently, the department was awarded an NSF grant titled "An Innovative Approach to Learning via Peer-to-Peer Undergraduate Mentoring in Engineering Technology Laboratories" that further refines and expands the scope of the CLABS learning experience by incorporating a new mentoring system as well as concept mapping as an instructional tool. In addition, the new grant signals the beginning of a multi-institutional collaboration with Texas A & M – Corpus Christi and the Houston Community College System on implementing the CLABS curriculum in new academic venues.

Course Description

The Senior Project course (ELET 4308) in its current form launched in fall 2004 in a new and modern laboratory space with a new scope and direction. The course itself was structured around several instructional components that worked in concert to provide students with a multi-faceted, hands-on, learning experience. The general components have remained consistent although aspects of these components have been modified and refined based on student outcomes and course assessment results. These course instructional components are described in the next section.

Senior Project Course Components

Books- Two books are assigned in the course. One on engineering design and the other covers creativity. Reading assignments are given routinely.

Lectures- Nine lessons are presented in the class. The lectures are synchronized with the two books and are supplemented with additional information. The lectures are presented in the form of discussions rather than the traditional lectures. The first lesson is an overview of the entire course. Students have access to the lecture notes through the course web portal, discussed later.

Homework- Each semester, four to five homework assigned. The homework has five to six questions and students work on the homework individually.

Exams- Closed book and notes midterm exam and final exam is given. Most questions are from the two books, lessons, guest speaker presentations and workshops.

Workshops- Three workshops are given at the beginning of the semester. The first workshop is a three-hour hands-on training to use the Microsoft Project. The Microsoft Project is used for Gantt chart to track teams' progress and is conducted by the Information Technology trainer at the University of Houston. In the second workshop, students are introduced to the UH policies regarding intellectual property and patent. The workshop is conducted by the office of Research and Intellectual Property Management.

The third workshop is on research in technical and science libraries and is presented by the College of Technology Librarian.

Guest Speakers-The guest speaker series is designed to introduce students to the real world challenges. The speakers are engaged in the cutting age of their industry. They often bring in a new perspective to the senior project. A few of the speakers are members of the ET industrial advisory board and are familiar with the curriculum and provide valuable feedback for the improvement of the senior project course. Others are entrepreneurs and CEOs and enlighten the students by discussing the success of their companies.

ET Faculty Speakers- Volunteer faculty members who are interested in mentoring students present their research and expertise. A separate policy governs the ET faculty mentorship. There is *no* separate grading standard for this group of students.

Laboratory Assistants Presentations- All assistants assigned to the course are formally introduced to the students. Each assistant makes a short presentation and students will get to know them and understand the areas of their expertise.

Combined Documents- The combined documents provides senior project students with policies, detailed guidelines for the progress report, proposal report and final project, grading forms, evaluation forms, etc.

Web Portal- A secured access web portal is provided for the course where supporting course materials are stored. The web portal provides specific folders for the ancillary documents, project teams, laboratory assistants and the faculty directing the senior project course. The ancillary documents folder houses the Combined Documents, creativity and innovation papers, technical papers on sensors and stepper motors, microcontroller documentations, MicroC library functions; parts list available in the lab, lecture presentation slides and past student projects. The laboratory assistants' folder archives all progress reports, proposal reports, final reports, homework, mid term and final exams. This folder is also used for communications with the senior project faculty. The senior project faculty folder is used primarily for development purposes.

Progress Reports- Each team submits a weekly progress report. Specific guidelines and requirements are provided to the students. Two assistants and the instructor review all reports. The graded reports are returned and discussed with the students. A grading form is given in Appendix A.

Project Proposal- The project proposal consists of a presentation and report. Each team must clearly address the following items in their presentation and report:

- Benefits of the product or process to the end customer
- Project objectives tied to the project specifications
- Strategy for achieving project objectives

- Detail plan of action divided into a number of tasks to be performed by individual member of the project team to achieve the project objectives
- Time schedule depicting weekly progress and individual/team assignments
- Cost analysis
- Design verification procedures
- Procedures to quantify prototype performance

Two assistants and the faculty member evaluate the reports based on performance rubric.

Final Project- The final project consists of a presentation, report and prototype demonstration. This is the most exciting event for the students and the department. UH Faculty, industry guests, staff and other students are present during the presentation and demonstration. The report consists of Executive Summary, Newsletter, Product Requirements, Design Specifications & Description, Construction Details, Cost Analysis, User Instructions, etc.

Assessment and evaluation play a key role in the Senior Project course. Each learning activity is accompanied by a rubric-based performance assessment usually taking into account multiple perspectives including the instructor, graduate assistants, and, during the final project presentation, industry representatives. In addition to performance assessments, student surveys are also implemented to gauge perceptions of course effectiveness. Two surveys are conducted during the first session. The first survey is a self-assessment of the student knowledge and information about their work schedule (most students work part time and few work full time). Similar survey is conducted at the end of the semester and the results are then compared. The purpose of this survey is to assess student's knowledge and workload and provide guidance if overload schedule is identified.
Results from these assessments are used to make pedagogical and curricular decisions regarding the direction of the course. The assessment tools themselves are consistently evaluated for their effectiveness and relevance to the instructional process.

Accomplishments

The Senior Project Course has led to several significant accomplishments by students including having their work published and, in some cases, patented. Please see appendix 1 for few samples of these projects.

The projects described in Appendix 1 are the culmination of several years of instruction and skill building. Inspired by these successes, the program continues to modify and refine the education process in order to solidify the foundation and ensure the long-term stability of the program.

The Relationship of Undergraduate Research to the Senior Project Course

It is clear that the University of Houston's adoption of undergraduate research-based learning as the QEP topic dovetails well with the Senior Project Course. In addition to

hands-on research skills, the course infuses the curriculum with opportunities for students to participate in oral and written communication exercises (e.g. proposal and final project presentations) that are consistent with Boyer Commission Recommendations for improvement [1]. Students in the upper level classes are also being asked to take part in the project rating process in junior level lab courses. The act of evaluating other's work within a technical context further enhances critical thinking skills at the highest level of Bloom's taxonomy.

Senior level students also have the chance to engage in paid, industry-sponsored professional activities. In order to increase their problem solving resources, industry personnel are increasingly presenting senior level students with opportunities to tackle real world problems that require timely solutions.

In the short term, the goals of the program include:

- Building on previous successes
- Monitoring student progress in the senior project pipeline by examining outcomes from redesigned sophomore and junior level courses.
- Monitoring and improving the assessment instruments.
- Encouraging additional faculty to take part in student mentoring.
- Encouraging continued student participation in department sponsored tournaments such as Botball, First LEGO© League, and Houston Robotics
- Dissemination of information collected from the instructional process.

Each of these activities further enhances the undergraduate experience by reinforcing a process of continuous improvement. Long term goals for the Senior Project Course present many challenges. However, some efforts along these lines are currently underway.

Long-term goals include:

- Increasing industry participation in mentoring and sponsoring student projects
- Facilitating joint projects with other departments within ET
- Facilitating joint projects with other schools at UH
- Participation in regional and national competitions
- Conference presentations by students
- More patentable projects
- More journal publications
- Increase student sense of community responsibilities

As stated previously, some of these goals are already starting to materialize. Several students have successfully applied for provisional patents and published papers based on their projects. However, the goal of the program is to make this type of success a commonplace occurrence.

The adoption of undergraduate research as a top priority for the University of Houston serves as a validation of the work taking place in the Senior Project Course. Indeed, the renewed focus should facilitate adoption of this approach in a variety of courses that would benefit from the model. As the University continues to build capacity for its QEP strategy, the Senior Project Course will be positioned as a leading example of the instructional effectiveness of this strategy undergraduate research.

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Biographies

FARROKH ATTARZADEH

Dr. Attarzadeh is an associate professor in the Engineering Technology Department, College of Technology at the University of Houston. He teaches software programming, operating systems, digital logic, and is in charge of the senior project course in the Computer Engineering Technology Program. He has developed a concept referred to as EMFA (Electromechanical Folk Art) as a vehicle to attract young students to the STEM fields. He is the Associated Editor for student papers at ***the Technology Interface*** (http://engr.nmsu.edu/~etti/), Manuscript Editor for the ***International Journal of Modern Engineering*** (IJME, http://www.ijme.us/), and Conference Associate Chair for the ***IJME-NAIT Joint International Confere***nce (http://www.ijme.us/IJME_Conference_2008/index.htm). He is a member of ASEE and has been with the University of Houston since 1983.

MIGUEL A. RAMOS

Miguel A. Ramos is the Director of Assessment and Accreditation Services for the College of Technology at the University of Houston. He earned a Ph.D. in Educational Research, Measurement and Evaluation from Boston College in 2004. Dr. Ramos has worked as Program Evaluator for Boston Connects, a school-community-university partnership designed to address non-academic barriers to school success via a web of coordinated health and social service resources in ten public elementary schools. He has also worked as a federal education researcher for the Southwest Educational Development Laboratory evaluating the effectiveness of reform models developed to improve student academic performance by enhancing systemic coordination of academic resources. In addition, Dr. Ramos has served as a consultant in a variety of contexts investigating a range of issues including program effectiveness, organizational communication, assessment and public policy, and research methodology.

ENRIQUE BARBIERI

He received a Ph.D. in Electrical Engineering from The Ohio State University in 1988. He joined Tulane University where he served on the faculty of the Electrical Engineering Department (1988-96) and was a tenured Associate Professor and Chair of the Electrical Engineering & Computer Science Department

(1996-98). In 2002 he joined the University of Houston as Professor & Chair of the Department of Engineering Technology. His research interests are in control systems and applications to electromechanical systems. He is a member of IEEE and ASEE and Chairs the Executive Council of the Texas Manufacturing Assistance Center.

Appendix 1

Endless Coffee Pot

Yesterday your boss told you he needed a report done so you could present it in the morning. Of course, it took you all night to finish, but you got it done. You had just enough time this morning to get a shower and throw some clothes on before going to work. On the way in to work, all you could think about was a fresh, steaming cup of coffee. But when you get to the coffee pot, some insensitive soul has left only enough coffee for a sip! Has this happened to you before? Unfortunately, this is an all-too-common scenario at businesses that can not afford a $500 commercial coffee machine. A senior project team at the University of Houston says, "NO MORE!" To solve this problem the team created the ***Endless Coffee Pot***. It loads itself with coffee and water, brews a fresh pot and even cleans itself, all without the single touch of a button. There are many different coffee makers out on the market today. Some will only brew coffee. Others will grind the coffee beans and then brew the coffee. And the fanciest of them all seems to do everything, but still demands a user to discard the used coffee grounds and filter. The Endless Coffee Pot does everything, including disposing of the used grounds and filter.

Endless Coffee Pot Prototype

Significance of the Endless Coffee Pot:

Accomplishments:

Patents Provisional Patent Granted
Publication: *The Technology Interface*, Vol. 8, No. 1, Fall 2007
Showcased at: First Lego League (FLL), Carver High School
Visits

Network Controlled Data Acquisition Drone

Current drone technology has come to a point where it is now being implemented in many aspects of the consumer level as well as for military purposes. Congress has requested that by 2015 a third of all military ground vehicles will be unmanned. Current drones being implemented by the military can be very costly for simple models as is the case of the Packbot currently being use in Iraq. The cost of one Packbot is estimated to be $50,000 to $100,000 a piece.

With this high price it is difficult to implement drones at a consumer or medium sized industry levels.

Another drawback from the drones currently in the market is the need for a standalone control unit. If this control unit is damaged or misplaced, it can cost hundreds of thousands of dollars to replace it and get the drone to be operational once again.

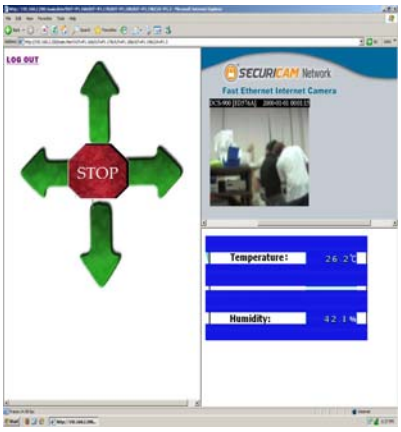
With these problems in mind, the ***Network Control Data Acquisition Drone (NCDAD)*** was created. The first objective was to make it affordable to the public as well as to the industry like security companies. The prototype was built at a cost of $490 with a developing cost of $15,727 dollars. This is comparable to the price of about 3 Packbots being manufactured by *i*Robot. With mass manufacturing the cost of one NCDAD would reduce significantly.

The second objective was to develop the NCDAD with a stand alone control unit by embedding the controls within the drone itself. Using any computer with network connectivity and an internet browser, the user can have the full control of the drone using a Graphical User Interface (GUI). This completely eliminates the need for a separate unit to control the drone.

With NCDAD now it is possible to connect to any existing WiFi network and gives the user full access to the controls, onboard sensors and video at an affordable price to the market.

The full capabilities of the NCDAD allows it to be implemented as a security device to eliminate the need for several security guards as the drone can be used as a patrolling agent when equipped with technologies to identify any kind of infiltration. For some models upgrades of weapons systems from something as simple as a teaser to a gun can be mounted on the drone.

Drone Prototype



User Interface

Significance of the Drone:

Accomplishments:

Patents Patent Application Filed

Publication:," Network Controlled Data Acquisition Drone,"
Proceedings of the 2008 ASEE Gulf-Southwest Annual Conference, The University of New Mexico – Albuquerque, March 26-28. Abstract accepted, paper submitted. *Note: students will present and compete in best papers and best posters.*

Showcased at: Carver High School Visits, The Department of Defense Conference

High Temperature Automobile Protection System (HiTAPS)

A new technology for has been developed to prevent fatal accidents from heat exhaustion in cars. This technology is genius and a definite leader of this era. The motivation behind this invention was the amount of children and animals that die because of overbearing heat during the summer time. It seems that many people, mostly parents, forget children they have in their car or they underestimate how quickly temperatures rise in a hot car. The result is usually the death of the children and the heartbroken parents begging for forgiveness. Some parents could even face fines and jail time in this devastating moment.
The technology is a High Temperature Automobile Protection System (HiTAPS). The inventers designed HiTAPS to detect if a child or animal is left in a car and alert the owner of an alarming temperature. HiTAPS contains a temperature sensor that detects the temperature of a car and uses 3 sensors to identify if there is a living being in the car. There is a motion sensor that senses if there is motion, the pressure sensor senses if there is pressure and the seat belt sensor is used to see if the seat belt is connected in the car. When temperature rises and either the motion sensor or the pressure and seatbelt sensors are activated, there is a signal that is sent to the owner of the vehicle, on a device that can be put on the keychain, to alert them that someone might be in danger because of the extreme heat within the car. The system waits for 2 minutes and if there is not response to deactivate the system, then the windows in the car are lowered about 1 inch and a loud horn is triggered to alert bystanders.

HiTAPS Prototype

This is brilliant because it is designed to help save lives. In addition, HiTAPS takes into consideration certain consequences like the heat of the car, if the owner doesn't respond and the level that the windows open so it will allow minimal airflow without having someone steal your car. HiTAPS have been tested thoroughly. It will be hitting the markets soon, look for it in the new vehicles.

Significance of the HiTAPS:

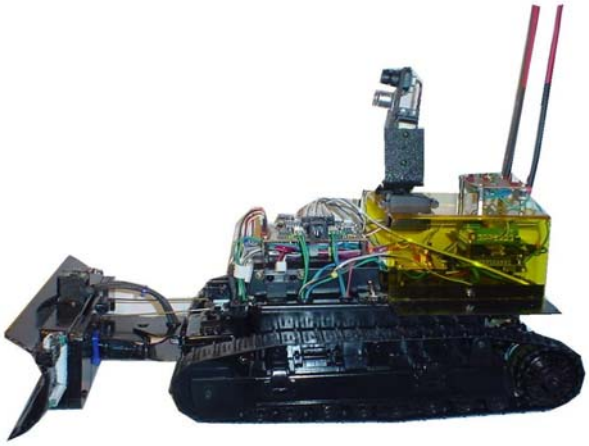
Accomplishments:

Patents Provisional Patent Granted
Publication: "High Temperature Automobile Protection System," *ASEE-CoED Journal, VOL. XVI, No. 4, pp. 68-75, October-December 2006 issue.*
Showcased at: First Lego League (FLL), Carver High School
Visits, Research and Scholarship Day @ UH, MAES, Dean's Newsletter

Robotic Bulldozer

As a child, did you ever want to have a toy that could do everything you wanted it to do all by itself? With this simple autonomous system that dream can come true. The concept is versatile enough to be developed into a high tech toy or implemented into a full size mechanical machinery application.

The main goal of this invention is to implement this autonomous system for a construction industry, but it has many other potential applications. It is designed to be more efficient, reduce man-hours and reduce the number of work related injuries. Once the system is activated, it will be given parameters at the start of a job which it will use to accomplish the tasks. The autonomous system may be remotely monitored and coordinated with other machines and employees by a remote operator to assure the system functions according to the designated tasks.



Robotic Bulldozer Prototype

This fully autonomous system features multiple sensors and devices to gather the field data it requires to operate safely within the specified requirements. It will be equipped with a Scanning Vision System, Collision Detection/Avoidance and Distance Measuring System, Terrain Scanning Elevation Mapping System, Tactile Blade Pressure Sensor System and Wireless Communications. All of these systems operating together will make the autonomous system the way of the future for the space, military, mining, agriculture, high tech toy and construction industries.

Significance of the Robotic Bulldozer:

Accomplishments:

Patents Provisional Patent Granted
Publication: The paper is revised and seeks international journals in robotics
Showcased at: First Lego League (FLL), Carver High School
Visits, Department of Defense Conference @ UH, Research and Scholarship Day @ UH, MAES

Automatic Clay Conditioning Foundation

Homeowners in the Houston area are astounded today by research produced by technologists at The University of Houston. The expansive nature of clay soils in and around Houston has plagued homeowners with damage to foundations for years. The most economical solution to this problem has been to water the ground around the foundation to control contraction of the soil thereby preventing damage to the foundation. The research produced at UH, however, shows that this method is nothing more than a placebo against this problem.

As the soil expands on one side of the foundation and contracts on the other the foundation is apt to tilt and thereby crack. Watering evenly around the foundation will expand soil on all sides, true, but the inherent moisture difference still remains. This means that the tilting of the foundation still remains. Maintaining even moisture on all sides of the foundation is the true answer.

An interview with Chuck Leudemann, construction specialist, reveals that foundations are placed on an even mixture of soil. This is accomplished by digging the area where the foundation is placed and mixing the soil with bulldozers before replacing it (5.1). The even clay content throughout the soil provided by this mixing creates the possibility of maintaining even moisture throughout the ground around a foundation. Incorporation of moisture sensors and independent watering zones in the Automated Clay Conditioning System for Foundations (ACCF) allows for control of shrinking and swelling of each area around a structure. Moisture is maintained evenly on all sides of the foundation creating a situation that while the foundation is still rising and falling with the soil it is doing so without tilting thereby relieving stresses on the structure. This relief of stress on the foundation prevents cracking and even possible expulsion from the ground!

ACCF Prototype

This answer proposed by the technologists at UH is ingenuities, and homeowners who use the system will profit from it. According Renea Gallagher, Realtor, the ACCF will improve property value of homes that use it by $10,000.00 (4.1). This is astounding as UH technologists estimate that the system will cost close to $5000.00 to buy and have professionally installed!

The ACCF monitors and maintains moisture about separate zones around the foundation effectively neutralizing the problem of expansive soils in and around Houston. Installation of the ACCF around your home benefits you through preventing damage to your foundation and increasing property value. Houston homeowners are proud to have such innovative technologist working for the well-being of the community at UH.

Significance of the Robotic Bulldozer:

Accomplishments:

Patents Provisional Patent Granted

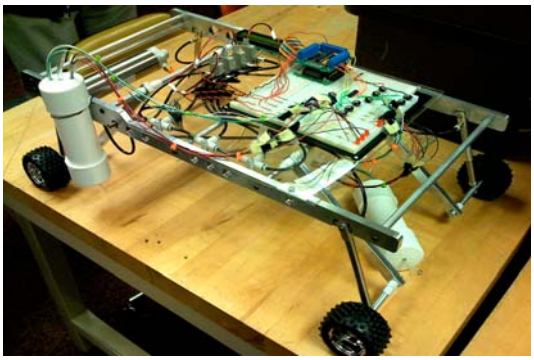
Publication: **"**AUTOMATED CLAY CONDITIONING SYSTEM FOR FOUNDATIONS,", the Technology Interface, Submitted February 2008.

Showcased at: Carver High School Visits

THE PUDDLE JUMPER: ACTIVE VEHICLE WATER LEVEL MONITORING SYSTEM

Do you like the handling and style of your car but worry about having flood damage or worse getting stranded in rising water? Flooding is a major concern for many motorists on rainy roads and areas prone to flooding. Considering that 67% of all flood related deaths are either from vehicles in water (65%) or hydroplaning (2%) and flooding accounts for over two billion dollars worth of damage to insurance companies just in Texas (not including damage not covered by insurance). This calls for the need for a system that can help prevent both personal and financial injury or loss. Data from the Flood Safety Education Project sponsored by Public Entity Risk Institute, the City of Austin, Guadalupe-Blanco River Authority (GBRA), Harris County Flood Control District (HCFCD), the City of Dallas, Lower Colorado River Authority (LCRA), San Antonio River Authority (SARA), and United States Geological Survey (USGS) gives clear evidence for concern of both monetary loss and injury that occurs due to flooding. The key benefits of this system are:

- Alerts the driver of the current water depth
- Alerts driver of dangerous road conditions due to high water
- Provides a level of safety to drivers of vehicles with low ride height clearance by lifting the vehicle.
- Saves money on insurance due to lower probability of water damage
- Saves mental anguish from damages and repairs caused by rising water or flood damages.
- A cost effective solution to possible damages to a vehicle while creating a Luxuriously smooth ride.



The PUDDLE JUMPER Prototype

Significance of the Puddle Jumper:

Accomplishments:

Patents Patent Filed

Publication: "Active Vehicle Water Level Monitoring System," Proceedings of the 2008 ASEE Gulf-Southwest Annual Conference, The University of New Mexico – Albuquerque, March 26-28. Abstract accepted, paper submitted. *Note: students will present and compete in best papers and best posters.*

Showcased at: Carver High School Visits, The Board of Regents Showcase