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ELECTRONIC PRODUCT DEVELOPMENT EXPERIENCES FOR UNDERGRADUATE STUDENTS: A NASA SPONSORED EXAMPLE

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Introduction

Recently, the Electronic Systems Engineering Technology program at Texas A&M University has undergone a major curriculum revision. The program, once focused on producing graduates for the general electronics and telecommunications industries, now has a strong emphasis on electronic product and system development. The primary reasons for this change are two-fold.

First, the United States has seen declining enrollments in engineering and technology departments over the past five years[1] and this has been no different for Texas A&M's Electronic Systems program. To address this, the faculty has identified a need for a unique "selling proposition" as one possible solution. The idea of careers in electronic product and system development has resonated well with new students and transfer students as well as their parents. While this concept of product development careers is not new in mechanical and manufacturing programs[2,3], very few electronics programs have adopted this concept. However, over the past six years, our electronics program has been steadily moving in this direction. In addition, an emphasis in product development lends itself well to the programs' existing interest in entrepreneurship education as evidenced by efforts at other schools.[4,5] In fact, all students currently undergo a capstone product development experience in their senior year. Working in teams of four students, they have to conceptualize a product and then build a functional prototype over a nine-month period. Many of these groups have either shown an interest or actually made efforts to commercialize their product. Figure 1 shows a few examples of the hundred or so products the students have already designed.

Figure 1 – Examples of products developed by ESET students starting top left, clockwise: E-Paper Pricing Tags; NASA Autonomous Mobile Robot; Auto-tuning Guitar; Phone Alert System for the Hearing Impaired.

The second reason for this change is the current job market for graduates. Virtually all recent former students now have careers that support either specific products or large systems through their life cycle, performing functions such as testing, product engineering, applications engineering, sustaining engineering, and systems integration. To a large degree, this can be attributed to the dramatic change in the program faculty. Today, all faculty members have degrees in engineering fields and the majority of the faculty has five plus years of industry experience supporting products and systems. Thus, the new program not only emphasizes the technical aspects of electronics and communications, but now includes course topics in product testing, project management, customer interaction, and the business aspect of product development.

As the faculty moves forward with this initiative, it has become increasingly important to ensure that all students experience multiple product development opportunities while pursuing their degrees. This not only gives them hands-on experience, an important trait of any engineering technology program, but it reinforces the concepts being taught in the classroom. It also helps the students develop life-long learning habits and best practices. To this end, the faculty, with the help of industrial partners, now ensures that both courses and capstone projects have a strong product development aspect. Through this vetting process, a "rubric" has been created that allows projects to be assessed for their product development "value." The rubric includes assessing funding, level of customer interest and support, and potential for commercialization.

This paper discusses the elements necessary for courses and capstone projects targeted at delivering a real-world product development experience. Examples of projects conducive to this initiative will be discussed including a detailed description of an ongoing NASA-funded product development experience. Finally, feedback from both students and industry on the quality and success of projects will be presented.

The Electronic Systems Engineering Technology Program

Overview

With the shifts in faculty expertise and opportunities for graduates mentioned above, it became clear that a comprehensive overhaul of the curriculum was needed. Over a period of approximately two years, the new electronic systems engineering technology curriculum was created through a process that involved faculty retreats and multiple cycles of industry feedback.[6] Throughout the process, an emphasis was placed on ensuring graduates would have the tools and experiences necessary to be successful in the electronics product and system development industries. This includes design and project management as well as support elements such as applications development, maintenance and test. Today, the new curriculum has four main areas of focus:

- Embedded systems: Modern electronic products and systems are almost exclusively microprocessor /microcontroller-based and are controlled through embedded software. Thus, the curriculum has a sequence of four embedded design courses that cover basic programming in assembly and C, microcontroller architecture, and software system design. In addition, the students can also take an elective in mobile device programming and database structures. The embedded sequence is designed around the TI TMS570 microcontroller. By using an advanced processor with multiple peripherals, the students are pushed to develop their embedded software skills. The idea behind this concept is that the students are better prepared to extend their knowledge to other platforms by learning on an advanced architecture such as the TMS570. This has been proven time and time again, as students in later courses successfully choose and use completely different microcontroller platforms for their projects (Microchip PIC, TI MSP430, etc.).

- Analog and digital electronics/interfacing: As with most typical electronics programs, the students receive a strong underpinning in both analog and digital circuits/electronics. This is particularly important in this curriculum, since most electronic products interface to the external environment through analog and digital sensors and actuators. In addition to the four analog and digital electronics courses, the students also take courses in instrumentation and control systems. To ensure the students have the technical tools necessary to do electronics design, previous efforts were made to introduce various industry-quality CAD tools across the curriculum, primarily in analog and digital electronics courses.[7]
- Communications: Today's electronic products and systems are generally required to communicate in some form, whether it is a computer that uses various data communication protocols such as 802.3, 802.11, and Bluetooth or a simple appliance that might use standard protocols to communicate between internal subsystems. To this end, the curriculum has a four-course communications sequence where the students are exposed to various wired and wireless data communication protocols. In addition, the sequence includes a course in electromagnetics where the students learn about high frequency and wireless system design. Finally, students can take an elective specifically in data communications where they learn to develop protocols from the ground up.
- Industry product development tools: The most innovative part and the pinnacle of the new curriculum is a sequence of courses that introduce students to industry practices in product and system development. Having program involvement with companies such as Cisco, Texas Instruments, National Instruments, and 3M during the curriculum development process was critical in the creation of these courses. This sequence includes courses in device/system testing, engineering statistics and data analysis, leadership, and product development business/engineering best practices.

In addition to revising the curriculum, the program name has now also been changed to Electronic Systems Engineering Technology (ESET) to better reflect the new emphasis on products and systems.

New Course Development

As part of the new curriculum, in addition to restructuring and augmenting existing courses, three new courses were developed. These supported both the embedded systems and the product development tracks as discussed above. The following section discusses these courses and how they impact the product development experience being delivered to the students.

<u>ENTC 269: Embedded C Programming</u>

As most of the product development activities within the ESET Program include an embedded intelligence device, the faculty decided to replace the typical C Programming course with an internally taught Embedded C Programming course and associated laboratory. In so doing, the students were engaged in the embedded software high-level language development environments at an earlier point in their academic careers. The students were also able to better understand the specific attributes and requirements of establishing and configuring an embedded development environment, utilizing drivers and source code for specific embedded peripherals, and how to compile/download/debug embedded software. With the new ENTC 269 – Embedded C Programming course being introduced at the sophomore level, ESET students now get a jump start on designing and developing algorithms that will be implemented on a high-end (TI TMS 570) microcontroller later in the embedded software course sequence.

ENTC 329: Six Sigma and Applied Statistics

The Six Sigma DMAIC process and many statistical tools are now introduced to students to improve processes and quality of products/systems. Prior to the new ESET curriculum, students took a general statistics course offered by Statistics Department. Due to the diverse backgrounds of the students in this course, the general statistics course did not have a focus on electronics as the new ENTC 329 does and, as a result, ESET students learned statistics but did not know how to apply the knowledge to the technical courses they later took. The new ENTC 329 course is more focused on applications to electronics systems and the students learn how the quality of their designs directly impacts the bottom line of the business. As part of the course, there are two hours of lecture as well as a three hour lab that is designed specifically to teach them how to use statistical tools to analyze test data, design experiments, and solve problems. Students also complete education in Six Sigma and also perform Six Sigma course projects. At the end of the course, they each receive their Six Sigma Green Belt certificate.

ENTC 333 Product Development

The Product Development Cycle is formally introduced to the students in the newly established Product Development Course. This course was added to the curriculum based on feedback from the program's Industry Advisory Council. Emphasizing the product development cycle was a suggestion the IAC made to better prepare students for the follow on capstone experience as well as an industry relevant teaching. Through a series of lectures and laboratories, the students are led through the product development life cycle, from ideation to termination. The course uses a classical lecture style each week to present the stages of product development, but then relies heavily on industry experts to present real world experiential cases in a laboratory setting. This style gives the students exposure to the lecture materials in a classroom setting with further exposure to that same material through the eyes of industry experts and experiential learning in the lab. The students are exposed to product development strategies as the required homework leads them down the path of researching a topic in product development and finally preparing a paper and classroom presentation of the researched material.

Product Development Experiences throughout the Curriculum

While multiple courses have been developed with a specific focus in product development, a primary tenant of the new curriculum was to incorporate experiential product development opportunities at all levels of the academic program. This would allow each ESET student multiple opportunities to work in small teams to accomplish some aspect of product development. Examples of these experiences include:

ENTC 151 – This freshman level course has a series of objectives, one of which is for new students to develop good team building skills and in so doing, practice group problem solving and innovation. In ENTC 151, therefore the product development element that is stressed the most is ideation. Transforming problem statements into well thought out and vetted solutions in a team environment is critical to future success as a contributing design/development team member. Beginning the design and simple prototyping activities while building interpersonal and communication skills helps each student take the first steps of technical product/systems development methodology. Being introduced to team problem solving early in their academic program also creates an increased level of engagement and ownership in the ESET Program.

ENTC 219 – At the sophomore level, the ESET Program seeks to demonstrate to its students an overall approach to product development that includes development, testing, optimization, and good quality documentation. Working in small teams of two, ENTC 219 students apply the concepts of combinatorial and sequential logic design to the creation of an autonomous robot that is capable of successfully competing in a drag race and road race event. In addition to integrating all aspects of the digital design process, the students are introduced to the ESET System Design Process, or SDP approach to designing product and systems. The associated labs also teach the students how to populate both through-hole and surface-mount technology printed circuit boards. Once the electronic hardware has been built, tested and installed on a team-designed robotic three-wheeled platform, the teams must then develop a hardware-based state machine and associated digital device modules such as a Pulse-Width Modulated (PWM) motor control element for each drive wheel. Integrating all of these subsystems into a complete system and optimizing performance are the final activities prior to the Race of Champions. In this race, where Xilinx provides a cash award for the first, second and third place teams each semester, the ESET students have the opportunity to learn through competition. In addition to learning motivation, the Race of Champions is also a great public relations event that is used to inform other undergraduate students within the Look College of Engineering about our educational program.

ENTC 359 - One of the key areas in the ESET program is electronic instrumentation. In ENTC 359, students learn data acquisition using LabVIEW and microcontrollers. Students first use LabVIEW to measure temperature and motor speed. Closed loop temperature control and motor speed control systems are developed in the labs. The Modbus digital communication protocol is used for data communication between multiple computers running LabVIEW. Students are tasked in a course project to design a PCB with a microcontroller, which accepts commands from a desktop computer, measures the temperature or motor speed, generates the control command, and sends the results back to the desktop computer. This course project provides learning opportunities for students in the areas of sensor, signal conditioning, serial communications, PCB design and population, microcontroller programming, testing, and system integration, all important aspects of electronic product development. This course prepares students for their capstone project courses where students put everything they learned together to develop an innovative electronic product.

ENTC 369 – As has been indicated, embedded software is a critically important element to the ESET product development curriculum. Being able to demonstrate the power and versatility of software solutions over hardware implementations is key to students engaging in real-time embedded software design, development, testing and verification. In the junior year, student teams choose one of a number of pre-defined course projects. One of these is Mobile Platform II. Whereas in ENTC 219, the teams implement hardware-based designs in Field Programmable Gate Array (FPGA) technology, in ENTC 369, teams select the design/development of an embedded software-based controller for this system. Having the ENTC 219 experience for direct comparison demonstrates the ease of modification, optimization and capability extension that are possible with using software approach. In most of the electronic product/system development activities undertaken academically or via funded applied research projects by the ESET Program, the ability to evaluate tradeoffs and make multi-faceted decisions is stressed as a critical aspect of the product development process.

ENTC 419/420 – Through repeated exposure to both a standardized design approach and a reoccurring opportunity to work in team environments from ideation through commercialization, ESET students prepare themselves for a two-semester experiential learning sequence referred to as Capstone Design. Here, three to four-person teams are formed through a self-selection process. Most students will capitalize on the multiple opportunities they have had to work in a team environment through their other courses in the ESET curriculum. Once the team is formed, they will operate as a startup venture for a period of two semesters. As they begin the first semester which is focused on project management planning and initial design, they must identify a private or public sector customer/sponsor who has a problem, need, or opportunity that requires the development, documentation, and delivery of a fully functional, pre-production prototype which meets a set of stringent technical aspects. In addition, the team must solicit the involvement of an ESET faculty member to be their technical advisor. Using their own company name, website and identity, the team executes the design, implementation, testing, validation, documentation and delivery phases of the product development process. In some special cases, ESET teams are joined by one or two business students who augment the project by providing business-related product development elements such as feasibility studies, market assessments, and business plans. In the second semester, the team-based startup companies must complete their designs and transition them to well-documented prototypes that are worthy of operational testing and evaluation. The intellectual property ownership that results from the Capstone projects is agreed to as part of the team/project selection process in the first semester.

The Product Innovation Cellar

An essential element required to enable product development projects is providing the students the necessary equipment and facilities necessary to be successful. Until recently, these facilities consisted primarily of faculty research labs where individual student teams were assigned space based on faculty interest in their projects. For those teams not given space in faculty facilities, a small lab with five individual suites was available with limited test and manufacturing equipment. While this methodology led to many successful projects, the results were often ad hoc and subject to the type of equipment available to the students working in a particular lab. To rectify this, the ESET faculty decided to create a common, multi-disciplinary facility available to all students working on product development projects. To this end, faculty visited similar facilities at schools such as Rice[8] and the University of Dayton[9]. With ideas in mind, the faculty then wrote several internal grants and was awarded $250k to create what is now called the Product Innovation Cellar, or PIC. The images of the new PIC can be seen in Figure 2.

The PIC, opened as of November 2012, is a 3400 square foot facility available to students and student teams working on product development projects. The facility is divided into six main areas:

- Open Concept Work Area: As the primary work area for all students, this area has up to twelve four-person workstations with power reels in the ceiling so that students can access power from virtually anywhere in the lab. The work stations consist of mobile 4ft x 4ft tables that can be rearranged to create flexible work areas as needed. The area has twelve mobile storage areas that are assigned to teams currently working in the lab. In addition, this area has a large screen and ceiling mounted projector so that group and sponsor presentations can be made when necessary.

Figure 2. Product Innovation Cellar, starting top left, clockwise: Student Work Area; Single Student Team Workstation; Electronics Manufacturing and Test Lab; Computer Lab.

- Mechanical Manufacturing Lab: Often neglected in electronic product projects is the area of mechanical design. Most electronic products require some form of mechanical design whether that is simply an ergonomic enclosure or, in the case of electromechanical systems such as robots, more sophisticated mechanical structures. In the past, ESET students have demonstrated the ability to extend their knowledge to mechanical designs. In addition, as the product development initiative moves forward, it is anticipated that there will be an increasing number of multi-disciplinary electronics/mechanical teams. To this end, a good facility for mechanical design and fabrication is essential. The new lab creates such a resource giving teams access to 3D printing capabilities, CNC machining, as well as typical manufacturing facilities including saws, drill presses, shears, and assorted hand power tools.

- Electronics Manufacturing and Test Lab: As most of the products produced by the ESET students are embedded intelligence-based, having access to PCB manufacturing and population facilities is essential. While most teams will outsource the final fabrication of PC boards to third party board houses, they still need the ability to rapidly prototype alpha designs. This new facility has rapid prototyping PCB facilities from LPKF (Portland, OR) as well as equipment for soldering thru-hole, surface mount (SMT) and fine pitch SMT components. In addition, the lab also has multiple benches with electronic test equipment.
- Computer Lab: While virtually all groups have personal laptops which have access to the wireless network from anywhere in the PIC, a CAD lab is available with the specialized software necessary to run equipment such as the 3D printer, the CNC machine, and the PCB rapid prototyping router.
- Industry Collaboration Conference Room: Because many of the product development projects involve individual or industry sponsors, teams need a professional, multi-media conference room to make one-on-one in-person or teleconferenced presentations. Also, in the capstone course sequence, each team must make weekly status presentations to advisors and sponsors. The new conference room in the PIC supports these interactions with equipment including a conference table, a ceiling mounted projector and screen, a white board, a full glass wall that can be used as a "white board", and video conferencing systems such as Cisco's WebEx.
- Parts Store: An ongoing issue when supporting product development is giving students access to supplies and parts in an efficient manner. While teams can always order parts via online stores, long lead times slow down the design/development process. The new PIC now has a parts store, run by ESET's local IEEE student chapter, that provides students access to commonly used parts such as microcontrollers, analog and digital interfacing components, and development boards without having to wait for shipping. Several companies are already donating bench stock to the store which reduces development costs as well.

The facility has only been operational for two months as of the writing of this paper, but faculty, students, and sponsors can already see the value-add to student product development projects.

Capstone Assessment Rubric

To identify a consistent level of acceptable projects that will provide ESET students with a challenging and rewarding product development experience, a two-fold assessment process is now used. The first assessment ensures that the project itself meets or exceeds a minimal level of technical rigor appropriate for a three- to four-person ESET Capstone student team. Known as the Technical Merit Matrix, this assessment tool which produces a merit factor from 0 to 1.8 is shown in Table 1.

Teams use this matrix in determining if a potential customer's/sponsor's project meets the minimally acceptable content. If not, it is possible for the team to add content such that it does meet expectations. The weighting factor for each merit factor that is to be achieved in the project is summed to produce a score from 0 to 1.8. The sum of these weighting factors must exceed 1.0, because this factor is used as a multiplication factor for the project team grade that is achieved at the end of the capstone experience. Generally, because all factors are not completed to a level that warrants full weighting, most teams will strive for a minimum of 1.3 to 1.4 to provide a buffer against this situation. It should be understandable as to why the most technical weight is given to hardware and software design, development, and test.

Table 1. Capstone Technical Merit Matrix.

	Technical Merit Factors	Weight
1	Contains a clearly described and completely understood technical challenge	0.1
2	Contains a requirement for system integration	0.2
3	Contains a requirement for system testing	0.2
4	Contains a requirement for theoretical analysis and simulation	0.2
5	Contains hardware design, development and test	0.3
6	Contains software design, development and test	0.3
7	Contains an enclosure design/fabrication requirement	0.2
8	Contains a requirement for documentation other than the project related	0.2
9	Contains a requirement for intellectual property protection	0.1
10	Contains requirement beyond Capstone	0.1

Recently added to the evaluation and selection process is the Product Development Rubric which provides a good indication of the viability that the project has for small business startup. With the achievement of an acceptable technical merit, the project then undergoes an assessment of its product development attributes. The 3 by 5 matrix shown in Table 2 indicates how this assessment is made.

Table 2. Product Development Evaluation Matrix.

	Low (1)	**Med (3)**	**High (5)**
Tech Merit	<1.0	1.0 – 1.4	1.5 – 1.8
IP Dev	None	Possible	Highly Probable
Commercialization	One of	Some interest	Demonstrated Interest
Funding	Possible	Some Interest	Currently Available
Customer Interaction and Commercialization Interest	Low	Medium	High

The team, technical advisor, and Capstone course director will provide input to this assessment. Once completed, the total points must exceed 17 to qualify as meeting the overall ESET product development objectives.

By using the two part assessment, the ESET program can maintain the technical content and rigor of the projects undertaken by its students while factoring in the important non-technical business-related aspects. In so doing, the ESET Program seeks to place emphasis on those projects that encourage and support good product development practices as well as having potential for follow-on commercialization activities. This rubric allows the ESET Program to better build a bridge from innovation to entrepreneurship as it continues to more fully integrate the product development life cycle processes throughout the undergraduate curriculum.

Example - The NASA Wireless Smart Plug

Overview

As an example of this two-phased assessment process, the ESET Program recently accepted a project sponsored by NASA-JSC as a Capstone-qualified project. Based on a NASA solicitation, two ESET faculty members submitted a proposal that was selected for funding. A fundamental element of the proposal was the integration of a Capstone team in the overall work to be performed. This new type of research project-based Capstone project added additional customer –based deliverables and significant changes in major milestone presentations. The project also spanned a period of time that exceeded the typical Capstone two-semester timeframe. To meet these requirements, the ESET faculty members created two teams, one providing the entry-level activities and the final activities to install, test, validate and transfer the product/system to the NASA-JSC Deep Space Habitat (DSH) mockup. The Capstone team was then charged with the actual design, development, test, and validation of the prototype. The overall goal of the project is to provide NASA with a new Wireless Smart Plug (WSP). The WSP provides an individual device level add-on capability to monitor all devices used in the habitat that attached to either or both of the 120VDC and 28VDC power busses, report power consumption in near real-time, and respond to directives from the centralized power system supervisor to activate or shed load. The conceptual block diagram of the WSP can be seen in Figure 3. Five units are required to be installed and tested at the NASA-JSC DSH mockup in June/July 2013 for field testing and acceptance. The contract was let to the Texas Engineering Experiment Station (TEES) in the summer of 2012, and the four-person Capstone team (XCLLabs) began its work during the fall 2012 semester.

Technical Merit Assessment and Product Development Rubric

As part of the Capstone process, once the XCLLabs student team was formed, the two-part evaluation/assessment process was conducted to determine the feasibility of the project as a Capstone effort. The Technical merit assessment resulted in a total weighting factor of 1.5. The technical challenge was given full weight for a number of reasons including the requirement of integrating the ISA 100.11a wireless communications protocol which is a relatively new and unknown standard with limited solution sets available. The other major technical challenge was the integration of two different teams to meet all sponsor requirements.

Full weight was assigned for system integration. The overall design must be capable of being self-tested as a complete system, but must also be integrated transparently into the DSH ISA 100.11a wireless infrastructure and controlled via the NASA power system supervisor.

The requirement for system testing is included in the Capstone project both within the Product Innovation Cellar at Texas A&M as well as a proof of concept demonstration at NASA-JSC as part of the hand over from the Capstone team to the ESET student team that will support the final integration and acceptance testing during the summer 2013. During the initial assessment made by XCLLabs in fall 2012, the team was not confident that it would have sufficient work to qualify for the weight associated with "Contains a requirement for theoretical analysis and simulation."

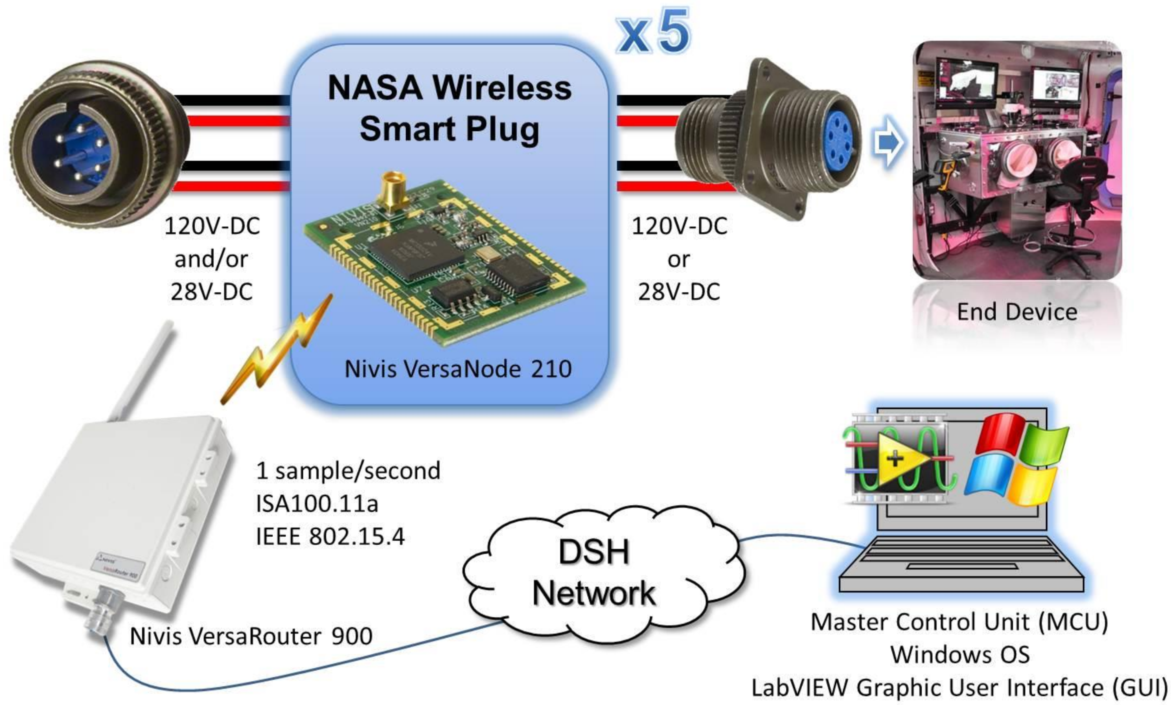

Figure 3 – Conceptual Diagram of the Wireless Smart Plug Product

The work as described and approved at the System Design Review, Preliminary Design Review and Critical Design Review includes sufficient work to provide full weight associated with hardware and software design, development, and testing. In addition, XCLLabs will design and fabricate a customized enclosure for the WSP that meets the size limitation for the device while providing an ergonomic interface for the mission specialists. One of the critical design constraints for the WSP is that it must consume minimal power in meetings its monitoring, communications and control functional requirements.

The team is seriously considering working with their project advisor and sponsor to prepare a paper for publication and presentation at an upcoming technical conference. This type of documentation is considered outside the typical project requirements so the team will receive the full weight of this factor once they have written and submitted the paper for publication. Because this is a federally funded research project through Texas A&M University, intellectual property ownership falls under the Bayh-Dole Act and thus no weight was assigned for IP protection. Finally, no additional activities outside of Capstone are currently being considered by XCLLabs. Based on the team's initial assessment of work to be performed, the technical merit for the project, provided all elements are met, is 1.5. Using the 1.5 technical merit assessments, the Product Development Matrix was completed for the WSP project and is shown in Table 3.

Table 3. WSP Product Development Assessment.

	Low (1)	Med (3)	High (5)
Tech Merit	**<1.0**	**1.0 – 1.4**	**1.5 – 1.8**
IP Dev	**None**	**Possible**	**Highly Probable**
Commercialization	**One of**	**Some interest**	**Demonstrated Interest**
Funding	**Possible**	**Some Interest**	**Currently Available**
Customer Interaction and Commercialization Interest	**Low**	**Medium**	**High**

The overall Product Development assessment rendered a value of 17 which indicates that the WSP project does indeed have the level of merit necessary for the ESET Program to include it in its product development portfolio. Specifically, the NASA requirement for a production-quality, space-worthy wireless power monitoring and control system to manage power consumption and control will provide the initial demand that will substantiate a new venture startup. Modifying the system design for use in earth-based residential and industrial settings will allow a consumer to better monitor power consumption and actively control energy usage in a “plug-and-go” process.

In contrast to a project that meets Product Development criterion, another recent opportunity came from the School of Veterinary Medicine. Here the research-practitioner needed an embedded system designed and developed to collect and analyze data collected during surgery on large animals. While the technical merit ranked the project at a 1.2, there appeared to be no IP forthcoming from the project and it was classified as a “One of” for its lack of commercialization potential. In addition, there was no interest from the customer to develop the operational prototype into a product or to engage in any commercialization activities that would distract from research. So, although the project’s Technical Merit indicated it exceeded minimal requirements, the Product Development score of 9 clearly showed that this project did not have sufficient customer support for product development and would probably not produce an opportunity for business startup or commercialization, This second project was therefore undertaken as a Mobile Integrated Solutions Laboratory (MISL) research project where funding received from the Veterinary School was used to fund two undergraduate students to develop, test and deliver the system required. The results of this project were not included in the ESET Product Development portfolio.

The overall lesson learned from the implementation of the new Product Development score is the value this score has in the decision making process. Only making project selections based on technical merit can result in projects that may offer significant technical learning but very little experience in actual product development. Although the student teams did meet their educational objective, their prototypes add no long-term value to the ESET Program or its goal of teaching innovation and product development skills to graduates of the program.

With the addition of the Product Development Rubric, the ESET Program can clearly indicate to its faculty, students, and current and potential project sponsors the direction it has set for the new undergraduate curriculum. The rubric was field tested during fall 2012 using the NASA-JSC WSP project and will be fully implemented for all Capstone projects beginning in spring 2013.

WSP Project Status and Lessons Learned

Currently, the Capstone team is in the middle of their implementation phase for the NASA Wireless Smart Plug. Since the project requires that they integrate into NASA's formal development processes the student team has delivered both a PDR (Preliminary Design Review) and CDR (Critical Design Review) to the engineering team at NASA and they are currently validating their alpha design. As is the goal, the students are learning many product development lessons that go beyond the technical design of their system. Two such examples include:

- About half way through their design, the customer informed them that their system had to use be capable of using power from either of the two separate power buses in the habitat, but could not simultaneously connect the separate bus grounds in order to avoid ground loops. This required multiple meeting with NASA engineers to develop a work around that would be accepted by the customer.
- As part of the project, the students' design is required to communicate with NASA's ISA100.11a network. The student team quickly realized that though their customer had stringent requirements for wireless communication, they could not provide the all of the necessary documentation required to implement the protocols they wanted the product to use. Once again this required that the team host multiple meetings with NASA engineers to solve the issue.

While a faculty member can lecture on the need to work closely with a customer to understand requirements, there is no substitute for real-world experience. As the WSP project progresses one can see the students' appreciation for customer relations and communications continue to grow. In their most recent decision which involved enclosure design, the team started their process by making a list of questions for the customer in an effort to avoid questions later.

Summary and Future Plans

To date, the ESET faculty has created a new program with a strong focus in the area of electronic product and system development. The curriculum has been completely revised to support this initiative with newly developed courses that introduce students not only to the technical aspects but also to industry best practices in product development. A new $250k facility has also been created to support student product development projects and foster true multidisciplinary activities within the College of Engineering as well as across the University. The PIC gives the students the resources to emulate industry-level design and development and also has the tools to support a wide range of multi-disciplinary projects.

However, the pinnacle of the new curriculum is the product development experiences that have been woven throughout the curriculum to support experiential learning. Starting in their freshman year, students are engaged in product development projects and this trend continues all the way to their senior year with the Capstone design course sequence. To ensure that these product development experiences are having the maximum influence on learning, all projects are now assessed through a “product development” rubric for quality and educational impact. With these changes, all students now receive multiple product development experiences as part of their degree, which better prepares them for careers in industry.

As the program moves forward, the faculty is committed to the continuous improvement of the product development curriculum, especially as it relates to the delivery of real-world experiences. Future plans include:

- Doing a formal assessment on the impact of using distributed product development experiences across the curriculum. Once the first group of students has completely finished the new curriculum, the industrial advisory board will be used to perform an assessment on the improvement of student education in the area of product development.
- At present, funded student projects are found through ad hoc and word-of-mouth processes. With the new need for quality product development experiences, especially in the capstone course, the faculty is developing a formalized methodology for soliciting potential projects from industry. This will include a rate schedule for projects as well as ensuring that all projects have been vetted using the product development rubric.
- An essential part of ensuring that students learn industry best practices in product development is to have them interface periodically with actual industry experts. To this end, the faculty is developing a sustainable industry mentor program that will be used to assign mentors to all teams working on product development projects.
- Finally, with the new capabilities offered by the PIC and the need for real-world projects, the faculty is working with other programs, departments, and colleges at Texas A&M to develop sustainable relationships that will create cross-discipline student teams. For example, teaming electronics students with mechanical students and/or business students as necessary.

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