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STRATA-1: A Public/Private/Academic Partnership for Undergraduate Applied Research

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STRATA-1:
A Public/Private/Academic Partnership for Undergraduate Applied Research

Undergraduate students learn and assimilate more when motivated. Few activities are more motivating to a young engineer than working on real-world, applied research projects. The Mobile Integrated Solutions Laboratory (MISL) at Texas A&M University has been highly successful in developing space-based embedded hardware/software products and systems. Many of these are used to monitor and control science experiments that are slated for operation on the International Space Station (ISS). Texas Space Technology Applications and Research (T STAR), a small start-up company, was recently contracted by NASA-JSC to assist in creating an experiment that will study the effects of micro-gravity on Regolith for over a year on the ISS. T STAR then approached MISL to provide the embedded intelligence system that will monitor, control, record, and report all aspects of the experiment during its year-long investigation. Three undergraduate students were assigned to the project which was delivered approximately six weeks after grant funding was received. NASA plans to have its experiment (STRATA-1) aboard the SpaceX-9 launch later this year. This paper provides an overview of the project, the students' approach to translating the problem statement into a functional and tested product, the lessons learned from a multi-partner development effort and an update of the project following installation and operation on the ISS.

Background and Introduction

The Electronic Systems Engineering Technology (ESET) Program at Texas A&M University has been restructured to focus extensively on an undergraduate experiential learning curriculum which emphasizes product and systems design and development. With a majority of the courses in the major having an integrated laboratory experience, students are provided a number of opportunities to construct working prototypes that implement the theory, mathematics and technology learned in the classroom. An example of this would be students in the entry-level digital design course integrate their knowledge of combinatorial and sequential logic circuitry to design, implement and document an autonomous three-wheeled robot[1]. Students then use these working prototypes to compete in a series of races to compare their designs to others in the class.

In some cases, ESET courses will have projects that have an industry focus or are supported by industry. The ESET Program has developed a spectrum of methodologies for interaction that increase the opportunities for ESET students to work on real-world projects. At the left end of the spectrum, industry can support a project that will be done as part of the class or the associated laboratory. Generally these are small efforts, but may result in a number of solutions due to the fact that multiple teams will be working on the problem. When appropriate, the public or private sectors may support undergraduate design and development activities through a gifting process. Here the external entity provides funding for a specific group of students to develop working prototypes that are then transferred to the sponsor. Most ESET Capstone projects will fall under this methodology, but it can be used to support other undergraduate courses, especially technical electives such as energy management. When this method is not suitable, the ESET faculty may choose to interact with the external sponsor through a research grant. The grant is similar to a gift but will generally have the faculty member leading a group of hired student workers rather than the students earning academic credit. This method works well when the timing of the project is not consistent with academic schedules or the scope of the project is greater or less than what will normally be taken on as part of a course or Capstone project. This method allows the faculty member to hire students specifically for their talents or interests from sophomore to senior level.

When the project has a significant number of deliverables or requires a higher degree of certainty in the outcomes needed by the external sponsor, a research contract can be set in place. However, now faculty members will probably be offloaded to work on the project rather than just manage the work of the undergraduates and graduate students or students from other disciplines such as mechanical engineering who may be hired depending on the scope of the applied research. Recently, some small businesses have approached the ESET Program to participate in SBIR/STRR proposal opportunities. In these cases, ESET faculty and undergraduate students will work in partnership with the small business and receive funding from a third party sponsor. Finally, faculty have started small businesses of their own and are pursuing product and systems development where ESET undergraduate students are hired by the small business to work external to the university. A good example of this is one faculty member who has a number of medical patents that his external company has created and is now looking to commercialize those through specific product development activities.

This spectrum of interaction methods allows for a number of different types of partnerships that provide a win-win outcome. First, the public or private entity will be able to transition their idea/problem/opportunity to a working prototype solution that allows for testing in a simulated operational environment and much better estimations on size, costs and capabilities. The ESET undergraduate students win by being able to augment their education through experiential learning as a team member developing real products and systems. In addition to the enhancements in their technical education, the students get the opportunity to interact with real customers and participate in a wide range of oral and written communications activities. Finally, these type of experiences, in some cases, lead to direct employment of student following graduation.

Small Business Support

As was clearly described in a recent paper delivered at the ASEE national conference[2], engineering technology has an increasing opportunity to support small local business startups. The paper discusses the educational importance of these activities, how they are symbiotic, and how their evolution should be repeated. The ESET Program is expanding its partnering with small business in a number of different ways not only to support the growth of these new ventures, but to provide unparalleled experiential education for its undergraduate students. When these projects stem from major initiatives undertaken by organizations such as NASA, Sumey[3] indicates that these projects positively affect engineering technology students in a variety of ways from increasing motivation and determination in freshmen all the way to raising the level of senior projects. Sumey continues by saying "these projects also clearly demonstrate the importance of the role of engineering technology as the bridge from technology to engineering and the tremendous value of hands-on experience."

Four years ago, the Department of Engineering Technology and Industrial Distribution renamed their traditional electronics engineering technology program to Electronic Systems Engineering Technology (ESET). In addition to changing the name, the curriculum was modified to include electronics and communications concepts as well as an emphasis in systems integration and embedded intelligence-based electronic products. The changes to the program were not only made in response to industry but also made it easier to differentiate the engineering technology program from the traditional electrical engineering degree offered at Texas A&M. Having a degree that centered on project-based learning and that prepared graduates for careers in electronic intelligence-based product development proved to be a drawing card for new students and the enrollment approximately doubled over four years. Finally, the product development emphasis supports both the College of Engineering strong interest in developing students' entrepreneurial and innovation capabilities. Currently, multiple student projects have assisted small (and large) businesses in developing and commercializing multiple new products.

The ESET curriculum has a traditional electronics-based technical core that emphasizes electronics, embedded systems and communications. In addition, the curriculum includes a product development emphasis through multiple courses including test, applied statistics, product development, and a capstone course sequence. This emphasis successfully integrates engineering and business-based product development concepts such as six sigma, quality function deployment, voice of the customer and the stage-gate process into the curriculum. Finally, the project-based nature of the majority of courses projects require students to work in teams and implement electronics-based solutions.

Over the past several years, the ESET Program has had numerous interactions with both industry and public agencies to support their product development opportunities. ESET typically determines which opportunities to support based on the value the experience provides to the undergraduate students from technical and business standpoints. These opportunities are typically funded through a grant process that either supports a student Capstone project or an activity supported through one of the applied research laboratories directed by ESET faculty. Typically, the funding is not done through a research contract process but is set up as a technical services contract. By setting up the project as a technical services contract, costs can be reduced and intellectual property negotiations are often avoided.

Capstone Projects

A signature component of the ESET program is the two-semester capstone sequence that is centered on product development experiences where students actually take a customer idea from concept to prototype. Through capstone, all ESET students are required to:

- Form a three- to four-person team that takes on the identity of a startup company
- Find a customer with an idea for an embedded intelligence-based product or system. This customer can be a faculty member, a business, a public entity such as NASA, or even in some cases, themselves
- Find an investor who can support their project with a $3k to $6k budget.
- Design and implement a professional and functioning prototype

In about eighty percent of the cases, the customer is a small or large company with an idea or concept that they are interested in commercializing. In the case of a small business, the need is usually immediate and important to the short term goals of the company. In the case of a large business, the capstone project is often an idea that the company is interested in pursuing but is not yet at a point to warrant using resources within the company itself. In those cases, the business is, in effect, using capstone as a workforce multiplier.

To support ESET students in performing this level of product prototyping, a resource is required that can support their prototyping efforts. For this reason, the Product Innovation

Cellar, or PIC, was built with $250k of support through the College's student fee-based differential tuition funds. The PIC is a 3400 square foot facility that is available to the students on a twenty-four/seven basis and that contains:

- electronic and mechanical rapid prototyping facilities
- an open and flexibly configured collaboration area where teams can work together on projects
- a facility where students can interact with their customers both in person as well as virtually
- a parts store (run by the IEEE student chapter)
- a full-time staff member who can provide technical and safety support

Through the use of the PIC, student teams can rapidly prototype ideas and can implement professional prototypes of their designs at a pace conducive to the capstone process.

Applied Research

In addition to capstone, students also have multiple, extra-curricular opportunities to participate in value-add activities that augment their product development education. With the industry-funded and applied nature of ESET faculty research, most students in the program will have multiple chances to work on real-world product development opportunities outside of class. The ESET Program has become more engaged in space-based product and systems development due to the increased interest and motivation of the ESET undergraduate students to participate in these high-visibility projects. The NASA Deep Space Habitat Smart Plug[4] development accomplished in 2013 is a good example of the educational value and real-world experience that ESET students take from participating in applied research. This provides a win-win-win situation for students, faculty and business. First, the students get real-world, compensated experience while still in college. Second, the faculty have access to a capable workforce that goes beyond the traditional graduate student. Finally, business has access to a cost-effective workforce that can assist them in the development of intelligence-based products and solutions.

An example of this interaction can be understood by considering one of the applied research laboratories within ESET, i.e. the Mobile Integrated Solutions Laboratory (MISL). MISL includes multiple ESET faculty members and is dedicated to applied research in the area of electronic intelligence-based product development for both industry and public partners. Over the past ten years, MISL has not only assisted small companies in the rapid development of product prototypes, it has also had an ongoing relationship with NASA's Johnson Space Center supporting STEM education and system development for space-based missions. In fact, MISL now places a strong emphasis on space-based systems. This market segment is ideally suited for MISL and ESET due to the need for embedded intelligence and their projects are well suited to the ESET undergraduate students' skillset. In addition, being involved in a space-based project is highly motivational to both students and faculty. Finally, the space-based market also has a large number of small startup companies needing technical support services. Because NASA Johnson Space Center (JSC) is near the University (within a two hour drive), MISL has developed relationships with multiple companies and contractors that support JSC and require new product and system development support.

A specific example of the public-private-academic partnership approach to undergraduate participation in applied research is the STRATA-1 Experiment proposed by 13 NASA Scientists. The scientists realized that to monitor and control their four-tube experiment, they would require a space qualified small-form factor embedded system. NASA reached out to a small startup company located in Bryan, Texas to provide this support. Once under contract to NASA, the company approached MISL to partner with them to leverage its compact NESI+ embedded intelligence technology. Thus, the public, private, academic partnership was formed. The remainder of this paper presents the design of the monitoring and control system, together with a current status update, lessons learn and recommendations for future partnership activities.

System Design

Overview

One example of the public/private/academic partnership model that ESET is now employing is the recent STRATA-1 experiment that the NASA Astrological Research and Exploration Science (ARES) Division will fly on the International Space Station (ISS) for approximately one year. The experiment studies regolith (the fine power-like substance found on the moon and asteroids). When NASA-ARES began the project in summer 2015, they had a limited budget and a very tight timeline to deliver the system to the ISS Payload Office for testing and verification needed to be included in the next launch cycle.

NASA-ARES scientists contacted a small startup company, Texas Space Technologies Applications and Research (T STAR) in Bryan, Texas to help them create the embedded hardware and software necessary to monitor, control, record, and report the operation of their experiment. The experiment as shown in Figure 1 requires the control of storage tubes, lighting, and photography which results in image capture and storage on high-capacity SD cards. The system is required to be fault tolerant and have a small footprint. Once T STAR was under contract to NASA-ARES, the president and CEO approached the Mobile Integrated Solutions Laboratory within the ESET Program to adapt its current space-qualified NESI+ embedded controller for use in the STRATA-1 experiment. Based on the time and footprint requirements of the project, NASA-ARES, T STAR, and MISL formed a tightly coupled development team. Three ESET students were chosen by the laboratory director and assigned to the project. Functional requirements and performance specifications were developed and the team begin the system design and development process. Ten weeks later, two units like the one shown in Figure 2 (Flight and Ground) were delivered to NASA-ARES by the T STAR/MISL team.

Strata-1:
A Study of Asteroid Regolith on ISS

PROJECT MANAGEMENT PI: Marc Fries, XI; PM: Lee Graham, XI; Deputy PM: Kristen John, XI

OVERVIEW

Strata-1 is a 2x2015, Class-1E payload being launched to ISS on SpaceX-10 in Spring 2016. Strata-1 will have gone from concept to flight-ready in just 10 months.

Strata-1 is an experiment to study asteroid regolith in a microgravity environment for an extended period of time. Regolith is the fine, pulverized material on the surface of airless bodies like the Moon, asteroids, and comets. Strata-1 includes four clear tubes containing different regolith simulant materials. It will autonomously image the movement of the simulants during its year on-orbit.

STRATA-1 SCIENCE QUESTIONS

How does regolith evolve under extended microgravity and ambient vibration?

What roles do particle density, particle shape, and particle composition play in the evolution of regolith?

Strata-1: An Experiment

STRATA-1 HARDWARE

Regolith Simulants:
1. Meteorite (ordinary chondrite)
2. Simulant (carbonaceous chondrite)
3. Silica Glass Beads
4. Silica Glass Fragments

FUTURE WORK

The science community has shown great interest in Strata-1. Therefore, plans for Strata-2 are already underway. Future Strata investigations could involve active components in the sample tubes such as probes or mechanisms to study regolith properties, impacts, and collisions. Strata could test anchors and sample collection techniques. It can also serve as a platform to study the dynamics of inter-particle interactions, planetary formation, and a number of regolith properties such as cohesion, adhesion, and the Brazil nut effect.

THE STRATA-1 SCIENCE TEAM

2015 IR&D Poster – EISD Technology Showcase

Figure 1. NASA Regolith Poster.

Figure 2. NASA Scientist, T STAR CEO and MISL Undergraduates work on STRATA-1.

The following section provides an overview of both the hardware and software designs. The overall hardware as depicted in Figure 3 is based on dual NESI+ boards controlling the left and right sides of the experiment and software design being based on an interrupt driven program developed specifically for the project. The operation of the left and rights sides of the experiment are synchronized through the use of switches on the front panel of the control and monitoring subsystem, dubbed the “electronics box” by the NASA-ARES scientists. The dual DC-DC converters are located in the center of the electronics box, the NESI+ boards are mounted on the left and right sides of the enclosure, and the circuitry necessary to operate the STRATA-1 regolith experiment consumes the remainder of the enclosure. Each NESI+ board and associated circuitry monitors and controls half of the regolith experiment mounted outside the enclosure.

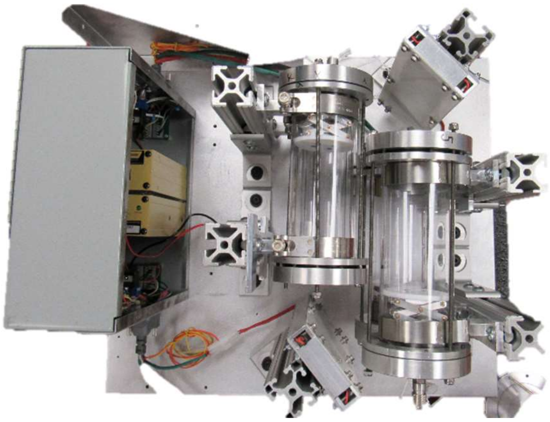

Figure 1. STRATA-1 Experiment with Electronics Box.

As mentioned earlier, the STRATA-1 team consisted of many different entities: the scientific design and analysis group at NASA, the local space commercialization business in T STAR, and the electronic controller design and development team in the MISL lab within the ESET Program. The design team worked through an iterative process in order to correctly design, develop, document, and deliver a fully functional system to the NASA scientists. A central point of this process was to have every stage, including the early conceptual development, reviewed and verified by the customer to minimize mistakes. This process also ensured successful completion with a fast turnaround. The embedded electronic system within STRATA-1 experiment was only one off the aspects of the project design, but was the sole responsibility of the MISL team. The electronics box focused on the use of the space-qualified NESI+ board which is a small form factor, embedded intelligence platform developed within the MISL lab. First, a conceptual block diagram (CBD) was developed to visually represent the capabilities of the system. After approval, the MISL team worked to develop a functional block diagram (FBD) to showcase all the parts chosen with pins, signals, and all interfaces required for proper operation and control. While the hardware was being designed, there was a simultaneous effort in the embedded software development in preparation for final system integration. All of these stages, explained next, were critical in the successful development of STRATA-1.

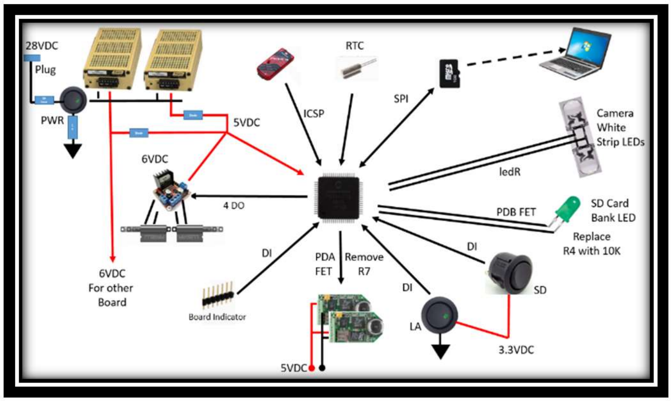

Figure 2. STRATA-1 Monitoring and Conceptual Design.

Hardware Design

Conceptual Design

The conceptual design phase consisted of generating the CBD shown in Figure 4 to illustrate the capabilities of the system to the customer in a pictorial format. The CBD represents each basic subsystem and its interfaces to clearly define how the complete system will function. A key item to note is that the

CBD only illustrates half of the design required to be implemented.

A design decision was made to implement the two NESI+ board system shown in Figure 5 to reduce the number of wires being interfaced to a single board and improve operation of the overall system. In so doing the system includes graceful degradation of operation as part of its overall design. Key features that were required by the customer were as follows: regulate the incoming 28 volts DC supplied by the ISS, control four actuators in two directions, independent control of four HD cameras, provide lighting for the picture taking process, accurate time keeping, and lastly control of a user interface panel on the front of electronics box. Other features such as event data logging to a microSD card were added to improve the overall design and functionality.

Figure 3. STRATA 1 Control and Monitoring Unit.

Functional Design

Once a conceptual understanding of the project had been verified by the customer the project transitioned into the functional design phase. First a functional block diagram (FBD) was used to layout each device's interconnections accurately down to the pin level. Once this document had been verified the design team implemented the electronics box one subsystem at a time.

The International Space Station provides a 28 volt DC supply to the Express Rack, where STRATA-1 will be installed, that will power STRATA-1. To regulate this incoming power to the required operational voltage, two commercial, off-the-shelf DC-DC power converters were selected. A single power unit could have been implemented but a two-supply implementation was chosen to provide further redundancy. These two converters each generate an adjustable +6Vdc output which were then connected through separate power diodes. Each diode output voltage was adjusted to +5Vdc and then connected together to implement load sharing within the electronics box. The ISS Power System is protected with a 3A fuse on the +28Vdc input line of the STRATA-1 system.

The NESI+ boards are used as the embedded intelligence of the electronic controller. A single electronics box uses two NESI+ boards configured with identical software and hardware. The only difference in hardware is a board identifier jumper that ties a digital input pin either low or high depending to denote if it is board 0 or board 1. Each NESI+ board controls half of the experiment. Each side is a completely independent of the other and controls the needed cameras, lights, and actuators of two of the four regolith tubes. To provide power distribution for a large number of devices, two 12-position screw terminal blocks, one per side, were installed inside the box. Two DB15 connectors are used to maximize cabling efficiency from within the electronics box to peripherals in the main experiment chamber. This allows for a clean interfacing methodology as well as facilitating the design and construction of the electronics box and testing with all peripherals independent of experiment chamber being constructed by NASA. In addition, this connection method allows for quick and easy replacement of the experiment from the electronics box should the need arise.

The NESI+ board has readily available support for picture taking, however, the customer required HD images and therefore the HackHD camera was selected. The HackHD camera uses an SD card on its own board to configure the camera and store the pictures. It is easily controllable through a digital IO pin from the NESI+ board. As the entire experiment is fully enclosed such that no ambient light could get in, LED control was required to illuminate the regolith tubes for the picture taking process. The LEDs were controlled through a PWM signal that was connected through an optical isolator. This approached was used due to the fact that the LED's require a greater voltage than the NESI+ board could provide. The images recorded on the cameras are passed through SD card extenders to the outside of STRATA-1 enclosure so that all four cards can be accessed by the mission specialists for download and analysis during the year-long mission. In addition to the SD cards that interfaced with the HackHD cameras, each NESI+ board utilizes a microSD card to store event information. The microSD card also stores a time file in case of accidental power reset of the STRATA-1 experiment.

The STRATA-1 scientists require that the material to be examined be compressed in the tubes while in the transport phase to and from the ISS. To compress the material, a DC linear actuator is used in conjunction with a small scale scissor jack that can compress or decompress the material in the tube. A dual H-Bridge is used with each NESI+ board to control the direction of two actuators. The H-Bridge is interfaced to the NESI+ board through the onboard expansion port which uses four digital IO pins, two per actuator, to control whether the scissor jack extends or retracts.

The last subsystem of the electronic controller is the front interface panel. NASA had a requirement to use 3 switches to control the different stages of the experiment. One switch is used as the master power switch, one for controlling the direction of the motor actuation, and the last for putting the system into a "pause" mode to replace the SD cards for subsequent image download. To indicate which state each NESI+ board was in there is also a single LED per board on the front panel. These switches are all interfaced through digital inputs to monitor the state of each switch. Since a two NESI+ board system is used, each switch had to be interfaced with both boards to ensure both sides of the experiment would function identically.

To ensure a flawless final hardware installation process each subsystem was wired up and tested independently before integrating the next subsystem. In addition, each side was completely configured outside the electronics box and fully tested prior to being installed to eliminate errors in the configuration process. This implementation methodology coupled with constant customer interactions allowed the STRATA-1 embedded design team to deliver a system that satisfied all functional requirements.

Software Design

Module Development

STRATA-1 software was developed in an iterative process that allowed maximum hardware and software integration. A need existed to create software that is simple to follow and just as intuitive to debug. When dealing with a multi-facetted software design, a good practice is to separate independent actions into completely isolated functions. Due to the integration of the NESI+ board into previous projects, many software libraries had already been created that could be leveraged to support integration of components within the STRATA1 design thus decreasing development time. There were four main components that the new software needed created to control the experiment: the cameras, the H-Bridge that drove actuators, the LED front panel, and lastly the button interface.

The finalized control of each interface was completely tested and verified on an individual basis allowing for a smooth transition to the final code. By implementing the software in this modular approach the overall development time was shortened and less system level debugging was required.

Storyboard Implementation

After all subsystems worked and were successfully validated, STRATA-1 software had all the tools necessary to complete the design except one. The next step in development was in the implementation of a storyboard as shown in Figure 6. A storyboard is a logic diagram that provides a high-level view into how the program will function. By using the storyboard, all project stakeholders can review and approve the monitoring and control algorithm.

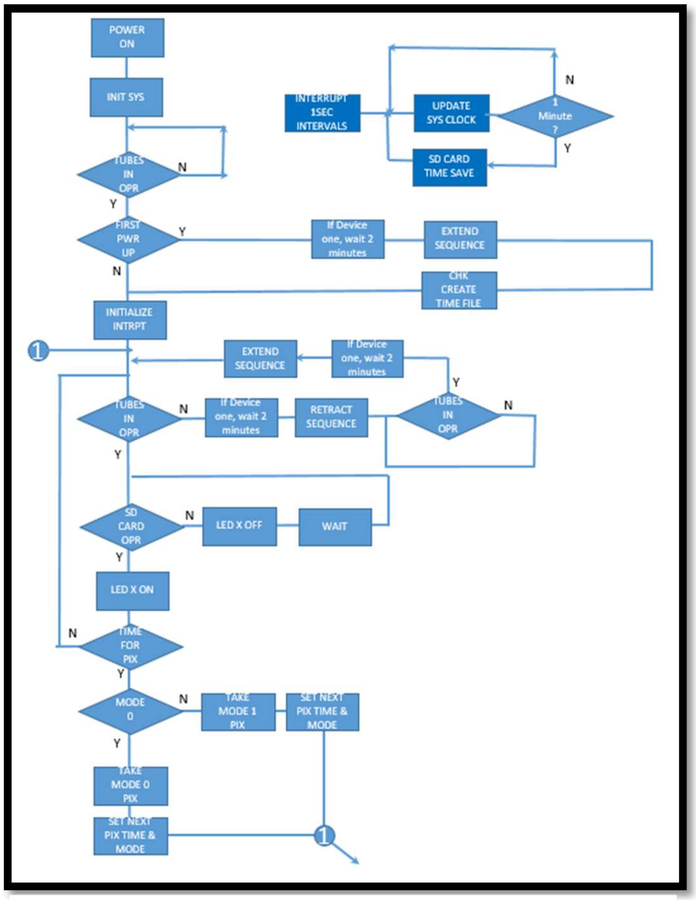

Figure 4. STRATA-1 Storyboard.

Lastly, there is a group of boxes that are not directly connected to the main branch. This is done deliberately, and allows us to define an interrupt. An interrupt in software is an event that happens independent of the main code and allows the microcontroller to execute a different action. Throughout implementation, the design team used a software interrupt to create a timer which accurately updated a time file every minute. This time file was used as a backup in the case of an accidental power reset or outage onboard the ISS.

When Strata-1 is first powered on, the NESI+ board performs an initial setup of the ports and devices to run correctly. After the system is initialized, the main program will begin execution. The switches on the front of the STRATA-1 box dictates most decisions made by the STRATA-1 software. The first decision determines if the Tube Operation switch is in the ON position. The software waits until this switch is activated. Upon activation, the software will begin another decision, and determine whether this is the first time the software has executed. The software does this by accessing the NESI+ microSD card, and reading the time file stored there. If the time file is not present, then this is the initial execution of the experiment. The system will then check to see which side of the experiment is being controlled, and begin the extend sequence.

These two tasks while simple to understand, need more context to comprehend why they are needed. In the instance of checking for the first power up, the need exists to handle power failures on the ISS. If the system were to lose power, when power is restored the software will restart from the beginning of the code. If we check for the time file, we can detect that the software has executed previously and the system must have lost power. The software can then skip the step of the extend sequence and essentially pick up where it was when power was interrupted. The other check that is made is to determine whether the code is being executed on NESI+ board 0 or board 1. To minimize power requirements, the NESI+ boards that are installed in the STRATA-1 experiment are operated with a time offset. This allows only one NESI+ board to take pictures and activate lights at any time, thus reducing the overall current draw of the system.

Continuing through the storyboard, the software will initialize the interrupt that drives the 1-minute time updates, and begins the main loop that the system will be in for extended periods of time. In loop one, the first thing the software will check is if the Tubes Operate switch is still active. If the switch is turned off, then the software would begin the ending sequence, and retract the tubes. Thus, at the end of the experiment, this switch will be positioned to begin the final sequence. A loop at the end of this sequence is added in case the switch is hit accidently, and allows the system to extend and continue the experiment without having to turn the system off.

Next, the software detects if the SD Card Replacement switch has been turned on. This switch is used when the mission specialists need to remove the SD cards from the camera extender cables and replace with fresh cards. When the switch has been activated the software will essentially pause and wait until the switch has been turned off, allowing the software to continue.

The last decision the software makes is detecting what mode it is in. The modes allow for taking 12 pictures spread over a minute, or taking two pictures in a row. Depending on what the time is, the software will make the corresponding decision and then loop back to the beginning of the loop.

With the storyboard clearly defined, the embedded software for STRATA-1 was successfully created. The ability to bring together the different subsystems that were created and tested allowed for easy integration into the main C file. This implementation methodology coupled with the ability to discuss problems with NASA scientists directly, allowed the STRATA-1 embedded software to meet all NASA’s requirements.

Current Status Update

To date, three STRATA-1 electronics boxes have been fabricated. Two of these (Flight and Ground) have been transferred to the NASA-ARES scientists. Both systems have undergone rigorous testing to validate correct operation over long periods of time and expected interaction with mission specialists once onboard the ISS. A third unit has been maintained by the ESET-MISL group for use in special testing or verification processes. This unit has paid dividends in providing the MISL team with a fully functioning unit that is identical to the Flight and Ground units maintained by NASA. An example of this value came when testing following delivery of the two units indicated that the design exceeded allowable levels in the Electromagnetic Compatibility (EMC). EMC deals with the unintentional generation, propagation and reception of electromagnetic energy which may cause unwanted effects such as electromagnetic interference (EMI) or even physical damage in operational equipment.

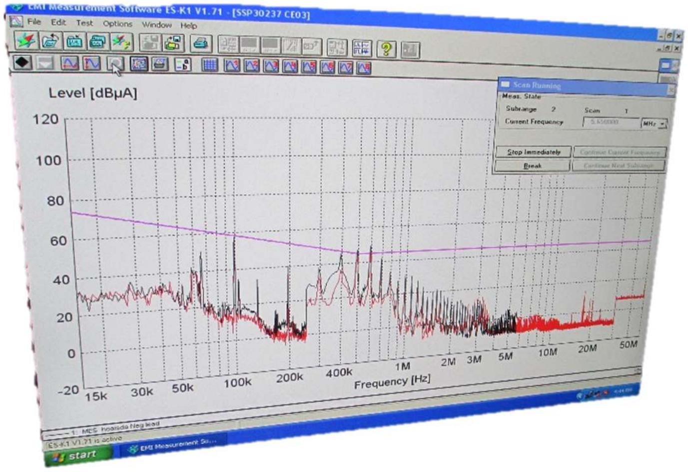

Figure 5. EMC Chart for STRATA-1.

Working with NASA engineers, T STAR and MISL was able to implement a solution to this unwanted interference. Once implemented, MISL students were able to evaluate the impact of the solution. As depicted in Figure 7, the requisite attenuation of the interference from 100 KHz to 600 KHz of the switching DC-DC converters was obtained. The team quickly modified the Flight and Ground units in time for re-certification testing to be performed. The Flight unit has been turned over to the ISS Payload Management team and is scheduled to be launched in March for transfer to the ISS to begin its one-year operation. Although the flight had been scheduled for an earlier date, the STRATA-1 experiment was delayed due to the explosion of SpaceX-9 Falcon rocket shortly after launch from Cape Kennedy.

The two ESET students responsible for the hardware and software design have been invited by the STRATA-1 scientists to the Mission Readiness Room at NASA-JSC when the STRATA-1 experiment is finally mounted on the Express Rack onboard the ISS and is prepared for power-up and operation. Accomplishments and recognition such as this will be long-remembered by the ESET undergraduate students who took on the challenge.

Lessons Learned

Through the past few years of supporting business in their product development initiatives, the ESET faculty have learned multiple lessons. Easily the most significant lesson is the value of these experiences to the educational mission of the ESET program. As stated previously, these product development opportunities are a win-win-win for students, faculty and the external partners. First, faculty have a requirement for maintaining active research programs and, in the engineering technology community, these programs are often focused on industry funding and applied research. Product development projects are an excellent foundation upon which to build these types of research programs.

However, it should be noted that this brings with it the unique challenge of finding a workforce that can support real-world projects and hands-on system development. One possible source for this workforce is graduate students. However, because Engineering Technology at Texas A&M University does not have a graduate program, these students would have to be hired from the other more traditional engineering programs and this poses two significant issues. First, graduate students from other programs are focused on the research they need to perform for their graduate advisor and thus there is no intrinsic motivation to support engineering technology projects. Second, their education is often more theoretical and they do not possess good hands-on skills. Fortunately, it has been repeatedly demonstrated that ESET undergraduate students can and do provide this workforce effectively providing the second "win."

Through the support of real-world, funded applied research experiences, ESET undergraduates augment their classroom learning through customer-based product and system development challenges both as part of their curriculum and as extra-curricular activities. Through course and capstone projects, the students work in teams on projects that go beyond simply learning theory and expose them to industry best practices. Also, many students continue their learning outside of the classroom by participating in paid opportunities supported through faculty research programs. Not only are they augmenting their skills, the opportunity to get paid often allows a student who has to work to support their college education to do so in an environment that adds to rather that distracts from their education. Finally, the opportunity to work on a next-generation product for a real customer with the idea that the work may find its way into the commercial sector is extremely motivational to most students and helps drive their learning appetite.

In addition, the ESET Program has found that students who are engaged in applied research projects tend to leverage these experiences in their involvement in other activities. Generally, students working on real-world projects are the first to volunteer to interact with visitors to the program and department. These visitors span a wide range from industry leaders to high school students wanting to know more about the ESET Program and its experiential education opportunities. Impromptu presentations and demonstrations build confidence and provide the students with opportunities to professionally communicate their work concisely and succinctly. In many cases, such as this, the students involved in the applied research will also generate and submit papers to national and regional conference on their own or with their faculty advisor and mentors. These types of validated communications skills continue to increase in importance to many small and large companies hiring entry-level engineers. Finally, applied research involvement provides these students with unparalleled challenges for innovation and "out of the box thinking" not readily found in a typical classroom or educational laboratory setting. These experiences provide ESET students with a high degree of confidence that carries over in all they do. An example of these experiences was captured in a video[5] that was produced by the Dwight Look College of Engineering and an associated article published in the Engineering Newsletter[6]. The video includes interviews with the NASA scientist, T STAR CEO and two of the three students involved in the system design, development, documentation and delivery of the STRATA-1 experiment now ready for deployment to the International Space Station.

The third win is for industry and the external partners. Quite often, small companies lack the internal support for new product development and large companies lack the manpower to support all of the opportunities they would like to pursue. Having the ESET program as a cost-effective resource allows these partners to investigate avenues they might not otherwise be able to pursue. In addition, supporting local and regional industry both with qualified graduates as well as with technical expertise is an important part of the engineering technology mission.

Another lesson learned are the pros and cons of creating and maintain multi-partner relationships. Over the past several years the ESET program has developed processes for managing issues associated with funding, workforce continuity and intellectual property. In terms of funding, the program typically supports industry through two mechanisms, gifts/grants and service contracts. When using capstone and course projects to support external partners, the primary vehicle for funding is through gifts and unrestricted grants. Thus, no deliverables are associated with the project and expectations are set up, at the beginning of the project, which clearly articulate that all funding is to support education. However, the customer is given access to the "know-how" generated by the students. This also begs the question of intellectual property. Because the University's stance is that all intellectual property created by students as part of a course belongs to them, the ESET programs requires that the students and their customer develop an IP agreement between all stakeholders before the start of the project.

In the case of work performed through faculty research programs, funding and intellectual property is usually handled through more traditional university contracting vehicles. It should be noted that while some faculty pursue a typical deliverables-based contract, more often faculty chose to set up the work as a technical services contract. This lowers the cost to the customer and often avoids the lengthy process of intellectual property negotiation. Finally, because undergraduates often provide the workforce for faculty research, workforce turn-over is often an issue. For this reason, most faculty have developed a hierarchical structure in their labs that fosters the transition of knowledge between senior-level and more junior-level students.

The final lesson learned is in the area of documenting requirements and specifications. As with any customer/client relationship, it is important to create and maintain a strong communications channel. For this reason, ESET students learn quality-function deployment (QFD) and voice-of-the-customer (VOC) concepts as part of their curriculum. They then use these concepts to determine customer root wants, product requirements, and design specifications. These are then documented and shared with the customer repeatedly during the projects durations. This ensures that the final product meets the customer's needs and that there are no "surprises" upon delivery of the final prototype.

Conclusions and Recommendations

STRATA-1 has been a highly successful project that demonstrates the impact that academia and undergraduate students can have on external customers. Specifically, it shows that:

- An academic research program can meet deadlines necessary when interacting with industrial and public sector customers.
- Faculty-led research programs can produce high-quality progress that meets demanding customer specifications (in this case, products of sufficient quality to fly on space-based missions).
- Undergraduate students have the skills and capability to create professional products and systems for demanding customer applications.
- Participation in external customer-driven projects can generate significant value to undergraduate education.

In addition, not only has the STRATA-1 project provided significant benefits to the ESET program, startup company T STAR, and NASA, because of the unique qualities of the project, it has also provided a high level of visibility for the ESET program within the College of Engineering and the University. Multiple news articles have already been released by NASA and the College on STRATA-1, a video interviewing all team members has been produced, and it is anticipated that once the project flies to the International Space Station, the ESET program will benefit from a second wave of coverage. Projects such as this tout the unique aspects of engineering technology and demonstrate the hands-on and industry-focused nature its programs.

In terms of future work, the ESET program has already demonstrated that a long-term partnership with public and private sector customers can lead to increasing levels of interactions. The goal of the program is to convert many of the "one-of" projects that have been done for past customers to similar relationships as with NASA. It is anticipated that more long-term partnerships will provide continuity to both the research and educational aspects of providing product development support to industry. In fact, this model has recently led to a long-term public-private-academic commercialization partnership that ESET will co-develop, integrate into education, and establish an open-community environment. Experiential education that includes undergraduates fully engaged in the design, development, documentation, and delivery of real prototypes, product, and systems comes at high costs, but the value it adds to entry-level graduates' capabilities to hit-the-ground-running far exceeds the investment.

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