ELECOMP CAPSTONE SUMMIT
FRIDAY, MAY 10, 2019

Celebrating 12 Years of Excellence 2008 – 2019

THE UNIVERSITY OF RHODE ISLAND
COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL, COMPUTER AND BIOMEDICAL ENGINEERING
ELECOMP CAPSTONE 2018-2019
URI Class of 2019

URI CLASS OF 2019
GROUP I
SPONSORING COMPANIES

AVTECH
GENERAL DYNAMICS
Electric Boat

FAR SOUNDER
Acumentrics
BOSCH
Thermotechnology

URI CLASS OF 2019
GROUP II
SPONSORING COMPANIES

ON Semiconductor
PISON
Taco Comfort Solutions
PEC
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Welcome: It gives me great pleasure to welcome you all to the Annual Summit of the ELECOMP Capstone Design Program. This year we are celebrating 12 Years of Excellence in Capstone Design for Electrical (ELE) & Computer (COMP) engineers. Our Program partners senior engineering students with industry sponsors to design, build, program and test solutions to real-world problems. We are excited to present 22 projects, by 52 seniors, after working on their projects for 2-semesters. I have allocated 7 min./project for the oral “rocket” presentations. The depth and breadth of work in these projects is outstanding and I hope it will inspire you all to sponsor challenging, and innovative, capstone projects during the next academic year.

Capstone Bridge: The ELECOMP Capstone Bridge mirrors the well-known Wheatstone Bridge extremely well; see the back cover. All facets of our Program, together with our talented seniors, with diverse skills, form the two known arms of the bridge. The third known arm is the sponsoring company, their Technical Directors and the problem to be solved. Only when these three arms are in perfect balance, and collaborate in excellent harmony, success is achieved in the unknown arm: The Anticipated Best Outcome of the Sponsor’s problem. The economic impact for all the sponsors will run into many millions of dollars!

Together with all my senior capstone designers, I would like to thank sincerely the 20 companies who became the third arms this year; 10 are first time sponsors! Without their generous support, it would be impossible to execute on all the facets of the program. Special thanks to all the Technical Directors for their time and efforts in mentoring the teams. I look forward to your continued support next year. THANK YOU.

Consulting Technical Directors: Sincere thanks to Mike Smith, Jeremy Peacock, Alex DePetrillo and Brenden Smerbeck for consulting on many projects. Their expertise helped the teams make significant progress during the capstone work session on Tuesday evenings.

“Before you are a leader, success is all about growing yourself. When you become a leader, success is all about growing others.”
– Jack Welch
former CEO of General Electric
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| 7:00 – 8:40 am   | • Breakfast<br>• Registration<br>• **Viewing of Capstone Project Posters**<br *
|                  | *Location: Higgins Welcome Center: Hope Room and Anchor Rooms*      |
| 8:50 – 9:00 am   | **Welcome**<br>Professor Harish Sunak, Capstone Program Director<br> *Location: Swan Hall Auditorium* |
| 9:00 – 10:27 am  | **Rocket Presentations I** (11 teams)<br> *Location: Swan Hall Auditorium* |
| 10:27 – 10:45 am | **Break**                                                            |
| 10:45 – 12:12 pm | **Rocket Presentations II** (11 Teams)<br> *Location: Swan Hall Auditorium* |
| 12:15 – 1:15 pm  | **Lunch**<br> *Location: Higgins Welcome Center, Hope Room*          |
| 1:15 – 2:00 pm   | **Poster Session & Demonstrations**<br> *Location: Higgins Welcome Center, Hope & Anchor Rooms* |
| 2:00 pm          | **Announcement of Top 5 Teams**<br> *Location: Higgins Welcome Center, Hope Room* |
| 2:00 – 2:45 pm   | **Reception & Videos**<br> *Location: Higgins Welcome Center, Anchor Room* |

**SAVE THE DATE!**

**ELECOMP CAPSTONE SYMPOSIUM**<br>**FRIDAY, DECEMBER 20, 2019**
ROCKET PRESENTATIONS
ELECOMP Capstone Design Program
Schedule of “Rocket” Presentations
Swan Hall Auditorium

Rocket Presentations I

9:00 – 9:07 am  Acumentrics, Inc.
9:08 – 9:15 am  AVTECH Software, Inc.
9:16 – 9:23 am  Bosch Thermotechnology Corporation
9:24 – 9:31 am  Cambridge Technology
9:32 – 9:39 am  eMoney Advisor LLC
9:40 – 9:47 am  FarSounder, Inc.
9:48 – 9:55 am  FM Approvals
9:56 – 10:03 am General Dynamics Electric Boat
10:04 – 10:11 am Hasbro
10:12 – 10:19 am Hexagon Manufacturing Intelligence
10:20 – 10:27 am IGT Global Solutions Corporation
10:27 – 10:45 am BREAK

Rocket Presentations II

10:45 – 10:52 am  Infineon Technologies Americas Corp.
10:53 – 11:00 am  Iradion AutoLase II
11:01 – 11:08 am  Iradion LASIMO
11:09 – 11:16 am  ON Semiconductor Bench Auto
11:17 – 11:24 am  ON Semiconductor SMPS
11:25 – 11:32 am  Phoenix Electric Corporation
11:33 – 11:40 am  Pison Technology Inc.
11:41 – 11:48 am  Raytheon
11:49 – 11:56 am  SES America
11:57 am – 12:04 pm Supfina Machine Company, Inc.
12:05 – 12:12 pm TACO Comfort Solutions
GRADUATES FROM OUR ECBE DEPARTMENT

Brenden Smerbeck (ELECOMP Capstone 2017) Acumentrics Inc. 2nd year TD
Mike Caneja (ELECOMP Capstone 2015) Bosch Thermotech. 2nd year TD
Alex DePetrillo (ELECOMP Capstone 2018) Consulting TD
Tyler Creighton (ELECOMP Capstone 2018) Consulting TD
Domenic Ferri (ELECOMP Capstone 2018) Consulting TD
David Cippoletta (ELECOMP Capstone 2014) Pison Technology
David Dionisopoulos (ELECOMP Capstone 2011) Supfina Machine
Kevin Toth (ELECOMP Capstone 2010) ON Semiconductor
Jeremy Peacock (ELECOMP Capstone; Double Major Expected 2020) Consulting TD

Sandro Silva (2002) PEC 3rd year TD
Mike Smith (2001) 3rd year Consulting TD
Robert Davis (1997) Infineon 2nd year TD
Mark Rodrigues (2010) Infineon 2nd year TD
Sam Karnes (2017) Pison Technology
Matthew Coolidge (2001) FarSounder
Amir Habboosh (1998) Raytheon
Robert Davis (2019) ON Semiconductor
GRADUATES OF OTHER URI DEPARTMENTS

Jonathan O’Hare (1994) Hexagon 3rd year TD
Christopher Kyes (2014) Taco Comfort 2nd Year TD
Jefferson Wright (2014) GD Electric Boat
Mike Kowalczyk (2009) Pison Technology

GRADUATES OF OTHER UNIVERSITIES

Peter Upczak Acumentrics 3rd year TD
Michael Mielke Iradium Laser 2nd year TD
David Connolly SES America 2nd year TD
Darryl Galipeau Infineon Tech. 2nd year TD
Phil Manning Taco Comfort 2nd year TD
Daniel Jaquez eMoney Advisor 2nd year TD
Tom Vrankar Raytheon 2nd year TD
Jerry Huson Bosch Thermotech 2nd year TD
Richard Grundy AVTECH Software
Sarathy Palaykar Bosch Thermotech
Roger Boydstun Bosch Thermotech
Seetharam Sivam Cambridge Technology
Mark Lucas Cambridge Technology
Gary Jutras eMoney Advisor
David Waite FM Approvals
Aaron Cunha FM Approvals
Yan Sun GD Electric Boat
James Brown Hasbro
Robert Corvese IGT Global Solutions
Philippe Quarmeau ON Semiconductor
Alain Laprade ON Semiconductor
Aakash Arora ON Semiconductor
Sidhant Srikumar Pison Technology
Nicholas Costello Taco Comfort
Bob Kellicker Taco Comfort
Adam Card Consulting TD

Thank You Technical Directors for your support and mentoring engineers of the future!

You are an important component of The ELECOMP Capstone Bridge: see the back cover
Project Motivation:

Mobile technology is one of the largest growing markets in today’s world. In order for these devices to be viable to consumers, it is necessary that batteries within these devices are not only powerful, but more importantly; safe. Smart batteries include many features, with their primary function as keeping the battery’s cells and the user safe during all stages of operation. As a result of these protection methods, smart batteries are less prone to hazardous conditions and thus more likely to outlast other types of batteries. This benefit has numerous applications in the automotive, medical, and government industries. Another advantage of typical battery management systems is the ability for the user to request different messages, such as voltage level, cycle count, and manufacture date, from the battery. From the vital battery information in these messages, it is possible for a user to observe the status of the battery and plan for maintenance or replacement of poorly-performing batteries. This need for safety is the project motivation for Team Acumentrics.

Anticipated Best Outcome:

The Anticipated Best Outcome for Team Acumentrics was to create a functional battery management system that can convert a regular rechargeable Lithium-Ion battery to a smart battery. The system is designed to protect the battery’s cells from potential hazardous conditions, such as overvoltage, undervoltage, and overcurrent states. When any of these conditions are detected at the analog front end, the circuits quickly cut off the input or output from the rest of the system to prevent damage. Additionally, the BMS must implement SMBus communication, and conform to standard smart battery specifications. This allows users to read characteristics of the battery such as remaining capacity, cycle count, and estimated time to empty.

Implications for Company and Economic Impact:

Smart batteries are an essential part of everyday life. Current battery management systems (BMS) are priced due to demand and the lack of competition. Because users are highly dependent on precise estimated runtime calculations and fast charging times, production companies can set the price high. If Acumentrics creates its own BMS, it will give the company two advantages. The first advantage is the possibility to implement their own BMS into their already existing products. This would save production cost and increase the product profit margin. The second advantage Acumentrics could benefit from is to enter the BMS market themselves. By selling this low-cost and high efficiency AcuBMS system on its own, they would have a competitive edge on price over the competitors.
PROJECT OUTCOME::

The Anticipated Best Outcome was not achieved.

KEY ACCOMPLISHMENTS:

**Microcontroller Programming:** The MSP430FR5969 microcontroller in the AcuBMS utilizes the timers and interrupt service routines (ISR) to sample from the built in analog-digital-converter. Programming these features requires knowledge of the relationship between the MCU hardware and register programming.

**Smart Battery Specification:** The MCU is programmed to conform to the Smart Battery Specification 1.1 (SBS 1.1). The SBS 1.1 is a standard guide that defines the relationship between a Smart Battery and other devices. This specification includes details on the communication protocol used to communicate to the product and the battery data that can be transmitted from the Smart Battery.

**ADC Sampling & Finite State Machine:** The internal analog-to-digital (ADC) convertor on the MSP430 has been programmed to convert signals from multiple channels (see in Figure 1). The timer and ISR of the MCU work together as parts of the finite state machine (see Figure 2) to trigger ADC interrupt. Within this interrupt, the ADC samples from each channel and stores the signals into memory. The signals are converted into current, voltage, and temperature values respectively. The SBS 1.1 battery messages are calculated using these three values, and then stored into memory. This entire process runs at a fixed rate of 10 Hz.

**SMBus Implementation:** The System Management Bus (SMBus protocol) is used to communicate the stored data between a smart battery and a host device. This protocol allows a user to access the battery data at any time. The MSP430 is programmed as a slave device such that is continuously waits for a master to initiate communication. When the master requests data from the slave, the ADC sampling process is interrupted to access a data register corresponding with the request. The slave then transmits this data to the master.

**Circuits Simulations:** Using National Instruments’ Multisim simulation software, we created our sub-circuits and a total system simulation. In order to protect our battery from reaching voltage levels that are too low or too high we created an Under-Voltage Circuit, a minimum Under Voltage Circuit and an Over-Voltage Circuit. Also, in order to limit the current draw and charge current we designed a Bidirectional Current Sense Circuit. These circuits completes our AcuBMS Analog Front End (AFE) protection. Each subcircuit was designed and simulated individually to verify proper functionality. The circuits were then combined into a full system simulation (see Figure 3). The simulations verified our concept and compatibility between the different subcircuits.

**Circuit Schematic for PCB Fabrication:** The battery management system was designed in Eagle schematic software and then fabricated a printed circuit board (PCB) composed of the selected components (see Figure 4). The AFE sub circuits are supplied with battery power or a charger input, therefore functioning independently of the MCU’s power. This design prevents dangerous voltage/current levels from reaching the more sensitive components in the system. After the transition from simulations to real-world board design, the team had to consider the importance and relevance of industry-standard components that would be compatible with the voltage and current levels in the board.

**Hardware and Software Integration:** Upon completion of the PCB, the microcontroller was flashed over JTAG. This uploads all instructions to the MCU to ensure proper operation with the rest of the system.
Fig. 1: Multi-Channel sampling using MSP430FR5969's analog to digital converters

Fig. 2: Finite State Machine of the AcuBMS as programmed on the MSP430
Fig. 3: Block diagram of Battery Management System

Fig. 4: Fully assembled prototype.
PROJECT MOTIVATION:
Room Alert provides business continuity by notifying staff if environment extremes threaten their computers, facilities and other assets. Thirty percent (30%) of unexpected downtime for a small to mid-sized business is caused by environmental factors. In the USA alone, that means that millions of businesses are impacted every year. Room Alert helps to monitor, alert, and ultimately prevent this downtime. Dust and other airborne particulates can have a significant impact on other environmental conditions and a facility as a whole. Not only can high levels of particulates impact workers’ health, but it can also cause premature wear on equipment, rapid filter clogs, and can even indicate that smoke or smoldering materials are present. Adding an intelligent particulate sensor that can detect that particulates are present will add significant value to Room Alert users and will provide new insights that could help reduce downtime and equipment damage.

ANTICIPATED BEST OUTCOME:
The anticipated best outcome is a fully-functional engineering prototype; composed of an electrical schematic, circuit board design, and a bill of materials that can be used to manufacture the product. All components and design choices should consider the eventual CE & FCC certification desired for this product. The sensor will be averaging data over time therefore sudden peaks will not be set off Room Alert. A mechanical enclosure design should also be included, and ideally would be tested with multiple variations that optimize airflow and particulate detection.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
One of the world’s largest retailers has expressed specific interest in deploying a sensor like this in their warehouses and distribution facilities worldwide. This would likely require several thousand to tens of thousands of sensors depending on how many are required for each facility. At an estimated list price of $145, this alone can represent significant revenue opportunity.
**PROJECT OUTCOME:**

The Anticipated Best Outcome was achieved.

**KEY ACCOMPLISHMENTS:**

**Learning C through hardware development:** Upon research, we will work with a PIC chip which includes using MPLab, a software tool to code and debug hardware components in C or in Assembly. A rough coding stretch has been made and with I/O pin adjustments. With testing the pins, it was a success that it is receiving/transmitting data. Now with utilizing UART (Universal Asynchronous Receiver/Transmitter), the next step is to see the values through an output console whether to adjust the code to its purpose.

**Importing programming codes to a PIC Chip:** A similar format of coding as we did for Arduino and Python; means it should not be as a problem to have the same idea of coding. The initial process on transmitting the hex file to the PIC Chip memory in order to function on its own without any code application to run for it is the next step after the code is functional.

**Arduino plot set to see data values in a graph:** Using Arduino to see the plot that shows an increase or decay of data. We can visually see if any of the substances used (smoke, mist, other particles) to make the sensor react no matter how high or low the substance is. Also, we were trying to implement a real-time graph through Python using Matplotlib.

**Finalizing MPLAB coding algorithm for PIC Chip:** Having been exposed to C, we now have a clear vision on how we want the PIC Chip to perform and with some other features such as smoothing, calculating voltage, and subtracting anything that hinders its signal data transmission. Using the Logic Analyzer, we can see the DAC (Digital to Analog Converter) output voltage to see if everything is in place. Therefore, we can modify the code or research on how to regulate what we want in the project. After all the long hours of researching with trials and errors, the code ran successfully along with the implementation on the PCB. Now the rest is on creating a case for our PCB and our prototype on the project will be complete.

**Created Schematic and PCB layout:** The schematic was created on DipTrace. We created all the parts in the programmer to fit the size and specifications needed for our final product. The next step was to convert it into a PCB, which DipTrace can also do. The components are all laid out perfectly on an existing board size Avtech wishes to use. We made mounting holes for our blower to be stabilized to the board and then the sensor will sit on top of it.

**Testing and Housing units:** Large Bins filled with dust and particulate were used for simulating a warehouse environment. The sensors and fans/blowers were placed inside and could record back very accurate data which help finalize the sensor selection. Next, a housing was created and put through the same testing, the results were just as efficient which helped prove that when packaged up everything was still going to work well.

**Housing for the product:** The housing for the final product will be based off an already existing unit that Avtech has. As of now, all are parts fit perfectly in the base of the housing but more holes and a taller cap will need to be made. A theoretical housing is in existences, with proper mounting holes and a general idea of the housing. The final enclosure is shown in Fig. 4.
**Fig. 1:** PIC chip flow chart schematic plan to operate when programming

**Fig. 2:** System block diagram for the hardware, PIC chip and Room Alert
Fig.3: Output voltage test from PIC chip, displaying before and after

Fig.4: Final enclosure with sensor and blower
PROJECT MOTIVATION:
Bosch products have the reputation of having the best products in the industry. The durability of these products have become more predicated on the complexity of their components and the software that drives them. As a result, engineers face more challenges during the early stages of testing. This is the motivation for this project, which is to develop a system that will monitor, analyze, and simulate data failures in HVAC systems. The architecture includes a control box that inputs customized data directly into the HVAC unit which can then monitor, store, and relay that data to a graphical user interface. This would allow for monitoring possible failures and would ensure the quality of their products remotely, with minimal physical interaction. This design would contribute to improving the reliability and life expectancy of Bosch products.

ANTICIPATED BEST OUTCOME:
The Anticipated Best Outcome is to design a modular platform capable of monitoring HVAC systems as well as simulating test scenarios. This platform should include an array of sensors for monitoring current operating conditions within the HVAC. A user shall be able to manipulate the various component signals through a control box that can be interfaced with any of Bosch’s current HVAC systems. A user can choose to connect to the system to view and store signals and data. This data can then be viewed at a later time to check for any errors or failures encountered during a simulation.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
The overall impact of this project would give Bosch another major advantage within the market and allow them to design products with even greater reliability. The desire to develop durable products is one of their main goals, and successful completion of this project would improve on those needs. This unique design would enhance portability, which allows ease of use in their testing facilities and would expedite testing. Along with being a cost effective measure, ultimately leading to higher customer satisfaction rates, this design would benefit the company and their consumers in the future.
PROJECT OUTCOME:

The Anticipated Best Outcome was achieved; all major goals were met and the system is ready for deployment in the field.

KEY ACCOMPLISHMENTS:

**Improved Design:** Created a detailed schematic for all of the existing sensor wiring (thermostat controls, PCB, and breadboard connections) for the conditions of improvement and functionality. Secured and fastened existing circuitry and hardware.

**HVAC System Components:** Researched the working parts of the Inverter Ducted Split Unit, which was critical for the component placement and control wiring between the units. The design will allow for the ease of interconnection between both units with bulk connectors that have the means of connecting or disconnecting all low voltage controls without handling any of the internal connections. This will also allow for an easier means for testing the Hammond Board on the HVAC unit with the use of banana cords.

**Control Wiring:** Upgraded the wiring by removal and replacement of the existing low voltage conductors between both units. Installed the new conductors within a raceway and increased the wire gauge to meet or exceed the minimum requirements set by UL and NEC electrical standards.

**PCB Design for CB1:** Developed a printed circuit board along with the components that were needed to be incorporated inside the Hammond Board. This PCB design will ensure a more stable connection with all of the components, while also ensuring the portability feature of the prototype. This PCB was updated in a new version to add additional features like a real-time clock and additional I/O's. (Figure 1)

**Hammond Box:** Fabricated a portable testing prototype that can be portable and able to run failure simulation for data analysis. This design is capable of being installed between the thermostat and the HVAC unit through a set of banana outlets for connections. This prototype also has three-position switches installed next to the individual controls that it is running on the equipment. Each switch can be set to be manually off, manually on, or on through thermostat control. Also installed on the cover, there is an additional override switch that can turn all of the controls off or on manually to override the thermostat. (Figure 2)

**User-Controlled Inputs:** Developed a portion of the design for having multiple relays, with their individual 5VDC and 24VAC coils, that will work in conjunction with multiple I/Os from the PCB’s and for the compatibility within the overall area inside the Hammond Box. By incorporating those relays to work with the SPDT switches and the individual thermostat controls on the cover, this will allow for ideally simulating single and/or multiple equipment failures. (Figure 3)

**Data Monitoring Architecture (CB2):** As the second major task, CB2 was designed to allow for monitoring of the system while running simulations. This system can be interfaced with CB1 so data can be viewed while running a simulation.

**Sensor Array Design:** CB2 features a sensor array consisting of thermistors, current sensors, and voltage sensors to monitor the components for problems. These sensors interface with a microcontroller to record the data.

**PCB for CB2:** Custom printed circuit board designed to house circuitry for multiple sensors connected to CB2. This includes up to five thermistors, four voltage sensors, and four current sensors. (Figure 4)

**CB2 Microcontroller:** Like CB1, CB2 also uses an Arduino Mega 2560 to monitor the system. The voltages from the sensor needed to be converted from 0 to 5V to a readable temperature, current, and voltage value. The signals are also sent through a serial port.

**GUI Design:** A graphical user interface was created to allow a user to view signals by simply connecting a USB cable into the control box. This way, failures can be diagnosed nearly immediately.
Fig.1: CB1 Inner Circuit Board and Microcontroller

Fig.2: Outer Cover of the Simulation Platform (CB1)
Fig. 3: Final System Architecture of CB1 and CB2

Fig. 4: PCB Housing Circuitry for the Sensors of CB2
Stepper Motor Motion Control for Scan System

Cambridge Technology manufactures Galvo based laser scanners which allow for easy laser control. The ScanMaster Controller (SMC) is a proprietary hardware system used for generating programmable control signals which can interface with many common lasers. The controller also can be integrated with the customer’s own software application or can be commanded through Cambridge Technology’s ScanMaster Designer (SMD) software. The purpose of this project is to add to the robustness of the SMC by integrating the ability to control external microstep motors. When a scanning head is mounted above the target plane, there does not currently exist any native way to expand or adjust the region that is “scannable” by that device. Without exerting extra effort to move the target surface, the customer’s designs are restricted to a fixed area. By introducing one or multiple stepper motors to the system, the customer will have the ability to dynamically change the area in which they can etch or drill their designs by moving the actual scanning head directly from the SMD and SMC.

ANTICIPATED BEST OUTCOME:

As per the original specification of the project, the Anticipated Best Outcome was to deliver a platform, embedded within the SMC’s dual-core Xilinx Zynq FPGA+ARM Cortex-A9 Processor environment, that manages the hardware and software interconnect to control a step-and-direction motor along a linear slide using precise motion control. The overall system should have maximized the operation of three integral facets: the FPGA logic necessary for step/direction pulse delivery, an intelligent software API for generating motion profiles and interfacing with the hardware fabric, and a demonstrated integration into the full Scan System product.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:

The addition of motor driving capabilities from the SMC will greatly expand the application space of Cambridge Technology’s Galvo based laser scanner solutions. It will allow for scanning systems to have a dynamic working range and be less limited by its stationary XY plane. Naturally, this imbues the product with more value to customers, and it will expand the potential market for the product because of the newfound ability to handle a wider breadth of issues faced by production companies and OEMs. A rough estimate for the impact of this feature on the revenue of the company is in the range of $250k - $500k from additional sales.
PROJECT OUTCOME:
The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Custom Logic Implementation: A black-box custom logic module for motion control has been successfully integrated into the SMC’s main logic element. We have also added writing support for the previously unused stepper motor ports on the SMC’s official I/O header, establishing a gateway to the outside world.

Step and Direction Pulsing via SMC: Established and tested the ability to generate pulse streams in the logic and drive an external stepper motor with those signals in either direction. Full control of the linear slide/cart from the ScanMaster Controller FPGA logic has been accomplished by parameterizing the different variables needed to translate distance into the necessary number of step pulses. These variables are further utilized when attempting to control the motor via the CPU cores.

Motion Profiling Algorithms: Developed rapid mathematical algorithms for generating velocity slopes based on settable acceleration parameters. We have written scripts to simulate our algorithms ahead of time, allowing us to know how a move will behave before even powering on the board. Fig. 1 shows two examples of graphs generated by our algorithms when passed through our simulator.

The Motion Control Software: We have implemented the motion profiling and translation algorithms in C++ and provided an API for setting move parameters from upper layers. All parameters necessary to describe a motion control environment are encapsulated inside of a custom software structure - therefore multiple motion axes are readily supported in the future. From the ScanMaster Designer, our underlying software is easily actuated via the program shown in Fig. 2.

The Motion Control Hardware: Developed a robust pulse delivery hardware system which communicates with the control software via the AXI interface. The software sends the period and pulse count commands into a FIFO from which our stepper state machine requests the 32 bit command that tells the motor how fast and how far to move. The state machine then provides the necessary parameters for motion to the pulse delivery servicer. The servicer, as its name implies, delivers the necessary number of pulses to the external step port at the commanded frequency. The speed of pulse delivery is managed by the pulse edge timer which signals the pulse delivery servicer when to toggle the step signal.

Motion Profile and Control Register Command Formats: We defined two completely custom command formats, depicted in Fig. 3, to interface directly with our hardware from any software application. The Motion Control Software has been specifically designed to translate the mathematical motion profile into a set of motion profile commands that follow the above standard and send them off to the FPGA fabric. Similarly, the software utilizes the control register command format to perform administrative interfacing with the hardware on an auxiliary, 2-way communication channel.

Integration into the Full System: As per the Anticipated Best Outcome of the project, the Motion Control Software and the Motion Control Hardware have been successfully ported into the full ScanMaster Controller. This means that the customer is able to configure a motion control axis to their particular environment and send move commands directly from Cambridge Technology’s ScanMaster Designer GUI. See Fig. 4 for the flow of information produced as a result of this project.

Robustness and Quality Checking: Performed extensive testing of the hardware and software under a variety of edge cases and operating conditions to make the framework more robust (improper command handling, maximum speed and acceleration testing, extended runtime stability, etc.). Several adjustments, performance optimizations, and bugs were identified and taken care of.
Fig. 1: The simulated results of our motion profiling algorithms. The programmer has control over how quickly the motor accelerates the platform. When 70% of the move is specified to be at constant velocity (left), the slope is quite steep, and the acceleration is high. When 30% (right) is commanded, the slope is noticeably less dramatic.

Fig. 2: Controlling our stepper motors and linear slide using Cambridge Technology’s proprietary ScanMaster Designer graphical user interface. The following 2 lines of commands in the SMD are all that is needed to set up and activate the underlying Motion Control Hardware and Motion Control Software:

```
Motion.Config(<axis>, <pitch>, <slide length>, <steps per rev>)
Motion.MoveRelative(<axis>, <distance>, <direction>, <velocity>)
```
Fig. 3: Our designs for command formats. The motion profile command format (top) allows for precise control over the velocity, acceleration, and distance of each movement command. The control register command format (bottom) was implemented for easy communication between the software and the state machine core of the hardware.

Fig. 4: A visual representation of the flow of control for our stepper motor positioning system under user input.
Application Deployment Tracking System

PROJECT MOTIVATION:
Successful web applications are built around the concept of continuous integration; the ability to modify existing features and add new features on-the-fly. Using a system that tracks the status of these changes is imperative to getting them in the hands of customers quicker. During a release of updated software there are several steps that require the input of many team members. This is because communicating what exactly needs to be accomplished in a coherent way is not trivial, which can result in delays on the completion of tasks. Delays in releasing have an impact on the ability of a company to react. Reaction time, given the right circumstances, can be costly. The main motivation for this project is to create a web application that would help to reduce the release cycle time of releasing updates to an application and therefore reduce the reaction time for the company.

ANTICIPATED BEST OUTCOME:
The best anticipated outcome is to develop a web application that displays build information. The data will be received from a server, which contains the build number, the status, start time, end time and the overall duration of the build. This information will be presented to the users, as a Gantt Chart. The chart illustrates the time schedule of each build and has it displayed as a type of bar chart. With the Gantt Chart highlighting the duration of each build, this will help project members plan accordingly depending on what has to be achieved.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
With the addition of build tracking software, employees will be better able to focus their efforts on development as what they have to accomplish will be clearly organized and communicated to them. The economic impact is expressed in the amount of time saved when searching for information about the build. The following formula is an approximation of the cost savings. If S is the average salary of the employee, and T is the average time that the employee spends looking for information then:

\[
\text{Approximate Hourly Wage Equivalent (H) } = \left( \frac{S}{50 \text{ weeks}} \right) / 40 \text{ Hours}
\]

\[
\text{Economic Impact } = H \times T
\]
PROJECT OUTCOME:
The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Research and Implementation of Test Driven Development: To avoid having complex classes that involve using several overly complicated methods, following the Test Driven Development process will help reduce the amount of time fixing the code and prevent not being able to follow what the class does. The cycle will start with creating a test, run the tests so that it fails, and write code until it passes the tests. This also helps keep the classes simple and easier to manage.

Research on Dependency Injection: eMoney Advisor has certain coding standards that we needed to follow throughout developing the application. One of the biggest coding standards that we have been exposed to was dependency injection. Dependency injection is a technique whereby one object (or static method) supplies the dependencies of another object. In other words, dependency injection is like the middleman that separates two objects from each other in order to make them independent.

Displayed Build Data using React and Pagination: Using the information from the mock server, we needed to display that data onto a table. Since there was already code that gets the data from the server, using React, we then placed it all onto a table. The data that was displayed, included the status, build number, duration, start time, and end time. To make sure only 20 builds were being displayed at a time, a pagination class would keep track of what was displayed and only 20 builds would be shown at a time.

Displaying build information as Gantt Chart: After being able to display build information in the form of a table, the final step is the transfer that data onto a gantt chart. With the gantt chart, it would help visually show the overall status of a build, which can help project members plan according to what the current status of the build is. To do this, we used Google React Charts to display the primary build details.

Attempted to Finish JumpCloud Login Configuration: In the beginning of the semester, login functionality for our application seemed to work on one of our base applications but not on the other. The other base application is where we wanted to be able to login but was not possible. We then attempted to figure out what the problem was, but could not due to the fact that the SustainSys package library we were using seemed to be incomplete.

Fetched Basic and Detailed Data From a Multiple Mock API Endpoint: We implemented the retrieval of data that we wanted using RestSharp and mock API endpoints. These were created using Postman, an API development environment. Once the application receives the data, it is then deserialized so that we would be able to use it in our application. This was all done using Newtonsoft. Newtonsoft is a Json library that helps .NET work with Json objects and Json data.

Update Existing Code to meet eMoney Advisor’s Coding Standards: The initial fetching code that fetched the data from the server was not up to par with eMoney’s coding standards. To fixed this, we had to go back and edit it in order to create something sustainable and scalable. In order to do that, we had to extract most things that were done into their own separate methods and follow the dependency injection technique.

Wrote Appropriate Unit Tests: In order to get a better sense of software development, we had to create unit tests for our code. Most companies use unit tests in order to create scalable projects and make it easier to detect if something was malfunctioning as soon as the new code is updated.
Fig.1: Test driven development (TDD) workflow. TDD is important to create scalable clean code.

Fig.2: Developed application workflow. This diagram highlights what processes the application goes through in order to function.
Fig. 3: Gantt chart example. This example Gantt chart is what our final Gantt chart will look like. It displays time information in a clean and readable way.

Fig. 4: Build information table. This table displays the build information that was retrieved from an eMoney server. The URL endpoints have been redacted.
PROJECT MOTIVATION:

FarSounder 3D forward looking sonar products feature a Transducer Module that both transmits acoustic energy and “listens” for returning echoes over an array of acoustic sensors. The received acoustic signals are digitized and processed to produce a three-dimensional representation of navigation hazards in front of the vessel. The position of the Transducer Module, in particular its roll and pitch, needs to be measured so that the processed data can be displayed with appropriate geo reference.

The sensor that is currently used to measure roll and pitch is too large, and also requires manual configuration. A device called an Inertial Measurement Unit (IMU) has been introduced to the market as a single chip device that can run on a few milliamps and take up negligible circuit board real-estate. FarSounder would like to take advantage of an IMU device, which is less expensive and a physically-smaller device, by having them soldered directly to the data acquisition circuit board.

ANTICIPATED BEST OUTCOME:

The goal of this project is to design and test an Inertial Measurement Unit (IMU) that can be included in the data acquisition circuit board within the existing Transducer Module hardware package. This device will be capable of measuring roll and pitch with sufficient accuracy, precision, and speed to reflect the conditions during which the received sonar signals are sampled. To achieve this, the team must identify a suitable replacement sensor through testing, data processing, and finally analysis. Comparisons between all chosen sensors will allow the team to come to a confident solution in the choice of a replacement sensor.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:

A significant impact to FarSounder’s Transducer Module is expected. The three major implications that FarSounder’s existing sensor provide are size, cost and availability. The company’s existing sensor is large enough to require a mounting bracket which imposes a large space requirement within the transducer for the sensor. The existing sensor has also recently reached its end of life. The IMU solution could diminish all of these problems. Economically, the company’s current sensor is expensive. Many modern-day IMUs are very accurate and inexpensive. A cheaper solution will decrease the cost for each product that it goes in, resulting in a significant cost reduction for FarSounder.
PROJECT OUTCOME:

The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Sensor Selection: Through research and communication with Application Engineers, the team selected four different sensors from three different manufacturers to conduct their testing upon. Key factors in the selection included sensor accuracy, data rate, and temperature sensitivity. Upon receiving sensors, the team began communication and understanding of each individual sensor. Using the evaluation software, the team was able to communicate with each sensor and output the raw data in the XYZ direction from both the accelerometer and the gyroscope. Through the use of the evaluation software and examination of sensor datasheets, the team became more confident in moving forward with the sensors that were selected.

Fabricated PCB: The team has designed and fabricated a circuit board(Fig. 1) that comprises all four test sensors simultaneously connecting to an Arduino Nano. The form factor of this PCB matches that of FarSounder’s existing sensor. The purpose of this board is to have a simple method to mimic the roll and pitch output of the existing sensor for all sensors. Using the Arduino Nano as the processor the team is able to compute roll and pitch from some of the sensors on the PCB. This information will be fed into the DSP of the transducer module to offset the data. This PCB will be mounted inside of the transducer which will allow the sensors to be tested in a real environment. The real environment will have the added noise from other components which will allow a real look at how accurate the sensor is compared to the existing sensor.

Custom Libraries & Arduino Communication: The team has utilized a combination of presently existing sensor communication libraries, along with custom libraries modified and designed by the team, for communication between the sensors being tested, and the Arduino on the PCB. Arduino code has also been created by the team that allows for selection of a sensor to output data from via a dip switch, applies a filter to the raw data converting it into roll and pitch information, and formats the information to match the output of the existing motion sensor.(Fig. 2) The data is then transmitted through serial communication to header pins on the PCB at the same output data rate as the existing sensor. Therefore, the output from the test sensors is the same as the existing sensor.

Boat Test: The team has created a mount(Fig.3) to simultaneously log data from all four test sensors as well as the exiting sensor, where all sensors are aligned in the x-direction for maximum comparison accuracy. This mount was used during a real world environment test, on a boat at sea for a prolonged amount of time. With data from all sensors, the team has performed initial processing and analysis on the data to compare each potential solution with the existing sensor.

Data Processing Software: Multiple scripts were created in Python and MATLAB for processing purposes of the boat test data. The purpose for the Python scripts were to format each individual sensors’ raw data into a suitable form from their respective evaluation software data logs. These newly formatted data logs were then input into a Matlab script that computes the roll and pitch information from the raw data, and filters it to make the data more accurate. A hand test was also completed and processed to measure the accuracy in a controlled environment. (Fig.4) The purpose of the filter is to fuse the accelerator and the gyroscope data. This is done because the gyroscope has a tendency to drift over time while the accelerometer is noisy measuring the immediate data. This filter allows a correction of both issues.
Roll Pitch Measurement for Sonar Geo Reference

Fig.1: Printed Circuit Board

Fig.2: Arduino Code Flow Diagram
Fig. 3: Boat Test Sensor Mount - Sensors Aligned for Maximum Accuracy

Fig. 4: Accuracy Comparison Between Sensor 3 and Existing Sensor
PROJECT MOTIVATION:

Visual Notification Appliances, or “strobes”, are the visual component of a fire alarm system to alert occupants to evacuate the building. FM Approvals tests and certifies visual Notification Appliances to two standards: FM 3155 and EN 54-23. Both standards require the measurement of light intensity output on-axis and also measurement of the spatial distribution of light intensity off-axis.

The current mechanism for testing the strobes require a manual adjustment of two separate turntables in relation to a light sensor to record light measurement at set angle combinations. Depending on the strobe and standard, a test will require hundreds of light intensity measurements to be taken which will take hours. Automating this process can save hours of tedious work while maintaining accurate readings, thereby saving considerable test time on each unit. Ideally the user will select a standard, run a test, and collect all necessary data from the testing suite.

ANTICIPATED BEST OUTCOME:

The best anticipated outcome of the project is to create a fixture with two motorized turntables and manual x, y, and z axis linear adjusters that work in conjunction with a light sensor each connected to a PC. The computer will have a GUI that requests the type of strobe and provides a selection of standards with the option for custom settings to modify these standards. After initiating the test, the system will automatically run through the angular positions specified by the selected standard and record the light intensity measured at each position. The operator can leave the equipment unattended.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:

The completion of the LumiNotify project will save hours for each visual notification appliance tested. Some of the more demanding standards will require up to hours of testing in an ideal situation, and performing these tasks by hand would take many hours of very boring work. Additionally, it is recommended that people working with these strobes take frequent breaks as the strobes will strain eyes after a period of time. Automating the two motors and data collection process will save time and effort while ensuring accurate measurements throughout the test and quite possibly prevent headaches and eye strain.
PROJECT OUTCOME:

The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

**Design of Fixture:** The redesign of the fixture allows for both motors to be the same model, by minimizing weight on the alpha axis motor; seen in Fig. 1. Moving the motors to the top half of the fixture facilitated the rotation of both angles while maintaining a center alignment with the strobe.

**Python Interface with Stepper Motors:** The motor driver is controlled with a proprietary standard, Advanced Positioning Technology (APT). The Python interface makes use of a library provided for free with Thorlabs products and allows a fast, effective way to control both motors with an automated application.

**USB Serial Data-Logging with ILT1700 Light Sensor:** The ILT1700 light sensor measures the intensity of the strobe by integrating the intensity over ten flashes. It features serial over USB port that sends data to the computer about eight times per second.

**USB Serial to Arduino:** An Arduino Uno works in conjunction with the ILT1700. Serial communication with the firmware running on the Arduino allows the host PC to remotely set digital pins which trigger functions on the ILT1700.

**GUI Window:** The GUI is designed using the C# .NET Framework in Microsoft Visual Studio. The simplified design of the GUI is meant to facilitate running a test using a set of standards. The manual provides better understanding of GUI functionality. Fig. 4 shows the main window of the program.

**C# Background Workers to Run Tests:** These background workers are run in the back end of the C# application and will handle the work needed to conduct a test. These background workers are in charge of initiating a test, but must also update any outside information to be displayed in the GUI. Communication with the stepper motors is conducted here as well as light measurement collection.

**SQLite Database:** The program uses a SQLite database to store data about the test, including preferences, settings, and standards between sessions as well as records the data during the test.

**Standard Management Window:** In the future, FM Approvals may need to add standards beyond those that exist today. This window allows for these standards to be added, edited, and deleted in an intuitive way with minimal effort. They are then saved in the database so they can be used at a later date.

**Output Data in Spreadsheet or Comma Separated Formats:** The output of the program will compile measurements from the database at the end of a test in either Excel spreadsheet (.xlsx) or comma separated values (.csv) format.

**ILT5000 Light Sensor:** This newer instrument includes features that enable better accuracy and can track the duration of a light flash. The ILT5000’s high speed USB connection and API provide a powerful interface with the C# application to collect accurate measurements. The ILT5000 pictured in Fig. 2 is a superior alternative to the ILT1700.

**Full C# Application:** After many of the different program components were tested, they were added into the main program. This program makes use of all the different components described above and wrapped into a single application. Fig. 3 shows the application from a software perspective including the external devices it connects to, specifically when using the ILT5000.

**Installer:** Creating an installer for this program allows for it to be conveniently moved and installed on different computers. It helps users setup the program to work right the first time it is launched.

**Documentation:** The last deliverable of the project is a manual that explains how the program works, its components, and how to use it. This allows for different employees to use it over years without struggling to understand its functions.
Fig. 1: Full Fixture Design

Fig. 2: The IL T5000 light intensity meter with attached photometer
Fig. 3: Component level diagram of project as relevant to software

Fig. 4: LumNotify Testing Suite GUI
**PROJECT MOTIVATION:**

In many cases, machine’s long-term performance is not well understood, and that performance can change based on the machines history. In order to have a clearer understanding of a specific machines performance, a “Digital Twin” of the machine can be created to using sensors to record the systems state and keep its history record. The Digital Twin is a new Internet-of-Things (IoT) concept that has potential to drastically change the operation of systems and components. Using this technology, operators will be able to make vital predictions of the machine’s long-term performance. Machine Learning and Artificial Intelligence can be integrated into a Digital Twin to allow it to make these predictions autonomously even send feedback to the system to optimize its performance. If designed for naval applications, the Digital Twin would be able to optimize performance reduce maintenance costs which are a significant part of the Navy’s operating budget.

**ANTICIPATED BEST OUTCOME:**

The Anticipated Best Outcome for the project was to create a Digital Twin prototype that is able to monitor the current state of the pump and predict its remaining useful life. It should be able to identify changes in the pump’s performance, remaining life, identify abnormal readings and present all this information to the user in real time. The best outcome of the project is to create a Digital Twin prototype that can accurately and reliably analyze performance and predict the remaining useful life.

**IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:**

The implications of this project are staggering. Digital Twin systems are sought after in nearly every industry in the world. Most physical machines or electrical systems could benefit from a digital twin monitoring its state and predicting its remaining life. At Electric Boat, this system could be integrated into components to monitor and optimize system performance, thus reducing maintenance time and saving money for both Electric Boat and the Navy. The system could also potentially save lives onboard submarines by highlighting components that are near the end of their life before they have a chance to break.
PROJECT OUTCOME:

The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Software Selection: Researched and performed a cost-benefit analysis on various programming languages and software. The software was selected based on its compatibility with the microcontroller and ability to interface with GUIs, embedded systems, and machine learning libraries.

Component Selection: We researched and selected a pump to use as the foundation for all of our data collection and work. We also selected a sensor suite and microcontroller that would feed data to our software for analysis. The pump had to be able to support a suite of sensors, and these sensors had to be minimally invasive.

Software Architecture: Designed a fog computing model (included in Fig. 2) to provide optimal performance of the application and allow for real time monitoring and interactions with the system. This was realized using serial communication, between the embedded system and back-end system, and embedded SQL for interactions with the database.

Construction of Hardware: The pump needed a water flow loop that would allow it to infinitely transfer water for data collection (Fig. 4). The sensors had to be mounted to the pump and connected to the microcontroller, then configured to deliver data accurately. A cart to hold the system was also assembled, and safety measures were added to prevent the water from damaging the electronics (Fig. 3).

Damaging of Diaphragms: In order to train the software with artificially aged performance history, we damaged the pump’s nitrile diaphragms at different stages. The best way that we found to damage these was to soak them in acetone for up to 2.5 hours. The acetone degraded the nitrile and caused the diaphragms to behave differently when installed. We attempted other methods of degradation, but acetone proved to be the most reliable and consistent.

Machine Learning Implementation: Implemented a bagged regression tree algorithm that is trained on data acquired from the pump at different stages of operation and ensured it was able to make predictions within an error range (Fig. 1). The damaged diaphragms were installed into the pump and data was collected to show what a degrading pump looks like to the software. One by one, the diaphragms were installed and tested until a good curve of data was collected and the application was able to identify that it was nearing the end of its life expectancy.

Life Expectancy Predictions: The application can analyze data from the water pump and make consistent, accurate predictions of the pump’s life expectancy, which was validated with extensive simulated data showing different scenarios and live testing using diaphragms degraded to different stages of wear-and-tear.

Graphical User Interface: In addition to meeting the anticipated best outcome’s requirements, the GUI (as shown in Fig. 1) allows the user to have some control over the display, with the ability to reset sensor averages, change how the data is visualized, and interact with the database even when the system is offline.

Data Logging: A time-series database was created in order to store data for future use with machine learning algorithms as well as allow the user to view the pump’s performance history to assess anomalies. The user is able to control how much data is seen.

User Notifications: The application gives clear graphical changes (Fig. 1) when the pump is operating abnormally or when its life expectancy reaches certain points, allowing the operator to easily determine when the pump needs maintenance or inspection.

Safety and Security: The systems implementation included taking appropriate measures of safety when adding sensors and other electrical equipment and potential cyber and cyber-physical security measures were well documented, but not implemented on the project.
**Fig. 1:** Digital Twin Graphical User Interface

**Fig. 2:** Digital Twin System and Software Architecture
Fig. 3: View of pump, flow rate sensor, and microcontroller inside box.

Fig. 4: Cart with water tank on bottom and pump with electronics on top.
PROJECT MOTIVATION:
The multinational toy and board game company Hasbro, is currently on the forefront of online connected versions of their popular game brands. While the online format helps implement the game rules, track scores, and connect friends and family from around the world, there is one major drawback. As of yet the gaming industry lacks a natural solution to replace physically rolling the dice. The die roll is highly tactile and gives the player the feeling of taking their own fate into their hands. Current solutions such as a random number generator can provide the same function as a die roll, it lacks however the physical connection to the game that players experience in rolling dice. Hasbro’s solution: to create a roll detection system enabling the online game to detect and record the manual die roll. The system will record the player’s roll naturally with minimal interference to gameplay giving a seamless experience.

ANTICIPATED BEST OUTCOME:
Team Hasbro’s best anticipated outcome is a well developed prototype that detects when a die is rolled in a specified location, and then classifies and prints which number was rolled. This project will utilize cutting edge Computer Vision digit recognition software to catalog die with a multitude of colors and digits, including the traditional six-sided pip die. The hardware must be robust and have the ability to recognize a die roll as well as provide sufficient lighting for filtering purposes. The system will be battery operated and therefore must be power efficient in order to last for the best gaming experiences possible.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
Team Hasbro’s best anticipated outcome is a well developed prototype that detects when a die is rolled in a specified location, and then classifies and prints which number was rolled. This project will utilize cutting edge Computer Vision digit recognition software to catalog die with a multitude of colors and digits, including the traditional six-sided pip die. The hardware must be robust and have the ability to recognize a die roll as well as provide sufficient lighting for filtering purposes. The system will be battery operated and therefore must be power efficient in order to last for the best gaming experiences possible.
PROJECT OUTCOME:
The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Master Classification Script: A python script to classify both pip and numerical die roll was written. This script includes all stages of the process from when the first image of the dice is taken to the printing of the digit prediction. Between start and end, several steps had to be implemented in order to increase the accuracy of prediction such as filtering background and noise, focusing on regions of interest, extracting the individual digits, rotation of digits, and classifying them before printing the predictions.

Initial Prototype Proof of Concept: The initial project prototype consisted of a black project box which contains the Raspberry Pi board, Camera, roll detection sensors, and camera mount. These parts of hardware were configured to fit the Raspberry Pi system.

Prototype II, III, and IV: Gian Calise, a mechanical engineer from Tufts University, was consulted in order to develop the aesthetic models for our final prototypes. Working closely with Gian the team developed several stages of the final prototype in order to account for measurements, aesthetics, and functionality components. The final prototype was 3D printed, and painted by the team to be presented.

Hardware/Software Integration: When importing the prediction script to the Raspberry Pi board multiple additional libraries and packages were downloaded and formatted to fit the Raspbian operating system. The scripts were edited as well to incorporate the differences in operating systems. On the final model the electronic components: camera, LEDs, LCD screen, accelerometer, were all connected separately and tested for functionality. These systems have to work together to achieve a common goal which is to detect, respond, and capture. First is the detection, this includes the pressure sensors relaying data to the analogue to digital converter. The response phase includes the neo-pixels and camera turning on because an object was detected on the rolling surface. Finally comes the capture procedure, the camera is the sole contributor to this step. Having all the hardware components talk to each other during these phases is done through python programming as well as through the modification of analog signals to digital signals.

Increase accuracy of classification: In the later iteration of the software we were having issues with the neural network’s accuracy when rotating the images and accounting for the upside down value. When adding a softmax layer it allowed up to determine whether a die was upside down however reduced the overall accuracy on the other images. In order to account for this the softmax layer was removed and the total accuracy improved to where it had been. The model was trained several times in order to increase reduce the total doubt, however when translating a handwritten data set to dice it’s not going to be 100%. The current accuracy is acceptable for Demo standards however for future work it is recommended to improve with a different data set.

Rewrite Programs into one Master Script: The Pip and Number classification scripts were previously both separate. However with the new master script being written the software actually runs the pip first and determines whether there are pips based on the size of the blobs detected. If no it then runs the numerical classification. The pip script is very short to run so in terms of performance it does not hinder the overall speed of the program very much, and when a pip is rolled, it indeed runs faster than the numerical dice.
Fig.1: Final model

Fig.2: Block diagram
Fig. 3: Software flowchart

Fig. 4: Wire diagram
PROJECT MOTIVATION:
The CMM, coordinate measuring machine from Hexagon, is a device that measures loaded parts. Typically these parts are loaded by humans and as a result is expensive to run. Because the process is simple, loading can be improved by automation. Automation is more time efficient because it will also be able to run on off-work hours and increase utilization of the CMM. Most industrial robots, however, are not safe for close interaction and need highly skilled humans to program them. Therefore, the introduction of a collaborative robot is needed for a streamlined human-robot interaction. This robot will be easily programmable and have safety features to protect their human operators. Lastly, the robot must be able to detect and report errors that occur while it loads and unloads the CMM.

ANTICIPATED BEST OUTCOME:
Our anticipated best outcome would be to create a software interface that will allow the user to initialize the robot with their specific part and pallet parameters on an intuitive interface. The interface will be operated by a human with minimal training and interaction. After the initialization is complete human interaction will only be to load data and to exchange parts. We will create subroutines that will dictate the robot’s movement. These subroutines will pick and place the part based on the part’s data.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
Productization of a ready-to-use cobot automation cell for manufacturing will be very disruptive if it truly doesn’t require any expert training for a first-time user. Increased simplicity on the operator’s side will lower the barrier for entry as well as reduce human error. Broader implications of this solution extend it to other forms of manufacturing involving light loads and a loading pallet. These other manufacturing opportunities have the potential to augment efficiencies in multiple manufacturing areas as well as inspire other forms of automation. Overall the CMM will be a more attractive option in the market since it will be packaged with an automated loader.
PROJECT OUTCOME:

The Anticipated Best Outcome was achieved.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

Robot subroutines implementation: This is the most essential part of our project because it is what all other code is based on. Part data will be used to tell the robot exactly where to go and how to pick and place a part. Subroutines will also open and close drawers. These subroutines will be called in sequence by a main manager program. The sequence will be the same for each part, only differing in part data and pallet location.

Draw handle reliability test: this was a big part of our project because of the time it took for us to finally decide which handle at what position we are using. A lot of this test is because the issue with the lock not working properly due to the way we are pulling the draw out, so after multiple test we have now decided to not use force moves on the routine, and we are using spring handle which solves a lot of this issue.

Formatting Data in Json: The json format is a dictionary format that allows easy access to data in a text file. It was our challenge to format these json files so that they can be used to input data to subroutines. Our current json action format, for example, will tell the robot what preparation pose it should take, what coordinates to pick from and how wide it’s grip should be when it picks a part.

Data Parsing and Architecture Organization: We have decided that we will use Json as opposed to XML and csv files to store our data. This is because Json is faster and is a more appropriate data format for our part templates. The Json format enabled us to to implement a modular data structure that would make it easy for a user to reuse data for the scheduling of jobs. The data structure was creating in parts. One part was information about the parts and another was information about the drawers. For the parts, we could store the type of part, cell location, gripper position, etc.. When a robot picks up parts it has a schedule on when it picks up each part. Not every part is the same. Which is why my program takes the cell positions of each part and congregates them into one array which will be used as the schedule. The schedule then refers to the templates for its data and then will take that data and give it to the robot to use.

Part Detection: It is important for the robot to sense whether it picks up a part or not. Otherwise it will act like it has the part and it will not alert the operator that the part has been missed. So we can tell the arm to go towards the part and stop if it passes a certain point or stop if it hits something unexpected. It then will grip. If it detects nothing then it will report to the operator that there is an error and it will respond appropriately.

Data Loading and Operation: One of the main requirements of our project is that it must be easy for an operator to operate. This capstone project allows the data to be created beforehand and allow to the operator to simply insert the data into the system. Regardless of the different amount of parts, so long as the data is specified for each part beforehand, the system will be able to place the parts into the measurement machine.
Fig.1: Robot Cell Setup with Coordinate Measuring Machine

Fig.2: Pallet Layout GUI Design
**Fig.3:** GUI Layout Block Diagram

**Fig.4:** Robot Workflow Block Diagram
PROJECT MOTIVATION:
Lottery terminals have been processing transactions via touchscreen interfaces for many years with online terminals. Tasks range from manually entering wagers using the interface to using playslips to process wagers. This project will explore the feasibility of developing a headless lottery terminal to process wagers. This would entail removing the current touchscreen based terminal interface and replacing it with a hands-free terminal that can understand voice commands and respond with appropriate speech responses.

ANTICIPATED BEST OUTCOME:
The Anticipated Best Outcome for our project is a functional prototype lottery terminal capable of receiving and processing voice commands and translating these commands into terminal functions. It will interact with a retailer in a natural way; allowing the retailer to place wagers, hands-free. When more information is needed to perform a task, the system will ask questions to obtain the information necessary. It will ask the user to verify that the data submitted is valid and without any error. The system will monitor the state of the terminal and communicate with the retailer when physical intervention is required. A requested quick pick lottery ticket should be processed and printed in under 4 seconds. While the terminal system was able to perform at a high on the MacBook where the software was developed, transferring over the terminal to our Raspberry Pi caused various issues. We were able to develop a functioning prototype, but it still has major unresolved bugs in the speech-to-text functionality which adversely affect its usability.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
Touch-screen interfaces are used in numerous IGT products. A voice-driven system would eliminate the requirement of both expensive and fragile digitizers found in both capacitive and resistive touch displays. A single touch screen display would cost the company upwards of $200. In Florida alone, there are more than 200,000 terminals currently in operation. This terminal could reduce the hardware cost since there would be no need to implement a touch screen display, potentially saving the company a substantial amount of money. Additionally, the viability of a voice-driven system extends to other products IGT manufactures and services they render, potentially reducing costs of hardware even further. In particular, a headless terminal such as this one would be a significant step for IGT in the market of terminals for visually impaired persons. While IGT has developed terminals which use simple speech-to-text in conjunction with screen interfaces, a truly “headless” terminal could be more robust and better render service to visually impaired customers.
PROJECT OUTCOME:
The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

High Level Design Document: A document outlining the important design decisions for the system was compiled. This included the design of our hardware and software of both our initial prototype and of the eventual final design.

Activity Diagrams: These diagrams were created to represent how the logic of our software is implemented within the terminal. They show the flow of actions that are involved when obtaining a lottery ticket, or accessing the terminal in general. A simplified overall activity diagram is shown in Fig. 1.

Use Case: Detailed all the possible flows of events as the user interacts with the terminal. It includes information on what specifically the terminal will output or expect to hear from the user at particular junctures.

Prototype block/wire diagram: Created a wiring diagram (Fig. 2) shows the hardware that is involved within the system from the microphone input to the printer output, and the different connections that made between the different hardware components and peripherals.

Speech-to-text (STT) software: Chose CMUSphinx as our speech-to-text engine since it could be run entirely offline. Of its many adjustable settings, we adjusted the acoustic model, language model, and dictionary of the recognizer to gain better recognition accuracy.

Implemented quick pick: A lottery quick pick is a lottery ticket purchased for one draw with six random numbers. Our lottery terminal is able to recognize a command for a quick pick with relatively high accuracy. Options are also given to print for multiple boards and draws should the customer request them.

Implemented manual picks: When requesting a manual pick, the user is able to specify the exact numbers that they would like to print on their lottery ticket. This process of choosing numbers can be repeated multiple times for however many boards the customer would like to purchase. Then the terminal will ask how may draws the user would like.

Implemented login, logout, and create user: A new user can be created while logged out. After logging in, the user is then able to fully utilize the multitude of implementations the terminal is designed for. At any point, the user can also log out so that another may log in.

Implemented automated trainer: The user is able to enter a training mode to teach the recognizer how to process different sounds. The terminal will prompt the user to say a number and when the user says that certain number, the terminal records the user saying it and plays it back to the user to ensure that the recording sounds correct.

Software Consistency Testing: Tests were ran in a quiet room while running speech recognition while speaking into the microphone. We observed the output as well as other potentially relevant information to determine how we could improve the accuracy and run time of our speech recognition software.

Driving LED Indicator: Successfully decoupled LED data stream from audio stream (which otherwise would use the same PWM peripheral on the Raspberry Pi). Implemented LED indication specified in our use case.

Connected printer: Successfully established connection with point-of-service (POS) printer and printed wagers on it.

Designed enclosure: Designed an enclosure in Solidworks for housing all of the hardware components of the project. Currently plans to 3d print this enclosure are underway. An exterior view of this enclosure design is shown in Fig. 3.

Final System Tests: Made sure that all of our internal systems are running reliably and consistently. These tests will include running through every scenario that our Use Case Document dictates, and making sure that our hardware and software are performing as they should. The final system hardware (sans enclosure) is shown in Fig. 4.
Fig. 1: Activity diagram outlining the logic implemented in the lottery terminal.

Fig. 2: Wiring diagram showing the hardware involved in the lottery terminal.
Fig. 3: Enclosure design in Solidworks of the housing of all the hardware components.

Fig. 4: Image showcasing all the components of the final system hardware.
PROJECT MOTIVATION:
Testing a product for reliability is a vital step before it can enter production. That is why Infineon subjects their voltage converters to high current loads for months at a time. Since testing lasts so long, it must be low maintenance. In other words, “Set it and forget it.”

Right now, Infineon has no ability to communicate with the devices under test (DUTs). There is also no ability to regulate the temperature of the system. The current solution is to use third party software to monitor the devices, but existing software is very expensive and cannot write to the DUTs. Since the new system would be an in-house program, it would save time and money over dealing with a vendor. The new program will be able to communicate with the DUTs, collect all the relevant data, and will be a significant cost reduction for Infineon.

ANTICIPATED BEST OUTCOME:
The Anticipated Best Outcome was achieved. The goal was to have full thermal control of all 60 sites. In order to streamline more complex calculations, namely RDS(ON) testing, temperature should remain constant. This was not possible as the fan speed of each site was set to a constant value. The new system has a graphical user interface (GUI) where Infineon application engineers can specify a desired system temperature. The system relays this information to a fan controller on each site, which dynamically sets the fan speed to maintain this user specified temperature.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
The new system will automate parts of the stress testing process for these voltage converters. Additionally, having thermal control of the system has many advantages, such as simplifying complex calculations and a better-quality stress test. Since the system is in-house and owned by Infineon, there is a lesser need for expensive third-party software and licenses. By reducing the need for third party licenses, along with other upgrades made by Infineon engineers, Infineon will save up to $400k per testing rack. With the company currently expanding their own manufacturing facilities, this could mean millions of dollars in savings.
PROJECT OUTCOME:
The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Hardware: To develop a temperature control system, an initial connection to the test system needed to be established. The test system has an I2C bus which connects all the devices to a multiplexer header. Using a test Arduino sketch and fan controller board, we were able to see all the devices on the I2C bus and develop our own code to read and write to the board. An Arduino was used to interface the testing board with the computer software. The test board and actual sites use the same device addresses, so the developed system was easily applied to the full system. A single site used for this initial testing is shown in Fig. 4.

Site Communication: One of the first major milestones was establishing communication to the devices on each site. This was done through Arduino using I2C communication protocol. To do this, the address of each device must be set to a unique value. Since the sites all use identical device addresses, this meant that only one set of addresses needed to be stores on the Arduino. The device used only allowed for 9 addresses per site. To bypass this, a multiplexer was used to mirror 5 site addresses on two channels. The redundancy in device addressing made expanding the communication Arduino sketches much simpler. The full system tower is shown in Fig. 1.

E-Fuse: The E-Fuse is designed to disconnect a site in the event of a voltage or current error to prevent overheating. This protects the system from damaging itself and is a crucial part of the temperature control system design. This was found to be controlled by a pin on the main board. When the GUI detects any type of fault the pin is set high, activating the E-fuse. The E-fuse is a pin on the site and is driven high to activate. Because there is no communication bus involved, an Arduino general programmable input/output (GPIO) pin is used to control this feature.

E-Load: The system itself is designed to stress test voltage converters under a high current load. This simulates years of use in only a few weeks. As of now, the load current is set manually with a potentiometer, which is tedious and takes valuable time out of the testing process. The GUI has the ability to talk with and directly program the electronic load. This gives the end user simple and intuitive control over each individual load board, saving time and improving efficiency.

Graphical User Interface: A fully customized graphical user interface (GUI) was delivered to the application engineers at Infineon. This GUI allows a user to specify a target temperature as well as seen the current thermal output of the testing rack. The user can view all 60 sites simultaneously, as seen in Fig. 2, allowing for error detection and thermal verification, or can view each site individually, as seen in Fig. 3, allowing for viewing logged data and error specifications. The Arduinos are completely handled by the GUI, from uploading the program to reading and writing information to the board. In addition, the load boards of each site can be controlled using the GUI. This results in a smooth experience for the end user and significantly more control than the previous interface.

Database: An SQLite database was used to log the information from the system and display to the user in the GUI. SQLite was chosen for its versatility and mobility, as a single .db file can be stored locally and accessed from the user interface. Eliminating the need for a separate SQL manager, such as SQL Server Management Server made it easier for the Infineon application engineers to install and implement the GUI on their company computers.
Fig.1: SPECTester system tower at Infineon Technologies lab in Warwick, RI. The system Features 60 individual sites for testing phase cards under varying loads.

Fig.2: GUI Panel View developed by team. Used for displaying the status of each site in a compact view.
Fig. 3: GUI Site View developed by team. Displays the current and logged information of a given site, as well as any faults that may have occurred. Allows for control of individual thermal systems by setting a target temperature or fan speed.

Fig. 4: A single site which was used to design and debug the system. An Arduino was used to interface the board to the GUI.
PROJECT MOTIVATION:
Mirror alignment is a crucial part of laser production but is a slow and tedious process. As of now, this process is done by a laser technician who will insert a long screwdriver into the system to adjust the mirror’s screws in order to align the fully reflective mirror with the partially reflective mirror on the other side of the laser. This process is inconsistent from technician to technician. With this enhanced project, it will be possible to produce aligned mirrors at a much quicker pace which will in turn decrease the total time of production. The alignment will be replicable and more reliable as the process will be done through calculations instead of by human eye. A real-time GUI will allow the user to follow this process by monitoring the position feedback from the autocollimator and the limit of torque exerted onto the screws.

ANTICIPATED BEST OUTCOME:
This project will have a big impact for Iradion Laser, Inc. with the best outcome being a production-ready workstation in a cleanroom environment that can auto-align a mirror for their lasers. Based off the work completed by last year’s team, improvements to the mechanical setup, materials, and motors was necessary before the company could integrate it in the assembly line. The final project will require parts that Iradion Laser, Inc. can purchase off the shelf, metal pieces that can live in a cleanroom environment, and allow the user to know the torque on each screw.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
A laser technician has the role of manually turning the screws on the fully reflective mirror in order to achieve the best attributes for the laser. The current tuning process is unreliable because the mirrors produced may become damaged from overturning. This project will enhance Iradion Laser, Inc.’s production of lasers with more accurately aligned mirrors in which are available quicker than before. In turn, the system will provide a more consistent product and increase the production efficiency of the manufacturing line.
PROJECT OUTCOME:

The Anticipated Best Outcome was not achieved.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

**Servo Motor and Driver:** The main goal for this project was creating a way for the user to know the torque on each screw while aligning the mirrors. Unlike stepper motors, servo motors power output is reliant on current. The servo motors used are displayed in Fig. 1, and each have their own driver connected to the FPGA. The motors are too large to be directly behind the screws so they are offset and use turning belts to turn the hex bits in the middle holder.

**FPGA & UART Communication:** The FPGA board connects everything together and communicates to the computer through the UART. The FPGA is behind the motors as shown in Fig. 2 which has the PMOD, UART and drivers connected. The main purpose of the FPGA is to receive and transmit signals from the driver and the C# code. The UART communicates through serial data. Both the Vivado code and C# code have processes to handle this communication. Calculation Code: The C# code is the brains of the operation. Based off the information from the FPGA and autocollimator the code will calculate the number of turns each motor needs to do. While turning, the C# code will receive the voltage output of the driver and calculate the current through a known resistor. Using the current, the torque will be calculated and realize if the motors are going to exceed the max torque.

**Torque and Current Relationship:** Conducting a simple experiment with a pulley system required the knowledge of the relationship of force, gravity, radius of the gear attached to the motor shaft, and mass unit hanging from the pulley. By measuring the current outputted from the driver and calculating the torque for the motor, the torque constant is found and implemented into the C# code. This allows the code to calculate the torque with respect to current while turning the screw.

**3D Printing:** To hold the three motors in an organized fashion, a wall and base were designed and printed with an extra side of support to account for the increase of size and weight of the motors, as shown in Fig. 1. A shaft to hold and extend the hex bit was designed, as well as a holder for the hex bits in the middle of the system. A stage for the motor system and for driver and FPGA setup attaches everything to the track system.

**Analog to Digital Converter:** The voltage output from VCC pin of the encoder at the driver is sent through a known resistor to input the voltage into the A/D converter. This current value is then read in the C# code to calculate the torque output which relates to the current value at that moment.

**Control and Communication Code:** The FPGA has processes to know what information to send and communicate to the C# code what is being sent. The block diagram from Vivado is seen in Fig. 4. This represents how the FPGA is setup to receive and transmit data between each block. Shown in Fig. 3 is the GUI that the user will implement limits to and begin the process.

**Mechanical Component Selections:** Through the help of a mechanical engineer at Iradion Laser, Inc., information of off the shelf mechanical parts were made available. The gears were chosen from a given catalog which matches and fits the motor's shaft diameter. The system will sit on a track system which will allow for ease of use for the technician. The hex bits are placed in the system for direct fit into the three mirror screws which will be turned.
Fig.1: Side view of the bases with motors on the rail with the autocollimator.

Fig.2: Back view of the setup with drivers and FPGA.
Fig. 3: Graphical user interface to display the feedback from the autocollimator and FPGA.

Fig. 4: Block diagram for the Vivado code, representing the FPGA, UART, and A/D data.
PROJECT MOTIVATION:
The Laser Simulation and Optimization, or commonly referred to by the acronym, LASIMO, is a project that has been established and intended for use with Iradion’s patented CO2 lasers. Construction of a laser resonator relies heavily on both experimentation and optical modeling. At this time, there are few resources that provide easy to use modeling software which caters to this type of laser despite its popularity within the industry. Due to the absence of a concrete theoretical modeling approach, design modifications inevitably result in extensive lead time and significant economic impacts. The LASIMO project aims to reduce necessary time and resources by providing an optical modeling platform that can efficiently and accurately predict the optical performance of these industrial lasers. With access to such a platform, it is anticipated that modification times will be reduced by up to 70%. This has the potential to be a key factor in Iradion’s projected growth and expansion.

ANTICIPATED BEST OUTCOME:
The anticipated best outcome of the LASIMO project is to accurately and efficiently model the negative branch, confocal unstable resonator that Iradion uses in their CO2 lasers. Through use of Matlab coding software, the project designers will develop a platform that matches the output of an Iradion laser. A number of values, such as the various cavity component measures, will be controlled within a GUI for ease of use. A manual will also provided alongside the program detailing how it is used and how it works. Overall implementation should be done in a way that is simple for the employees to understand.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
Currently, Iradion optimizes their laser models, however, they do it manually, which causes data variance and significant resources. When the company implements a small modification, which can include use of new components, it costs them time and money. Currently, it costs Iradion about 6 weeks in time and $8,000-$10,000 for each desired adjustment, and 8 changes occur annually. Implementation of this software will allow Iradion to reduce these costs that similar companies already do from having such software and also allow them to perform other important checks on their lasers more easily.
PROJECT OUTCOME:
The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Basic Knowledge Acquisition of Laser Optics: Received basic knowledge on laser science and optics, refining it over time through teaching from our TA and through books we’ve read.

Light Diffraction: Learned about diffraction and various equations that relate to it, as it serves as a foundation for current work.

Laser Safety: Learned about laser safety when it comes to working with and around high power CO2 lasers at the Iradion facility.

Far Field Waveform: Through use of the Fraunhofer equation, successfully modeled far field waveforms for both rectangular and circular apertures.

Near Field Waveform: Through use of the Fresnel equation, successfully modeled near field waveforms for both rectangular aperture and a circular apertures.

Lens Propagation: Modeled the waveform for a frequency passing through a lens, the format serving as a basis for current and future work.

Field Intensity: Modeled field intensity using Fourier convolution, including a variation for 2 lenses and a point source. It showed potential errors in some of our data calculations through the formulas we used.

Galilean Telescope: Modeled the Galilean Telescope in a few different ways, taking care due to a bit of struggle with the propagation format we were using. The end results were eventually refined and corrected.

Holes and Grating: Modeled square grating and other types of periodic transparency functions in Matlab. These problems experimented with how placing grates and holes can change how the final field intensity output looks.

Model the Laser Cavity: Briefed on how to model the laser cavity and managed to attain a basic model and idea that was on the correct track by the end of the fall semester.

Complete Laser Resonator Model: The initial laser cavity was given further progression up until its completion during the second semester. Many refinements were implemented into the resonator model, such as a shifting function that allows output data to be more intuitively understood for analysis, as well as optimizations for the code run more efficiently.

Enable Wavefront Incidence Angle: Integrated functionality that allows for analysis of the beam’s output with the mirrors at differing angles than their neutral position. This allows for relative checks for power loss and was key for checking measurement competency.

Output Beam Quality Data Analysis: Perform output beam sampling to define the figures of interest such as the beam radius and beam divergence which enable industry standard quantitative beam quality definitions, such as “M2” or beam cross sectional distributions (example shown in figure 1).

Develop Hands-On Laser Measurement Competency and Build Portfolio of Data: Working with the Iradion R&D team, we were able to development data sets to tune and validate the simulations outputs (results shown in figure 2). The data of interest were parameters such as power by mirror angle dependence, and beam waist as a function of propagation distance.

Compare Theoretical Model Results to Experimental Output: Using the collected data, the optical model was tuned for efficiency and accuracy (with results seen in figure 3). Using a trial and error method, we performed rigorous testing to flush out any errors and improve accuracy, as well as to approach identical analysis procedures in the simulation as performed in actual laser data development.

Design and Implement Graphical User Interface with Supporting Documentation: Using MATLAB, package the complete optical modeling platform into a easy to use intuitive application (shown in figure 4). The App is easily accessible and mounted within the MATLAB editor toolbar next to other stock applications provided by Mathworks. A user manual/documentation to accompany this final deliverable has been provided to Iradion.
**Fig.1:** Cross sectional views of the 3D intensity plot.

**Fig.2:** Actual laser measures taken at the facility and documented for comparison.
Fig. 3: Comparing theoretical vs. actual laser data to determine accuracy.

Fig. 4: Beam quality characterization, one of the many functionalities of the Unstable Resonator Simulation graphical user interface.
PROJECT MOTIVATION:
Currently the test for measuring transient thermal resistance is an arduous process. The engineers at ON semiconductor conducting the tests have to set up the equipment manually and record the results from an oscilloscope by eye. After this test the device must cool down before the next test can occur. Oftentimes, the engineer will step away to conduct other work during this cooldown period. This process is time consuming and inefficient. The ultimate design of this project is to have one initial setup for a particular device in order to conduct all of the tests and data collection automatically and efficiently. This includes the system accounting for the cool down requirements before conducting consecutive tests. This will allow the engineers to work as efficiently as possible saving the company countless amounts of man hours in the long run. As the old adage goes “time is money”.

ANTICIPATED BEST OUTCOME:
A printed circuit board will allow for the testing of various components by merely switching out daughter cards from the main motherboard. This motherboard will include both the discrete and smartFET topologies. The thermal resistance will be measured over the course of twelve tests connected to various resistances. The engineer should be able to set the test conditions in the GUI and allow the data to be collected throughout the day. This data will be populated in an excel spreadsheet for later review by the engineer. This should design should allow for the estimation of thermal resistance on a device by device basis.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
The automated system will free up the engineers to work on other projects and engage with customers. This will save significant man hours. The current test will alleviate a tedious test and replace current simulated values with concrete real numbers. These numbers will allow ON Semiconductor to provide its customers with a greater comprehension of device performance as well as how it compares to other devices on the market. These results will allow the engineers at ON Semiconductor to provide feedback for device improvement, and give customers concrete values why their component is better than that of its competitors.
PROJECT OUTCOME:

The Anticipated Best Outcome was achieved.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

Initial Schematic Design: Combined two circuit topologies into a single circuit. These circuits are used to measure either SMART or Discrete FETS. This will allow for both testing designs to be implemented on the same PCB. Jacks were added into the schematic to allow for this modularity to be achieved.

Push-Pull Design: In order to choose which resistance is to be used during which test a push-pull design between a PMOS and NMOS was used. These transistors are controlled through a PIC microcontroller which receives a signal from a DLP controller which receives commands from the computer program. This design is shown in Fig. 1

I/O Reduction: Reduced the number of input and output needed. Made the push/pull switch topology in the two measuring circuits common. This reduction in input and output needed simplifies the code that the computer engineer needs to create. It will simplify the debugging process in the event that there is a problem with the program.

PCB Layout of the Motherboard: From the combined circuit topology created in OrCAD the combined layout for the motherboard consists of components which allows for a range of tests to be performed.

PCB Design Files: PCB design files were produced for manufacturing purposes.

Soldering the motherboard: The printed circuit board is completed and the components have been soldered to this board. The banana jacks are color coded to simplify the setup process for the engineers conducting the tests. The populated motherboard is shown in Fig. 2.

Various Bench Equipment Communication: Communication with Power Supplies, Multimeter, and Oscilloscope have been achieved using Visual Basic, and GPIB communication. We were able to control the output voltage of the Power Supplies, and measure the DC voltage and current from the Multimeter through Graphical User Interface written in Visual Basic. The communication with the Oscilloscope has been accomplished using a USBTMC communication as it didn’t support GPIB for sending commands. We were able to get specific data points from the waveform, and log it in Microsoft Excel. Refer to Fig. 3.

Device Testing: Initial testing indicates that the motherboard and daughter card function properly together. The motherboard successfully automates the testing process and we are able to control the level of resistance used for desired power pulses via microcontroller. The PC is able to communicate with microcontroller via SPI frame, and successfully records data from the oscilloscope.

Designing the PCB layouts for daughter cards: Daughter cards for devices under test have been designed and produced. The daughter card we have designed so far is designed according to JEDEC (Joint Electron Device Engineering Council) standards. This design is shown in Fig. 4.

Graphical User Interface Design: The initial user interface program design was improved by adding the flexibility of testing the bench equipments and also the communication with microcontrollers. Hence, it’s ready for final real-test environment. The code for GUI has been cleaned, and organized for future development of the program.

Communication with Microcontrollers: Programmed the DLP microcontroller to send command data to the PIC microcontroller.

Debugging: Initial testing proved unsuccessful, troubleshooting found the issue. Various nmos devices in the push/pull switching topology were incorrect in the PADS library. Issue was rectified with PCB modification. Parts of the board were cut, and new connections were soldered to desired pins.

Integrate with the program: Once the board is tested and determined to be accurate the final step will be to ensure that the automation process is successful by running the range of tests using the computer program to control the various bench equipment and change between which resistance is used.
Fig.1: Push pull circuit topology

Fig.2: Assembled Motherboard
Fig. 3: System Level Block Diagram

Fig. 4: Daughter card populated with device to be tested
PROJECT MOTIVATION:
Many customers are not power supply experts but they must develop power supplies for their systems. They often encounter difficulties when trying to find a solution that satisfies both performance and stability requirements. To aid their design process, ON Semiconductor has previously provided design aids in the form of Microsoft Excel or MathCAD files which help them perform the necessary calculations. From these calculations, they can test out the recommended component values by performing a SPICE simulation or building an evaluation board. Both of these steps are often difficult and time-consuming for the customer, but they need to verify the performance and stability of the power supply. It would be more efficient and economical for the customer to have access to an executable file that can import the power supply system requirements and calculate the circuit and compensation component values that are necessary for their design.

ANTICIPATED BEST OUTCOME:
The anticipated best outcome for our team’s project is a configurable tool suite for ON Semiconductor DC/DC converters, developed using MATLAB to perform the necessary system calculations, evaluate the system transfer function, provide bode plots, and provide help for external component selection. The software tool should receive the component values from the customer’s inputs and enable simulation of the customer’s application. The results should be displayed as bode plots for gain and phase. Parameters for future products should be implemented in external files rather than in the main code.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
The Switch Mode Power Supply Design tool will enable customers to more easily design and simulate power supplies. This will create a faster design process with results displayed interactively. A full design and simulation environment will be launched from the tool which will enable unique design modifications and simulations that are based on the tool’s outputs. This will improve customer support during the design-in process, so that the application engineers will infrequently need to be involved in the product selection and proof of concept phase. This tool should increase the number of design-ins on new customer product lines.
PROJECT OUTCOME:

The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

**Software Design and Development:** Made UML class and activity diagrams for each fundamental part of the graphical user interface. The diagrams and the flowchart document the intended functionality of the user interface, incorporating all elements of the team's flowchart and all previously defined functional requirements and features of the graphical user interface.

**Schematic:** Imported the schematic of the NCV891930 as a JPEG and PNG file into MATLAB and programmed text boxes for user entry in surrounding areas around every single component that should be able to be altered.

**User Inputs and Text Boxes:** All of the text that is entered into the text boxes is selectable and able to be copied by the user. At the same time, the capability has been created to show recommended values for each component. Based on certain user entries, error messages, help messages, and questions can be outputted to the user.

**Multiple User Input Mechanisms:** Fully implemented the slider for user entry (and integrated it into the GUI using normalized units), including minimum and maximum parameters for the inputs. The slider moves to a specific position, which corresponds to the user entry that is inputted into the text box above it.

**Bode Plots:** Implemented the various types of bode plots that are needed in the GUI. Enabled a cursor function that can be used to locate the position of everything on the bode plots. Using the cursor mode and keyboard commands, the clients of the design development tool can select multiple data points on the plot.

**Dynamic Visual Representation of Data:** Implemented a display crossover frequency, phase margin, and gain margin above the bode plots. As the component values and other adjustable inputs are changed, the graph and the statistics will change.

**Output Window:** Set up the entire window of graphs with options for tasks such as printing and saving when the user runs the program. The graphical user interface will sustain its high resolution settings, no matter what the size of the window is changed to.

**Part Configuration Files:** A part configuration file was first developed using Microsoft Excel spreadsheets to contain all important parameters for the NCV891930 and NCV97400. These spreadsheets were then converted to CSV files to bypass licensing issues for users who do not own Microsoft Office.

**MathCAD Conversion:** The sample MathCAD files used for the customer design process were converted to MATLAB scripts. This includes functions that can work with values imported from the part configuration files as well as regenerative functions that use the values entered in the graphical user interface.

**Intermediate Graphs:** Several graphs are needed for debugging the mathematical operations derived from the sample MathCAD files. These graphs show the gain and phase at several points in the code and they are available to engineers for testing future products before releasing an updated software package. The final graph is displayed in the graphical user interface which updates when new component values are entered.

**Support for SI Unit Prefixes:** By default, MATLAB does not support for prefixes such as milli, micro, nano, and pico. Conditional statements were added to convert user inputs that contain SI prefixes to a number format that MATLAB can interpret. This will make it easier to enter numbers with a large or small order of magnitude.

**Power Dissipation/Efficiency:** Along with the required gain and phase calculations, many other equations were added to calculate the power dissipation of each component and the integrated circuit. These values are used to calculate the power efficiency overall.

**Screen Resolution Compatibility:** All GUI components are defined in normalized units. In other words, the size of the text and buttons are a function of the window size. This makes the software package compatible with all screen resolutions.
Fig. 1: A prototype for the graphical user interface

Fig. 2: The slider is utilized to change component values
Fig. 3: The graph with cursor functionality and relevant graphical information displayed.

Fig. 4: Screenshot of the CSV file for the NCV891930.
PROJECT MOTIVATION:

Electromagnetic interference (EMI) distorts signal transmission in copper wires. Current power grid substations are rarely shielded from electromagnetic interference, which makes them particularly vulnerable to serious equipment failures, possibly leaving entire cities or counties without power for weeks. Fiber optic cables are immune to EMI and thus, provide a reliable and effective solution to this problem. Fiber provides superb signal quality while not conducting any electricity. Fiber is also resistant to fluctuations in environmental conditions and can be directly placed in water without affecting the signal. Additionally, the glass core makes tampering with fiber optic cables impossible, offering a higher level of security. Fiber optics are a safer, more rugged alternative to copper cabling especially in electrical facilities where strong electromagnetic fields are present. Integrating fiber optics is the next step to modernizing the power transmission and distribution industry and is the motivation for our project.

ANTICIPATED BEST OUTCOME:

The anticipated best outcome of this project is to produce two manufactured printed circuit boards to interface via fiber optic cabling. Once connected to their respective cabinets (High Voltage and Local Control) the two boards will be able to effectively communicate back and forth using bidirectional fiber optic transmission. The Local Control Cabinet (LCC) will control the state and position of each disconnect and ground switch in the High Voltage Cabinet (HVC). The cabinet will also have the capability to operate a switch or simply provide information to the user.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:

This technology will ultimately yield a wider range of product selection for potential customers of Phoenix Electric Corporation. Fiber optic applications currently exist in the power industry, however, they are considered newer technologies. This product can potentially place Phoenix Electric Corporation on the forefront of custom high voltage equipment installation. The replacement of copper cabling with fiber will significantly cut down the cost of labor for installations. In addition, fiber optic transmission offers a more secure system, immune to electromagnetic threats. And now with the constant need for system security, this enhancement will likely inspire greater appeal to possible customers.
PROJECT OUTCOME:

The Anticipated Best Outcome was not achieved.

KEY ACCOMPLISHMENTS:

Serial Communication Protocol: Created a proof-of-concept using two Cmod S6 Diligent breakout boards to implement the serial communication protocol and send/receive data using a low voltage differential signal output. This test proved the protocol could work across some channel between two different Spartan 6 FPGA.

Start Bit Detector: This VHDL entity block served to determine when a “start sequence” was received across the communication channel to the receiving FPGA. As the most complex entity, the start bit detector was essential to the grand design of the serial communication protocol.

Local Control Cabinet (LCC) PCB: Designed schematics and board layout using the CircuitMaker software. The LCC board is a 7 layer board with 3 power planes and 4 signal layers. The LCC board uses 48 ON/OFF checks, 8 main contact checks, and 12 relay control signals to control the state of the high voltage equipment. The board also includes an onboard FPGA with a programming header and separate programmable memory IC.

High Voltage Equipment (HVE) PCB: Designed schematics and board layout using the CircuitMaker software. The HVE board is an 8 layer board with 4 power planes and 4 signal layers. The HVE board uses 8 ON/OFF checks, 8 main contact checks, and 12 relay control signals to interface with the LCC and control the high voltage equipment.

PCB Power Requirements: We were successful in generating 12VDC from 125VDC and 1.2VDC and 3.3VDC from 12VDC.

FPGA Programming: The FPGA that we chose was the Spartan 6 by Xilinx. We chose the Spartan 6 because of its low power draw, ease of programming, cost effectiveness, and number of I/O pins. A major accomplishment of this project was being able to program and send signals to different components on the board from the FPGA. This showed that the circuits that were designed in the PCB were correct and worked as they were intended to.

ON/OFF/MC Continuity Checks: Programmed FPGA to send a high signal to one of the continuity check pins & set a diode on board to turn on when the return path saw a high signal.

Relay Control: We were able to successfully control the operation of the relays by connecting a load on the output of the relays. Will need to add heat sinking in the future for the 15A load.

Fiber Optics: The boards have fiber optic communication using BiDi transceivers. This allows for serial communication between the High Voltage equipment and the Local Control Cabinet.

Testing: Once the boards were received, they were powered up and a smoke test was performed. Once it was confirmed that the board passed the smoke test and no shorts were found, we began to test the components on the boards. We were able to test each major circuit from the PCB design using a VHDL test code, a multimeter and an oscilloscope to confirm that the signals were being sent to the correct location. We were able to confirm the following: power generation, power generation diodes, status diodes, program the FPGA, MC continuity check, OFF/ON continuity check, LVDS PECL chip, and that the FPGA can switch relays.
Fig. 1: Local Control Cabinet and High Voltage Equipment field installation

Fig. 2: Master Configuration between High Voltage Cabinet and Local Control Cabinet
Fig. 3: High Voltage Board Layout with each circuit section highlighted

Fig. 4: Final Board High Voltage Board (left) and Local Control Cabinet Board (right) with transceivers and fiber connected
PROJECT MOTIVATION:
The objective for the Pison iOS integration project is to extend Pison’s existing Windows and Android systems to encompass macOS and iOS systems. Device compatibility will increase Pison’s competitive market-space; by incorporating the largest device platforms, Pison can offer their device to a wider range of customers. Ultimately, this equates to greater profits and overall recognition within the wearable and assistive technology markets.

Another motivation of the Pison iOS integration project is saving Pison’s engineers time by writing code that is portable and compatible with Pison’s pre-existing Java system. Without interfacing with Pison’s existing system, every addition would need to be rewritten for the macOS and iOS platforms. Instead, by adding Bluetooth functionality and bridging it with their existing system, we allow Pison to transfer all of the work they’ve done to the macOS and iOS platform. Saving time while producing cross-platform software provides invaluable resources for the development of Pison products.

ANTICIPATED BEST OUTCOME:
The anticipated best outcome is to have a fully functioning macOS platform. The macOS platform will be a dynamic library that will contain method definitions for Pison’s existing Java System. The Pison engineers will load the dynamic library into the Java system and be able to communicate with the macOS Bluetooth hardware. The library will contain a Bluetooth manager class written in Objective-C, a callback class written in Objective-C++, and a Java Native Interface written in pure C++. The dynamic library will give the user all the same functionality as Pison’s existing Windows and Android systems.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
Our project is unique in that there currently does not exist an open-source library that allows Java to directly access Apple’s Bluetooth hardware. Additionally, there is a very limited number of resources that explain the Java Native Interface, which is critical to accomplish this. By making the Pison iOS Integration Project open source, Pison creates an insightful resource to share with other developers translating a Java system to an Objective-C system to gain compatibility with Apple’s Bluetooth hardware. Economically, completion of this project prevents the need for Pison engineers to rewrite all current and future Java code in languages that are compatible with Apple’s Bluetooth Low Energy hardware.
PROJECT OUTCOME:

The Anticipated Best Outcome was not achieved.

KEY ACCOMPLISHMENTS:

**Low Energy Bluetooth (BLE):** Researched Bluetooth LE and how it communicated with devices. Implemented code to communicate with a Low Energy Bluetooth device.

**Objective-C:** Learned Objective-C to implement Bluetooth manager code. Created programs to check the team’s understanding of the features unique to Objective-C.

**Java Native Interface (JNI):** Learned how to interface Java and Objective-C. Implemented a program to demonstrate how to use JNI to call to Java. Wrote a native Java program, compiled it to create a native library. Wrote C++ code that defines the Java methods. See Fig 1 for more information about the JNI process.

**Noble:** Noble is an existing platform that utilizes many aspects of the Core Bluetooth Framework that the project relies on. Using Noble and Node.js, a code that scans and connects to local peripheral devices was created. The scanning code was the starting point for using core Bluetooth in this project.

**Setup Bluetooth Manager (Objective-C):** The initial function allocates the space in memory for the Central Manager and then initializes it. It sets all helper variables and booleans to their appropriate values, which later ensures the code is happening sequentially, the central manager is not busy, the information is retained through strong pointers, etc.

**Scan and Connect to Device (Objective-C):** To circumvent the need for wait functions and additional booleans, the scan function repeatedly calls itself until the manager has hand enough time to power on. The connect function is then invoked; capable of getting a list of known peripherals by their identifiers, will automatically connect to Pison devices based on their UUID.

**Populate Services and Characteristics (Objective-C):** Apple provides two functions that are automatically invoked upon a service or characteristic of the device being discovered. Because the Java code needs something to call when it’s ready to get the services and characteristics, however, invokable helper functions had to be added to pass this information to the JNI.

**Read, Write, and Notify (Objective-C):** Reads the Uart transmitter characteristic value and prints it to the console so that the user is able to see what is being received. Takes a value from the user and writes it to the Uart receiver characteristic. Monitors the Uart transmitter data and detects changes in data and notifies the user of changes. See Fig 2 for more information about the Bluetooth manager dependencies.

**Callback class for Objective-C++ library:** An Objective-C++ code that wraps the Objective-C code so it can be called from the Java Native Interface implementation which is written in pure C++. Implements functions that call all of the Bluetooth manager class functions. Implements functions to read the Objective-C objects because the pure C++ JNI code cannot have any link to the Objective-C code.

**Setup Bluetooth Manager (C++/JNI):** Initializes the central manager from the Bluetooth code and the Java Virtual Machine pointer. Calls the setup function from the Callback class and reads the state of the central manager. Change the Bluetooth status to Bluetooth manager state. To see how the files are organized to make a JNI call possible, see Fig 3.

**Scan and Connect to Device (C++/JNI):** Makes four calls into the callback library to scan, check if devices have been discovered, and read their UUID and device name. Also invokes two helper functions that convert the object to Java.

**Populate Services (C++/JNI):** Converts the native device to a Java device, and calls into the callback library to populate services, which in turn invokes the method that waits within the Objective-C code for a service to be discovered and returns it. See Fig 4 for more information about the JNI conversion from Objective-C to Java.
Fig. 1: Example of the Java Native Interface (JNI) process. The diagram shows how the JNI passes information as well as calling methods from Java and functions from C++.

Fig. 2: Flowchart of the Bluetooth Manager Class. This shows the dependencies of the central manager which controls the Bluetooth hardware.
Fig. 3: Shows the file hierarchy within the Pison iOS Integration Project. Displays the division of major files and the dynamic BLE library.

Fig. 4: Example of object conversion from Objective-C to Java. The Java functions call C++ functions which then call to the Objective-C class using the Objective-C++ wrapper. Each function call returns information to Java using the reverse function call path.
PROJECT MOTIVATION:

Hydrophones are underwater receivers akin to audio microphones. Reference hydrophones are calibrated hydrophones used in support of underwater acoustic systems, such as sonar and acoustic communications systems. The purpose of this Capstone project is to integrate the data acquisition and control functions of a multi-channel test facility into a single-channel capability, transforming the analog reference hydrophone to a digital one. The electronics (with embedded software) will be contained in a small enclosure which provides the interface to an analog hydrophone, provides programmable gain and filtering, analog-digital conversion, two-way synchronization with the transmitting system under test, and an Ethernet interface for control and data. Software on a PC will be required to control the electronics and collect the received data.

ANTICIPATED BEST OUTCOME:

The Anticipated Best Outcome was not achieved. The best outcome of this project would be a working hardware interface to a selected reference hydrophone with programmable gain, filtering, test tone, adjustable sample rate, and external trigger. The computer would provide the command and control functions to adjust the hardware settings and capture the data from the digital hydrophone, while displaying the time series and FFT. The analog interface was designed and simulated. The firmware and software were completed.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:

If Best Outcome is achieved the Digital Reference Hydrophone (DRH) will be used as a tool in the development and testing of Raytheon’s own underwater transducers. Raytheon will have the ability to synchronize measurements of Systems Under Test with reference hydrophone measurements. The resulting increase in data reliability will give Raytheon the ability to distinguish between test anomalies and true design issues. As a result this change will significantly reduce the time required to diagnose and debug issues with ongoing designs, thereby significantly reducing the development cost and turnaround time for new systems.
PROJECT OUTCOME:
The Anticipated Best Outcome was not achieved.

KEY ACCOMPLISHMENTS:

**General block diagram** - A block diagram was crucial to understand the full scope of the project and was also used to create a schedule. As a result a diagram of the complete unit including interfaces to subsystems was built. (Figure 1)

**State Diagrams** - Used to structure programs and designs, visualizing the operations of each component. It’s very helpful in determining whether changes need to be made to function to spec. On the software side, we used them to sketch and plan the interaction of methods and classes in order to do things like run the main loop on the Java side. For example, we would decide when the main loop would send a packet to check the status of the hardware. (Figure 2)

**Full User Datagram Protocol Server and Client** - Built in C on the embedded side, and Java on the PC side. The two programs are capable of sending commands to the embedded system from the PC, and sending acoustic data to the PC from the embedded system. The server side on the embedded system is also capable of taking the PC commands and manipulating the board to perform certain functions based on those commands. In addition, the PC client spins off a separate program written in C to transcribe the acoustic data sent from the embedded system into a text file.

**A First Stage Bootloader for Board Writes and for Running** - Two separate FSBLs are required in the current version of the Xilinx SDK, one to program the design directly into the board’s onboard NOR flash memory, and the other to load the design from that memory after a power cycle.

**Functional System in Vivado** - To begin implementation of our design on to the board all of the clocks and BRAMs must first be configured in Vivado. A preliminary design was completed that brought out all the necessary ports to finish the FSBL. The handoff file was created and is now ready to be used in the SDK. (Figure 3)

**Stage 1 & 2 Analog Front End** - The first stage of the AFE is composed of an active bandpass filter. This stage has three requirements: impedance matching, filter the incoming signal and supplying gain. The goal is to equalize the input signals of all the 4 hydrophones so that they have similar signal voltages going into the second stage of the AFE. The second stage is composed of 3 lowpass filter and one amplifier circuit that provides additional gain to the signal. This stage has two requirements: filter the incoming signal and supplying gain. All of this has to be performed without producing too much noise so that the data is not compromised.

**Schematic Capture** - The schematic captured contains the connection of the analog components and the connections from the hardware to the FPGA. It lays out the path from the hydrophone as an analog input signal through the active filters to the ADC. The schematic also contains the connections between the ADC and the FPGA, as well as the path from the FPGA to the hardware. This input is used as a Test-tone to test the hardware. It also contains the schematic for the power supply of the FPGA MicroZed and analog components. (Figure 4)

**Completed Programmable Logic** - VHDL Modules were written and simulated in Vivado to service each portion of our project. The functions of the VHDL code include: an ADC Interface, ability to externally trigger, accept a trigger, create a test tone, read the parameters from a BRAM, and place all of the samples into BRAM. The hardware has the ability to communicate effectively with the software to monitor the status of the finite state machines. The simulation was performed by creating testbenches that were able to simulate the logic that was implemented.
Fig. 1: Block Diagram of completed device

Fig. 2: State Diagram of Ping Pong Buffer
Fig.3: Block Diagram of Programmable System in Vivado

Fig.4: Schematic Capture of the Analog Front End
PROJECT MOTIVATION:
The main component of this project is Blank Out Signs (BOS), which are LED arrays that can display messages to motorists. As opposed to a Dynamic Message Sign which is more akin to an LCD monitor for a computer and more complicated to implement. A BOS operates by running current across resistors to create contacts that act as switches to different sign circuits with the assistance of a low-cost microcontroller to display various predefined messages. A good example of this is a typical lane control sign on the highway which designates open and closed lanes. Since the messages are pre-programmed, it can be difficult to change what is displayed, and very costly to implement an over land communication system. SES America hopes to use modern technology to retrofit old BOS technology with wireless communication capabilities. This will simplify the process of changing the sign’s message by providing a user friendly web application to send messages to the desired sign.

ANTICIPATED BEST OUTCOME:
The Anticipated Best Outcome of this project is to successfully interface a cellular modem with a microcontroller in order to send and receive messages from a web application to a sign. This cellular modem and microcontroller system must be able to retrofit onto the existing Blank-Out Sign architecture. The web application must be able to communicate with the cellular modem via the internet and the LTE network thereafter. The web application must also store information about a signs location, status and message. The ability to display these messages remotely is critical to achieving the best outcome.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
The most apparent implication of this project is the ability to alert motorists of roadway hazards more efficiently and allow road workers to change the sign’s messages safely and out of harm’s way. The organization that utilizes this product will be able to block off certain roadways and redirect traffic away from newly created obstacles such as car accidents. This could potentially save the average motorist thousands of dollars in accidents per year. Since one of the key requirements of the product is to be backwards compatible with the existing blank out sign architecture, this could in turn save companies an exuberant amount of money in updating their sign architecture. Being able to control these signs remotely will allow for placement of signs in rural areas of the world while still maintaining the typical functionality through the LTE network.
PROJECT OUTCOME:

The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Web Application Overhaul: PHP to Javascript - Last year when this project was entered in the capstone program, the team had developed the entire project in PHP and HTML with a few functions in Javascript. One of the major changes we made to the project this year is changing all of that PHP and HTML over to Javascript entirely. In this new implementation we are using the MERN web development stack. MERN stands for Mongo, Express, React, Node. MongoDB is a noSQL database. Express is a framework for routing on web servers. React is a client side development framework. Finally, Node is a web server developer framework. This change is important because it localizes the whole project to one language for every need.

Deployed Application to EC2 Instance - Deploying the application to the EC2 instance allows us and others to access the web page which is an integral portion of our project. The application is hosted on Amazon Web Service's EC2 Instance which essentially acts as a server in the cloud that applications can run on. On this instance, we have deployed a database as well to store user information and sign information.

Integration of Cellular Modem Communication to Web Application - Connecting the cellular modem and Arduino system to our application was a major milestone for our group. This opens a line of communication between one master sign and the application. The cellular modem sends a series of requests to the application that returns the message desired by the user and defined by an Over the Air protocol developed by SES America for the purpose of sending data over the LTE network. The cellular modem sends out requests that constantly check whether the sign is updated or not.(Fig. 4)

Unique Users and Role Based Access Control - All data from the web application will follow the CIA Principles of Confidentiality, Integrity, and Availability. Secure user authentication allows us to ensure that only registered users can alter their signs in our web application. Each log in and sign up request is validated with a schema validator to guarantee that the data being entered is valid. Each user will have a unique session with JSON Web Tokens (JWT) that will be authenticated with each request. If a request token’s timestamp doesn’t completely match the one on file, then the user will be denied access to their account. This is to prevent multiple sign ins on the same account. In addition, we established permission levels with Role Based Access Control. This controls what functions the user can perform. A normal user can view and modify their signs, while the Admin can view signs and change permission levels of any registered user in the system. (Fig. 3)

Sign Display and Functionality - The sign displays a message that is retrieved from the application and whose functionality is defined by the Over the Air protocol (Fig. 2). This is known as the “Display Message” function and is one of a few functions of the BOSCON system. The next major function is the “Forward” function. The Forward function sends along the message in a chain from master sign to slave sign. The received message is then displayed on the slave sign. The final function of import is the “Relay” function. The Relay function is a command sent to the first slave sign that tells that sign to forward the message to another slave sign(Fig. 1.). Currently, the Relay and Forward functions are being simulated with an LED circuit connected to an RF transmitter and receiver since we lack the proper hardware to fully outfit two more signs.
Fig. 1: The master-slave sign relationship. The application sends the command to a master sign that can then relay and forward the message based off of the command sent.

<table>
<thead>
<tr>
<th>Commands</th>
<th>Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 0 0</td>
<td>0 0 0 0</td>
<td>Blank operation</td>
</tr>
<tr>
<td>0 0 0 1</td>
<td>0 0 0 1</td>
<td>Display a message</td>
</tr>
<tr>
<td>0 0 1 0</td>
<td>0 0 1 0</td>
<td>Return a status message</td>
</tr>
<tr>
<td>0 1 0 0</td>
<td>0 0 1 1</td>
<td>Relay a message</td>
</tr>
<tr>
<td>1 0 0 0</td>
<td>0 1 0 0</td>
<td>Forward a message</td>
</tr>
</tbody>
</table>

Fig. 2: Table outlining the Over the Air protocol and the corresponding bit values. The command is the upper half of the byte while the value is the lower half of the byte. For example, a 0001 command value and 0010 would display a “No Right Turn”
Fig. 3: This diagram describes the general flow of the security steps taken to ensure that the user performing functions on the web application is correctly verified.

Fig. 4: Communication system for a master sign in the network. Includes cellular modem, Arduino, and two relays.
TECHNICAL DIRECTORS:
David Dionisopoulos
James Lospaluto

TEAM MEMBERS: (L to R)
Adam Warriner (E)
Mason Dumaine (C)
David Dionisopoulos
James Lospaluto

PROJECT MOTIVATION:
The Supfina Machine Company utilizes several techniques in their surface finishing machines, with differing use cases. One of Supfina’s previous machines, the Nano, has generated significant interest from industry players for the potential of cup-wheel flat finishing. This technique is able to achieve incredible surface tolerances at high part process rates. Currently, the most problematic limitation of this method is the small maximum workpiece diameter. To meet the demands of its customers, and to expand its surface finishing product line, Supfina commissioned an overhaul of the SM-814.

Informally known as the big brother of the Nano, this platform previously proved the viability of this technology on larger workpieces. By applying the lessons learned from the Nano, the 814 machine will be updated so as to provide the benefits of both platforms. Modern automation techniques combined with a doubled maximum workpiece size will produce a truly unique surface finishing platform.

ANTICIPATED BEST OUTCOME:
Team Supfina’s anticipated best outcome is to design and implement the electrical hardware and software for the new SM-814. The machine will be able to flat finish a workpiece surface to a Ra (roughness average) of less than 0.05μm. These exacting tolerances must be achieved in a cycle time of less than 30 seconds for stock removal of less than 100 microns. The design of the hardware and software both require significant focus on the safety of the mechanical hardware and, more importantly, the safety of the operator. The final end goal being a fully functional superfinishing machine.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:
The completion of a physical 814 machine will not only enhance Supfina’s surface finishing product line, but also the further development of their technology. Although Supfina already has impressive capabilities in the surface finishing industry, this machine provides a truly unique augmented platform with which their cup-wheel technology can be perfected. This machine will serve as the floor model at Supfina and be used in demonstrations for customers interested in purchase. It will also be used in Supfina’s process research and development lab, where it will be used to test applications and perform contract work for customers.
PROJECT OUTCOME:
The Anticipated Best Outcome was achieved.

KEY ACCOMPLISHMENTS:

Flowcharts for program routines: Defines the general operations and ordering for routines of particular importance, such as the homing and auto sequences. The program flow defined in these charts was then used to create the program’s ladder logic routines. Figure 2 provides an example of two rungs of ladder logic, and an accompanying translation into a logical flow chart. Rungs of ladder logic are evaluated sequentially left to right, top to bottom, until a logical check fails. At that point, the next rung is evaluated. This figure demonstrates the use of several basic ladder components, including open and closed bit checks, and a timer.

Hardware and software configuration: Communication between the machine components is set up through the standardized procedure defined in the Allen Bradley machine automation pipeline.

Auto and Homing program sequences: These sequences lay out the exact sequence of actions that the machine performs. The automated part processing mode of the machine starts in the auto sequence. Once the part is finished, the homing sequence is invoked to return the machine to its rest state. The homing sequence is also used when an error occurs, and the machine needs to recover.

Motion control routines: The motion control routines define physical movements of the vertical, cupwheel, and workpiece axis. These routines specify how particular motion commands should be carried out. Many calculations are done to ensure precise movements, and takes into consideration many small details such as the wear on the cupwheel abrasive.

Fault management routine: When the machine behaves in an undesired or unexpected way, a method of determining what happened is required. This routine defines all the possible faults, and there

Human Machine Interface: The HMI, shown in Figure 3, is a touch screen control interface designed for effective communication with the PLC while remaining intuitive to the user. The layout of each screen on the HMI needed to be made first. This includes page navigation, button placement, and color schemes. Then every button and data display on the HMI needed to be linked to its specific IO tag assigned in the PLC program. The last step was adding descriptions for each fault monitored by the PLC to be displayed to the user.

Electrical Hardware Selection: Extensive research and power data calculations for the six motors used in the machine were done in order to select the appropriate servo drives, wire gauges, and motor overload switches. All relays, transformers, breakers, and sensors were selected based on the specifications given by the mechanical engineers at Supfina. All electrical hardware selected was listed and submitted to the purchasing department to ensure we remained under the given budget.

Electrical schematics: The schematics are broken into four sections. First is the electrical cabinet, displayed in Figure 4, which houses the majority of the electrical hardware and power distribution for the machine. The machine schematics show the wiring of the electromechanical hardware within the machine, such as the motors, door lock, and internal light. The operator panel holds the HMI, the emergency stop button, the system on/off buttons, and the light switch for the internal light. The last section was the cooling system which has the wiring for the rinse pump, the magnetic separator, and the flow sensor.

Machine Debugging: The first step of debugging is to upload the PLC and HMI programs to their respective controllers. Then power on the machine to ensure proper power distribution. Next, the faults defined in the fault routine are tested. Each fault message has its firing conditions applied to ensure correct operation. Lastly, the machine is tested for accuracy in its designed functions.
Fig.1: The completed SM-814 machine

Fig.2: The top chart displays a very basic pair of ladder logic rungs. The bottom chart provides a translation of the ladder logic into a simple flow chart.
Fig. 3: HMI on the “Main Screen”

Fig. 4: The completed electrical cabinet
PROJECT MOTIVATION:

The Agricultural and Mining industries use pumps for irrigation and water removal respectively. The pumps are located out in the field or down in a mine. It’s a time consuming process for the operators to regularly drive to the location of these pumps in order to turn them on/off and see how they’re performing. When something goes wrong with the pumps, the operators have no idea or are notified too late of the problem. Causing a delay in service and costing the customer time and money.

The Cellular Pump Controller (CPC) would allow customers to remotely monitor and control the pumps, and in turn, would save them time, money, and energy. Customers would be able to monitor and change the speed of the pump as well as get alerts right when something goes wrong. This means the customer would no longer need to perform routine maintenance checks and would only need to service the pumps when necessary.

ANTICIPATED BEST OUTCOME:

The best anticipated outcome would be a working prototype of the cellular pump controller which would contain the software and hardware to allow the pump(s) to be controlled and monitored via a mobile application. A printed circuit board (PCB) layout for the prototype should be developed. The pump controller would also transmit data over a cellular network to interact with amazon web services (AWS)(Fig. 1). A final report on goals achieved and next steps for further development of the product should be produced, along with a proof of concept design for beta testing and a current bill of materials.

IMPLICATIONS FOR COMPANY AND ECONOMIC IMPACT:

Having the CPC will start to expand the company further into internet of things (IoT) business as well as their original markets. Many companies are starting to get into the IoT and it will help show Taco continued relevance and importance by moving into that new market. Once this device is working, it can be implemented to remotely monitor and control Taco’s pumps all around the world. This gives Taco an advantage on the competition by giving a way for their customers to easily monitor their products unlike any other company. It also helps lay groundwork for continued research into IoT technologies.
**PROJECT OUTCOME:**

The Anticipated Best Outcome was achieved.

**KEY ACCOMPLISHMENTS:**

**Amazon Web Services (AWS):** AWS is the backbone of the project. It is used as a storage cloud or non-local storage device for variables and values. The values are either “desired values”, the values we want the pump to show, or the “current values”, the actual values of the pump and the sensors. Both the pump controller and the app monitor these values and update themselves accordingly. AWS also monitors one of these fields for an error alert. If something goes wrong it will notify a user via text.

**Security:** Special security features had to be implemented for interacting with AWS. The app has a sign in/ sign up screen when first launching where someone at Taco can choose the users access. The cellular pump controller (CPC) needs to have special files placed onto the device prior to being placed into the field. These files are also a way to gain access to AWS.

**Embedded Code:** The embedded code is placed on the CPC. This code needed to be able to monitor the sensors, interpret the sensor readings, and if something goes wrong immediately send an alert to AWS. It also needed to not continuously send error if one was previously sent. Lastly it updates AWS about every 30 min even if everything is fine to keep AWS updated. As the cellular connections you pay for amount data sent per month a cost effective time was needed.

**Cellular Connection:** Connect and talk to a cellular modem over a serial communication. Currently it talks over the Verizon network as a way to stay connected even in a remote location.

**React-Native App:** A working application that has ability to both see current values on AWS and change in desired values, as well as having authentication through AWS cognito (Fig 4)

**Sensor Readings:** The sensors included are a differential pressure sensors, a differential pressure sensor, a flow sensor, and a depth sensor. These sensors are wired to the microcontroller through the pluggable terminals on the PCB. The microcontroller then interprets this data and displays it on the application in readable values. (FIG 2)

**Custom PCB:** The PCB allows the sensors to be wired to the microcontroller with pluggable terminal blocks. The PCB also contains the user interface, AC/DC converter, 2 DC/DC converters, an op amp system, as well as a security chip. The AC/DC converter will take in the 24VAC input from the transformer and converts it into the 24VDC that the sensors use. The first DC/DC converter turns the 24VDC to 15VDC that powers the op amp. Then the 15VDC is converted into the 5VDC that will power the microcontroller as well as the cellular modem. (Fig 3)

**Battery Backup System:** A system that is run by a standby chip on the microcontroller. When there is power failure, the battery provides uninterrupted power for the microcontroller. The microcontroller then sends an error message to the user saying that something went wrong and the pump needs to be checked. This battery will last 10-20 minutes, which is more than enough to get the message to the user.

**User Interface:** The user interface will show the customer on site what is happening with the pump. On the PCB it displays, using LEDs, the status of sensors, running status of the VFD, and the cellular strength of the modem. It allows for easy troubleshooting of the CPC when on site.
Fig. 1: A figure showing the key components of the entire project

Fig. 2: Block Diagram Showing the sensor setup
Fig.3: A beta version of the App that can be used to interact with the CPC Displayed on a Google Pixel 2 (Android Emulator)

Fig.4: Image of the custom PCB. It contains the sensor connections, AC/DC converter, DC/DC converter and user interface.
10 Things That Require ZERO Talent
by Molly Fletcher
https://www.linkedin.com/in/mollyfletcher1/

How often do we equate success with talent? All the time. But the reality is, success isn’t created by talent alone. Just like we might see immense talent squandered, we also see underdogs unexpectedly overachieve. Here are 10 behaviors that we can always control that require zero talent yet have a huge impact on our success.

1. **Being on time.** Punctuality is a keystone habit that requires organization and planning ahead—both of which lead to greater success.

2. **Work ethic.** This is the discipline of showing up consistently and making the best decisions that lead to peak performance.

3. **Effort.** Effort is a mindset as much as it is a behavior. Few athletes worked as hard as major league pitcher John Smoltz, who is now in the Baseball Hall of Fame. I saw him extend his career by years through sheer effort and commitment.

4. **Body language.** How you move and express yourself around others shapes who you are and how you are perceived. Anyone can improve.

5. **Energy.** Everyone has energy to devote to a goal, and the decision of how much to give. Be conscious about where yours goes.

6. **Attitude.** It’s up to you to keep going. No one else can decide that. A great attitude maximizes the talent that you do have and offsets what you lack.

7. **Passion.** Perhaps the single most important way each one of us can suffocate the fear that keeps us from peak performance.

8. **Being coachable.** Anyone can become a better listener, learn from feedback, and embrace the success of others.

9. **Doing extra.** Go the extra mile. That extra work and preparation fosters confidence. Sustain, and exceed your own expectations, your success by consistently working beyond what is required.

10. **Being prepared.** Only you can give yourself the time and space to be as ready as you can be. Make it a habit, and you will make the most of your talent. There is great truth in the saying: Failing to prepare is preparing to fail.

Remember that talent is never enough. The best of the best don’t rest on what they were born with—they dig down to get the most they can. Try these 10 things (or just one!) and over time it will pay off.
New College of Engineering Building

““My single best piece of advice: it’s very important to have a feedback loop, where you’re constantly thinking about what you’ve done and how you could be doing it better, and questioning yourself.””

— Elon Musk

““Leaders are made, they are not born. They are made by hard effort, which is the price which all of us must pay to achieve any goal that is worthwhile.””

— Vince Lombardi

American Football Coach and NFL Executive

Jack Murphy
ELECOMP Capstone Design Program Assistant
URI Class of 2022
Business/Marketing Major
The unknown resistance $R_x$ is to be measured; resistances $R_1$, $R_2$ and $R_3$ are known and $R_2$ is adjustable. Only when the bridge is adjusted to be in PERFECT BALANCE, the measured voltage $V_G$ is zero, and the unknown $R_x$ is determined.

Now we can see the parallel with the 3 important aspects of the Capstone Bridge:

R1: ELECOMP Capstone Design Program

R2: ELE & COMP Seniors with diverse talents

R3: Sponsor’s Technical Director & Problem to be solved

When these aspects are in perfect balance and collaborate in excellent harmony, SUCCESS is achieved in the UNKNOWN ($R_x$): The Best Outcome of the Sponsor’s Problem