ece

4805/4806/2804

Virginia Tech ECE 4805/6 and Select Projects from ECE 2804

April 2021

VIRGINIA TECH

The Major Design Experience provides each of our participating students a culminating project experience. This evening's MDE Expo is an opportunity to share and showcase the results of 26 project teams comprised of 111 students focused on the design, build, test, and delivery of a real-world project for 14 unique industry sponsors. Those sponsors serve as customers throughout the project. Some of these sponsors supported as many as four different team projects during this MDE cohort.

In addition to the 26 MDE design teams, we have four additional projects on display in our Poster area. Two of these projects were selected from the current semester's ECE 2804, Integrated Design, course which provides a team of sophomore students a first opportunity to design, build, test, and deliver a project solution in the second semester of their sophomore year. The remaining two projects are not specific to a course but illustrate what students in ECE completing their sophomore year can achieve, and COVID limited the availability of other venues to share these projects.

MDE students contribute their knowledge and skills as part of an engineering project team focused on engineering their solution through an entire design cycle where teamwork, communications, planning, and testing are all necessary to achieve the success on display at our Expo. We have students who have never met some teammates in person, like some industry teams. Their entire class was taught remote online. Local students had access to the design studio. All were supported by shipping parts and equipment among team members around the globe. Planning had to consider location and shipping times as well as engineering considerations. Some delivered well beyond what we thought possible under COVID conditions, and some will discuss remaining work. These students represent our next generation of engineers; ready to address and overcome society's emerging global challenges.

This experience would not have been possible without the support of our 14 industry partners, our subject matter experts, and a host of other professionals committed to providing our students these exceptional engineering challenges. Thanks to all.

Congratulations to each of the 111 students; their dedication and diligence are evidenced in these 26 projects. On behalf of these students, and from me personally, thanks again to our industry sponsors, our subject matter experts, and our MDE faculty for their tremendous support in developing our next generation of engineers.

Luke Lester
Roanoke Electric Steel Professor and Department Head
Bradley Department of Electrical and Computer Engineering

Welcome to the Bradley Department of Electrical and Computer Engineering Major Design Experience (virtual) Expo. The 2021 Spring Exposition provides us the opportunity to celebrate the achievements of 111 ECE students who have come together to form 26 project teams under COVID conditions. These students' entire MDE experience was within the context of COVID. Their resilience and ability to adapt well beyond any previous expectations is evidenced here tonight by their results. Their entire course was remote online. Some of their teammates were in remote, and in some cases, austere conditions. These students have truly proven their readiness to rise to world challenges and to tackle our greatest emerging issues.

The primary MDE program goal is to provide our ECE students a "real-world" engineering experience and expose them to a first instance of engineering in a safe, controlled environment. This is not what this class received. These students established and maintained remote communications among their teams and with all of their stakeholders. They developed creative strategies to build, test, and deliver their projects. This is not the MDE experience we intended for the students, but this class understands risk and mitigation in ways only read about in our earliest MDE cohorts. The students shipped equipment among sites; conducted planning, development, testing, and customer meetings via Zoom. They created shared collaboration sites and many thrived… producing beyond expectations.

The students could not have adapted and delivered without the tireless efforts and support of our SMEs and 14 unique sponsor/customers. MDE is made possible with the dedicated support of our sponsors and subject matter experts whom we thank profusely, and this cohort highlights the limitless boundaries of those contributions. Thank you for your commitment to encourage and facilitate our Virginia Tech ECE students as they take their next steps making their contributions to society by engineering and delivering quality solutions to meet the needs.

The MDE program would like to thank Luke Lester for his vision to establish the MDE program and for his continued support in every aspect of the program. Special thanks to the instructors and teaching assistants who make this all possible. Because of each of you, we are all better indeed!

To our ECE students: Your entire culminating experience was in the context of a pandemic, but you overcame so many challenges and you are just about ready to become Engineers! Continue to grow and thrive as you invent the future as only VT ECE Hokies engineers can do!!!

J. Scot Ransbottom
Major Design Experience Director

Sponsors

We greatly appreciate their support.

Texas Instruments

Virginia Tech

TMEIC
We drive industry

Bradley Department of Electrical and Computer Engineering
Virginia Tech

VPT
Power Your Critical Mission Today

Wiley|Wilson
Constant Progress

Project Leadership

This class is only possible because of the commitment, dedication, and spirit of the following Customers and Subject Matter Experts. Thank you!

Sponsor	Customers	Project	Subject matter expert (SME)
Analog Devices	Mike Jones	Communication Ecosystem Development	Louis Beex
CISCO	Jim Warren, Tony Ricer	Containerized DevSecOps Architecture	Michael Irwin
Collins Aerospace	George Cooley	Phased Array Antenna Controller	Manteghi Majid
Collins Aerospace	Lucas Brady, Kelly Bernabe	Automated Modular Tooling	Andrea L'Afflito
Collins Aerospace	Magdi Essawy	Temperature Differential Power	Dong Ha, Minh Ngo
Collins Aerospace	Jonathan Kolbrak	Universal Power Amplifier Test Controller	Peter Han
Lockheed Martin	Tony R Keith	Next Generation CubeSat Bus	Kevin Shinpaugh
Micron	Brian Huber, Luca DiGirolamo, Zuzana Steen	Organic (Polymer) Electrodes for Flexible Electronics	Marius Orlowski, Amrita Chakraborty
Micron	Brian Huber, Luca Di Girolamo, Zuzana Steen	Thermally Immune ReRAM Memory Array with Graphene Enhanced Electrodes	Marius Orlowski
MITRE	Dale W. Herdegen, Andy Thompson, Julia B Huynh, Dennis Milam, Dave Maples	Distributed High Frequency Beamforming	Louis Beex
MITRE	Olivia Blackmon, Nick McLoota, Scott Kordella	Drone-Based Water Monitoring Sensor	Scott Bailey
NAVAIR	Jasur Mirzakhmedov, Chase Templeton, Kevin Robertson, Andrian Jordan, Israel Jordan	IEEE Robot Competition Electrical Team	Arthur Ball
NAVAIR	Jasur Mirzakhmedov, Chase Templeton, Kevin Robertson	IEEE Robot Competition Embedded Team	Arthur Ball

Sponsor	Customers	Project	Subject matter expert (SME)
Teledyne	Doug Baker	Remote Monitoring of Vacuum Gauge Tubes	Adnan Sarker
Texas Instruments	Mark Easley	TI-RSLK MAX RFID Sensor Accessory and Gripper Attachment	Peter Han
TMEIC	Thomas Tainer, Matthew Mandros, Ashin Thomas	Inertial Measurement Unit Analysis and Prototype	Ryan Gerdes
Virginia Tech Center for Energy Harvesting Materials and Systems (CEHMS)	Lei Zuo	Inductive Wireless Charging under Seawater 1	Lei Zuo, Minh Ngo
Virginia Tech Center for Energy Harvesting Materials and Systems (CEHMS)	Lei Zuo	Inductive Wireless Charging under Seawater 2	Lei Zuo, Ming Ngo
Virginia Tech ECE	Jaime De La Ree	The Beat Goes On: Next Gen Heartbeat	Jaime De La Ree
Virginia Tech ECE	Yuhao Zhang	Machine Learning Model for Wide-Bandgap Semiconductor Design	Cindy Yi
Virginia Tech ECE	Yizheng Zhu	Low-Cost, Wearable Fiber-Optic Curvature Sensing System for Biomechanical Characterization of Upper Extremity Motion	William Yu
Virginia Tech ECE	Luke Lester	Washington Quarter Identification with Machine Vision	Creed Jones
VPT	Dan Sable	Magnetic Levitation Team 1	Matt Strehle
VPT	Dan Sable	Magnetic Levitation Team 2	Campbell Lowe
VPT	Dan Sable	Magnetic Levitation Team 3	Robert Crnkovich
Wiley Wilson	Steve Bowman, Mark Adkinson, Dan Morton	Campus Electrical Distribution Planning	Minh Ngo, Jaime De La Ree

Guest speakers in order of appearance:

In addition to our project sponsors and subject matter experts, there were many others that significantly contributed to the success of this class. We want to take this opportunity to express our deep-felt appreciation and thanks for their contributions.

William Baumann

Virginia Tech - ECE

Design Studio Safety Training and Material Procurement Instruction

Grant Brewer

Virginia Tech - LINK | The Center for Advancing Industry Partnerships

Innovation and Intellectual Property Management.

Agenda

2:30 pm	Students arrive and check in
3:00 pm	Registration
3:30 pm	Presentations begin (Welcome)
5:15 pm	Presentations end
6:30 pm	Awards
7:00 pm	Event Close

Team tracks

Track 1

3:45 **Micron**
Organic (Polymer) Electrodes for Flexible Electronics

4:00 **Micron**
Thermally Immune ReRAM Memory Array with Graphene Enhanced Electrodes

4:15 **Collins Aerospace**
Phased Array Antenna Controller

4:30 **Collins Aerospace**
Automated Modular Tooling

4:45 **Collins Aerospace**
Temperature Differential Power

5:00 **Collins Aerospace**
Universal Power Amplifier Test Controller

5:15 **Virginia Tech ECE**
Machine Learning Model for Wide-Bandgap Semiconductor Design

Track 2

3:45 **MITRE**
Distributed High Frequency Beamforming

4:00 **MITRE**
Drone-Based Water Monitoring Sensor

4:15 **NAVAIR**
IEEE Robot Competition Electrical Team

4:30 **NAVAIR**
IEEE Robot Competition Embedded Team

4:45 **Virginia Tech ECE**
Washington Quarter Identification with Machine Vision

5:00 **Analog Devices**
Communication Ecosystem Development

Track 3

3:45 **VPT**
Magnetic Levitation Team 1

4:00 **VPT**
Magnetic Levitation Team 2

4:15 **VPT**
Magnetic Levitation Team 3

4:30 **Virginia Tech ECE**
The Beat Goes On: Next Gen Heartbeat

4:45 **Virginia Tech ECE**
Low-Cost, Wearable Fiber-Optic Curvature Sensing System for Biomechanical Characterization of Upper Extremity Motion

5:00 **TMEIC**
Inertial Measurement Unit Analysis and Prototype

5:15 **Wiley Wilson**
Campus Electrical Distribution Planning

Track 4

3:45 **Virginia Tech Center for Energy Harvesting Materials and Systems (CEHMS)**
Inductive Wireless Charging under Seawater 1

4:00 **Virginia Tech Center for Energy Harvesting Materials and Systems (CEHMS)**
Inductive Wireless Charging under Seawater 2

4:15 **Teledyne**
Remote Monitoring of Vacuum Gauge Tubes

4:30 **Lockheed Martin**
Next Generation CubeSat Bus

4:45 **CISCO**
Containerized DevSecOps Architecture

5:00 **Texas Instruments**
TI-RSLK MAX RFID Sensor Accessory and Gripper Attachment

Project teams

Communication Ecosystem Development

CHALLENGE

Our challenge was to expand the communication ecosystem for ADI's Quad-MxFE platform by writing beam-steering algorithms and developing a linear phased antenna array. The major deliverable of our project was to create a demonstration of the board's capabilities.

LEFT TO RIGHT: Adam Vaughan, John Hiemstra, John Roth, Lizzy Morris, Matthew Herrity | **SME: Louis Beex**

Adam Vaughan

Appomattox, Va.

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I aspire to work in the American defense industry advancing communications and signal processing technologies for applications such as electronic warfare, satellite communications, and other related fields.

Class comment: I appreciate the professional connections made with our project's customer and subject matter expert, as well as the opportunity to work with a real-world customer to produce a meaningful and valuable product.

John Hiemstra

Chantilly, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I aspire to work in signal processing with a position that will be meaningful and allow me to continuously expand my knowledge in the field.

Class comment: I appreciated how the course encompassed the entirety of a project and allowed us to see the whole process instead of focusing on a single part of it.

Lizzy Morris

Columbus, Ohio

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I will be pursuing a career in microelectronics and PCB design. I hope to work in new product development and eventually become a technical expert in my field.

Class comment: I appreciate that this class gave our team the opportunity to see the business side of engineering. This was a unique opportunity for us to learn team management skills that aren't always stressed during internships or co-ops.

Matthew Herrity

Lovettsville, Va.

Bachelor of Science in Computer Engineering and Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I would like to work in a position that will allow me to do both software and hardware development.

Class comment: I appreciate the practical experience this project gave me. The rest of college glosses over the planning and resource acquisition that was a highlight of this course.

John Roth

Fairfax, Va.

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I look forward to expanding my RF/Microwave skillset in the defense industry and using my technical knowledge to eventually manage and lead teams.

Class comment: : I appreciate the professional experience this class provided and the opportunity to apply what I learned in my classes to real-world problems.

PROJECT SPONSOR: MIKE JONES

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Containerized DevSecOps Architecture

CHALLENGE

Our objective was to establish and demonstrate a scalable reference architecture and a supporting budget to automate the deployment of a containerized application across distinct containerized development, stage/pre-production, and production environments.

LEFT TO RIGHT: Charles Ranson, Charlie Kelley, Osadebe Osakwe | **SME:** Michael Irwin

Charles Ranson

Appomattox, Va.

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I hope to provide solutions that help advance society in an ethical manner.

Class comment: I appreciated the opportunity to have an open-ended project that allowed me to learn from experienced professionals.

Charlie Kelley

Charlotte, N.C.

Bachelor of Science in Computer Engineering
Computer Engineering (general)

Aspirations: I would like to have a career as an embedded system engineer.

Class comment: I appreciated the interactions with our customers, our SME, and our mentor. These interactions went beyond the typical classroom experience by providing something similar to workplace communication and presentations.

Osadebe Osakwe

Lagos, Nigeria

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

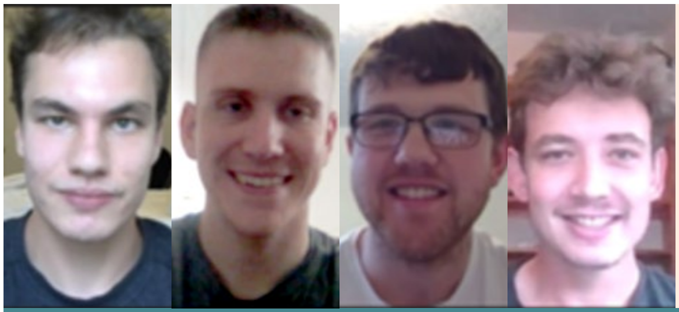
Aspirations: I aspire to solve problems by leveraging technology, especially in low-income areas.

Class comment: I appreciate the professional experience that this class provided me by allowing me to work with an established company.

PROJECT SPONSORS: JIM WARREN, TONY RICE

CISCO

Antenna Controller



CHALLENGE

Our objective was to design and build a circuit to control the net beam direction of a set of antennas via phase shifting. We also had to implement wireless communication using a microcontroller to control the circuit remotely.

LEFT TO RIGHT: Matthew Tobin, Daniel Felkel, Nelson Hurley, Matt Evans | **SME:** Manteghi Majid

Matthew Tobin

McLean, Va.

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I aspire to work in a career that requires me to think critically and solve problems every day.

Class comment: The class introduced me to the procedures and challenges associated with working on a project in a professional setting.

Daniel Felkel

Coventry, Rhode Island

Electrical Engineering
Radio Frequency and Microwave Engineering

Aspirations: I will be commissioning as a 2LT in the U.S. Army in the Cyber branch where I will use my skills as an electrical engineer to further the Army's mission.

Class comment: This class helped me better understand what to expect when working on an engineering project in a professional setting.

Nelson Hurley

Bristol, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work with power systems and power control.

Class comment: This class has given me experience with real-world projects that I can apply to my future career as an engineer.

Matt Evans

Robbinsville, N.J.

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I hope to work as an RF or systems engineer either in the commercial wireless communications field or the defense industry.

Class comment: This course offered the opportunity to apply topics from classes at Virginia Tech to practical scenarios that we might face in the industry.

PROJECT SPONSOR: GEORGE COOLEY

Collins Aerospace

Automated Modular Tooling

CHALLENGE

We designed and built an autonomous sensing system that is controlled by means of a Raspberry Pi, a camera, and a rangefinder. Our system is used to align a single modular tooling base in order to increase efficiency in manufacturing processes.

LEFT TO RIGHT: Matthew Du, Jeannette Judenberg, Michael Otooni, Marcus Volpert, Calvin Truong | **SME:** Andrea L'Afflito

Marcus Volpert

Manassas, Va.

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I aspire to take the knowledge I learned from school and apply it to my professional career in electrical engineering.

Class comment: I appreciated the professional experience provided in this class and the opportunity to apply knowledge from my classes to a real-world problem.

Calvin Truong

Fairfax Station, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: After graduation I hope to become an electrical engineer working with embedded systems. I aspire to use my knowledge and experience to make an impact on future technology.

Class comments: After having the opportunity to apply my knowledge in a professional manner, I can confidently say that I am much more prepared to join the work force. The most important lesson I learned from this experience was how to effectively communicate with clients, teammates, and supervisors.

Matthew Du

Baltimore, Md.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to pursue a career at Textron Systems and become a multifaceted electrical systems engineer focusing on robotics and autonomy.

Class comment: I appreciate the opportunity to directly work with a customer, learn about their wants and needs, and develop a viable product solution to their problem.

Jeannette Judenberg

Marietta, Ga.

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I hope to have a career working with the electrical systems of aviation equipment.

Class comment: I enjoyed the challenge of catering to clients while working with other engineers.

Michael Otooni

Warrenton, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work full-time at a government agency and commission into the Army reserves.

Class comment: I'm very thankful to have had the opportunity to work on a project in industry and gain professional experience through this class.

PROJECT SPONSORS: LUCAS BRADY, KELLY BERNABE

Collins Aerospace

Temperature Differential Power

CHALLENGE

We designed a system that uses the temperature differential inside of an aircraft engine to harvest and deliver power to a sensor in a high-temperature environment.

LEFT TO RIGHT: Shashwat Singh, Aaron Evans, Juliet Anderson, Devin Durham, Connor Morrissey | **SMEs: Dong Ha, Minh Ngo**

Shashwat Singh
Mumbai, India

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I am a passionate believer in the concept of "power for all" and want to have a career in the power electronics sector applying the skills I learned through months of undergraduate research with thought leaders at Virginia Tech. I would like to help make models and machinery smarter, safer, mass-economical, and self-reliant.

Class comment: I liked the professional structure of this course and learning about problem identification, solution designing, prototyping, testing and debugging, client satisfaction, and project delivery.

Aaron Evans
Forest, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: After I graduate, I plan to get a job in the field of power systems engineering. I also hope to get my professional engineering license after working in the industry for a few years.

Class comment: I really enjoyed the experience of working in a team to solve a large, complex problem. The class taught me valuable communication skills and ways to work on a team effectively, which is something I will carry with me when I begin my career.

Juliet Anderson
San Cristobal, Galapagos, Ecuador

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I will work for a microchip manufacturing company as I enjoy the clean room environment and the practices involved. I hope to use that experience to eventually make a meaningful contribution to the recycling of circuit boards.

Class comments: I appreciate that this class helped me learn new skills that I can employ in future endeavors.

Devin Durham
Pulaski, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: After graduating, I would like to work with power electronics for space or defense projects. I would also like to work in the field of power protection later in my career.

Class comment: I appreciated the opportunity to learn about what having a job will be like. I also appreciated the opportunity to learn about PCB design during this project. I am very thankful for the lessons I learned through this project, and I will remember them for the rest of my career.

Connor Morrissey
Vienna, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to become an expert in power electronics and solve challenging problems.

Class comment: I enjoyed applying what I've learned over the course of my education to solve a difficult problem with my team. Communication with the customer and SMEs to determine expectations, relay project updates, and solve problems has provided many lessons that will be valuable in my career.

PROJECT SPONSOR: MAGDI ESSAWY

Collins Aerospace

Power Amplifier Test Controller

CHALLENGE

The objective of our projective was to automate testing equipment used for the execution of Mixer Spur, P1 dB, and Pin v. Pout tests for RF devices. The controller will be a Raspberry Pi that uses a user-friendly, open-source Python code.

LEFT TO RIGHT: Qihang Shan, Ryan King, Taha Rangwala | **SME:** Peter Han

Qihang Shan

Handan, Hebei, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to have a career working on circuit design.

Class comment: This class was a great opportunity for me to practice the theory I've learned over the course of my education.

Ryan King

Warrenton, Va.

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I want to investigate new methods of communication via satellite optimized for space environments.

Class comment: This class is a nice break from the regular environment of college classes (no tests, no written "homework", etc.).

Taha Rangwala

Westford, Md.

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I would like to make a lasting impact as a computer engineer by working on projects relating to autonomous systems.

Class comment: I appreciate the professional experience and collaboration that is provided from this class and the opportunity to work on a real-world problem applying what I learned in my classes at Virginia Tech.

PROJECT SPONSOR: JONATHAN KOLBRAK

Collins Aerospace

Next Generation CubeSat Bus

CHALLENGE

The aim of this project was to ensure the successful operation of the CubeSat by developing an LED-printed circuit board to indicate its real-time status. Multiple temperature sensors were added to the CubeSat to monitor the temperature of various subsystems, and a low-cost model of a deployable and retractable UHF antenna was developed using a burn wire mechanism for rapid lab testing.

LEFT TO RIGHT: Derin Araci, Jonathan Stroud, Renee Rodgers, Veena Sreekantamurthy, Yiwen Gu | **SME: Kevin Shinpaugh**

Derin Araci

Fairport, N.Y.

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I want to work in a field related to satellite communication systems and contribute to the next generation of satellite technology.

Class comment: The Major Design Experience has taught me how to apply my knowledge gained from the classes I took while at Virginia Tech to real-world problems.

Jonathan Stroud

Leesburg, Va.

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I want to be a part of the next generation of space technology and innovation.

Class comment: I appreciate the opportunity to gain experience with a real-world design project that is applicable to my interest in working in the space industry.

Renee Rodgers

Bowie, Md.

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I would like to work within the Department of Defense on research, development, and application of photonics technology. I hope to contribute innovative ideas that can be applied to help our country and the people that protect it.

Class comment: Throughout this experience, I enjoyed working with my teammates on a project to develop something new and exciting. I also appreciated that this class showed us how to face many challenges that can emerge from real-world engineering.

Veena Sreekantamurthy

Yorktown, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to have a career related to signal processing and communications in which I can develop technology that will help people.

Class comment: This class taught me how to break down and solve real engineering problems. I also got the opportunity to meet many engineers from different backgrounds and learn new information from them.

Yiwen Gu

Shanghai, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

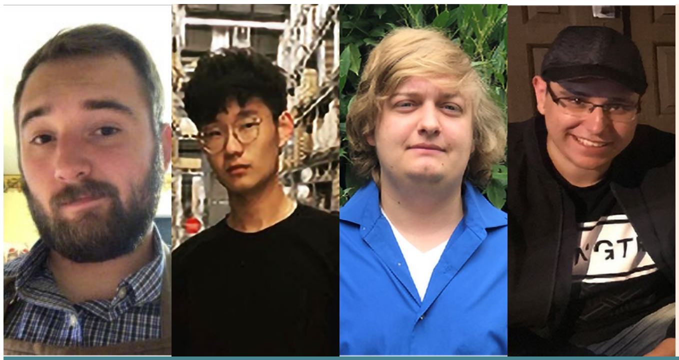
Aspirations: I want to become an electrical engineer specializing in energy and power system engineering. Specifically, I would like to have a job related to alternative renewable energies like wind turbines or solar panels.

Class comment: I learned a great deal about professional teamwork skills, how to write professional reports, and professional presentations.

PROJECT SPONSOR: TONY R KEITH

LOCKHEED MARTIN

Organic (Polymer) Electrodes for Flexible Electronics



CHALLENGE

The purpose of this project was to construct flexible electrodes by doping organic polymers with a graphene nanoplatelet powder. Flexible electrodes are a key ingredient of flexible memory cells like ReRam in the growing field of flexible electronics.

LEFT TO RIGHT: Chris Schoeb, Junming Liang, Nicholas Cappo, Ziad Aboud | **SMEs:** Marius Orlowski, Amrita Chakraborty

Chris Schoeb

Chesterfield, Va.

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I want to design PCB AOS and eventually move into management.

Class comment: Getting to do hands-on work for my project was very rewarding. Being in the Micro-Nanosystems program and getting to see how everything begins was so much fun.

Junming Liang

Qingdao, Shandong, China

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: My future aspiration after completing my bachelor's degree is to pursue a Ph.D. and continue my research in power electronics.

Class comment: I appreciate all the undergraduate research experience opportunities that professors extended to me.

Nicholas Cappo

Leesburg, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: : I would like to work on semiconductor device fabrication and testing along with integrated circuit (IC) design and testing.

Class comment: Through this course, I gained experience working with a team over an extended amount of time and enhanced my ability to find, understand, and apply relevant research to a project.

Ziad Aboud

Cairo, Egypt

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to continuously challenge myself to expand my knowledge of my field of study and create something of value for others.

Challenge:: I appreciated the real-life experiences the mentors in this class shared from their career and the opportunity to consider how this knowledge might impact my future choices.

PROJECT SPONSORS: BRIAN HUBER, LUCA DIGIROLAMO, ZUZANA STEEN

Micron

Thermally Immune ReRAM Memory Array with Graphene Enhanced Electrodes

CHALLENGE

We deposited graphene on a ReRAM memory array in order to improve the thermal and electrical properties of the array. By doing this we hope to improve the overall lifetime of the memory array.

LEFT TO RIGHT: Ankit Bhardwaj, Jeric Demasana, Nick Spicer | **SME:** Marius Orlowski

Ankit Bhardwaj

Sonipat, Haryana, India

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I want to pursue a career in power systems that will allow me to impact society in a positive way and make life easier for others.

Challenge: This class taught me many valuable lessons like teamwork, decision-making, problem-solving, etc. However, the most important lesson I learned was to show gratitude. I also learned that being organized, planning, communicating well, and having a back-up plan are critical factors for being successful.

Jeric Demasana

Arlington, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to work in the semi-conductor industry and solve challenges we are currently facing in that field. I would also like to grow as a person and apply the engineering skills that I have learned throughout college.

Class comment: I have learned that communicating with your teammates regularly is important to drive the project forward. Also, this course was a great experience for us to get hands-on training in the clean room.

Nicholas Spicer

Roanoke, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work in manufacturing and focus specifically on electrical safety.

Class comment: I appreciate the training and experience I have gained in the clean room and working with semiconductor devices.

PROJECT SPONSORS: BRIAN HUBER, LUCA DI GIROLAMO, AND ZUZANA STEEN

Micron

Modeling Distributed High Frequency Beamforming

CHALLENGE

We created an interactive GUI that models RF array configurations for monopole antennas, allowing a user to steer peak and null power directions. This capability will be used by Marines in the field to ensure reception at the intended receiver while remaining undetected by adversaries.

LEFT TO RIGHT: Amanda Hess, Chris Tousignant, Colton Baldridge, Even Clark, Pete Woodall | **SME:** Louis Beex

Amanda Hess

Loudoun, Va.

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I want to use what I learn to develop advanced technology for the betterment of my country and planet.

Class comment: Working on a project from the perspective of the creator for a contracted product was very valuable. I learned important lessons about dealing with the schedules of different individuals and different teams.

Chris Tousignant

Leesburg, Va.

Bachelor of Science in Computer Engineering and Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I hope to use my knowledge of signal processing to develop systems that protect U.S. soldiers overseas.

Class comment: I am grateful for the opportunity to work with experts in the wireless communications field and the guidance that they provided me regarding my future career.

Colton Baldridge

Lynchburg, Va.

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I hope to make the world a better place by working on advancing space systems.

Class comment: I enjoyed working on an open-ended problem that was representative of what's done in the real world.

Evan Clark

Chesapeake, Va.

Bachelor of Science in Computer Engineering and Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I would like to work on cutting-edge research in optoelectronics in the defense industry.

Class comment: I loved working with great teammates and amazing experts who taught me a great deal about this field. I think beamforming is really cool, and I had a lot of fun applying the skills I gained at Virginia Tech to make a real-world tool to help with beamforming.

Pete Woodall

Jacksonville, Fla.

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I hope to apply my skills throughout my career to help improve the world through engineering.

Class comment: I thoroughly enjoyed learning about beamforming and working with Mitre this year.

PROJECT SPONSORS: DALE W. HERDEGEN, ANDY THOMPSON, JULIA B HUYNH, DENNIS MILAM, AND DAVE MAPLES

MITRE

Drone-Based Water Monitoring Sensor Using Laser Induced Fluorescence

CHALLENGE

The goal of this project was to design, build, and test a remote sensing system using a laser, spectrometer, and Raman scattering to detect the presence of chlorophyll in a body of water, which is a reliable signifier of water health. Future plans for this project include mounting the components on a commercial drone.

LEFT TO RIGHT: Nick Ryerse, Ian Kelley, Lauren Mead, Afia Habib, Halea Fowler | **SME:** Scott Bailey

Nicholas Ryerse

Ashburn, Va.

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I hope to have a career working with lasers in the field of remote sensing.

Class comment: I enjoyed the teamwork aspect and goal-oriented nature of the class. I thought that the project in the class prepared me for my future career.

Ian Kelley

Arlington, Va.

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I hope to have a fulfilling career as an engineer. I want to be able to work on exciting projects to which I am able to make meaningful contributions.

Class comment: I enjoyed the opportunity to work on a well-defined engineering project that will prepare me well for my career.

Lauren Mead

Arlington, Va.

Bachelor of Science in Electrical Engineering and Bachelor of Arts in Spanish

Aspirations: After graduating, I would like to pursue a job in the space systems industry working with satellites. As a long-term career goal, I would like to grow into leadership roles, mentor other electrical engineers, and contribute to the advancement of the profession.

Class comment: I appreciate that I was able to work on a project that had not been done before at Virginia Tech. Designing, building, and testing showed me a more realistic view of what it would be like in industry, and I really enjoyed the thought and creativity that went into it.

Afia Habib

Vienna, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: Following graduation, I hope to apply what I learned from Virginia Tech towards promoting accessibility and inclusion in my field.

Class comment: I appreciated the opportunity to work closely with our company sponsor. It gave me an idea of what to expect out of full-time work, and I learned a lot about the intricacies that go into making a project happen.

Halea Fowler

Bluefield, Va.

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I am heavily inspired by Katie Bouman, who played a large part in the first black hole imaging. I want to be a leader in innovation through photonics and imaging.

Class comment: This class gave me valuable insight into the expectations of companies and customers. I also found that a well-balanced team with a common goal can accomplish more than five of the same person!

PROJECT SPONSORS: OLIVIA BLACKMON, NICK MCLOOTA, AND SCOTT KORDELLA

MITRE

IEEE Robot Competition Electrical Team

CHALLENGE

We designed, built, and tested an autonomous robot to compete in the IEEE 2021 SoutheastCon Hardware Competition. The competition involved navigating a Pacman style game course while avoiding ghosts and collecting pellets to score points.

LEFT TO RIGHT: Christopher Stafford, Connor Lawler, Drew Klesat, Luke Betts, Yixin Lu | **SME:** Arthur Ball

Christopher Stafford

Giles County, Va.

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I want to use the skills and knowledge that I have obtained to benefit others in ways that are both useful and create a higher quality of life.

Class comment: I enjoyed this real-world design experience and especially interacting with our customers, subject matter experts, and team members. Thanks to this course, I am better prepared to resolve unexpected challenges and effectively relay potential solutions to others.

Connor Lawler

Millersville, Md.

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I am looking forward to using my skills as an electrical engineer to serve the country.

Class comment: I appreciated the real-world structure the class was taught in.

Drew Klesat

Mechanicsville, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to pursue a career in RF and electromagnetics.

Class comment: This Senior Design class gave me valuable experience in a professional environment that allowed me to apply my knowledge from classes at Virginia Tech to a challenging real-world problem.

Luke Betts

Chincoteague, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: After graduation, I hope to work in the space industry at NASA's Wallops Island Flight Facility. My goal is to further my knowledge of the space industry as I work my way through the ranks at NASA's Wallops Flight Facility.

Class comment: I appreciated the opportunity this class offered to get hands-on experience with real customers that allowed me insight into how the job force operates on a day-to-day basis. It has also helped me understand what it takes to work on teams and how to handle issues that could affect my ability to get the job done.

Yixin Lu

Xi'an, Shaanxi, China

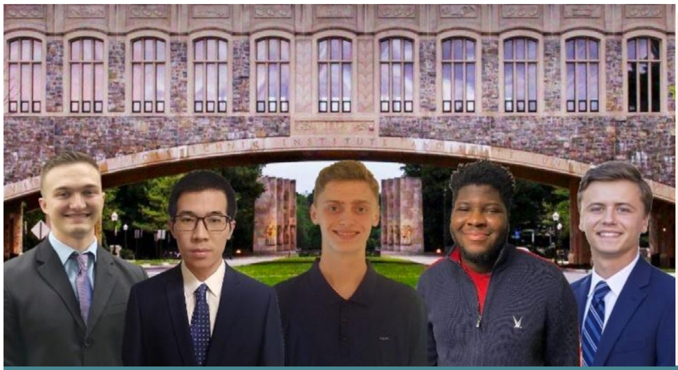
Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I aim to excel at communication and teamwork and become a good leader in a large team.

Class comment: This course provided me with an opportunity to learn how a large company's design process works. It gave me a chance to practice my communication and teamwork skills and taught me how to communicate with customers.

PROJECT SPONSORS: JASUR MIRZAKHMEDOV, CHASE TEMPLETON, KEVIN ROBERTSON, ANDRIAN JORDAN, AND ISRAEL JORDAN

IEEE Robot Competition Embedded Team



CHALLENGE

The goal of this project was to work with a hardware team to design and implement the software for an autonomous robot participating in the IEEE SoutheastCon competition. The robot had to navigate a Pac-Man maze while avoiding ghosts and collecting pellets to outscore other teams during a 5-minute time limit.

LEFT TO RIGHT: Kyle Wiggins, Yiming Luo, David Moss, Itiade Adegbulugbe, Matt Genberg | **SME:** Arthur Ball, Mark Carnie

Kyle Wiggins

Woodstock, Md.

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: After graduation, I want to apply my electrical engineering degree into my career in the U.S. Army. Following that I want to apply my experience and education towards a career in cyber security.

Class comment: As an electrical engineering major, much of my degree has focused on hardware design. Working on the embedded systems of this project has granted me the opportunity to try something that I have not had as much experience with, allowing me to expand my understanding of what it means to be an engineer.

Yiming Luo

Ningbo, Zhejiang, China

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: After graduation, I want to devote myself to developing advanced computer vision systems for autonomous systems, such as driverless cars and industrial robots.

Class comment: I appreciated the opportunity to work on a team. This professional experience taught me the importance of collaboration and communication skills. Meanwhile, I also learned that it is always necessary to leave extra time to deal with unexpected issues.

William Moss

Vienna, Va.

Bachelor of Science in Computer Engineering
Controls, Robotics, & Autonomy

Aspirations: After graduation, I will be working for Robotic Research LLC developing vision systems with an FPGA.

Class comment: I really appreciated the technical feedback from our SMEs throughout this course, as well as the mentoring of Professor Meadows.

Itiade Adegbulugbe

Lagos, Nigeria

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I hope to go on to work in the computer hardware design industry. I plan to get a master's degree before I go on the job market.

Class comment: : I've gained more experience by working on this project as part of this team. I've enjoyed the test run for what work is going to be like after school and also enjoyed the chance to make use of some of the things I learned at Virginia Tech.

Matt Genberg

Oakton, Va.

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I hope to utilize my skills in software engineering to further humanity's exploration of space.

Class comment: I'm grateful for the non-technical lessons this culminating project taught me, like how to effectively work on a team, maintain a long-term schedule, etc. These will be valuable skills as I begin my career in industry.

PROJECT SPONSORS: JASUR MIRZAKHMEDOV, CHASE TEMPLETON, AND KEVIN ROBERTSON

Remote Monitoring of Vacuum Gauge Tubes

CHALLENGE

Our goal was to create a stationary vacuum sensor that is accessible over a cellular network through a serial connection interface. The final system will deliver sensor data to a cell phone over SMS or through the existing serial interface.

LEFT TO RIGHT: James Davis, Jonathan Kayne *(This team was in a shared COVID-19 pod)* | **SME:** Adnan Sarker

James Davis

Springfield, Va.

Bachelor of Science in Electrical Engineering

Controls, Robotics, & Autonomy

Aspirations: I hope to apply myself in the field of engineering and never stop learning new things in this field.

Class comment: I found the process of applying our knowledge to solve a professional issue to be very meaningful. I also appreciated the chance to explore the difference between theoretical knowledge and practical knowledge in this field.

Jonathan Kayne

Candler, N.C.

Bachelor of Science in Electrical Engineering

Radio Frequency & Microwave

Aspirations: After graduation, I will be working for Lockheed Martin Space Systems, where I hope to gain more experience as I continue my education in radio communications.

Class comment: This design project allowed me to apply knowledge and skills that I have learned throughout my undergraduate career, mainly in Printed Circuit Board (PCB) design, for a specific industry need.

PROJECT SPONSOR: DOUG BAKER

TELEDYNE TECHNOLOGIES
Everywhereyoulook™

TI-RSLK MAX RFID Sensor Accessory and Gripper Attachment

CHALLENGE

The aim of this project was to modify the TI-RSLK MAX robot to incorporate an RFID sensor capable of scanning NFC tags and a gripper arm that can hold a 12 oz. aluminum can.

LEFT TO RIGHT: William Ogle, Cody Luong, Amarchand Niranjan, Zhiheng Luo, Matthew Bocharnikov | **SME:** Peter Han

William Magellan Ogle

Chantilly, Va.

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I want to pursue a career in embedded systems and solve niche problems.

Class comment: Senior Design gave me great, practical engineering experience working with a team to solve a hard problem. The long duration of and necessary teamwork for this project made it an experience I had never had before.

Cody Luong

Norfolk, Va.

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I would like to have a career focused on telecommunications.

Class comment: Working under deadlines with weekly meetings gave me valuable experience that will be applicable to my post-grad career and the real world.

Amarchand Niranjan

Kozhikode, Kerala, India

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: In the future, I want to work in the medical industry, maybe for a biotech company, and make more friends along the way. Graduate school is also one of my options after I get some work experience.

Class comment: I really loved working with my teammates as they were easy to communicate with and learned from each other throughout the project.

Zhiheng Luo

Shanghai, China

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I plan to earn a master’s degree and then a Ph.D.

Class comment: I appreciated the experiences of working with teammates randomly assigned for an entire year on one project. The timeframe was much longer than typical teamwork projects so that teammates could better sync with others' pace.

Matthew Bocharnikov

Blue Grass, Va.

Bachelor of Science in Computer Engineering
Computer Engineering (general)

Aspirations: I aspire to prototype and design in order to build a more advanced future. I also want to become more knowledgeable on an array of computer engineering subjects.

Class comment: I appreciated the team and work experience that I gained through this project. I was able to better understand how to effectively work in a team environment to produce a final prototype.

PROJECT SPONSOR: MARK EASLEY

Texas Instruments

Inertial Measurement Unit Analysis and Prototype

CHALLENGE

Inertial Measurement Units (IMU) devices can be used to help orient shipping containers in exact stacks to prevent collapses and serious harm to people and goods, allowing greater efficiency of product movement. The goal of this project was to use MATLAB simulations to analyze existing IMU devices on the market to select the best fit to meet the specifications of the project. We then tested the chosen IMU on a BeagleBone Black to verify its capabilities.

LEFT TO RIGHT: Anne Bray, Brian Sternback, Brian O'Keefe | **SME:** Ryan Gerdes

Anne Bray

Manassas, Va.

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: My career aspiration is to become a software project manager and contribute to the development of cutting-edge technology.

Class comment: I appreciated the multi-faceted nature of the project and the breadth of networking and technical lessons that I learned through this class.

Brian O'Keefe

Midlothian, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to apply everything I've learned at Virginia Tech to a career in control systems and to hopefully make a positive impact on the environment.

Class comment: I appreciate the opportunity to apply technology to a system that could potentially make many people's lives easier.

Brian Sternback

Marlboro, N.J.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: My main career goal is to work on a project that benefits my community as a whole, whether it be by providing power to those who need it or serving those whose work best improves quality of life in my community.

Class comment: Working on a team of fellow engineers-in-training has given me the opportunity to learn how to interact with and support fellow engineers on a project. This has been a good experience in how to best navigate the desires of the company sponsoring the team, the practical application knowledge of the subject matter expert, and the constraints of a real-world project.

PROJECT SPONSORS: THOMAS TAINER, MATTHEW MANDROS, AND ASHIN THOMAS

TMEiC
We drive industry

Inductive Wireless Charging Under Seawater 1

CHALLENGE

Our team designed a power management system that takes the output from a three-phase generator on a buoy in the ocean and stores it in a battery used by a remotely operated vehicle surveying the ocean.

LEFT TO RIGHT: Danielle Lester, Jayesh Mohite, Joseph Lin, Qiaosheng Zhang, Russell Lutge | **SMEs: Lei Zuo, Minh Ngo**

Qiaosheng Zhang

Wenling City, Zhejiang, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to work in State Grid Cooperation of China

Class comment: I appreciate the professional experience in circuit designing, PCB designing and soldering offered by EE classes. These classes and teachers teach me to be an electical engineer in real world.

Danielle Lester

Milwaukee, Wis.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: After continuing my education in Virginia Tech's master's program, I hope to use my research on power electronic systems to improve renewable energy systems.

Class comment: I greatly appreciated the exposure to PCB design and hands-on learning without having to follow a textbook offered through this course.

Jayesh Mohite

Doha, Qatar

Bachelor of Science in Computer Engineering
Computer Engineering (general)

Aspirations: I would like to have a career as a software engineer.

Class comment: Through this course, I did a lot of research on subjects I had never studied before.

Russell Lutge

Midlothian, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I am interested in working on the development of the smart grid and the integration of renewable power sources into the power grid.

Class comment: I appreciated the hands-on nature of the class, as well as the professional atmosphere. I enjoyed solving a real-world challenge and how we were allowed to use whatever approach our team saw fit.

PROJECT SPONSOR: LEI ZUO

VIRGINIA TECH™

Inductive Wireless Charging Under Seawater 2

CHALLENGE

The aim of our project was to create a system capable of using inductive power transfer to charge an autonomous underwater vehicle so it can quickly return to operation.

LEFT TO RIGHT: Andrew Guthrie, Nick Squitieri, Christian Sponseller, Alex Kim, Benjamin Alden | **SMEs:** Lei Zuo, Ming Ngo

Andrew Guthrie

Chantilly, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I aspire to create solutions for the energy challenges of the 21st century, specifically by working on microgrids and the integration of renewable energy sources.

Class comment: This class provided me the opportunity to study and design a project that I've always been interested in. Also, I enjoyed the opportunity to be creative while applying principles from previous classwork.

Benjamin Alden

Philadelphia, Pa.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to work in the renewable energy industry.

Class comment: The Major Design Experience at Virginia Tech expanded my knowledge of transformers and magnetics beyond what is covered in the undergraduate curriculum and gave me an appreciation for wireless charging.

Christian Sponseller

Camp Hill, Pa.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I aspire to be a hardworking, competent electrical engineer in the power electronics field. I would also like to be an engineering manager.

Class comment: I enjoyed learning about a new type of technology (wireless charging) and using the knowledge gained from my previous years at Virginia Tech to solve a challenging problem.

Nick Squitieri

Ridgefield, Conn.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: My career aspiration is to be on the front lines of the energy transition working on renewables and smart grids.

Class comment: Having such a knowledgeable subject matter expert really helped me internalize what I learned in class and then be able to conceptualize, design, and build my part of our scope.

Seung Hyun Kim

Woodbridge, Va.

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I would like to get a position that will allow me to learn more about RF or work with prototypes as a field test engineer.

Class comment: I enjoyed working with very friendly classmates along with a knowledgeable subject matter expert who helped me learn more about the topic.

PROJECT SPONSOR: LEI ZUO

VIRGINIA TECH™

The Beat Goes On: Next Gen Heartbeat

CHALLENGE

The aim of our project was to design and develop a stethoscope and electrocardiogram (ECG) to simultaneously obtain audio and visual representations of a user's heartbeat. The user will be able to listen to and view these representations.

LEFT TO RIGHT: Jacob Rickman, Julia Farrell, Kadisha Mercado, Maddie Sheehan, Vince Carroll | **SME:** Jaime De La Ree

Jacob Rickman

Chincoteague, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan on pursuing a career in the space industry. I hope to be working on launchpads at Wallops Island, Va.

Class comment: I appreciated the opportunity to work on a medical issue that could revolutionize the tele-health medical industry.

Julia Farrell

Mechanicsville, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I will be working in Electrical I&C for Dominion Energy at Surry Power Station. I look forward to applying what I learned at Virginia Tech and growing as an engineer!

Class comment: I enjoyed the experience of getting to work for a customer and delegating tasks between teammates. I had no prior knowledge of how medical devices are made and enjoyed getting to research them!

Kadisha Mercado

Severna Park, Md.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to use my technical skills in electrical engineering to help develop new technology to help positively impact society.

Class comment: I valued the opportunity to be able use what I have learned over the course of my education to work on a real-life problem. Through this course, I was able to work on my technical skills by designing and building technology but also my communication skills with my team and our customer.

Vince Carroll

Salem, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to pursue a career in which I am continuously learning and contributing to technological developments. The two fields I'm most interested in are photonics and energy & power.

Class comment: This class allowed me to work on a real-world project while also gaining experience with the process of how engineers solve problems in the professional world. The class also taught me the valuable lesson that failure is only a failure if you don't learn, adapt, and continue on from that failure.

PROJECT SPONSOR: JAIME DE LA REE

Machine Learning Model for Wide-Bandgap Semiconductor Design

CHALLENGE

Our challenge was to develop a machine learning algorithm that reverses the design process for high-voltage power electronic devices. Our algorithm takes an I-V curve provided by the user and returns the measurements for a SiC Schottky diode.

LEFT TO RIGHT: Joseph Berger IV, Nicholas Dyben, Katherine Franz, Yuanhao Wang, Paul Kuzio III | **SME:** Cindy Yi

Joseph Berger IV

Alexandria, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: Upon graduation, I will attend Navy OCS and then serve as on officer on a submarine. I have a desire to work in national defense and related industries.

Class comment: This class gave me a great opportunity to work with machine learning and its applications in electrical engineering. It's an important technology that is going to be a part of many fields in the near future.

Nicholas Dyben

Basking Ridge, N.J.

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I wish to continue increasing my technical knowledge and apply myself to the betterment of my nation.

Class comment: This class was a professional experience and an opportunity to apply myself to subjects beyond my coursework and implement what I learned into a final deliverable product.

Katherine Franz

Arlington, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to always keep learning new things.

Class comment: I appreciated the professional experience that is provided from this class and the opportunity to work on a real-world problem applying what I learned in my classes at Virginia Tech.

Paul Kuzio

Chesapeake, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to apply what I've learned at Virginia Tech to research new and innovative technologies.

Class comment: I have enjoyed learning about machine learning, how it can be applied to real engineering problems, and experiencing a professional relationship with a client.

Yuanhao Wang

Chengdu, Sichuan, China

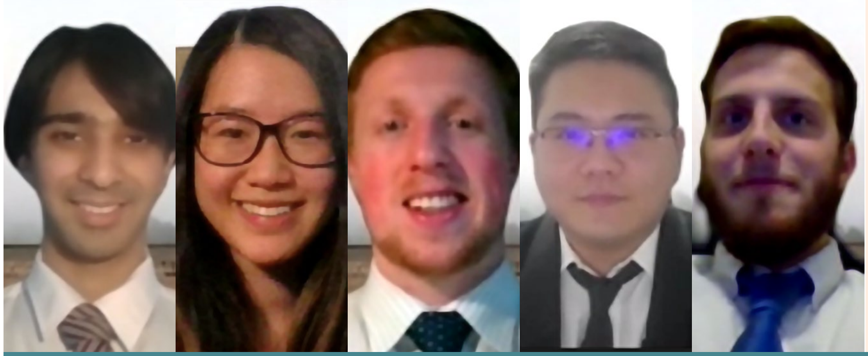
Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: I hope I can design and construct intelligent robots that can serve people in different areas.

Class comment: I appreciate the opportunity to work on a real-world problem applying what I learned in the past and cooperating with other people to solve difficulties as real engineers.

PROJECT SPONSOR: YUHAO ZHANG

Low-Cost, Wearable Fiber-Optic Curvature Sensing System for Biomechanical Characterization of Upper Extremity Motion



CHALLENGE

The goal of our project was to design and build a wearable, fiber-optic-based curvature sensing system to monitor, collect, and display biomechanical data from a user's joint movement. The data will be used to further research in Cerebral Palsy (CP) and to personalize treatment options for patients with CP.

LEFT TO RIGHT: Zayeem Zaman, Maureena Ma, Craig Macagney, Xingsi Gao, Dillon Conner | **SME:** William Yu

Zayeem Zaman

Chesapeake, Va.

Bachelor of Science in Computer Engineering and Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I hope to contribute toward exciting, new innovations in the fields of photonics, holography, and/or chip design and computer architecture.

Class comment: I appreciated getting to work hands-on with optical fibers, building a system between analog measurement data and a digital interface (the microcontroller).

Maureena Ma

Thiensville, Wisc.

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I would like to use the versatility of my electrical engineering background to explore and apply my knowledge in many different industries, from industrial automation to medical technology.

Class comment: I enjoyed working on a diligent team with a diverse skillset to bring this project to fruition. Taking this course during the COVID-19 pandemic provided the additional challenge of working remotely, which is a valuable skill to have moving forward.

Craig Macagney

Pequannock, N.J.

Electrical Engineering (ECRA)

Aspirations: Upon graduation I hope to explore career opportunities that allow me to work on hardware and software within the communication systems field.

Class comment: The two aspects of this course that I enjoyed the most were the hands on experience and the ability to learn about new areas of electrical engineering that I was previously unfamiliar with.

Xingsi Gao

Anshan, Liaoning, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to be a microcontroller design engineer.

Class comment: I enjoyed working with the team to solve difficulties encountered in the project and make a satisfactory finished product. This class gave me a sense of what I might face in the future and how to deal with it.

Dillon Conner

Shipman, Va.

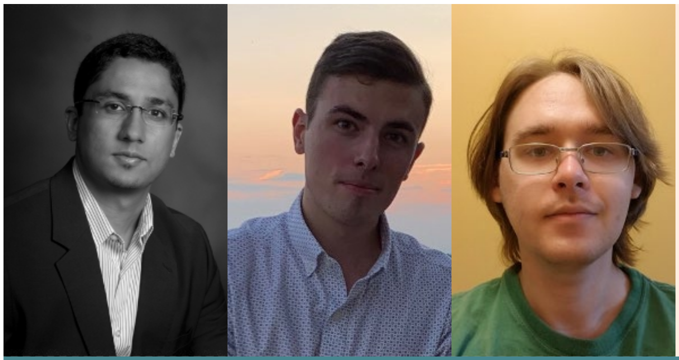
Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I want to do something I love, but I'm not sure what that is yet.

Class comment: I appreciated getting experience working within a team from different backgrounds with different expertise.

PROJECT SPONSOR: YIZHENG ZHU

Washington Quarter Identification with Machine Vision



CHALLENGE

The objective of this project is to design, build, and test a machine vision lighting and imaging apparatus with software that can detect and read imperfect hollow font text appearing on coins.

LEFT TO RIGHT: Fahad Pasha, Jackson Campolattaro, Justin Nalchajian | **SME:** Creed Jones

Fahad Pasha

Sharjah, United Arab Emirates

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I have spent much of my career studying and protecting innovation. I would like to continue adding skillsets, such as coding and project management, to my toolbox so that I can play a greater role in innovation management.

Class comment: I really enjoyed working with my peers who helped accelerate my ability to learn Python, more than perhaps a class in Python would have.

Jackson Campolattaro

Ashburn, Va.

Bachelor of Science in Computer Engineering
Computer Engineering (general)

Aspirations: Upon graduation, I plan to earn a master's degree in computer science at a university in Italy, with a focus on research in high performance computing. After graduation I hope to go on to work in a position where I can contribute to important open source software projects.

Class comment: This class was a fantastic opportunity to work on a team with a variety of skills and specialties, a more industry-like experience than team projects in other classes. This, along with regular communication with our client, made this one of the most valuable team experiences I've ever been a part of.

Justin Nalchajian

Springfield, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to find optimize and new applications for underutilized technology.

Class comment: I appreciate working with a diverse team of skilled individuals to build something new.

PROJECT SPONSOR: LUKE LESTER

Magnetic Levitation Team 1

CHALLENGE

The aim of this project was to design, prototype, and build a creative multi-solenoid magnetic levitation system that can suspend an object in air and move the object horizontally using a digital control system

LEFT TO RIGHT, BACK TO FRONT: Stephanie Flear, Renee Wilson, Jonathan Grabski, Zackary Andraka | **SME:** Matt Strehle

Stephanie Flear

Manassas, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to address the global energy crisis through smart, green technology. My greatest career aspiration is to devote myself to my work, embodying "Ut Prosim" with those I work for and with.

Class comment: I have truly been inspired by this class. Being able to work alongside a company full of passionate engineers, many of whom are Virginia Tech alumni, has motivated me to love the mission of my work as much as this company does. I also have enjoyed being able to work with peers as personally as possible during the pandemic, learning how to have effective teamwork in this new environment that will transfer well into a job after I graduate.

Renee Wilson

Springfield, Va.

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I hope to work in a lab where I can continue doing hands-on electrical engineering that makes a positive impact on the world.

Class comment: I really appreciate the opportunity this project gave me to get my hands dirty and do some real hands-on engineering and problem-solving.

Jonathan Grabski

Burke, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to enter the biomedical device industry after graduation. Having worked on experimental cancer therapy devices with Virginia Tech's Therapeutic Ultrasound Lab (TUSL), I'd like to continue in the field and explore the different avenues open to electrical engineers in biomedicine.

Class comment: The technical freedom that this class provided has given me much more confidence to make critical decisions on a deadline. The possibility of failure that comes with that design freedom exists in this class in a way that it doesn't in normal courses. ECE 4805-6 was a healthy "push out of the nest."

Zackary Andraka

Owings, Md.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I wish to use my developed engineering and problem-solving abilities to design, analyze, and test controls systems.

Class comment: This course provided the most realistic professional group project I experienced in my entire academic career, and it's a shame that more classes do not offer the same.

PROJECT SPONSOR: DAN SABLE

Power Your Critical Mission Today

Magnetic Levitation Team 2

CHALLENGE

The goal of this project was to use a PID controller to suspend an object in air with magnetic levitation for an interactive racing game. Players can use a three-button controller to move the object laterally to stay on the digital track projected behind the suspended object.

LEFT TO RIGHT: Christopher Mitchell, Connor Flanagan, William Hall | **SME:** Campbell Lowe

Christopher Mitchell

Hampton, Va.

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: After graduation, I will be working in circuit design at a large defense contractor. I would also like to eventually work with robots in my career.

Class comment: I appreciate the opportunity to work with other classmates and have full control over a long-term project. It was a fun and creative way to apply the knowledge that we have learned over the course of our education.

Connor Flanagan

Woodbridge, Va.

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: Short term, I'd like to join an organization in which I can continue to learn and develop into a professional engineer, specifically within the space and defense sector. Long term, I'd ideally rise into a leadership position or start my own engineering related business.

Class comment: I admired that this course allowed students to implement their years of study into a physical product while pushing them to develop professional skills necessary for life after graduation.

William Hall

Fairfax, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to use my knowledge to help develop efficient and robust electrical systems used in sustainable energy technology. I will give back by tutoring and mentoring students in the STEAM field.

Class comment: I enjoyed learning more about the skills and interests of my teammates. I also will value trying new things from an technical and professional standpoint that this class allowed me to do.

PROJECT SPONSOR: DAN SABLE

VPT
Power Your Critical Mission Today

Magnetic Levitation Team 3

CHALLENGE

The aim of this project was to build, test, and expand upon magnetic solenoid levitation systems to produce horizontal movement across multiple solenoids using both analog and digital control to levitate buildings in a miniaturized city model.

LEFT TO RIGHT: Yiren Zheng, Ritwik Dutta, Isabella Bartolome, Josh Sutton | **SME:** Robert Crnkovich

Yiren Zheng

Foshan, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I want to be an integrated circuit chip designer.

Class comment: The project was cool, and I got to learn a lot about how to solve real-world problems.

Ritwik Dutta

Kolkata, West Bengal, India

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I would like to work in the microprocessor and the electronic circuit design industry for a couple of years and pursue an M.B.A. degree to move into a management position in the future.

Class comment: I am thankful to my teammates who were an integral part of this journey. I have gained a lot of experience in the circuit design aspect of this project, and I hope to continue working in this area for the betterment of this industry.

Isabella Bartolome

Fairfax, Va.

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: After graduation, I look forward to exploring electrical engineering's applications in a variety of industries, including in aviation and biomedical technologies. Ultimately, I hope to advance and better society with whatever my contributions in engineering may be.

Class comment: The cooperation and teamwork skills I acquired this past year were especially meaningful. I will surely be able to apply what I learned while working with my team to the increasingly collaborative workplace that I will soon be entering.

Josh Sutton

Montpelier, Va.

Bachelor of Science in Electrical Engineering
Controls, Robotics, & Autonomy

Aspirations: My dream is to develop new technology to improve the world we live in. As such, I am continuing my studies at Virginia Tech through their Accelerated Master's Degree Program to further my understanding of control systems.

PROJECT SPONSOR: DAN SABLE

VPT
Power Your Critical Mission Today

Campus Electrical Distribution Planning

CHALLENGE

We designed an electrical distribution master plan for an urban campus in Richmond. We evaluated expected future growth, recommended improvement projects to implement over the next 25 years, and proposed changes to reduce the campus electricity bill by 10% annually.

LEFT TO RIGHT: Madison Burke, Sengal Ghidewon-Abay, Brendan Moseley, Lukas Reed, Scott Tillotson | **SMEs: Minh Ngo, Jaime De La Ree**

Brendan Moseley

Emporia, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to use the knowledge from my college career to make an impact somewhere that I am needed.

Class comment: I like that this class gives you a chance to see things from other people's perspectives and get a taste of how professional cooperation works.

Lukas Reed

Pearisburg, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to work in the power engineering field to help ensure this country receives dependable and secure power delivery. I would like to be out in the field and get hands-on experience with power systems.

Class comment: I am thankful that our team had the opportunity to work alongside real-world engineers to produce a product that we could be proud of. This project puts our technical skills to the test and improved our soft skills.

Madison Burke

Virginia Beach, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I plan to continue working in the field of electrical engineering to find innovative and practical solutions to challenging problems.

Class comment: This project has been a great way to get exposure to power planning practices and an invaluable team-building and leadership experience.

Scott Tillotson

State College, Pa.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I will attain my Ph.D. in order to become an engineering professor and help future generations of engineers improve the world.

Class comment: Working with a real-world customer, with all of its benefits, setbacks, and complications, was an excellent experience. Fortunately, I had an amazing team and we were able to work through this challenging project together.

Sengal Ghidewon-Abay

Glen Allen, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I will be pursuing graduate studies in electrical engineering and research on machine learning and its applications within power systems. My dream is to research methods of generating affordable renewable energy to disadvantaged populations.

Class comment: This class was a great opportunity to apply what was taught in the classroom to real-world applications while also interacting with industry professionals. I learning valuable skills that will be applied throughout my career.

PROJECT SPONSORS: STEVE BOWMAN, MARK ADKINSON, AND DAN MORTON

Vaccine Pickle

CHALLENGE

In the midst of the COVID-19 pandemic our challenge was to bridge the gap between vaccine distributors and the general public. In response our team developed a web application to allow users to receive instant email notifications of vaccine availabilities near them.

LEFT TO RIGHT: Abel Thomas, Dhwan Wanjara, Mayank Hirani

Land Traversing Robotics Platform (LTRP)

CHALLENGE

The goal of this project is to design, fabricate and validate a versatile robotics platform capable of long-range operation over various types of terrain. The robot is designed with simplicity, ease of maintenance, and modularity in mind. The major deliverable of the first stage of the project includes the complete powertrain which includes two brushless DC electric motors and six pneumatic wheels connected with shielded HTD 5 timing belts. In future stages of this project, attachable subsystems will be added to the base robot, including sensors and interchangeable, quick-mount robotic subsystems.

Michael Yanoschak

915MHz Radio Weather Station

CHALLENGE

We implemented a system to send temperature and humidity measurements over a 915MHz radio channel using a pair of Arduino Unos and RFM69 radio transceivers. We then intercepted one of our radio transmissions with a software-defined radio and demodulated the signal to get our original data in MATLAB.

LEFT TO RIGHT: Daniel Stover, Evan Allen

Evan Allen

Virginia Beach, VA

Computer Engineering
Networking and Cybersecurity

Class comment: I learned there is no substitute for real-world testing. Things that worked in simulation usually didn't the first time in real life, and we learned to embrace it.

Daniel Stover

Leesburg, VA

Computer Engineering
Controls, Robotics, and Autonomy

Class comment: However long you think designing and implementing a system is going to take, double it, because there is always something small that you will overlook.

Audio Direction Finder

CHALLENGE

An array of three microphones detects a 1kHz audio signal. Our circuit processes the three individual signals and calculates what direction the sound is coming from. This information is displayed to the user with a GUI and LED display.

LEFT TO RIGHT: Mason Ahner, Jared Beller, John Fiorini

Mason Ahner

Hatfield, PA

EE CRA

Class comment: Professor Sarker is an amazing mentor, he guided us through our work and had a lot of wisdom to share"

Jared Beller

Richmond, VA

EE Photonics

Class comment: The real world and i dealized models are similar, but when a system needs to be precise, the differences are very apparent."

John Fiorini

Basking Ridge, NJ

EE Space Systems

Class comment: We are continually faced by great opportunities brilliantly disguised as insoluble problems.

Project Contributor Acknowledgements

Many people contributed to this program that we want to acknowledge and thank:

Luke Lester
for his vision and continued unyielding support to make this class available for students.

Sook Ha, Toby Meadows, and Ken Schulz
for being our instructors, mentors, teams, and for making the class better.

Greg Atkins
for developing an outstanding class website.

Mary Brewer, Nicole Gholston, Kimberly Johnston, Susan Broniak, Minerva Sanabria, Jamie De La Ree, Paul Plassmann, and Laura Villada
for setting up information sessions and guiding students into the class.

William Baumann
for allowing us complete access to the design studio and conference room, and providing assistance to students in need.

Karin Clark and Lisa Young
for being our partners and diligently working to secure industry sponsorships.

Arthur Ball
for supporting our competition challenge teams.

Kim Medley
for ordering our materials and helping us solve supplier issues.

Kathy Atkins and Melanie Gilmore
for providing financial guidance and support.

Roderick DeHart and Brandon Russell
for solving our many IT issues.

Duane Blackburn, Almuatazbellah (Muataz) Boker, Scott Dunning, and Sam Yakulis
for their support as panelists for the 2021 Spring Expo technical presentations.

Alex DeReiux
Teaching Assistant and MDE Alumni

for helping guide and mentor students in their engineering notebooks (IPNs).

Special thanks to Amrita Chakraborty
Teaching Assistant specializing in Semiconductor Projects

Provided excellent safety, tool, semiconductor processing, and mask design training.

Project posters

Quad-MxFE Communications Ecosystem Development

Team Members: Adam Vaughan, Lizzy Morris, Matt Herrity, John Hiemstra, John Roth

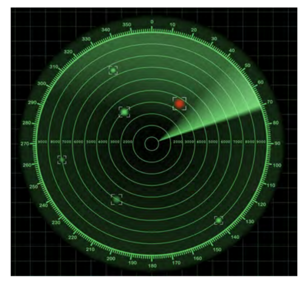
Customer: Michael Jones, Charles Frick **SME:** Louis Beex **Mentor:** Ken Schulz

Motivation

Beamforming, Beam-steering, Phased-Array RADAR: These are key terms you might hear in a sci-fi film. However, they are also key concepts in the world of RF and Microwave engineering. These technologies are crucial for:

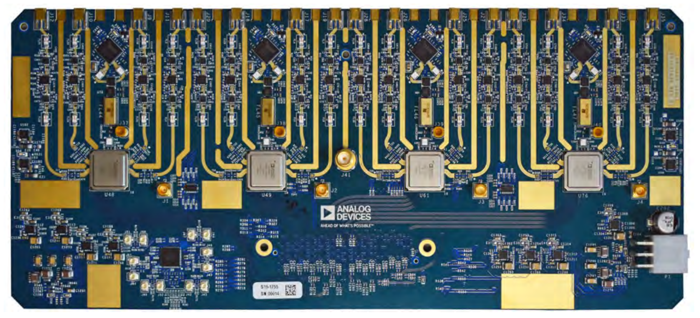
- Superior stealth and detection capabilities of the DoD's surface and air vehicles
- The success of 5G's ultra-wideband and incredible speeds
- Sustaining complex links with satellites in orbit that provide services such as the GPS in our cars and phones

Beamforming, beam-steering, and phased-array RADAR are technologies that have a wide range of applications, and will continue to grow in the future with autonomous systems, cellular networking, and more!

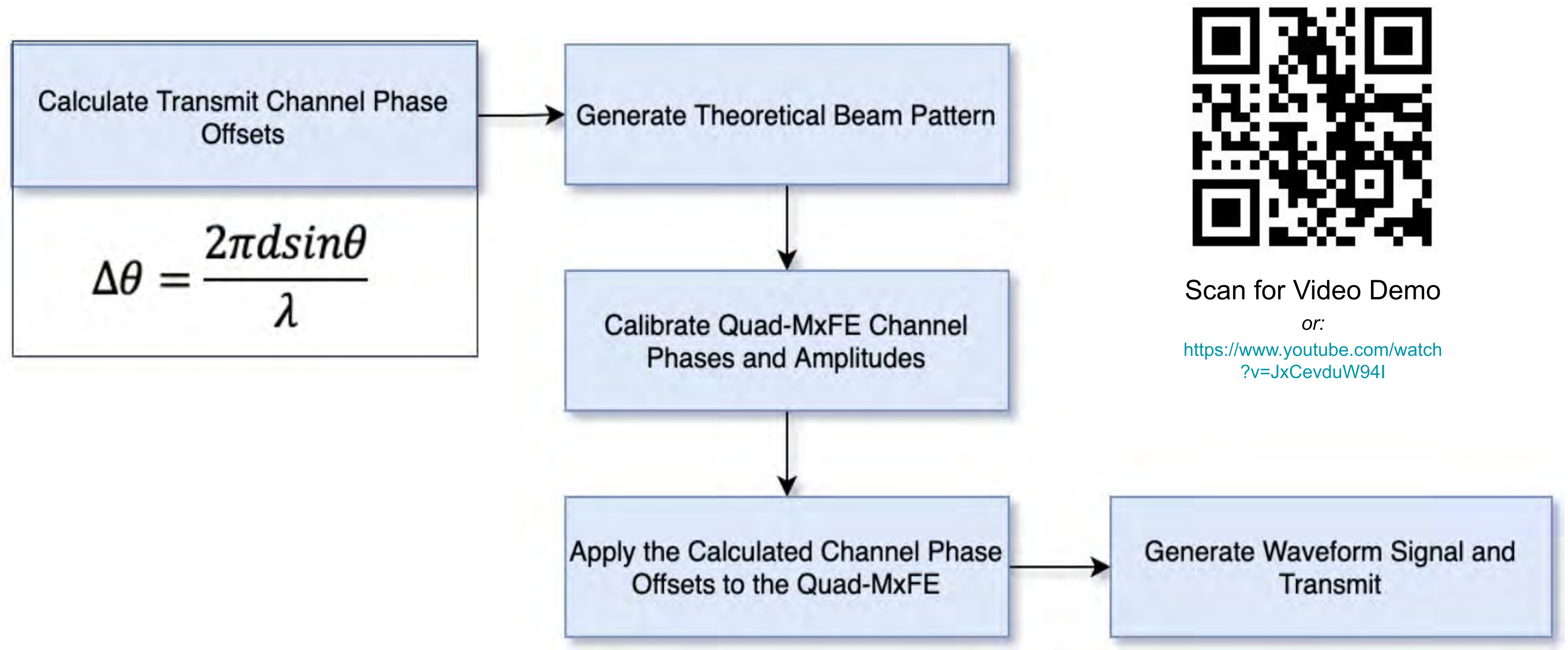


Objectives

- Successfully demonstrate useful capabilities of ADI's Quad-MxFE development board
- Utilize MATLAB to implement an algorithm that performs beam-steering for information transfer using ADI's Quad-MxFE development board platform
- Design a graphical user interface (GUI) to provide user control to demonstrate the beam-steering algorithm and its function
- Design a phased antenna array printed circuit board (PCB) to be used for information transmission
- Verify that the transmitted signal is the desired signal using a receive capture with a software defined radio (SDR)



Algorithm Summary



$$\Delta\theta = \frac{2\pi d \sin\theta}{\lambda}$$

Scan for Video Demo
or:
https://www.youtube.com/watch?v=JxCevduW94I

Figure 1. Algorithm Summary

Graphical User Interface (GUI) and Testing Setup

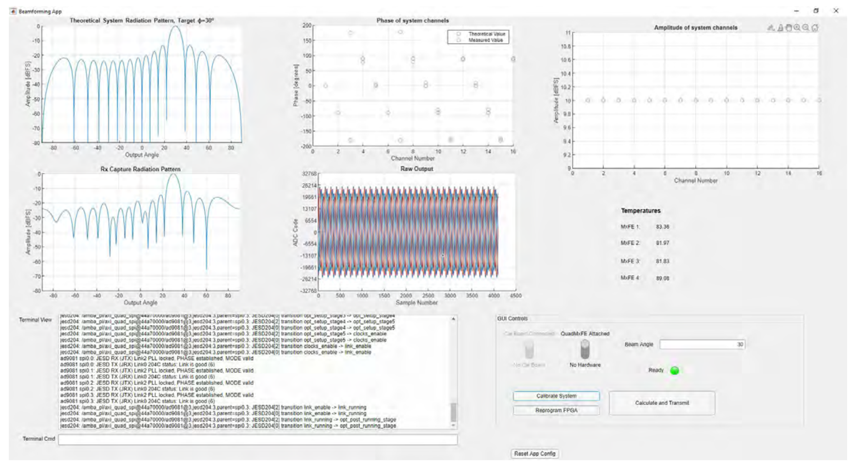


Figure 2. Graphical user interface used for user control of system.

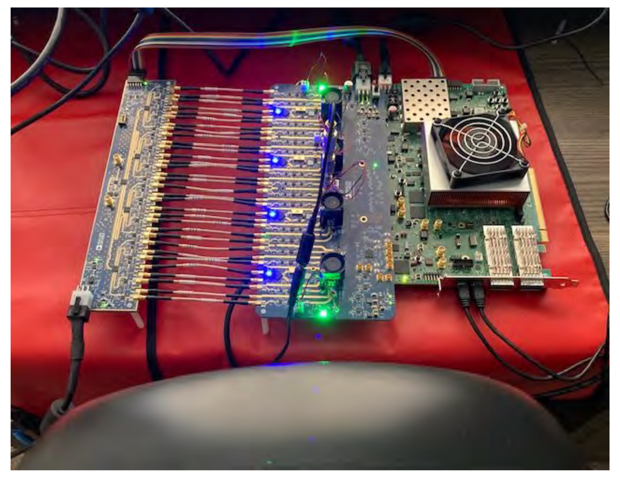


Figure 3. Quad-MxFE and FPGA testing setup

Beam-Steering Test Results

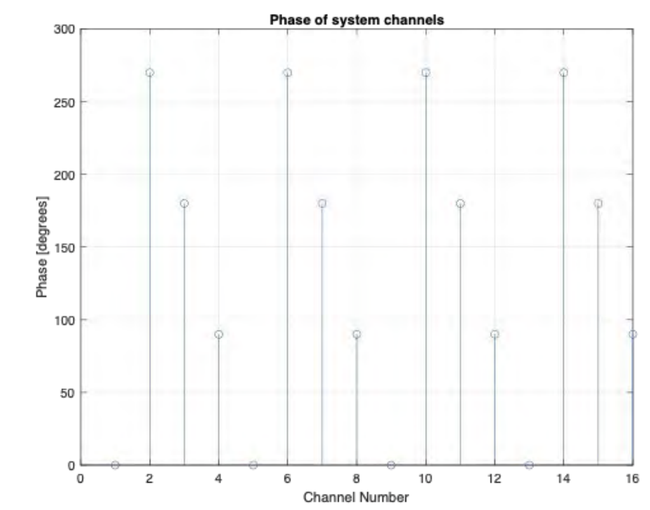


Figure 4. Calculated channel phase offsets.

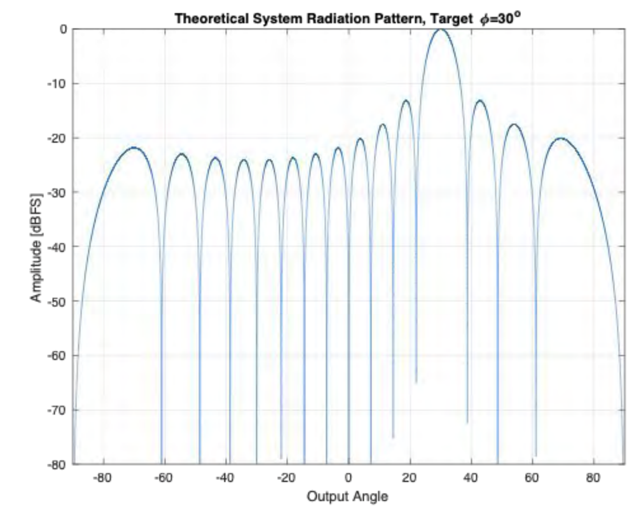


Figure 5. Theoretical calculated beam pattern.

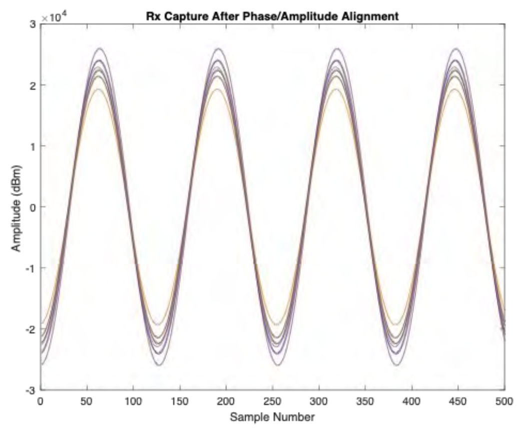


Figure 6. Rx capture following phase and amplitude system alignment

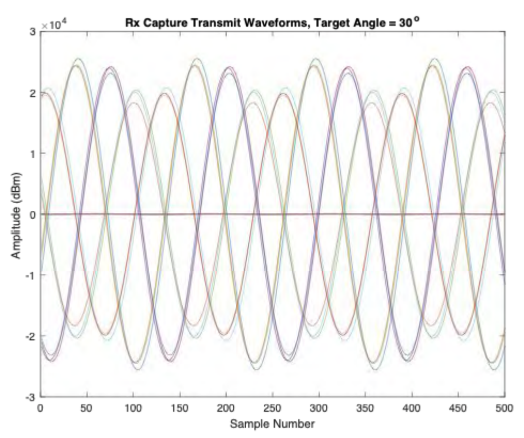


Figure 7. Rx capture with calculated channel phase offsets applied to Tx waveforms

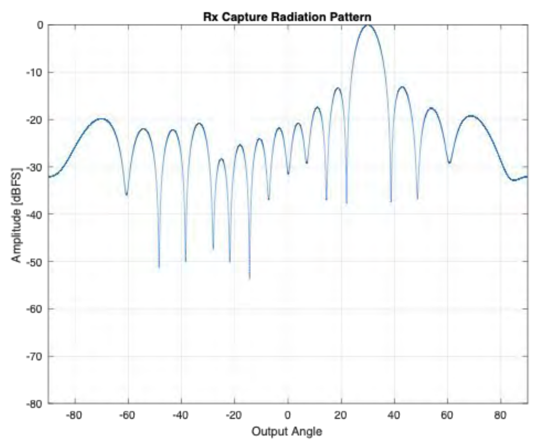


Figure 8. Beam pattern generated from Rx capture data (see Figure 7)

Antenna Board Design Process

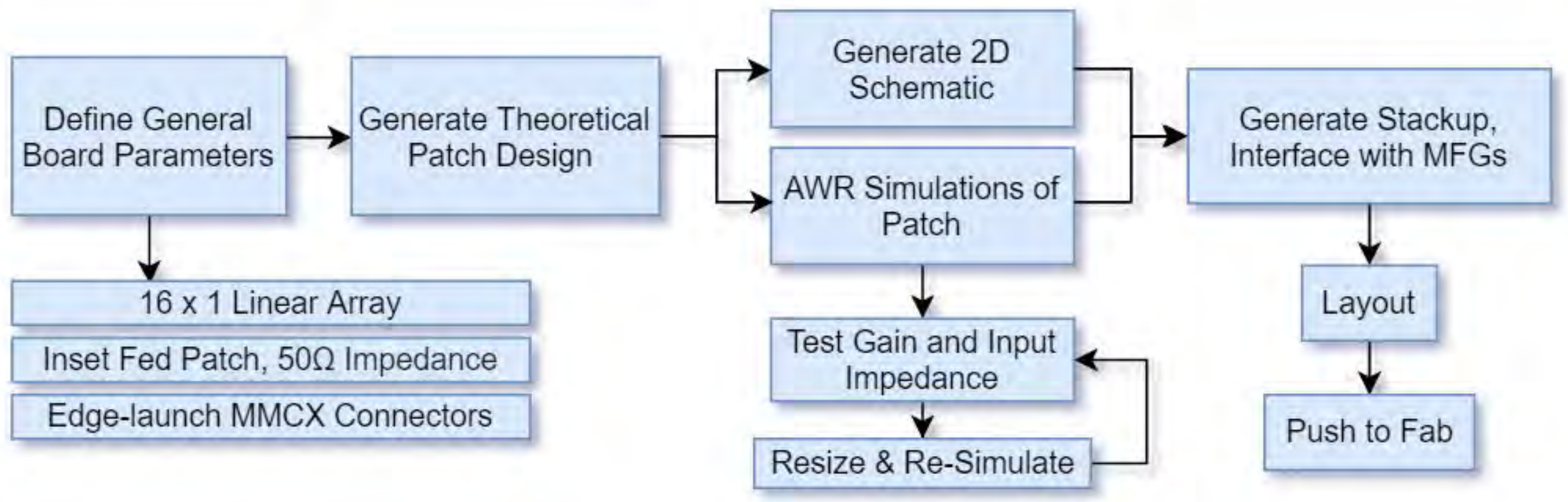


Figure 9. Antenna board design process.

Antenna Board & Patch Analysis

- Nominal Input Impedance of 48.35Ω
- Designed for ε_r = 4.34 and h = 1.6mm
- S11 = -28.48dB @ 3.2GHz
- Directivity of ~4.84dB
- Inset feed provided greater bandwidth as opposed to a quarter-wave feed

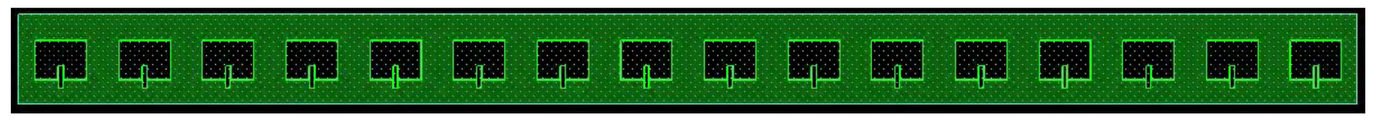


Figure 10. Array PCB Layout

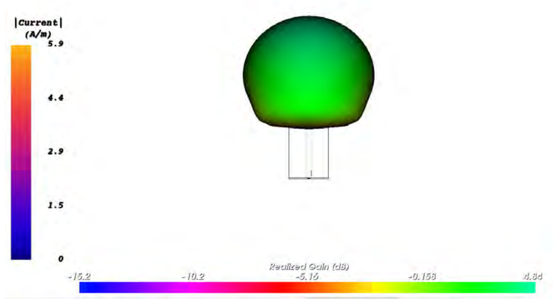


Figure 11. Patch Antenna 3D Radiation pattern

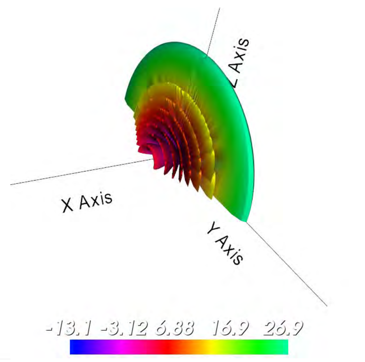


Figure 12. 3D Array Factor

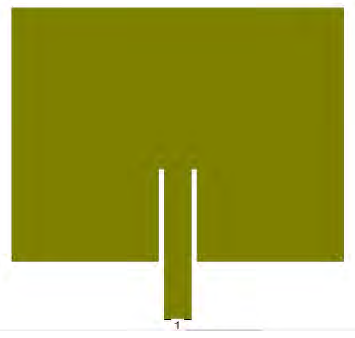


Figure 13. Patch Antenna

Challenges

- Unable to meet in person with team to discuss and resolve issues due to COVID-19
- Long lead time on necessary equipment and hardware due to shipping delays
- Virginia Tech licensing issues with Cadence Allegro software caused more problems than were anticipated
- Steep learning curve on Cadence Allegro PCB software used to design phased array antenna board
- Several bugs in the provided Quad-MxFE sample MATLAB scripts caused delays in algorithm development

Conclusions

- Beam-steering algorithm, GUI design, and antenna board design were ultimately a success
- COVID-19 made it difficult for subteams to integrate their separate sub-system designs into one system for testing, thus the design and prototyping process took longer than anticipated
- Initial goal was to develop a system for over-the-air energy transmission; however, due to the many challenges listed above, most prominently COVID-19, this design and fabrication process took longer than expected, and adequate testing was not performed prior to the project's deadline

Acknowledgements

We would like to especially thank the following individuals for their continual help and support throughout the entire project:

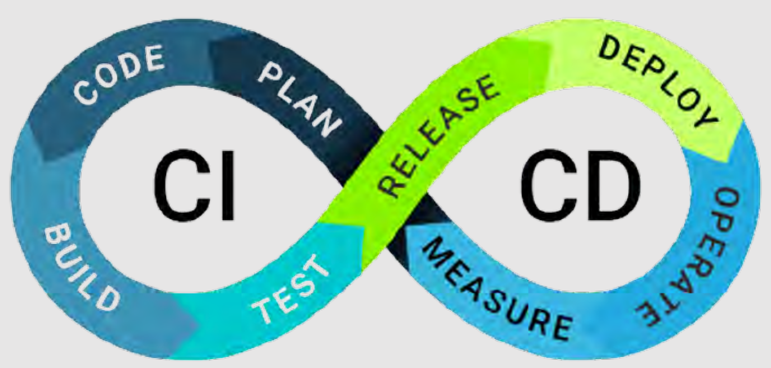
- Mike Jones & Charles Frick (Customer Points of Contact; Analog Devices, Inc.)
- Louis Beex (Subject Matter Expert; Virginia Tech)
- John Ghra (Software Support Point of Contact; Virginia Tech)

DevSecOps Architecture

Team Members: Charles Ranson, Charlie Kelley, Osadebe Osakwe
SME: Michael Irwin **Customer:** Tony Rice **Mentor:** Toby Meadows

Purpose

Deploying applications to the cloud, especially in a containerized environment is useful in reducing complexity and cost. Providing a reusable architecture to deploy a wide variety of applications across a series of development environments is essential to this project.



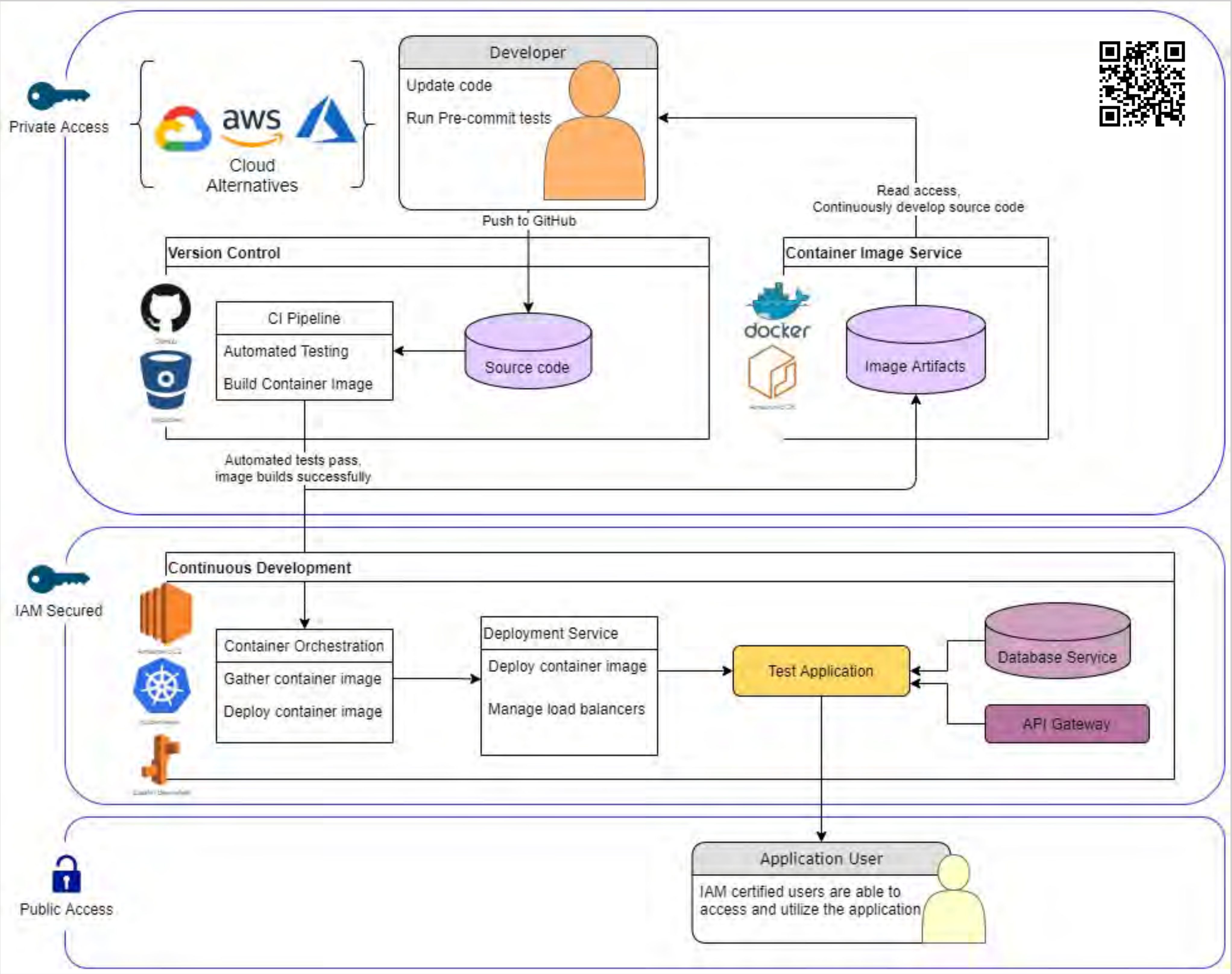
Requirements

- Establish and demonstrate a scalable reference architecture to automate the deployment of a containerized application across various environments.
- Automate the integration and containerization of a variety of applications.
- Provide security features utilizing least privilege access.

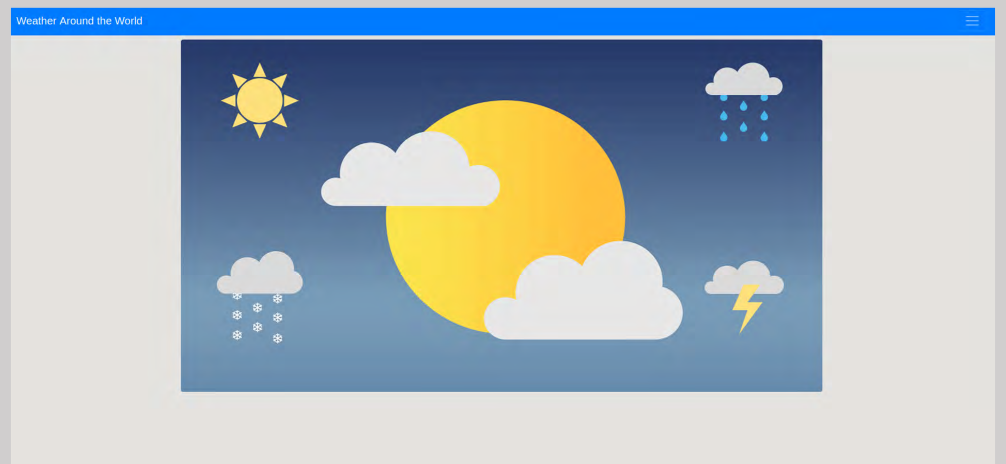
Design Methodology

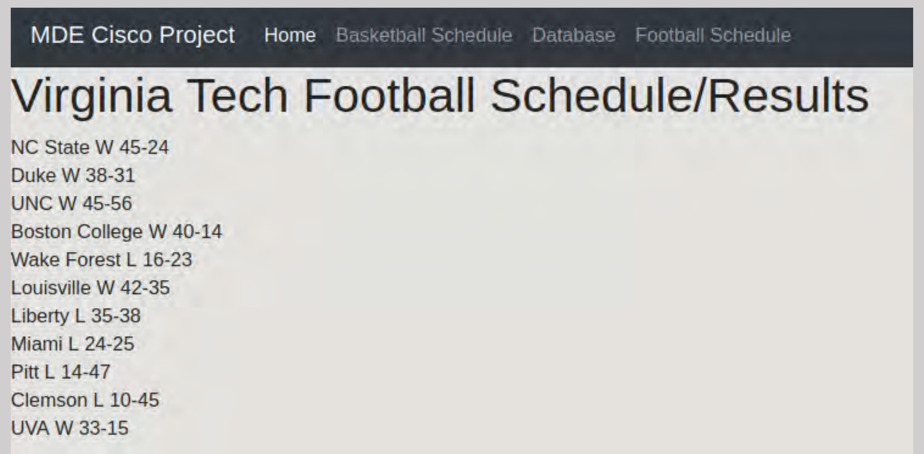
- Divided tasks into sprints that were guided from customer, mentor, and SME feedback.
- Allowed for a reusable architecture that can accommodate a multitude of applications.
- Able to implement security features via least privilege access continuously throughout project development.

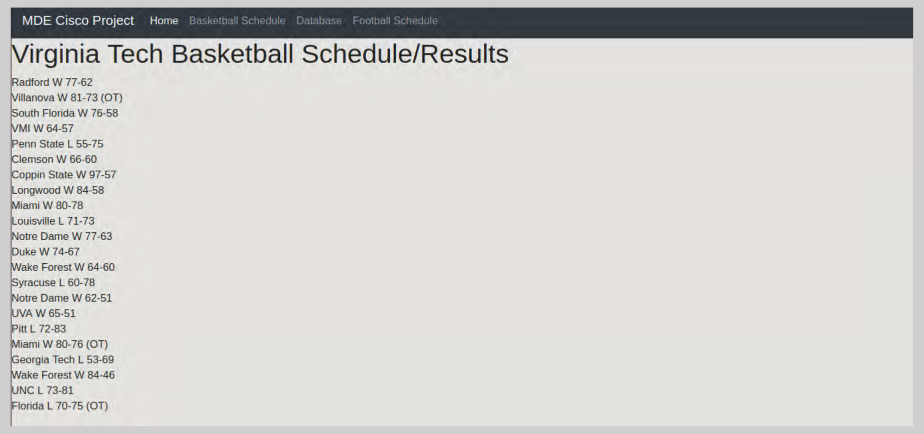
Architecture Diagram



Example Applications







Weather Application that determines weather conditions including lunar phases, current temperature, and sunrise/sunset times about user specified locations anywhere around the world.

Virginia Tech sports application that logs schedule/results for football and men's basketball.

Each application demonstrates interchangeability of items in the architecture diagram.

Key Features

- Automation of each task within the pipeline triggered by a push to the source code repository and then dependent on successful automated builds and deployment.
- Providing a secure architecture by isolating the source code via private repositories, verifying commit signatures, and providing hashes for each commit while also securing the cloud services by creating IAM roles with least privilege access in mind.

GnuPG iam AUTOMATION

Attributes

- This project is scalable and can be configured for networks that contain multiple applications using services like Azure VNet and Docker Swarm.
- Utilizing automation allows developers to easily integrate and deploy code using this architecture.
- Adjusting services to meet budget requirements can be accomplished with ease due to reusability of the architecture.

Analysis and Conclusion

- This project automates the integration and deployment stages of the pipeline while also providing security features to ensure the reliability of the architecture.
- This will allow for developers to increase productivity and design more complex applications that can be quickly deployed.
- Reusability, automation, and security are important principles that allow for the pipeline to show maturity and dependability.

Acknowledgements

We would like to thank each of the following:
- Michael Irwin for all his help, especially in helping us learn about containers, cloud services, and integration services.
- Tony Rice for helping guide our project and providing useful incite and experience to DevSecOps architectures.

Phased Array Antenna Controller

Team Members: Matt Evans, Daniel Felkel, Nelson Hurley, Matthew Tobin
SME: Dr. Majid Manteghi **Mentor:** Prof. Kenneth Schulz
Customer: George Cooley, Collins Aerospace

Introduction

Motivation

- Antennas are used to transmit and receive signals and are therefore used in every single wireless communication system or device.
- People often use or see numerous antennas per day such as a cell phone, radio, laptop, and more.
- Every antenna has a pattern that describes how strong it can transmit or receive in a certain direction: this is the aspect of the antenna utilized to control it.

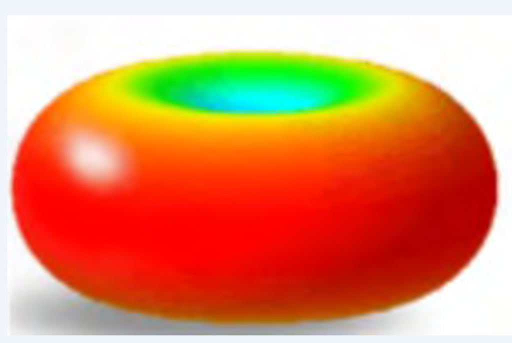


Figure 1 Simulation of omnidirectional antenna

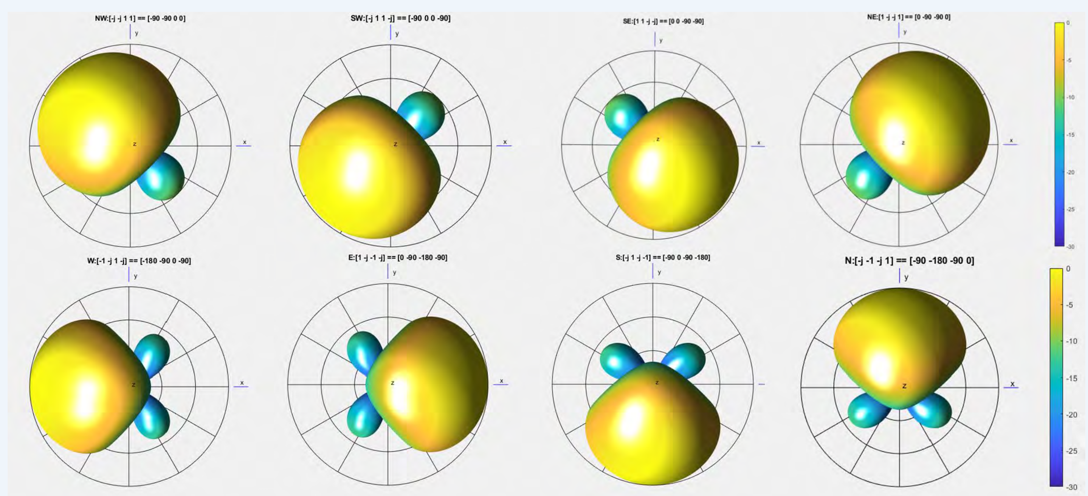


Figure 2 Simulated antenna patterns in 8 possible directions

Phased Array Antenna System

- Constructive and deconstructive interference steers the net beam direction of a set of antennas
- Maximizes strength of transmitted and/or received signals in some direction while minimizing in another direction
- Is used in applications such as radar and radio broadcasting to maximize range and gain while minimizing unwanted interference

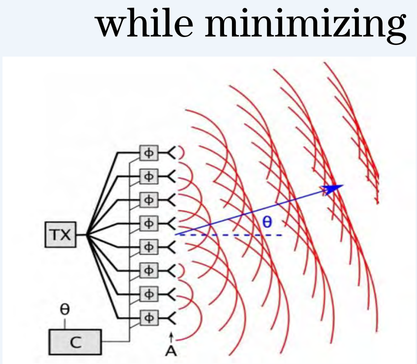


Figure 3 Visualization of beam steering through phasing.

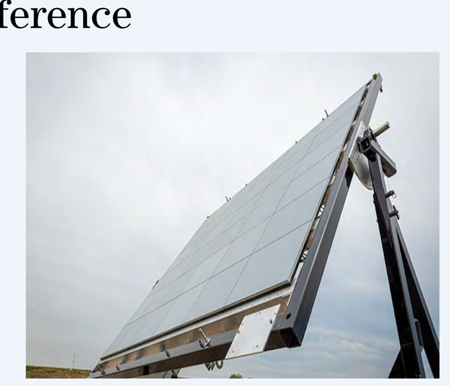


Figure 4 Phased array developed by Lockheed Martin and Ball Aerospace for U.S. Space Force

Project Objectives

- Design a circuit to divide input RF signal into four outputs representing antennas
- Design a controller to manipulate the phases of the output signals so that, were those outputs fed to antennas, the net beam formed would be in one of eight cardinal directions, as selected by the user
- Design the circuit to operate at HF 28 MHz
- Design the circuit to operate at four, three, and two antennas
- Create an GUI to control the Arduino board through Bluetooth

Method

- Develop GUI to allow user to choose beam direction
- Design phase shifters to output signals with relative delays of 90 and 180 degrees
- Use microcontroller and relays to control phase delay at each output

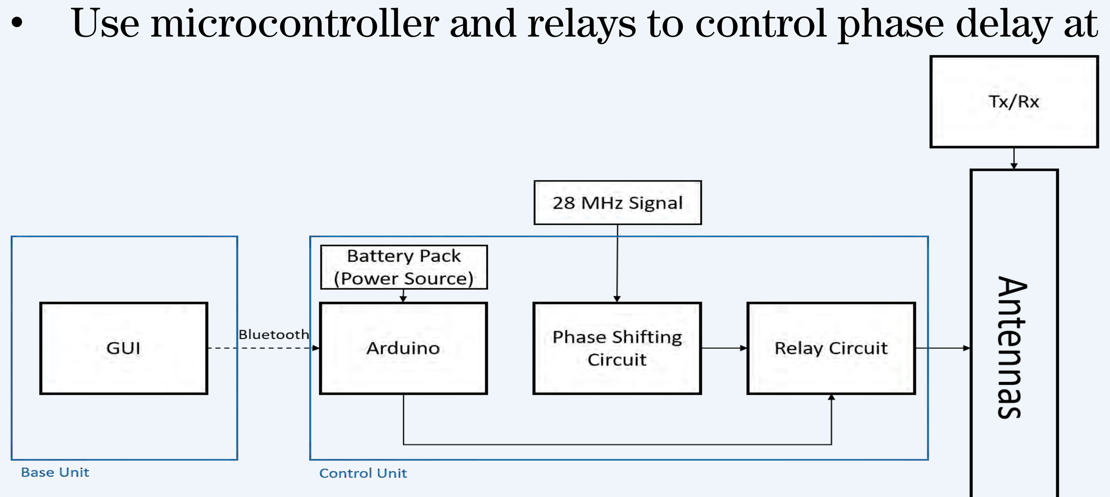


Figure 5 System Block Diagram

Design

Controller and User Interface

- GUI allows for the selection of beam direction and the number of antennas made using python
- Arduino board receives information from base unit via Bluetooth, then switches the relays for the selected direction.

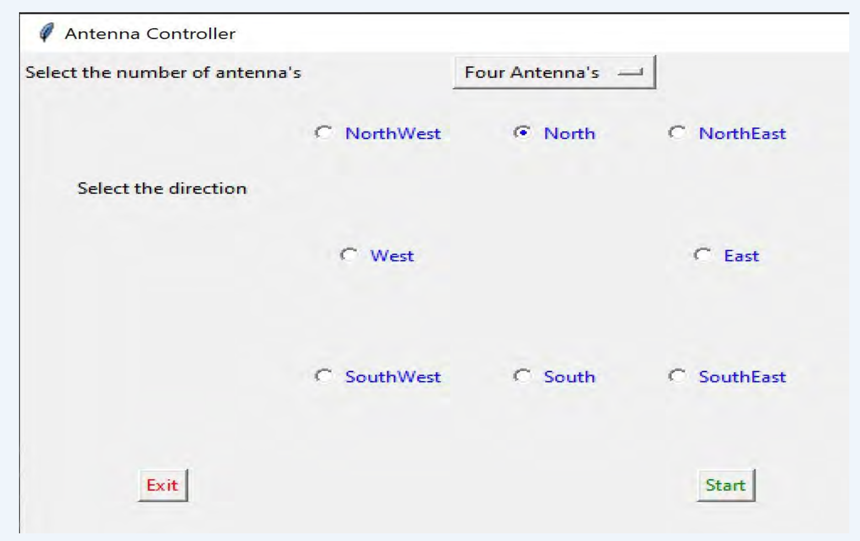


Figure 6 GUI allows user to select beam direction

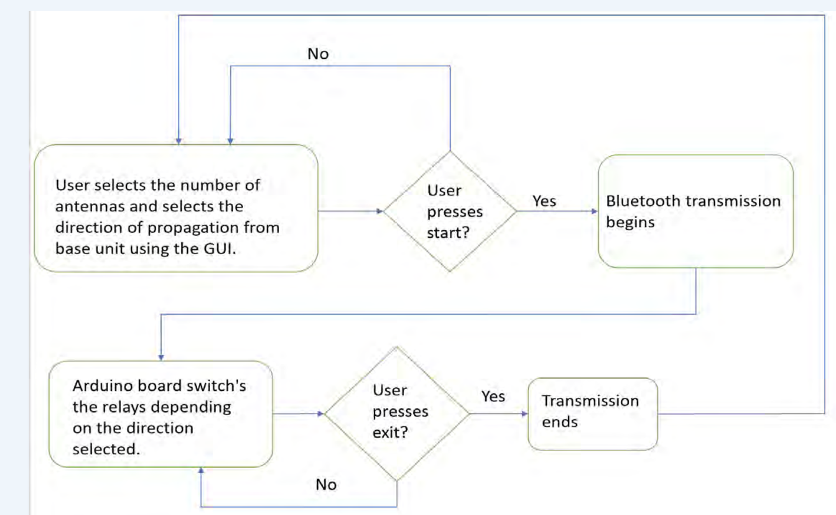


Figure 7 GUI logic diagram

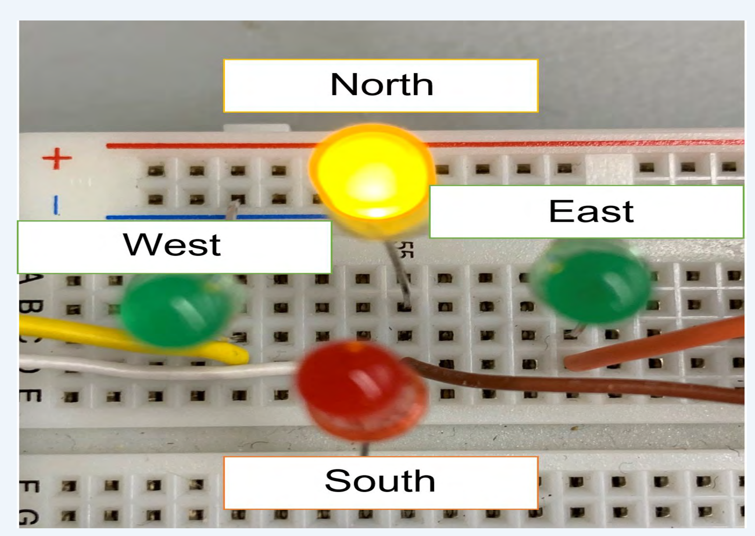


Figure 8 Demonstration of relay circuit with leds

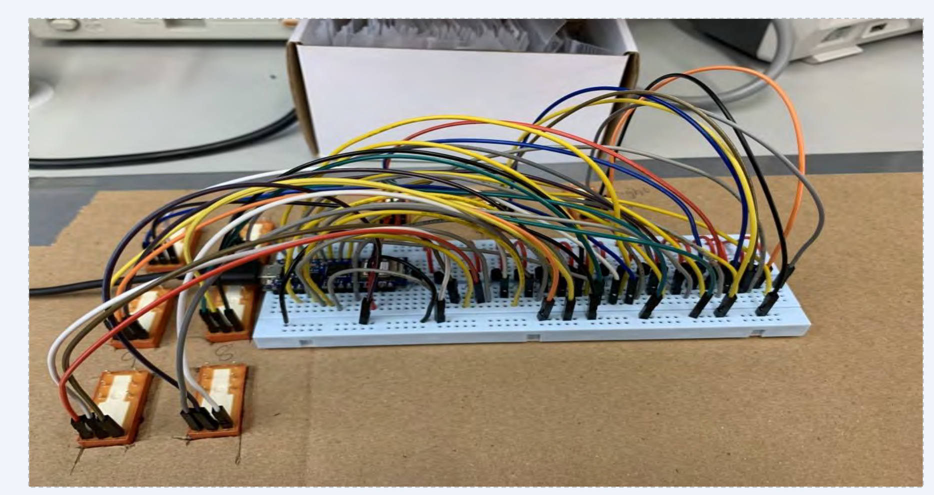


Figure 9 Photo of relay circuit on breadboard

Phasing Circuit

- Phasing circuit takes RF signal as input and outputs RF signals with phase shifts
- Choosing the appropriate phase shifts for each antenna cause the antenna beam to be pointed in a different direction

$$L = \frac{Z_0}{2\pi f_0}$$

$$C = \frac{1}{2(2\pi f_0)^2 L}$$

Figure 10 Equations used to determine L and C

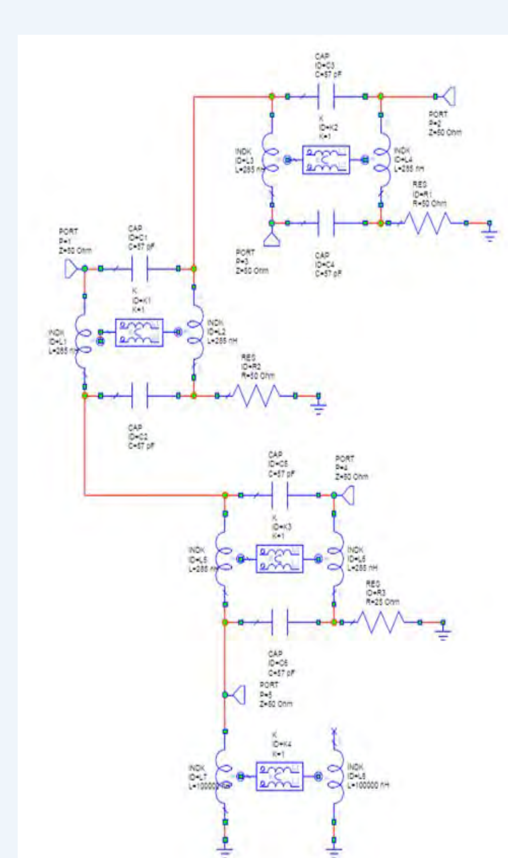


Figure 11 Schematic for Phasing Circuit

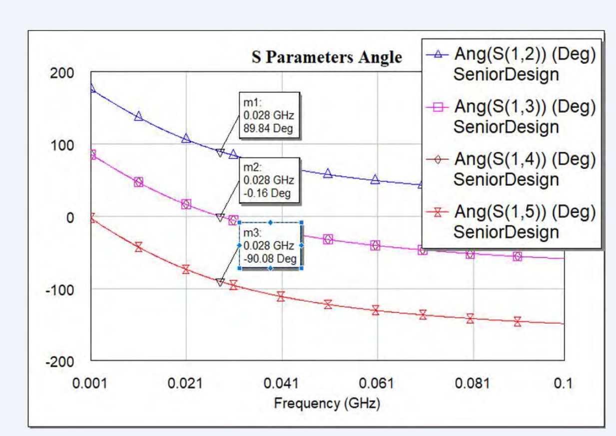


Figure 12 Input to Output S Parameters - Phase

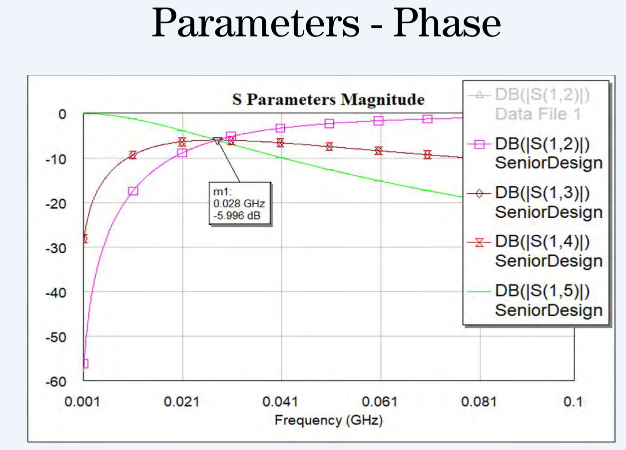


Figure 13 Input to Output S Parameters - Magnitude

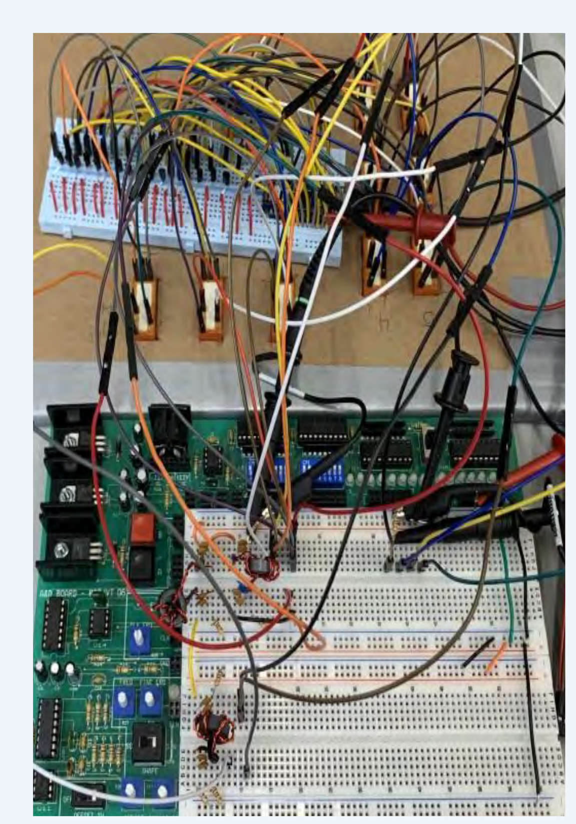


Figure 14 Photo of the relay and phasing circuit

Printed Circuit Board

- Circuit performance will improve
  - Long wires add impedance and noise
  - PCB would remove long wires therefore improving performance
- Will make the system easier to reproduce

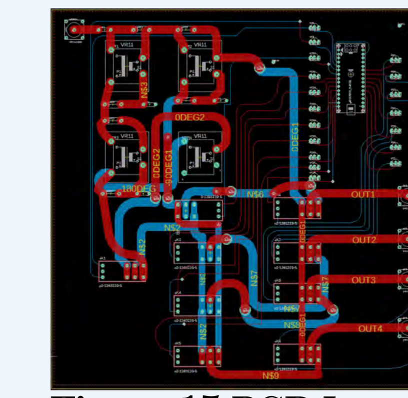


Figure 15 PCB Layout

Results

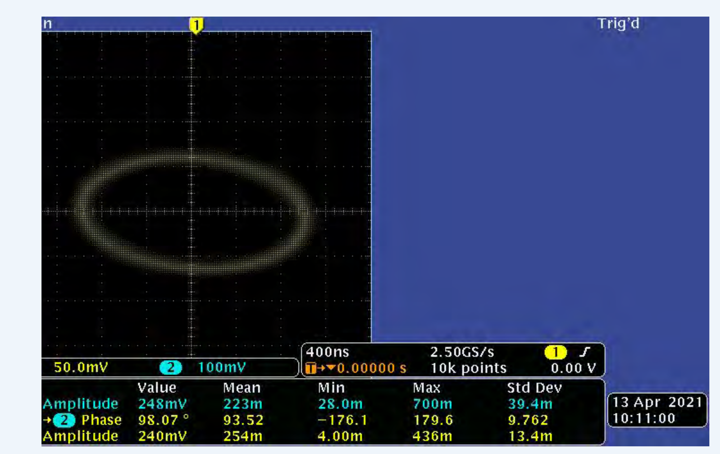


Figure 16 Phase difference between antenna 1 and antenna 2

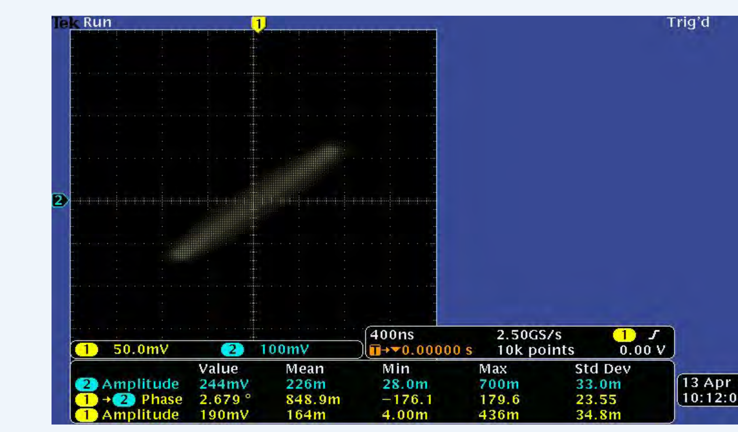


Figure 17 Phase difference between antenna 1 and atennat 3

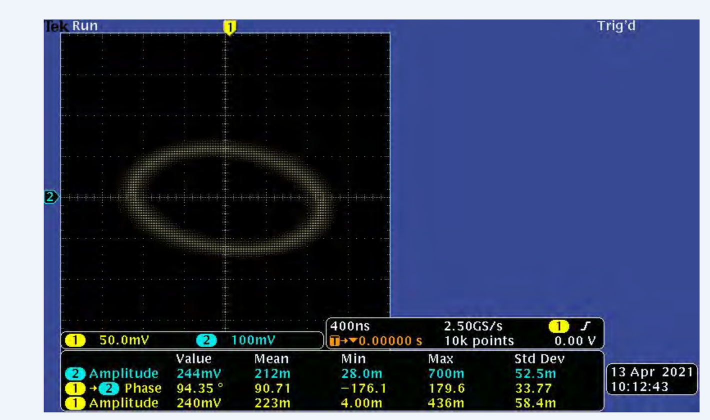


Figure 18 Phase difference between Port 1 and Port 4

- The phase difference between antenna 1 and antenna 2 was off by __3.52___
- The phase difference between antenna 1 and antenna 3 was off by __0.85___
- The phase difference between antenna 1 and antenna 4 was off by __0.71___
- With these differences, the system would still work

Conclusions

- The circuit results so far indicate the circuit will perform as expected given four antennas
- The GUI, phasing circuit, relay circuit and design of the PCB are complete
- The circuit still needs to be placed onto the PCB board and tested

Future Work

- One aspect of the project that could be expanded on in future work is making the controller functionable with two or three outputs representing antennas.
- Instead of using dummy loads to represent the antennas, a monopole or other type of omnidirectional antenna could be tested and possibly implemented.
- Implement the phasing circuit on a printed circuit board (PCB).

Acknowledgements

We would like to thank George Cooley, Prof. Schulz, and Dr. Manteghi for their continued support through the project.

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Modular Manufacturing using Automated Sensors

Calvin Truong, Jeannette Judenberg, Marcus Volpert, Matthew Du, and Michael Otooni

calvin11@vt.edu , jennyj7@vt.edu, marcusv1@vt.edu , msdu21@vt.edu, and micco17@vt.edu

Project Goal

- Design a sensing system to automate the robotic control for modular tooling processes of an airbus A320 inlet assembly. Reduce misaligned holes drilled in the Bulkhead.
- Two Step Process
  - Attach Inner Barrel to Forward Bulkhead
  - Attach Forward Bulkhead to Nose Lip

Project Purpose

- Demonstrate robotic Proof of Concept
  - 3D simulation of automated modular tooling
  - Improve tooling head alignment
  - Reduce cost of materials and lead time
- Improve ergonomic environment and safety

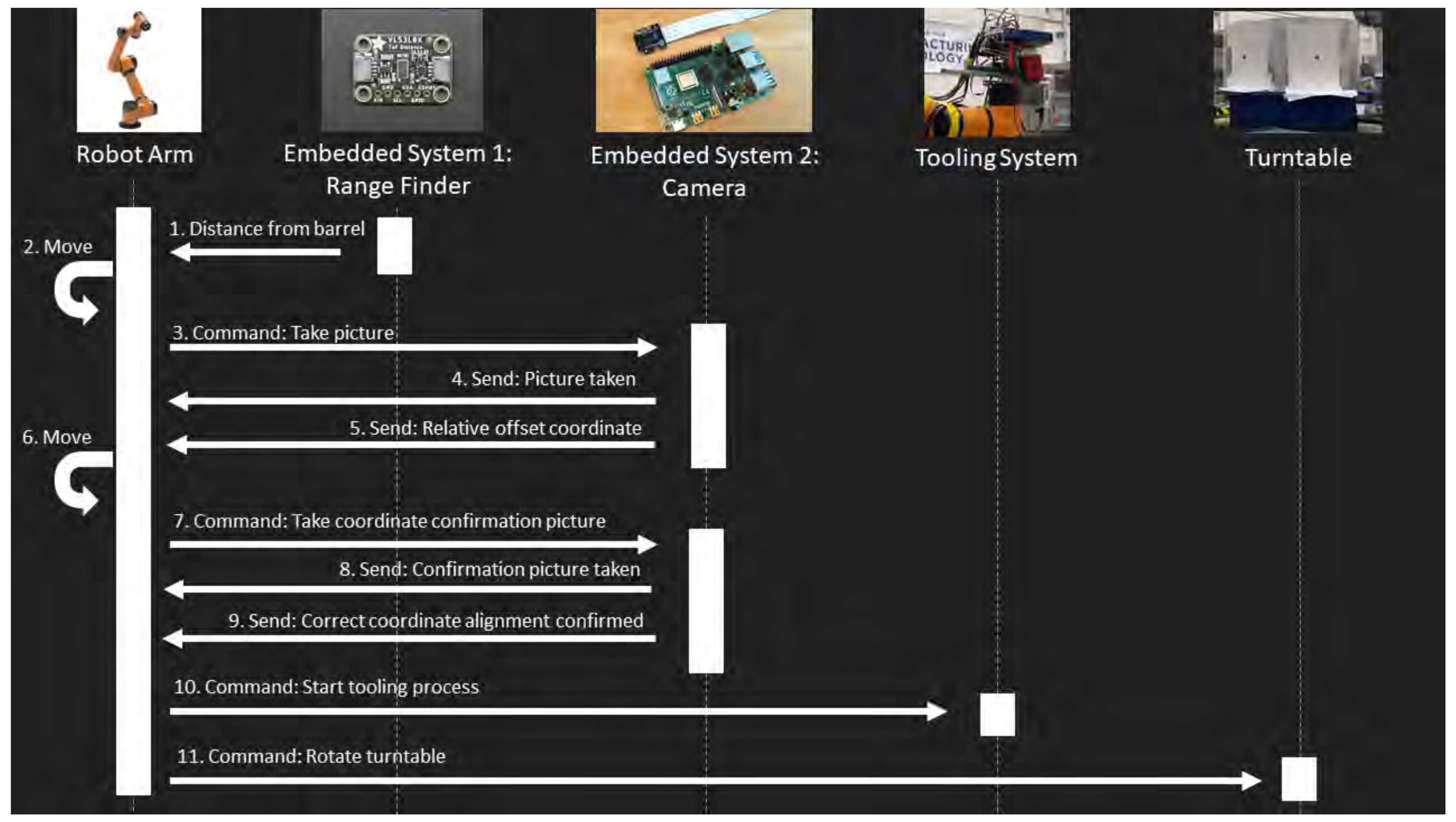
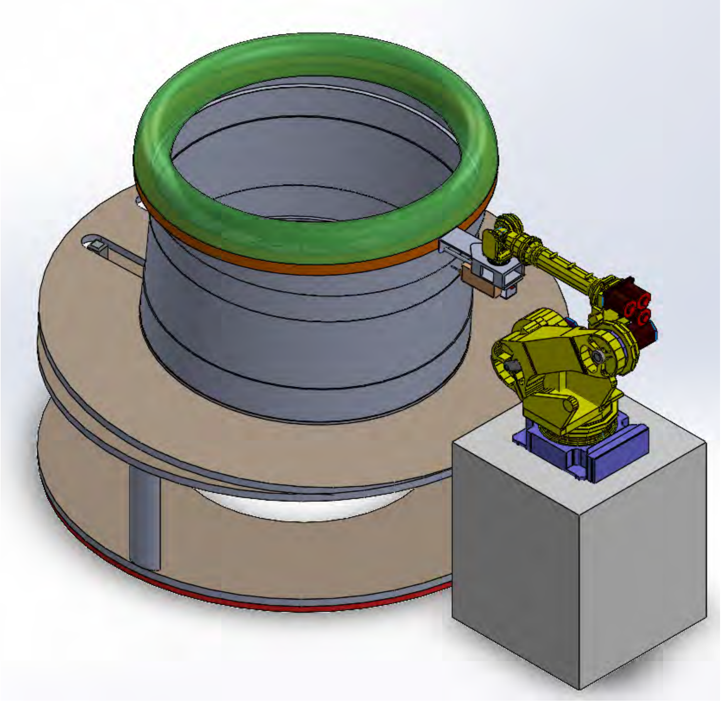


Figure 1. Sequence Protocol Diagram

3D Simulation

- SOLIDWORKS Motion Study
- Joint deliverable between the ECE and ISE Department Senior Design Teams.



[Full Simulation Video](#)
[Riveting](#)

Figure 2. Simulated Assembly

Local Model of FANUC Arm (AUBO i5)

- FANUC (actual production) vs AUBO i5 (learning lab)
  - VT's AUBO i5 arm was selected due to its availability and similarity to FANUC Arm
    - Both arms have 6 degrees of freedom range of motion
    - AUBO i5 is 40% scale of FANUC R-2000IA

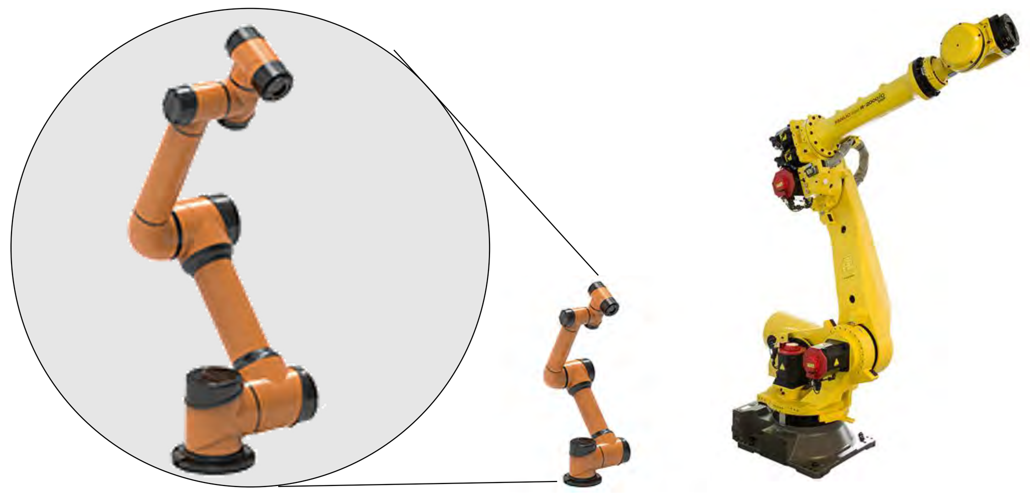


Figure 3. AUBO (Left) vs FANUC (Right) Arm Comparison

- AUBO i5 is controlled with the AUBO Programming Environment

  [Arm Maneuverability](#)

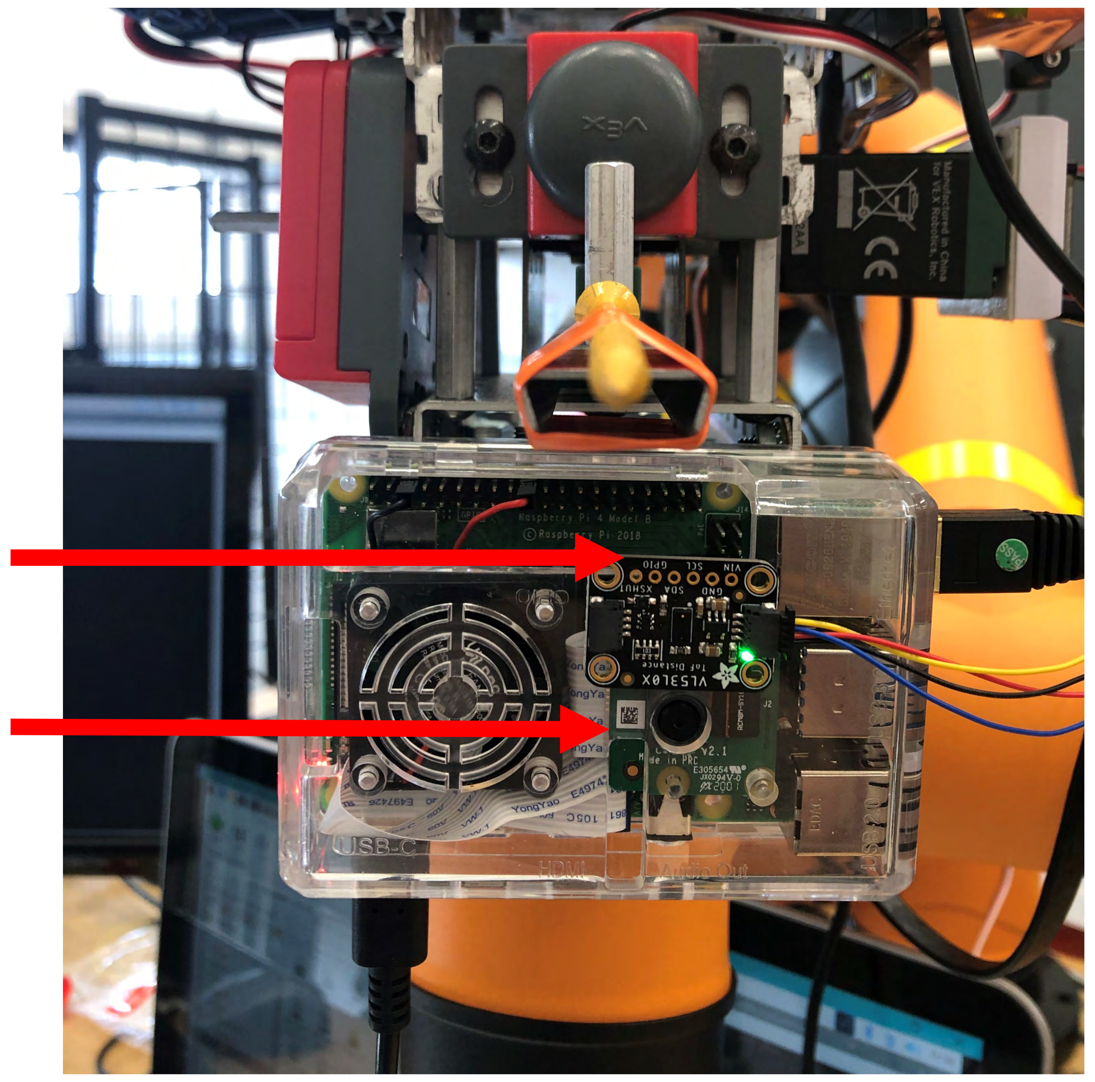


Figure 4. Sensor System

Embedded System: Range Finder

- Range Finder controls Z position
  - Analog signal sent to arm
  - Distance mapped to Analog Signal

$$D_{total} = \frac{Analog\ Signal\ (Volts) * 1(meters)}{3.3\ (Volts)} - D_{e.e.\ to\ LIDAR}(meters)$$

[Range Finder Video](#)

Embedded System: Camera

- Camera controls X and Y position
- Camera takes a picture of reference point and sends back the X and Y distance to move the end effector

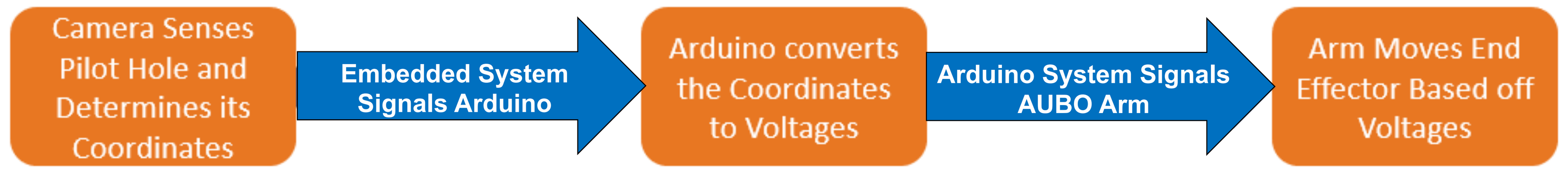


Figure 5. Overall System Diagram

System Deliverables

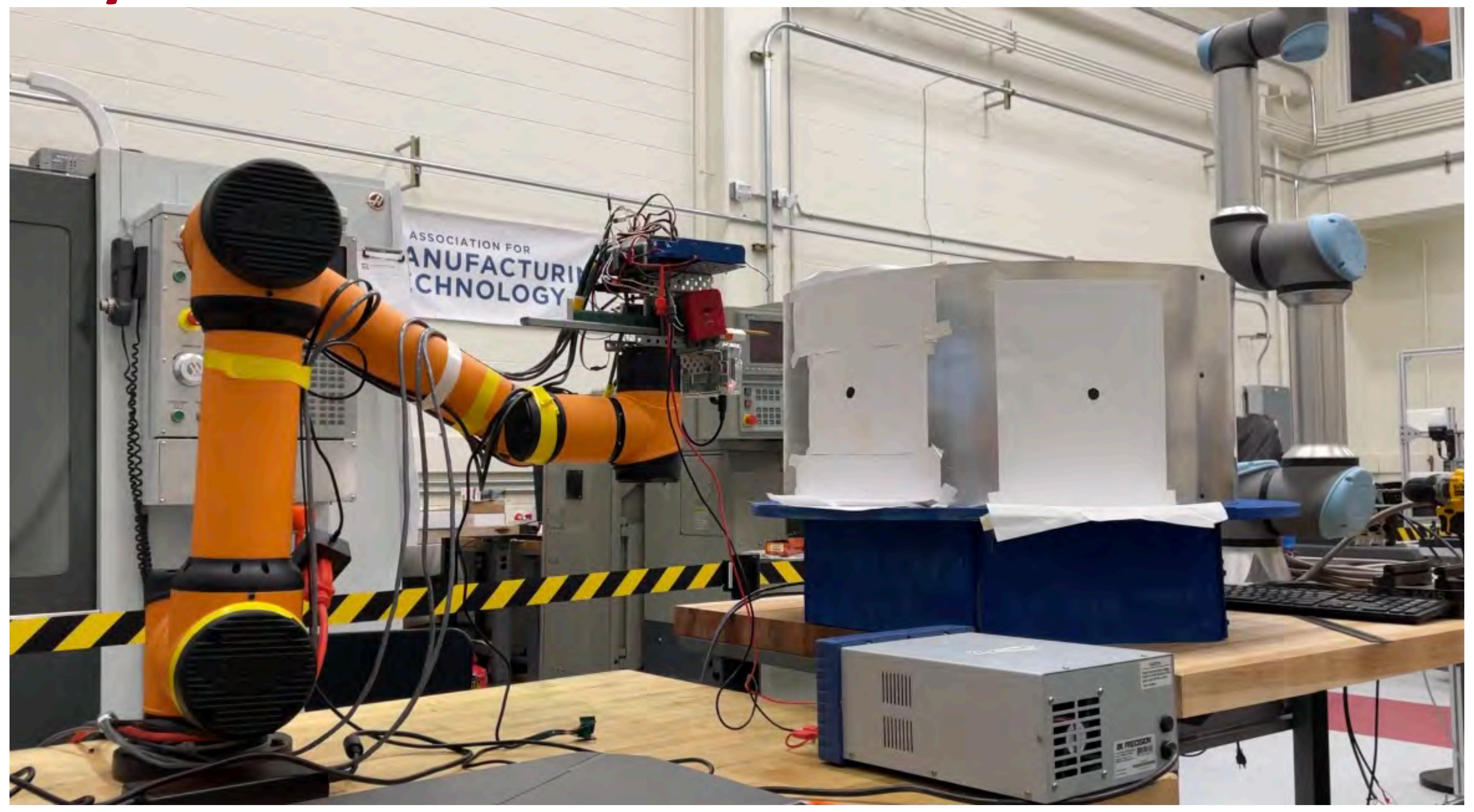


Figure 6. Overall System Diagram

[Sensor System Demonstration](#)
[Close Up of Sensor System](#)

Conclusion

The sensor system increases the accuracy, speed, and safety by automating the assembly of the A320 inlet. It also decreases the cycle time and removes the manual operations of the tooling process.

Overall, the results of our solution proves the validity of automating the current manufacturing process of the inlet assembly.

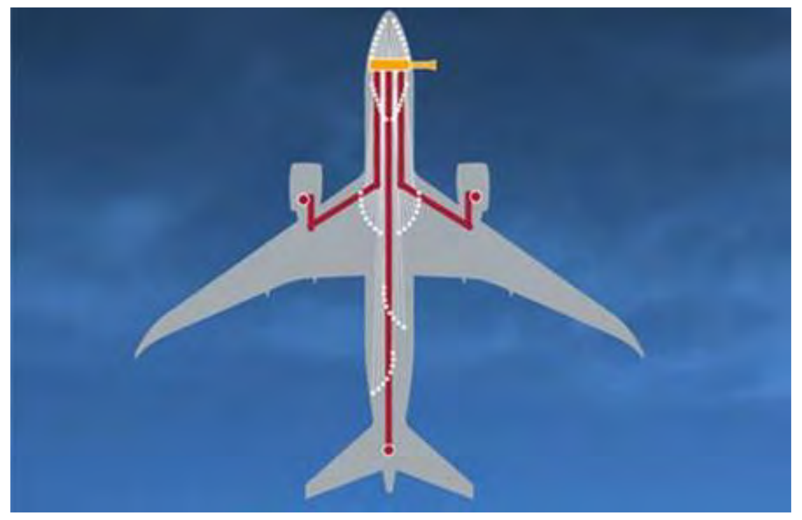
Acknowledgments

- Collins Aerospace for the support to work on this real challenge
- Our great customers, Lucas Brady & Kelly Bernabe, who also taught us engineering and project management as done in industry
- Our partners, the ISE Team, for cooperation throughout the project
- Benjamin Standfield (VT grad student) for help in the lab
- Dr. Andrea L'Affitto for his dedication and willingness to teach

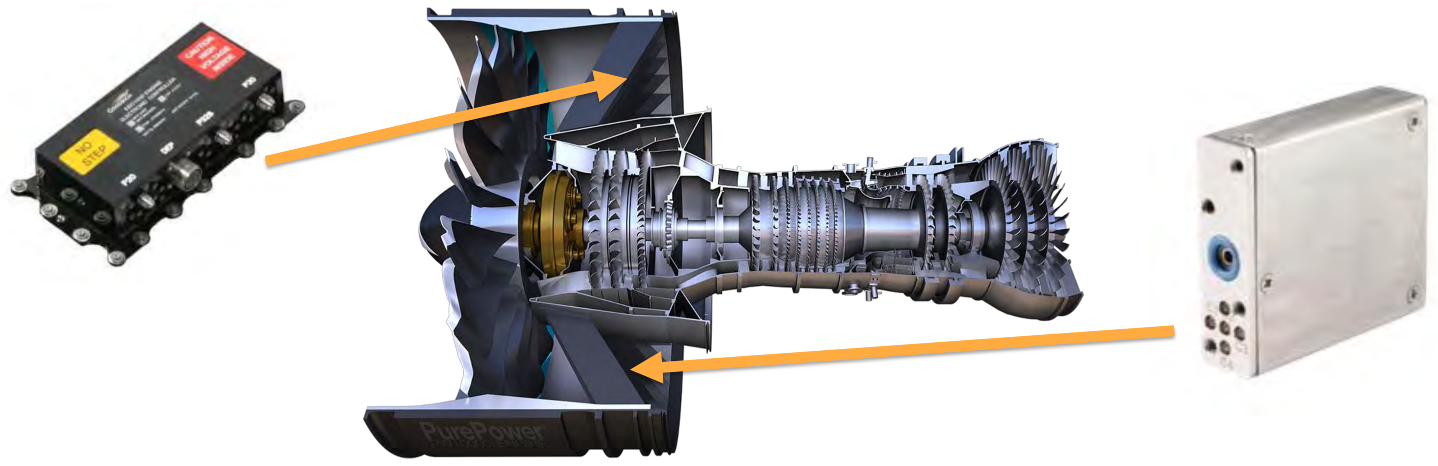
Temperature Differential Power

Juliet Anderson, Devin Durham, Aaron Evans, Connor Morrissey, Shashwat Singh
Customer: Dr. Magdi Essawy   SME: Dr. Dong Ha, Minh Ngo   Mentor: Prof. Kenneth Schulz

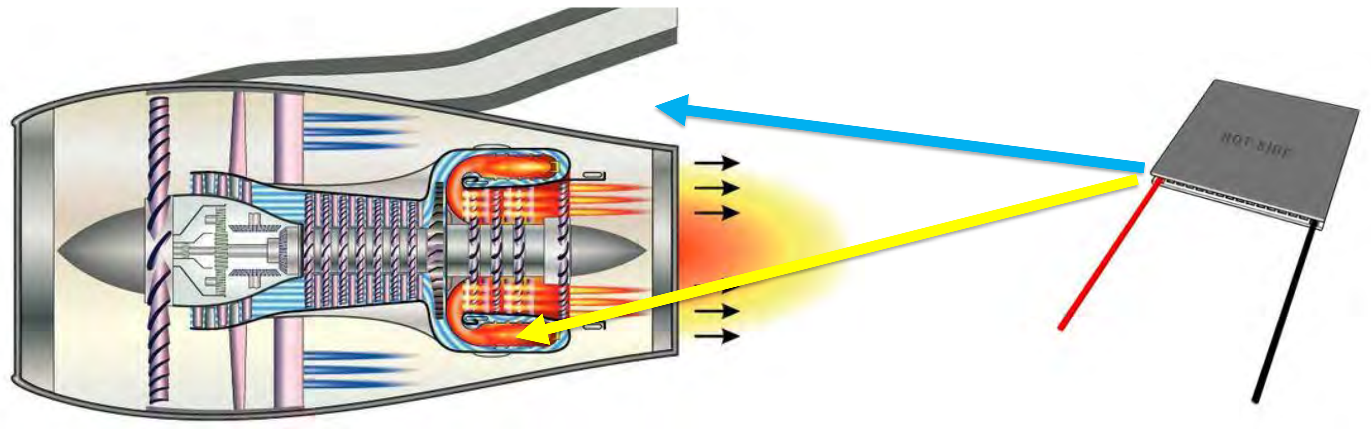
Introduction



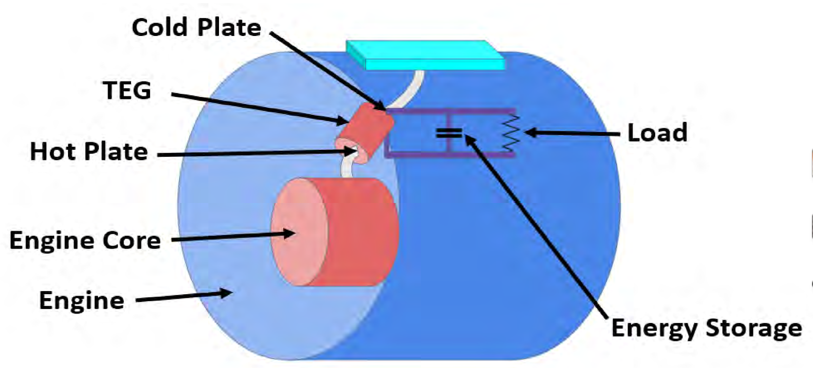
- Power distribution from the main power bus to the engine is a difficult task in modern aircraft, due to high temperatures and little free space.



- However, to ensure safe operation, an array of sensors are needed to monitor engine health and performance.



- Using a thermoelectric generator (TEG), the high temperature differential between the high-temperature core inside the engine and low temperature air outside the engine can be used to harvest energy.

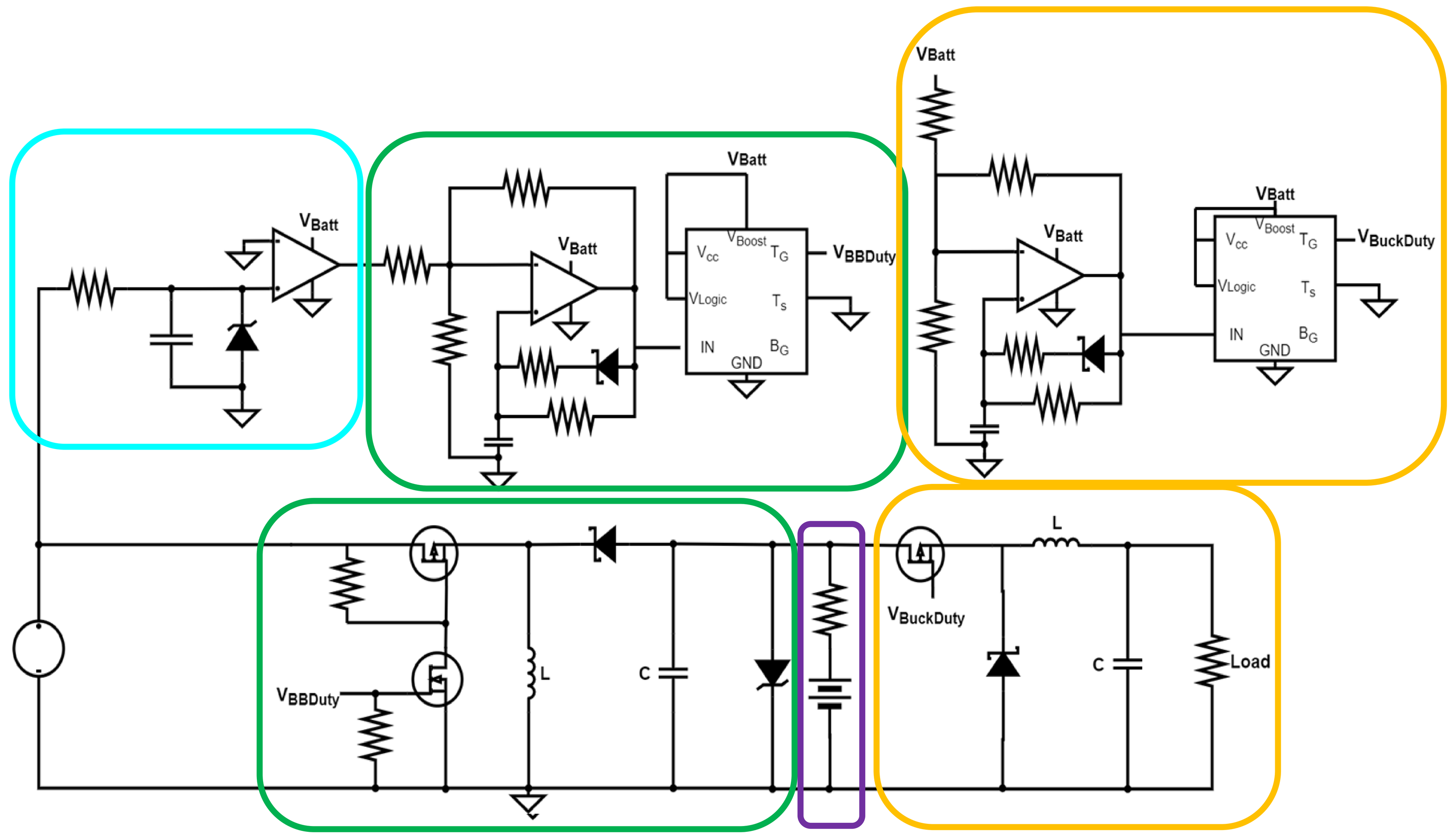


- Implementation of an energy harvesting and storage circuit will allow for maximum power transfer from the TEG, and ensure reliable delivery of power to the sensor.

Requirements

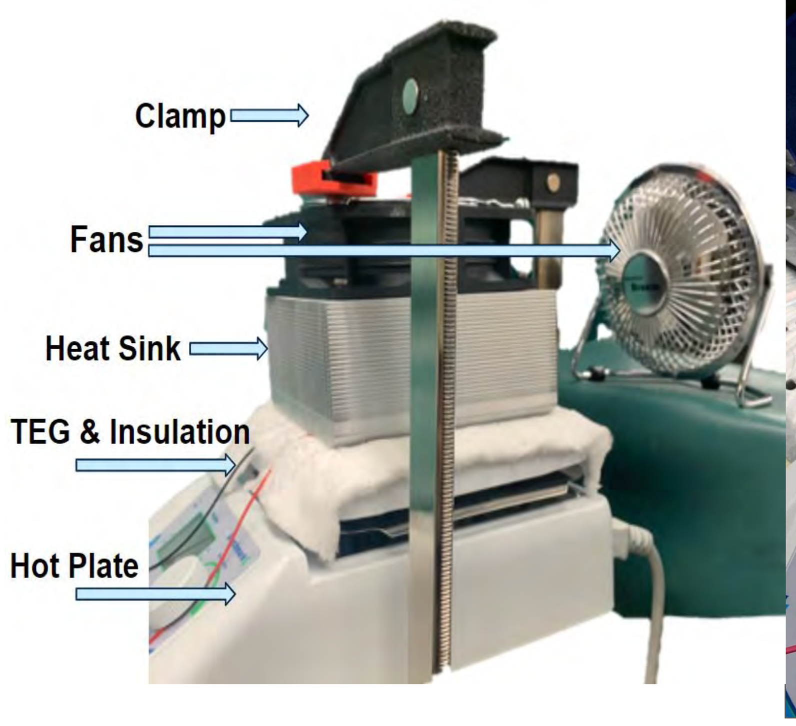
- Designed circuit must utilize a temperature gradient from 30°C to 300°C.
- Designed circuit must be suited for high ambient temperature environments of up to 85°C.
- Circuit must deliver a constant output power of 1 W ± 5%, at a regulated voltage of 5V ± 5%.
- Circuit must have a rechargeable energy storage mechanism capable of powering the load during ascent and descent.
- Size constraints: Circuit must be able to fit within 100mm x 100mm x 150mm.
- Weight constraint: Circuit cannot weigh more than 5 lbs.

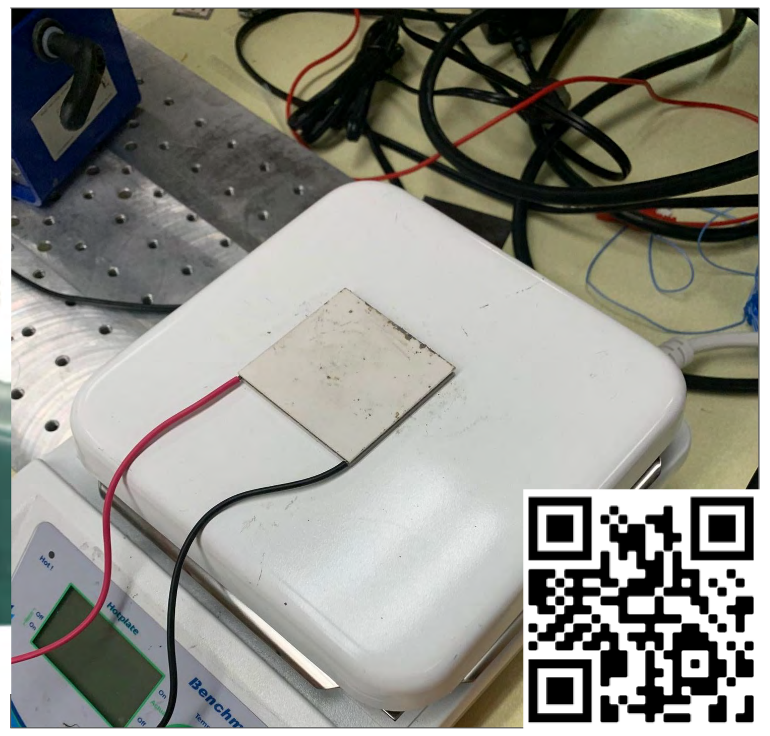
Design Method



- **Wake-Up Circuit**
  - Ensures that energy is only harvested when there is a temperature gradient across the TEG. It also acts as an overvoltage protection device.
- **Buck-Boost Converter**
  - Matches the TEG impedance for maximum power transfer and boosts the voltage for charging the energy storage.
- **Buck Converter**
  - The buck converter is used as a voltage regulating circuit to convert the output voltage of the buck-boost converter to the desired output of 5V and 1W.
- **Energy Storage**
  - A lithium-ion battery is used to store energy delivered by the buck-boost, and can supply power to the load when there is no input from the TEG.

Thermoelectric Generator (TEG)





A Thermoelectric Generator (TEG) is used to harness thermal energy from a temperature gradient. To create this temperature gradient, the TEG device is placed between a hot plate and a large heatsink. The setup is pressed together using two clamps, ensuring equal force distribution and surface connection across the TEG. The hotplate is then heated up to 300°C while the heatsink is kept at room temperature.

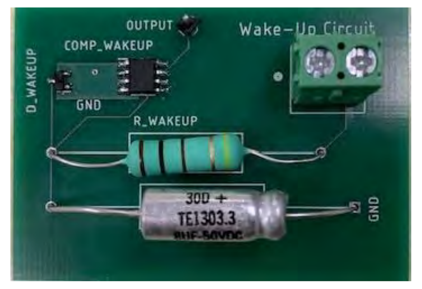
The TEG was rated to produce 13 V (open circuit) at a 270°C gradient. Due to some non-idealities, we saw a drop in the output voltage and efficiency of the TEG test setup. The test results are tabulated alongside.

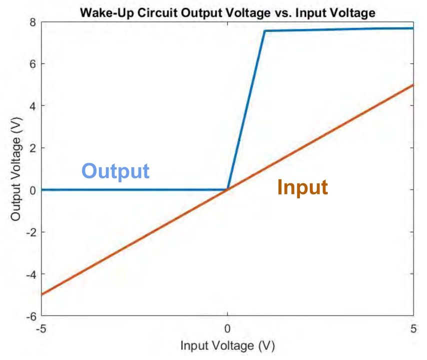
TEG Test Results

	Measured
Open-circuit	11.0 V
Across matched impedance	5.1 V

Results

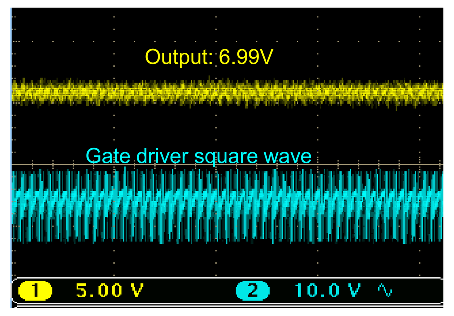
- **Wake-Up Circuit**





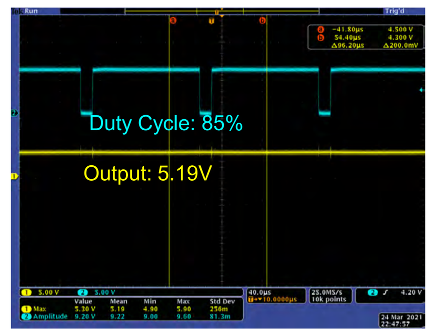
	Simulated	Achieved
Output Voltage with 0V Input	0V	--
Output Voltage with 6.7V Input	8.2V	7.78V

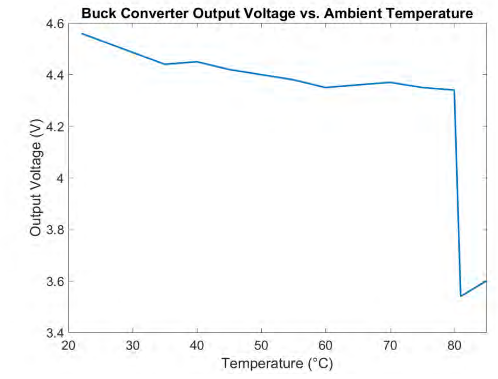
- **Buck-Boost Converter**



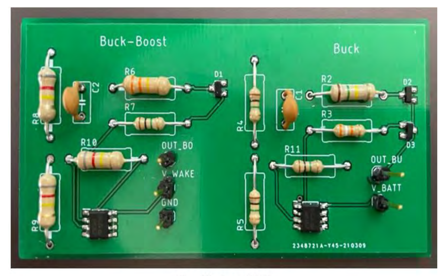
	Simulated	Measured
Output Voltage	8.76V	6.99V
Ripple	2%	18.34%
Frequency	22 kHz	2.7 MHz
Duty Cycle	39%	80%

- **Buck Converter**

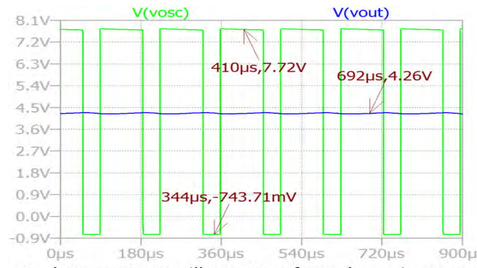




- **Oscillator + Gate-driver**



Oscillator PCB



Buck Converter Oscillator Waveform shown in Green

	Simulated	
Buck converter	Duty Cycle:	84.6%
	Frequency:	7.52 kHz
Buck-boost converter	Duty Cycle:	39.22%
	Frequency:	21.8 kHz

Conclusions

- All individual circuits were tested but there was not enough time to test the system together as a whole.
  - Overall circuit was within size constraint if they were stacked on top of each other.
- The buck converter and wake up PCBs produced the desired results.
- The buck-boost converter and oscillator still need further testing and debugging.

Challenges

- Improper PMOS switching led to inefficient boosting of the buck boost PCB output.
- Despite the fiberglass wool insulation, the hot plate heated-up the heat sink, thus dropping the temperature gradient and the generated voltage.
- High ambient temperature increased the parasitic resistances causing non-idealities.

Future Plans

- Troubleshoot the oscillator & buck-boost PCBs.
- Integrate a control circuitry - Pulse Width Modulation (PWM) of the square wave - to ensure maximum efficiency while switching the Mosfet in the buck-boost converter.
- Thermally isolate the hot plate & heat sink in the TEG test set-up and ensure even calibration of the clamps for uniform pressure on the TEG surface..

Acknowledgments

We would like to thank the following people for their support in this project:
- Dr. Magdi Essawy of Collins Aerospace
- Subject Matter Expert: Dr. Dong Ha and Minh Ngo of the ECE department
- Mentor: Prof. Kenneth Schulz

Universal Power Amplifier Test Controller

Team Members: Ryan King, Taha Rangwala, Qihang Shan
Customer: Jonathan Kolbrak **SME:** Prof. Peter Han **Mentor**: Prof. Ken Schulz

Introduction

Executing radio frequency tests can be time consuming. A test controller can automate this process to save time and headache.
The three tests we are implementing are: Mixer Spur Test, P1dB Test, and Pin vs. Pout Test

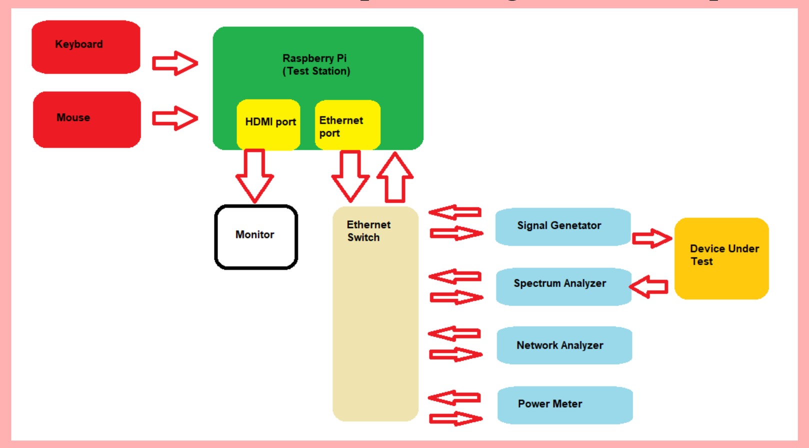
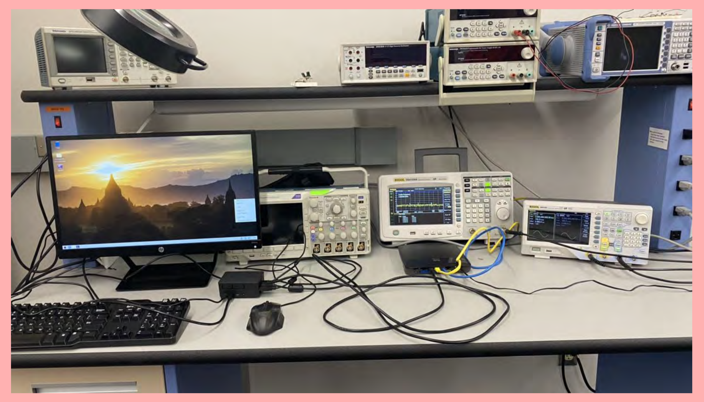


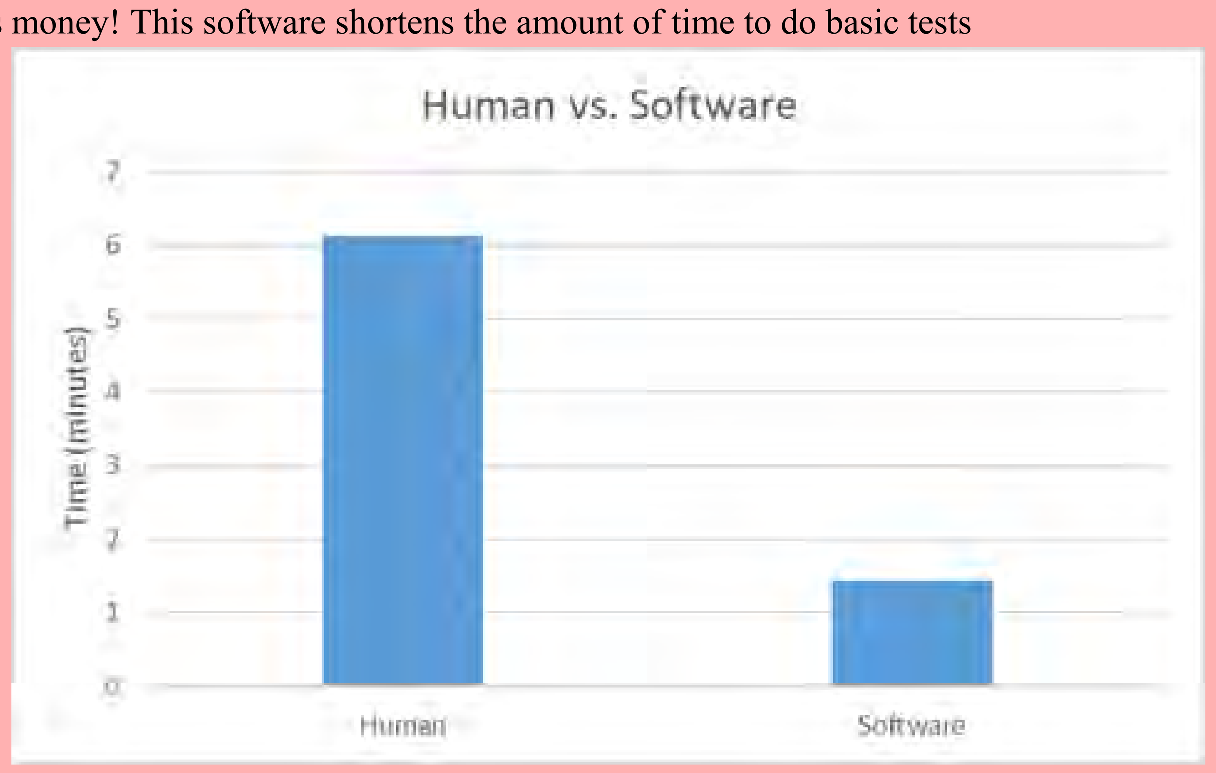
Diagram of Test Controller Setup



Test Bench Setup

Efficiency Comparison

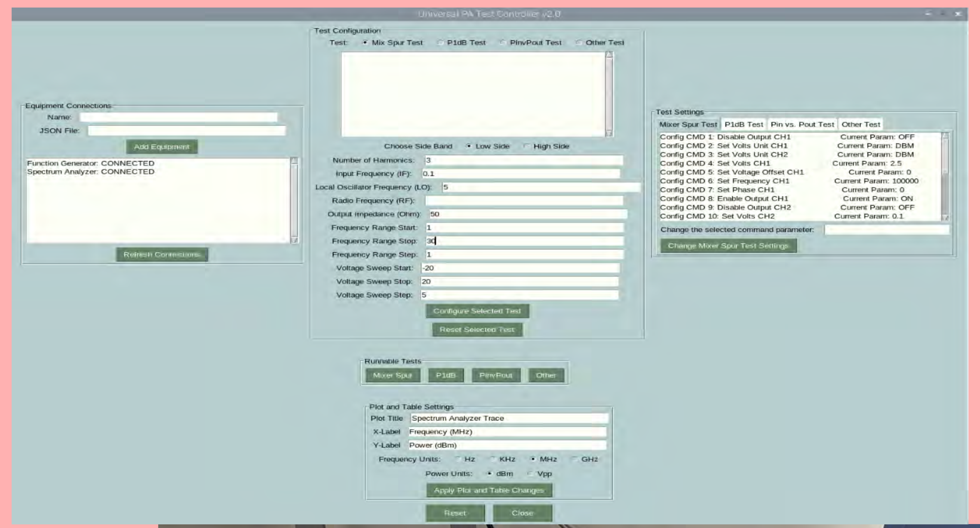
- Pin vs. Pout test took us 6.13 minutes to do by hand
- The software took 1.45 minutes finish the test
- Time is money! This software shortens the amount of time to do basic tests



Plot of Human Calculations vs. Software Calculations

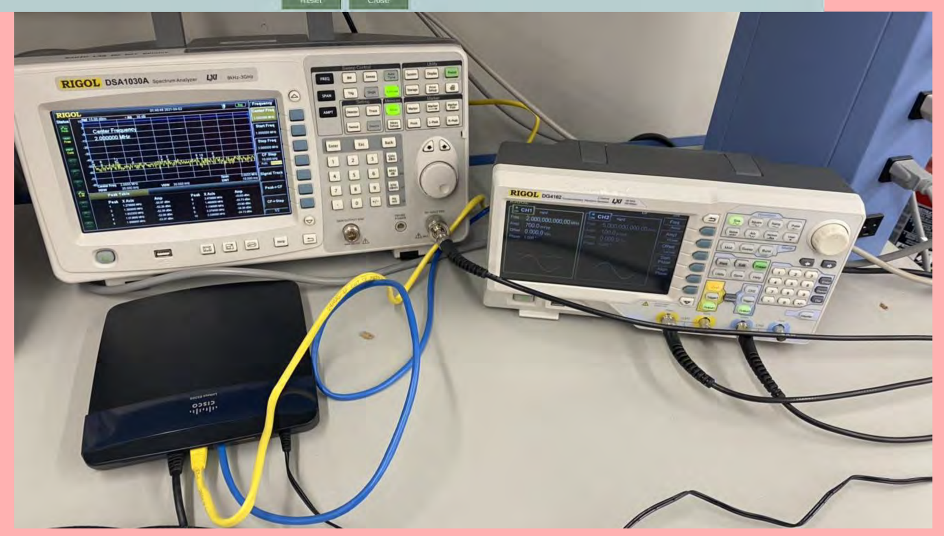
User Interface and Connectivity

The Graphical User Inteface (GUI) is how the user will perform different tests and change settings as well [1]



<u>User Interface</u>

- Add multiple pieces of testing equipment [2]
- Configure, execute, and reset tests [2][3]
  - Default tests: Mixer Spur Test, P1dB Test, and Pin vs. Pout Test
- Change test parameters [2]
- Modify plot and table settings [4][5]



<u>Connectivity</u>

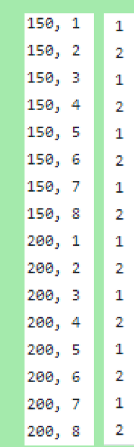
- Instructions are given to test equipment
- Ethernet connections
- Ethernet switch connects computer with test equipment

Functions and Input Parameters

This Test Controller is capable of three default tests and a user can add more tests if it is configured correctly. (Note All Powers are measured in dBm; input can be Vpp or dBm)

Required parameters for each tests:

<u>Pin vs. Pout Test</u>	<u>Mixer Spur Test</u>	<u>P1dB Test</u>
PowerIn.txt	Number of Harmonics	Input Impedance
PowerLoss.txt	RF, IF, LO Frequency (2 of 3)	Frequency (Start, Stop, Step)
	Frequency (Start, Stop)	Voltage (Start, Stop, Step)
	High or Low Side	



PowerIn.txt, PowerLoss.txt

Calculation for Mixer Spur Test

High Side Frequency Output =

$$|m * (IF \text{ or } RF \text{ or } LO) + n * (IF \text{ or } RF \text{ or } LO)|$$

Low Side Frequency Output =

$$|m * (IF \text{ or } RF \text{ or } LO) - n * (IF \text{ or } RF \text{ or } LO)|$$

Sample of User-Input Parameters on GUI

Experimental Setup

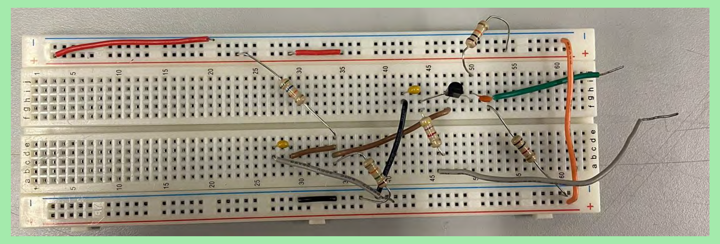
Testing Equipment Needed:

- Function generator
- Spectrum analyzer
- RF device for testing
- DC power supply

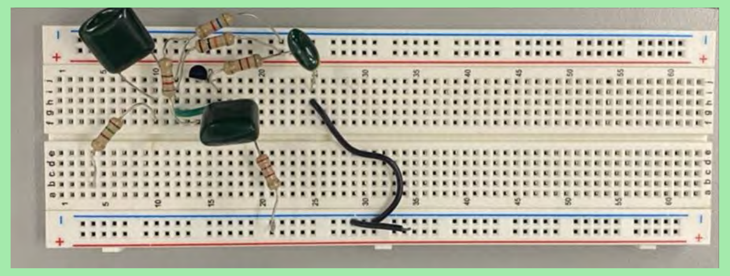
Testing Equipment Used:

- Rigol DG4162 Waveform Generator
- Rigol DSA1030A Spectrum Analyzer
- Class A BJT Common Emitter Amplifier
  - Based on Reference [6]
- NPN-based AM Mixer Circuit
  - Based on References [7][8]
- Raspberry Pi

Raspberry Pi 4 Model B 4GB



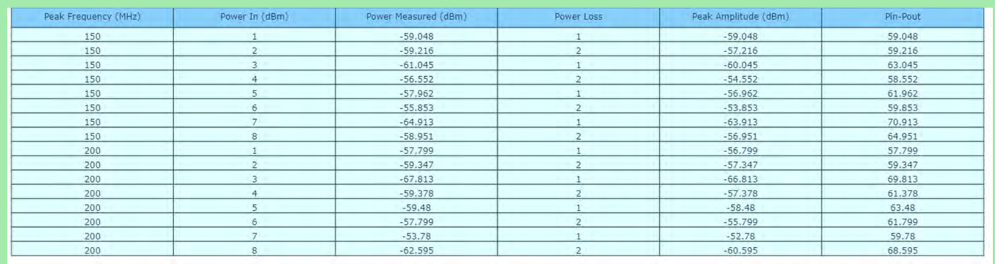
AM Mixer Circuit



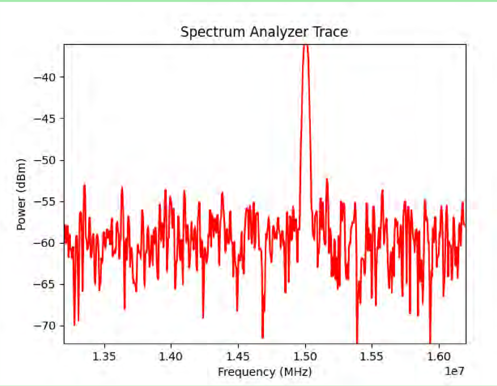
CE Amplifier

Test Results

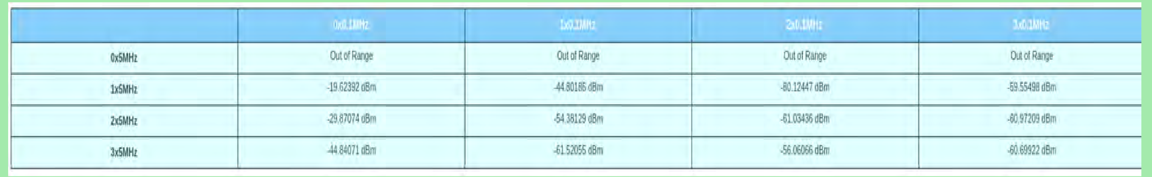
The three implemented runnable tests are Pin vs. Pout, Mixer Spur, and P1dB test. All tests are abortable by existing out the spectrum analyzer trace window.



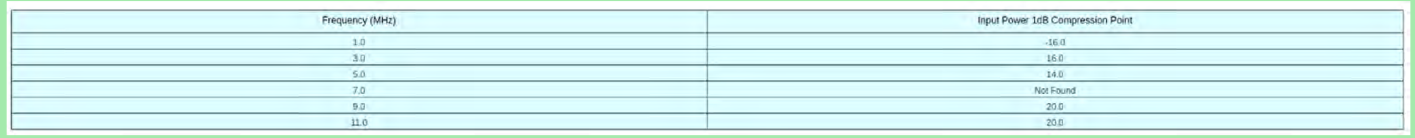
Pin vs. Pout Test output



Spectrum Analyzer Trace



Mixer Spur Test output



P1dB Test output

Analysis and Conclusions

- The Mixer Spur test and P1dB test both deliver proper results
- The Pin vs. Pout test should be nominal, since the algorithm is from the previous group's efforts for this project
- More RF devices should be tested to further validate the algorithms
- Program tested on Raspberry Pi Model 4 B with 2GB of Ram, a Raspberry Pi Model 4 B with 4 GB of Ram, and Lenovo Flex 5 Laptop.
- Program can execute RF tests much faster if the device it is running on has more processing power
- Program is open source and can be found at the following URL: https://github.com/TahaRangwala/CollinsTestController-v2.0

Setbacks and Challenges

- Understanding SCPI (Standard Commands for Programmable Instruments) was necessary to control the test equipment. They were difficult to decipher at first.
- Controlling the test equipment via Raspberry Pi causes slow communication with test equipment.
- Algorithm would encounter glitches if the test equipment was updated too quickly. It requires a small timeout during a test if test equipment is updated.
- This project is a continuation of a project from the previous year. The code from that group was not commented and documented well.
- COVID-19 pandemic was a general impetus. Most prominent was that it was hard to demonstrate product to relevant personnel.

Acknowledgements

We extend our gratitude to the following personnel:
Prof. Peter Han (Subject Matter Expert)
Jonathan Kolbrak (Customer)
Prof. Kenneth Schulz (Mentor Professor)

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Next Generation CubeSat System

Updated Antenna and Science Subsystems

Team Members: Derin Araci, Yiwen Gu, Renee Rodgers, Veena Sreekantamurthy, Jonathan Stroud

Customer: Mr. Tony R Keith, LMCO **SME:** Dr. Kevin Shinpaugh **Mentor:** Dr. Scot Ransbottom

Motivation

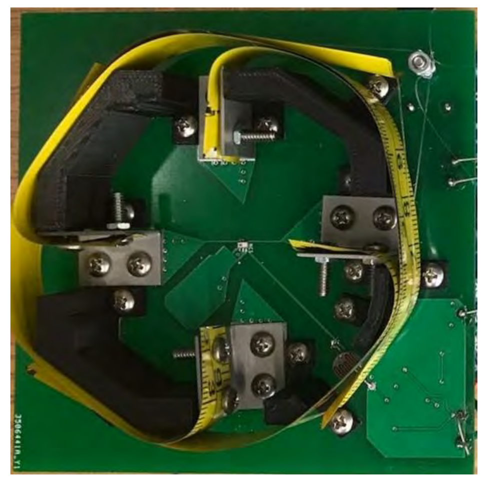
CubeSats provide a great opportunity to learn about satellite design and operations on a smaller scale. By developing CubeSats and their subsystems, the next generation of engineers will help advance space technology.

The previous CubeSat did not communicate with the ground after launch; we focused on this problem.

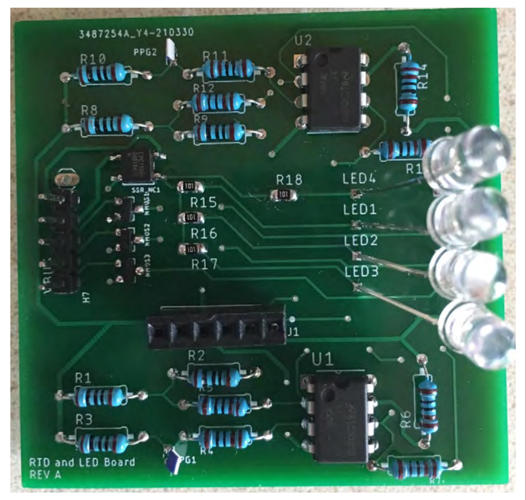
CubeSats leaving the ISS

Deliverables

Antenna Subsystem

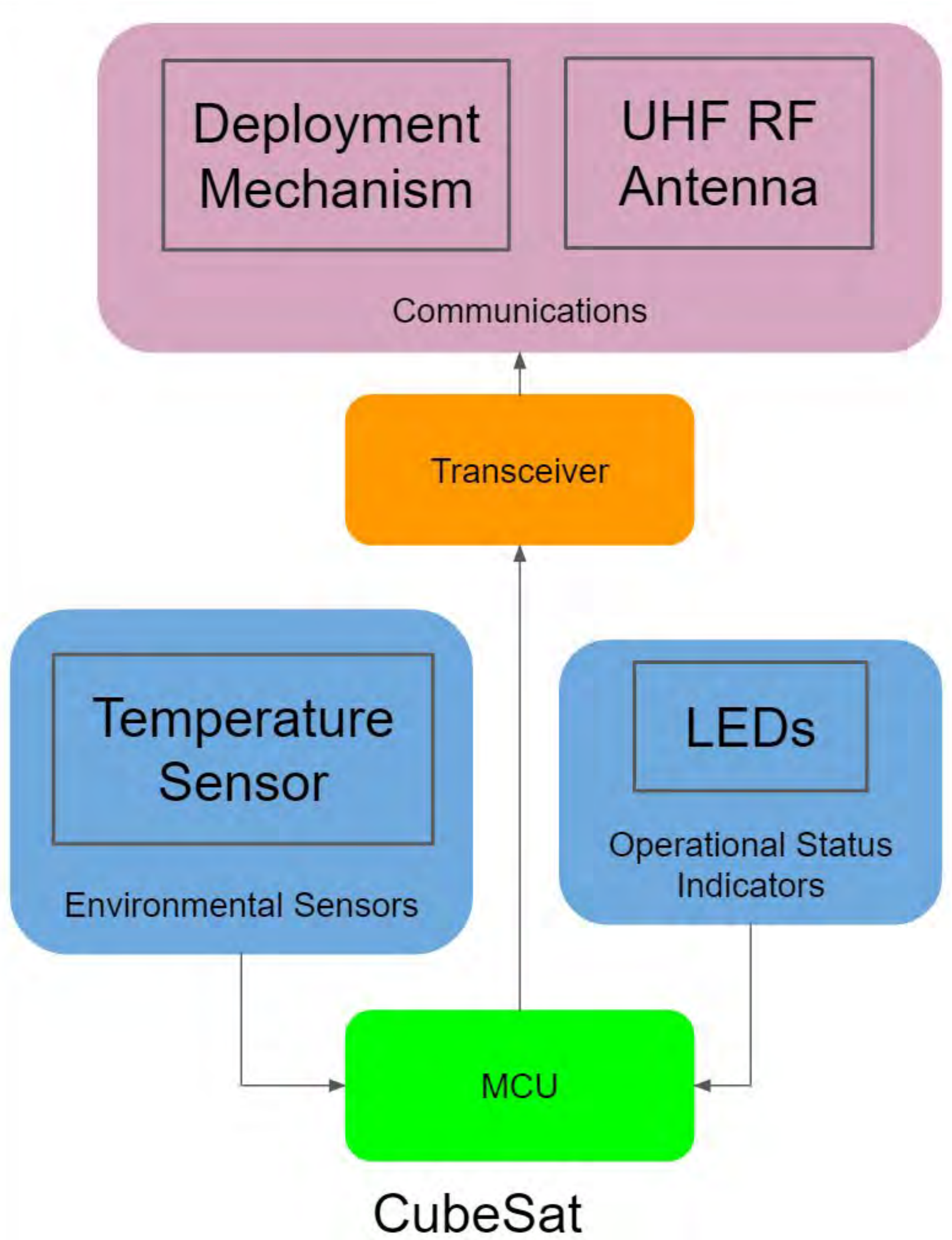


Science Subsystem



Software control system for CubeSat states and data

System Level Diagram



Antenna Board

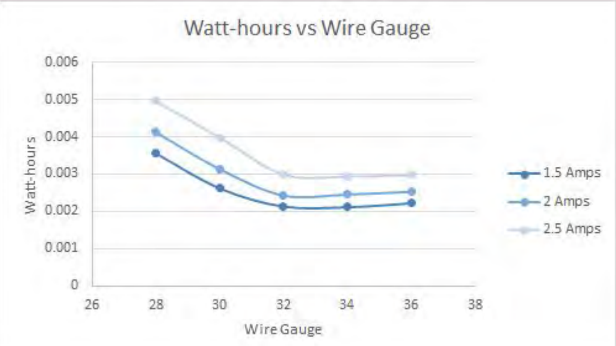
Deployment Mechanism

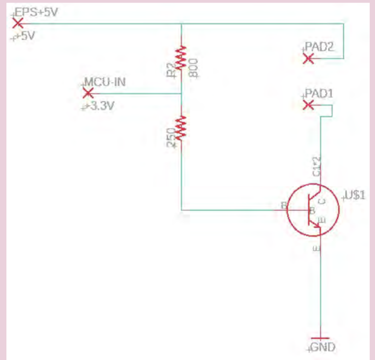
Burn Wire Mechanism

- Calculated burn time for different gauges of nichrome wire and currents
- Selected 32 gauge at 1.5 amps to minimize power consumption

$$time(s) = \frac{Temp * mass * c}{I^2 * R}$$

c = specific heat capacity

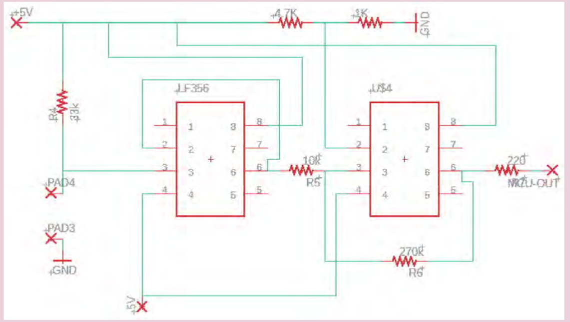




Burn Wire Schematic

Safety Sensor

- To avoid any unnecessary power consumption, a light sensor was implemented onto the antenna PCB to turn off the burn wire circuit if it detected light

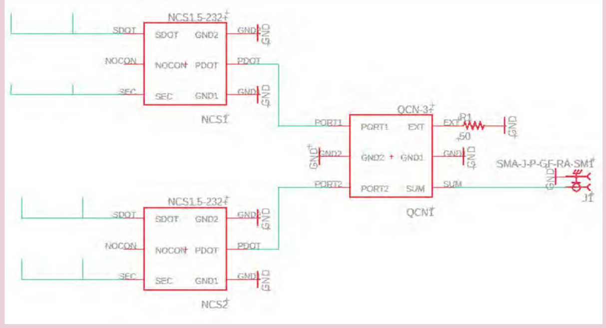


Light Sensor Schematic

Antenna

Antenna Electrical Hardware:

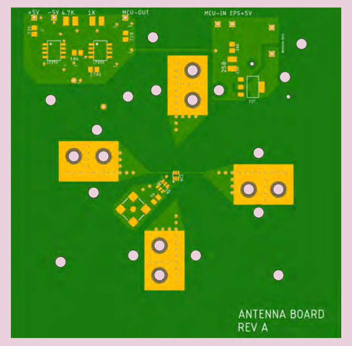
- Balun Transformers (2x)
  - For broadband impedance matching
- Half Wave Dipoles
  - For compact design and moderate gain
- 90 Degree Hybrid
  - For splitting input signal and shifting the phase for one of the signals



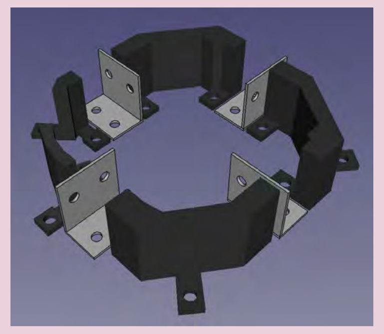
Antenna Schematic

Antenna Mechanical Hardware:

- Custom made corner bracket
  - Allows antennas to deploy parallel to PCB
- 3D printed "walls" to guide antenna during deployment



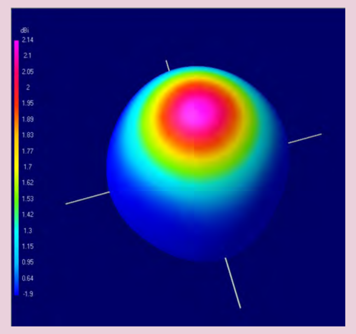
Antenna Top View



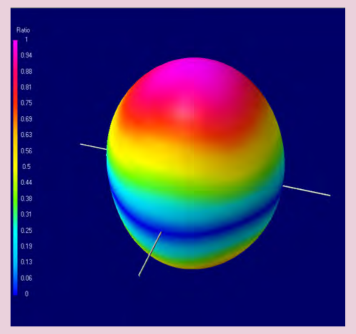
Mechanical Hardware

Antenna Characteristics:

- Operating frequency range is 401.11MHz - 401.13MHz
- Gain is 2.14dBi
- Circularly polarized
- Compact design



Antenna Gain



Antenna Polarization

Radio Board

EnduroSat Transceiver II

Science Board

Temperature Sensor

- We designed and developed a circuit, characterized the digital data, and collected temperature readings.
- The RTD is representative of all sensors

Resistance Temperature Detector (RTD)

- Temperature range: -70℃ to 500℃
  - Allows extreme space measurements
- High accuracy to 1℃
- Nominal Resistance: 100Ω at 0℃

ADC Readings	Actual Temperature (°C)	Measured Temperature (°C)	Difference (°C)
869	-18	-18.00	0.00
1149	-14	-6.06	-7.94
1163	-10	-5.46	-4.54
1162	-8	-5.51	-2.49
1201	0	-3.84	3.84
1854	24	24.00	0.00
		Average Accuracy	-1.85

- Temperatures characterized in Eq.1 relating multiple ADC digital readings, n, to various environment temperatures, t.

$$t\ (℃) = 0.0426(n) - 55.054 \qquad (1)$$

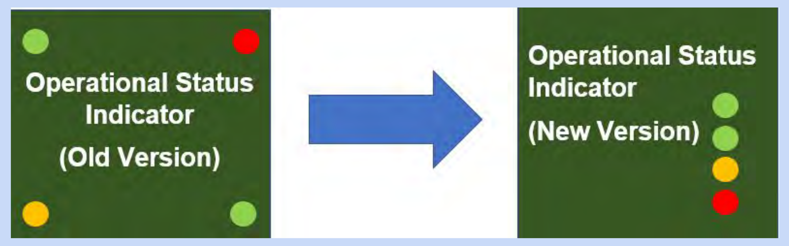
Operational Status Indicator

- LEDs must be seen from space; powered for 10 min; have known orientation

LED indicators Comparison Table

Color	Brightness	Wavelength	Visibility Distance (At Night)
Super Bright White	8,000 ~ 10,000mcd	6,000 ~ 8,000K	150m+
Super Bright Red	8,000 ~ 10,000mcd	620 ~ 625 nm	125m+
Super Bright Orange	8,000 ~ 10,000mcd	600 ~ 610 nm	125m+
Super Bright Yellow	8,000 ~ 10,000mcd	585 ~ 590 nm	125m+
Super Bright Green	10,000 ~ 13,000mcd	520 ~ 525 nm	150m+
Super Bright Blue	3,000 ~ 5,000mcd	465 ~467 nm	50m+
Violet	100 ~ 180mcd	395 ~ 400 nm	50m-
Basic Red	150 ~ 200mcd	620 ~ 625 nm	50m-
Basic Green	150 ~ 200mcd	570 ~ 575 nm	50m-

- We chose these colors: Super Bright Green, Super Bright Red, Super Bright Orange
- No super bright white LED because of the white and blue Earth in the background.



- Since the CubeSat will rotate after deployment, the old version would cause confusion between the two Green LEDs. The new indicator layout has a known orientation to solve this problem.

Motherboard

TI TMS570LC4357 Hercules Microcontroller

RBF Pin

EPS Board

NanoAvionics CubeSat 20W Electrical Power System

PC104 header

0 minutes

Deployed from ISS

- EPS On (Green LED1)
- MCU On
- RTD On

10 minutes

Operational Status Indicator Off

- Turn on Solid State Relay

40 minutes

Antenna Deployment

- Released via burn wire circuit
- Data transmission

Analysis

- We used a transceiver link over the unlicensed 433 MHz band with the Arduino IDE
  - Testing: Case 1
    - Antenna used as transmitter
    - Sent 'Hello World' data packet
    - Received reply
  - Testing: Case 2
    - Antenna used as receiver
    - Received 'Hello World' data packet
    - Sent reply
- The link worked as expected

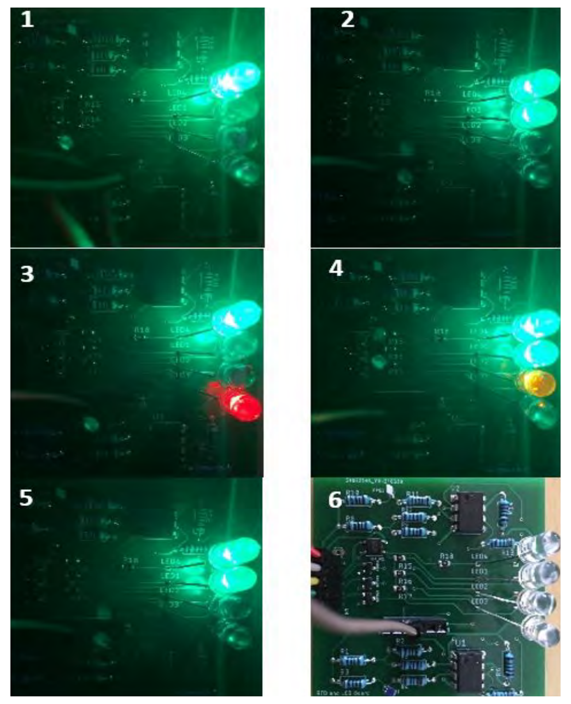
Case 1: Antenna Used as Transmitter

Case 2: Antenna Used as Receiver

- We integrated the System
  - System Control Software
  - Performed as expected

1. Green LED1 On
   - EPS On, RBF Pin removed
2. Green LED2 On
   - MCU ON
3. Red LED On
   - MCU Fault detected
4. Yellow LED On
   - Low Charge detected.

   RED LED Off
   - Fault resolved
5. Orange LED Off
   - CubeSat nominal
6. 10 minute timer expired, Indicator Board Off



Challenges

- Original problem scope misaligned to team's skill set
- Scope renegotiated
- Deliverables adjusted

Future Plans

- Complete the integration of the system
- Improve reliability and robustness for less likely scenarios
- Expand data bus capabilities
- Reduce power budget for subsystems
  - More efficient burn wire
  - Refine power vs visibility tradeoff for LEDs

Acknowledgements

Sincere appreciation to the following people:

- Mr. Tony R Keith
  - For sponsoring the project and keeping it space-focused
- Dr. Kevin Shinpaugh
  - For his patience, guidance, and technical assistance
- Mr. Zach Leffke
  - For his CubeSat expertise in antennas and RF systems

Thermally Immune ReRAM Memory Array with Graphene Enhanced Electrode

Team Members: Ankit Bhardwaj, Jeric Demasana, Nick Spicer
Customer: Luca Di-Girolamo, Micron **SME:** Marius Orlowski
Mentor: Prof. Kenneth Schulz **GTA:** Amrita Chakraborty

Motivation

To decrease the degradation rate of the surrounding cells of an active cell by enhancing the thermal conductivity of the ReRAM memory array through the deposition of graphene on the copper electrode.

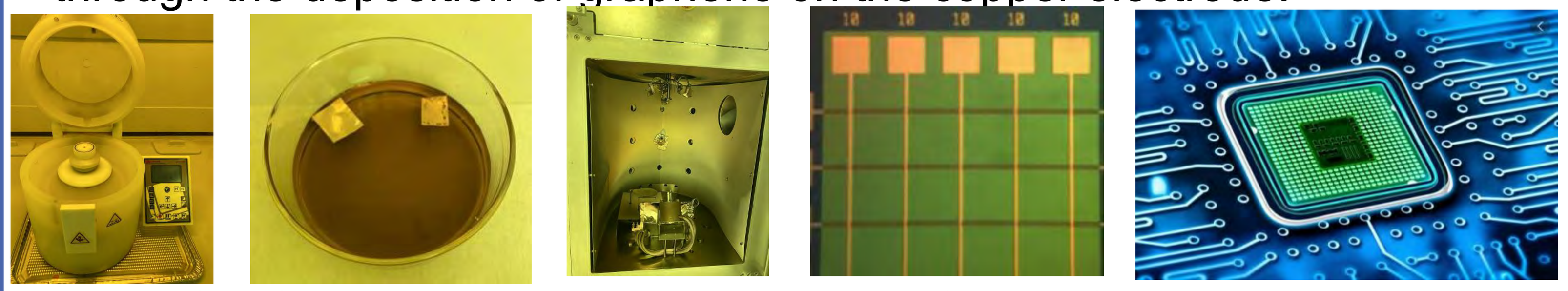


Figure 1A: Spin Coating 1B: Etching Process 1C: PVD 1D: Crossbar Structure 1E: ReRAM Memory Array https://www.industryglobalnews24.com/global-silicon-oxide-siox-reram-technology-market-is-expected-to-grow-at-cagr-236-by-2028-due-to-various-technological-advancements-says-absolute-markets-insights

Objectives

- Transfer a single sheet of graphene on oxidized Si wafer
- Deposit graphene onto the existing active electrodes of a ReRAM memory array
- Integrate the graphene coated material into the memory array
- Compare the performance of the graphene enhanced arrays to the conventional memory arrays

Theory of Operations

Electrical Operations:

The application of external voltage pulse across the ReRAM cell enables the transition of the device from a high resistance state (HRS) or OFF state to a low resistance state (LRS) or ON state and vice versa. The initial voltage required to establish the first connection between the active and inert electrode is known as forming voltage. The state can be switch from HRS to LRS and LRS to HRS by applying voltages, Vreset and Vset respectively.

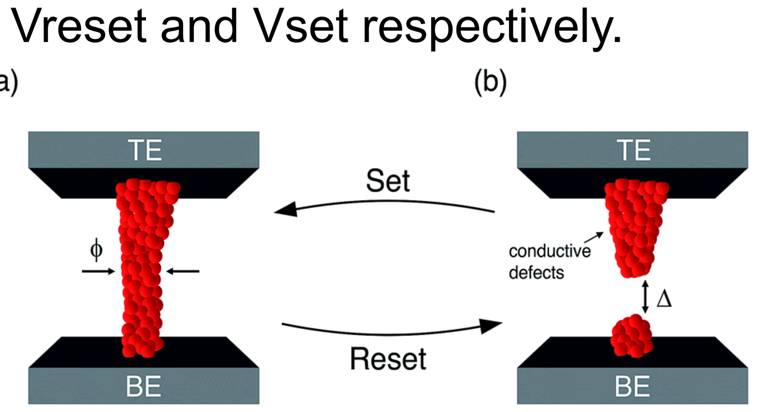


Figure 2:ReRAM Cell Switching
https://pubs.rsc.org/-/content/articlelanding/2018/fd/c8fd00106e#!divAbstract

Thermal Operations:

Every time an individual cell switches from LRS to HRS or vice versa, heat is dissipated to its neighboring cells. This phenomenon is referred to as thermal crosstalk which is detrimental to the life span of the memory array as each neighboring cell is degrading at a faster rate. Graphene being one atom thick Carbon atom arranged in a hexagonal lattice is an excellent conductor of heat and electricity which allows it to be used in various applications. Using Graphene as a material enhancing the electrodes' thermal conductivity decreases the rate of degradation due to thermal crosstalk.

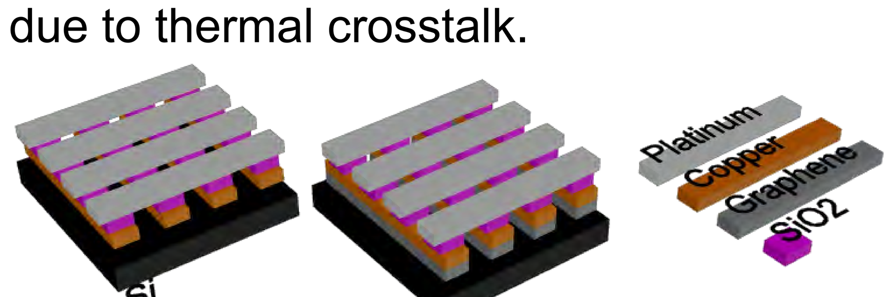


Figure 3A: ReRAM memory array B: Graphene Enhance ReRAM C: Key

Sample Cleaning Procedure

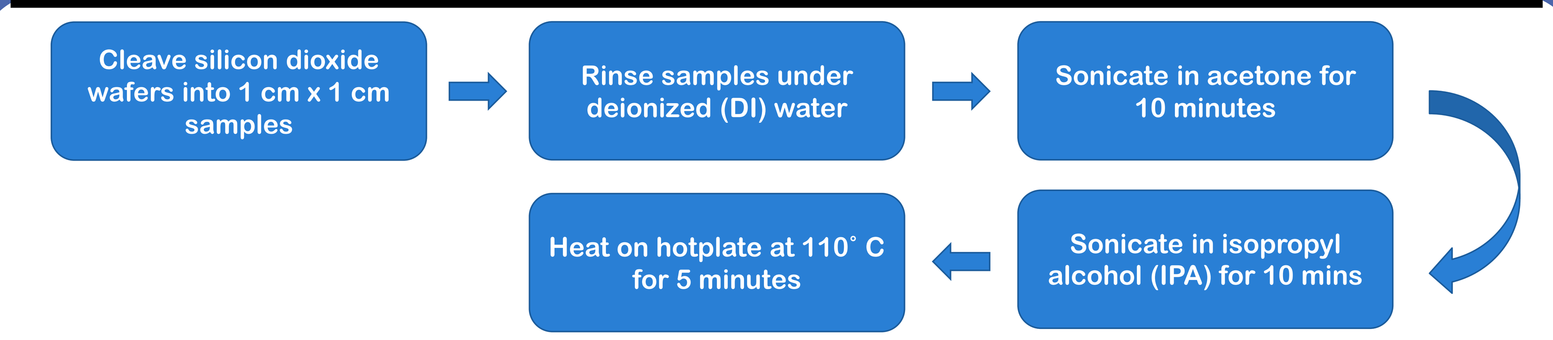


Figure 4: Steps to clean sample

Fabrication Process

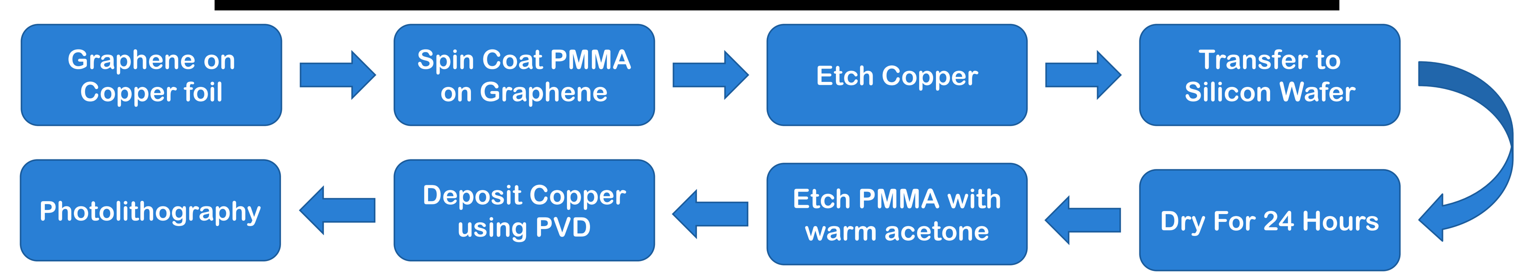


Figure 5: Steps of Deposition Process

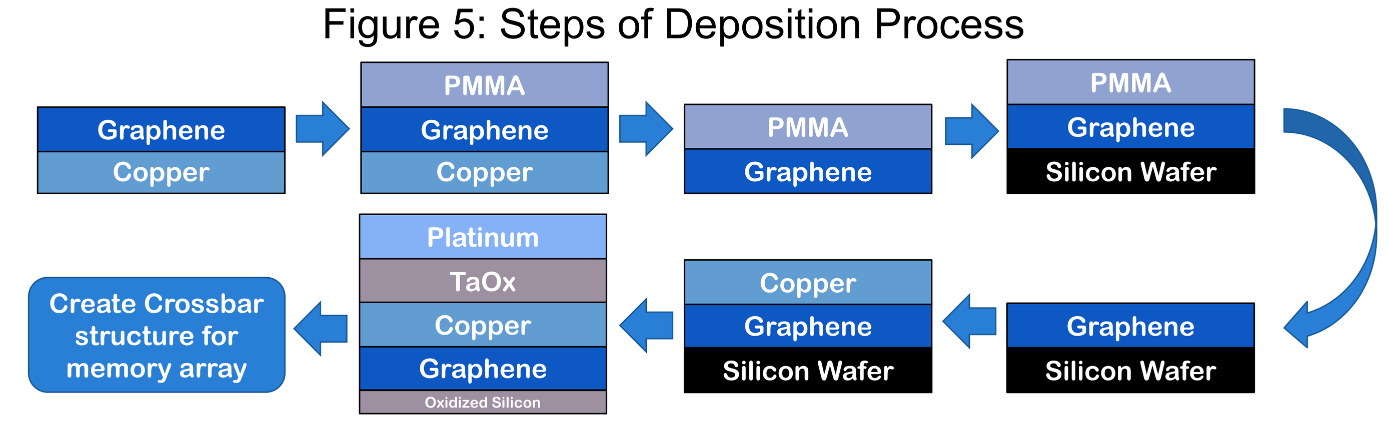


Figure 6: Process of Building ReRAM Memory Array

Observations

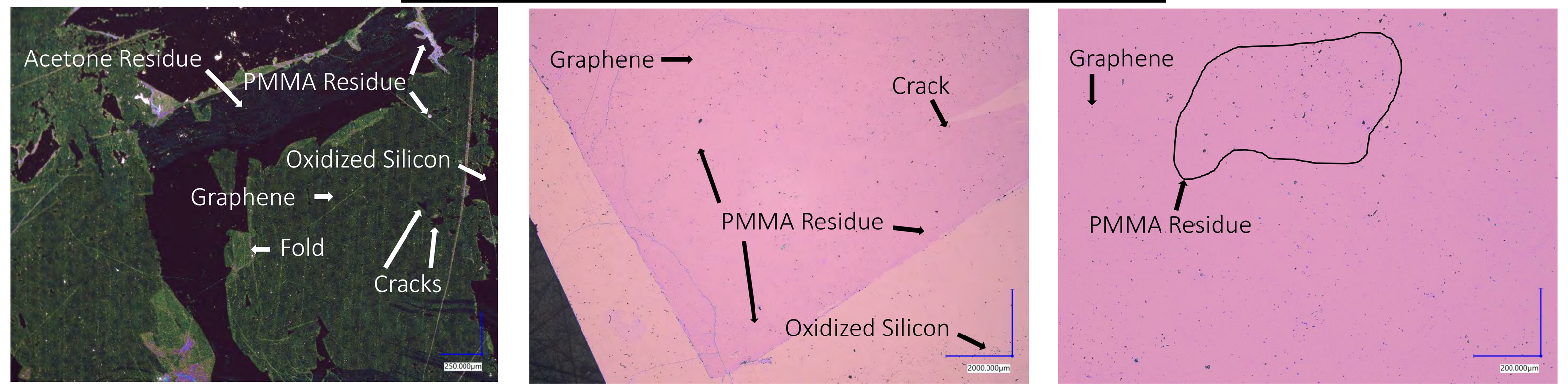
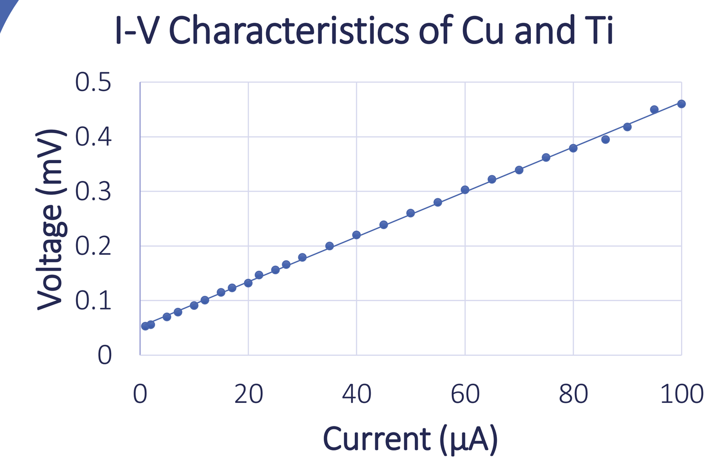
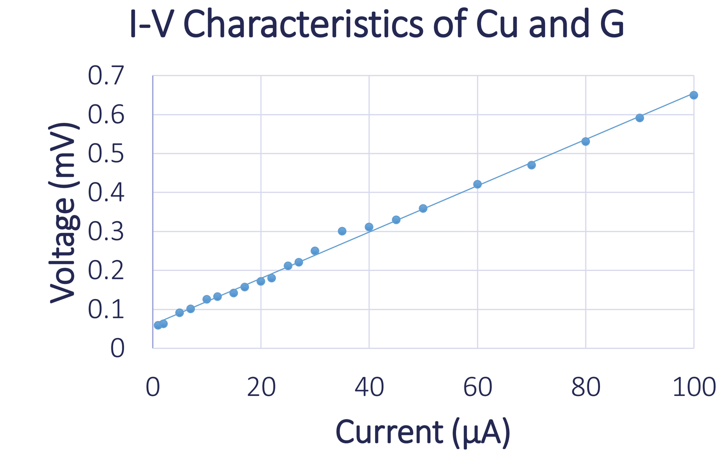


Figure 7A: Graphene deposited on silicon using a single layer of PMMA etched by cold acetone. 7B: Graphene deposited using a single layer of PMMA etched by warm acetone. 7C: Graphene deposited using 2 layers of PMMA etched by warm acetone.

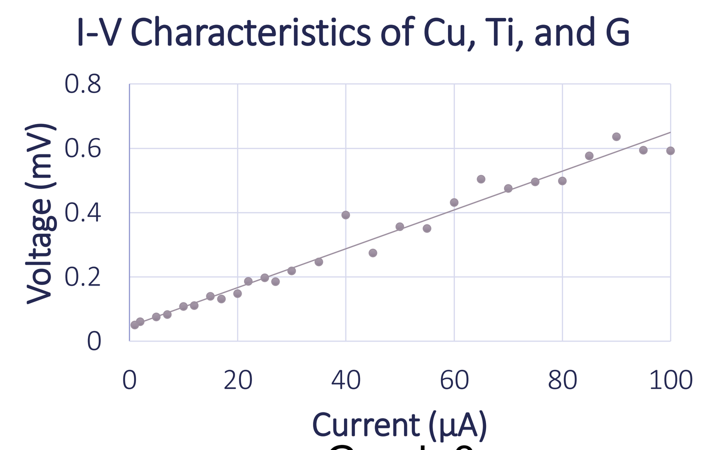
Test Results



Graph 1



Graph 2



Graph 3

- A four point probe is used to measure the sheet resistance of the ReRAM memory array with and without graphene to further determine the electrical conductivity of the device. Electrical conductivity μ_{el} is used to estimate the thermal conductivity μ_{th} ($\mu_{el} \sim \mu_{th}$).

Analysis and Conclusion

- The graphene enhanced ReRAM memory array shows a substantial improvement in its electrical and thermal performance compared to a non-enhanced ReRAM memory array.
- The doubling of PMMA layer on the graphene sheet showed minimal improvement compared to a single layer deposition when it came to removing PMMA on graphene as both showed about the same results.
- The application of warm acetone as opposed to room temperature acetone helped in removing the PMMA layer due to its improved reaction at higher temperatures. Initially, the sample was shaken during this process, but it was later stopped as it was found that it causes the graphene to break apart or to tear.
- The thermal resistive network for the graphene enhanced copper electrode is shown in Figure 13 and the total thermal resistance was derived in Equation 1. By finding this equation we can see how each component of the electrode affects the thermal resistance of the network.

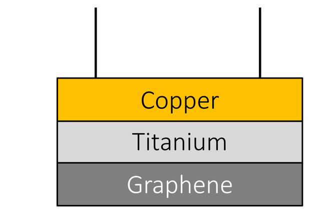


Figure 8: Graphene Enhanced Copper electrode

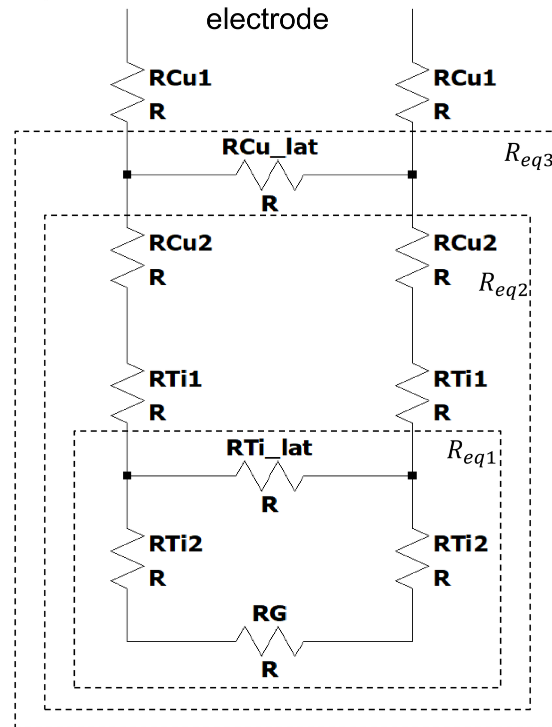


Figure 9: Thermal Resistive Network Schematic

$$R_{tot} = 2 * R_{Cu1} + \frac{R_{Cu,lat} * 2(R_{Cu2} + R_{Ti1}) + \frac{R_{Ti,lat} * (2 * R_{Ti2} + R_G)}{R_{TI,lat} + 2 * R_{Ti2} + R_G}}{R_{Cu,lat} + 2(R_{Cu2} + R_{Ti1}) + \frac{R_{Ti,lat} * (2 * R_{Ti2} + R_G)}{R_{TI,lat} + 2 * R_{Ti2} + R_G}}$$

Equation 1

$$R_{eq1} = \frac{R_{Ti,lat} * (2 * R_{Ti2} + R_G)}{R_{TI,lat} + 2 * R_{Ti2} + R_G}$$

Equation 2

$$R_{eq2} = 2(R_{Cu2} + R_{Ti1}) + R_{eq1}$$

Equation 3

$$R_{eq3} = \frac{R_{Cu,lat} * R_{eq2}}{R_{Cu,lat} + R_{eq2}}$$

Equation 4

$$R_{tot} = 2 * R_{Cu1} + R_{eq3}$$

Equation 5

Future Plans

- Work on a graphene transfer recipe to get a cleaner sample without any residual PMMA.
- Try a different method of transferring graphene to oxidized Si wafer as the transfer method of scooping out graphene with it is impractical
- Try a more direct approach of measuring the thermal properties of the ReRAM memory array (e.g. IR camera with a resolution of 5μm)

Challenges

- To deposit one-atom thick material (graphene) controllably on Si wafer
- First attempts at transferring graphene were not clean
- Finding a direct test of the thermal conductivity were either expensive or unavailable
- The copper etchant was not removing the copper completely with the initial process (difficulty overcome)

Acknowledgements

We would like to thank the following people for there support

- Luca Di-Girolamo (Customer)
- Kim Medley (Purchasing)
- Donald Leber (Cleanroom Manager)

Organic Electrodes for Flexible Electronics

Team Members: Chris Schoeb, Ziad Aboud, Junming Liang, Nicholas Cappo
Customer: Alex Lee, Micron **SME:** Dr. Marius Orlowski **Mentor:** Prof. Kenneth Schulz
GTA: Amrita Chakraborty

Motivation

Research and development of alternatives to replace conventional solid metal lines used in flexible electronics with organic polymer doped with a substance to boost its electrical conductivity and thermal performance such as graphene and metal nanoparticles. This has applications in the growing field of flexible electronics used in clothing, prosthetics, solar panels et Al.

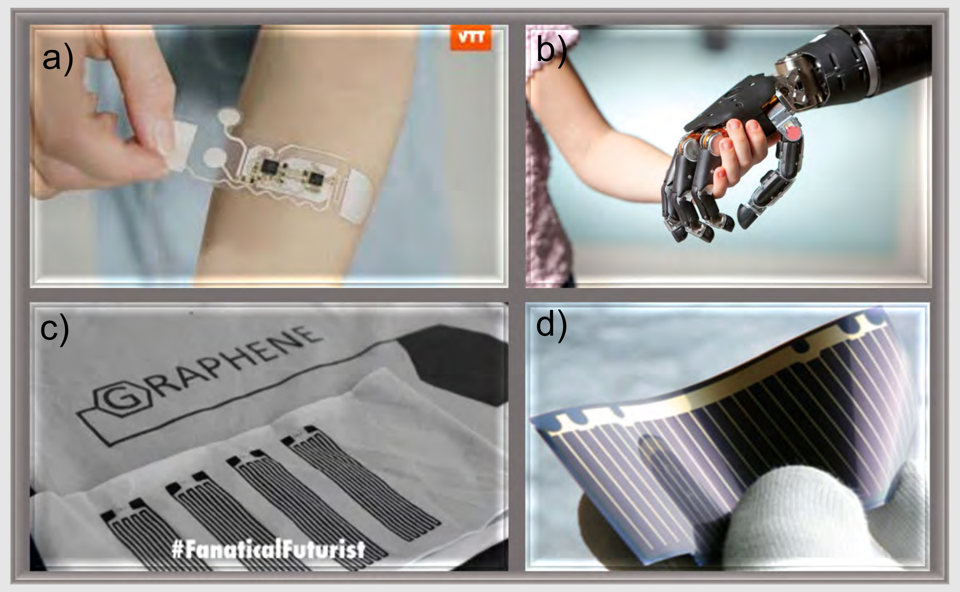


Fig. 1. Flexible Electronics: a) Biosensors, b) Prosthetics, c) Batteries and d) Solar Cells.

Fig. 1 shows a few of the many applications of flexible electronics. Biosensors and smart bandages are made to heal wounds faster and monitor health conditions while flexible wirings and sensors can be used in prosthetics to create a type of "electronics skin". Flexible solar cells, batteries and memory devices pave the way for flexible computers that can be built into clothing, camping equipment, consumer electronics and other applications.

Objectives

- Successfully creation of a GNP-Polymer composite. (GNP = graphene nanoplatelets)
- Electric conductivity comparable to copper (10^4 S/m or a magnitude less)
- Substantial flexibility and elasticity while maintaining electrical properties (applications such as foldable phones and prosthetic limbs)
- Ability to withstand high thermal environments (environments such as fast switching states in memory cells or high performing CPUs)
- Inexpensive compared to current microscale wiring

Theory of Operations

- By doping a conductive polymer with conductive nanoparticles, we can achieve a highly conductive and flexible material while bypassing the high costs and complex fabrication processes associated with other organic electrodes.
- Compared to doping with metal nanoparticles like Au, using GNPs as the conductive particles simplifies the doping process, reduces material costs and increases thermal stability while retaining good flexibility and conductivity.
- To achieve uniformity, we must overcome the Van der Wal forces existing between the molecules of the dopant using stirring and sonification.
- The conductive polymer P3HT was used due to its electrical properties and prior research involving P3HT-GNP composites.

Experimental Roadmap

1. GNP powder of 150nm particle diameter and 2.5um diameter were placed into two separate samples containing 10ml of toluene. These solutions were sonicated for 1 hr. and stirred for 1 hr. to observe the effect of the particle size on the distribution of particles in solution.

Fig. 2. 2.5um GNP-toluene

VS

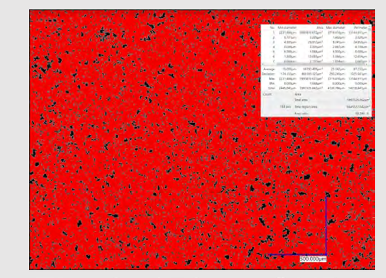


Fig. 3. 150nm GNP-toluene

2. Depositions of the conductive polymer P3HT and P3HT after aging for 2 months were made to compare the effect of aging on the homogeneous distribution of the polymer.

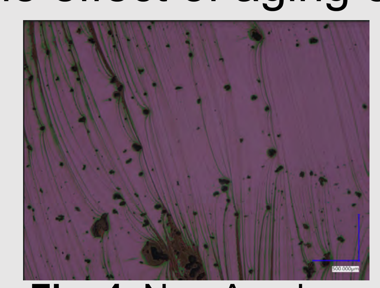


Fig. 4. Non-Aged P3HT

VS

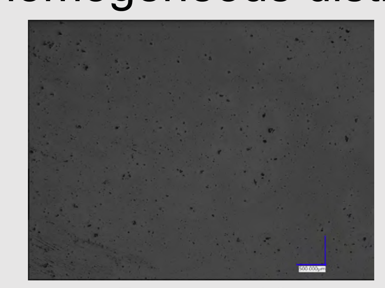
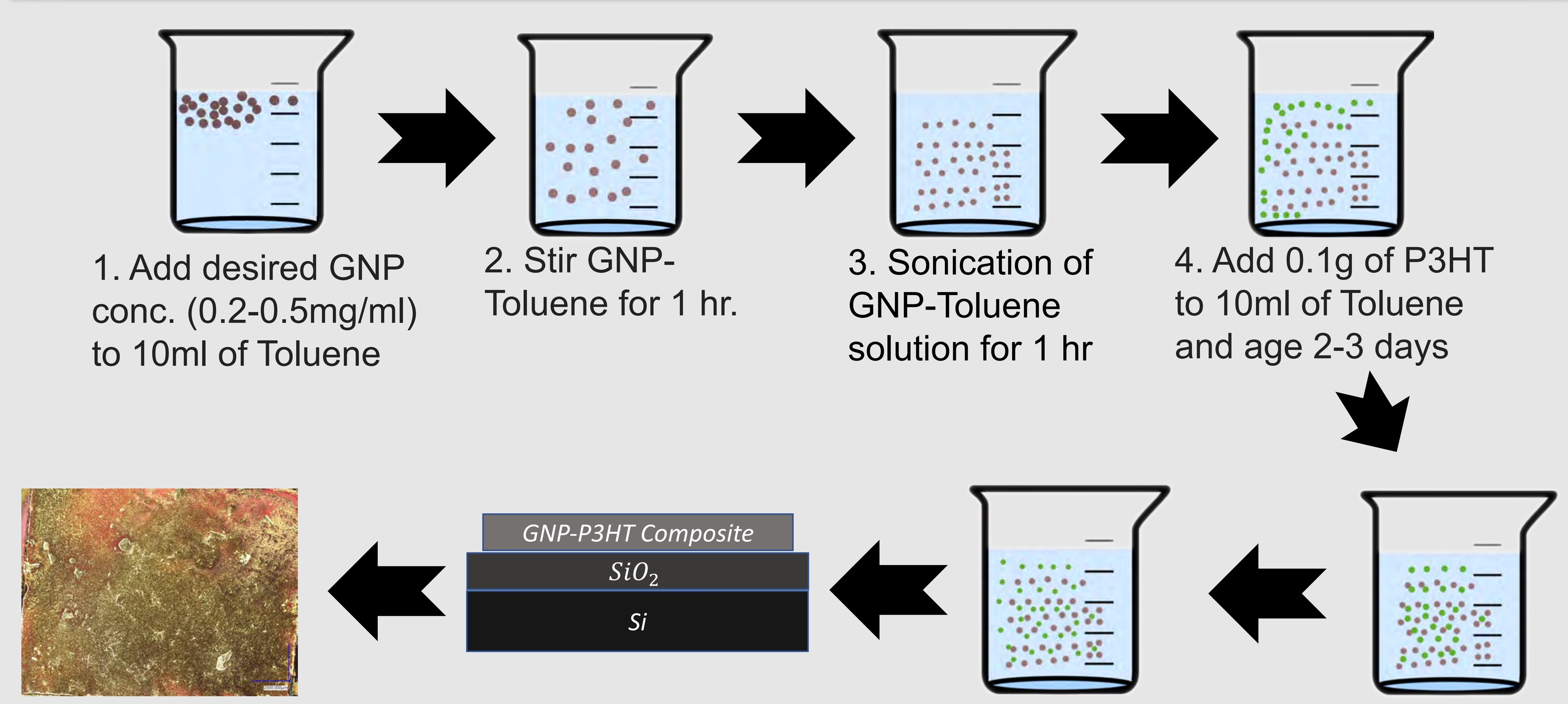


Fig. 5. Aged P3HT (2 Months)

3. From these experiments it was determined the GNP-polymer composite would be made using GNP powder with particle diameters of ~150nm, aged P3HT(2-5 days) and a sonification time of at least 1 hr.

Sample Fabrication Process



1. Add desired GNP conc. (0.2-0.5mg/ml) to 10ml of Toluene
2. Stir GNP-Toluene for 1 hr.
3. Sonication of GNP-Toluene solution for 1 hr
4. Add 0.1g of P3HT to 10ml of Toluene and age 2-3 days
5. Stir GNP-P3HT-toluene solution for 1 hr.
6. Sonication of GNP-P3HT-Toluene solution for 1 hr.
7. Deposit GNP-P3HT solution on cleaned (approx. 1x1cm) SiO2/Si
8. Dry overnight.

Test Results

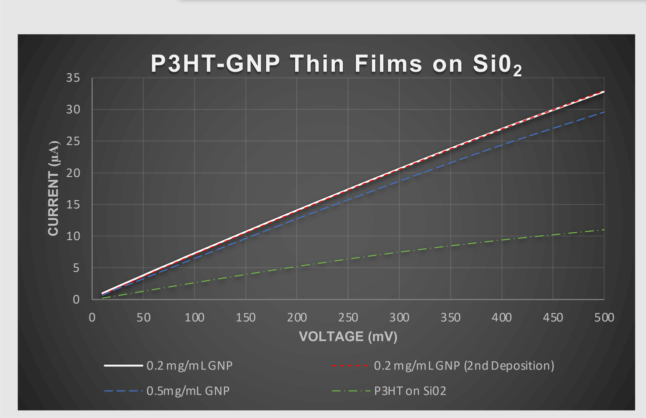


Fig. 6. I-V curves of P3HT-GNP thin films on silicon wafer with SiO_2 layer.

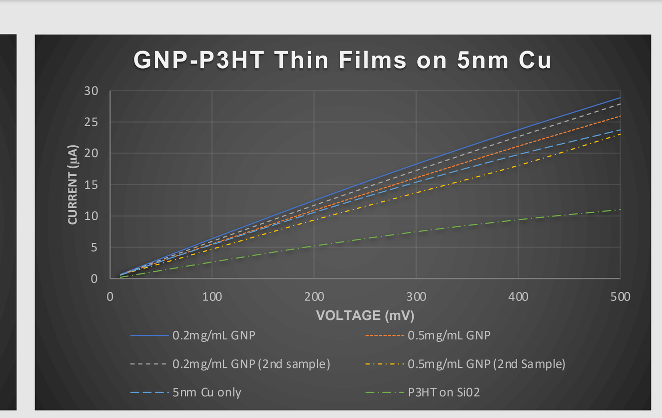


Fig. 7. I-V curves of P3HT-GNP thin films on silicon wafer with 5nm Cu layer.

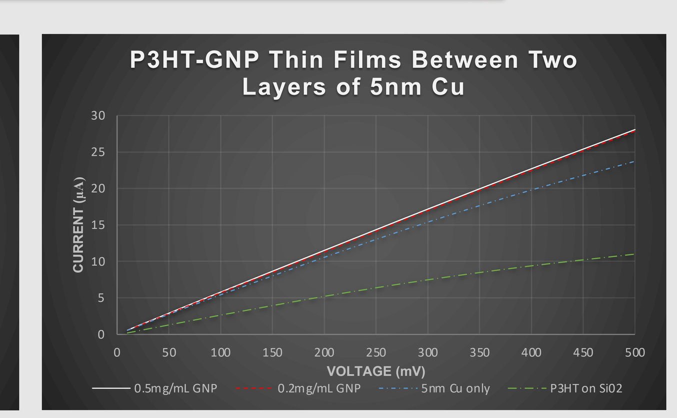


Fig. 8. I-V curves of P3HT-GNP thin films on silicon wafer between two layers of 5nm Cu.

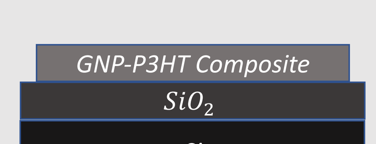


Fig. 9. Structure of depositions in Fig. 6.

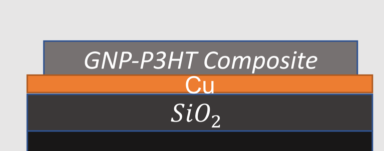


Fig. 10. Structure of depositions in Fig. 7.

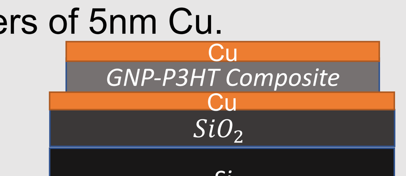


Fig. 11. Structure of depositions in Fig. 8.

Analysis and Conclusion

The following conclusions were made from our experiments.

1. Not only could the even distribution of GNP particles be increased by using smaller particles as shown in Fig. 2. and Fig. 3 but by increasing sonification times GNP particles became more evenly dispersed as shown in Fig. 12.

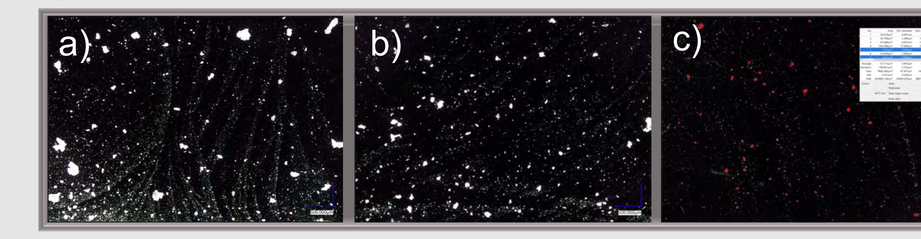


Fig. 12. GNP-Toluene thin films at: a) 1hr of sonification, b) 2hrs of sonification, c) 4hrs of sonification.

2. The I-V curves in Fig. 6. show by doping P3HT with GNP's the conductivity increases. Also, as the doping concentration rose from 0.2mg/mL to 0.5mg/mL the conductivity began to decrease. This effect may be attributed to the GNP particles beginning to clump up and interfere with the lattice structure of the P3HT, but further research is required to prove this.
3. Fig. 10. and Fig. 11. show the structure we used to simulate the effects of doping the P3HT-GNP composite with copper nanoparticles, due to the effects of using PVD below 5nm. As can be seen by Fig. 13. & Fig.14 this addition of copper has little effect on the conductivity but can be necessary for certain devices such as ReRAM electrodes.

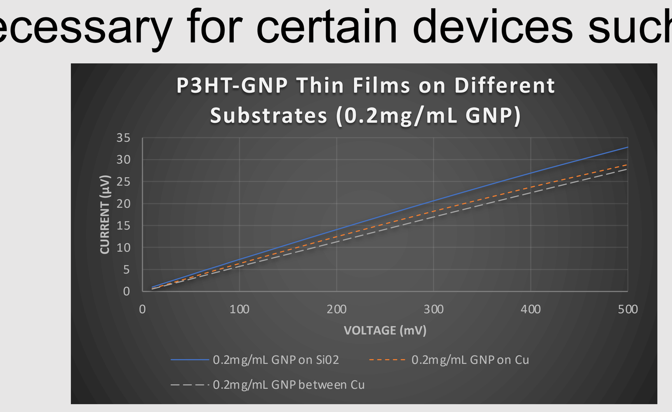


Fig. 13. I-V characteristics of P3HT-GNP thin films on multiple substrates with 0.2mg/mL GNP.

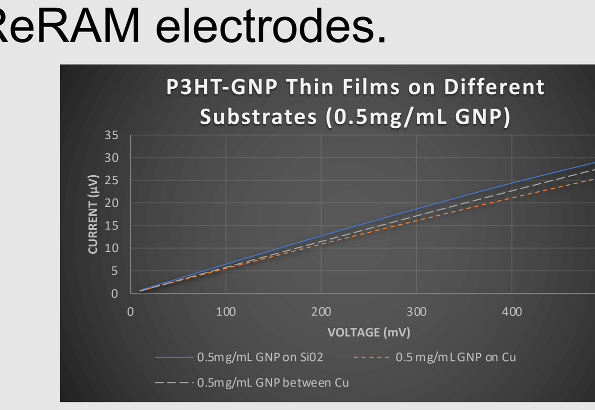


Fig. 14. I-V characteristics of P3HT-GNP thin films on multiple substrates with 0.5mg/mL GNP.

Future Plans

1. Create additional samples of GNP-P3HT with varying GNP concentrations to find the relationship between doping and conductivity.
2. Use the polymer PEDOT:PSS as a cheaper replacement for P3HT and determine its effect on the flexibility, conductivity and reproducibility.
3. Use the material as an electrode in an ReRAM memory cell structure to test its feasibility in flexible memory applications.
4. Test the thermal conductivity and stability of the GNP-P3HT material through various tests.
5. Apply spin coating techniques to the fabrication process given proper safety devices, allowing for better control of the deposition thickness.
6. Using flexible substrates deposit material on these substrates and take flexibility measurements on how strain effects conductivity.

Acknowledgements

We would like to thank the following people for their support and assistance.

- Alex Lee (Micron Customer Contact)
- Donald Leber (Cleanroom Manager)
- Dr. Yuhong Kang (Provided additional graphene particles and research assistance)
- Kim Medley (Order Placing)

Distributed High Frequency Beamforming

Team Members: Amanda Hess, Chris Tousignant, Colton Baldridge, Evan Clark, Pete Woodall. **SME:** Dr. Louis Beex

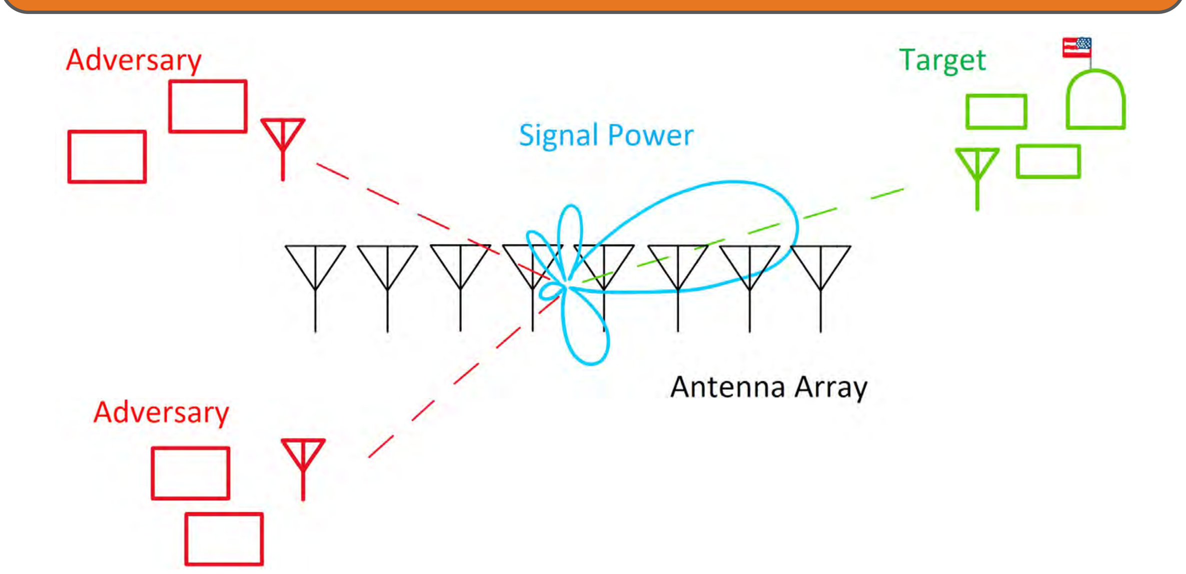
Motivation

Marines often operate in advanced locations that are within range of an adversary's weapons. At such locations, remaining undetected is crucial. Typical Marine radios emit their signal in all directions, meaning Marines can be easily detected. The goal of this project is to use distributed beamforming to focus the signal towards intended receivers and away from adversaries. This should increase safety of deployed Marines by keeping them undetected.

Objectives

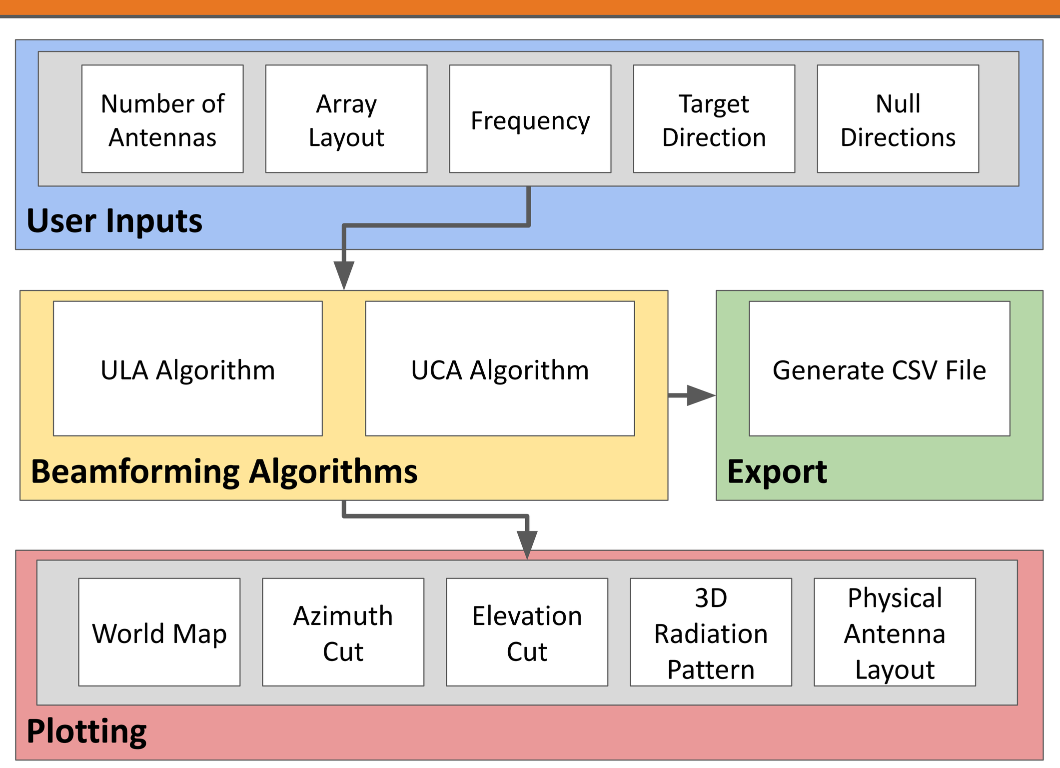
- Create a software model for an antenna array of 2 to 8 monopole antennas
- Shape the radiation pattern to direct power in a target direction and limit power in other specified directions
- Ensure the peak of the main lobe is within 5° of the target direction
- Ensure the nulls are 30dB down and cover at least 3° of azimuth
- Implement Uniform Linear Array (ULA) and Uniform Circular Array (UCA) antenna layouts

Concept of Operations

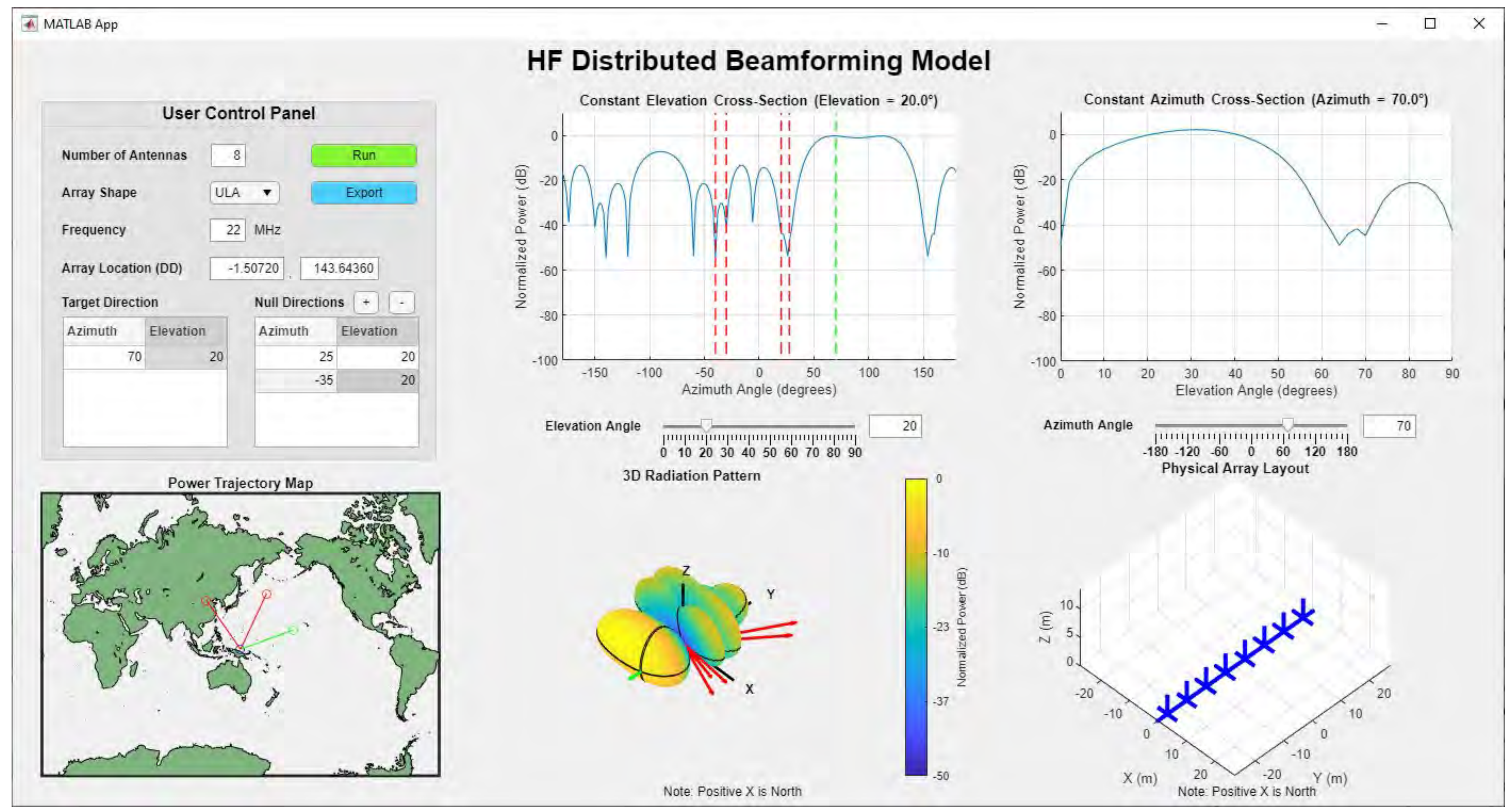


In the image above, the antenna array directs power towards the target receiver and minimizes power in the directions of the adversaries. The signal strength in a given direction is represented by the blue beam pattern's distance from the center of the array.

System Block Diagram



Results

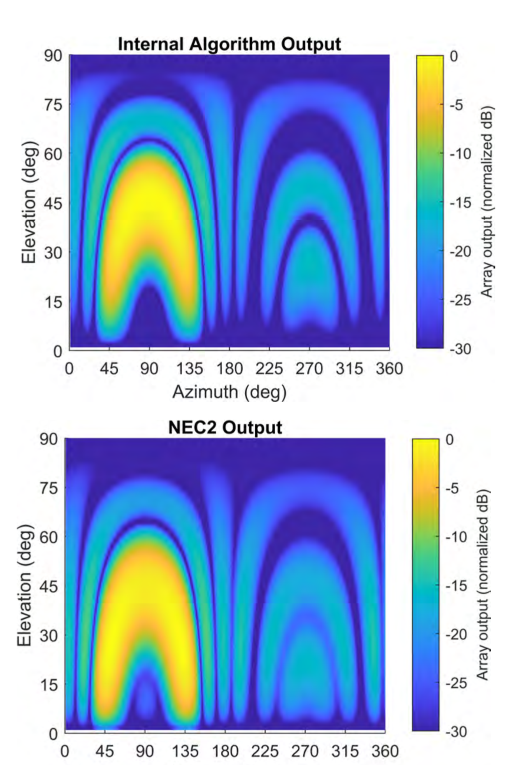


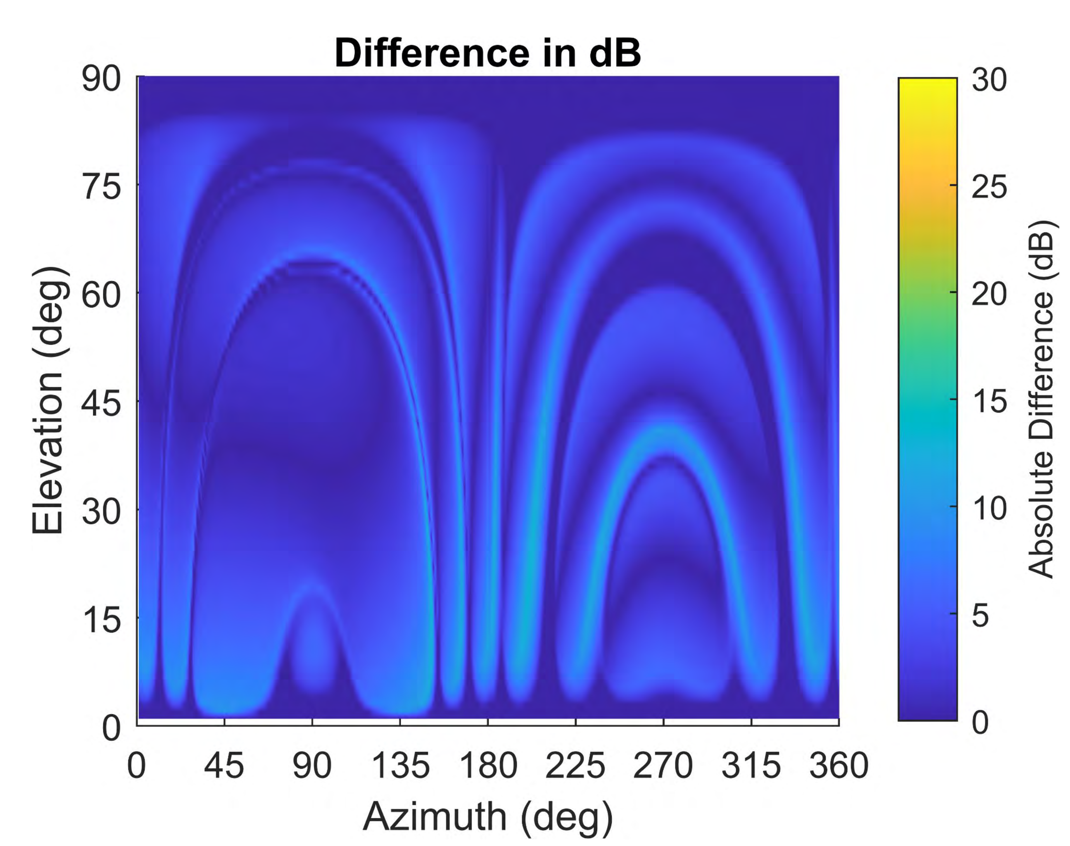
GUI Overview: The user inputs the target and null azimuths and elevations, number of antennas, array shape, and transmit frequency. The magnitude and phase for each antenna are computed. An internal algorithm then computes the radiation pattern and displays it.

Results: For the ULA, the nulls should be placed at least 30 degrees from the target. Given this constraint, the beamforming algorithm is always able to come up with a solution that achieves a relative attenuation of at least 30 dB in the null directions.

Application: The drastic reduction in transmit power in the directions of suspected adversary receivers could reduce the probability that friendly Marines are detected, leading to safer operating conditions.

Validation





- Validation images show:
  - 8-element ULA
  - target azimuth 45°
  - target elevation 20°
  - null azimuth of 335°
  - null elevation 20°
- Output compared to NEC2 EM simulation software with an identical array
- Mean absolute error of 2.7dB
- Data bounded to 0dB and required attenuation of -30dB
- The null is more than 30dB down and 3° wide, exceeding requirements
- The peak is within 5° of target, meeting requirements

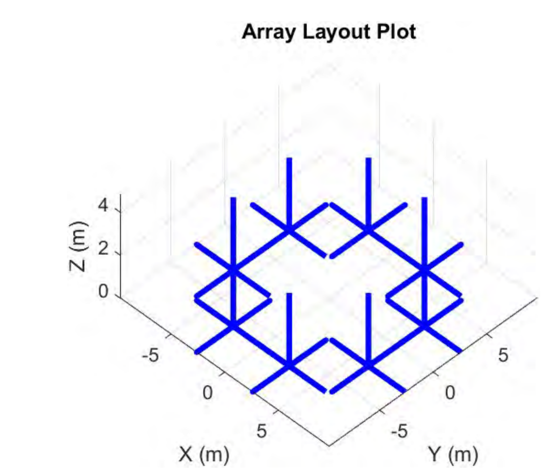
Conclusion and Future Work

Simulation and external validation have shown that the beamforming model is successful in directing power towards a target receiver while reducing power in desired directions. Future work required to enhance the performance and accuracy of this simulation include:

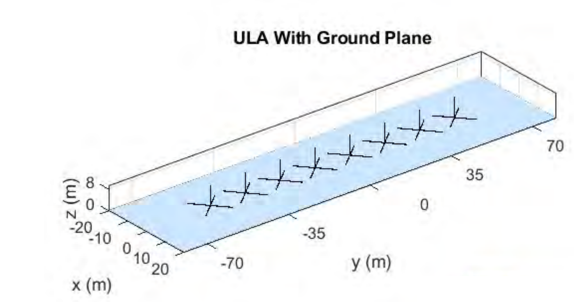
- Altering the UCA beamforming algorithm to reduce power transmitted in the null directions
- Enabling the model to accept arbitrary antenna placement, rather than predefined antenna layouts
- Modeling additional antenna geometries, such as half-rhombic, long-wire, and dipole antennas
- Performing calculations that account for the non-ideal conductivity of ground

Challenges

UCA Beamforming: The UCA algorithm required a completely different approach than the ULA. Individual antenna weights were found by using an iterative minimization technique. This required additional research into disciplined convex programming frameworks.



Infinite Ground Plane: To properly compute radiation pattern output, a ground plane was necessary. This required use of MATLAB's conformal array, which allows for full customization. This added computational complexity, but enabled the addition of a virtual infinite ground plane.



Demonstration Video

This video shows a demonstration of the functionality of the distributed HF beamforming application. It summarizes the basic flow of information and discusses how to interpret the results at a high level.

References

[1] J. Okkonen, "Uniform Linear Adaptive Antenna Array Beamforming Implementation with a Wireless Open-Access Research Platform," M.S. thesis, Department of Comp. Sc. and Eng., Univ. of Oulu, Finland, 2013. Accessed on: January 30, 2021. [Online]. Available: https://warpproject.org/trac/raw-attachment/wiki/PapersandPresentations/Files/Okkonen_Masters_Thesis.pdf

[2] H. Pessentheiner, "Beamforming Using Uniform Circular Arrays for Distant Speech Recognition in Reverberant Environment and Double-Talk Scenarios," M.S. thesis, Signal Processing and Speech Comm. Lab., Graz Univ. of Tech., Austria, 2012. Accessed on: February 12, 2021. [Online]. Available: https://www2.spsc.tugraz.at/www-archive/downloads/thesis_reduced_file_size.pdf

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Acknowledgements

Dave Maples	MITRE Contact
Dale Herdegen	MITRE Contact
Ed Ille	MITRE Contact
Andy Thompson	MITRE Contact
Toby Meadows	Faculty Mentor

College of Engineering
Bradley Department of Electrical and Computer Engineering
Virginia Tech

WATER MONITORING SENSOR USING LASER INDUCED FLUORESCENCE

Team Members: Halea Fowler, Afia Habib, Ian Kelley, Lauren Mead, and Nick Ryerse
Customer: Dr. Scott Kordella, MITRE
Subject Matter Expert: Dr. Scott Bailey Team Mentor: Professor Toby Meadows

BACKGROUND

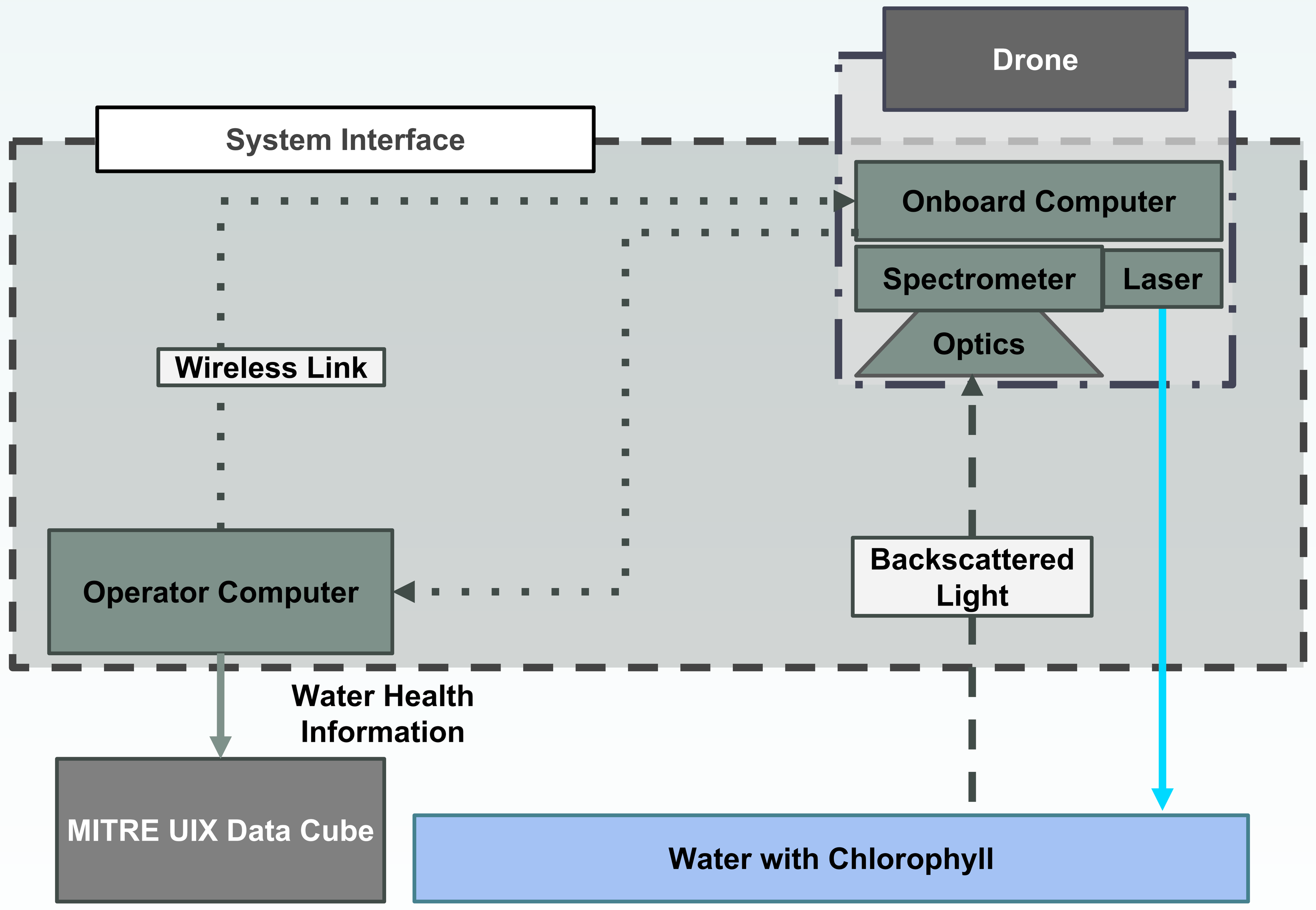
- Small, upstream waterways need a remote sensing method of chlorophyll detection
- Develop an instrument that can determine low levels of chlorophyll in a body of water
- Ultimately, the system will be integrated with a drone for increased monitoring.
- This iteration of the project is focused around proof of concept.

KEY REQUIREMENTS

- When the ratio of the fluorescence and Raman peaks is at least equal to 3 chlorophyll is detectable in a sample.
- A 1W laser that is at most 10 meters from the tested site will be used to obtain results.
- The system will be at most 6.2 kilograms so that it can be eventually used on a drone.

CONCEPT OF OPERATIONS

- Currently ground system to detect chlorophyll from local water samples that will eventually be a drone-mounted instrument
- Backscattered light spectrum from onboard laser
- Estimate chlorophyll content of water from spectrum
- Communicate position and chlorophyll content to ground based operator



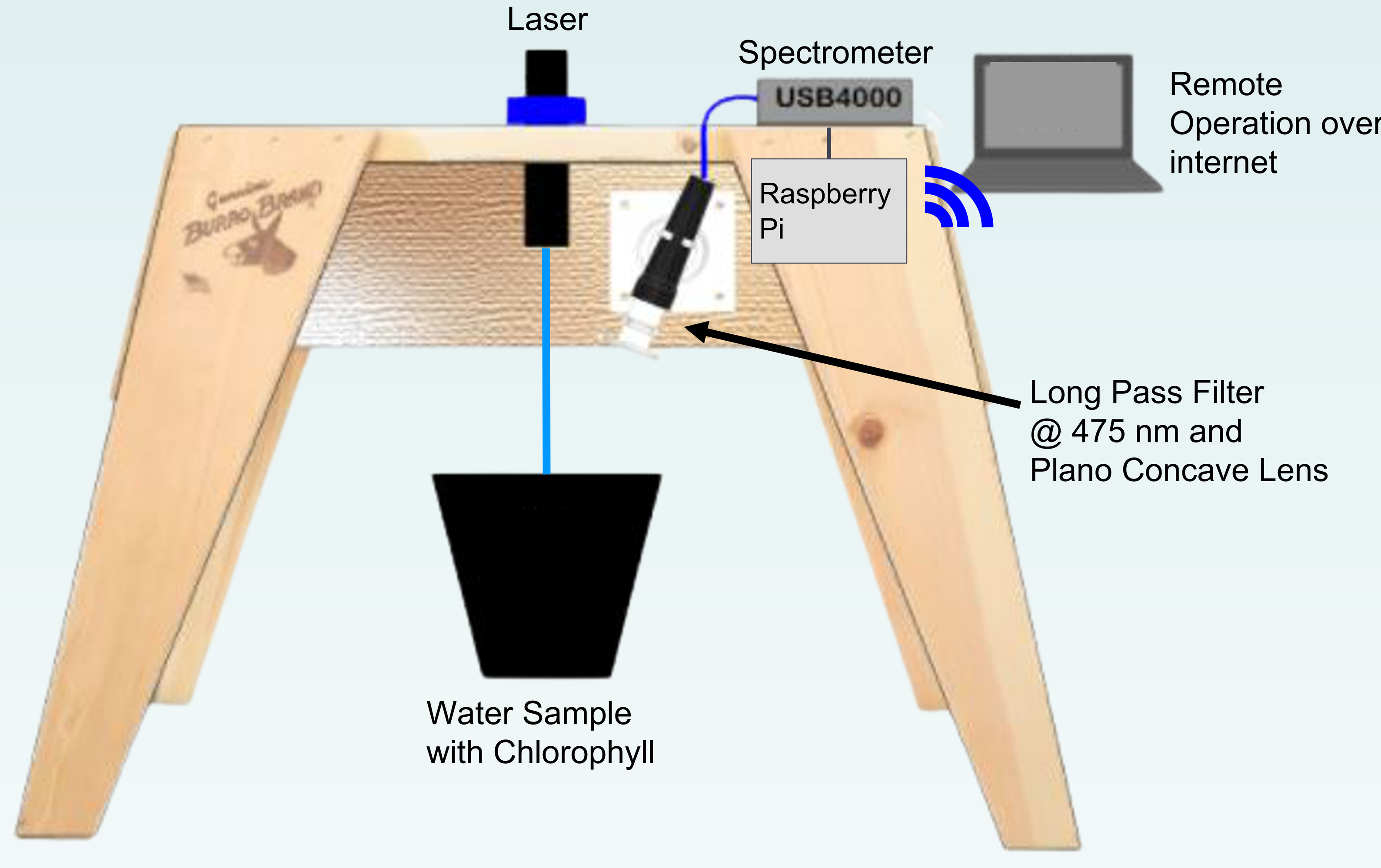
This is future concept which involves the drone. Our currently system is based off this model that the next group will eventually accomplish

ACKNOWLEDGEMENTS

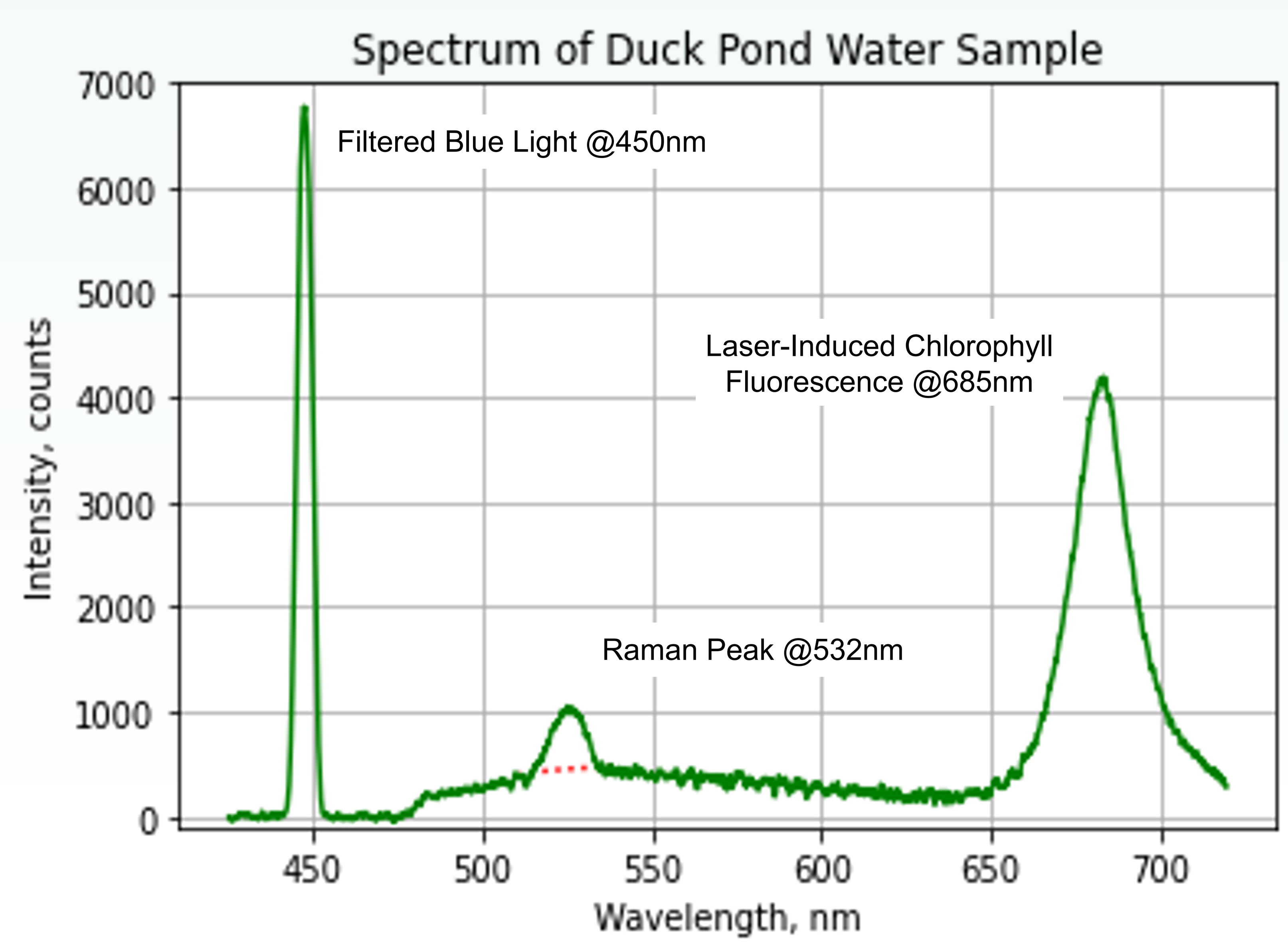
The team would like to give a special thanks to the following people for their contributions to our project: Dr. Scott Bailey, Dr. Scott Kordella, Dr. John Grossman, Dr. Michael S. West, Mr. Nick McLotta, Ms. Giovanna A Casalino, Ms. Sheyda Davaria, and Professor Toby Meadows

TESTS AND RESULTS

- A laser is shined into the test sample and excites the particles in the water.
- The spectrum is then displayed on a monitor connected to a local host.
- The ratio between the fluorescence and Raman peaks is determined.
- The chlorophyll content is determined by comparing the results to spectrums of known chlorophyll concentrations.



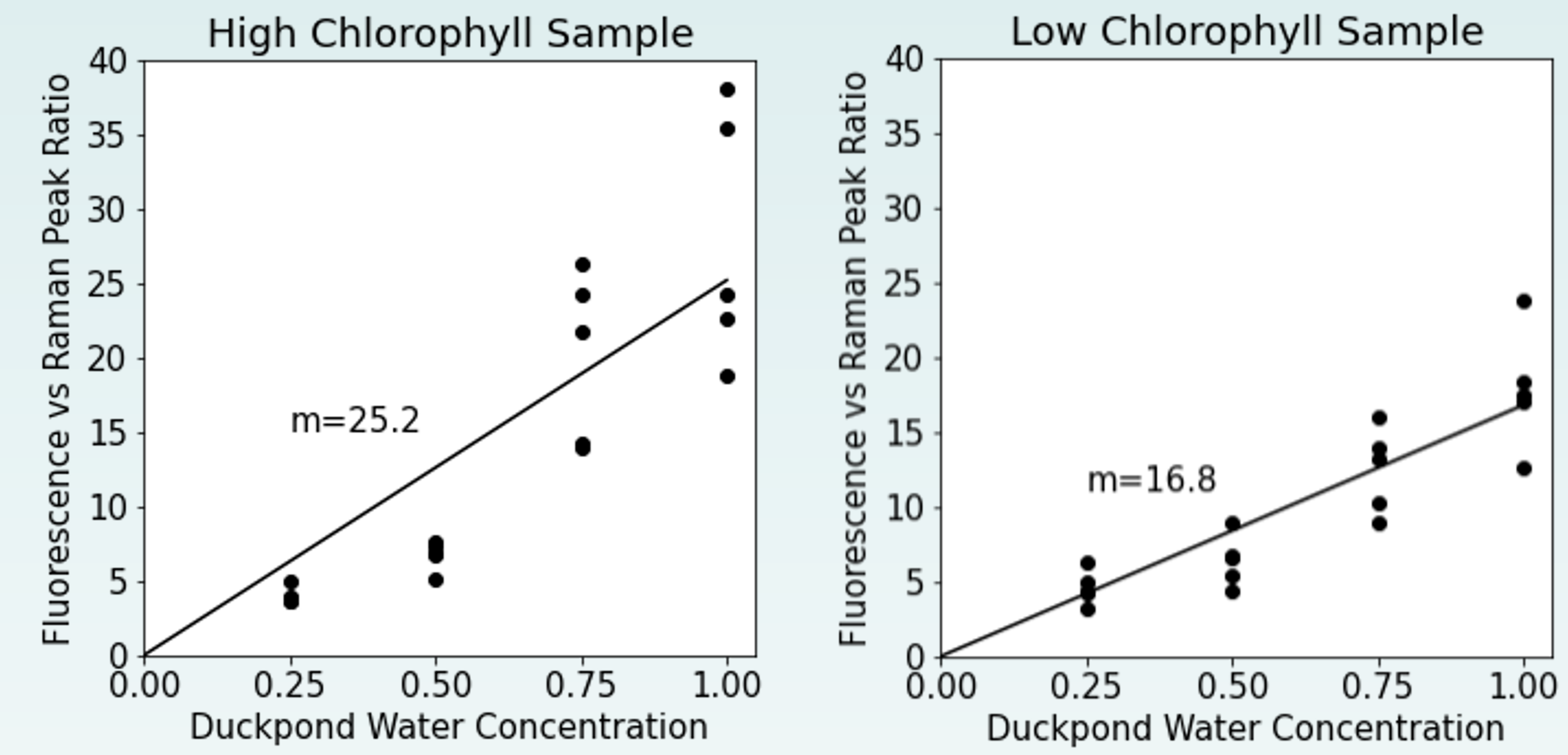
Experimental Set-Up



Spectrum of Laser-induced Fluorescence of Chlorophyll in Water

CONCLUSIONS

- The system was able to detect the ratio between the Raman and chlorophyll peaks
- The peak ratio has a linear relationship with chlorophyll concentration
- The system meets range and weight requirements and can operate remotely
- The system will be best suited for smaller amounts of chlorophyll and clear water



Plots showing linear relationship between chlorophyll levels in water and measured peak ratio between 685 nm (chlorophyll peak) and 527 nm (raman peak)

ISSUES AND CHALLENGES

- Pigments and dirt in water made measurements uncertain
- Optical receiver needs careful alignment for maximum signal strength
- Not tested in field conditions
- Difficult to accurately measure chlorophyll levels due to inexact production method
- Laser is battery powered and button operated

FUTURE DIRECTIONS

- The system will be integrated onto a drone.
- Using different laser wavelengths to detect other substances in water.
- A GPS unit could tag chlorophyll measurements with a specific location.

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[1] Duan, Z., Li, Y., Wang, J. et al. Aquatic environment monitoring using a drone-based fluorosensor. Appl. Phys. B 125, 108 (2019). https://doi.org/10.1007/s00340-019-7215-y
[2] Bristow M., Zimmermann R. (1991) Remote Water Quality Monitoring with an Airborne Laser Fluorosensor. In: Pawlowski L., Lacy W.J., Dlugosz J.J. (eds) Chemistry for the Protection of the the Environment, 75-96. doi:10.1007/978-1-4615-3282-8_6
[3] Bristow, M. P. F., D. H. Bundy, C. M. Edmonds, P. E. Ponto, B. E. Frey, and L. F. Small, Airborne Laser Fluorosensor Survey of the Columbia and Snake Rivers: Simultaneous Measurement of Chlorophyll, Dissolved Organics and Optical Attenuation. Int. J. Remote Sensing. 6, 1707–1734, 1985

NAVAIR IEEE Electrical and Embedded Robot

Team Members: Itiade Adegbulugbe, Luke Betts, Matt Genberg, Drew Klesat, Connor Lawler, Yixin Lu, Yiming Luo, David Moss, Chris Stafford, Kyle Wiggins

Key Requirements

The team has been tasked to compete in the IEEE 2021 SoutheastCon Hardware Competition. This involves the design, construction, and programming of an autonomous robot. The robot must be capable of following:

- Navigating a game board
- Collecting pellets then returning them to a home base to earn points
- Distinguishing/avoiding ghosts found throughout the board.

To succeed in the competition, the team must score the most points within a five minute period. The score is determined by the number/type of pellets collected and avoidance/contact with ghosts.

Game Board Build

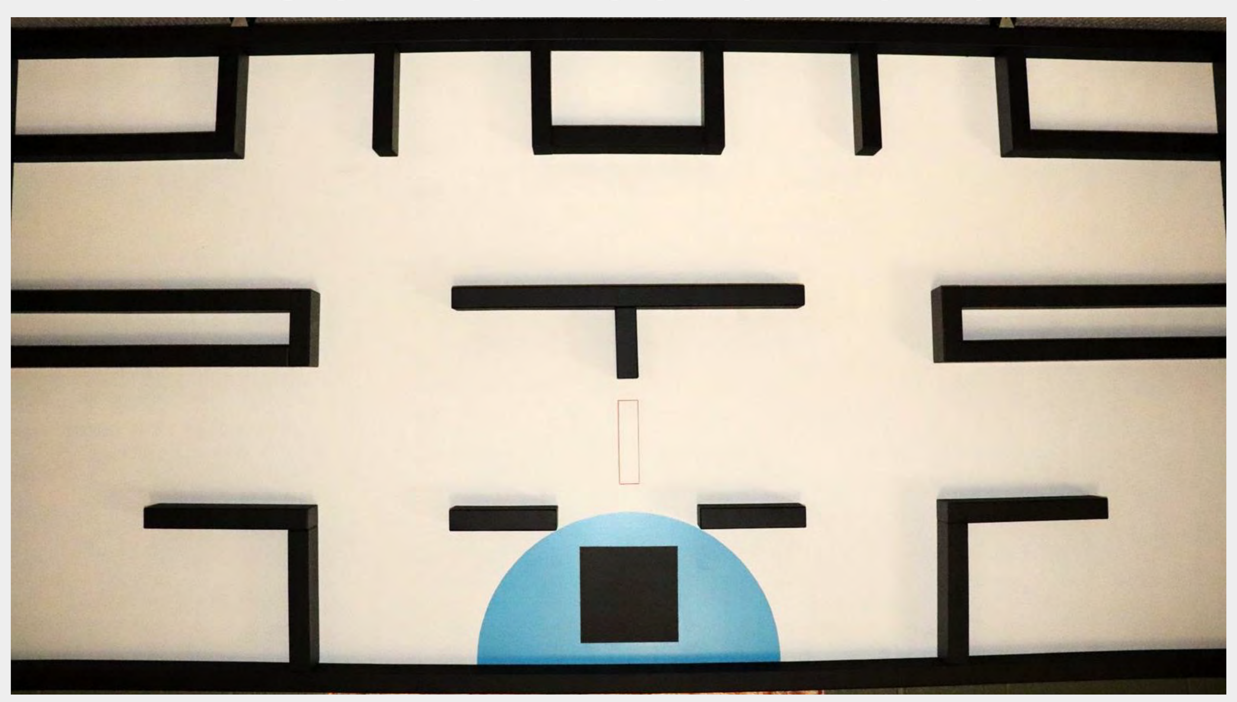


Figure 1: Game Board

Context Diagram

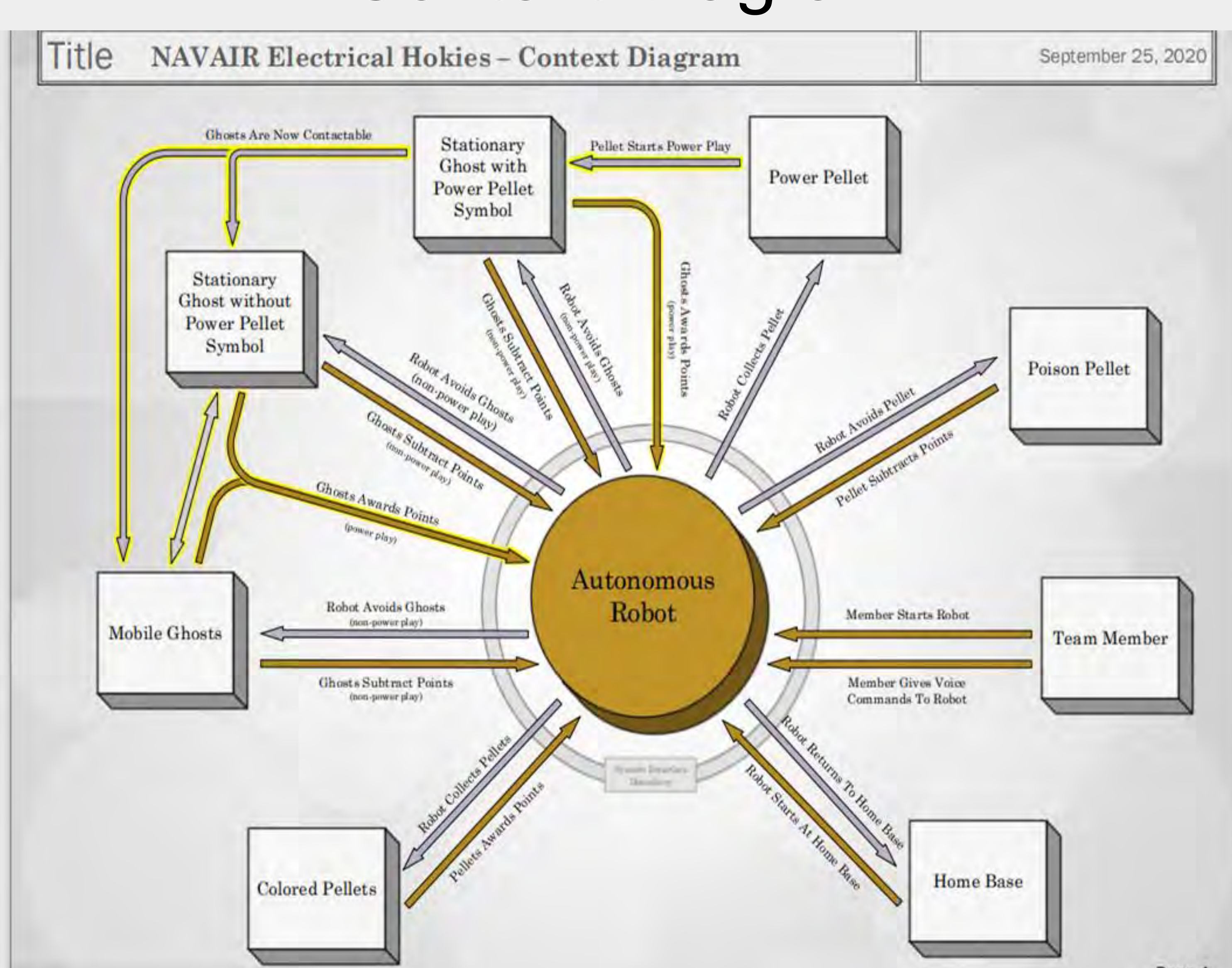


Figure1: NAVAIR IEEE Electrical Robot System block diagram

System Block Diagram

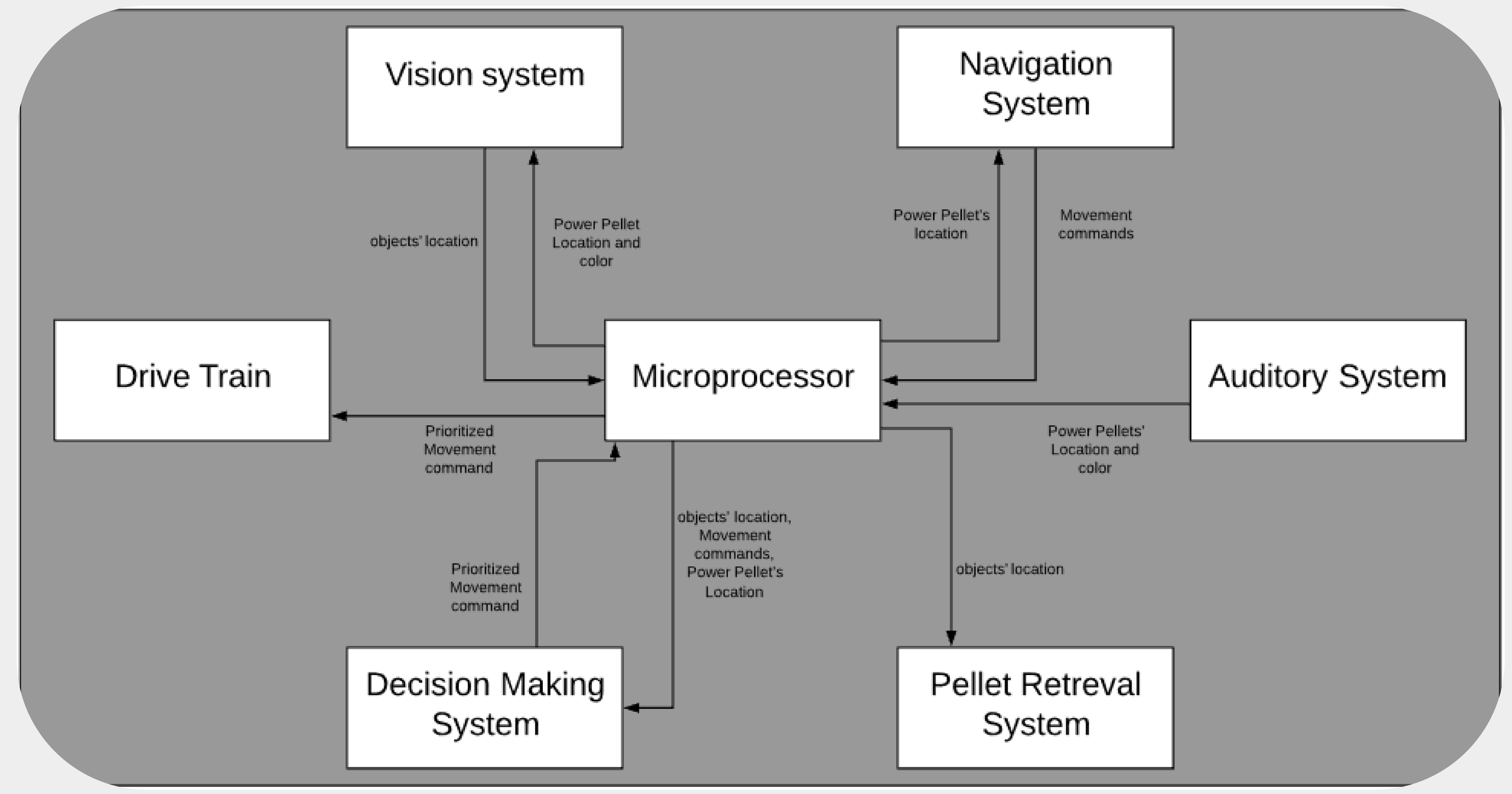
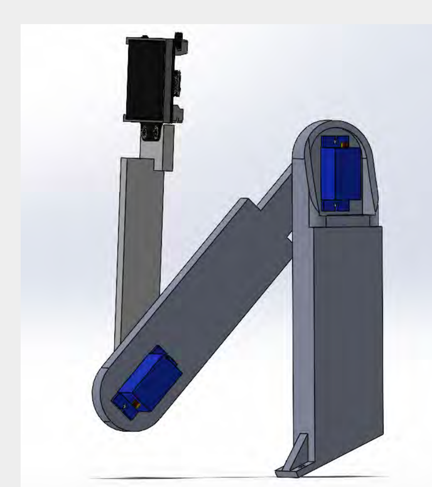


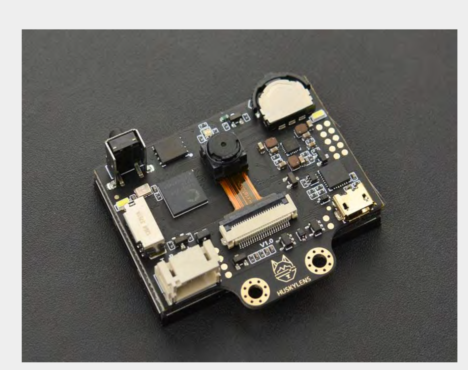
Figure1: NAVAIR IEEE Electrical Robot Software System block diagram

Vision System

Hardware: camera arm and Huskylens



- 12.3 in Height after extended
- Controlled with 2 micro servo motors
- 3D Printed
- Huskylens Camera
- Vision Sensor attached



- A commercial vision sensor
- Built-in modes
  - Color Sensing
  - Pattern Recognition

Vision System

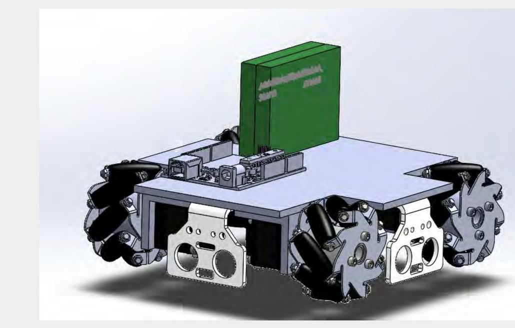
- The vision system can switch between color sensing and pattern recognition according to the information from auditory system and navigation system.
- The supporting program of the vision system collects, storages, formats, and returns information about pellets.

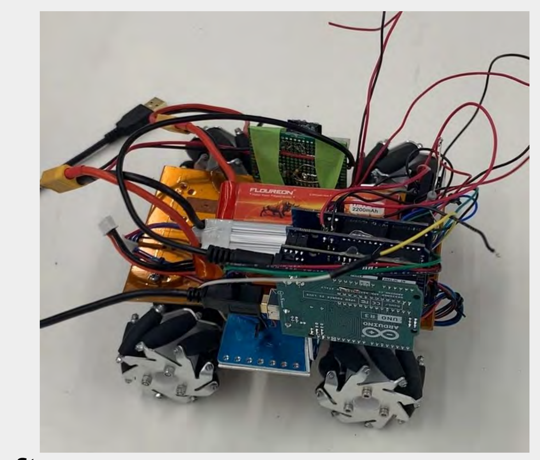
Testing

The vision system is able to differentiate pellets with differents color and pattern and return accurate coordinate information. The QR codes below include testing videos.

Navigation System

Hardware: Chassis and Drivetrain





- **Mecanum Wheels**
  - Drive wheel radius = 30mm (1.1811 in.)
  - Enable the robot to move all direction without changing the front.
- **Stepper Motors**
  - High torque
  - Precise control
- **Arduino Shield Motor Controllers**
  - Control two stepper motors each
  - Stackable
- **Metal Chassis**
  - 4 ultrasonic sensors attached
  - Two Lithium Batteries (Motors for wheels/Electrical components)
  - Battery Specifications:
    - 11.1V 2200mAh 25C

Software

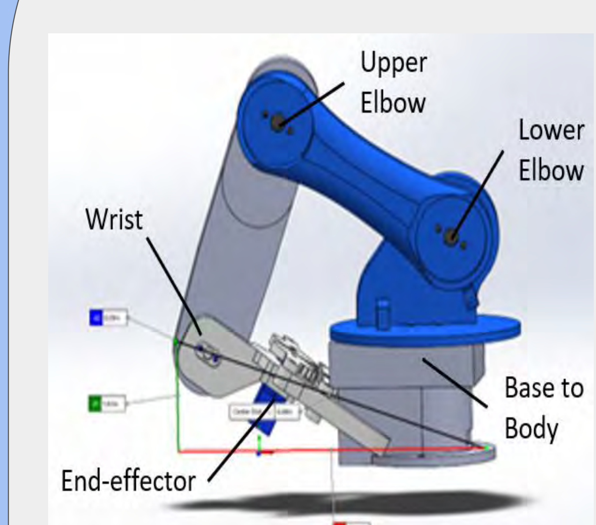
- This system collects distance data from four ultrasonic sensors to implement an adaptive wall-following algorithm that can navigate a Pac-Man maze with pseudo-random obstacles

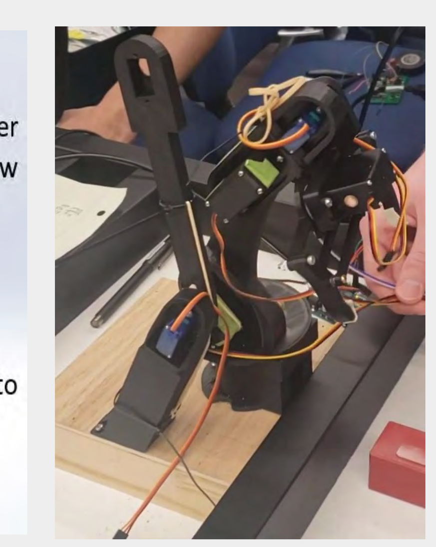
Testing

- The navigation system is able to read accurate information from the ultrasonic sensors. The robot can correct itself to stay on course and move to the desired locations around the game board. Some videos of testing throughout this system's development are shown below.

Pellet Retrieval System

Hardware: Arm

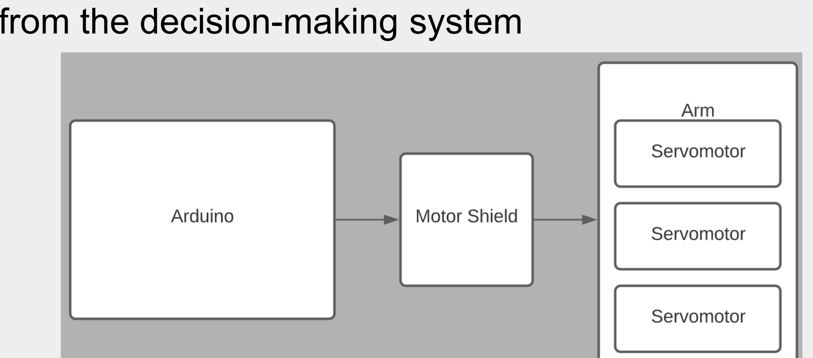




- Starting Height: 6.44 in
- Width : 3.82 in
- Starting Length: 6.17 in
- Extended Length: 8.67 in
- 3D Printed

Software: Arm Control

- Designated the necessary location coordinates into the system using forward kinematics so that the arm could position to the desired locations and retrieve the pellets after indication from the decision-making system



Testing

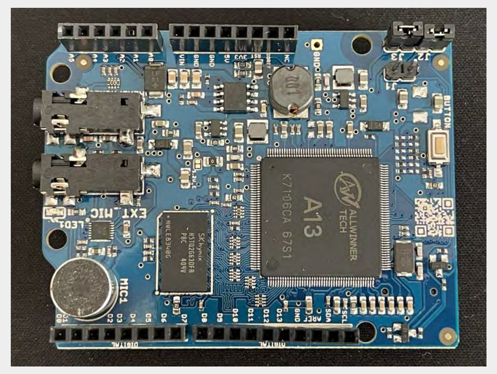
- Each servo is calibrated and powered appropriately. All servos on the arm can move freely and collect the pellets and return them to the body for transport. It can interact with other systems to complete its desired task.

NAVAIR IEEE Electrical and Embedded Robot

Team Members: Itiade Adegbulugbe, Luke Betts, Matt Genberg, Drew Klesat, Connor Lawler, Yixin Lu, Yiming Luo, David Moss, Chris Stafford, Kyle Wiggins

Auditory System

Hardware



- A cloudless Speech Recognizer / Voice Synthesizer for the Arduino platform

Software

This system enables the robot to interpret auditory commands from the driver

This functionality is used to communicate the locations of certain objects to the robot so it can plan its route accordingly

Testing

The auditory system is consistently able to identify the commands it is given. It is somewhat inconsistent at recognizing the callsign that indicates the beginning of a command, but this issue is easily addressed by using audio feedback from the robot that indicates when it recognizes the callsign.

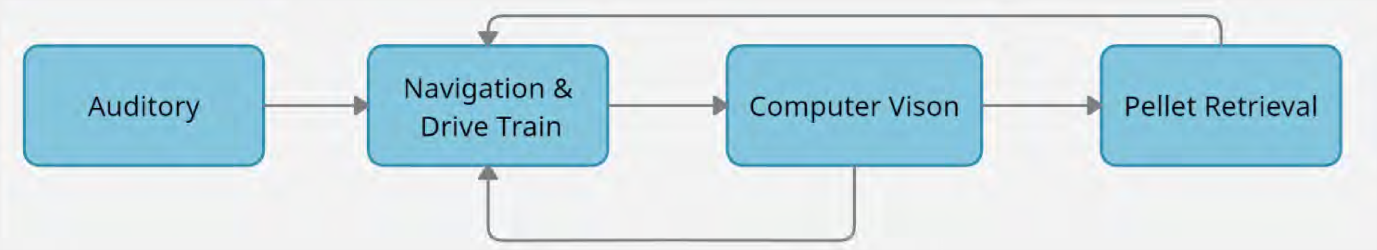
Decision Making system

Hardware

- An Arduino Uno that facilitates the necessary communication

Software

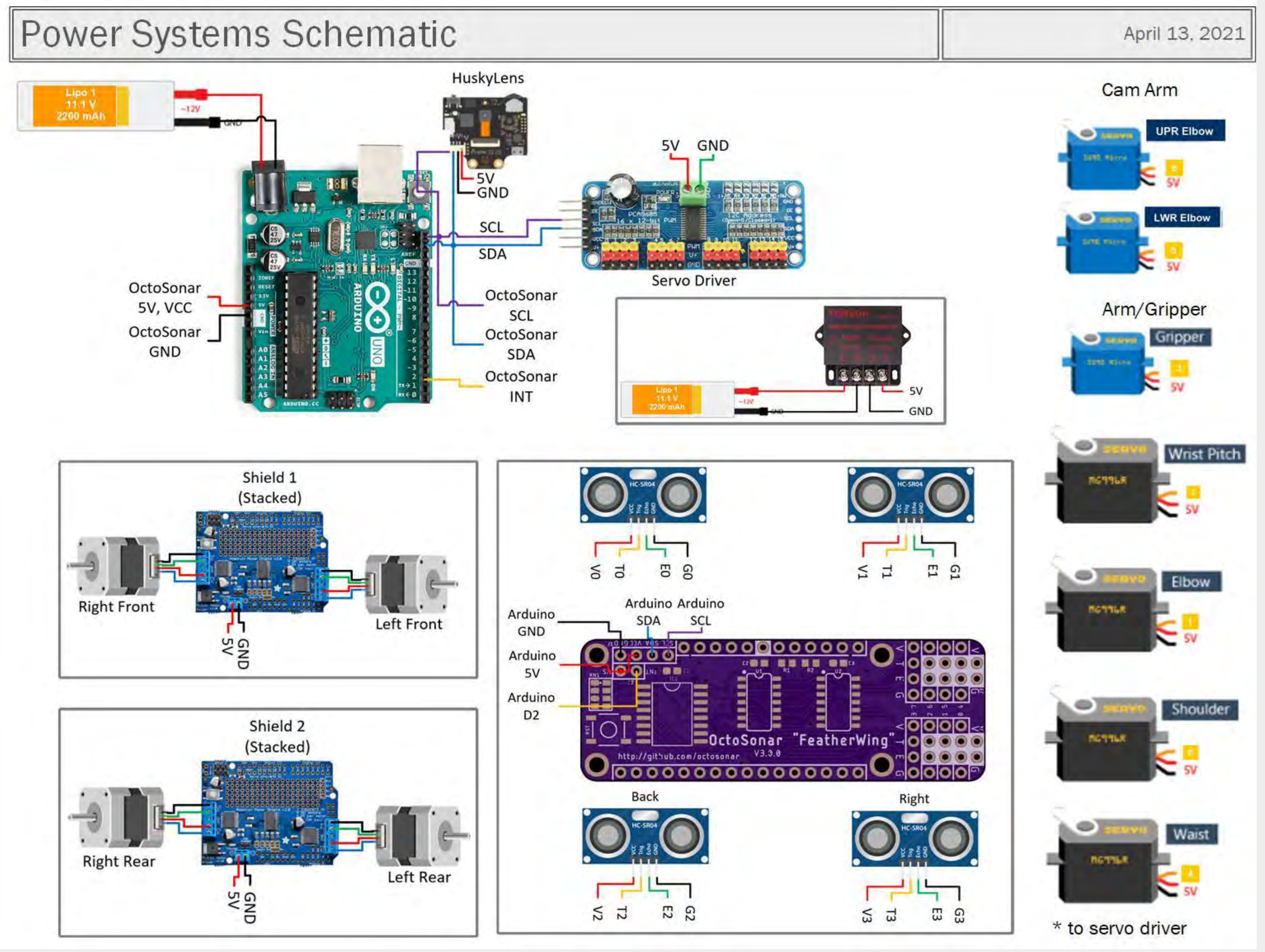
- Used to enable communication among the various subsystems essentially acting as a central data hub
- It controls the robot by determining the action/s needed and calling up the required subsystem hence also being in charge of prioritization



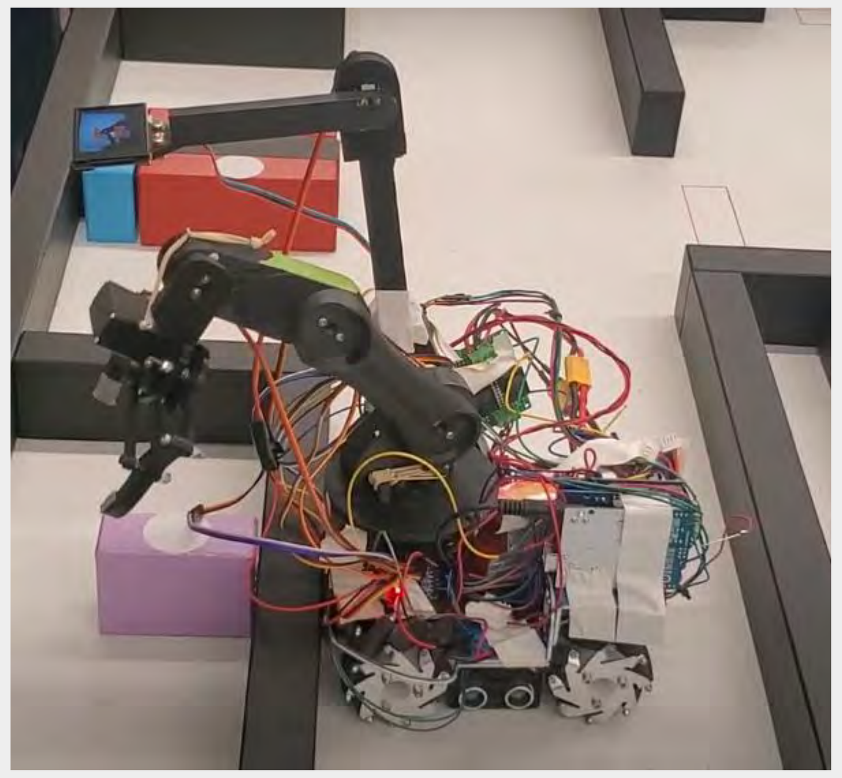
Testing

Decision Making System: All subsystems have been integrated. Testing has been done to demonstrate that concurrent system in the image above can work together.

Power Systems Schematic



Final Run



Lesson Learned

- The team learned that communication and planning skills are essential to the success of a complex project.
- It was helpful for the team to use task and scheduling documents to keep track of progress made as well as outstanding needs for the project.
- Starting as early as possible and anticipating problems arising helps give the team the best chance of success.
- Allocation of tasks and simultaneous but separate testing of major systems can improve the rate at which they are completed.

Difficulties and challenges

- The team was unable to have the robot working as desired by the competition date.
- The arm was having difficulty picking up blocks if they were in a certain position.
- The team broke several servo motors during the process of the build.
- The plexiglass chassis required redesign because it had too much flex which caused errors in the embedded teams calculations, so it was replaced with a metal chassis.
- Lighting glares on the metallic blocks caused problems with the CV. To resolve this, the squares were painted as per IEEE standards to match the color of the bocks.
- The micro servo for the camera mount joint and wrist joint was unable to provide the torque required of the joint.
- The stepper motors had issues overheating in the first configuration. It was determined that they were receiving too much power and a 5V supply instead of a 12V would allow them to operate as desired.
- The ultrasonic sensors had interference issues with their original configuration. It was found that twisting all power wires on the robot and moving the ultrasonic wires to the top of the chassis greatly reduced any noise.

Conclusion

- All subsystems were integrated in the final design of the robot.
- The team was able to successfully run the robot such that it would collect the power pellet and collide with a ghost.
- With future development, the team could work to locate and deliver other pellets to the home base to achieve a greater score.

Acknowledgement

We would like to thank the following people for their support throughout the project:

Customers: Andrian Jordan, Israel Jordan, Jasur Mirzakhmedov, Chase Templeton, Kevin Robertson

Mentor: Professor Meadows

SME: Dr.Arthur H. Ball, Mark Cairnie

NAVAIR IEEE Electrical and Embedded Robot

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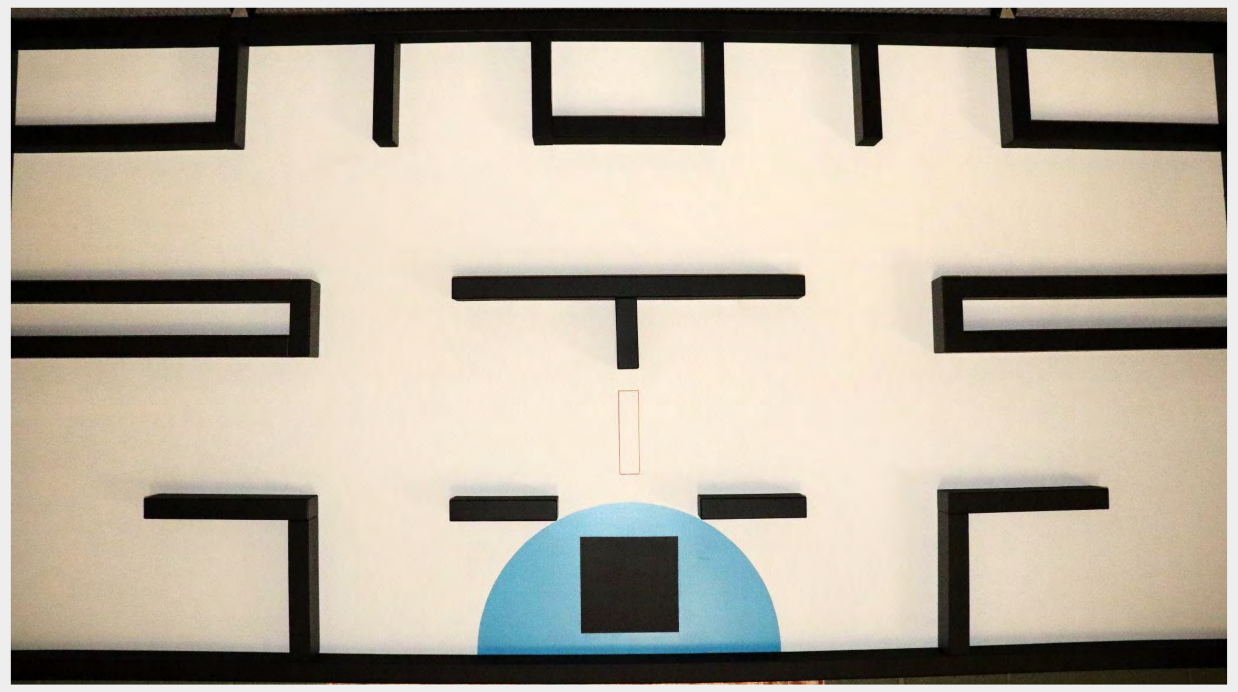

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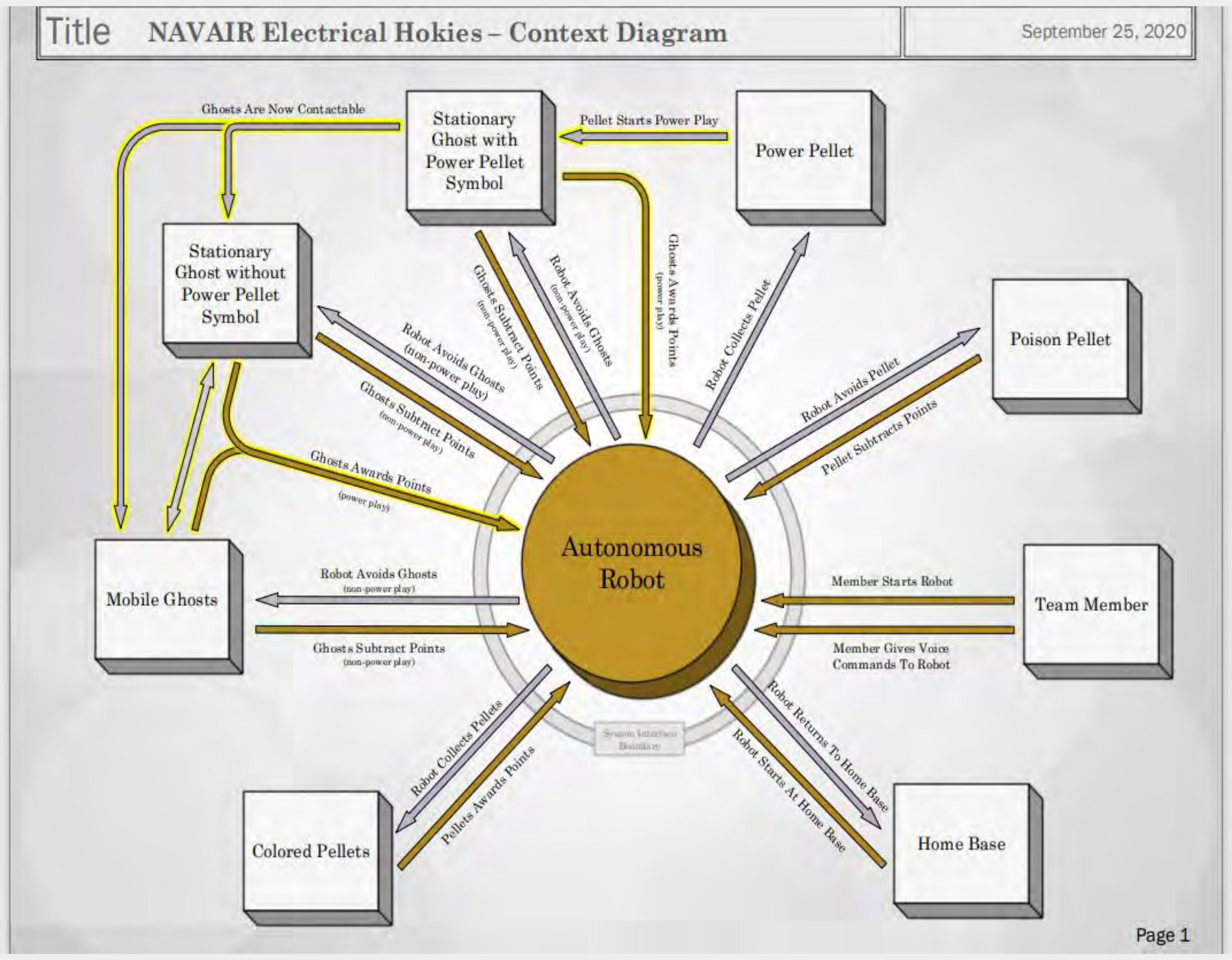

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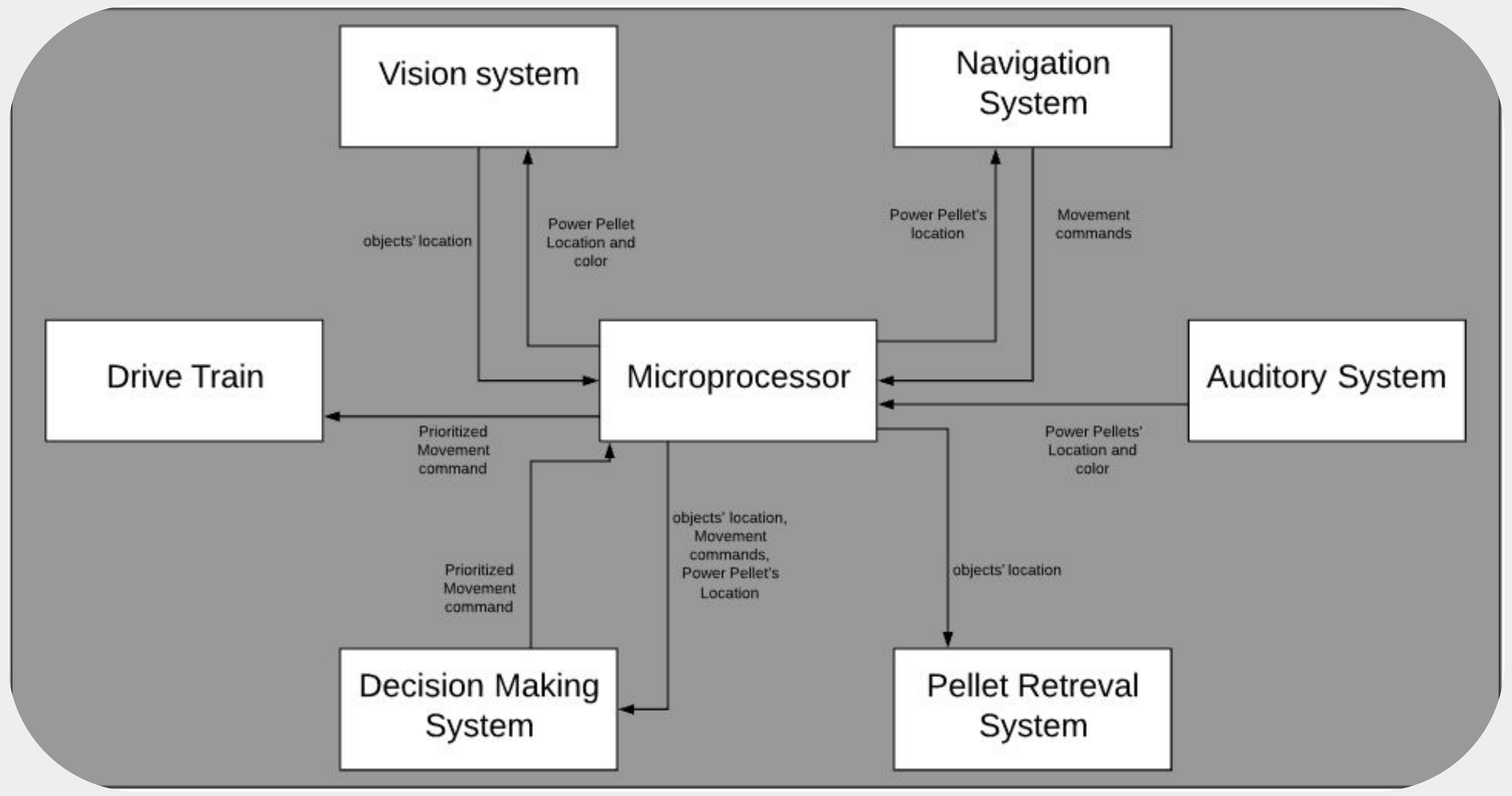

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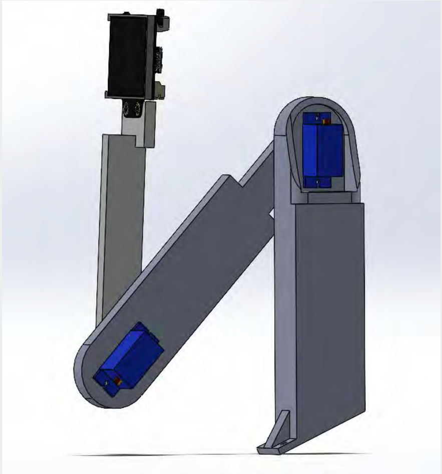

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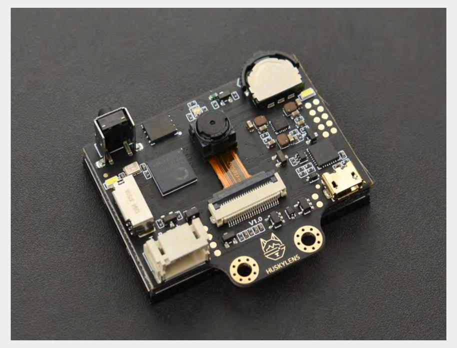

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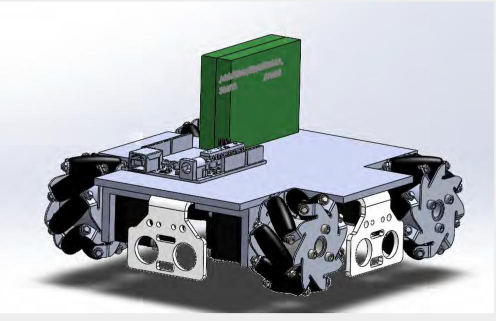
- The supporting program of the vision system collects, storages, formats, and returns information about pellets.

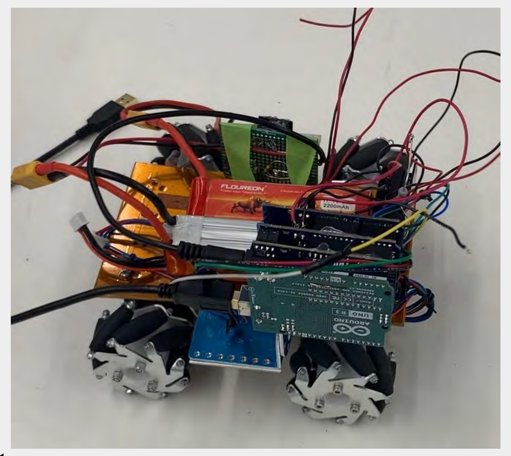
Testing

The vision system is able to differentiate pellets with differents color and pattern and return accurate coordinate information. The QR codes below include testing videos.

Navigation System

Hardware: Chassis and Drivetrain





- **Mecanum Wheels**
  - Drive wheel radius = 30mm (1.1811 in.)
  - Enable the robot to move all direction without changing the front.
- **Stepper Motors**
  - High torque
  - Precise control
- **Arduino Shield Motor Controllers**
  - Control two stepper motors each
  - Stackable
- **Metal Chassis**
  - 4 ultrasonic sensors attached
  - Two Lithium Batteries (Motors for wheels/Electrical components)
  - Battery Specifications:
    - 11.1V 2200mAh 25C

Software

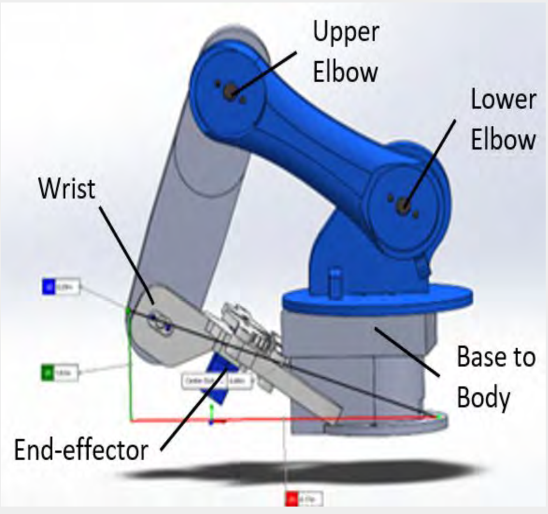
- This system collects distance data from four ultrasonic sensors to implement an adaptive wall-following algorithm that can navigate a Pac-Man maze with pseudo-random obstacles

Testing

- The navigation system is able to read accurate information from the ultrasonic sensors. The robot can correct itself to stay on course and move to the desired locations around the game board. Some videos of testing throughout this system's development are shown below.

Pellet Retrieval System

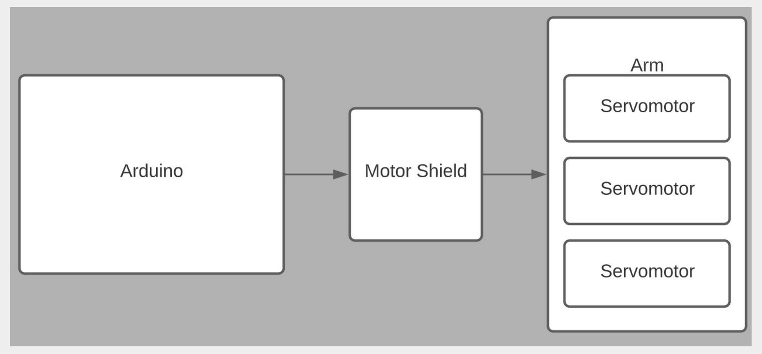
Hardware: Arm



- Starting Height: 6.44 in
- Width : 3.82 in
- Starting Length: 6.17 in
- Extended Length: 8.67 in
- 3D Printed

Software: Arm Control

- Designated the necessary location coordinates into the system using forward kinematics so that the arm could position to the desired locations and retrieve the pellets after indication from the decision-making system



Testing

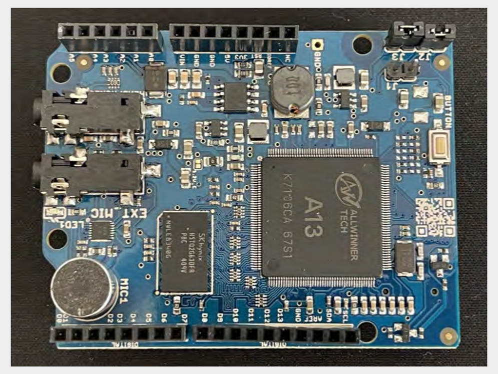
- Each servo is calibrated and powered appropriately. All servos on the arm can move freely and collect the pellets and return them to the body for transport. It can interact with other systems to complete its desired task.

NAVAIR IEEE Electrical and Embedded Robot

Team Members: Itiade Adegbulugbe, Luke Betts, Matt Genberg, Drew Klesat, Connor Lawler, Yixin Lu, Yiming Luo, David Moss, Chris Stafford, Kyle Wiggins

Auditory System

Hardware



- A cloudless Speech Recognizer / Voice Synthesizer for the Arduino platform

Software

This system enables the robot to interpret auditory commands from the driver

This functionality is used to communicate the locations of certain objects to the robot so it can plan its route accordingly

Testing

The auditory system is consistently able to identify the commands it is given. It is somewhat inconsistent at recognizing the callsign that indicates the beginning of a command, but this issue is easily addressed by using audio feedback from the robot that indicates when it recognizes the callsign.

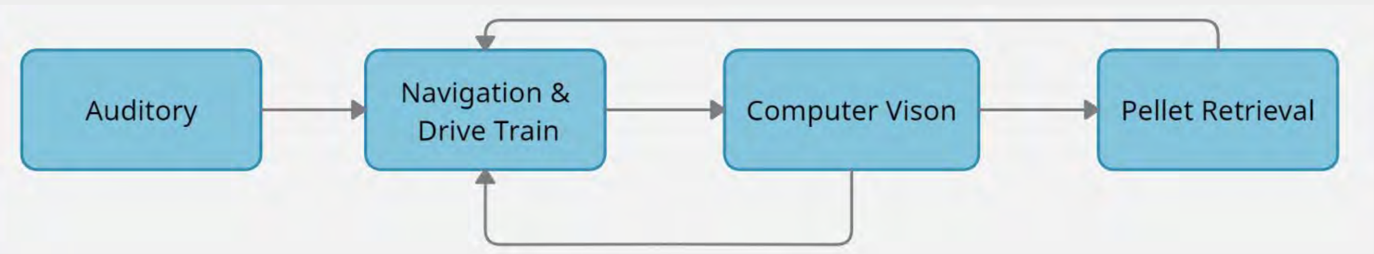
Decision Making system

Hardware

- An Arduino Uno that facilitates the necessary communication

Software

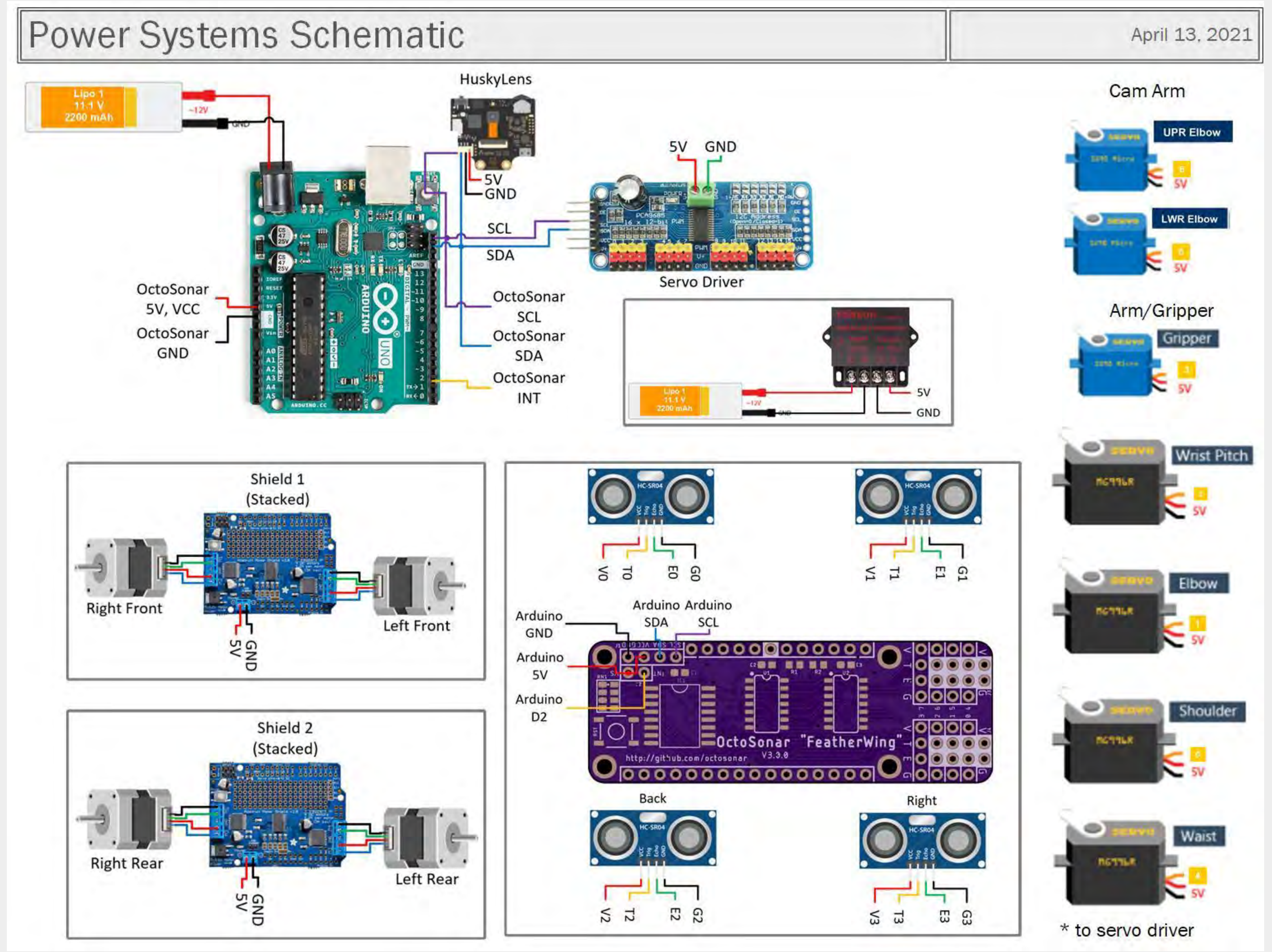
- Used to enable communication among the various subsystems essentially acting as a central data hub
- It controls the robot by determining the action/s needed and calling up the required subsystem hence also being in charge of prioritization



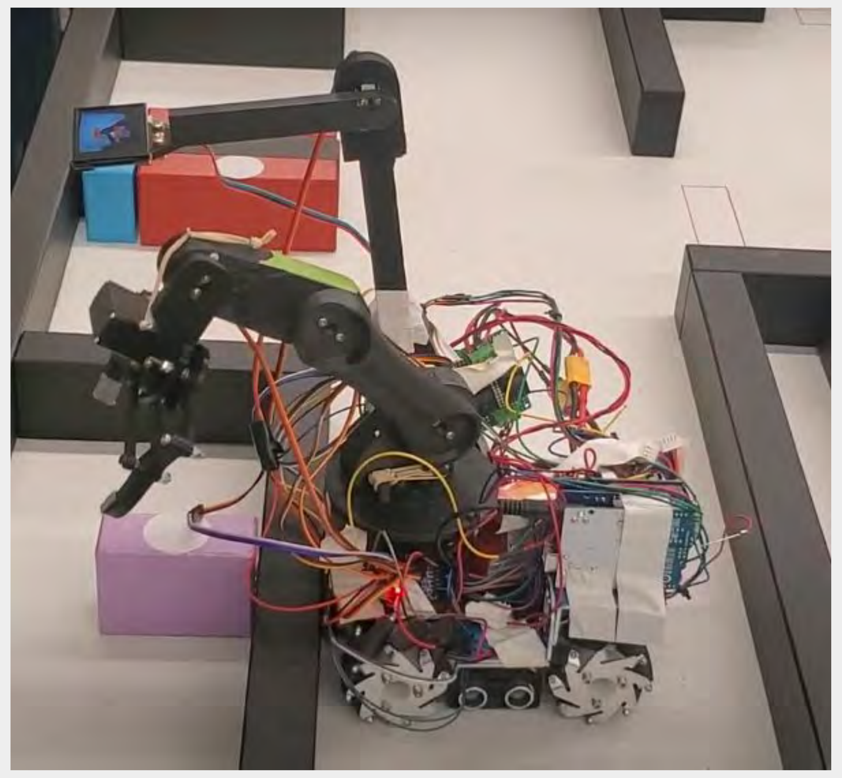
Testing

Decision Making System: All subsystems have been integrated. Testing has been done to demonstrate that concurrent system in the image above can work together.

Power Systems Schematic



Final Run



Lesson Learned

- The team learned that communication and planning skills are essential to the success of a complex project.
- It was helpful for the team to use task and scheduling documents to keep track of progress made as well as outstanding needs for the project.
- Starting as early as possible and anticipating problems arising helps give the team the best chance of success.
- Allocation of tasks and simultaneous but separate testing of major systems can improve the rate at which they are completed.

Difficulties and challenges

- The team was unable to have the robot working as desired by the competition date.
- The arm was having difficulty picking up blocks if they were in a certain position.
- The team broke several servo motors during the process of the build.
- The plexiglass chassis required redesign because it had too much flex which caused errors in the embedded teams calculations, so it was replaced with a metal chassis.
- Lighting glares on the metallic blocks caused problems with the CV. To resolve this, the squares were painted as per IEEE standards to match the color of the bocks.
- The micro servo for the camera mount joint and wrist joint was unable to provide the torque required of the joint.
- The stepper motors had issues overheating in the first configuration. It was determined that they were receiving too much power and a 5V supply instead of a 12V would allow them to operate as desired.
- The ultrasonic sensors had interference issues with their original configuration. It was found that twisting all power wires on the robot and moving the ultrasonic wires to the top of the chassis greatly reduced any noise.

Conclusion

- All subsystems were integrated in the final design of the robot.
- The team was able to successfully run the robot such that it would collect the power pellet and collide with a ghost.
- With future development, the team could work to locate and deliver other pellets to the home base to achieve a greater score.

Acknowledgement

We would like to thank the following people for their support throughout the project:

Customers: Andrian Jordan, Israel Jordan, Jasur Mirzakhmedov, Chase Templeton, Kevin Robertson

Mentor: Professor Meadows

SME: Dr.Arthur H. Ball, Mark Cairnie

Teledyne Remote Monitoring

Team Members: Jonathan Kayne and James Davis - Customer: Doug Baker
SME: Md Adnan Sarker - Mentor: Toby Meadows

Introduction

The Teledyne Remote Monitoring project is a student led endeavor with the goal of solving an issue faced in industry. We began with identifying key requirements and constraints then prototyping and testing.

Background

Teledyne Hastings makes vacuum gauges for devices that need to be under vacuum pressure, such as cryogenic containers.

Cryogenic ISO Tank

Cryogenic Transport Trailer

Objectives

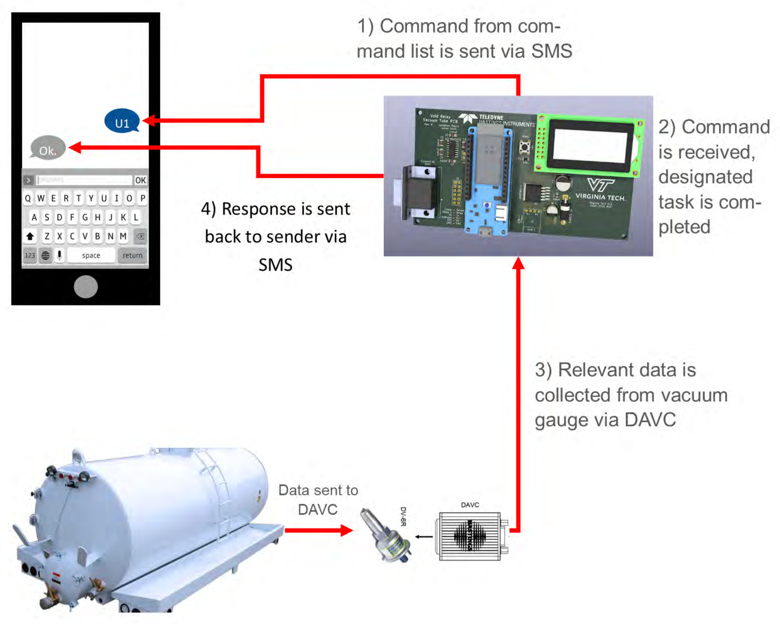
To implement a system to allow DAVCs to communicate over a cellular network via SMS. Must meet these Key Requirements:

1. Communicate with DAVC via serial connection
2. Receive and interpret commands over SMS
3. Regularly check vacuum pressure levels
4. Send SMS response, automatically or on demand
5. Remain functional for at least a year

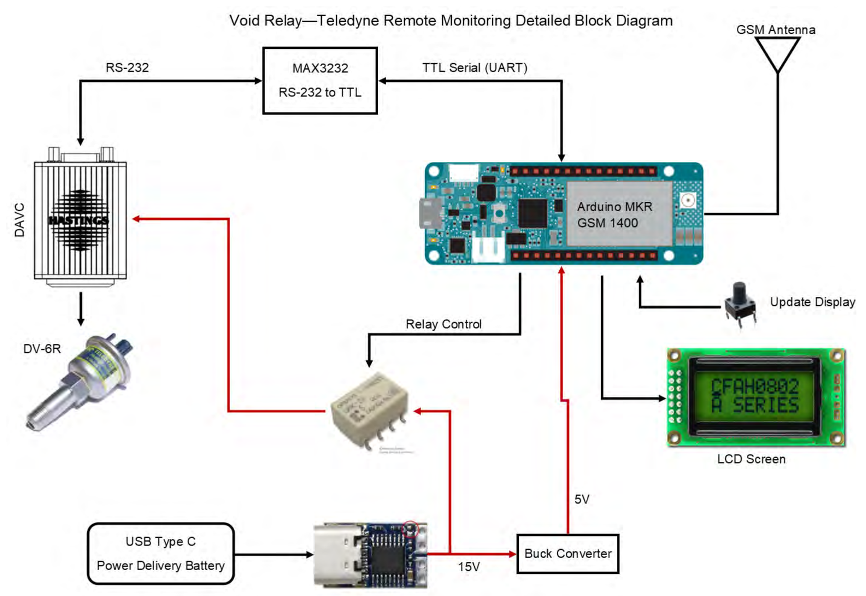
DV-6R Teledyne Vacuum Gauge

DAVC - Talks to DV-6R

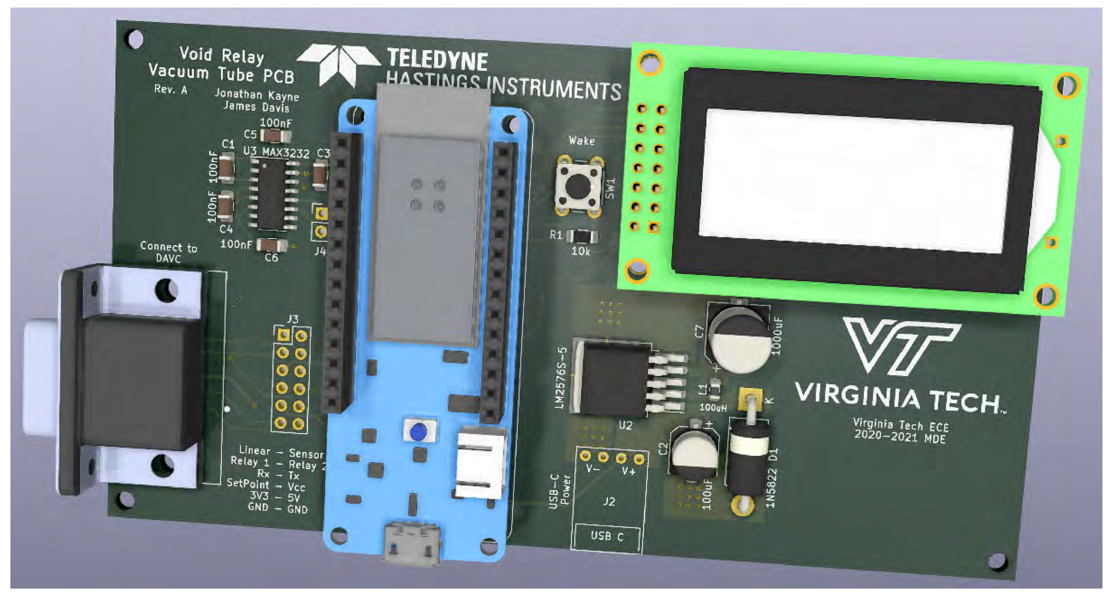
Method and Prototypes



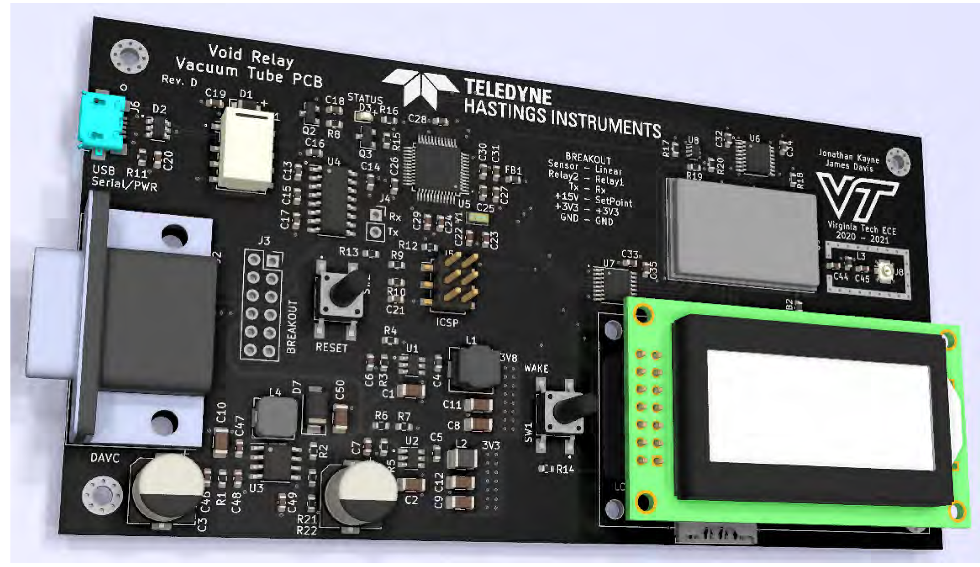
Concept of Operations



Block Diagram of System



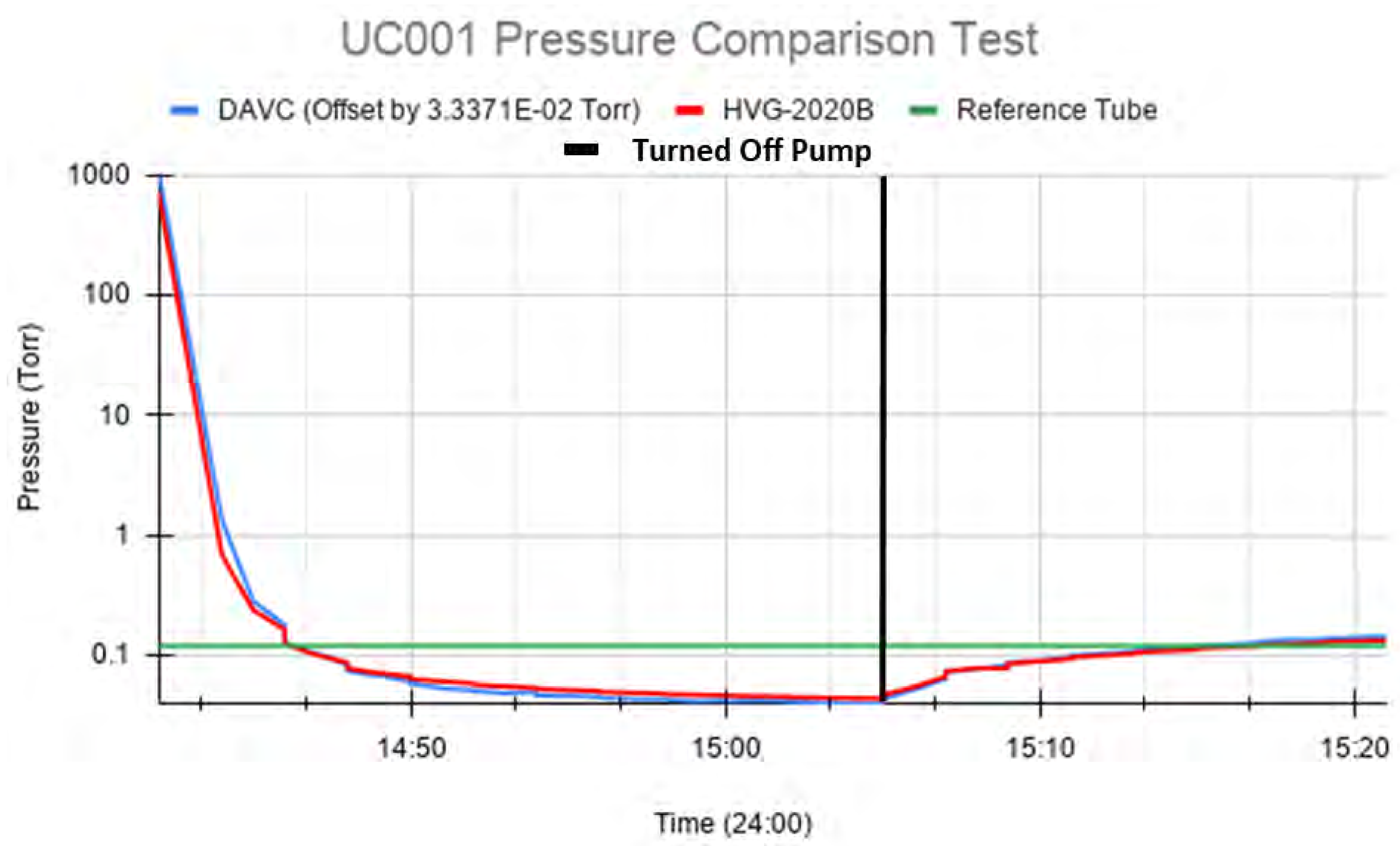
First PCB - Based on Block Diagram



Final Design- Meets All Key Requirements

Results

After the prototyping phase came the test phase, where we showed that our system met all the key requirements. The pressure test was to show that our system did not modify the data.



Pressure Comparison Test Results

Test Demo

Functionality Test Video

Challenges

The main challenge in this project was the exorbitant power consumption for a year. The solution to this was to to accommodate a basic solar panel to supplement the daily power consumption.

Basic Hobby Solar Panel

Conclusion

Our final device met all of our key requirements.

1. The PCB connects to the DAVC via RS-232 (Confirmed in prototypes MK.I-II)
2. SIM card allows reception of SMS (Confirmed in prototype MK.III)
3. Program checks pressure levels daily (Confirmed in prototype MK.III)
4. Uses SIM card to send out relevant data (Confirmed in Test Demo)
5. Simplified interfacing with solar panels solves power issues (Confirmed in prototype MK.V)

Acknowledgments

We would like to thank the following for their continued assistance in this project:

- Doug Baker (Customer), for feedback and support
- Dr. Greg Earle, for usage of vacuum pump
- Md Adnan Sarker, for subject matter advice
- Toby Meadows (Mentor), for continued support and feedback

Sept. 2020 - May 2021

Modification of TI RSLK Robot to include Remote Control, RFID, and Gripper

VIRGINIA TECH

Team Members: Mathew Bocharnikov, Zhiheng Luo, Cody Luong, Amarchand Niranjan, William Ogle
SME: Prof. Peter Han **Mentor:** Prof. Kenneth Schulz **Customer:** Mark Easley,TI

TEXAS INSTRUMENTS

Motivation

Robot Educational Kit

- RFID sensor
- gripper movement
- 7-segment display
- remote control
- bump sensors
- IR sensors
- TI - RSLK Max
- Wario Kart

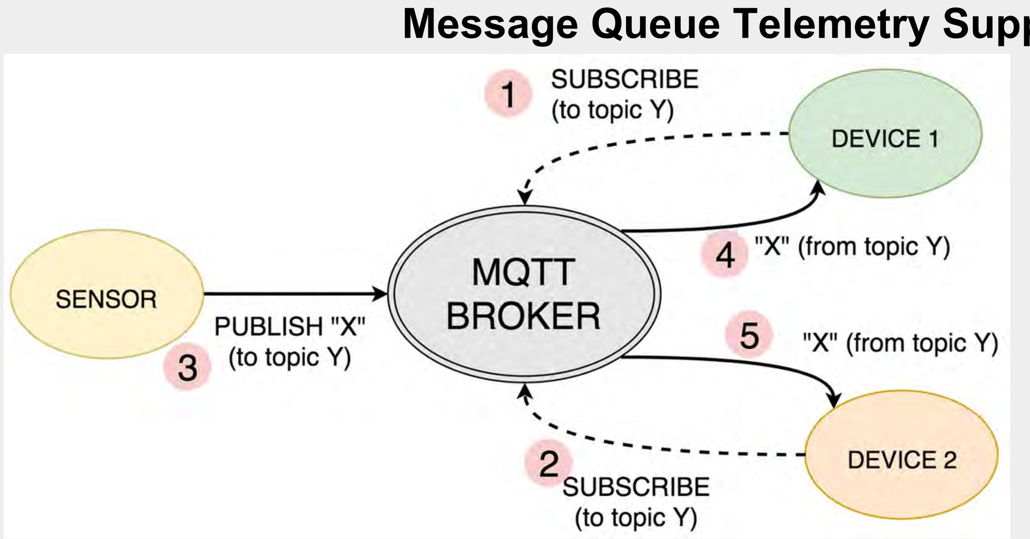
Major Specifications

The RSLK MAX robot will be able to:

- Move either autonomously or remotely through a MQTT connection
- Scan an RFID tag by moving over it and perform actions based on the type of tag identified
- Use the attached servo gripper to pick up an empty standard 12oz aluminum can
- Detect obstacles using a combinations of sensors and adjust movement accordingly
- Demonstrate the above through demo code samples

Remote Control

Message Queue Telemetry Support

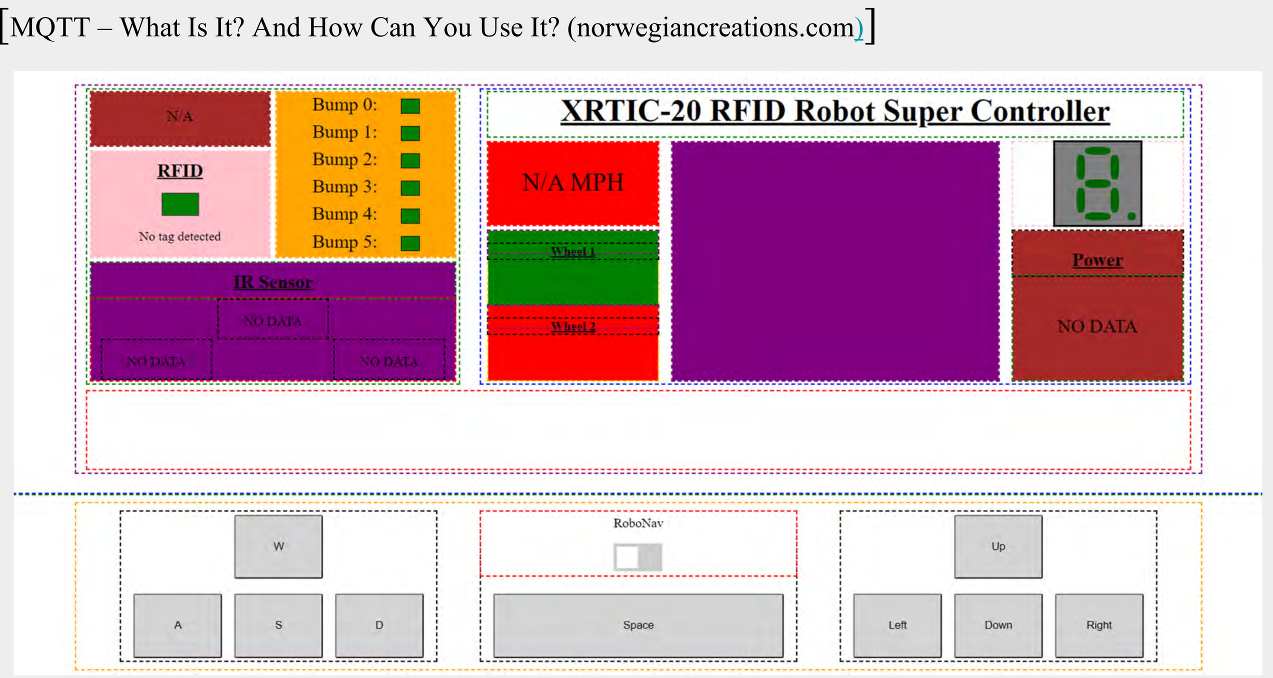


MQTT is a communication protocol in which a central broker passes information in real-time between connected devices

[MQTT – What Is It? And How Can You Use It? (norwegiancreations.com)]

AirMQTT

We utilized a free broker hosting platform called AirMQTT to host the broker for our project.



Our HTML based controller, which sends commands over MQTT

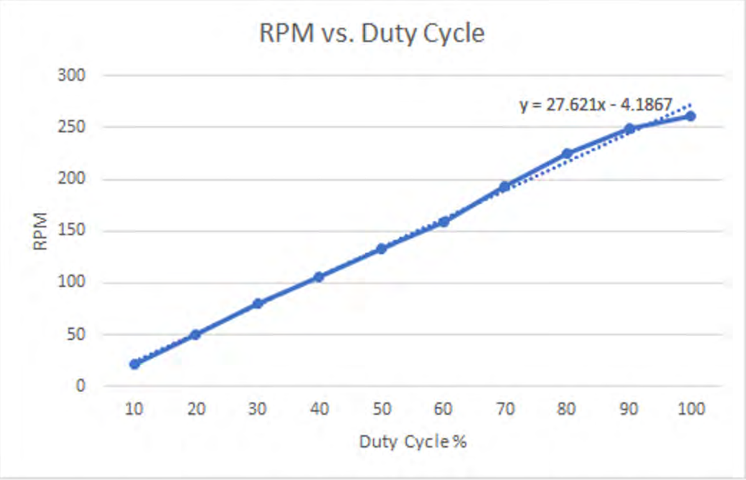
Drive

Overview

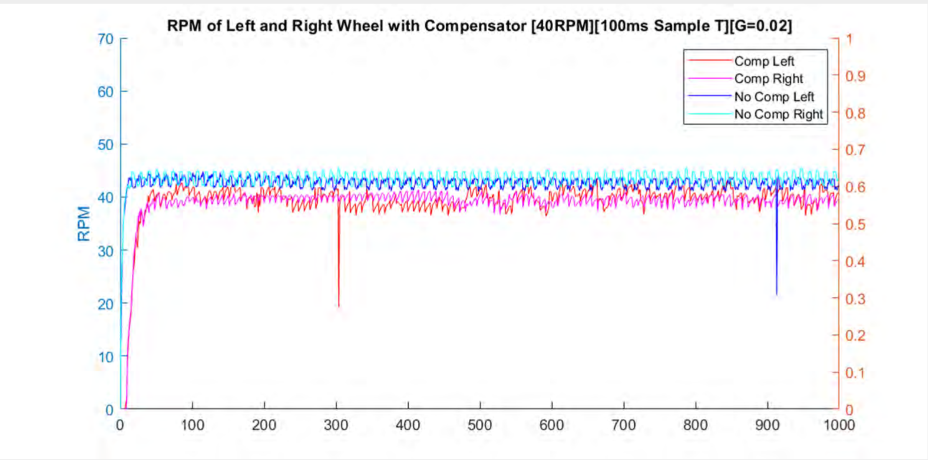
- Propelled by two brushed DC motors
- Powered by 6AA batteries
- Wheel diameter of 70mm
- Maximum RPM (no load) of ~260
- Interrupt driven encoder reading for RPM measurement
- Functions to move for a desired time or distance

"RoboNav"

- Simple obstacle avoidance algorithm
- Uses thresholds and data from the distance sensor
- If an object is close on the left, turn right, and vice versa



RPM vs. Duty Cycle
The RPM of the wheels linearly correlates with the applied duty Cycle according to the following equation:
RPM = 276.2*DC - 4.187



Control System
We implemented a control system to always keep the wheels at the desired RPM. See how the compensated RPM graph more closely matches the desired RPM of 40.

Rotation Relationship
The individual wheel rotation to achieve an overall rover rotation is given in the following equation, where θ_w is the wheel relative rotation of both wheels, θ_r is the heading of the rover, W is the width of the rover from wheel to wheel, and D is the diameter of the wheel.

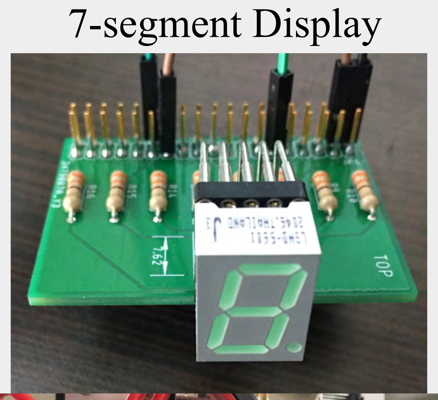
$$\Delta\theta_w = \Delta\theta_r \cdot \frac{W}{D}$$

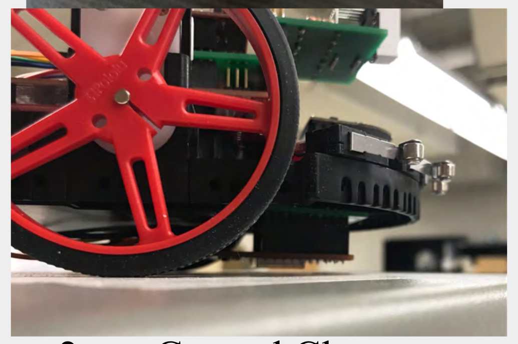
Distance Relationship
There is also a relationship between wheel rotation and distance traveled, which is shown on the right, where θ_w is the wheel relative rotation of both wheels, d is the desired distance, and R is the radius of the wheel.

$$\Delta\theta_w = \frac{180 \cdot \Delta d}{\pi \cdot R}$$

RFID & 7-Segment Display

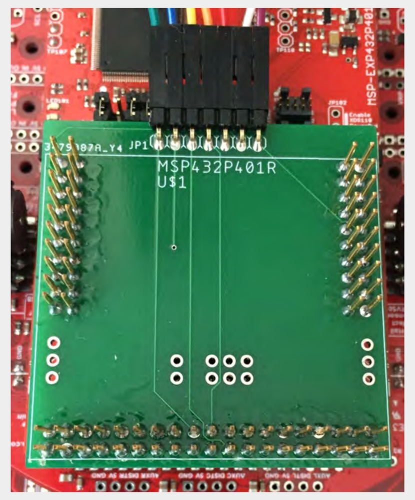
7-segment Display





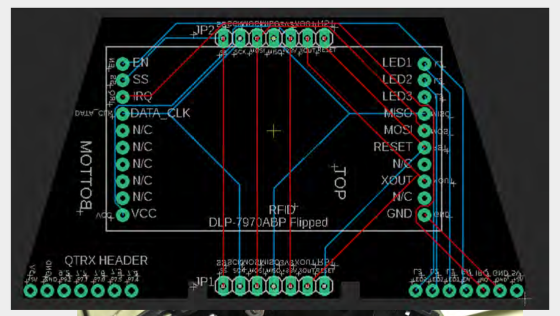
2mm Ground Clearance

- DLP-TRF7970 NFC
  - Detects ISO/IEC 14443A (type 2) and 15693 (type 5)



RFID Breakout Shield

PCB Designed in Eagle



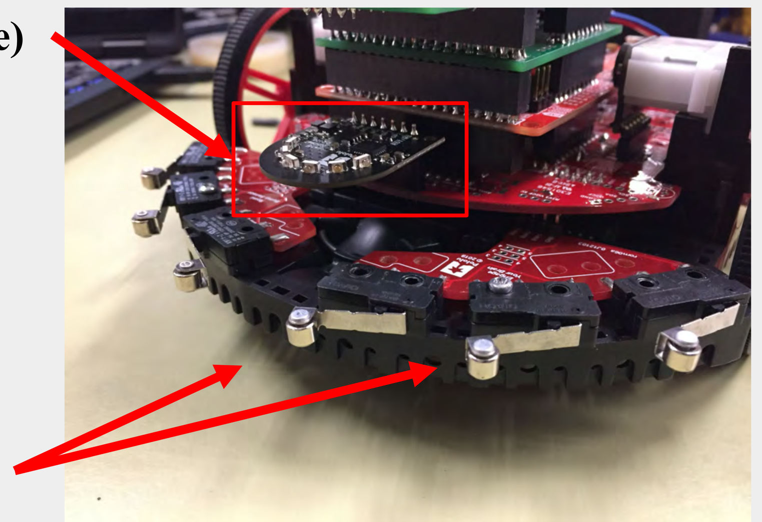
Undermounted RFID

Sensors

IR sensor (senses distance)

- Used in RoboNav
- Pololu OPT3101 IR Time of Flight
- Senses distance in three directions
  - Front, ~45° left, ~45° right
- Six frontal bump sensors account for any low-profile objects that the IR sensor may miss

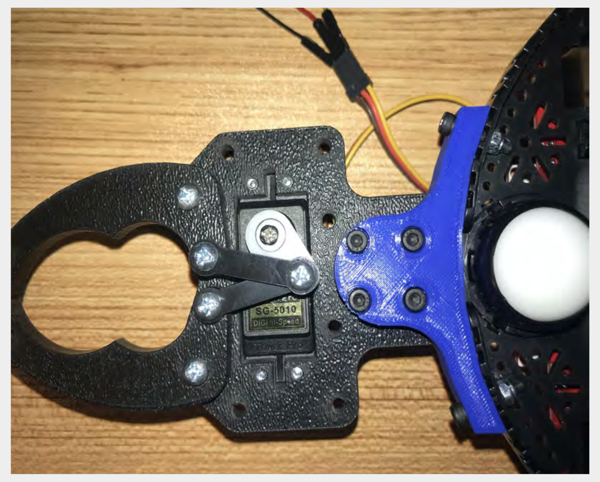
Bump Sensors



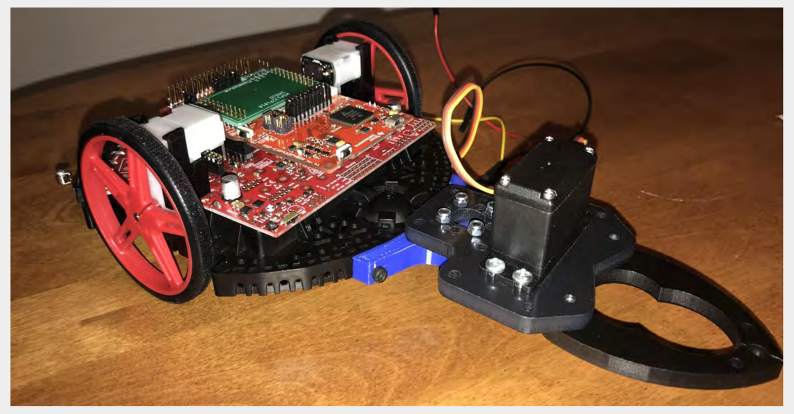
Gripper

- Servo City Gripper Kit A
- Single servo
- PWM control

- Library Functionality
  - Toggle open/close
  - Move to degree



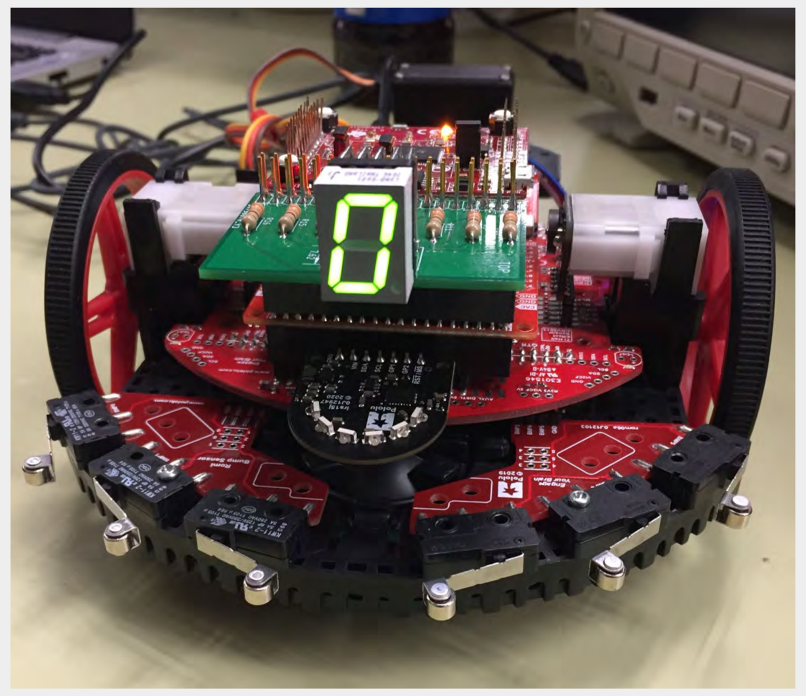
A simple, single degree of freedom, two-fingered gripper. We designed 3D a printed strut to attach the gripper to the chassis.

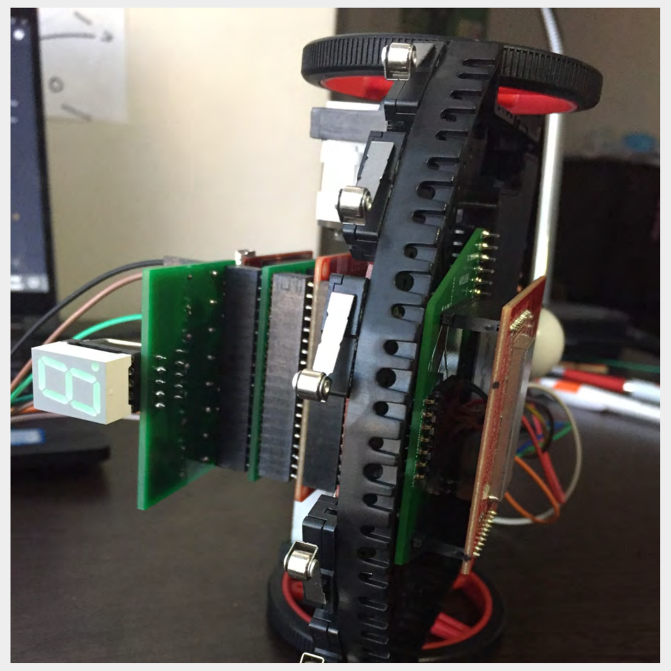


Gripper is mounted on the rear of the rover to the chassis, which powered by a servo, which can be set to different positions by varying the pulse width of its input signal.

Integration and Challenges

- Many major design decisions were made to incorporate certain subsystems
- RFID caused issues that were both expected and unexpected
- Shared resources with many needing pin reassignments
- Constantly creating solutions for new problems that arose after fixing old ones
- COVID-19 caused complications in both shipping times and work efficiency





TMEIC – INERTIAL MEASUREMENT UNIT ANALYSIS AND PROTOTYPING PROJECT

TEAM BLUE
Anne Bray, Brian O'Keefe, Brian Sternback
SME: Professor Ryan Gerdes   Mentor: Professor Toby Meadows
Customer Contact: Matt Mandros, Ashin Thomas, Thomas Tainer

PROBLEM STATEMENT

- This project sought to locate an IMU device that could best track positions of large objects
- Having a minimal error is necessary when transporting heavy containers to prevent stacks from toppling and causing injury to goods and people (*see Fig 1*)
- Once a suitable device has been purchased, its qualifications could be prototyped to verify its capabilities in the context of the system (*see Fig 2*)

Fig 1: Shipping Port with Rows of Stacked Containers

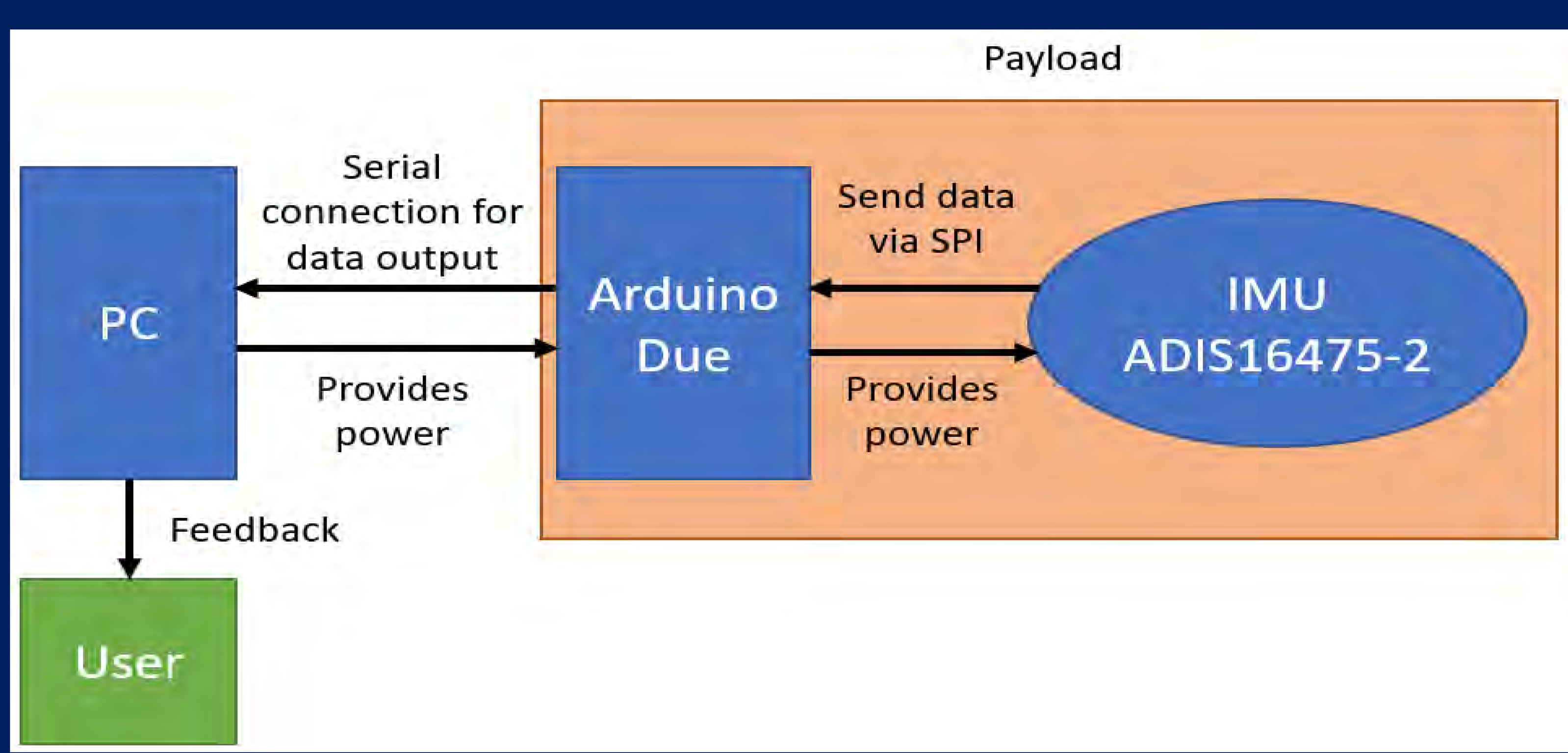


Fig 2: System Context Block Diagram

KEY REQUIREMENTS

- The device had to have sensor capabilities that could be accurate to a defined standard
- The device also needed to be able to operate in environmental conditions that can be found at a port
- Any devices and equipment necessary for this project's completion had a hard fiscal limit of $1,000

METHODOLOGY

- The team explored IMUs available from Analog Devices
- Most qualities were confirmed by datasheets, but some needed to be derived through other means
- The devices that met most qualifications confirmed by the datasheets were given the most attention for simulations

PERFORMANCE SIMULATIONS

- To determine the accelerometers' bias stabilities, several simulations were performed through MATLAB
- Varying test conditions revealed the error between true and simulated data, seeking low cumulative error across them
- Types of conditions used include stationary, step-function, and corkscrew motion simulations (*see Fig 3* and *Fig 4*)

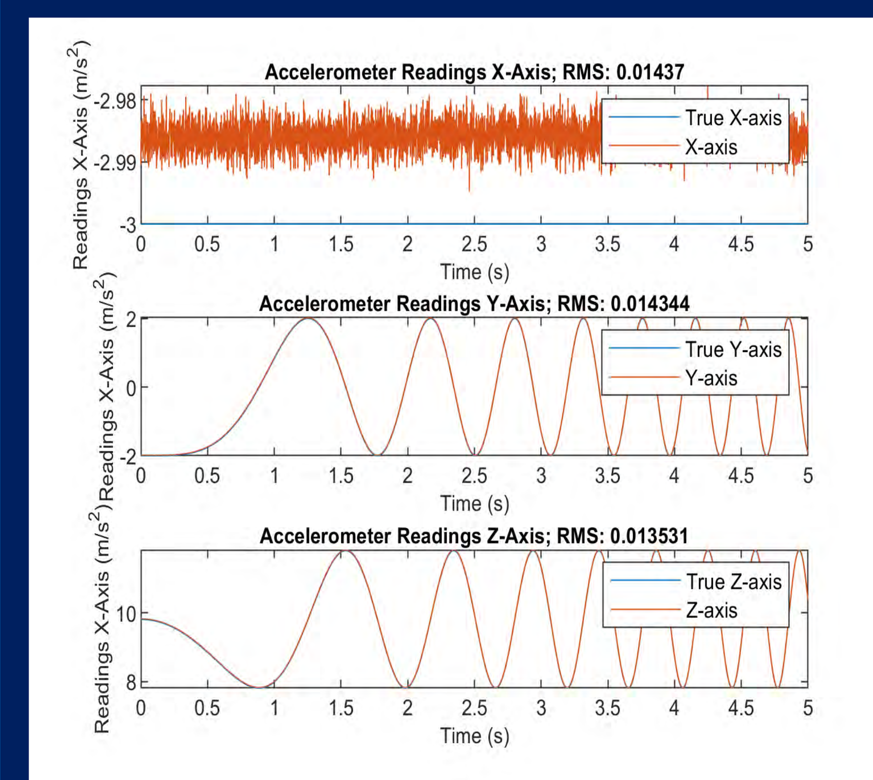


Fig 3: Accelerometer readings for the ADIS16475-2 IMU X-Axis corkscrew simulation test.

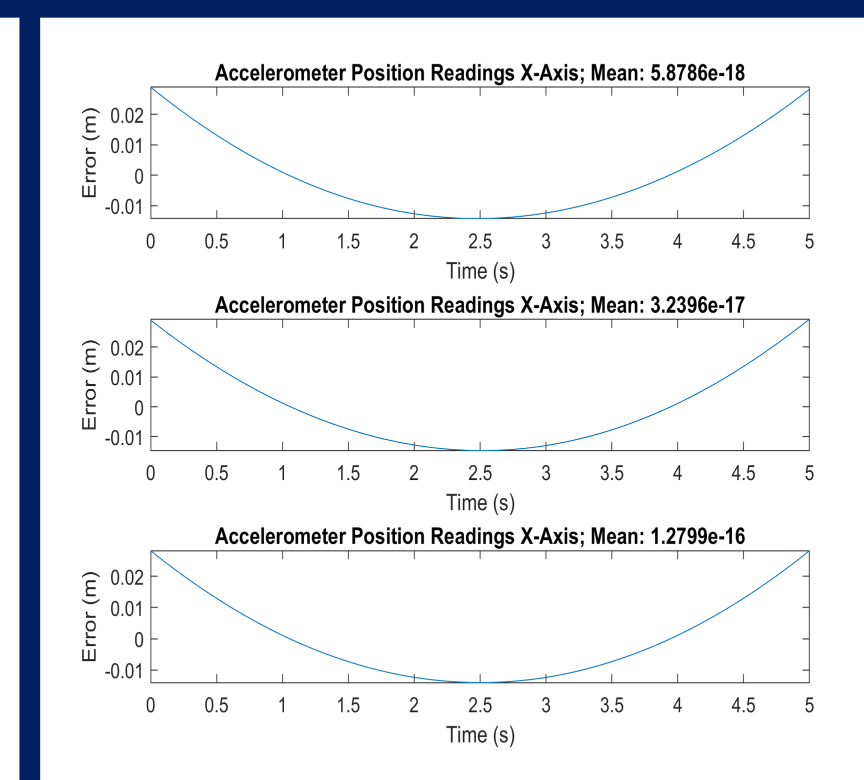


Fig 4: Error of accelerometer readings for the ADIS16475-2 IMU X-Axis corkscrew simulation test.

STATISTICAL VARIANCE

- In order to demonstrate the value of the simulations, confidence in their accuracy and precision is needed
- Such confidence was determined through a confidence interval, or an index used to represent the average error
- This project desired a confidence interval of 95%, meaning that the data produced would fall within 1.96 standard deviations of the mean
- Using MATLAB, a confidence interval for each IMU was taken across several simulations (*see Fig 5*)

95% Confidence Interval

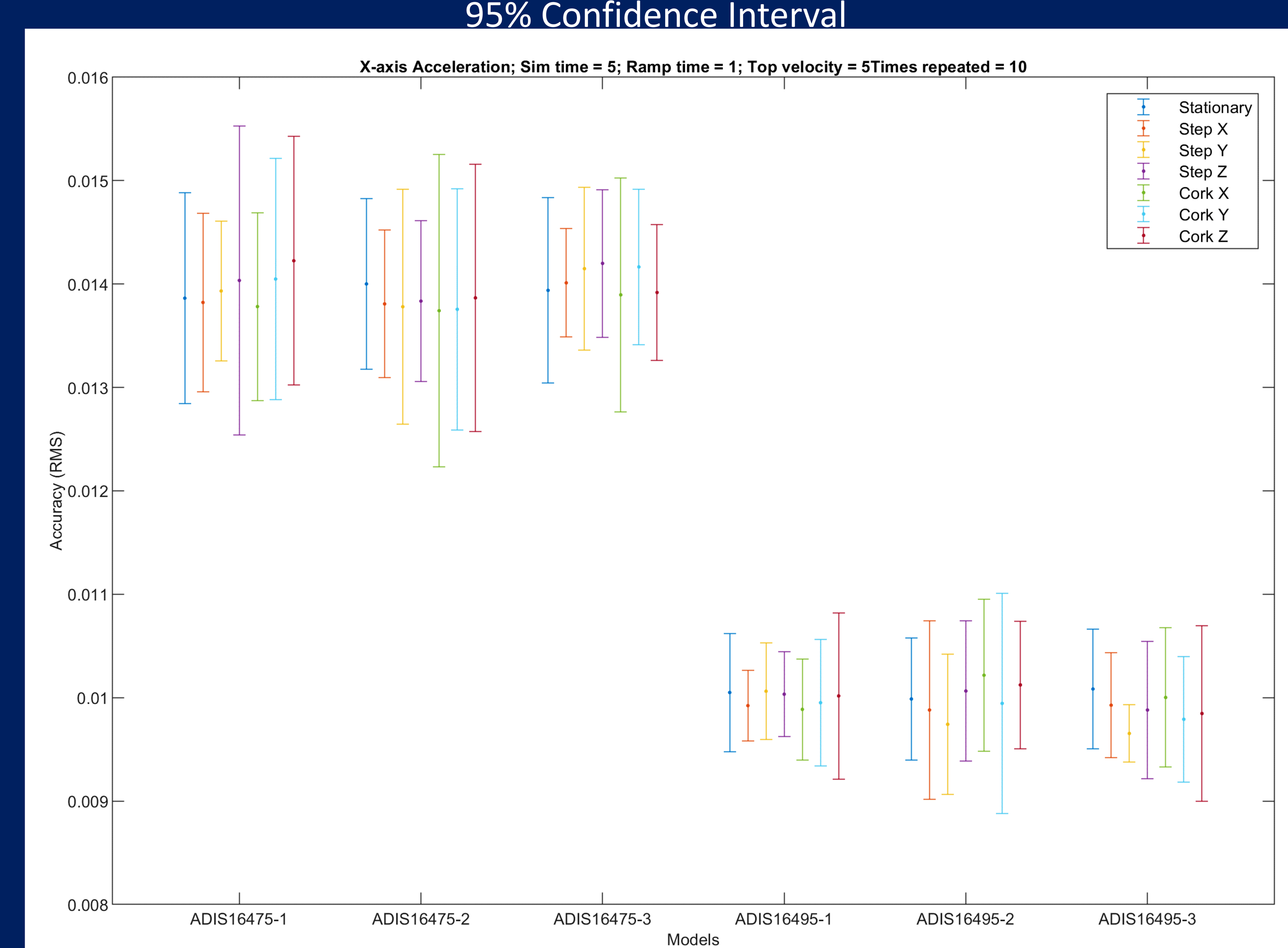


Fig 5: Confidence intervals for all seven simulations and all IMU models. Tests were run 10 times to generate a median RMS values and confidence intervals.

SIMULATION RESULTS

- Following the simulations, it was determined that the best performing IMU devices were of the ADIS16495 models.
- These models, however, well exceeded the budget of the project, forcing their exclusion from the team's recommendation
- Following the price crunch, it was determined that the best remaining devices were of the ADIS16475 models, specifically the one designated ADIS16475-2

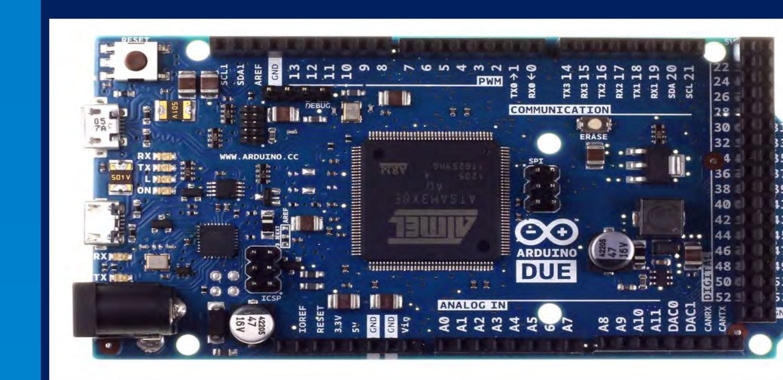


Fig 6: Arduino Due

Fig 7: ADIS16475-2 with Evaluation Kit

TESTING AND INTERFACING

- The primary interfacing process involved the use of SPI to communicate between the Arduino Due (*see Fig 6*) and the ADIS 16475-2 IMU (*see Fig 7*)
- Testing method involved dangling the device and a secondary GPS to test for motion and position tracking *(see Fig 8)*
- This test imitated the z-axis motion caused by a crane with some noise elements *(see Fig 9)*

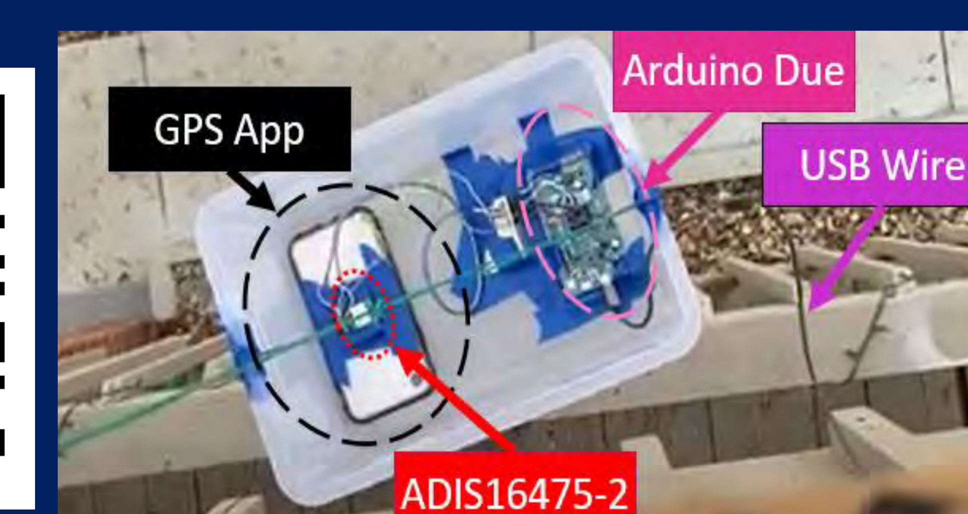


Fig 8: Setup for Z-direction testing

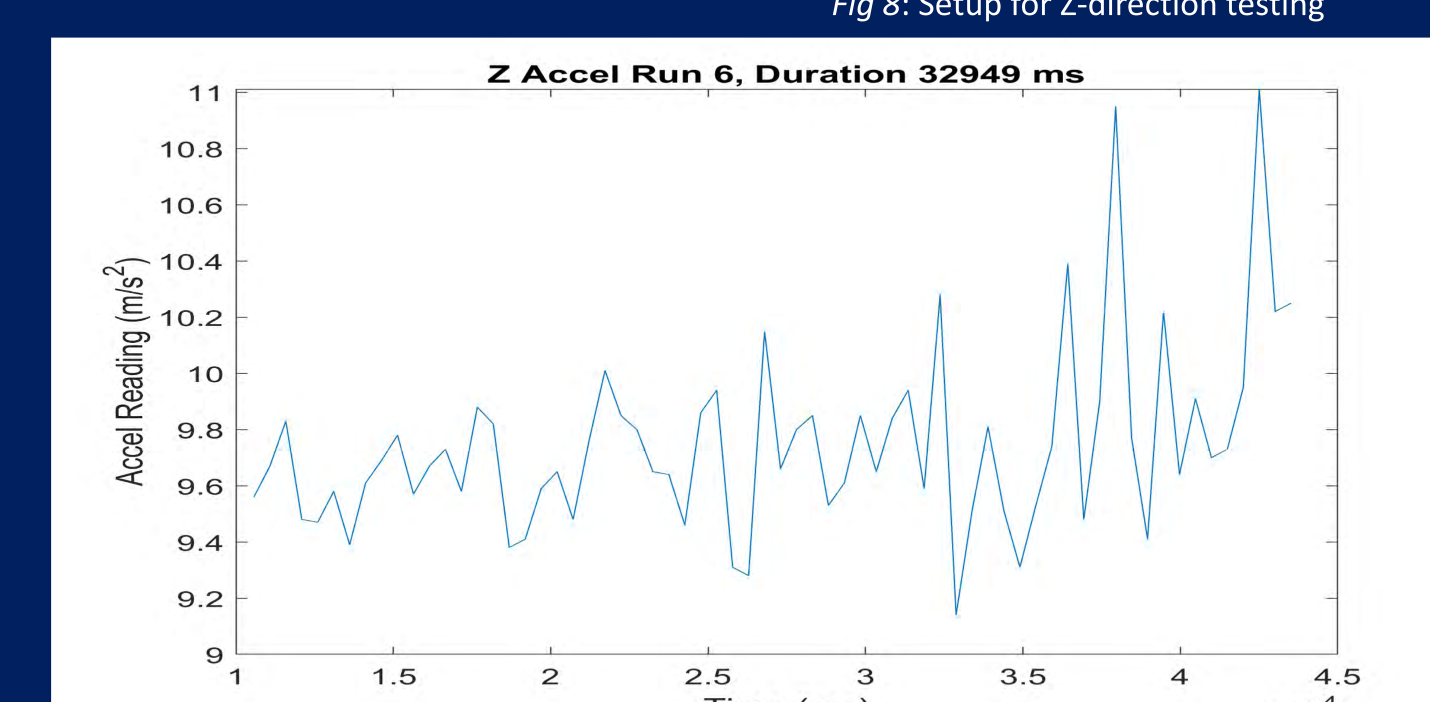


Fig 9: Z-axis acceleration test measurement.

FUTURE

- Further testing will be conducted by the sponsor to recreate these results, including tests from a proper shipping crane
- Additionally, the interfacing will be improved to better translate raw data from the device to information more readable to humans

Magnetic Levitation System

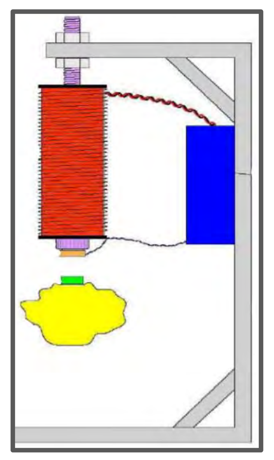
Electromagnetic Wave Riders

Team Members: Zackary Andraka, Stephanie Flear, Jon Grabski, and Renee Wilson

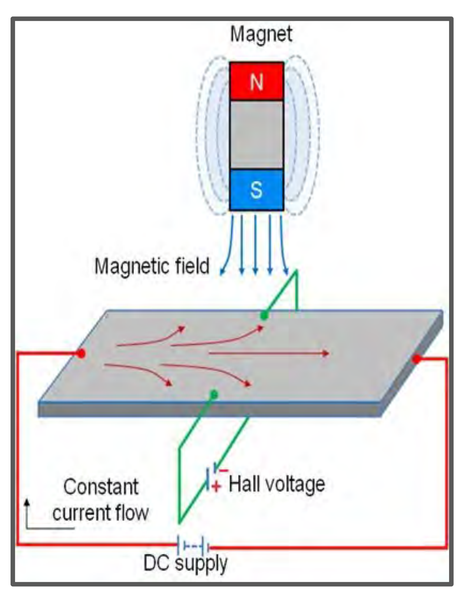
Customer: Dr. Daniel Sable, VPT Inc. **SME:** Matthew Strehle

BACKGROUND

Magnetic levitation is a concept in research today for various applications, including technologies like levitated trains. VPT, Inc. is a provider of power electronics for use in avionics, military, space, and industrial applications. These electronics are used also in magnetic levitation systems. VPT, Inc. is sponsoring this project to research, design, and build a magnetic levitation system that implements solenoids from the top only to levitate an object in air.



Basic System Design



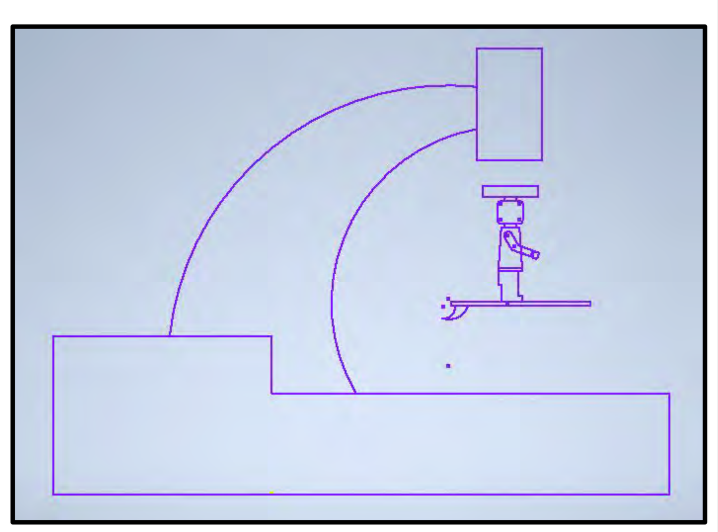
When current is run through a solenoid, it produces a magnetic field. This magnetic field can be measured through the Hall Effect, which is the voltage difference across an electrical conductor that is transverse to an electric current in the conductor and to an applied magnetic field perpendicular to the current. The Hall Effect voltage is an input to a compensator circuit to stabilize the system, which is inherently unstable when there is a solenoid above the levitated object. The compensator is used to move the right-hand pole to the left-hand plane, therefore stabilizing the system.

OBJECTIVES

Project Mission Statement: The team will design and implement a magnetic levitation system with digital control and a creative housing to stably levitate and manipulate an object attached to a permanent magnet.

System Requirements:

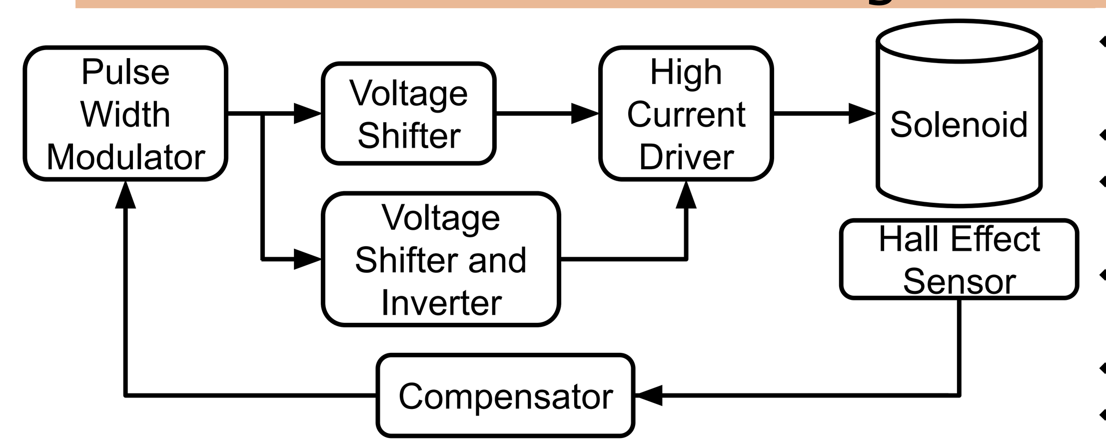
- ❖ Levitate the object for an indefinite amount of time
- ❖ Move the object vertically (3 cm) and horizontally (5 cm)
- ❖ Incorporate creative design element or theme.
- ❖ Re-stabilize (within 30 seconds) after outside disturbance
- ❖ Location of the electromagnetic solenoids: above levitated object
- ❖ Location of sensors: between solenoids and levitated object.



Creative Design: Lego Surfer Levitated Under Wave

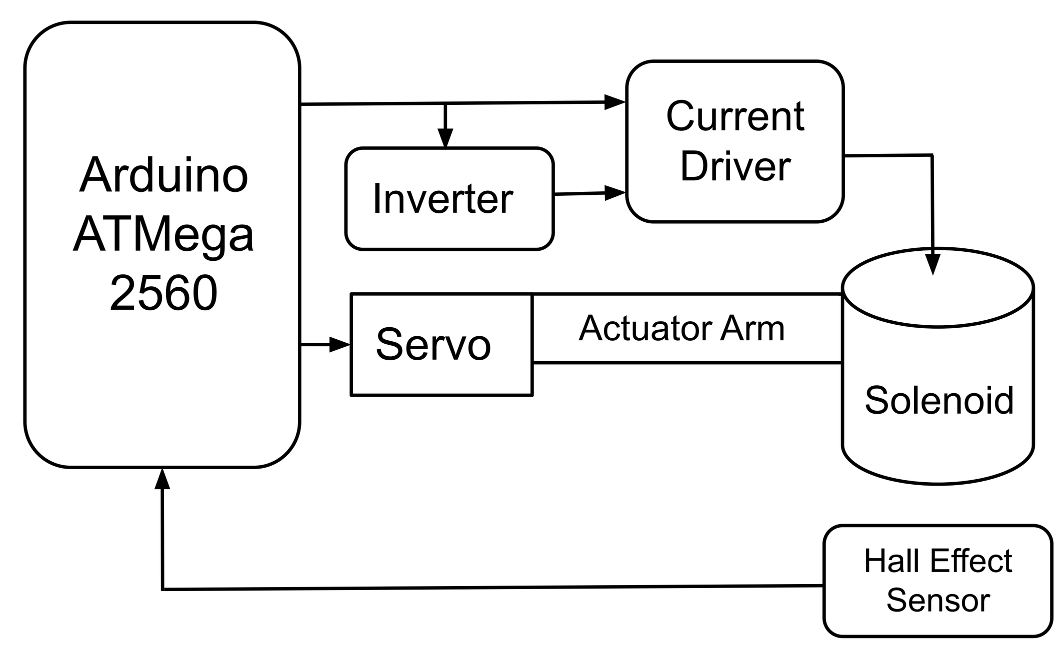
OPERATION

Initial Single Solenoid System



- ❖ Hall Effect sensor measures the magnetic field of the levitating object
- ❖ Compensator regulates overall system
- ❖ PWM outputs a square wave with varying duty cycle
- ❖ Voltage Shifter and Inverter creates signals needed by the current driver
- ❖ Current driver powers the solenoid
- ❖ Solenoid levitates the object

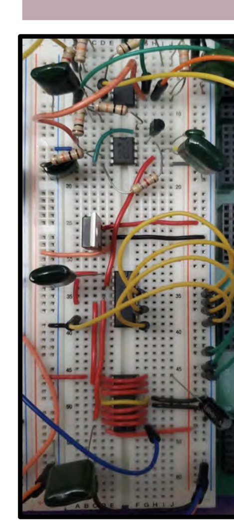
Final Digital System



- ❖ Arduino compensates the system with a PD control loop and outputs the PWM
  - ➢ Eliminates the need for a PWM chip
  - ➢ Eliminates the need for a voltage shifting circuit
- ❖ Single solenoid digitally controlled system is connected to a linear actuator allowing for horizontal movement
  - ➢ Linear actuator powered by a micro servo
- ❖ High current driver powers the solenoid which levitates the object (same as analog)

IMPLEMENTATION

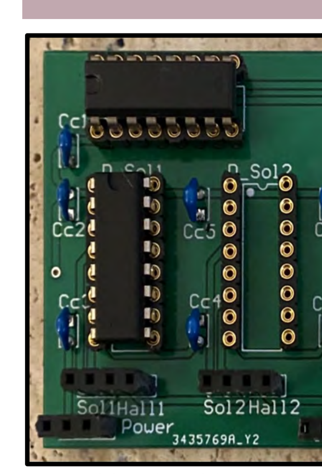
Initial



Breadboard Analog Circuit

- ❖ Breadboard induces a lot of noise
- ❖ Inconsistent and unreliable
- ❖ Very Large → only 1 solenoid system on a 2.2"x7" board
- ❖ Difficult to understand

Final



Multi Solenoid PCB Implementation of Electrical System

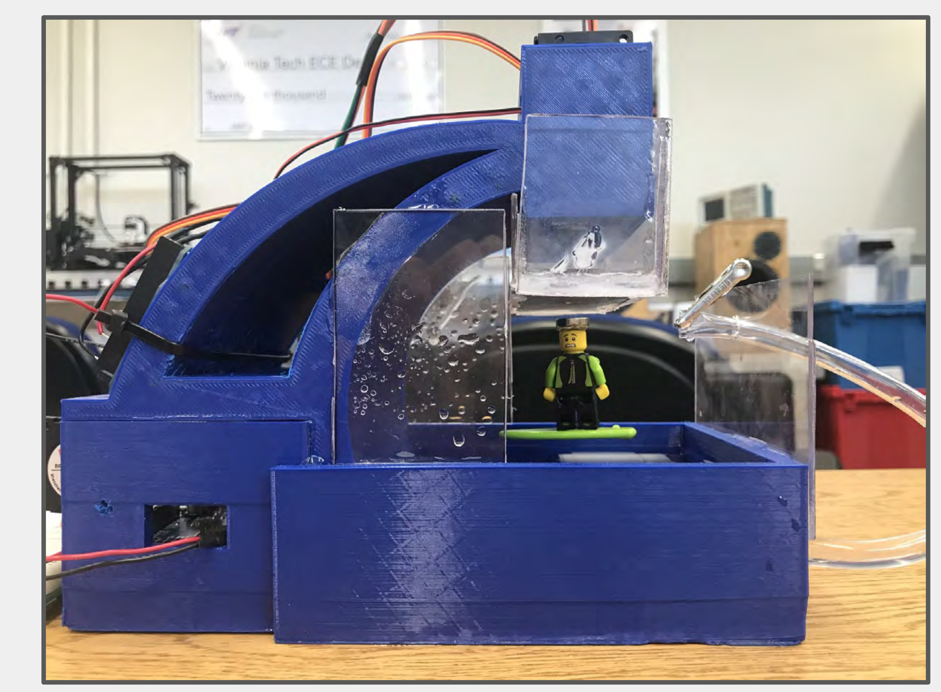
- ❖ Noise issue eliminated by large ground plane and embedded traces rather than jumper wires
- ❖ Much easier design to understand
- ❖ Increased reliability
- ❖ Much smaller → 5 solenoid system on a 3.5"x 2" PCB
- ❖ Designed schematic/layout in Altium printed using JLCPCB

RESULTS

System Capabilities:

- ❖ Stable, constant levitation
- ❖ Vertical movement by 1 cm
- ❖ Horizontal movement by 5 cm
- ❖ Disturbance rejection by water spraying onto the surfer

Final system video: CLICK HERE



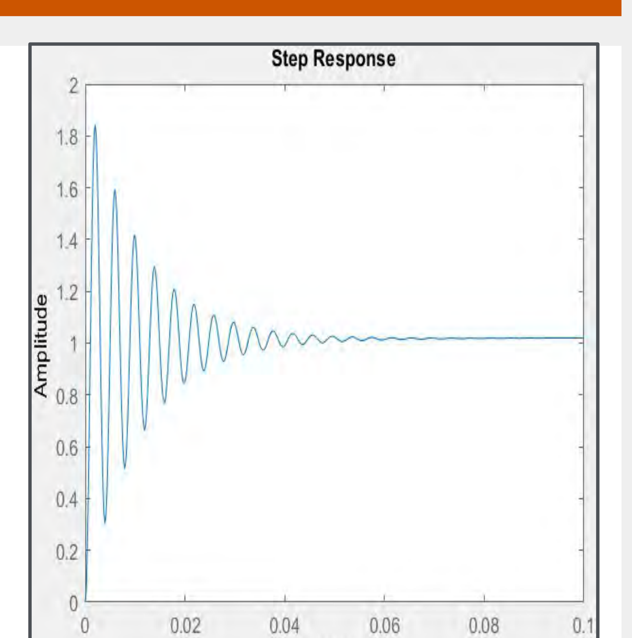
CONCLUSIONS

Our team was able to meet a vast majority of the requirements. We were successfully able to design and build a magnetic levitation system that was digitally controlled and in a wave structure with a Lego surfer levitating. The levitated surfer moves left and right as if actually surfing. We were not able to achieve this with multiple solenoids in the digital design, but instead used an actuator to horizontally move the surfer.

If we were to continue the project, we would implement larger solenoids to increase the weight of the object that can be levitated. We would also add a user-controllable digital GUI, in order for the capabilities to be chosen by the user on demand.

CHALLENGES & SOLUTIONS

- ❖ The system is inherently unstable; try hanging one permanent magnet from another
  - ➢ The solution is to introduce a system compensator so the circuit returns to stable position
- ❖ The transfer function contains a right-half plane pole which cannot be removed with proportional gain alone
  - ➢ Add one pole and one zero to the compensator to shift the right-half plane pole until is is in the left-half plane
- ❖ The team did not have as much expertise in digital compensation as in analog
  - ➢ The microcontroller used for digital compensation was chosen to trade some functionality for ease of access and broader open-source documentation



LESSONS LEARNED

During the design and development of this project, our team learned valuable lessons about engineering in application. Listed below are some of these lessons:

- ❖ It is extremely rare for a system to work on a first design so plan ahead
- ❖ Electrical components always have some degree of error -- have extra components on hand to ensure proper performance
- ❖ Communication is key to solving all problems

ACKNOWLEDGEMENTS

Thank you to VPT, Inc., for sponsoring this project and for the constant support of our team. Thank you to Dr. Sable, our customer, and Matthew Strehle, our Subject Matter Expert (SME), for walking alongside us during this journey and providing us with their expertise.

Thank you to the Bradley Department of Electrical and Computer Engineering for the Major Design Experience (MDE) and for all resources, professors, and access to labs that aided this project.

Electromagnetic Levitation System

Members: **Chris Mitchell, William Hall, Connor Flanagan**
SME: **Campbell Lowe** Customer: **Dr. Dan Sable, VPT** Mentor: **Dr. Scot Ransbottom**

Introduction

Magnetic levitation is an unstable system; therefore, feedback compensation is required to be added to the system to stabilize the suspended object with a time-varying field. The purpose of this project is to demonstrate an understanding of control systems by implementing an interactive magnetic levitation system. As a group, the team created a magnetic racing game where users press buttons to move a magnetically suspended object left and right to stay on a virtually displayed track.

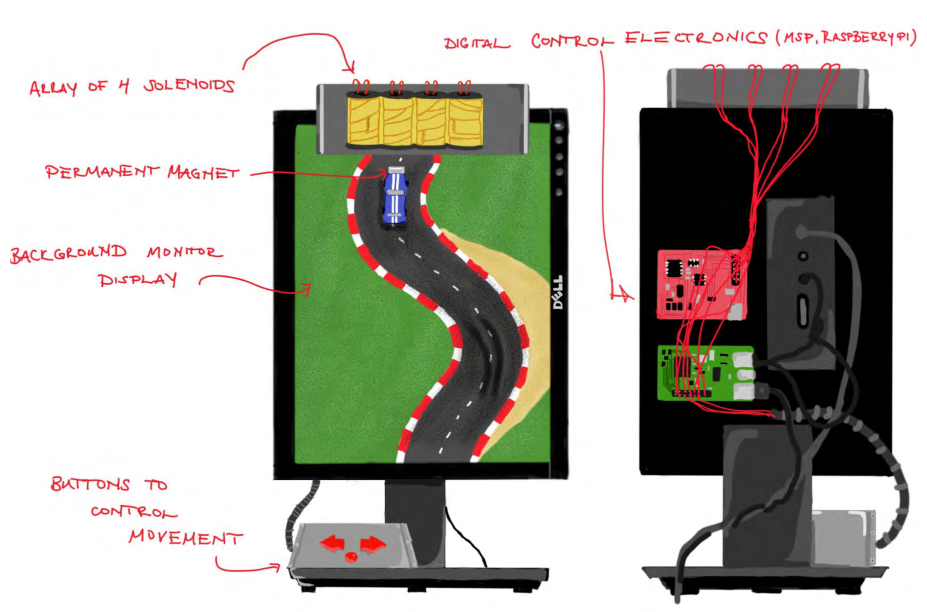


Figure 1: Initial Concept Art

Objectives and Results

Levitation Objectives	Analog	Digital
Levitate a ping pong ball for an indefinite amount of time	O	O
Sinusoidal reference tracking for up to 400mVpp at 1Hz	O	O
Levitate under square wave transient disturbances of 200mVpp at 1 Hz	O	O
Levitate a ping pong ball for an indefinite amount of time under two magnets	O	O
Move a ping pong ball left and right under two magnets	O	X
Levitate a ping pong ball for an indefinite amount of time under three magnets	O	X
Move a ping pong ball left and right under three magnets	-	X
Levitate a ping pong ball for an indefinite amount of time under four magnets	X	X
Move a ping pong ball left and right under four magnets	X	X

Game Objectives	Status
Develop a procedurally generated randomized track pattern	O
Implement multiple game speeds for harder difficulty settings	O
Implement a 'Game Over' status when the player runs off the track	O
Track the player's three longest times on the track in a high score table	O
Create a 3 button controller for the user to select and move their character	O
Map the object's physical location to the corresponding location in the game	-

Meets Requirement	Partially Meets Requirements	Does Not Meet Requirements
O	-	X

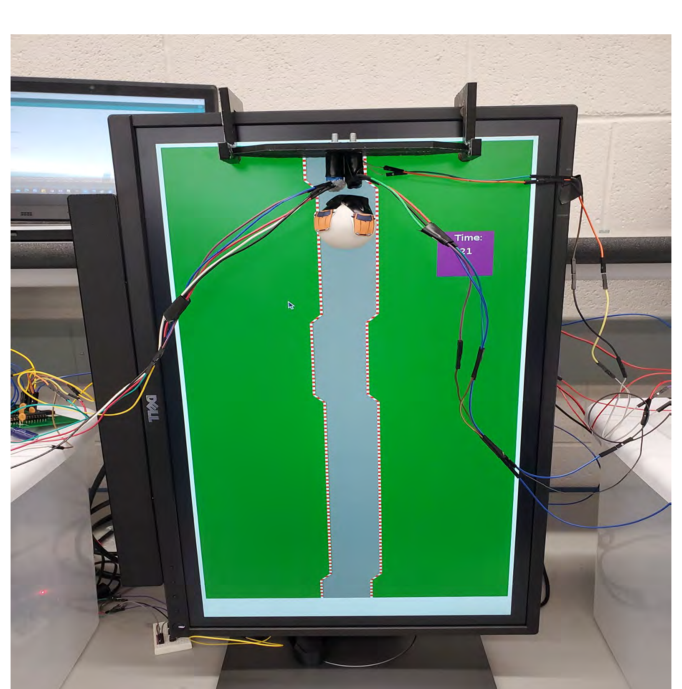


Figure 2: Final Racing Game

Analog Control Design

The magnetic control circuit include 5 main components:

- **Hall Effect Sensor** - determines vertical position of the object
- **Op-Amp Compensator** - uses feedback and a bias to create an error voltage
- **PWM** - provides a signal to the magnet driver
- **Inverter** - mirrors the PWM signal and scales the voltage to 5V
- **Magnet Driver** - provides current to the solenoid based on PWM duty cycle

To stabilize the magnetic levitation system, a type II compensator was designed. The compensator creates an error signal based on the Hall effect sensor output and the set bias voltage. The error voltage then maps to a PWM duty cycle.

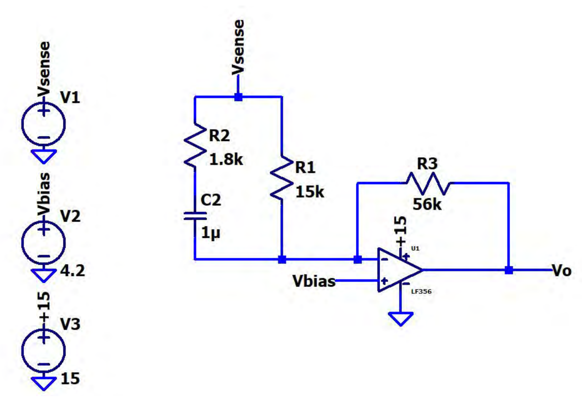


Figure 3: Analog Compensator Design

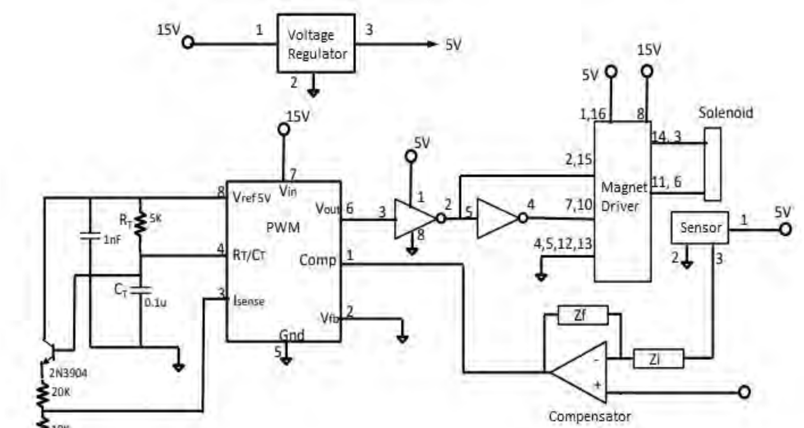


Figure 4: Analog Control Circuit [1]

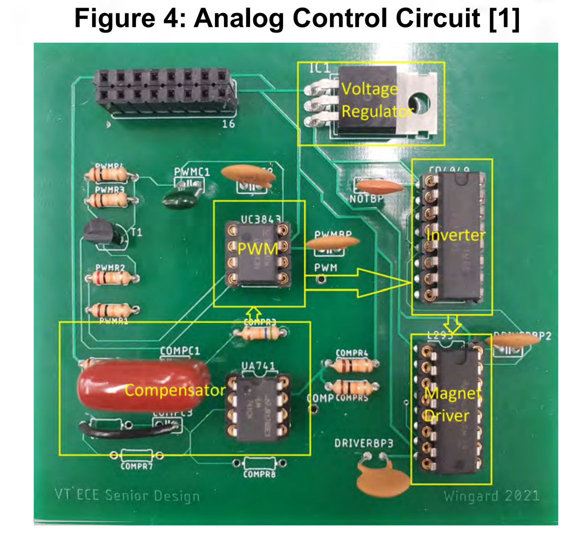


Figure 5: Analog Controller PCB

The design was tested on a breadboard, then translated to a PCB for the final product. Each magnet in the array is controlled by a single controller. To allow for user controls, the bias voltage of each controller was supplied by DACs (MCP4822) controlled by an Arduino Mega 2560. Click here to see the analog controller's tracking ability.

Digital Control Design

Transitioning to digital provides greater user control and allows for active changes to the controller during operation. The analog controller was translated into the z-domain with a sampling frequency of 4kHz. Using a bilateral z-transform, the controller was converted into the discrete time domain and implemented on an Arduino Mega 2560. The Arduino replaces both the compensator and the pwm ic from the analog circuit design. However, a second order low pass filter, shown in figure 6, was required to remove the noise and the 100Hz component of the hall effect sensor reading caused by the ADC sampling time. Currently, the digital controller is able to support indefinite levitation under two magnets. Click here to see the digital controller's tracking ability.

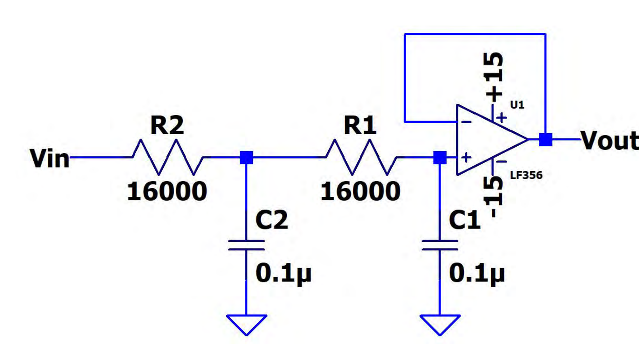


Figure 6: Second Order Low Pass Filter

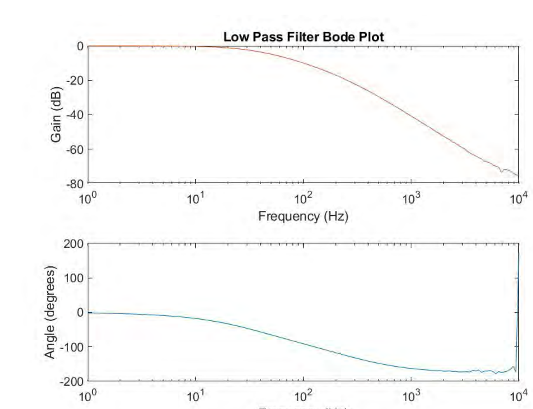


Figure 7: Low Pass Filter Bode Plot

Solenoid Holding Structure

- Several design iterations considered
- First design attempted to use hinge for balance
- Second design attempted with adjustable bolts
- Curved back of monitor made both prototypes fail

- Final design allows solenoids to overhand near the top of a computer monitor
- Screw solenoid core secured into horizontal slit
- Shape of structures fits perfectly to *Dell* monitor used
- Designed in *Solidworks* and fabricated using a 3D printer

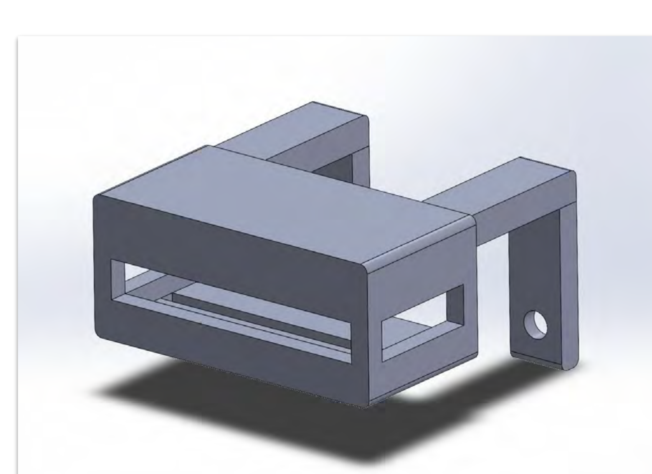


Figure 8: First Prototype Design

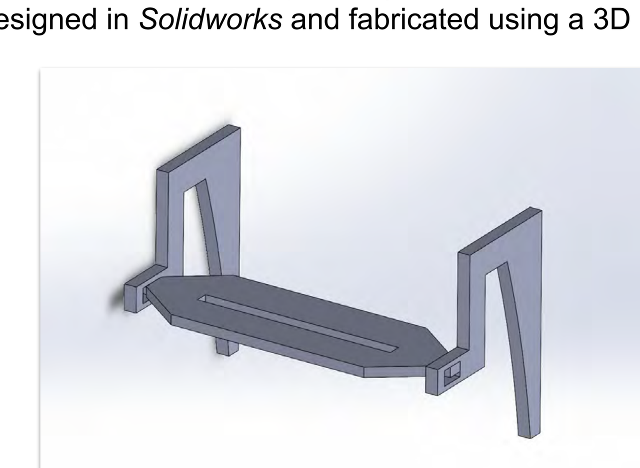


Figure 9: Final Design

Game Design

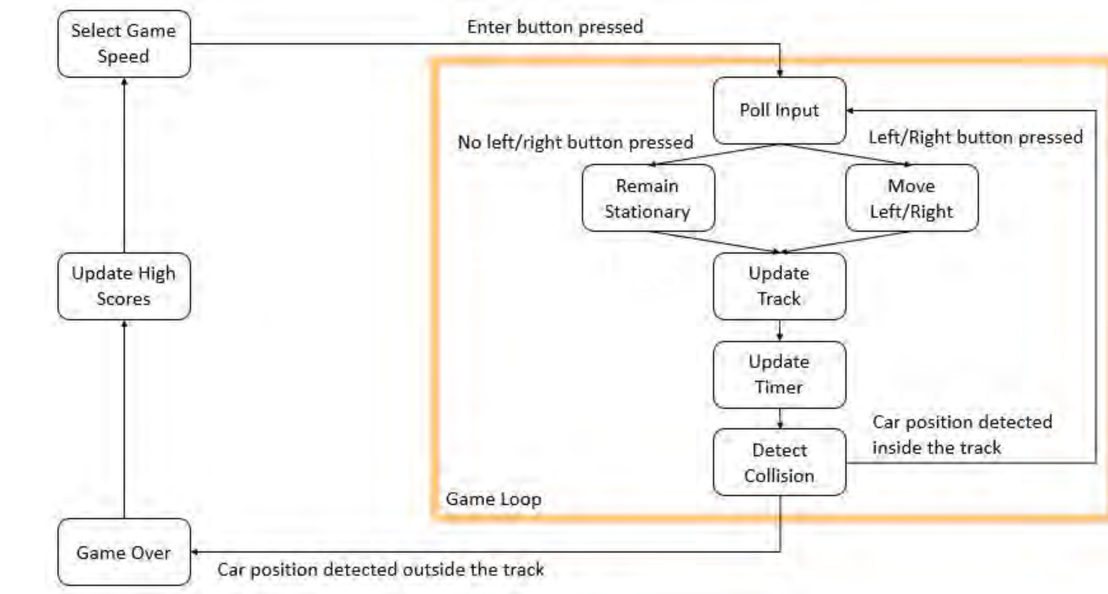


Figure 10: Game Loop Flow Chart

The game loop shown above, in figure 10, was implemented onto a raspberry pi with javascript. Javascript was chosen due to its built in canvas, making drawing the track easy. The raspberry pi took button inputs through the GPIO. Button inputs were mapped to keyboard presses using a python script and the uinport library. The mapped button inputs were handled by the game loop to move the character left and right and to make selections.

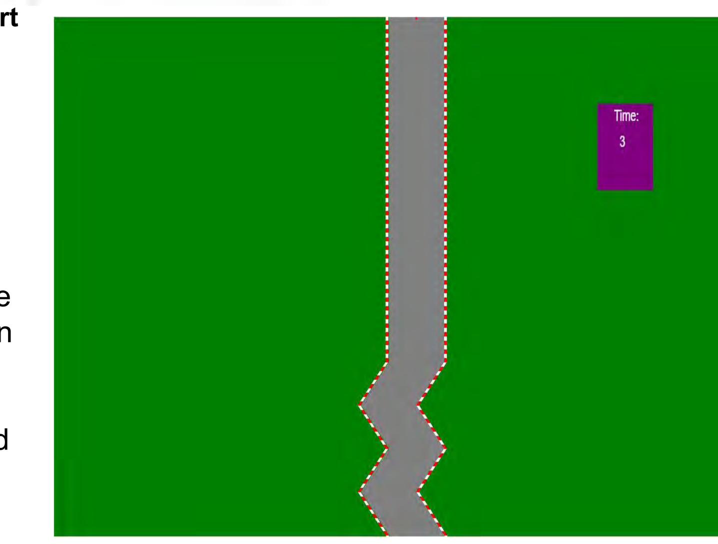


Figure 11: Screenshot of the Game Track

Demos

Scan this QR code using your phone to be linked to a video playlist of this project's test and development

Future Plans

In the future, the team would like to:

- Add a third magnet to the system
- Go fully digital with the magnet's control
- Use larger solenoids to transition to levitating a toy car

References

[1] D. Sable, "Mag Lev Project Intro," 09-Sep-2020

Acknowledgement

We would like to thank our customer, **Dr. Dan Sable,** and our SME, **Campbell Lowe,** from VPT for volunteering their time, talent, and funding to our project.

We would also like to thank our mentor **Dr. Scot Ransbottom** for coaching and encouraging us. Lastly, we thank the **Virginia Tech Electrical and Computer Engineering** department for providing us with equipment and a workspace for our project.

Magnetic Suspension System - Controlled Futuristic City Levitation

VIRGINIA TECH

Team Members: Josh Sutton, Ritwik Dutta, Yiren Zheng, Isabella Bartolome

Customer: Dr. Dan Sable **SME:** Robert Crnkovich, VPT Inc. **Mentor:** Dr. Scot Ransbottom

VPT

Introduction

The concept of levitation presents various potential opportunities benefiting different industries. Achieving levitation of objects has the potential to minimize structural wear over time by levitating certain mechanical structures that would cause friction otherwise, seen in Fig 1 [1]. This project's goal is to design, construct, and test a system that suspends an object in mid-air and moves it laterally using multiple electromagnets.

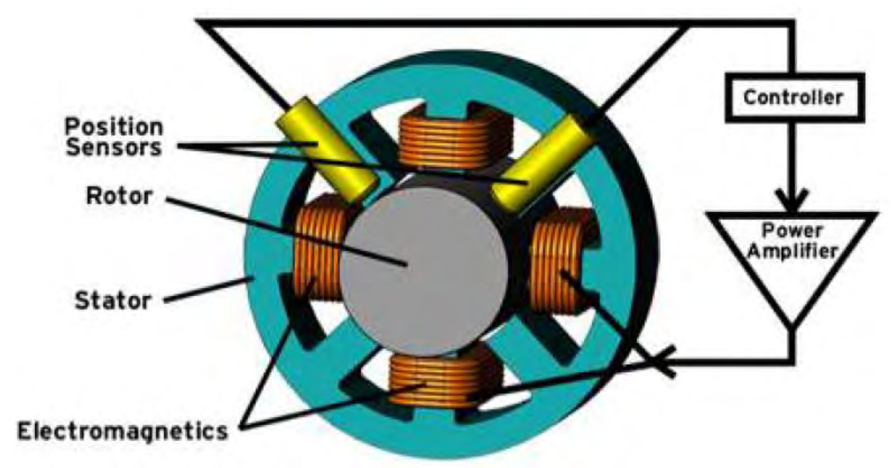


Fig 1: Magnetic bearing example showcasing use case of magnetic levitation [1]

Objective

The primary objective of this project is to construct a levitation control system that allows for a range of disturbances and acceptable inputs.

The list of our objectives include:

- Research and build a unique analog compensator design
- Develop a working printed circuit board (PCB) of analog system
- Achieve stable levitation using a microcontroller, Fig 2
- Demonstrate horizontal movement across an array of solenoids, Fig 3
- Implement a creative design and application for magnetic levitation

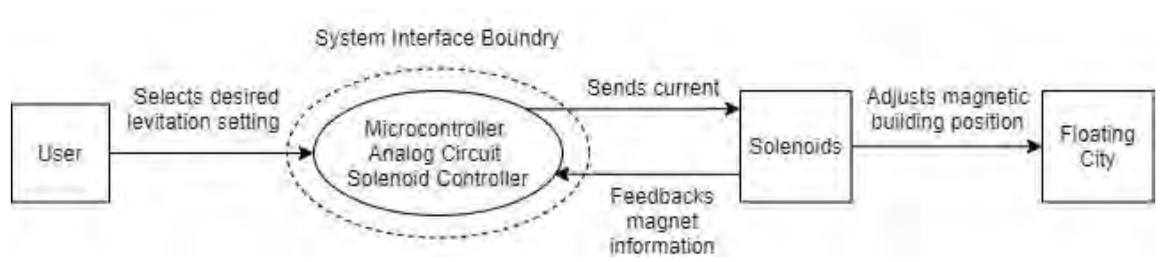


Fig 2: High level realization of microcontroller control design

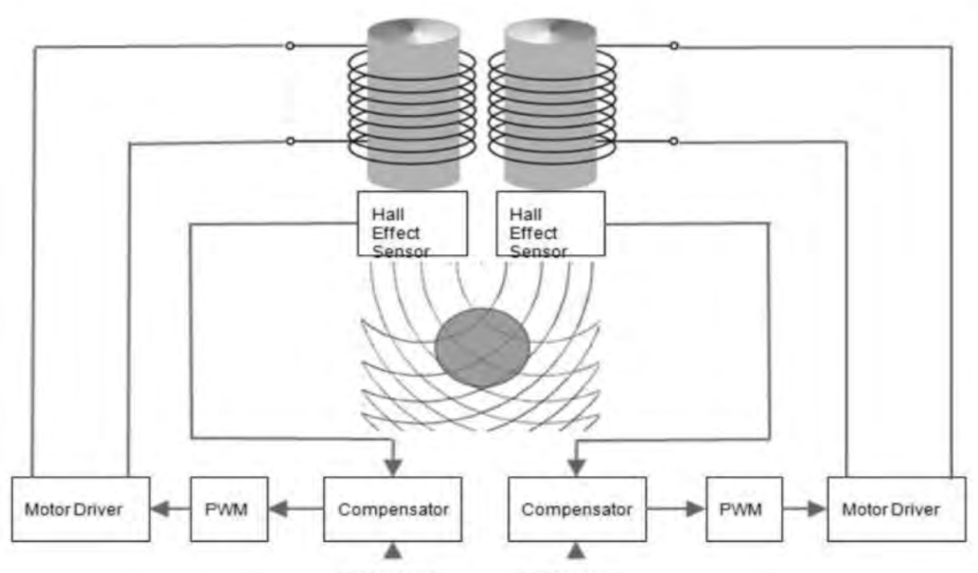


Fig 3: Horizontal movement design concept [2]

Methodology

Analog Control

Tackling these objectives begins with constructing a functional schematic basic analog design for magnetic levitation. Following the design provided by [2], a combination of a pulse-width-modulator (PWM), inverter chip, and a motor driver results in the designed schematic in Fig 4 with our own designed analog compensator lead-lag design.

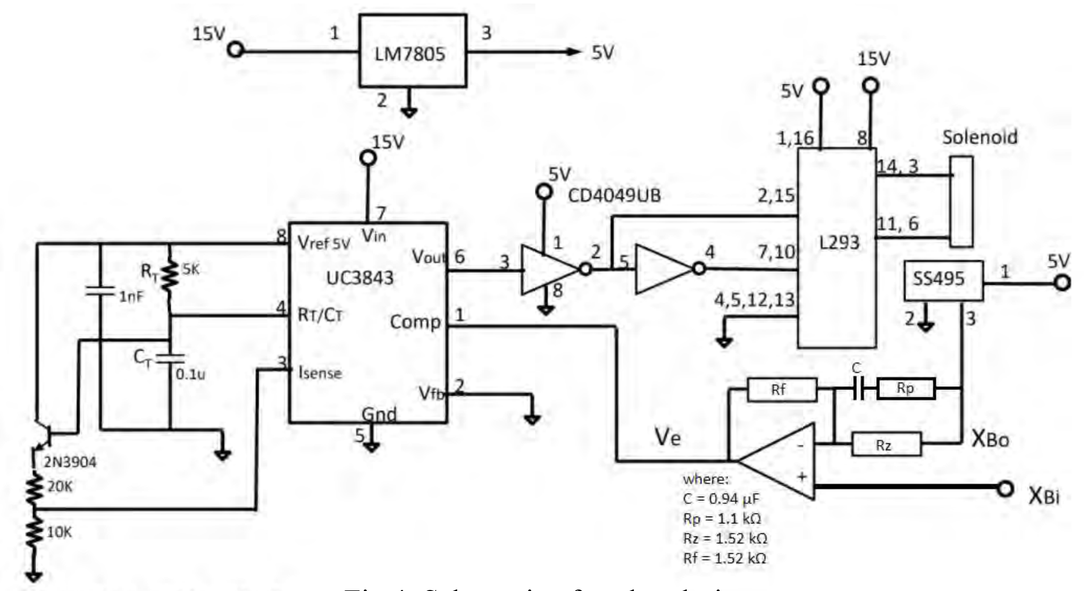


Fig 4: Schematic of analog design

By researching the levitation problem as the control of a naturally unstable system, our compensator for the above schematic was designed about controlling this theoretical unstable system. Fig 5 shows the found compensator step response compared with the theoretical response. Since the system could not achieve perfect 50% duty cycle levitation, fluctuation in the measured step response occurred. The similarities between our circuit and simulation demonstrates an understanding of the unknown plant system dynamics our designed control system achieves to levitate.

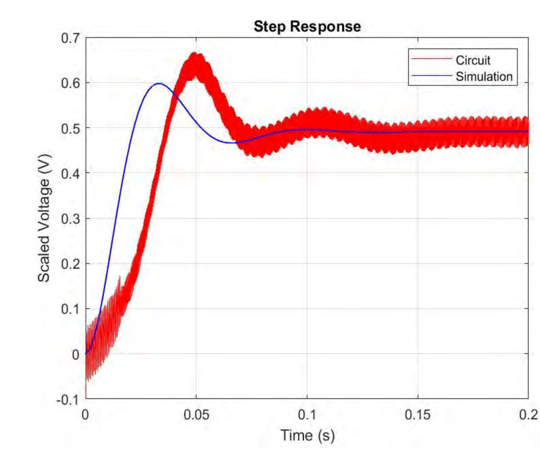


Fig 5: Step response comparison

Printed Circuit Board (PCB) Design

The board design seen in Fig 6 is a single PCB that controls two solenoids simultaneously. The two layouts have essentially the same components, including a PWM chip, op-amp, and motor controller. Each layout has its own unique compensator design that controls its corresponding solenoid to achieve magnetic levitation. The PCB is powered by a 15V external power supply and a voltage regulator that outputs 5V to power some of the components, including the inverter chip and hall effect sensor.

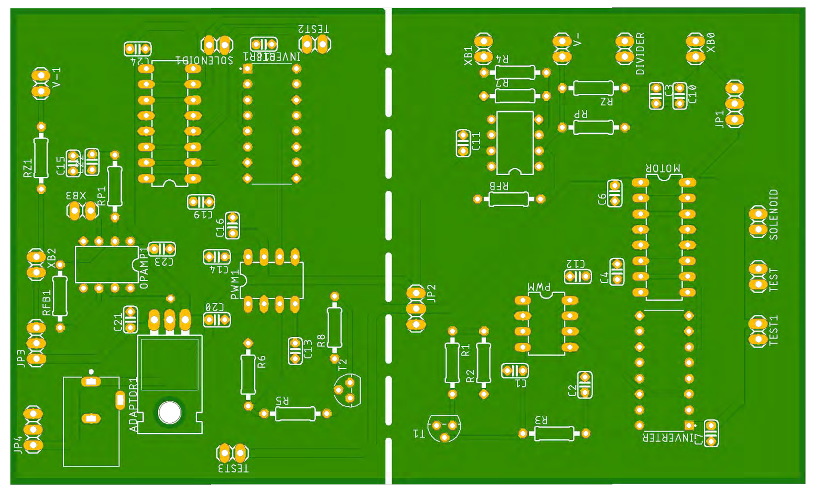


Fig 6: Two solenoid single PCB board

Digital Control

With a stable continuous control system design, the digital control system was based of the discrete time transformation. By using MATLAB to take the Tustin bilinear transform, Fig 7 shows the conversion of continuous to discrete to the implemented microcontroller difference equation.

$$\frac{s + 70}{s + 980} \rightarrow \frac{12.58z - 12.36}{z - 0.7817} \rightarrow y_k = 0.7817y_{k-1} + 12.5813u_k - 12.363u_{k-1}$$

Fig 7: Transforming our compensator design into microcontroller difference equation

Our team used the Arduino Mega to act as our digital controller, as it has a 16 MHz clock speed, 10-bit ADC, and can measure voltages from 0V to 5V. An interrupt service routine (ISR) for ADC sampling was implemented to regulate the sampling frequency at 4 kHz. With the known sampling rate, the Nyquist frequency of 2 kHz was used in designing a second order low pass anti-alias filter to filter out high-frequency noise, Fig 8. By implementing these features and adjusting the PWM output to center at 50% duty cycle, Fig 9 demonstrates digital control levitation following similar characteristics as the analog control.

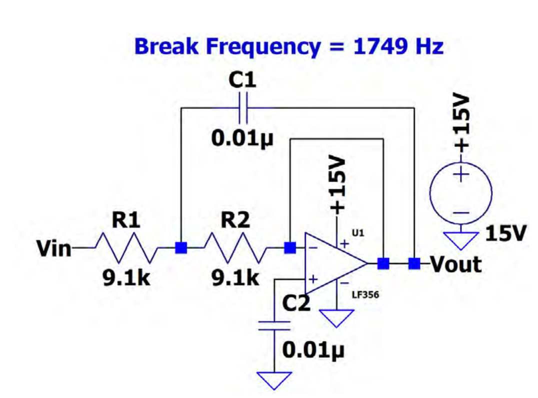


Fig 8: Anti-aliasing filter design

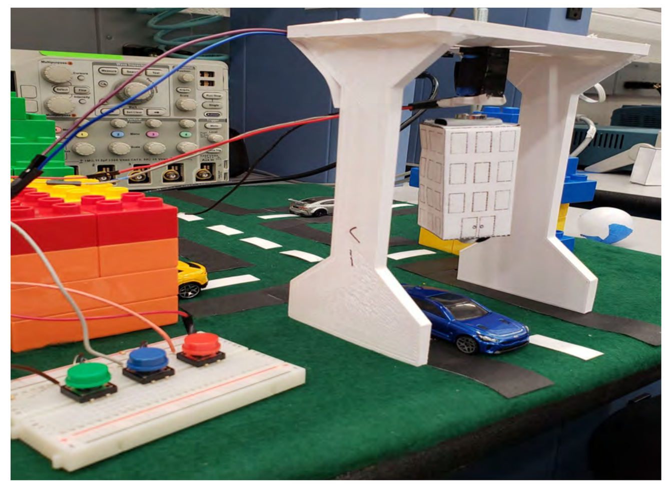


Fig 9: Levitation using Arduino Mega

Horizontal Movement

To achieve horizontal movement, the system first needs to be stabilized with an appropriate reference voltage. Two sine waves with a frequency of 500 mHz and a phase shift of 180 degrees, an amplitude of a couple hundred millivolts, and a reference voltage value to power the two individual systems. After a few minor adjustments with the amplitude, the magnet can be seen traversing in the horizontal direction as seen in Fig 11. Implementation of more than two solenoids can be done using the same method and technique with the phase shift being 360 divided by the number of solenoids.

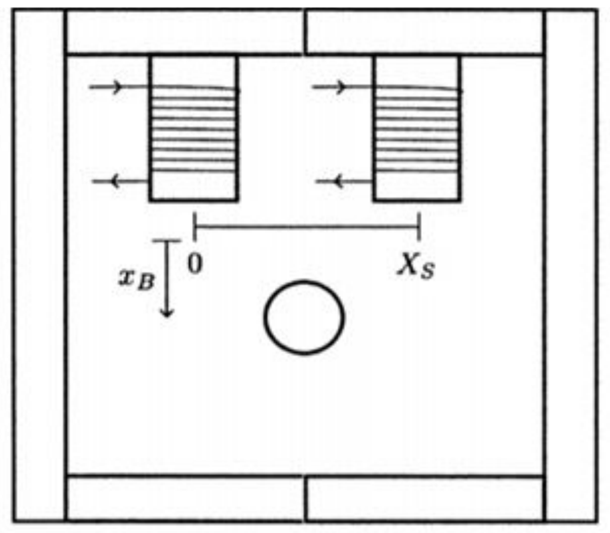


Fig 10: Setup of a two-solenoid system [3]

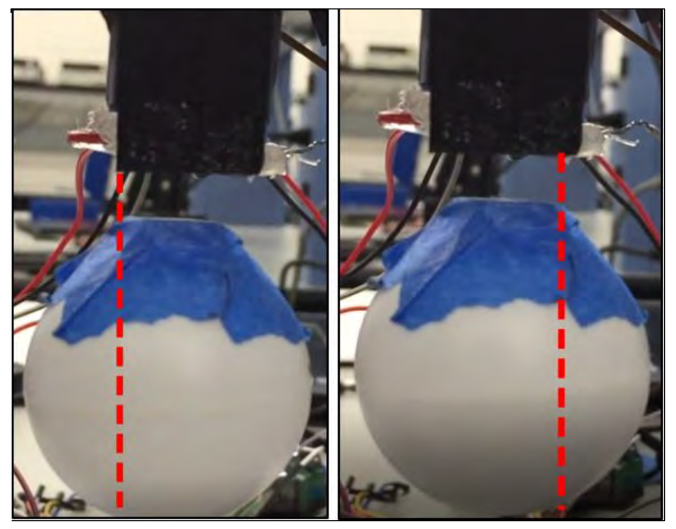


Fig 11: Horizontal movement of a two-solenoid system using analog circuit theory

Results & Conclusion

Objectives:	Analog Control			Digital Control		
Modes:	Voltage Offset	Amplitude	Frequency	Voltage Offset	Amplitude	Frequency
Disturbance Rejection	3.63 V	N/A	N/A	4.01 V	N/A	N/A
Sine Wave	3.59 V	100 mV	1 Hz	3.91 V	200 mV	0.5 Hz
Square Wave	3.61 V	80 mV	0.5 Hz	3.91 V	200 mV	1 Hz
Horizontal Movement	3.40 V	200 mV	0.5 Hz	N/A	N/A	N/A

Our team's final product is a futuristic city that showcases the various functionalities of our magnetic levitation system. The platform is designed as a standard neighborhood with houses and streets and three separate 3D-printed housing systems levitating paper crafted buildings, Fig 12. The first housing system showcases digital control levitation, with push buttons for the user to adjust the magnet position. The second system demonstrates basic magnetic levitation behavior with sinusoidal and square wave responses. The third system features our two-solenoid horizontal movement. Videos of our system can be viewed using the QR-code in Fig 13.

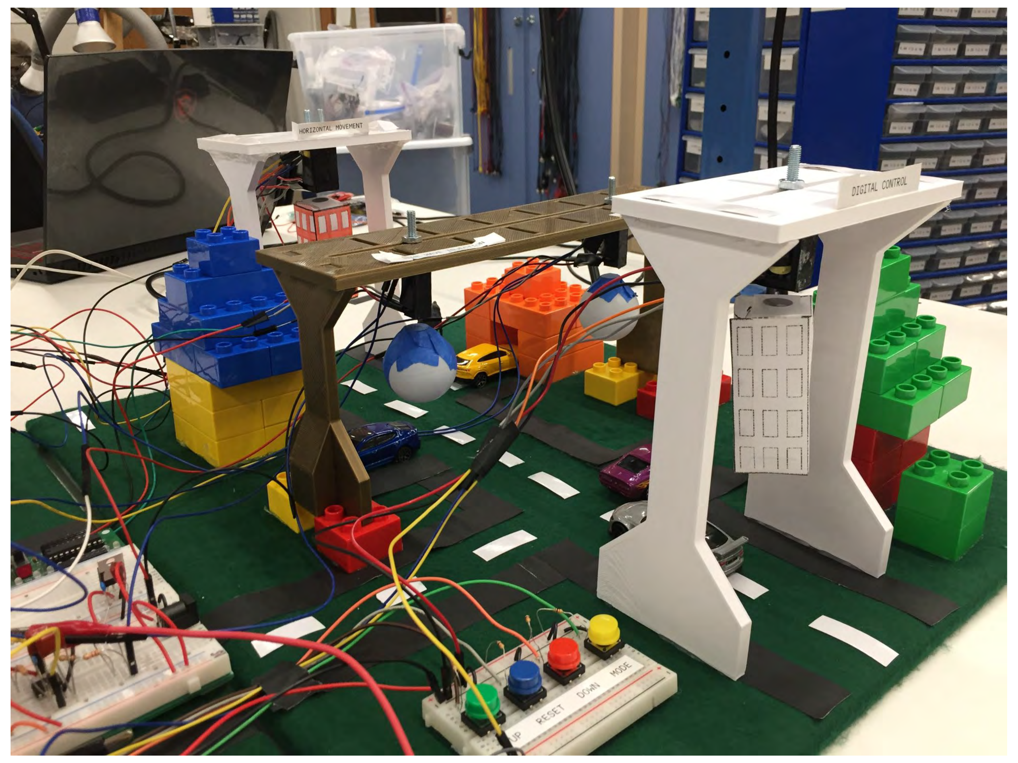


Fig 12: Levitating city model showcasing each stage of our progress over a city

Fig 13: Videos of our system

Through the past two semesters, our team has achieved stable magnetic levitation using both analog and digital controls. Though we were unable to accomplish our initial goal for five-solenoid horizontal movement and joystick control, we were able to focus our efforts in developing more robust levitation systems using the Arduino Mega for digital control and by ensuring the durability of our printed circuit boards and two-solenoid horizontal movement configuration.

Acknowledgments

Special thanks to Robert Crnkovich, Dr. Dan Sable, and VPT Inc. for their sponsorship and for guiding our efforts in the development of our final product. Further thanks to Dr. Steve Southward from the Virginia Tech Mechanical Engineering Department for assistance with the digital control.

References

[1] A. Nayak, M. Tech, and Subudhi, "Controller Design for Magnetic Levitation System A Thesis Submitted in Partial Fulfillment Of the Requirements for the Degree Of Control and Automation," 2013. Accessed: Mar. 26, 2021. [Online]. Available: http://ethesis.nitrkl.ac.in/7418/1/2015_Controler_Nayak.pdf

[2] 2020. *ECE 4805 Major Design Experience Magnetic Levitation Project*.

[3] P. Hlebowitsh, "The Road to Multi-Dimensional Magnetic Levitation: Realizing Two-Dimensional Control in Classical Feedback," 2012. Accessed: Mar. 26, 2021. [Online]. Available: https://dspace.mit.edu/bitstream/handle/1721.1/77014/825767394-MIT.pdf?sequence=2.

Semiconductor Feature Prediction via Machine Learning

Team Members: J. Berger IV, N. Dyben, K. Franz, P. Kuzio III, Y. Wang
Customer: Y. Zhang **SME:** Y. Yi **Mentor:** S. Ha **GTAs:** B. Wang, F. Nowshin, K. Bai

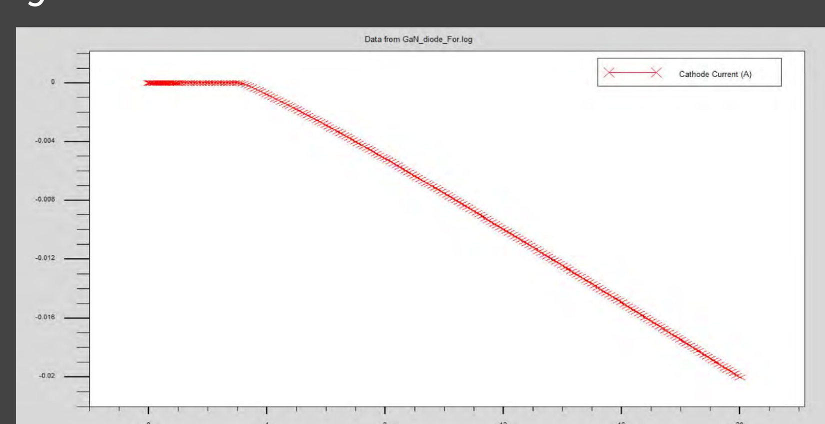
SMaL Think Fast! Semiconductor Design from Machine Learning Technologies

Motivations

- Modern technologies are rely on semiconductor devices
- Current simulation methods are slow and resource intensive
- How can we improve these methods with machine learning?

Objectives

- Use machine learning to create faster and less expensive simulation tools
- Create a network or series of networks that can:
  - Predict characteristic IV curves accurately and quickly
  - Predict the doping concentration from IV curves generated by those networks via some deep learning algorithm

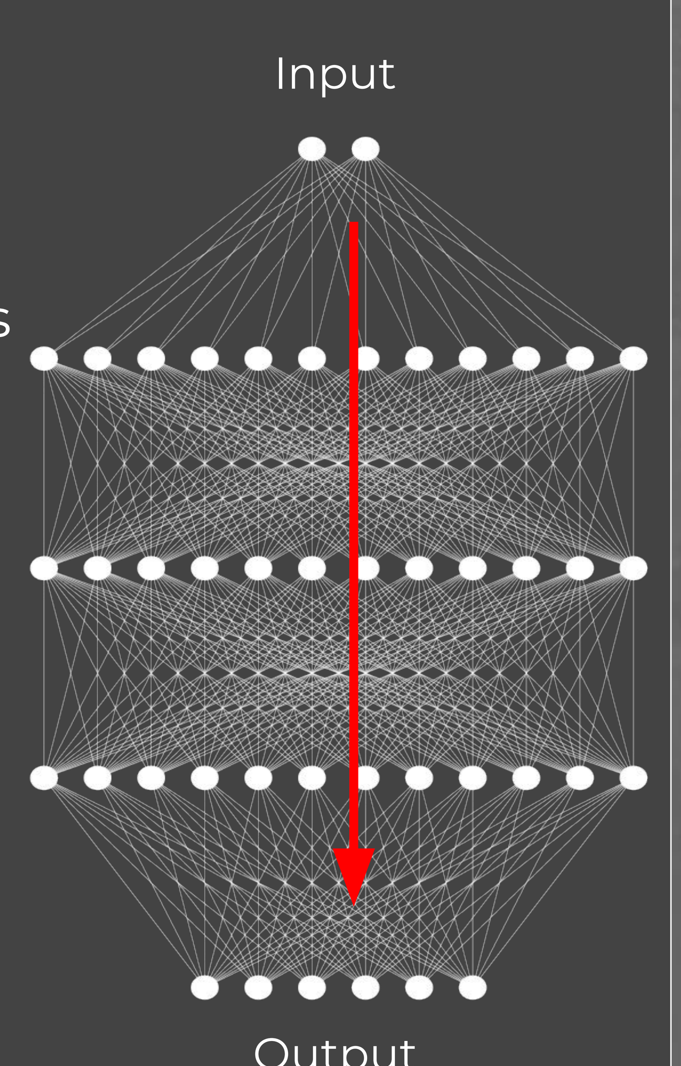


Design Procedure

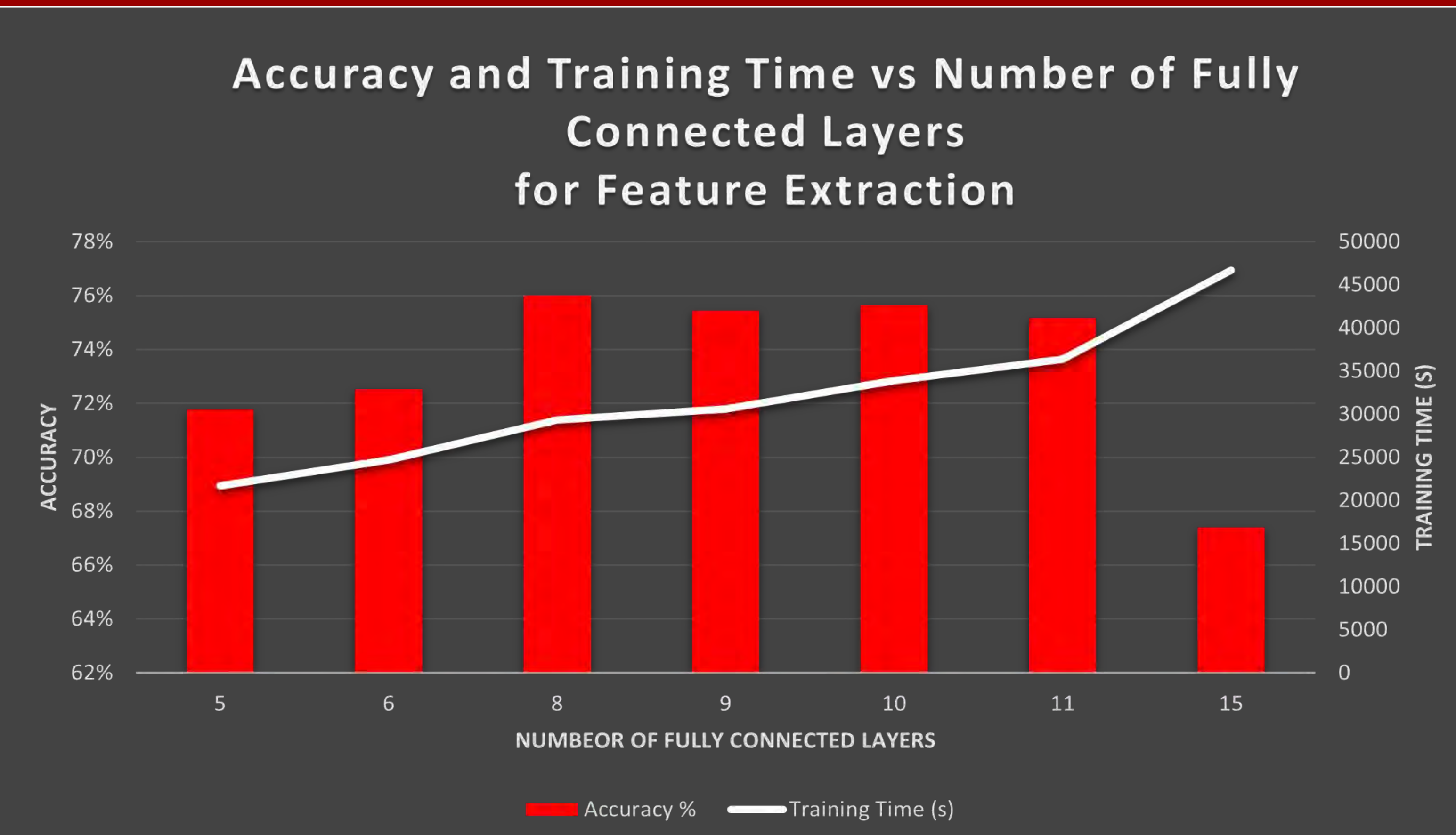
- Create a series of networks to be trained on Silvaco simulation data
- Create training data with physical simulation code
- Use a solver to lower the Mean Square Error that creates the loss function

$$MSE = \frac{\sum_{i=1}^{n}(y_i - \hat{y_i})^2}{n}$$

- Iterate over number of networks, type of data to be trained on, and connection structure between networks until finding most effective network architecture



Training and Tests



- Tested to find tradeoff between accuracy and training time
- Determine ideal number of layers for networks designs

Networks I & II For IV Curve Prediction

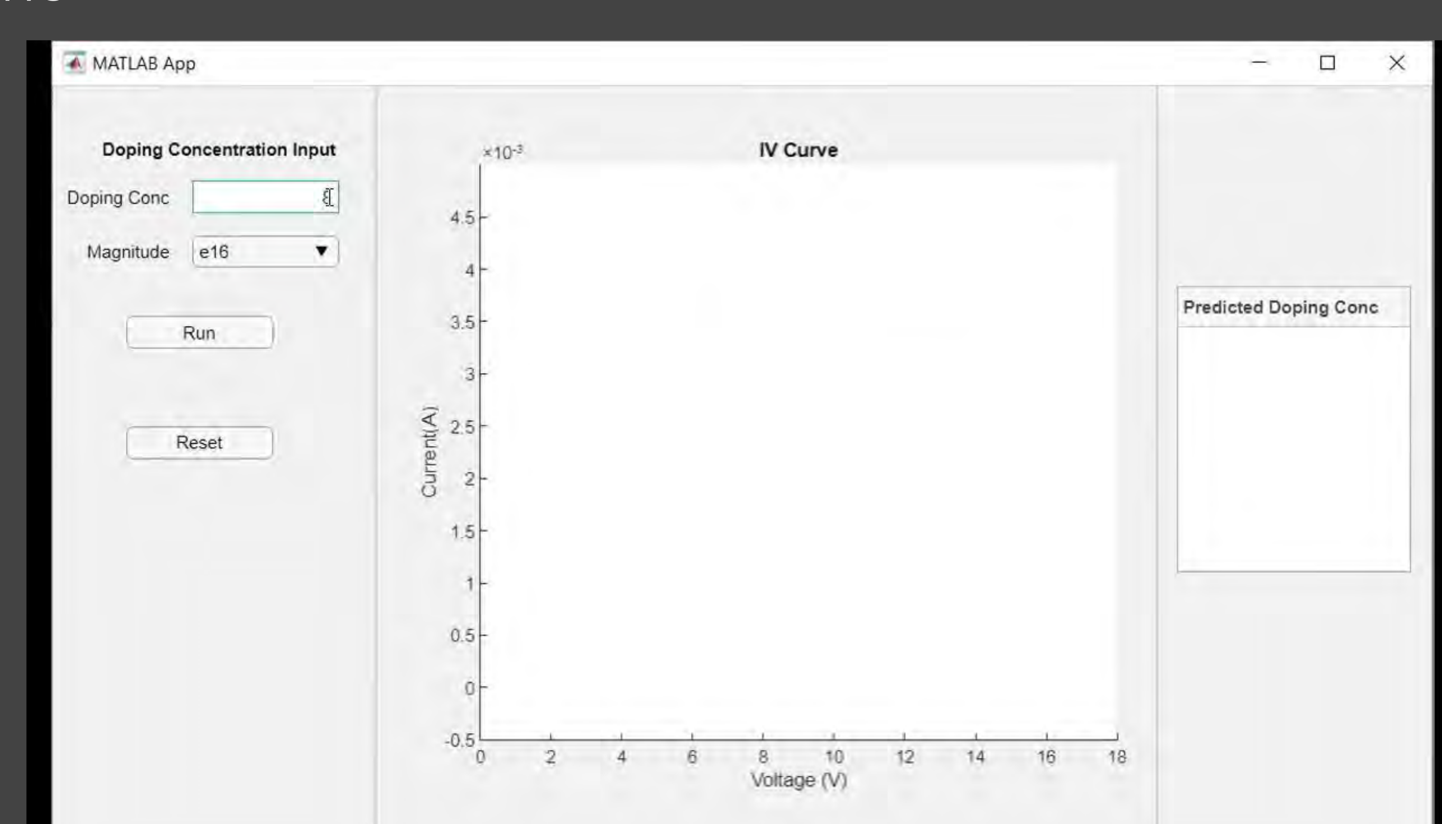
Input Layer
↓
Fully Connected (256) Layer
↓
reLu Layer — Repeated 8x
↓
Softmax Layer
↓
Classification Layer

Networks I - V For Feature Extraction

Input Layer
↓
Fully Connected (256) Layer
↓
reLu Layer — Repeated 10x
↓
Softmax Layer
↓
Classification Layer

Results

- Silvaco - **90 second (avg)** IV curve generation time
- FFN - **0.213 second (avg)** - 400x faster IV curve generation time



Challenges

- Provide high-quality work on a novel subject matter
- for the team
  - **Learned** from research and experience how to work with and understand machine learning tools
- Compare network designs between a deep reservoir Echo State Network and a deep Feed Forward Network
  - Successfully replicated physical simulation performance with an FFN, which **outperformed** the ESN
- Work in an environment that necessitates remote collaboration
  - Held meetings with teammates over Zoom and managed code via a team Github

Analysis and Conclusions

- **IV Curve Prediction:**
  - High accuracy (>85%)
  - Any errors within reasonable boundaries
  - Produced results 400x faster than Silvaco
- **Feature Extraction:**
  - Similar architecture to IV Curve Prediction
  - Acceptable accuracy (~75%)
  - Mixed performance, especially for the GUI
  - Produces results between 5-10 seconds
- **Echo State Network Alternative Comparison:**
  - Did not yield results comparable to FFN

Future Plans

- Further develop the GUI for the Project
- Increase Accuracy of FFNs by adding additional data
- Increase the number of Features used to predict the IV curve
- Increase the resolution of figures produced by the software

Acknowledgements

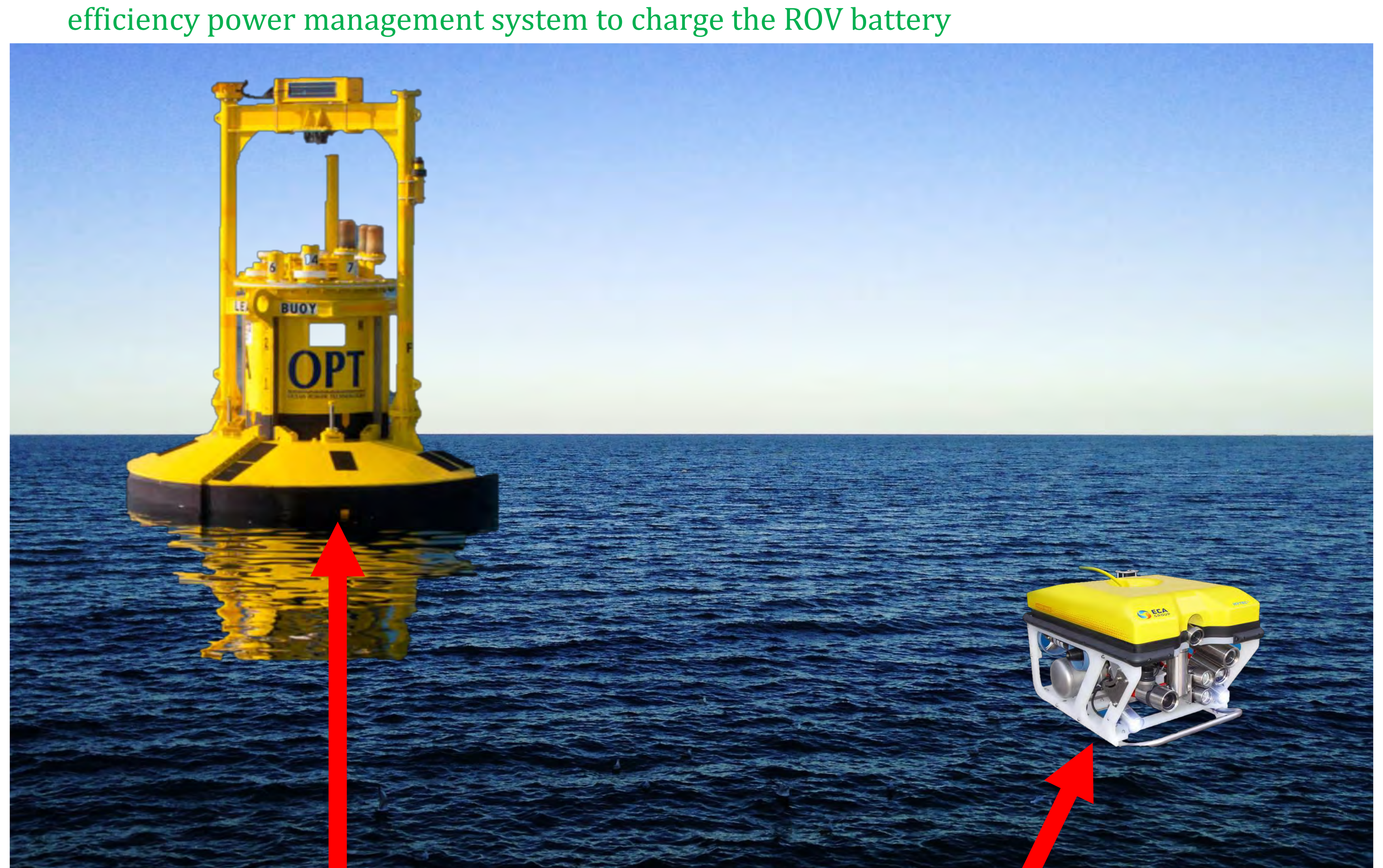
- **The team would like to thank:**
  - Prof. Cindy Yi and Prof. Yuhao Zhang of Virginia Tech for their technical expertise
  - Prof. Sook Ha of Virginia Tech for her mentoring to help keep the project on track

Power Management System for a Wave Energy Converter

Danielle Lester, Joseph Lin, Russell Lutge, Qiaosheng Zhang, Jayesh Mohite
Sponsor: Dr. Lei Zuo, Virginia Tech Center for Energy Harvesting Materials and Systems

MOTIVATION

- Ocean observing allows us to detect hurricanes, collect water samples, and monitor ocean habitats
- Battery life is greatest limitation to ocean missions; ROV's cannot venture far from shore
- Wave energy can be used as renewable energy source to increase these missions, we need an efficiency power management system to charge the ROV battery



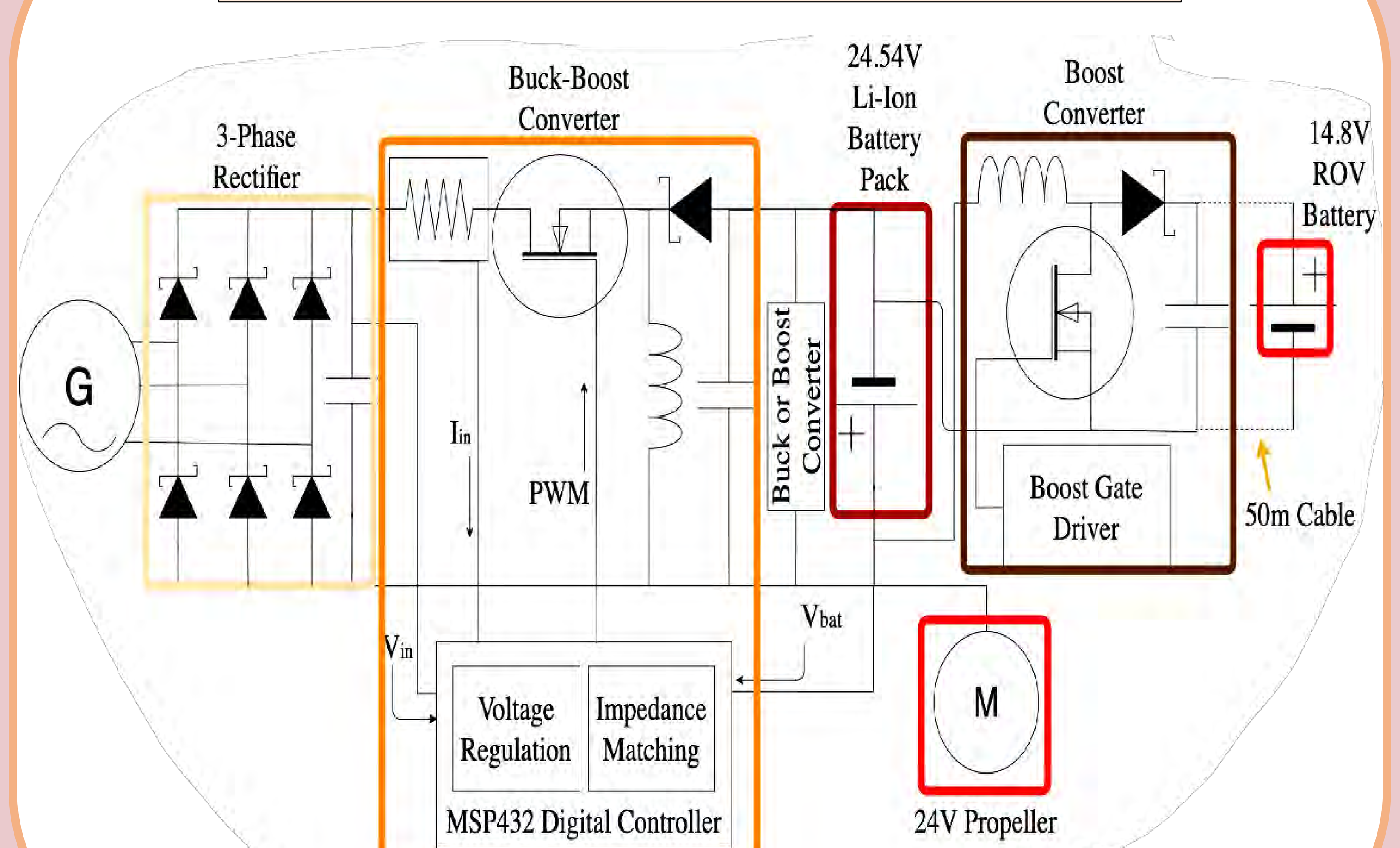
Wave Energy Converter with Power Management System

Remotely Operated Vehicle (ROV)

OBJECTIVES

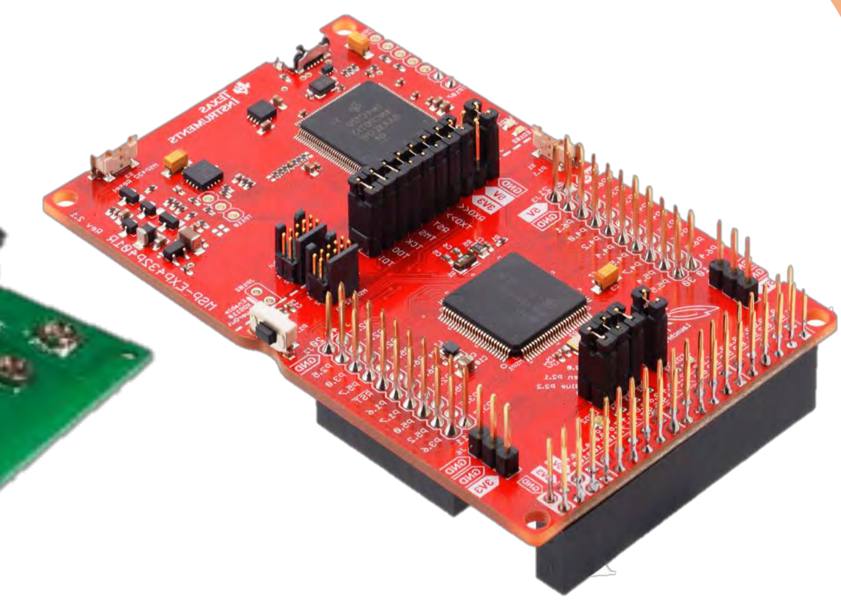
Convert AC to DC	3 Phase Passive Rectifier
Safely Charge Battery at Constant Voltage With Max Power	Buck/Boost Converter with MCU Impedance Matching
Power Propellers to Move Buoy and Charge ROV Battery	Lithium-Ion Battery With Boost Converter

PROPOSED CIRCUIT SOLUTION



HARDWARE

3 Phase Passive Rectifier PCB

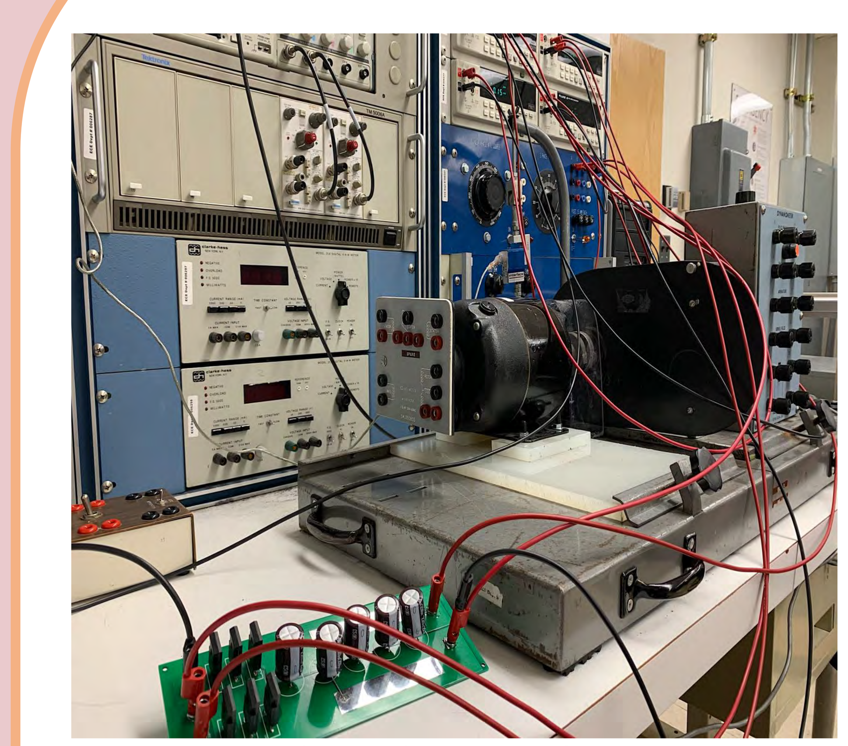


Buck-Boost Microcontroller MSP432

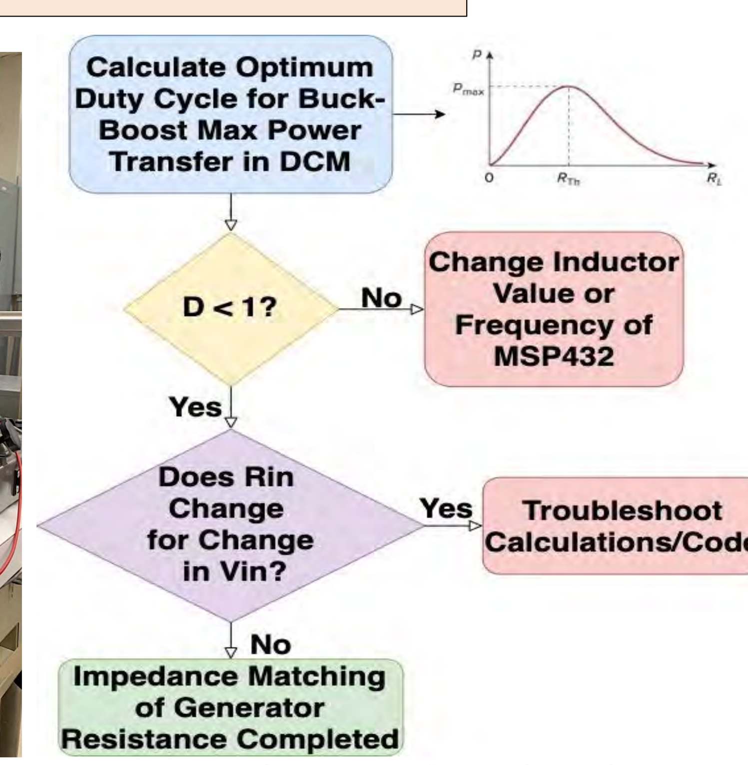
Buck-Boost Converter PCB

Boost Converter PCB

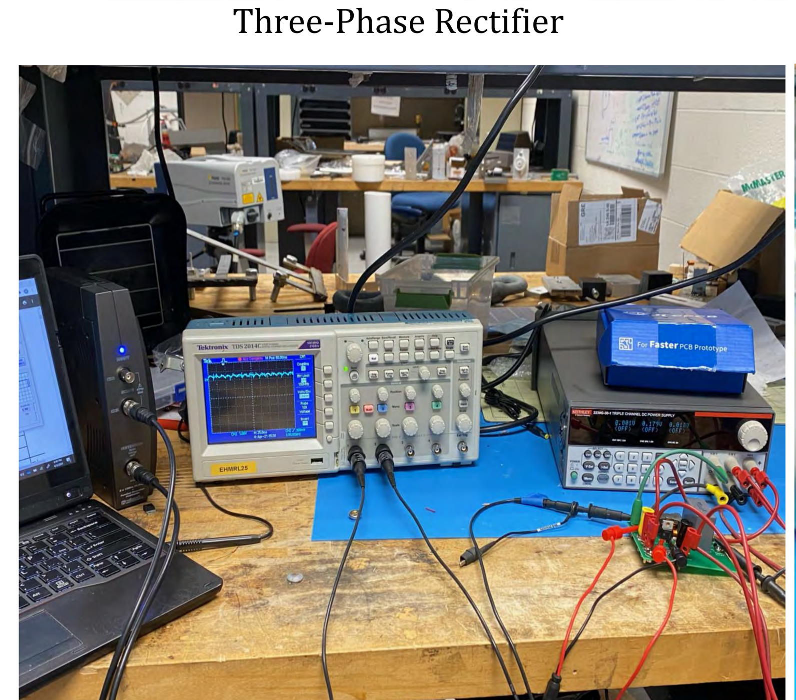
TESTING SET UP



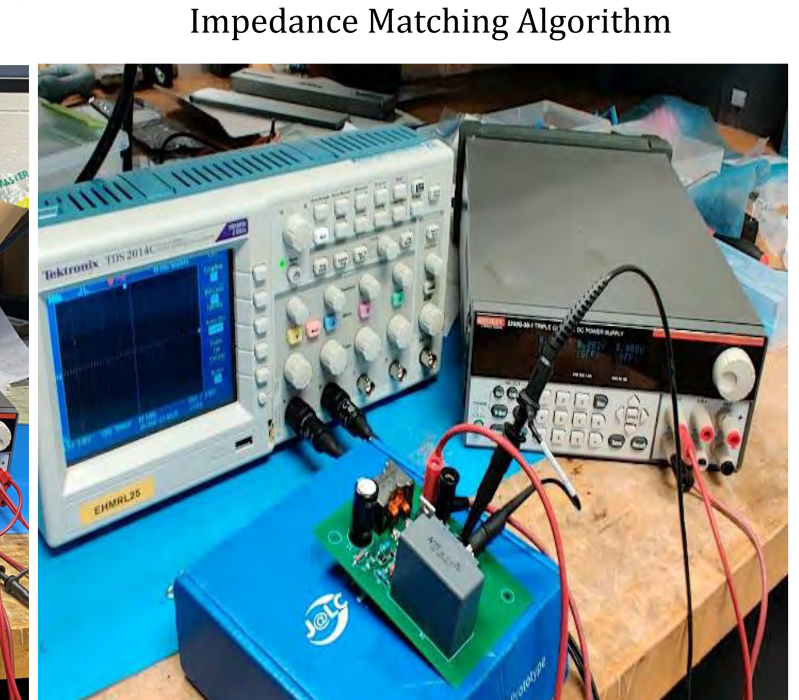
Three-Phase Rectifier



Impedance Matching Algorithm

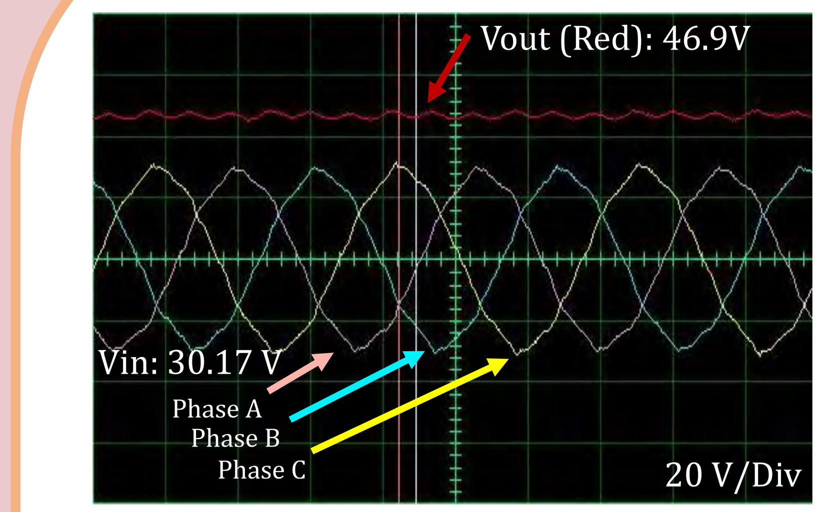


Buck-Boost Converter

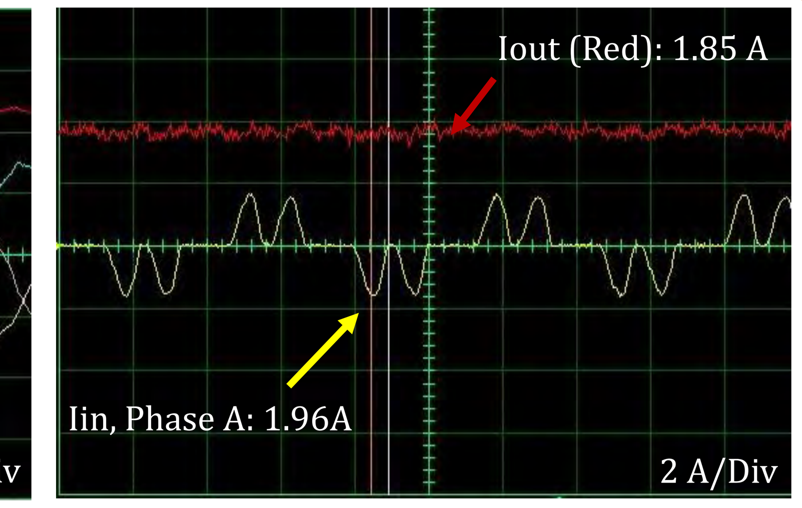


Boost Converter

RESULTS



Rectifier Voltage Scope Measurements



Rectifier Current Scope Measurements

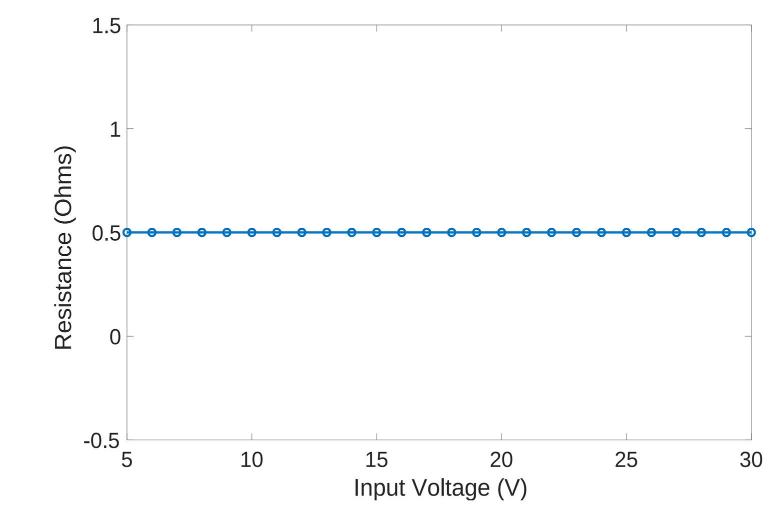
$$L = 6.2uH \quad R_{in,target} = .5\Omega$$

$$R_{load,battery} = 3\Omega \quad T_{MSP432} = \frac{1}{10{,}000}s$$

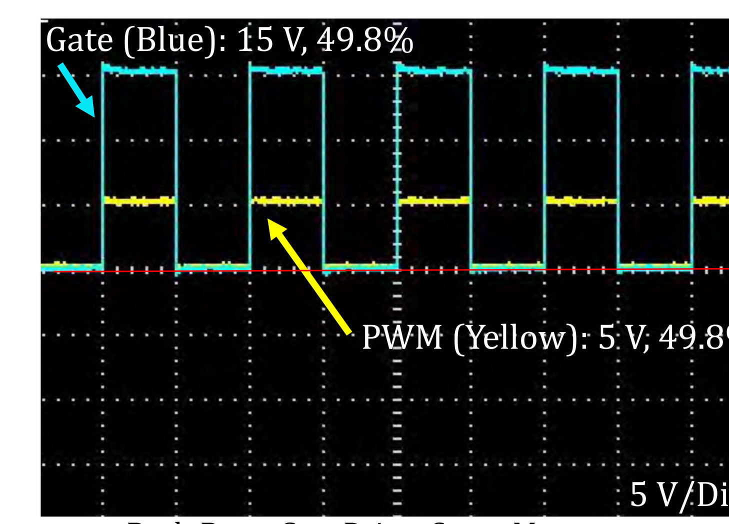
$$D_{optimal} = \sqrt{\frac{2L}{R_{in,target}T_{MSP432}}} = \sqrt{\frac{2*6.2uH}{.5*100us}}$$

$$D_{optimal} = .4980 = 49.8\,\%$$

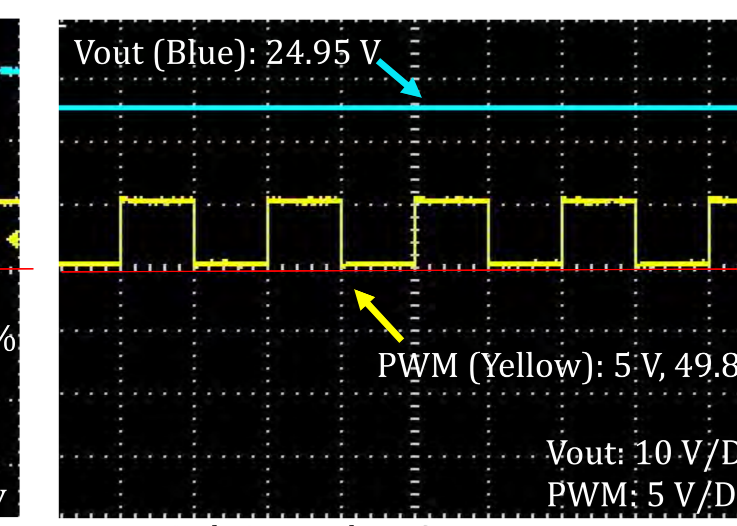
Buck-Boost DCM Max Power Transfer Calculations



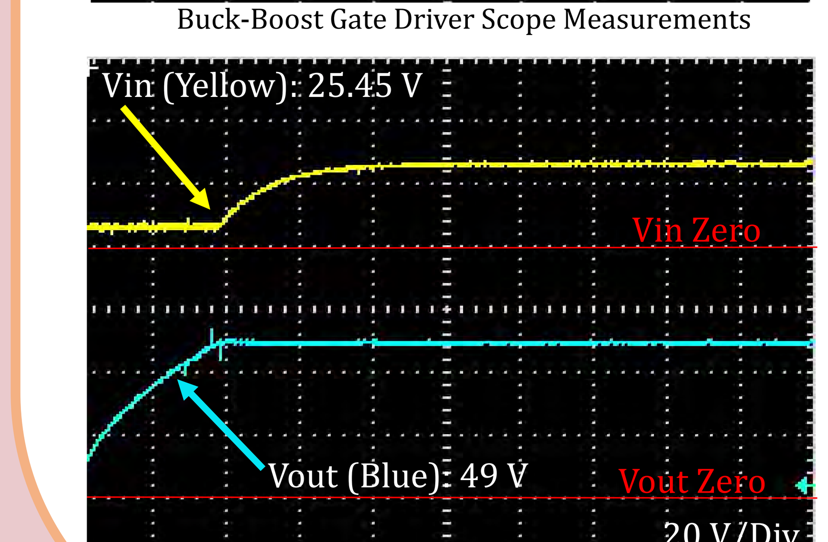
Input Voltage vs. Calculated Impedance Matching Resistance



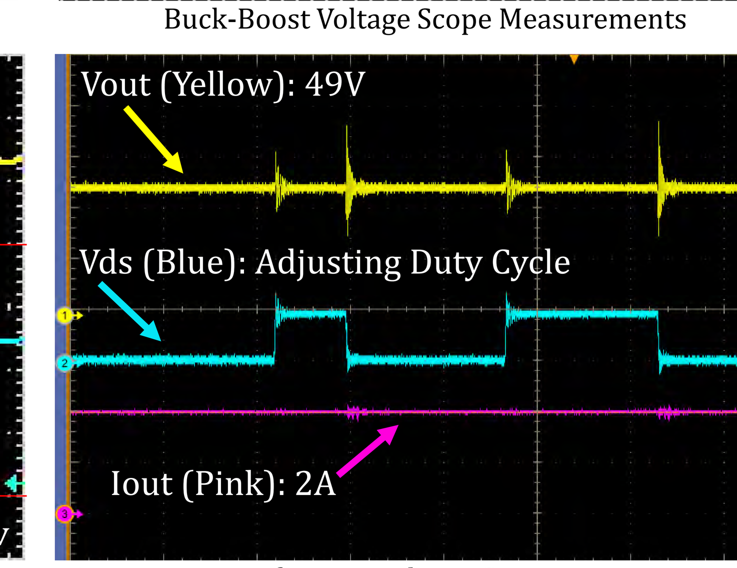
Buck-Boost Gate Driver Scope Measurements



Buck-Boost Voltage Scope Measurements



Boost Voltage Scope Measurements



Boost Vout, Mosfet V_{DS}, and Iout Scope Measurements

CONCLUSION

Please feel free to watch this short video of the testing setup we used to achieve all our objectives of converting AC to DC voltage, safely charging a battery, and boosting the battery voltage to power the propellers and ROV on the wave energy converter.

ACKNOWLEDGMENTS

We would like to thank Dr. Zuo, Professor Schulz, Minh Ngo, and the Virginia Tech Electrical Engineering Department for the funding and support of this project

Design of a Wireless Charging System for an Autonomous Vehicle Application

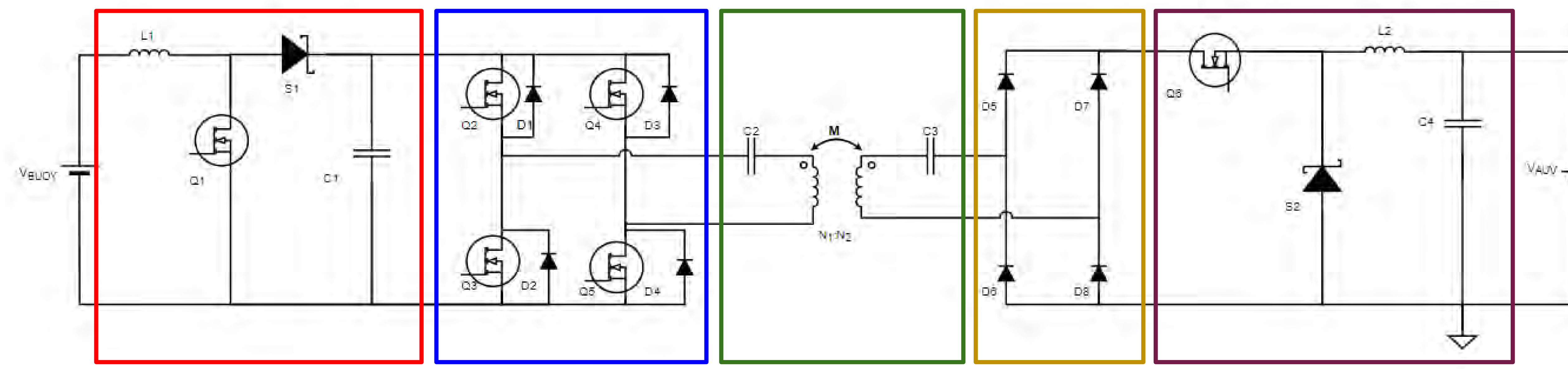
Team Members: Benjamin Alden, Andrew Guthrie, Alex Kim, Christian Sponseller, Nick Squitieri
Mentor: Prof. Kenneth Schulz
Customer: Dr. Lei Zuo
SME: Minh Ngo

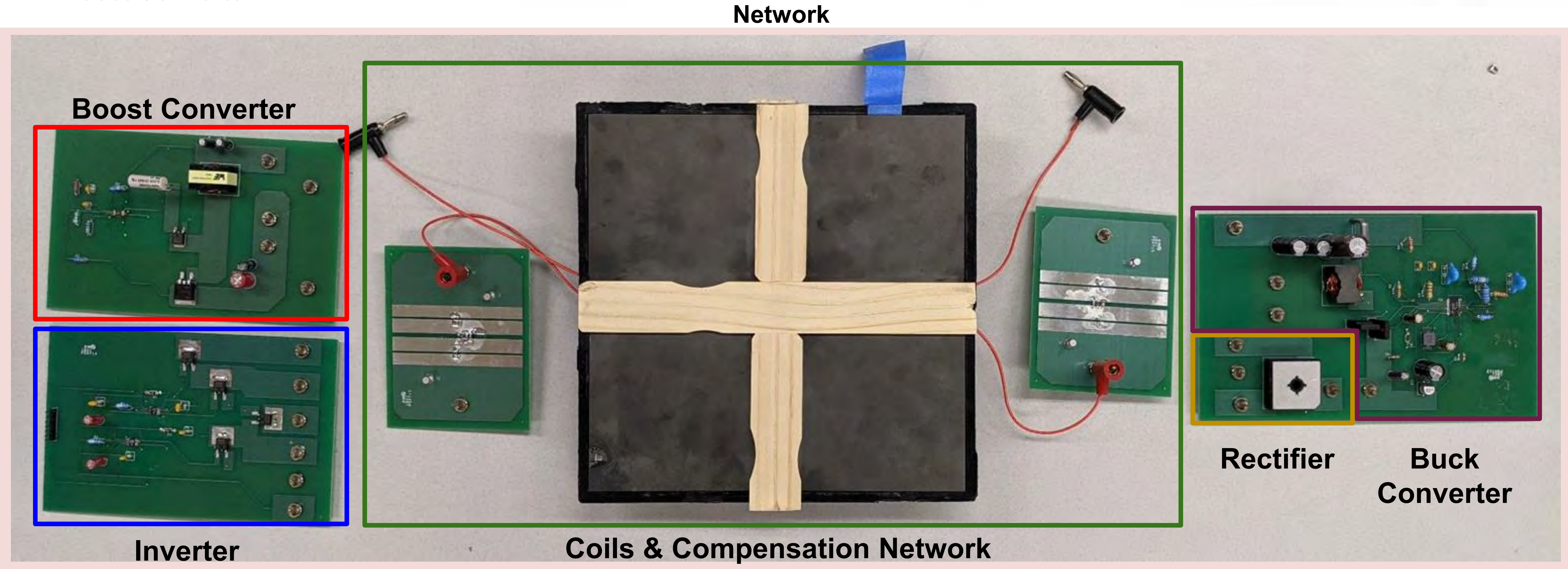
Introduction

Autonomous Vehicles (AVs) are often deployed in remote environments for monitoring applications. Re-charging the battery usually requires bringing in the vehicle which is cost and labor intensive. The proposed solution is to design a wireless charging system which allows an autonomous vehicle to remain in the field while charging at a docking station, thus extending the mission duration, and reducing operating cost. The proposed solution is to design a wireless charging system which allows an autonomous vehicle to remain in the field while charging at a docking station, thus extending the mission duration and reduce operating cost. The wireless charging system will include a boost converter, full bridge converter, wireless charging coils, coil compensation network, and a battery charging buck converter. The requirements of the system include:

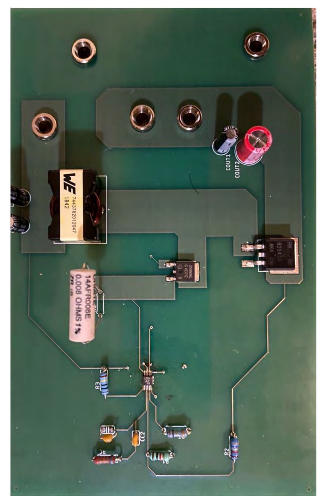
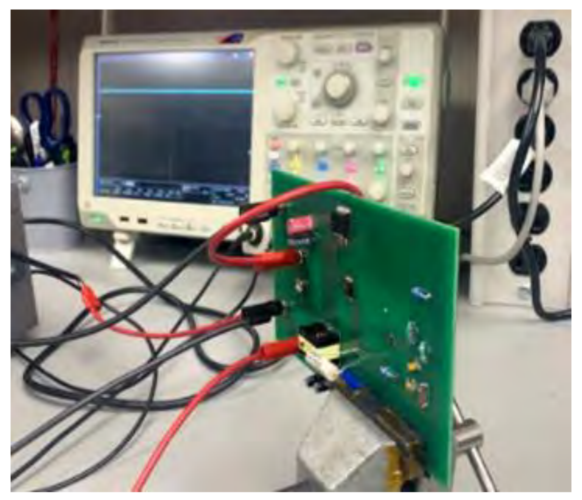
System Specifications

Vin	Vout	Power Rating	Freq
14-48V	24-48V	500 W	300 kHz



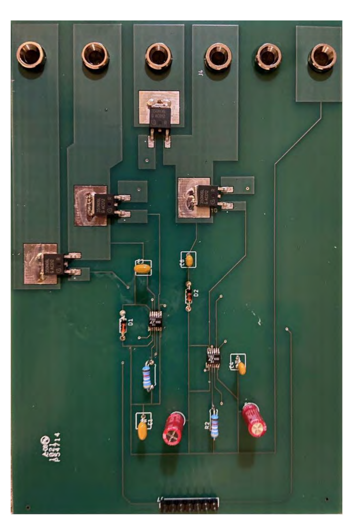
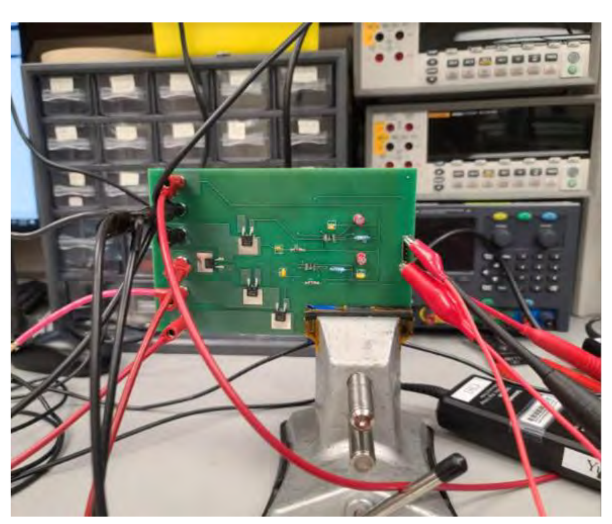


Boost Converter

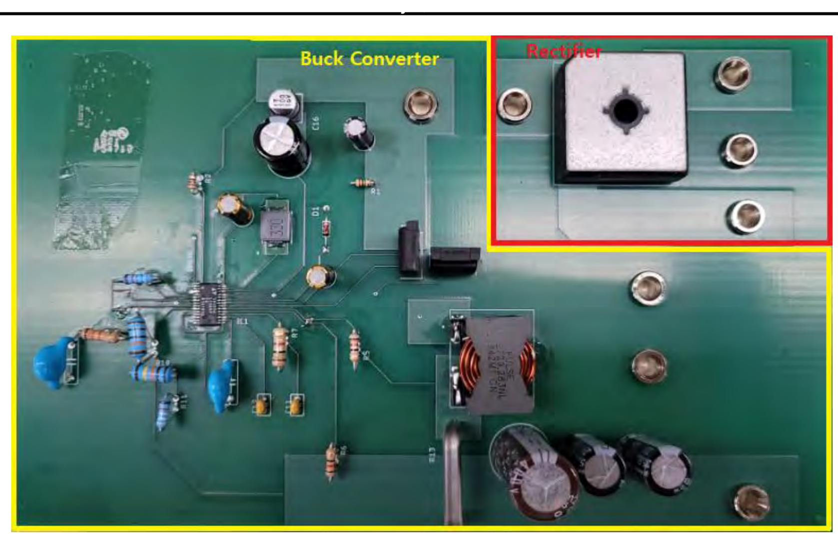
	Expected Range	Actual Values (±10%)	Tested Values
Input Voltage	14-48 VDC	25.9 VDC	25 VDC
Output Voltage	36-48 VDC	48 VDC	45.6 VDC

Inverter

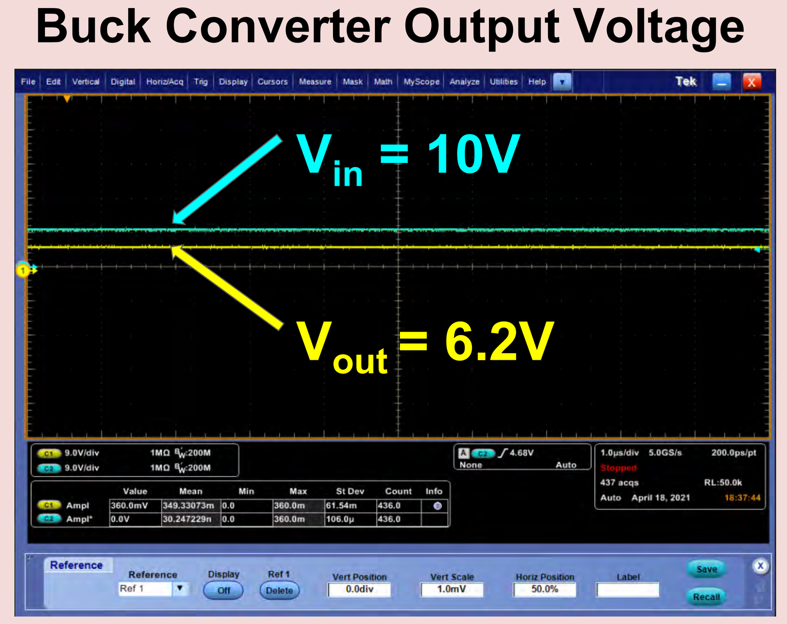
	Expected Values	Actual Values	Tested Values
Waveform	± 48 V Square	± 48 V Square	± 10 V Square
Input Voltage	48 VDC	48 VDC	20 VDC
Frequency	250-300 kHz	300 kHz	300 kHz
Dead Time	100-200 ns	150 ns	150 ns

Rectifier and Buck Converter

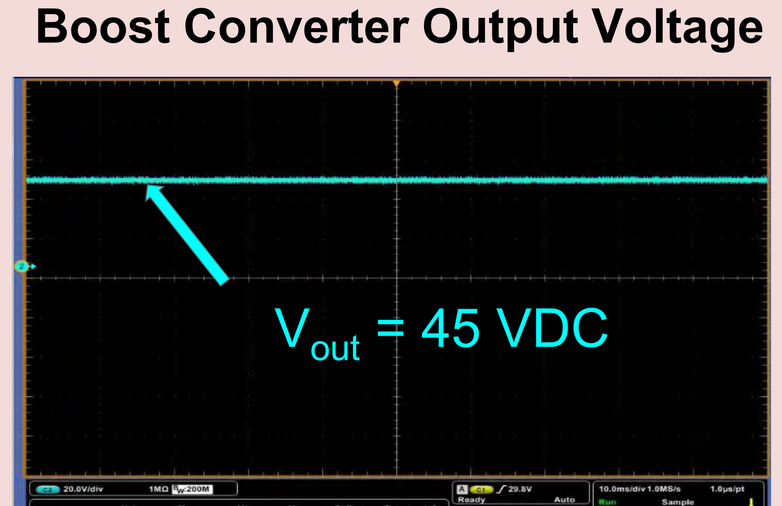


	Expected Value	Tested Value
Input Voltage	48 VAC	10VAC
Output Voltage	30 VDC	6.2VDC

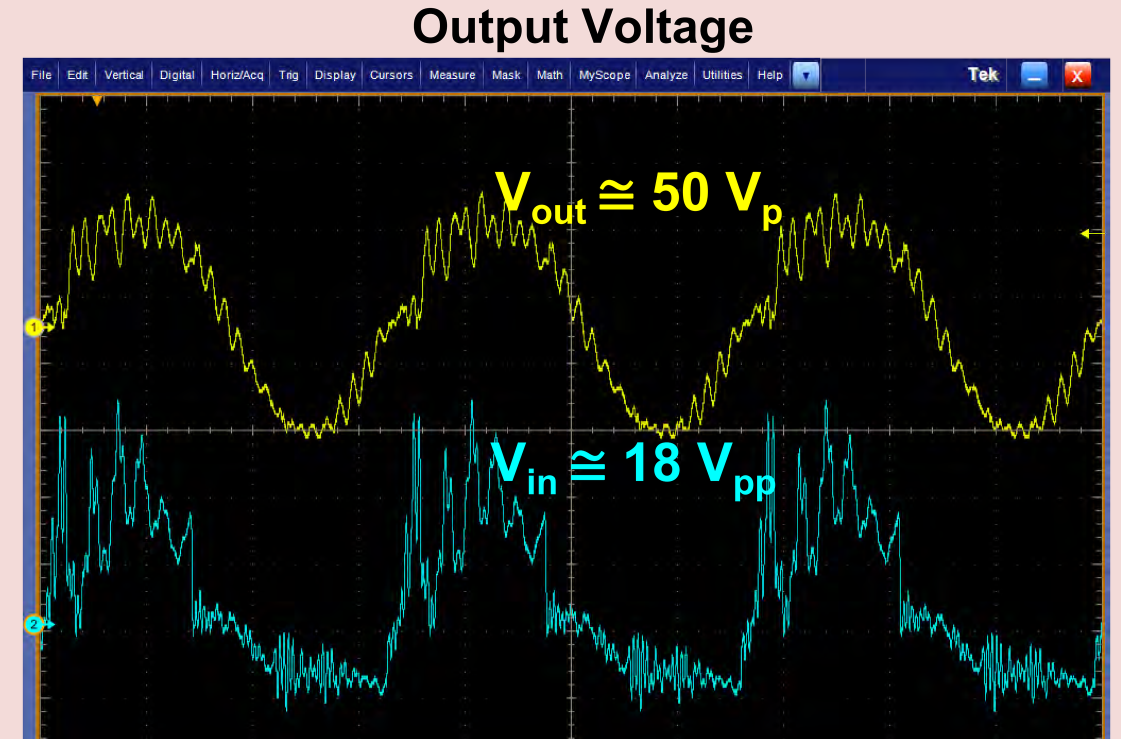
Buck Converter Output Voltage



Boost Converter Output Voltage

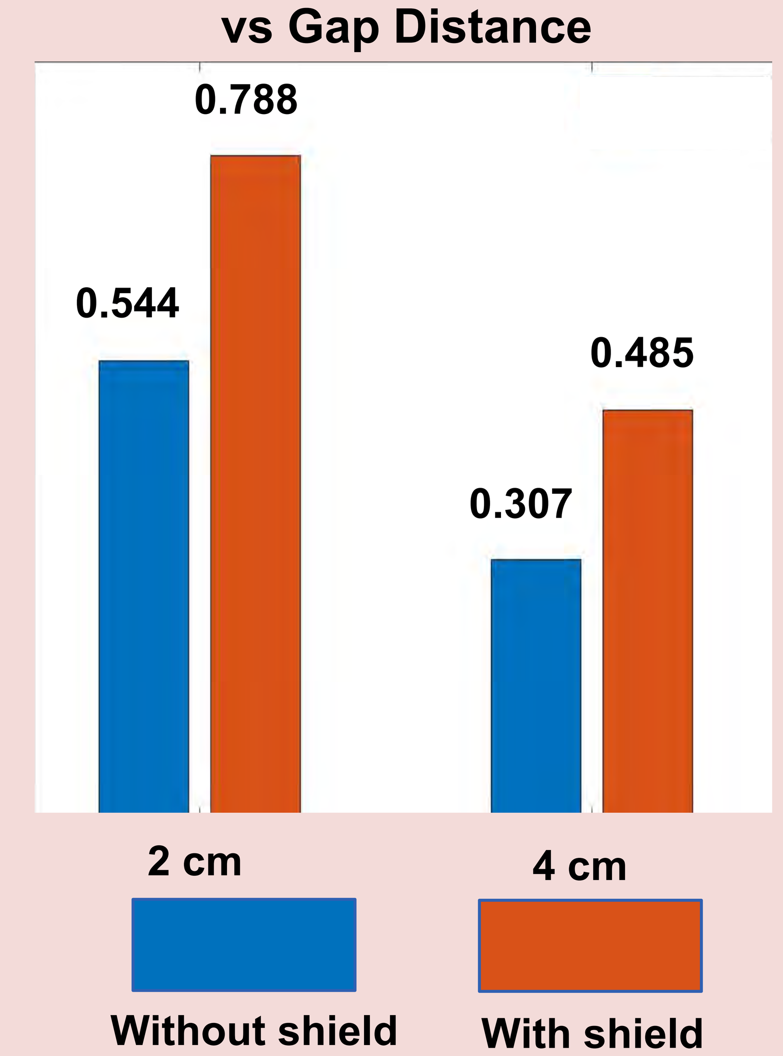


Wireless Charging Coil Input and Output Voltage

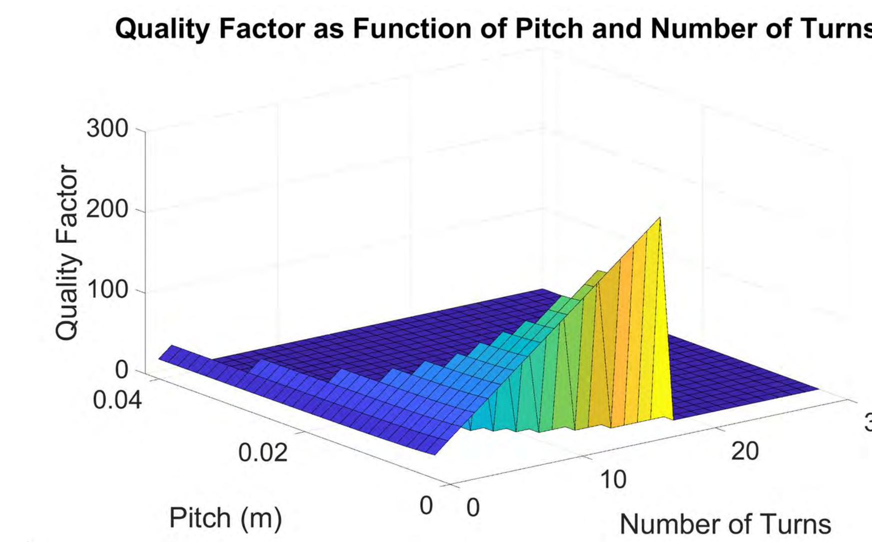


*Input voltage provided by inverter

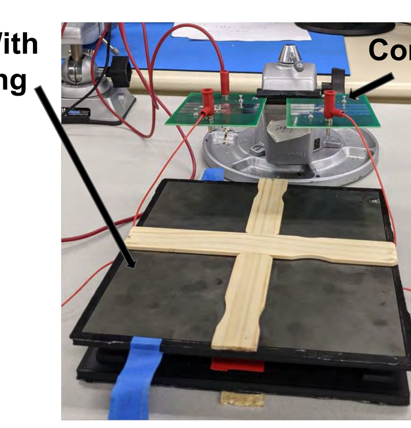
Coupling Coefficient vs Gap Distance

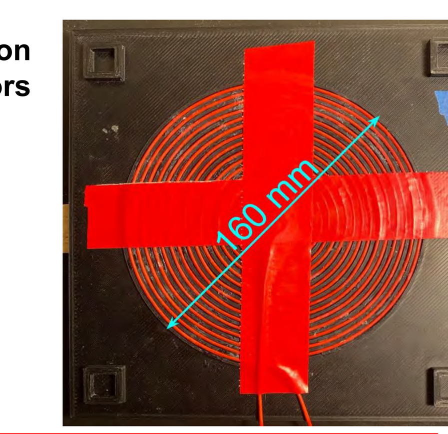


Inductive Power Transfer Coils



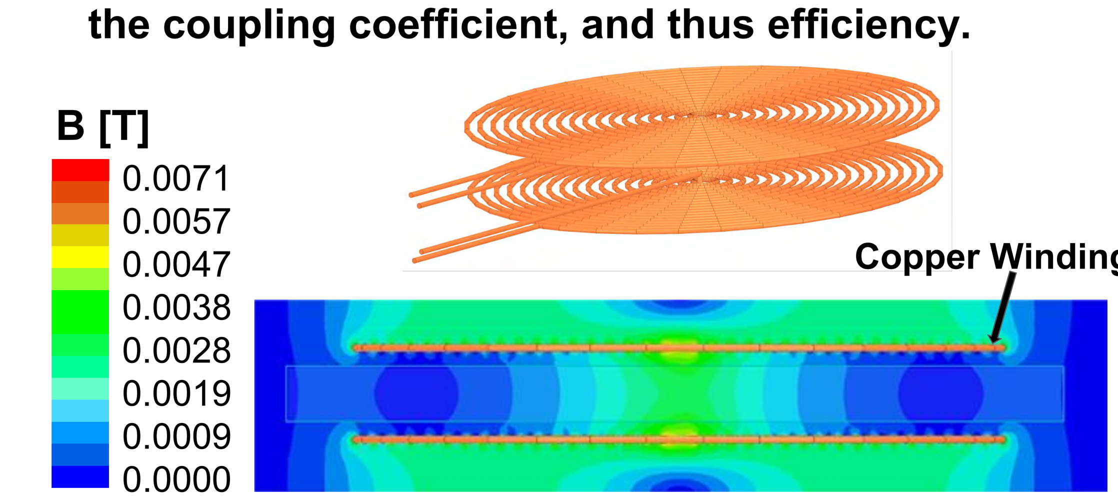
Pitch (mm)	Outer Diameter (mm)	Inner Diameter (mm)	Number of Turns	Quality Factor
3.937	202.4	4	18	255.987





3D Simulation without Shielding

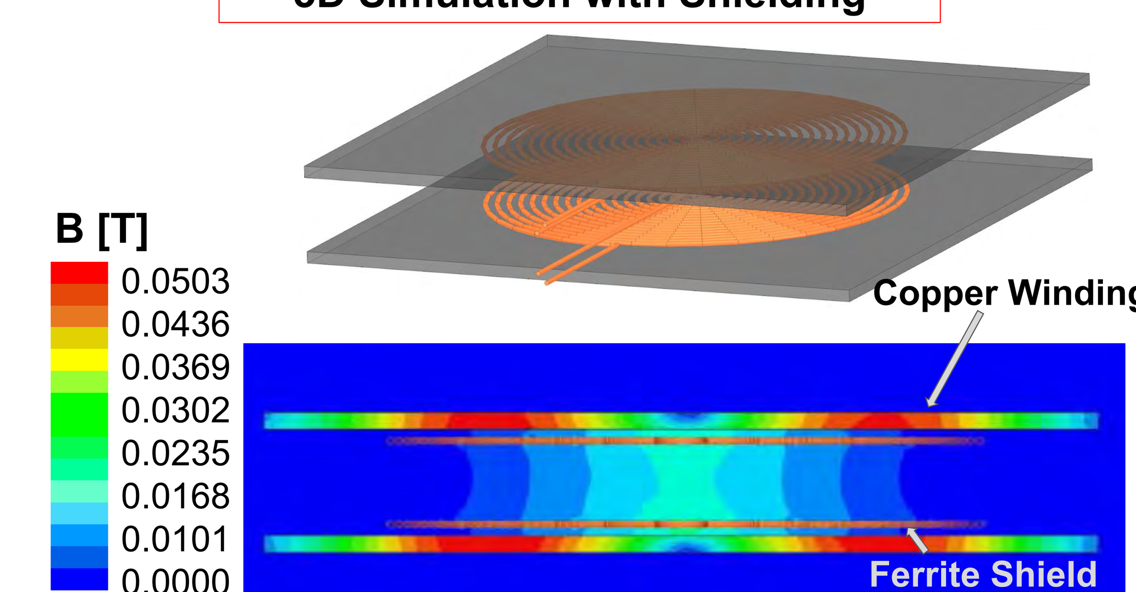
3D simulations using ANSYS were run to determine the coupling coefficient. The introduction of ferrite shielding greatly increases the coupling coefficient, and thus efficiency.



Simulation Results Without Shielding

Receiver Self-Inductance	Transmitter Self-Inductance	Mutual Inductance	Coupling Coefficient
9.0792 µH	9.0792 µH	2.5427 µH	0.28

3D Simulation with Shielding



Simulation Results With Shielding

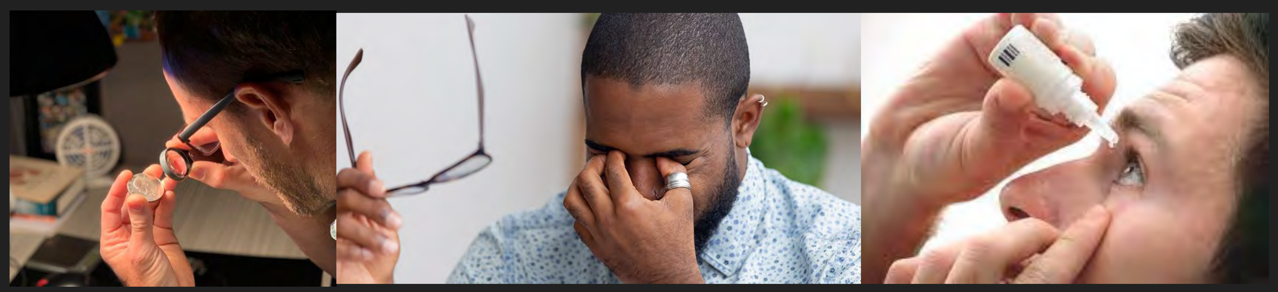
Receiver Self-Inductance	Transmitter Self-Inductance	Mutual Inductance	Coupling Coefficient
43.65 µH	43.65 µH	32.11 µH	0.736

Washington Quarter Identification

Team Members: Fahad Pasha, Justin Nalchajian, Jackson Campolattaro
SME: Dr. Creed Jones Customer: Dr. Luke Lester Mentor: Prof. Kenneth Schulz

Motivation

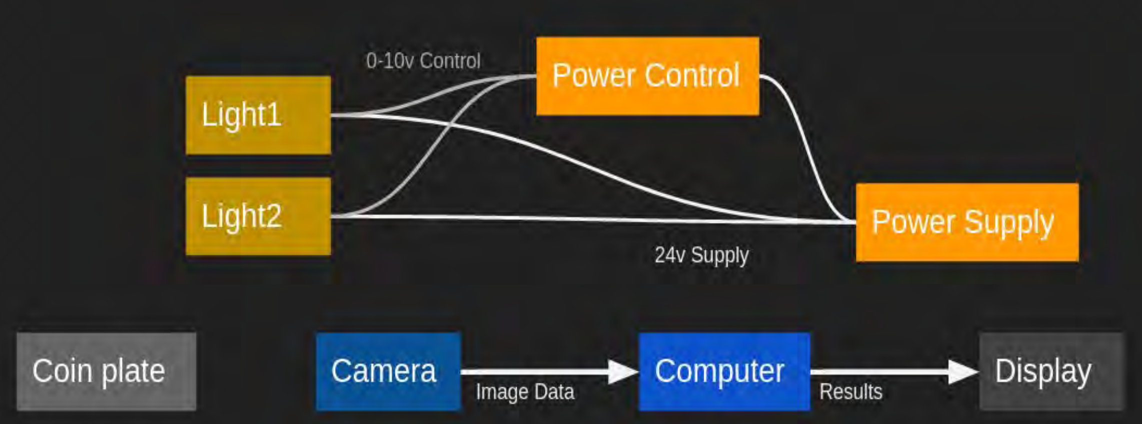
A common task in coin collecting is to document the dates and mint marks of large numbers of coins. This is challenging because spending extended amount of time performing this task can cause eye strain. Our goal is to design, build and test a machine vision camera apparatus that can extract the date and mint mark of a washington quarter coin and apply a grading scale to the coin.

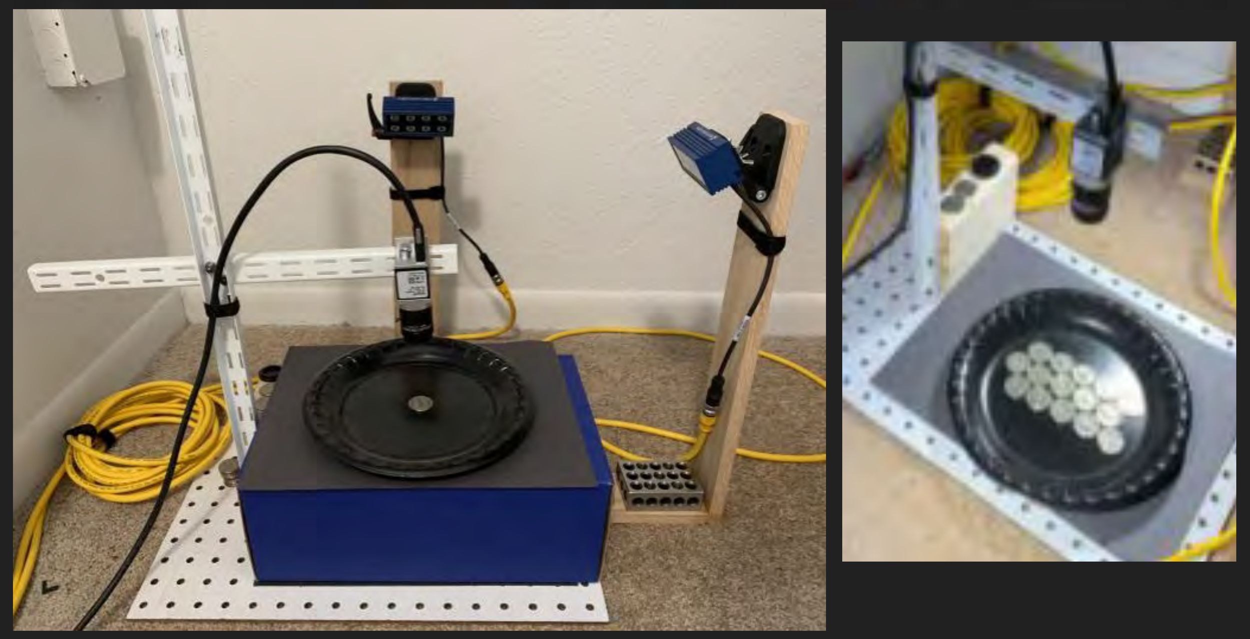


Objectives

- Explore the ideal lighting geometry for text recognition on coins.
- Investigate image processing techniques to preprocess text captures for OCR.
- Develop a software pipeline with a high throughput to process multiple coins.
- Develop a system of determining the quality of each coin

Hardware Structure





Software Structure

The program was separated into a collection of independent modules, to subdivide the challenge into smaller problems which could be built and tested on their own.

```
main.py
quarterid
├── capture.py
├── coin_isolation.py
├── coin_read.py
├── coin_regularization.py
├── image_logging.py
├── ocr
│   ├── easy.py
│   └── hu_moment.py
├── orientation
│   ├── template_generation.py
│   ├── template_match.py
│   └── templates
│       └── edges.png
└── preprocessing.py
```

Coin Location

Hough transform is the technique used for finding circles with a reasonable degree of accuracy

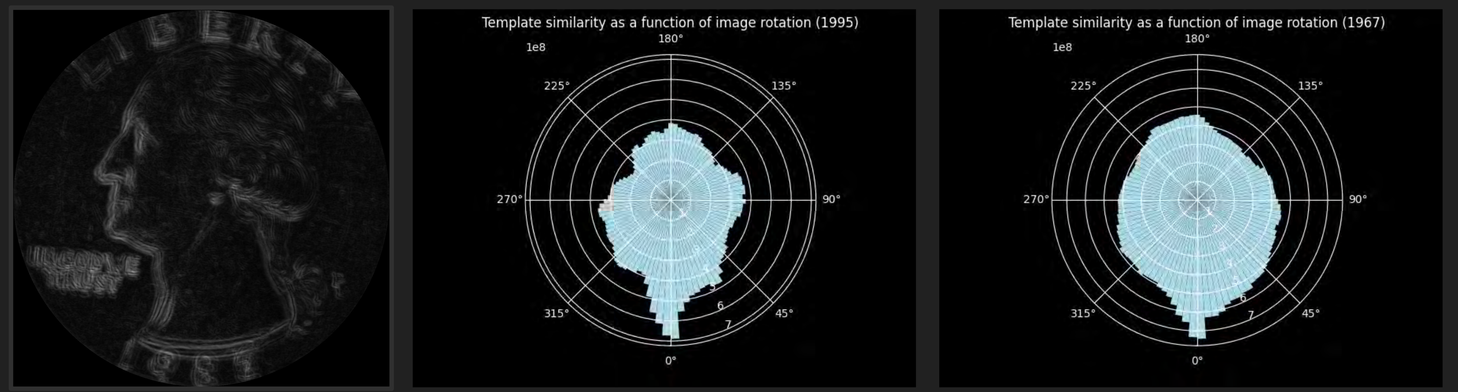
When used in combination with a blur and a thresholding operation, It was able to identify coins of a fixed radius with high reliability

Coin Isolation

Once coins are located, they can by isolated. Each coin's image is separated from the original canvas, and a mask is used to eliminate background contamination, guaranteeing that every coin is on a black background.

Coin Orientation

The coin's orientation is determined using template matching. The image with unknown rotation is shifted through all 360 degrees, and its edges are compared with an averaged template, based on the edges of known-good coin images. The rotation that results in the closest match with our template is selected.

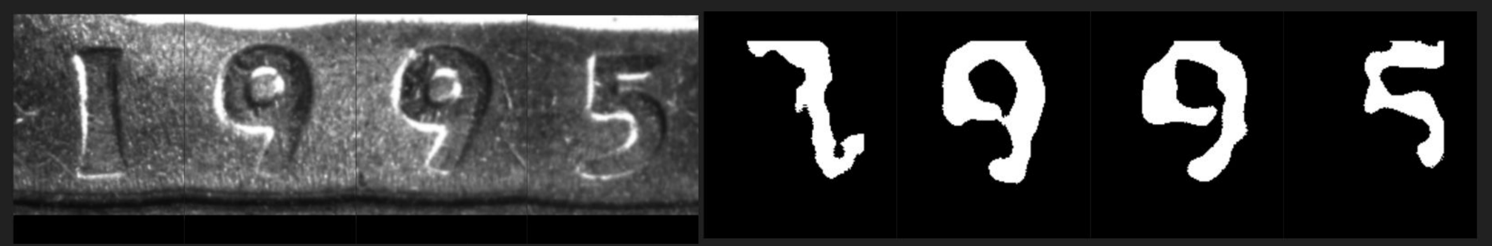


Character Isolation

Once we have our coin oriented correctly, we can make precise and reliable statements about the location of each character. For the date, this was done by rotating the coin such that each digit was upright, and then taking a slice of the canvas containing the digit. This allows us to treat each digit separately.

Character Preprocessing

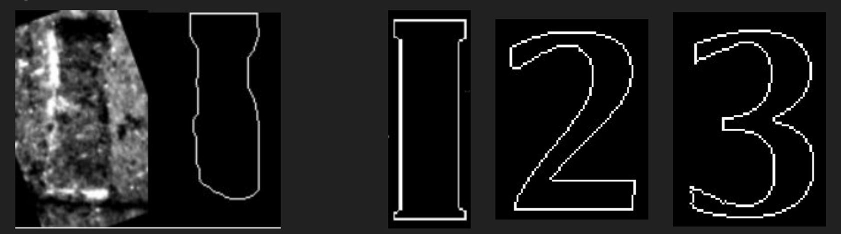
Preprocessing of each character starts with a threshold operation and a blur operation to remove some high-frequency noise, followed by an adaptive binarization. Low frequency noise is removed by eliminating all but the largest feature remaining in the image.



Character Recognition

Two approaches are used in combination for character recognition.

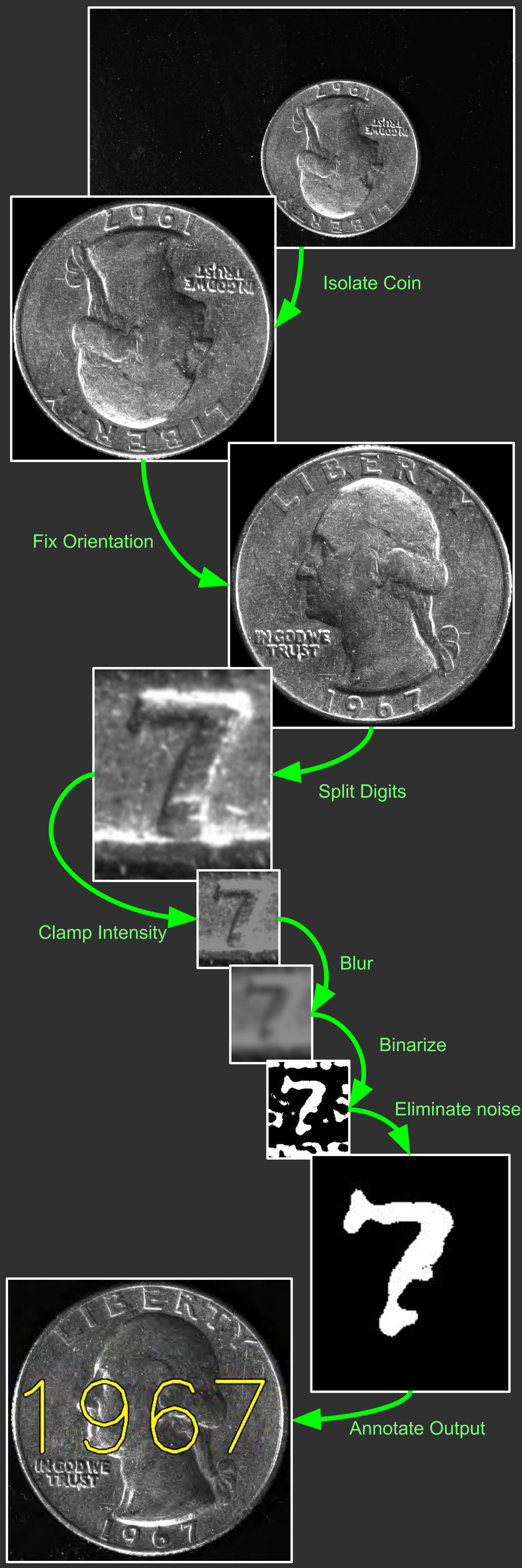
- EasyOCR: This deep-learning based text recognition library is used to read each digit of the date separately. We set a restrictive allowlist to that it's more likely to find the digits that we're looking for. For example, we know that the millennium will always be a 1 or a 2, so we restrict the algorithm to only choose a 1 or a 2 when evaluating the first digit.
- Hu Moment: This characteristic-property based method is used to recognize the mint mark. It's also used as a failsafe when the EasyOCR approach cannot recognize a digit. It compares the shape of the blob representing a digit to the shapes of different templates, and returns the closest match.



$\mu_{pq}=\iint(x-x)^p(y-y)^q f(x,y)\,dxdy$

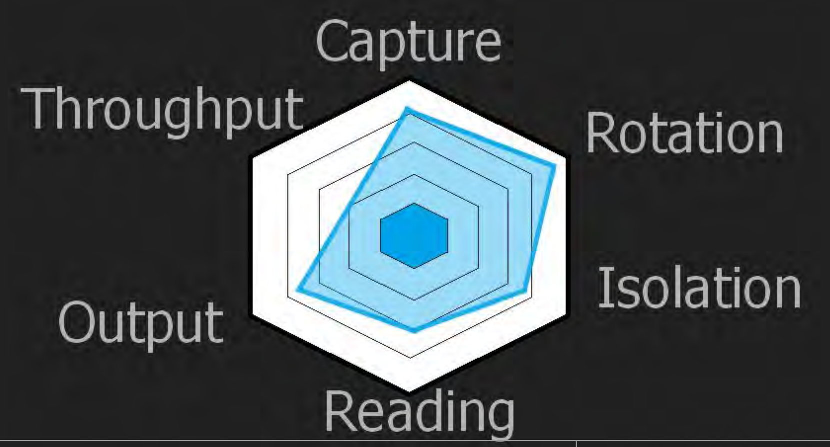
Our Flow of Operations

From top to bottom, the steps our system takes to process a coin.



Gap Analysis

This graph shows the gap between our ideal Flow of operations and our progress.



Project Requirements	Progress
Capture a 7x7 Grid of Coins	1-2 Coins reliably
Count Scratches with 95% accuracy	Scratch Count Abandoned
Determine Mint Mark with 95% accuracy	50% Accuracy
Determine Date with 95% accuracy	70% Accuracy
Grade Coin according to Sheldon Scale	Unimplemented
Below 5% false negative rate for Date and Mint Mark	Untested

Challenges

The Font used by the U.S. Mint does not match default fonts used by easyOCR, rendering the 1 specifically unreadable by the code until a backup method was devised using the Hu Moment

Due to lighting issues, we have trouble working with more than one or two coins at a time. Notice how only a select few of these coins are lit properly.

Analysis and Conclusions

- By testing different lighting geometries we were able to increase the text readability in our images.
- Dark field lighting provided the ideal geometry for text recognition at: 45 degrees light angle, 90 degrees relative angle.
- Lighting geometry ideal for text recognition performs poorly for scratch count and vice versa.
- The use of blur and binarization greatly improved the accuracy of locating coins and reading the date
- easyOCR is a great tool to get started with, but due to the specific challenges of a custom hollow font text, the limitations prevent it from being the best solution

Next Steps

- Increase throughput via parallel processing of multiple coins simultaneously
- Create an enclosure to protect from ambient lighting and changes in location
- Building a machine learning solution as an alternative to easyOCR for text recognition
- Purchasing an LED ring light to replace the bar lights
- Invest in an industrial document camera for a more permanent solution
- Develop solution to read text and determine coin quality simultaneously

Acknowledgements

We would like to thank the following for their help throughout the development process

- Dr. Creed Jones
- Dr. Luke Lester
- Prof. Kenneth Schulz
- Tomás E. Goldaracena (Graftek Imaging)

Wearable Fiber Optic Sensor

Team Members: Dillon Conner, Xingsi Gao, Maureena Ma, Craig Macagney, Zayeem Zaman
SME, Customer: Dr. Yizheng Zhu and Professor Shuxiang Yu **Mentor**: Professor Toby Meadows

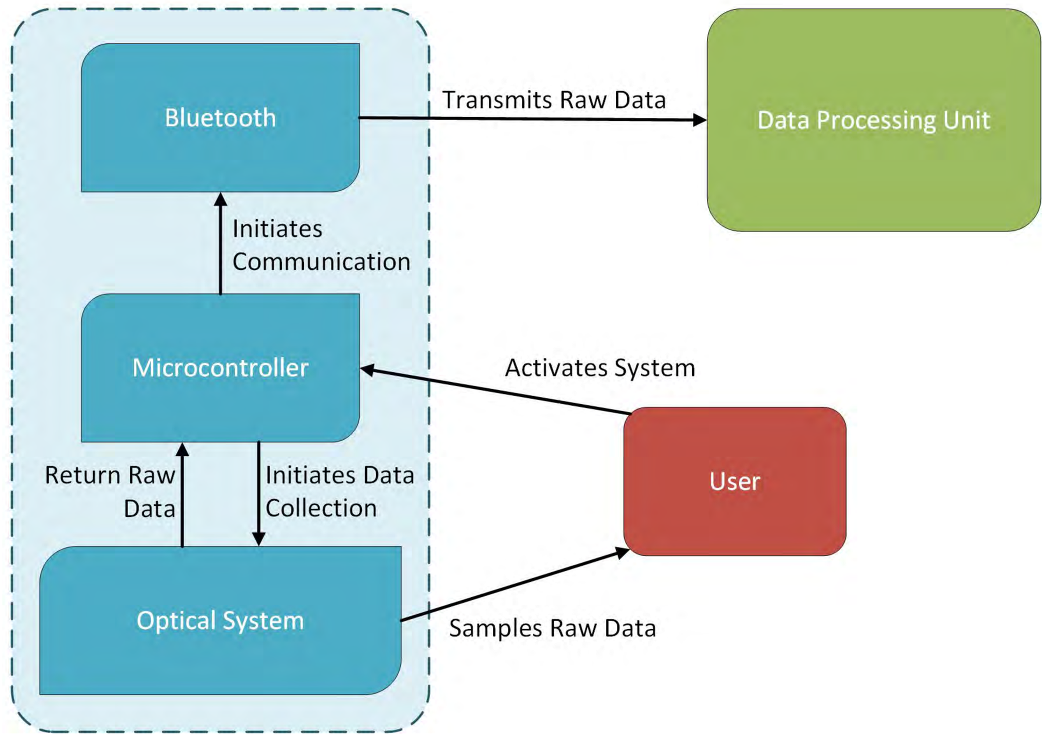
Background

- Cerebral Palsy (CP) is a congenital, non-progressive group of disorders that affects movement and balance
- Currently, there is no cure for CP
- Many treatment options for CP are generic and not tailored to individual patients, but CP affects each patient differently
- The goal of this project is to develop a system that will assist in personalizing treatment options for patients with CP

Objectives

- Create a wearable, fiber-optic curvature sensing system for monitoring bending motion of the human joint
- Display bending angle data in real-time user-interface
- Store data for later analysis of patient's movement capabilities

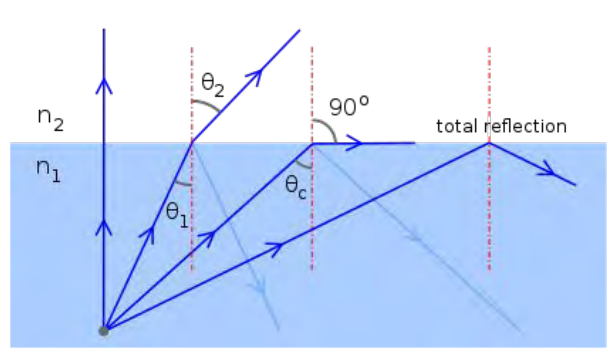
System Architecture

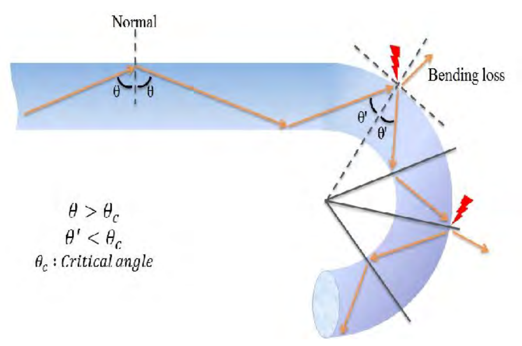


Concept of Operations

General Concepts:

- Total internal reflection is a reflection principle where energy is conserved
- Optical fibers use total internal reflection to transmit light





System Goals:

- Modify fiber cladding to allow light to escape at different angles
- Measure amount of light lost through fiber to determine bending angle

Demonstrations

System Demo

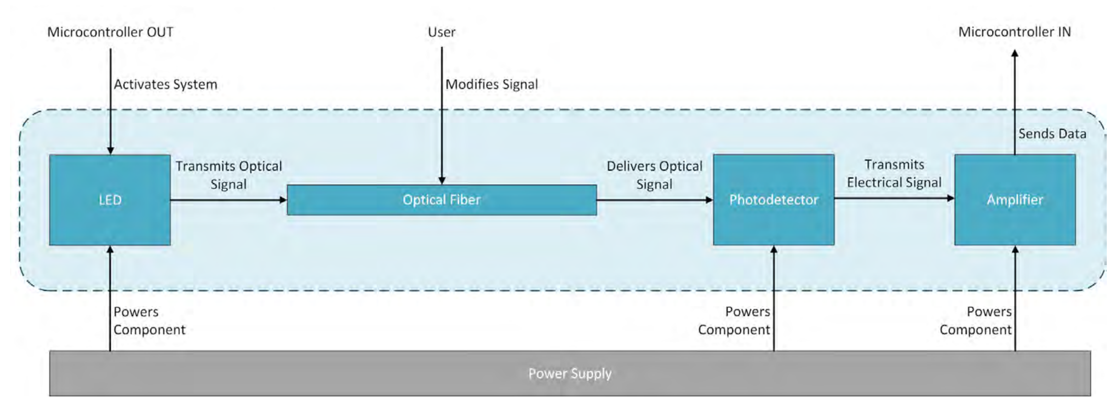
https://tinyurl.com/wearablefiberdemo

Fiber Characterization

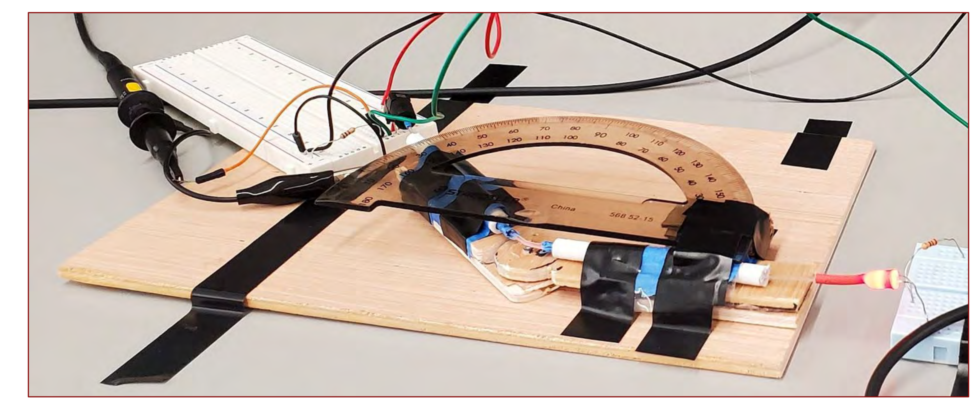
https://tinyurl.com/fibercharacterization

System Design

Optical Subsystem

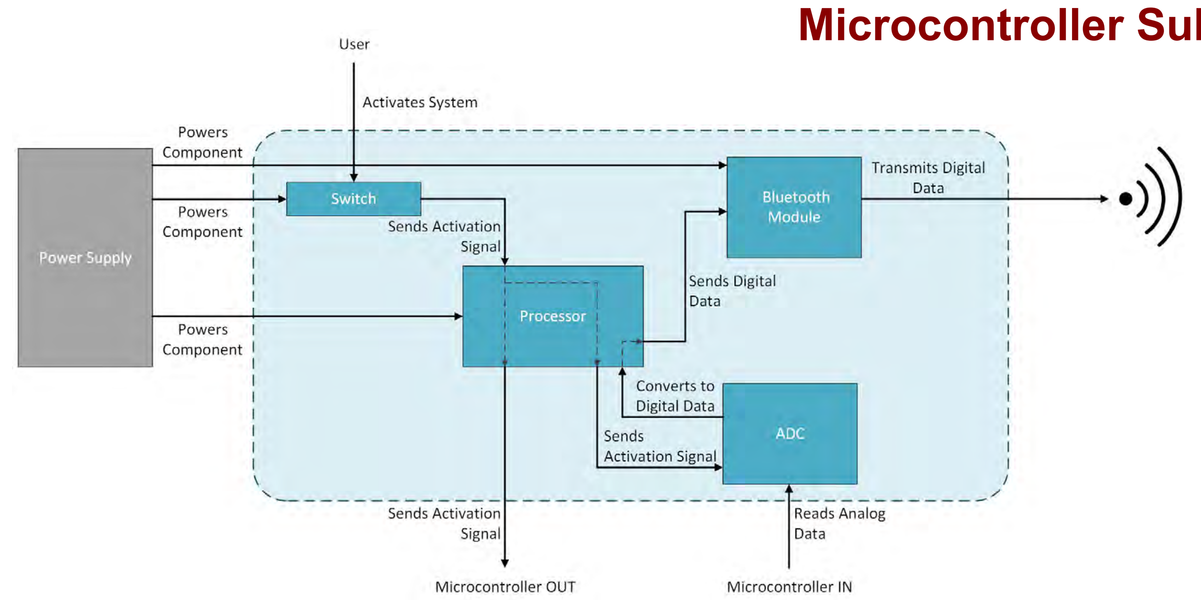


Optical Block Diagram

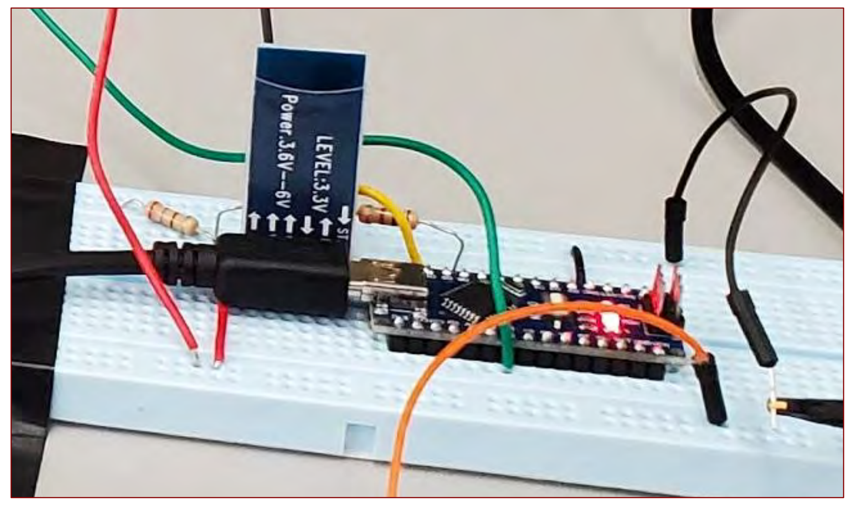


Optical System Prototype

Microcontroller Subsystem

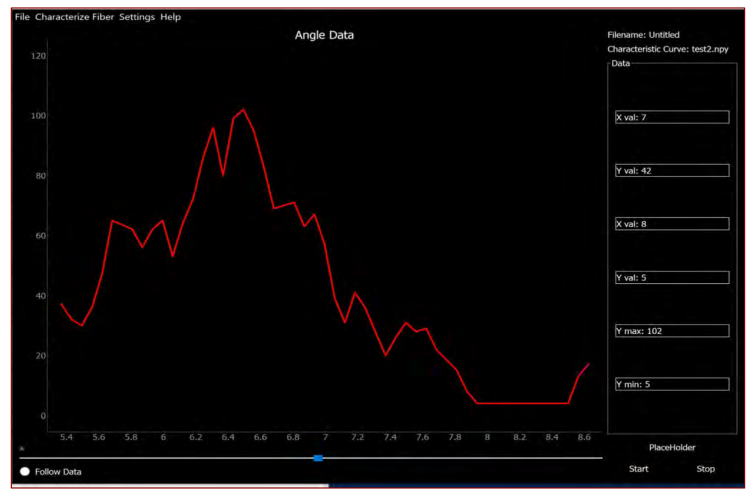


Microcontroller Block Diagram

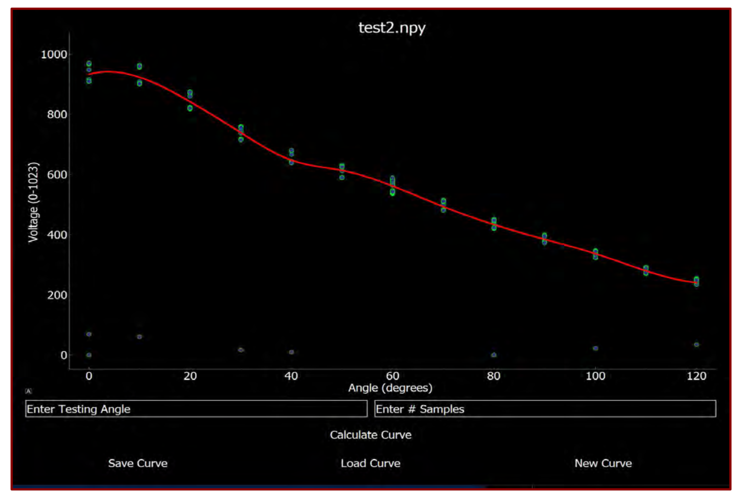


Microcontroller System Prototype

Data Processing Subsystem

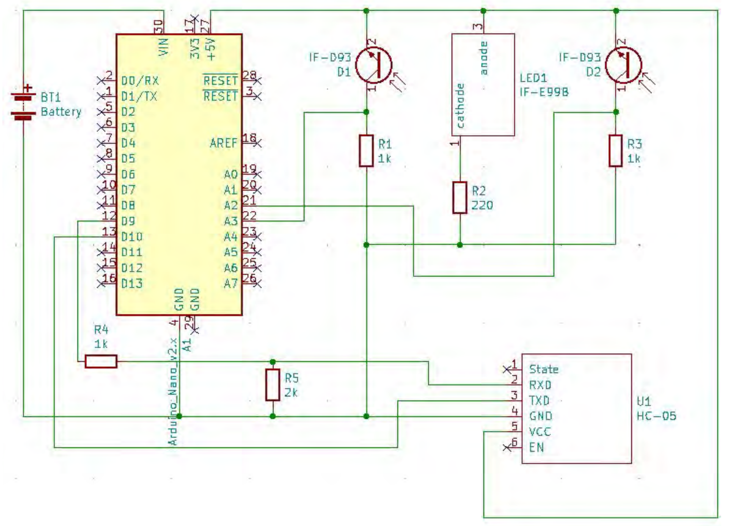


Angle Measurement Window

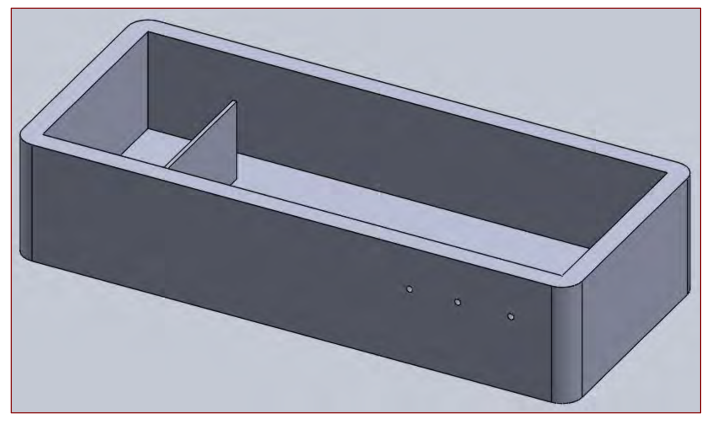


Fiber Characterization Window

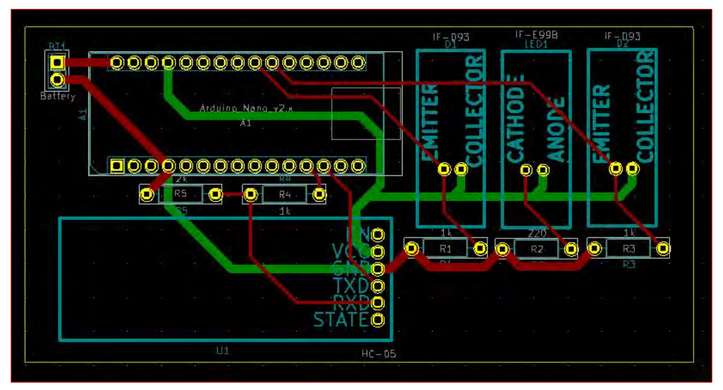
Wearable Design



Circuit Schematic for PCB Design

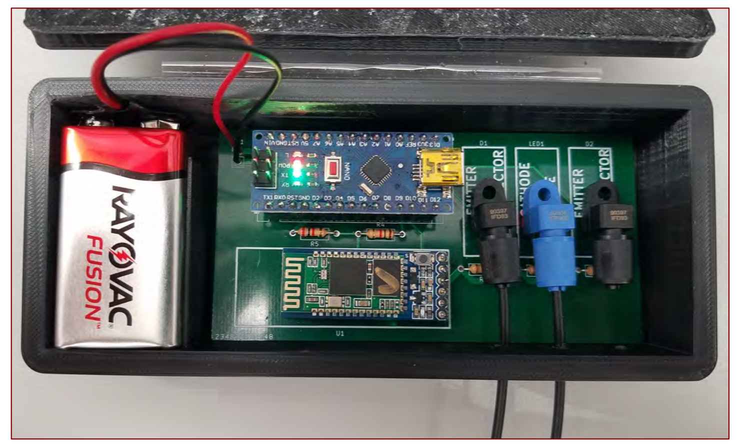


CAD Case Model for Circuitry

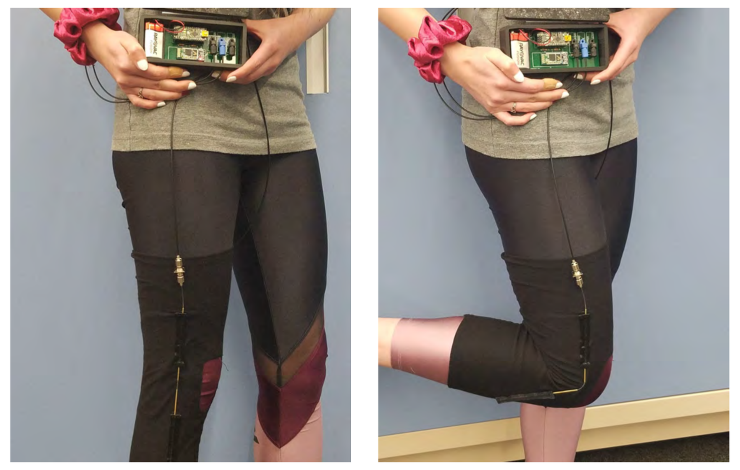


PCB Design for Wearable System

Knee Brace with Fiber Sewn In

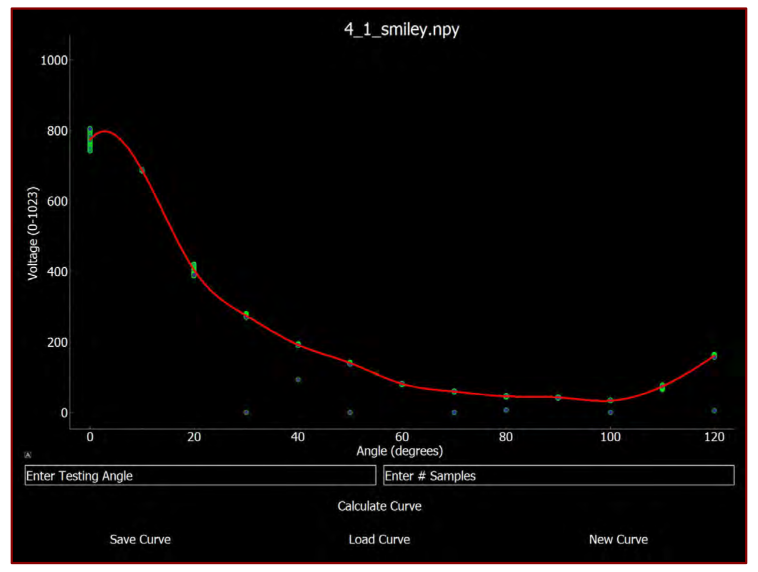


Wearable System Circuitry

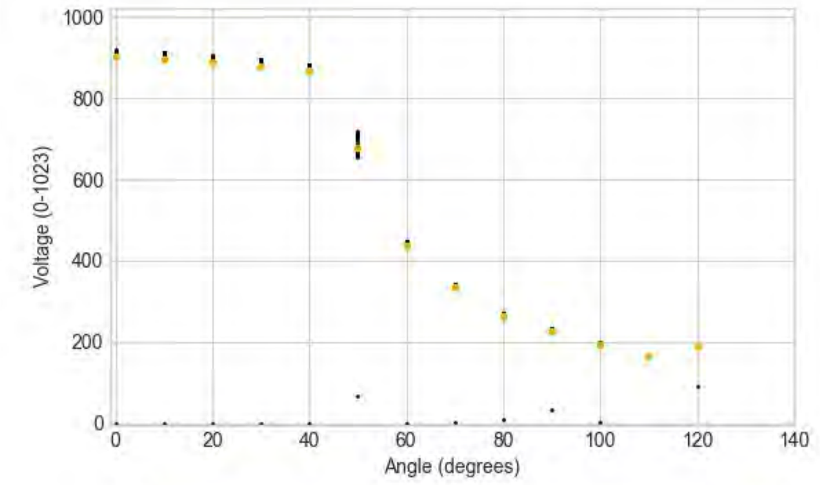


Wearable System Worn on Knee

Results and Analysis



- The graph to the left shows the voltage output for each angle a **test** fiber was bent at during its initial characterization
- This dataset demonstrates a material issue: the plastic of the fiber kinks and deforms after multiple bending tests, causing back reflections of light
- The back reflections result in the increase of data points near the end of the data set and make it difficult to characterize the fiber accurately
- The more the fiber is bent, particularly around a rigid fulcrum as done in the table-top system, the more the material will deform



- The graph to the right shows the voltage output for each angle the **final** fiber was bent at during characterization
- The points are monotonically decreasing, allowing for distinguishment between different bending angles and thus allowing for complete characterization of the fiber
- The largest changes in voltage outputs occur in the middle region of the graph, starting from 50° - this is the threshold bending angle for the fiber in order to truly lose light

Challenges

- Transitioning the system from a tabletop prototype to a wearable and portable system
- Creating periodic, repeatable surface modifications to promote bending light loss in the fiber
- Implementing single-end interrogation with an optic coupler and reflective surface
- Ensuring the design and results of the project are replicable and consistent for future use

Conclusion

- A table-top system measuring the bending angle of a fiber was developed, built, and successfully tested
- A program was designed to characterize the fiber and output voltage curves representing the data points for each bending angle of the system
- The table-top system was used with the program to characterize a fiber for the wearable system
- A PCB and CAD case were designed to condense the entire system for wearability
- A sleeve was sewn for holding the fiber in place for the wearable system
- A user-interface was designed to show the bending angle in a real-time display and to store the bending angle data for later use
- Implementation of single-end interrogation in the wearable system failed to demonstrate bending angle output loss, likely due to the lack of a good reflective surface
- Project documentation and program files were compiled in preparation for project hand-off to PhD candidates Guannan Shi and Jacob Black from Dr. Yizheng Zhu's research group

Future Plans

- Finalize single-end interrogation with current optic coupler and reflective surface at open end of fiber
- Implement reference fiber using additional optic couplers to provide an initial light source reading for a baseline measurement and to act as a calibration method for the system
- Research additional polymer-based fibers that are more flexible compared to the commercial PMMA and polystyrene optical fiber used to create this prototype
- Explore periodic, repeatable surface modifications with new fiber for repeatability and consistency
- Addition of a low-pass filter on the PCB in order to filter out the square-wave noise of the system
- Update user-interface to include display options for different users (ie. researcher vs pediatrician)

Acknowledgements

We would like to thank the following people for their support and guidance on this project:

- Dr. Yizheng Zhu and Professor Shuxiang Yu, our subject matter expert and customer
- Professor Toby Meadows, our project mentor
- Guannan Shi and Jacob Black, PhD candidates from Dr. Zhu's research group
- Dr. Xiaoting Jia and PhD candidate Yujing Zhang from the Center for Photonics Technology
- Dr. Luke Lester and PhD candidate Seied Ali Safiabadi Tali from the Optoelectronics Laboratory

Low Cost Digital Stethoscope

Team Members: Vince Carroll, Julia Farrell, Kadisha Mercado, Jacob Rickman, Maddie Sheehan
SME & Customer: Dr. Jaime De La Ree   Mentor: Prof. Toby Meadows

VIRGINIA TECH
BRADLEY DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

Background

Location
- Reach people far away from cardiologists
- Target those unable to travel or in rural locations
- Convenient, despite location

Health
- Diagnose heart problems early on
- Directly interact with cardiologists and physicians
- Users can get the help they need

Cost
- Low cost to give everyone equal opportunity
- Socioeconomic status will not affect the ability to seek help

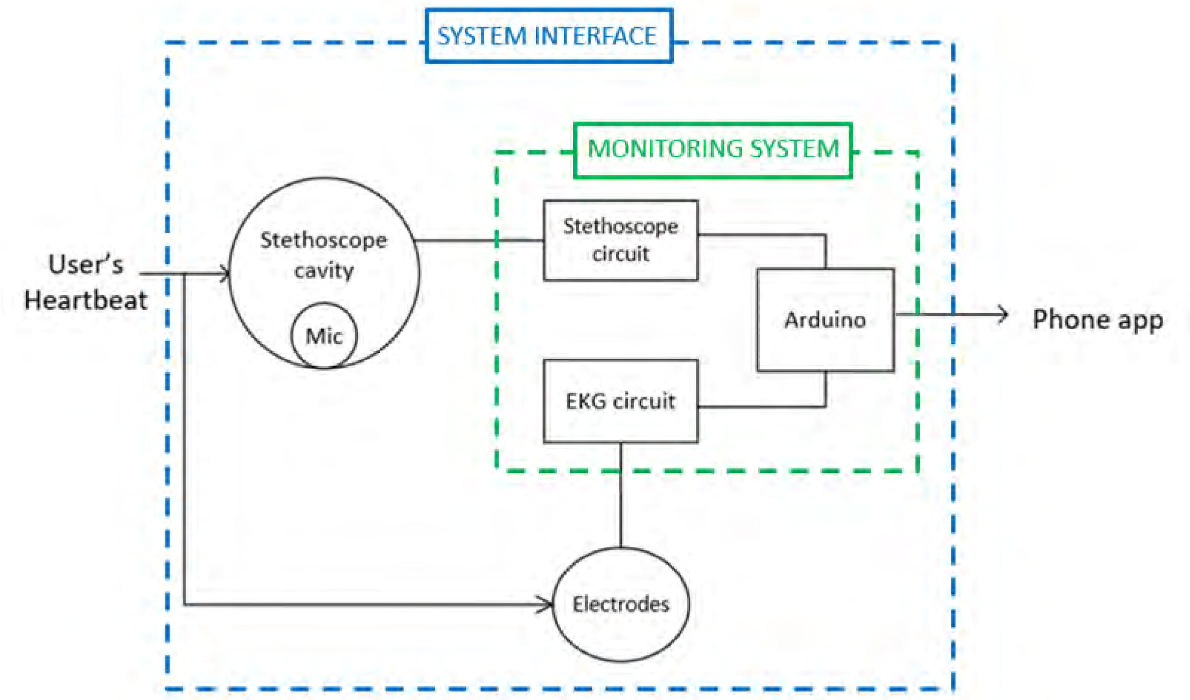
Objective

The purpose of this project is to give equal access to healthcare for all despite location and socioeconomic status, therefore, the device will be low cost and portable. This product can help diagnose heart conditions early and get users the care they need. This team is developing a stethoscope and electrocardiogram (ECG or EKG) to simultaneously obtain audio and visual representations of a user's heartbeat. The overall goal of this project is to develop an app that will allow consumers to view and listen to their heartbeat and then share the data with a medical professional.

Key Requirements

Key Requirements		
01	Build Stethoscope Circuit	• Designed 2 stage Stethoscope Circuit • Outputs heartbeat through self-wired headphones
02	Build Electrocardiogram Circuit	• Currently, there are 2 different electrocardiogram circuits possible to use • AC Lab ECG Circuit: works according to the 3 stage design • Arduino ECG Circuit: built based off of Arduino design, works as designed
03	Synchronize Electrocardiogram and Stethoscope Circuit via Arduino	• This requirement was a stretch requirement • Was not completed, but is being left for the next team
04	Additional Filtering via MATLAB	• MATLAB code that filter the noise out of a circuit is built • Step to flag irregularities were started

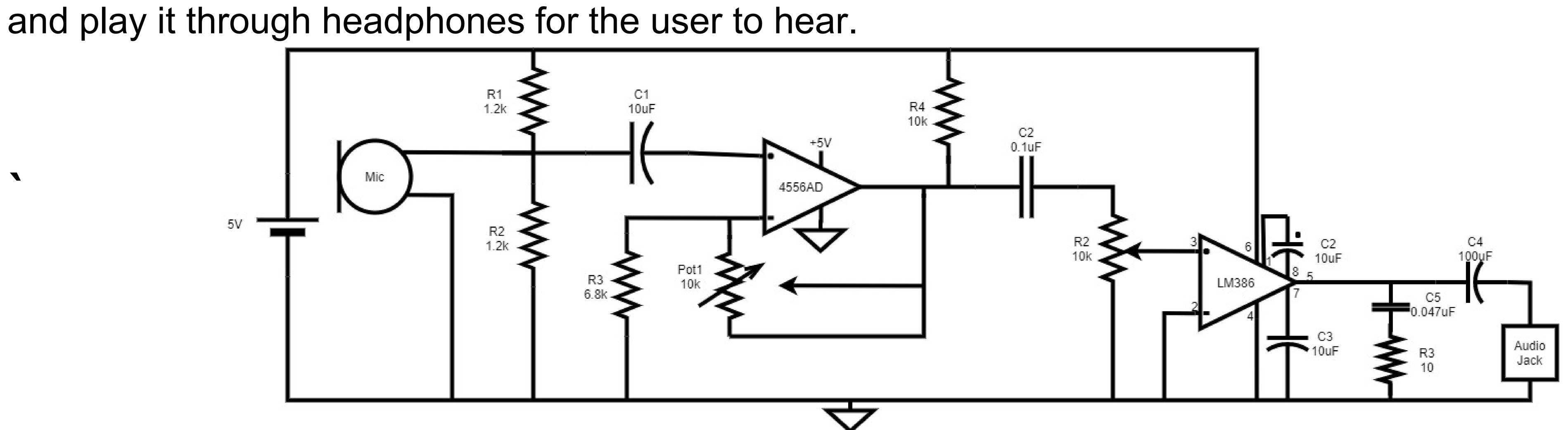
System Architecture



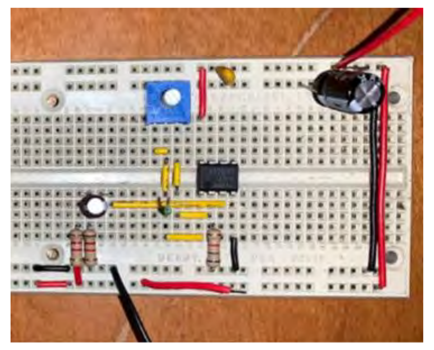
Subsystem Design and Testing

Stethoscope Circuit

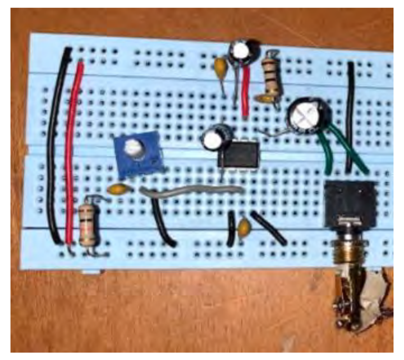
The purpose of the stethoscope circuit is to take a heartbeat signal from a microphone, amplify it, and play it through headphones for the user to hear.



Stethoscope Circuit Schematic.



Audio Collection and Noise Cancellation

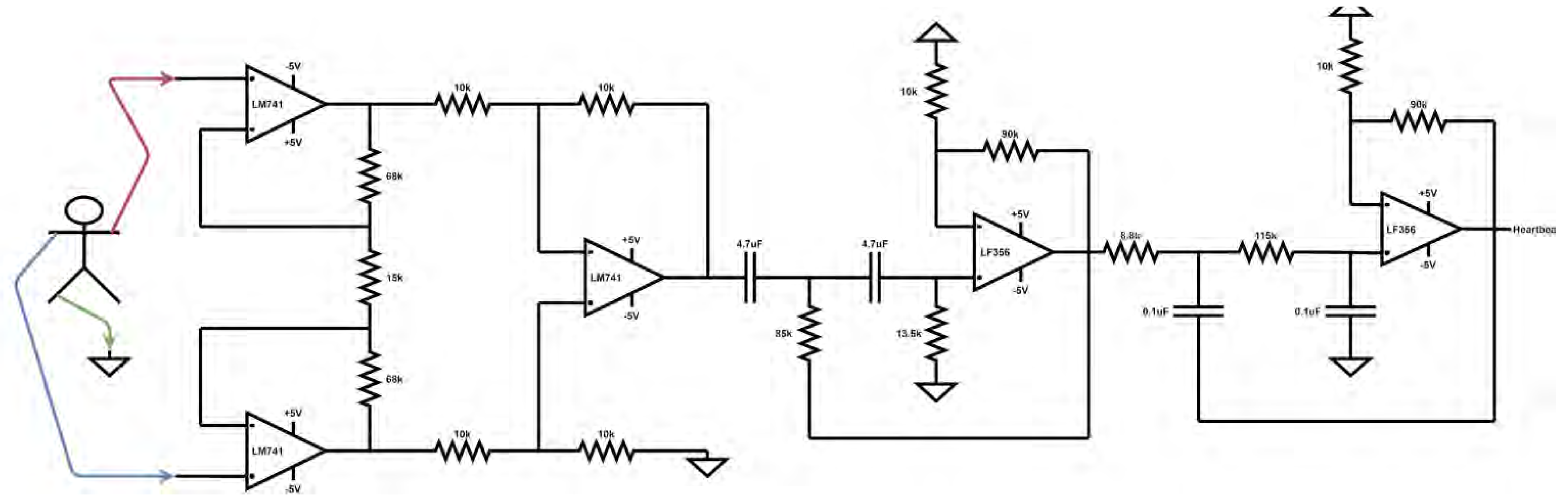


Sound Amplifier

Stethoscope Circuit Output

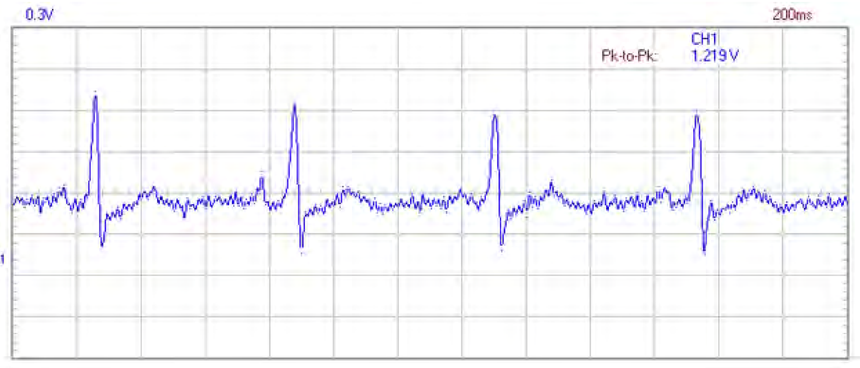
Electrocardiogram Circuit: AC Lab Circuit

The ECG circuit is used to amplify the electrical signal of the heart and filter out noise around the heartbeat.



ECG Circuit Schematic.

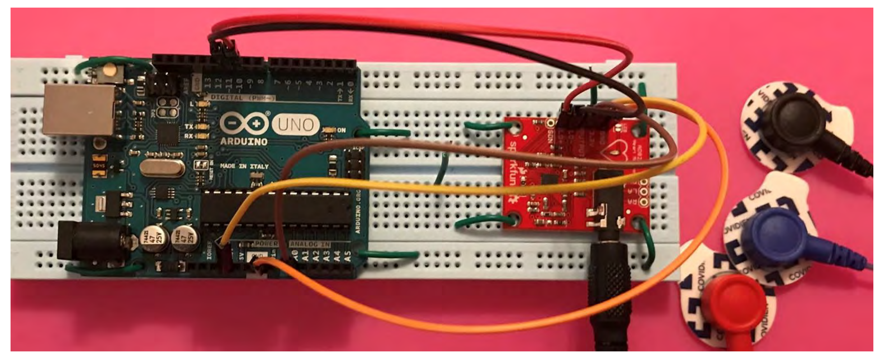
ECG Circuit Prototype



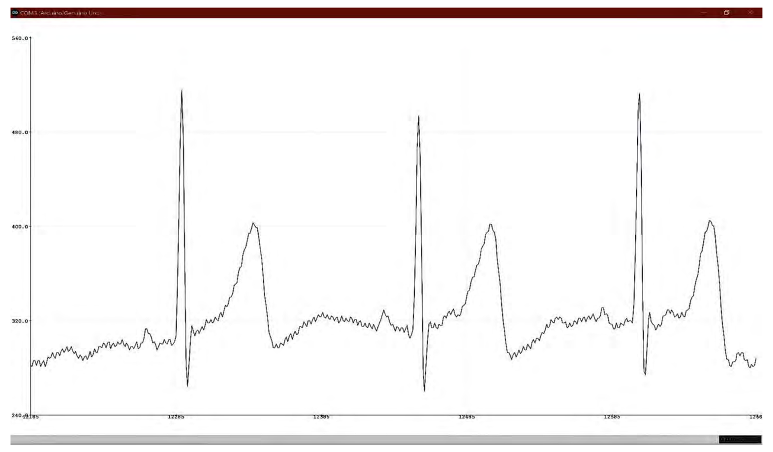
Sample heartbeat using the ECG circuit.

Electrocardiogram Circuit: Arduino Circuit

The Arduino ECG Circuit is an alternative to the built ECG Circuit. The hope is that this circuit could assist the next team in synchronizing the stethoscope and ECG outputs.



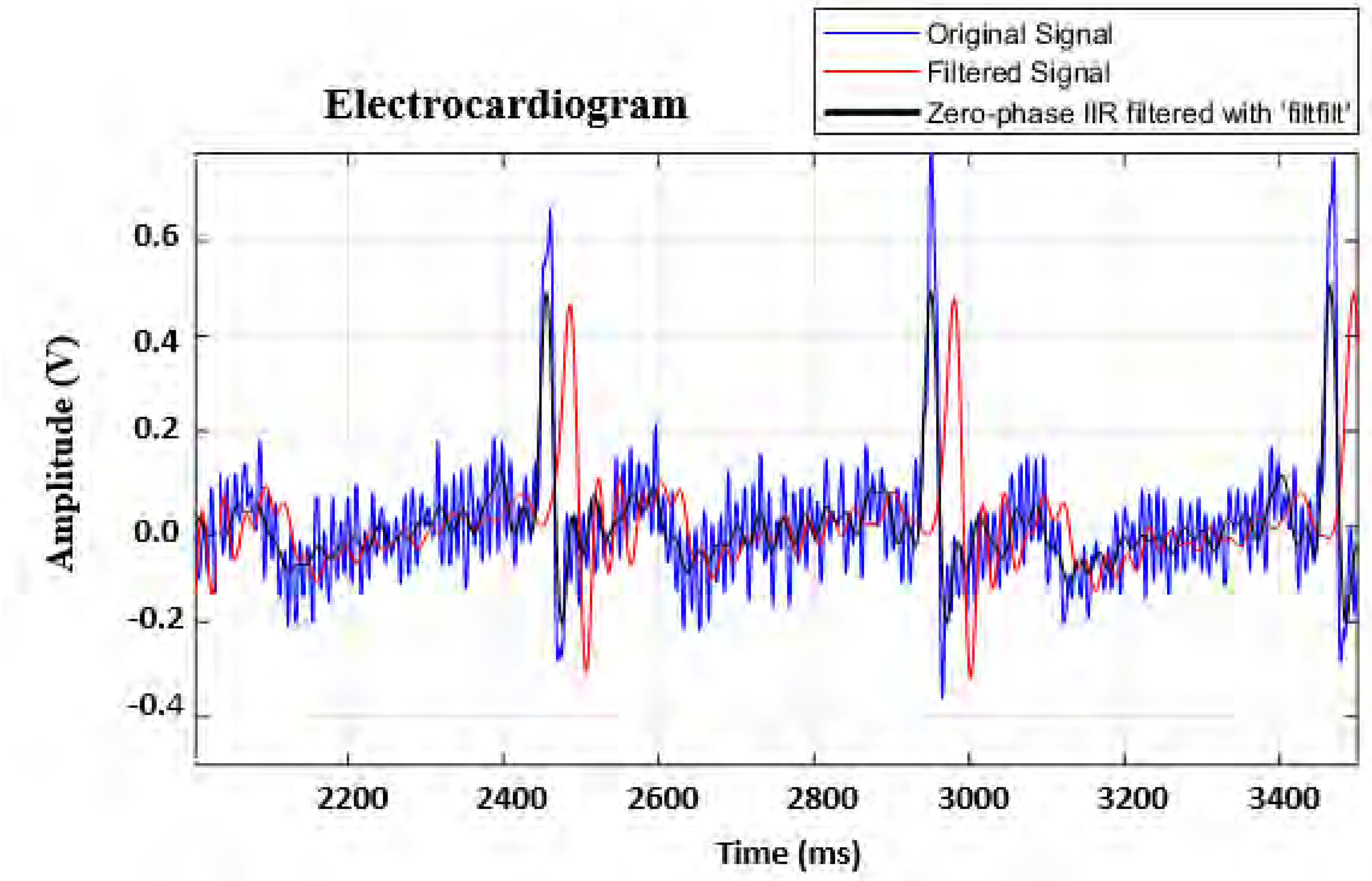
ECG Arduino Circuit



Sample heartbeat from Arduino Circuit

MATLAB Filtering

The team used MATLAB as a tool for analysis of heartbeat waveforms. MATLAB enabled the team to be able to potentially detect any irregularities within a given heartbeat. The process requires knowledge of Fourier Series, Fourier Transforms and the Welch's Method.



Background

The team hopes the project will be continued by a future MDE team. Future plans could include:

- Designing an app or website for consumers to view, listen to, and share their heartbeat with medical professionals.
- Synchronize the output of the ECG and stethoscope circuits through the Arduino.
- Develop final product packaging through PCB Design and 3D print an enclosure for the entire device with help from Aileen De La Ree Valencia.
- We have compiled documentation for each aspect of the project to assist the next team in starting the project.
  - To view the most up to date documentation use the QR Code below:

Ackknoledgments

Team HeartThrobs would like to thank the following people for their support and mentorship over the past year.

- Dr. Jaime De La Ree for his support and assistance throughout every stage of this project and for believing in us.
- Dr. Leyla Nazhand-Ali for help with the logistics of the MATLAB code
- Dr. William Baumann for his help with the AC Lab ECG Circuit
- Prof. Rick Cooper for his help with the AC Lab ECG Circuit

Campus Electrical Distribution Planning

VIRGINIA TECH

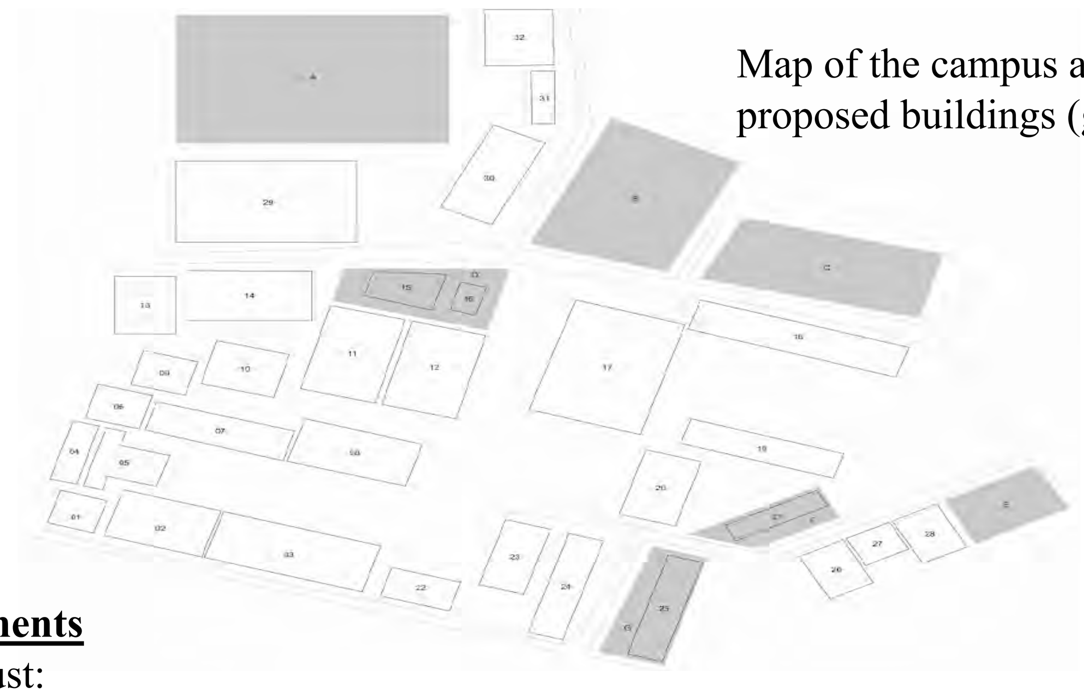
Team Members: Sengal Ghidewon-Abay, Brendan Moseley, Lukas Reed, Madison Burke, Scott Tillotson

Customer: Dan Morton, Wiley|Wilson SME: Minh Ngo Mentor: Prof. Toby Meadows

Wiley|Wilson

Motivation

The current system is an urban campus in Richmond currently running on a 4.16 kV system. In need of an upgrade due to increased student enrollment, building growth, and electrical load increase.



Map of the campus and future proposed buildings (grey)

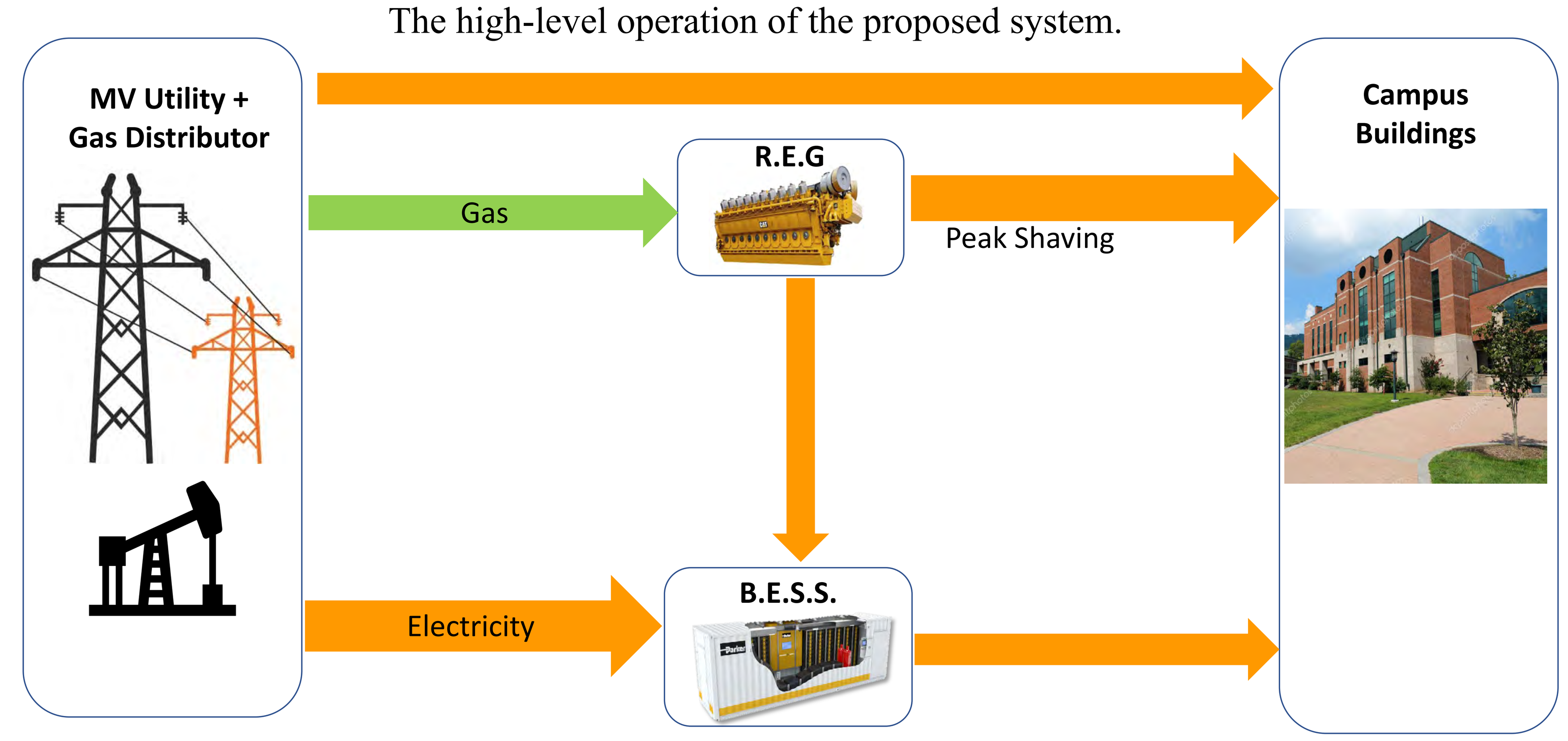
Key Requirements

The system must:

- Have enough capacity for the current and future loads.
- Continue to function should any single component fail.
- Provide power to every load on the campus.
- Account for the capacity of the 4.16kV mechanical chillers that comprise the central utility plant.

Concept of Operation

The high-level operation of the proposed system.



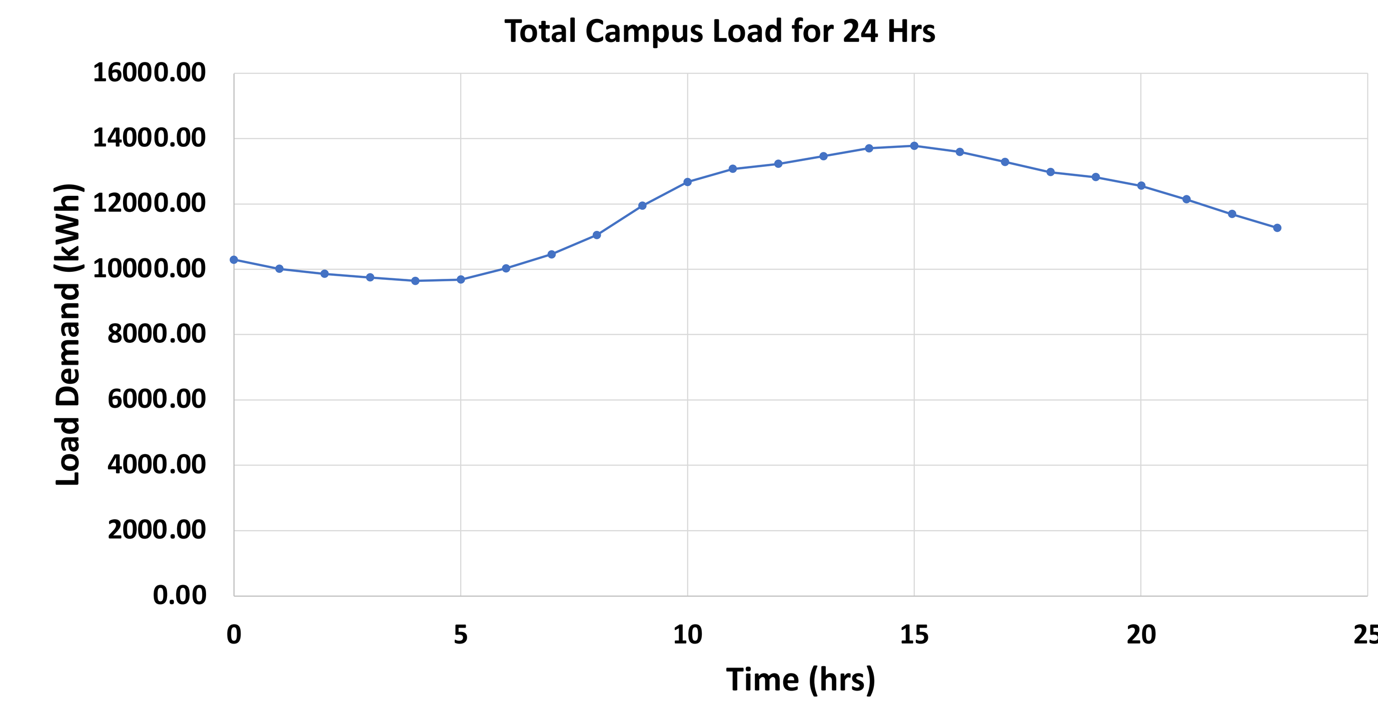
The electric utility service will provide power directly to the campus buildings through underground power lines.

The campus will use a Reciprocating Engine Generator (R.E.G.) to generate energy during peak times. Land will be set aside to implement a Battery Energy Storage System (B.E.S.S.) in the future.

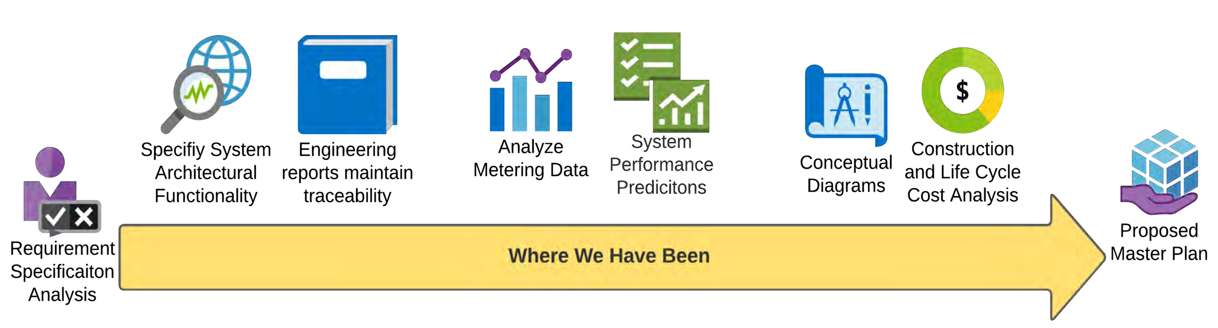
Analysis of Load Data

In order to determine the future load data, normalized curves of the different building types were created. From the current and future load data:

- Discovered that the peak load experienced by the campus is 13.782 MW
- Decided on a flat-rate utility schedule
- Only one meter would be needed for the campus after comparing the North and South side of the campus



Deliverables



Decision of Topology & Generation Technology

	Reliability	Cost	Versatility	Operability	Final Score
Weight	5	2	4	5	
Radial	1	5	2	5	38
Loop	4	4	3	3	49
Primary Selective	4	3	4	3	51
Composite	5	1	5	1	50

	Cost	Land Use	Water Requirements	C02 Emissions	Flexibility	Thermal Efficiency	Final Score
Weight	2	3	3	4	3	4	
Gas Turbine	3	3	5	4	3	2	63
Reciprocating Engine	4	4	3	3	4	3	65
Steam Turbine	1	2	1	1	2	5	41

Analysis of System Alternatives

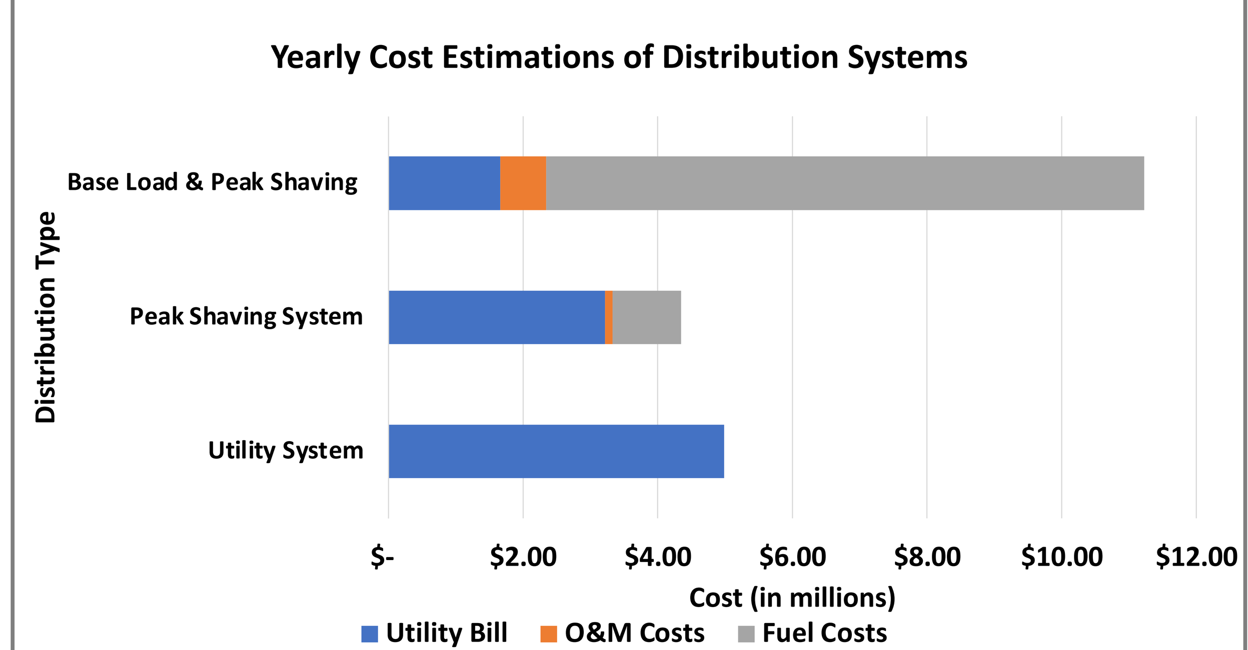
The **utility system** receives all electricity from the utility and doesn't use any on site generation.

The **peak shaving system** generates electricity whenever the campus demand surpasses a predefined peak value.

The **peak shaving system with base generation** uses a combustion turbine to generate a constant base power, and a REG for peak shaving during peak times

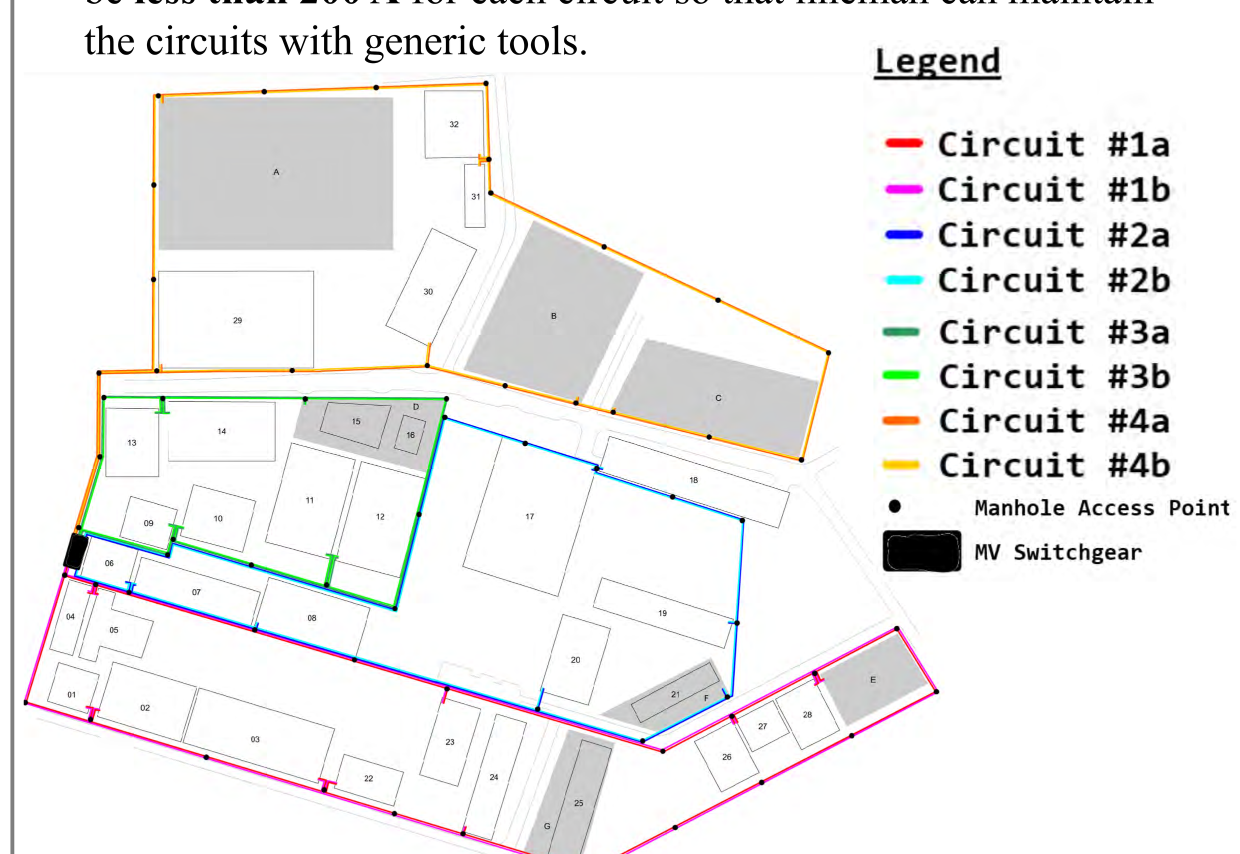
Conceptual Calculations

Dominion Energy's GS-4 Schedule (Large General Service Primary Voltage) was used to calculate the utility bills. After determining the fuel and O&M costs for each system, the **Peak Shaving System** was deemed the best.



Feeder Cable Layout

Customer load data was analyzed to determine the demand of the buildings on the campus. The line ampacity was designed to be **less than 200 A** for each circuit so that lineman can maintain the circuits with generic tools.



Construction Cost

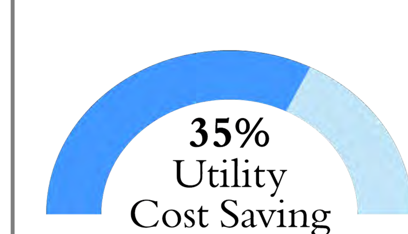
The total construction cost of the system including building materials, equipment, installation and labor was determined to be **$4,792,645.67**

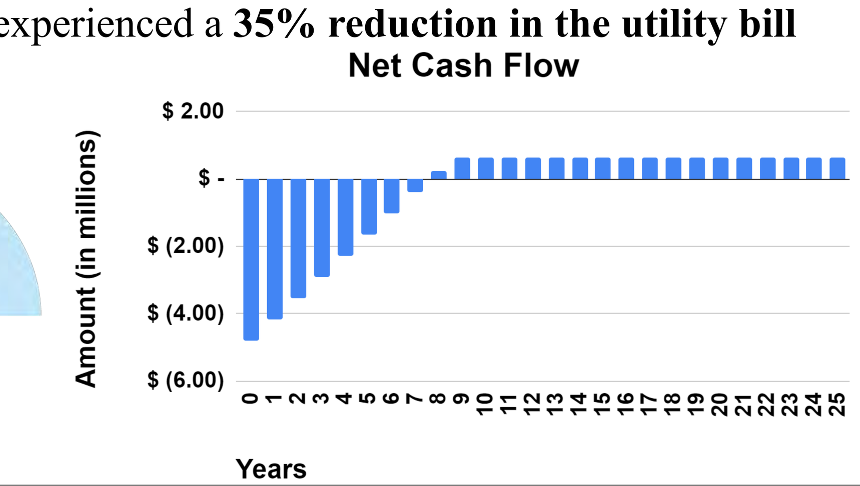
Life Cycle Cost Analysis

The annual cost to operate and maintain the system including fuel cost was determined to be **$4,340,000**

Using **$640,000** as annual payment from peak shaving utility cost savings, the simple payback period was calculated as **8 years.**

The system campus experienced a **35% reduction in the utility bill**





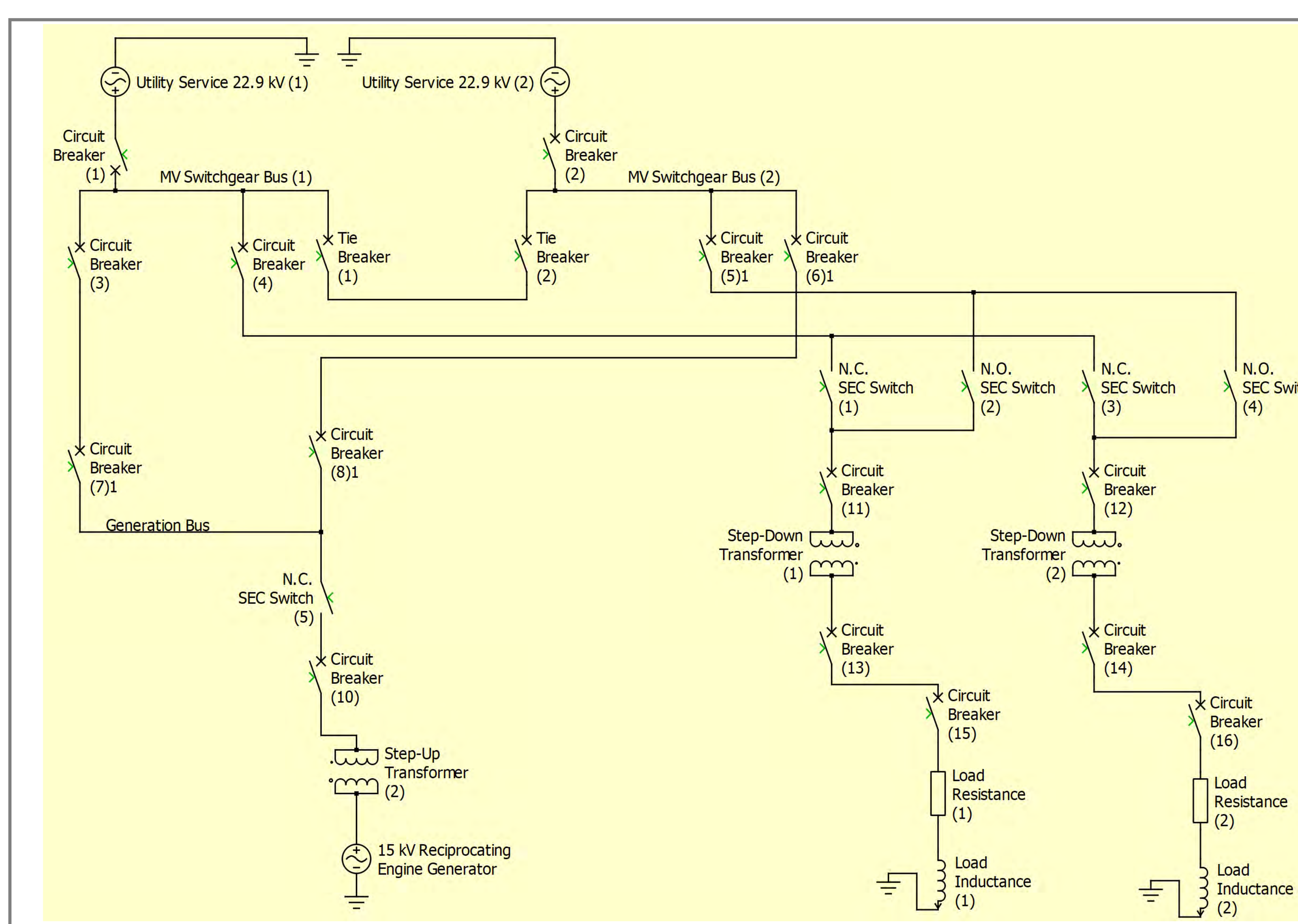
Conclusions

- System Layout: Looped Primary Selective
- On-Site Generation: Reciprocating Engine Generator
- Utility Rate Schedule: Flat-Rate with Peak Shaving

- The system:
  - Met future demand growth by predicting load data for the next 25 years
  - Is resilient by way of the looped primary selective topology
  - Accounted for the capacity of the chillers by including current loads when determining future load demand.

Acknowledgements

The Campus Electrical Distribution Planning team would like to thank Wiley|Wilson for sponsoring this project, the customer point of contact Dan Morton. The team would like to thank the ECE graduate department, faculty, and staff at Virginia Tech; our Subject Matter Expert Minh Ngo for his continuous advice and guidance, Dr. Jaime De La Ree for his consultation, and our mentor Professor Toby Meadows for his direction and feedback throughout this Senior Design process.



Single-Line Diagram

The importance of the single line diagram is to show the physical layout of the generation equipment, circuit breakers, transformers, and switches from the substation to the customer.

Sample student project teams posters

VIRGINIA TECH

Vaccine Pickle

Created By: Abel Thomas, Dhwan Wanjara and Mayank Hirani

Project Description

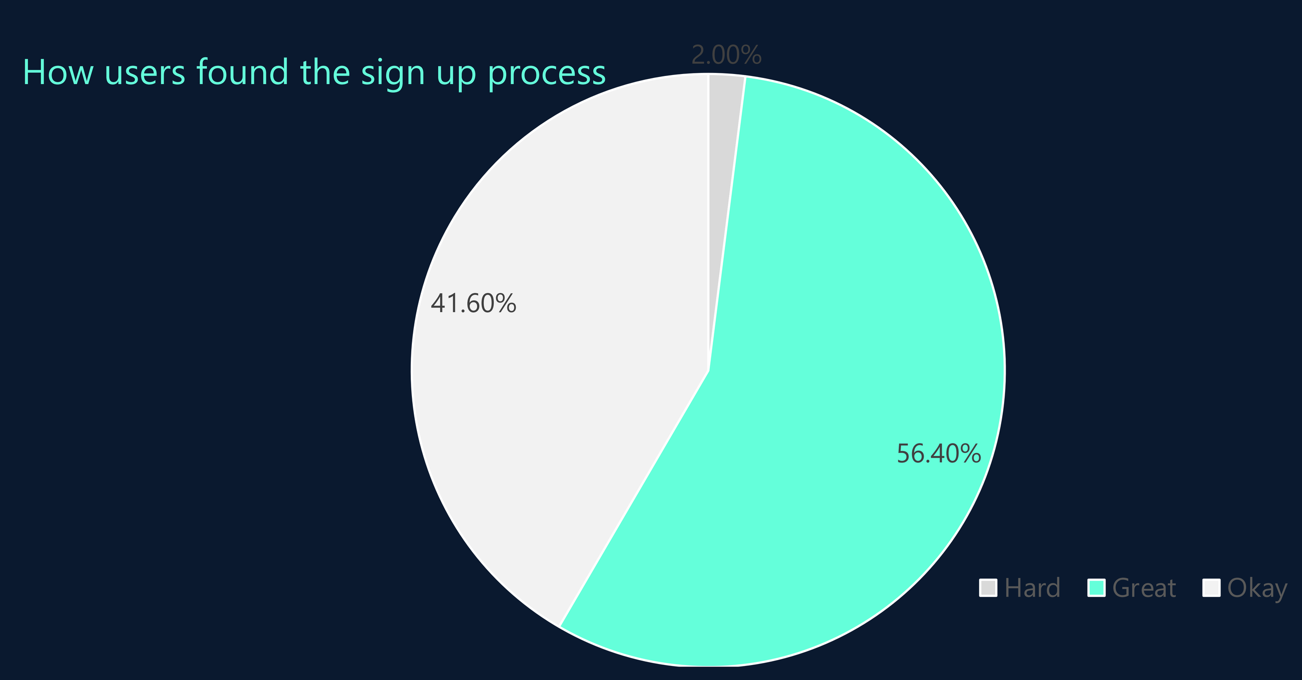
Vaccine Pickle is a web application that instantly notifies an individual when a Covid-19 vaccine appointment becomes available within the desired. The user simply signs up and provides their email and the Vaccine Pickle notifies them via email regarding availabilities.

Purpose

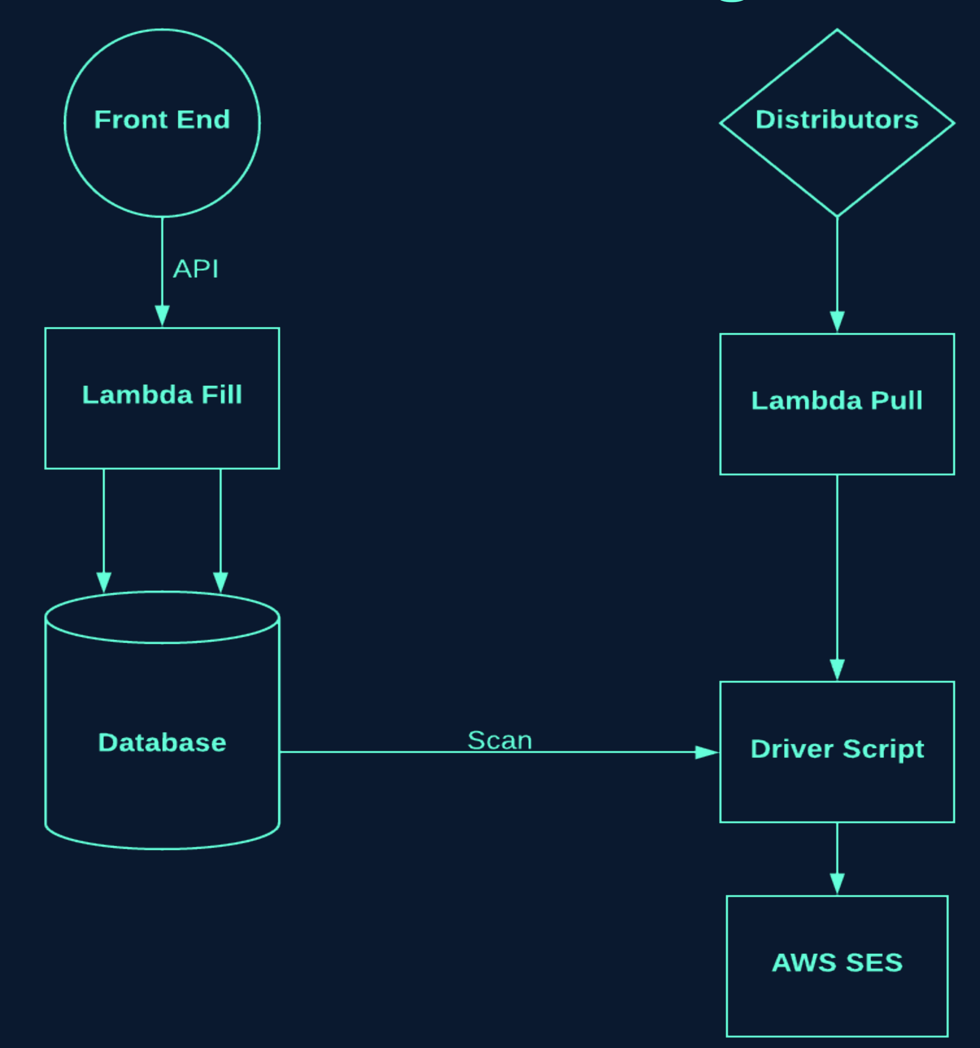
The goal of our project was to bridge the gap between the vaccine distributors and the eligible population and streamline the process of getting a vaccine. There was clear need for a tool like vaccine pickle amid this global health crisis. Vaccine Pickle is UT Prosim in practice.

Approach

Vaccine pickle is centered around the principle of simplicity. This can be seen in our approach to the project. The user interface and experience have been made as simple as possible while allowing users maximum control about the notifications they receive. The chart below shows overwhelmingly that our users found the sign up process easy and appealing.

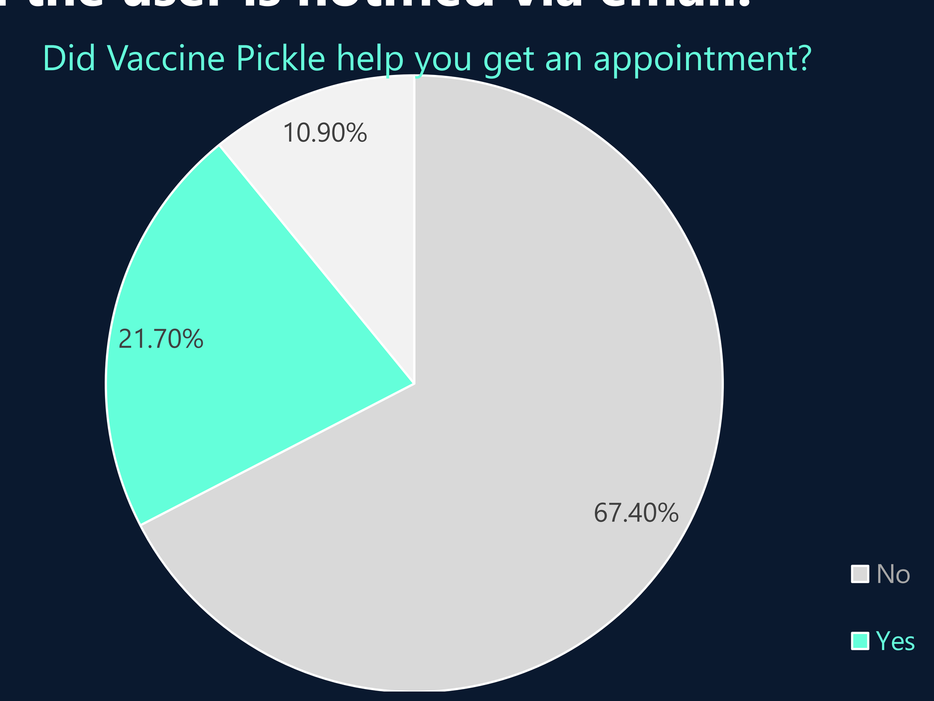


Technical Design



Vaccine Pickle can be dissected into 3 major components.

- The Python script that polls availability of every store then parses it into a geojson object.
- The simple and easy to use front end that collects user data and stores it in our database.
- The notification script which cross-references the user requests to current availability, If the requirements are met then the user is notified via email.

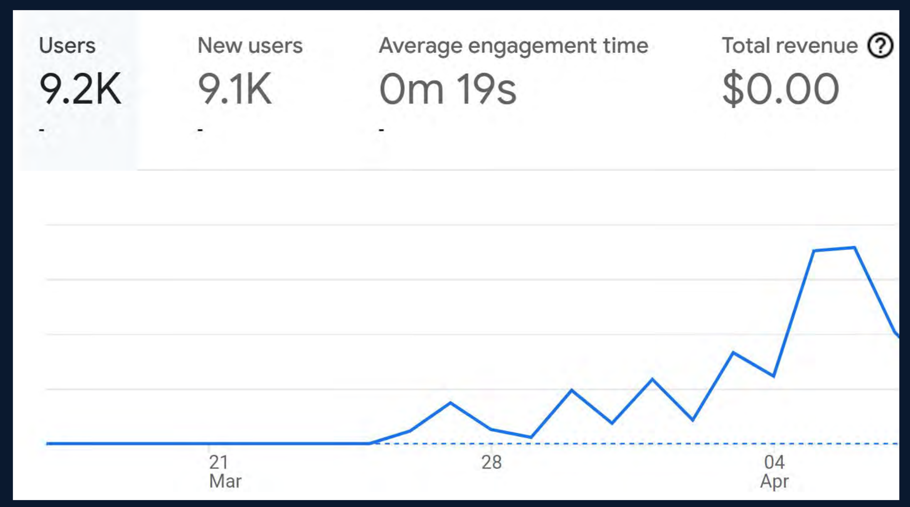


Challenges

A significant challenge we faced in developing Vaccine Pickle was to make this application scalable. Some decisions we made in the infancy of the project like using the gmail api and poor database practices stunted our progress. However, investigating and improving these bottlenecks has helped us significantly improve Vaccine Pickle

Conclusion

Since the beginning of our official launch, we've had over 2,000 subscribers to our application. 40 percent of those users obtained appointments through our application. From our Google Analytics we've had over 9,200 users. Overall, we have been successfully able to fully implement a web application to help others obtain a vaccine



Future Study

We plan to continue adding more distributors and streamlining the process of getting a vaccine. We are currently in the process of allowing users to select specific vaccines types and time slots. In the future we plan to implement a predictive model that notifies users of vaccine availability in advance.

Acknowledgements

Our team would like to thank Dr. Cooper and ECE department for giving us the opportunity to present our project.

Land Traversing Robotics Platform (LTRP)

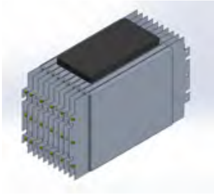
Michael Yanoschak

Introduction

This project started as an interest in off-road robotics platforms with applications ranging from disaster relief to defense. Using these robots as inspiration, the main challenge was to design a capable robotics platform that could be adapted for these roles in the future, while remaining cost-effective.

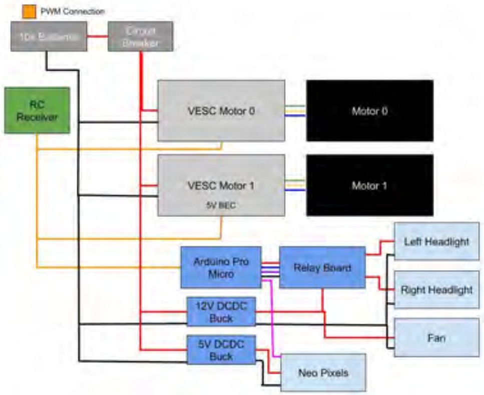
Design Requirements

- Robust and simple drivetrain
- Easy access for maintenance
- High torque powertrain
- Large battery capacity
- Expandability of both mechanical and electrical systems



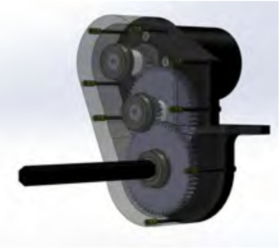
Drivetrain Information

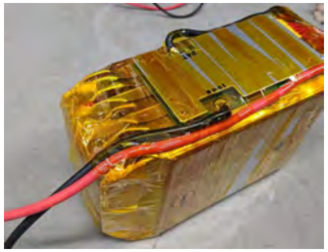
- Chassis made from 6061-T6 aluminum bolted and riveted together for ease of maintenance
- Six 10” pneumatic wheels connected with 20mm HTD5 timing belts
- Center wheels lowered ¼” relative to outer wheels for maneuverability
- 3D printed parts for pulleys, bearing blocks and wheel hubs
- Thirteen minutes of total time to replace a belt or pulley



Powertrain Information

- Locomotion enabled by two 6374 190KV brushless motors
- Geared down using two-stage gearboxes with a gear ratio of 9.68 to 1
- 2.1kW of continuous power and 7kW peak power
- Hall Effect sensors enable the robot to optimize torque





Batteries

The power source for this robot is comprised of two 8Ah 10s Lithium-ion batteries. The batteries are hand-assembled using recycled hybrid-electric bus pouch cells. The cells are capable of 200A of continuous discharge, but are monitored by 45A BMS’s that ensure the batteries are safe. The safety features include over-discharge, over-charge, over-current and cell balancing.

Control System

Two VESCs control the brushless motors that provide 50A of continuous current as well as 150A of burst current. The Hall Effect sensors detect motor position to provide optimal torque at any speed. Velocity curves can be set and read by the Hall Effect sensors which allow for multi-terrain usage and to set a holding torque.

Control signals are sent using an RC transmitter and receiver that use standard PWM communication protocol. The Embedded Systems class (ECE 2564) provided a foundation of what PWM is as well as what Duty Cycle is. At the current stage of development, the drive signals are mixed on the RC transmitter, but in the future could be mixed onboard using a microcontroller to enable better drive fidelity.

The onboard microcontroller interpretes different channels of the RC receiver to control the onboard lights by timing the high period of the RC PWM which ranges from 1ms to 2ms. The headlights can be sequenced using the two relays on board and the LEDs on top can be addressed individually.

Issues and Failures

The biggest issue faced during this project was caused by the electrical noise produced by the phase wires of the brushless motors. Originally, an ODRIVE motor controller was used because of its capability to drive two motors simultaneously. A single circuit board was desired as it makes manufacturing easier while also appearing more aesthetically pleasing. However, the electrical noise caused by the motor phase wires’ proximity to the Hall Effect sensors would crash the ODRIVE. This was fixed by switching to the VESCs.

The mechanical issues have been caused by the failure of 3D printed parts breaking under high-stress conditions. These failures are resolved by re-printing at a higher infill density to increase the allowable strength of the parts.

Future Plans

As this robot was designed with modularity in mind, there are improvements that can and will be done. Currently, a new battery pack design is being developed that will enable the robot to have a longer run time as well as lowering the center of gravity for better stability.

Smaller subsystems that can be mounted on top have also been considered which include, but are not limited to, a robotic arm to pick up material, and possibly a gyro-stabilized turret that operates relative to the robot.

Contact Information

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Linkedin: https://www.linkedin.com/in/michael-yanoschak

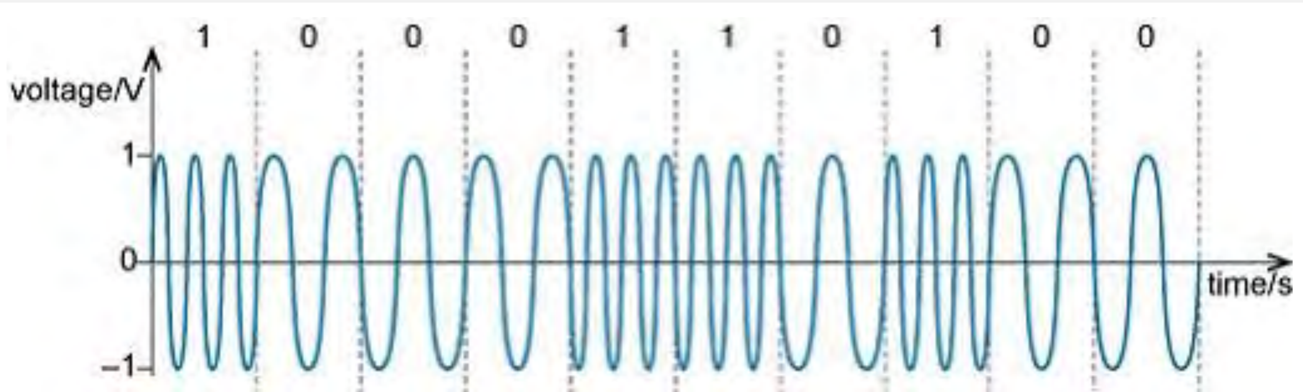
915MHz Radio Weather Station and Frequency-Shift Keying Demodulation

Evan Allen, Daniel Stover
Virginia Tech Department of Electrical and Computer Engineering
ECE 2804 Sophomore Integrated Design Project

INTRODUCTION / BACKGROUND

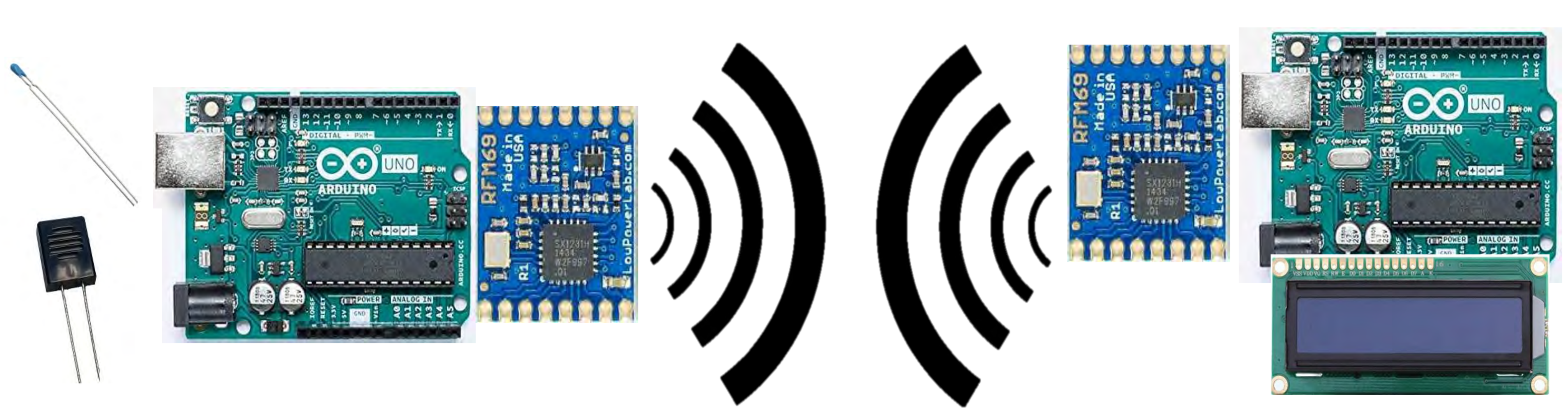
Motivation. Transmitting and receiving data over a long distance has many important applications in the modern world. Packaging digital data into radio signals is a common method of sending information over a long distance. We chose to build a weather station because it was a suitable implementation for learning about radio communications, as it enabled us to send weather sensor data from one location to another using a frequency-shift keying (FSK) modulation format centered at 915MHz for the data.

915MHz frequency-shift keying (FSK). FSK is a modulation scheme that represents a binary 0 and 1 with two different frequencies, as depicted in the image below. For our transceivers, each bit is represented by the frequencies that are 250kHz above/below 915MHz.



Frequency Shift Keying Diagram [1]. Different bits (or groups of bits) are encoded as different frequencies.

OVERVIEW



Sensor Station
NXRT15XV103FA1B040 thermistor
HS12SP humidity sensor
Arduino Uno
RFM69 915MHz radio transceiver

Receiver Station
Arduino Uno
RFM69 915MHz radio transceiver
LCD1602 liquid crystal display

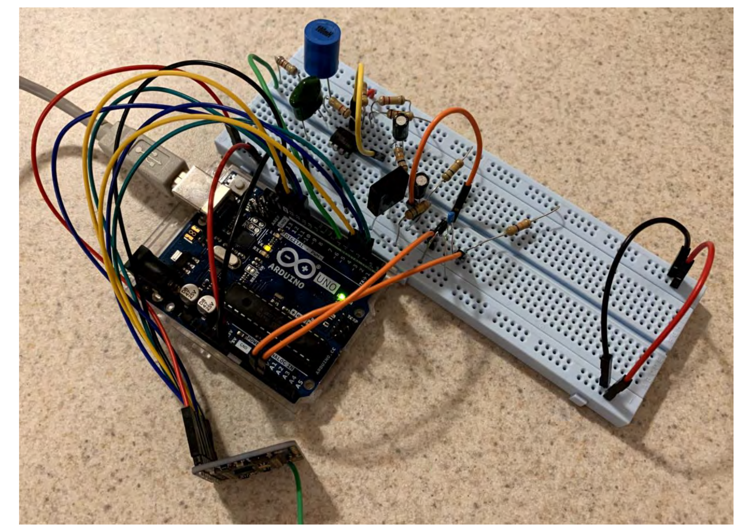
We split our system into two main stations: a **sensor station** and a **receiver station**. They communicate using RFM69 radio transceivers.

Sensor station. The sensor station measures temperature and humidity from onboard sensors and then broadcasts that information at 915MHz using frequency-shift keying (FSK).

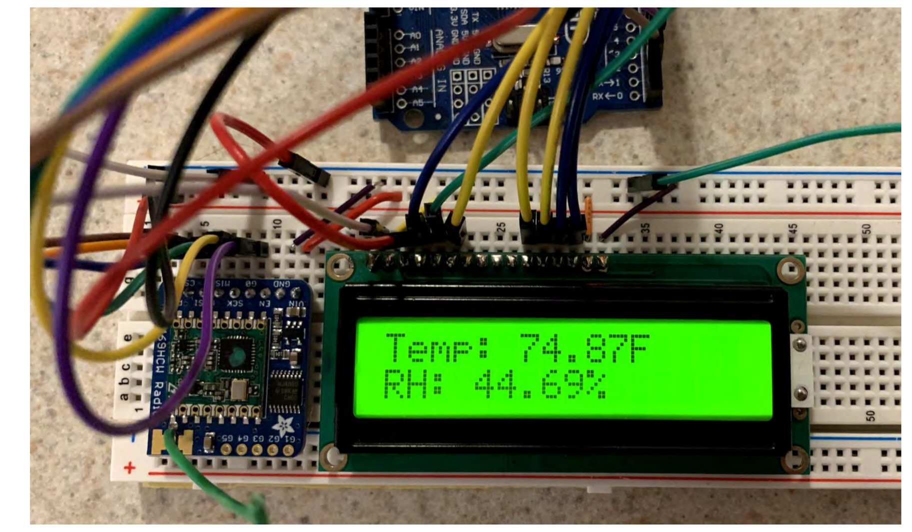
Base Station. The base station receives these broadcasts and displays them on an LCD screen.

MATLAB Demodulation. We also intercepted these communications with a software-defined radio (SDR) and demodulated them in MATLAB.

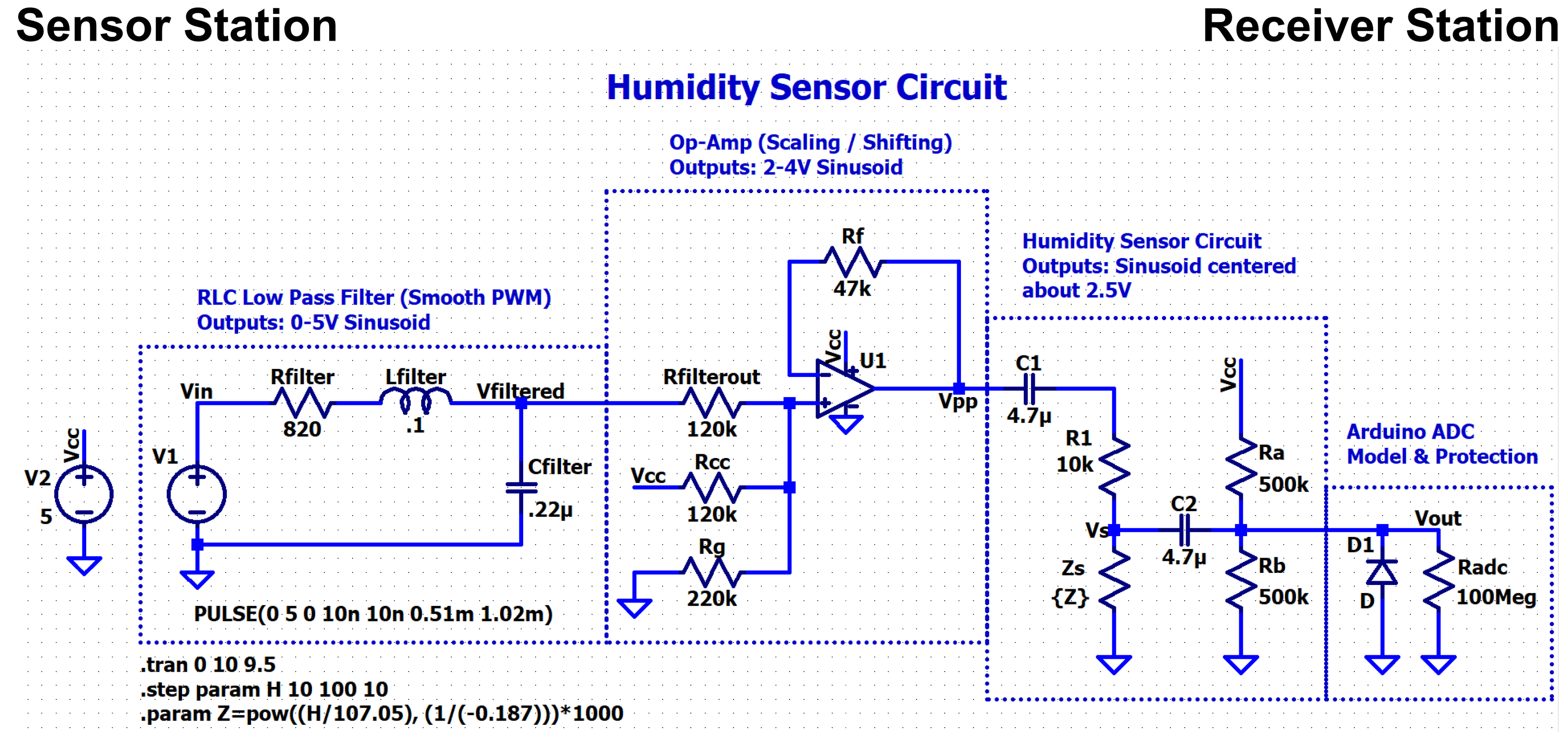
SENSOR AND RECEIVER STATIONS



Sensor Station



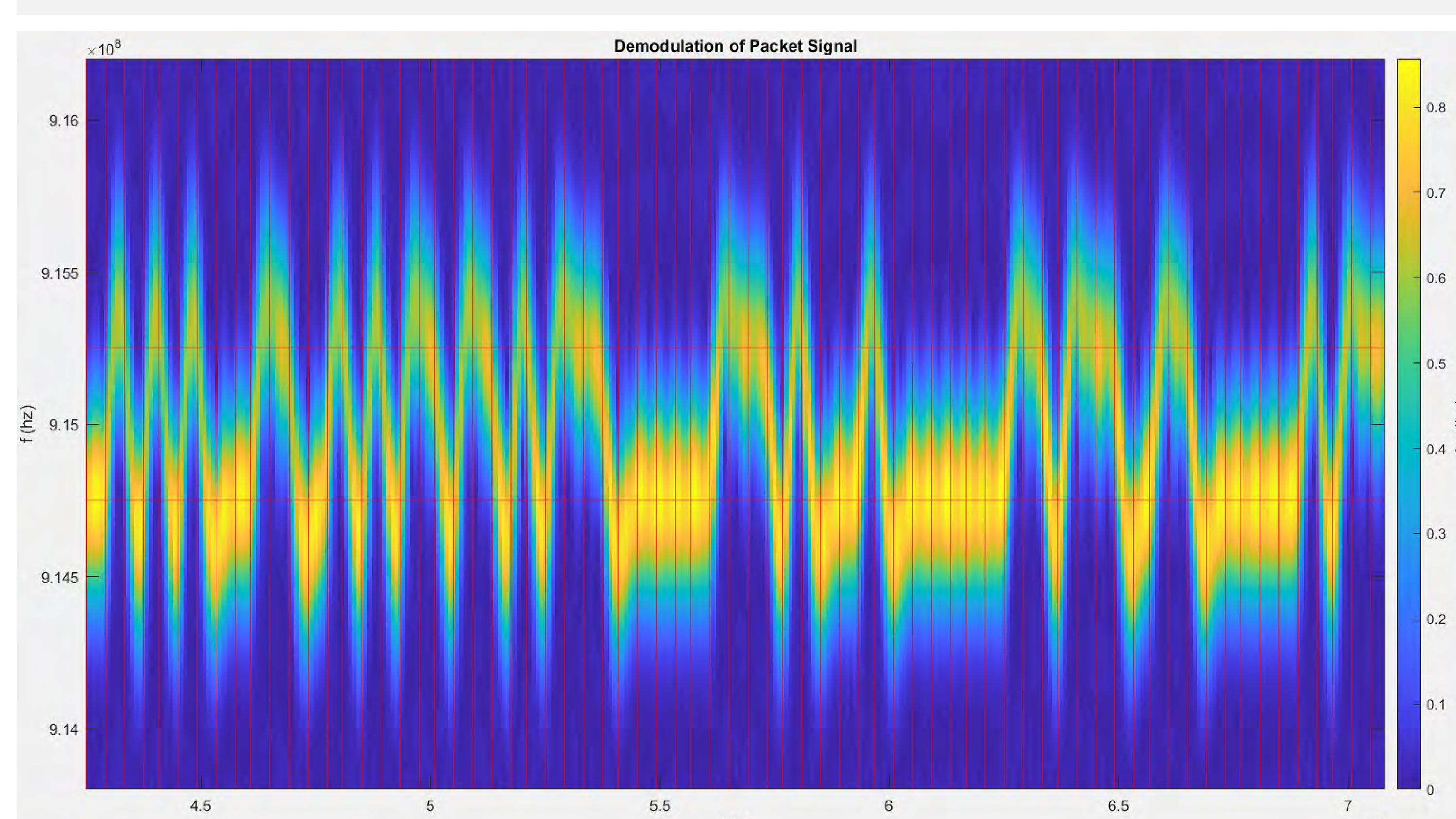
Receiver Station



RADIO SIGNAL DEMODULATION

We captured a FSK radio transmission from our system and demodulated it in MATLAB via the following steps:

1. We sliced out the signal itself and then plotted it as a spectrogram (shown below).
2. We sampled it at the signal's bit rate and recorded a 1 or 0 depending on which frequency the signal was highest at. This stream of bits represent a single sent packet.
3. We extracted the "data" portion of the packet and converted it to ASCII characters to reveal the original message (see top right).



RESULTS

Weather station. Our final system met all project specifications we defined early in the planning phase. This includes a functional weather station that displays the temperature and humidity measured by the distant sensor station, as shown in the Transmitter and Receiver Arduino serial monitor output images below.

Signal MATLAB demodulation. Our MATLAB script demodulated a raw radio FSK packet received by the SDR. The decoded message is shown below in the MATLAB Demodulation Output image.

Transmitter:

```
Temp: 74.09F, RH: 44.69%
Sending Temp: 74.09F, RH: 44.69%
Got a reply: Got: Temp: 74.09F, RH: 44.69%
```

Receiver:

```
RFM69 radio @915 MHz
Received [24]: Temp: 74.09F, RH: 44.69%
RSSI: -26
Sent a reply
```

MATLAB Demodulation output:

output_str
1x24 char
1
1 Temp: 70.62F, RH: 34.36%

CONCLUSIONS

Relevance. As a sophomore integrated design project, this hands-on engineering design challenge gave us the opportunity to apply the circuit analysis, signal processing, and programming techniques we have been learning this year in the ECE sophomore curriculum.

Future plans. We currently plan to continue development of our system in the upcoming future. These plans mainly include designing and manufacturing a printed circuit board (PCB) for our sensor station circuit to replace the Arduino and breadboard.

Takeaways. Throughout the project, we learned how to design second order filter circuits, op-amp circuits, as well as radio signals/modulation and FSK demodulation.

REFERENCES

[1] "Exploring communications technology," *OpenLearn*. [Online]. Available: https://www.open.edu/openlearn/science-maths-technology/exploring-communications-technology/content-section-1.5. [Accessed: 19-Apr-2021].

Audio Direction Finder

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INTRODUCTION

Identifying the direction of a signal is a very useful bit of information. This knowledge is needed in many situations, from signal reconnaissance in national security tasks, to beamforming signals in 5G networks.

During the spring 2021 semester, our group was tasked with designing an audio direction finder that locates a 1 kHz audio source for the ECE 2804 Integrated Design Project course. Throughout the semester, we devised an approach for estimating sound direction and built a device to perform this task. We also created PCBs which integrate our breadboard prototype into a small, handheld unit.

This poster recaps the work we did during this project as well as what we learned in the process.

DEVELOPMENT

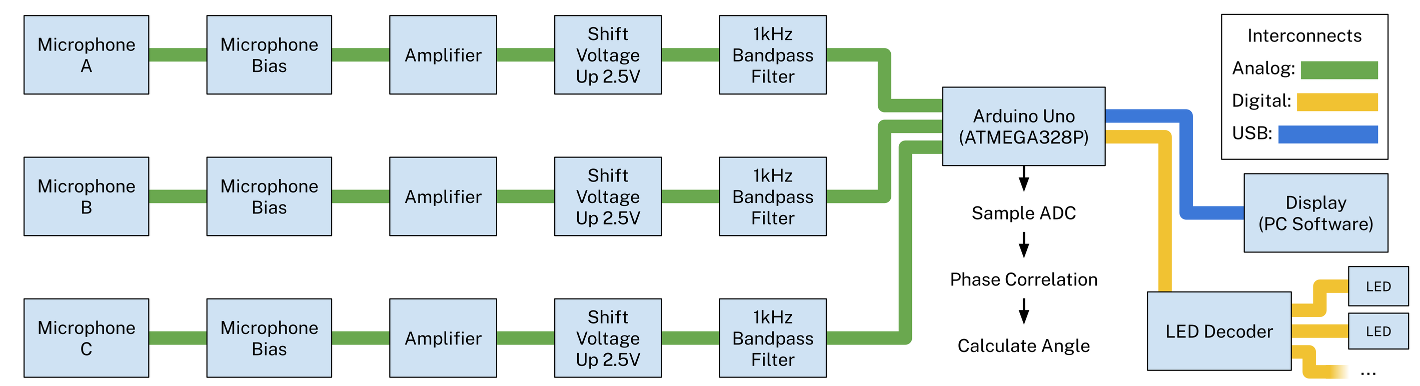
We approached this project in a structured manner, dividing the progress into three individual milestones spread throughout the spring semester. Each milestone focused on a different subsystem or aspect of our device. A block diagram depicting each subsystem can be seen above. Our milestones were:

- Milestone 1: Bandpass Filter, Microphone Biasing, Analog Amplifier
- Milestone 2: Arduino Software, I/O Expansion for Display LEDs
- Milestone 3: PCB Manufacturing, Software GUI, 3D Printed Housing

Our development began with the creation of the analog circuits including the microphone bias, signal amplification, and bandpass filter system. Each circuit was modeled on LTSpice.

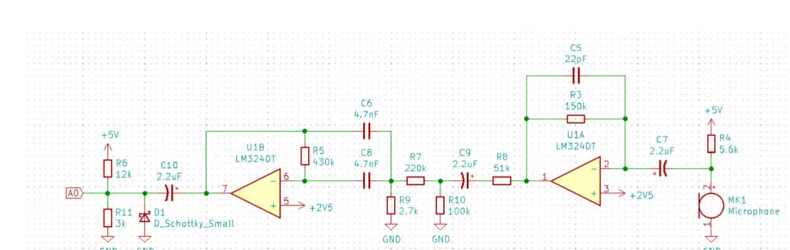
We then developed the Arduino software needed for calculating the phase difference between the three electret mics. The Arduino used its hardware timers for a consistent sampling rate and performed a discrete Fourier transform to determine the phase shift between each channel. The display was also being developed at this point, controlling the LEDs with a 3x8 decoder as the Arduino did not have enough I/O ports for individual LED control.

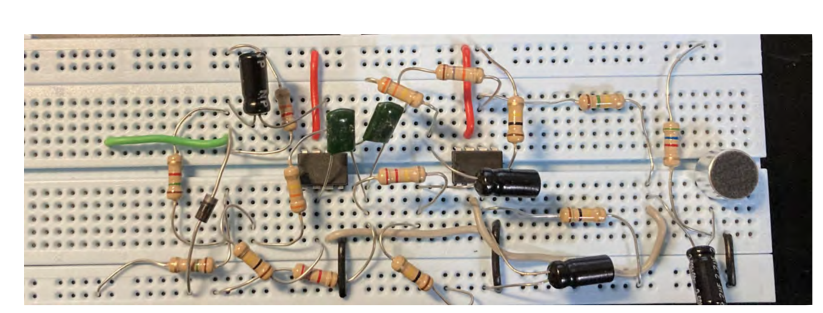
In the final stage of the project, PCBs of our design were manufactured and assembled. During testing, we noticed the UART lines between our USB chip and MPU were flipped, so we cut the wires in the board and soldered new wires on top. A GUI for viewing the output of our devices was developed with Processing. We also modeled a 3D printed housing for keeping the boards together and protected. These both can be seen to the right.

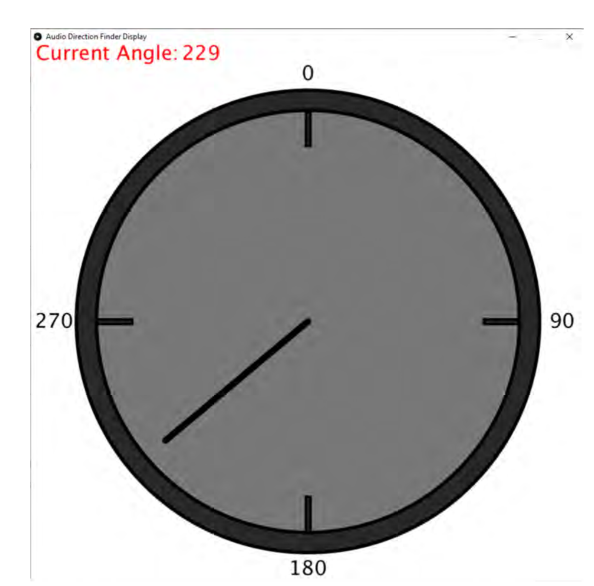


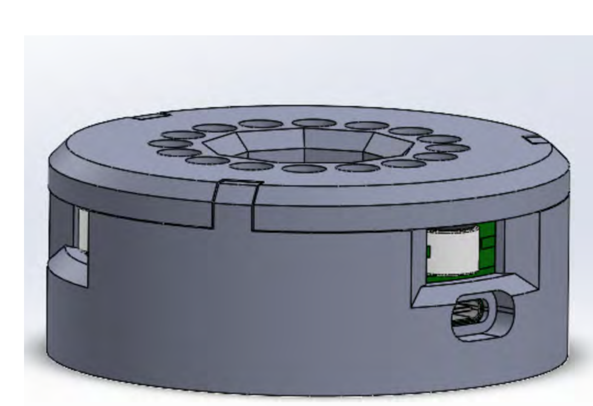
TESTING

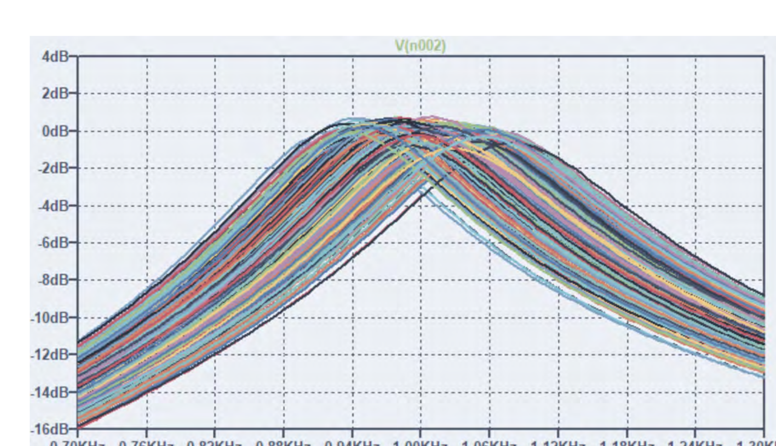
To test our various circuit designs, we simulated them in LTSpice. To account for part tolerances, all of our audio components were simulated with Monte Carlo methods to make sure we were not relying too much on the properties of ideal components. A simulation of our bandpass filter can be seen below. Once the results from simulation seemed acceptable, physical prototyped were created on breadboards. These physical models were then tested using the Analog Discovery 2 Oscilloscope kits. Our final audio signal circuit can be seen below in both breadboard and schematic form.





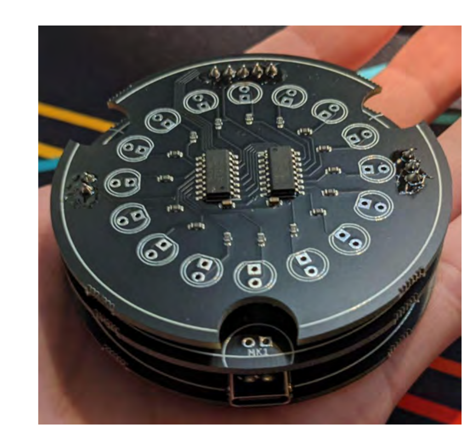


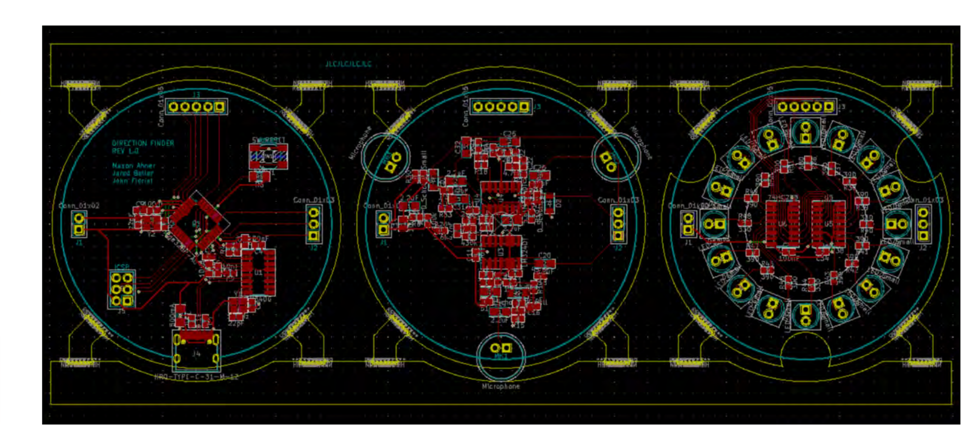




PRODUCTION

Once our designs were tested and verified, all circuits were modeled in KiCad. This included three copies of the audio system, the display circuitry, and a full replacement for the Arduino, based on the same ATMEGA328P MPU. Three separate schematics were created for each system and then they were routed into three circular boards. The three boards were panelized into one for manufacturing and then the panel was sent to JLCPCB in China for manufacturing and SMT assembly. After a bit more than a week, the boards arrived and we soldered on the remaining through hole components, such as the LEDs and pin headers. After fixing the aforementioned UART issue, the boards were flashed with the Arduino bootloader and then our code was up and running, after a few of the port numbers were changed around.





CONCLUSION

The final result was a functioning device that could successfully locate the direction that a 1kHz audio source is emanating from. The device was not quite as accurate as we hoped, but when only looking at the display board, the 16 LED resolution hides most of the jitter.

Through this project, we learned many things. Working as a team during the pandemic was tough as we were only able to meet in person a few times throughout the hole project. Despite this limitation, using the internet we were able to stay in touch and collaborate even if we couldn't meet. This project also allowed us to apply many of the concepts from our signals and embedded systems classes. Such as the frequency domain, Nyquist-Shannon sampling theorem, communication protocols, and hardware interrupts. Finally, the experience of designing and ordering custom PCBs was a brand new experience for us. Through this project, we gained valuable skills that we hope will help us not just later in school, but also in our future careers.