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Virginia Tech ECE

Two-semester Major Design Experience (MDE)

December 3rd, 2020

VIRGINIA TECH™

The Major Design Experience provides each of our participating students a culminating project experience. Each student contributes their collective knowledge and skills as part of an engineering project team to solve meaningful challenges for an exciting, real-world project. This year, these students met with challenges (and opportunities) well beyond any we programmed or intended for them due to the global pandemic. These students completely reworked and revised their entire project plans when they were instantaneously required to work remotely and separately for most all of their project. Their post Spring Break realities required them to rapidly re-establish remote, distributed communications; and conduct detailed project planning and re-factoring to ensure they could complete their projects under unfavorable conditions. Each team developed two project plan alternatives for completion of their projects. Teams conducted remote video meetings, planning, and work sessions to share expertise and guide remote operations. Some shipped parts back and forth. While these are not our intended plan, the students thrived and rose to meet the challenges with a resilience that is impressive.

This year's Expo event is a synchronous, virtual event seeking to celebrate these students and their projects. We still seek to showcase the teamwork, communications, project management, and engineering prowess of 30 students across seven projects; we also seek to highlight their adaptability and resilience. Every team planned and produced an interactive, virtual project poster session and a technical presentation of the success of their project results. Some are well beyond what we thought could be achieved under COVID-19 conditions, and some will include discussion of remaining work. These students are our collective contribution to the next generation of engineers; ready to overcome the global challenges of tomorrow.

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

Congratulations to each of the students; their dedication and diligence are evidenced in these seven 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 *(virtually)* to the Bradley Department of Electrical and Computer Engineering Major Design Experience Expo. The 2020 Fall Exposition provides us the opportunity to celebrate the achievements of 30 ECE students who found responsible means to come together on seven project teams under extraordinary conditions. These students have demonstrated a resilience and an ability to react to unplanned risks well beyond any exercise we could ever incorporate into the program. Mere weeks after receiving their project assignments, most every aspect of their professional plan and environment changed. What you see at this Expo is the result of deliberate risk mitigation planning and driven execution under formerly inconceivable conditions. These students have truly proven their readiness to rise to world challenges.

A key element of the 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 class did not receive that. The students were unexpectedly geographically dispersed and limited in their access to materials and equipment. Rather than stop work, the students refocused their efforts to re-establish communications, inventory and account for their people, and their projects. These teams developed alternative strategies for the build, test, and deliver phases of their projects. This is by no means, the MDE experience we intended for the students, but this class understands risk and mitigation in ways previous classes only read about. The students adapted; they shipped equipment among sites; conducted planning, development, testing, and customer meetings via Zoom. They created shared collaboration sites and many thrived… producing well beyond expectations.

The students could not have adapted and delivered without the tireless efforts and support of our SMEs and Customers. MDE is made possible with the dedicated support of our sponsors and subject matter experts whom we offer our most sincere appreciation and this semester amplifies this reality. Thank you for your commitment to shape and enhance the Virginia Tech ECE students as they prepare for next stage of their journey to make the world a better place by engineering and delivering meaningful solutions no matter what challenges they may encounter.

The MDE program would like to thank Luke Lester his vision to establish the MDE program and for his continued support in the most strenuous conditions. 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: Well done!!! You didn't ask for a culminating experience in this context, but you have met many challenges and you are ready for your next great experience! Boldly take the next step forward and invent the future as only ECE Hokies can!!!

J. Scot Ransbottom
Major Design Experience Director

Sponsors

We greatly appreciate their support.

PROJECT SPONSOR: THE AEROSPACE CORPORATION: JOHN JANESKI, HANNAH WEIHER, HOWARD GE

PROJECT SPONSOR: BRIAN WALTER

PROJECT SPONSOR: ARMY NIGHT VISION: CLINTON FARRELL

PROJECT SPONSOR: GENERAL MOTORS

PROJECT SPONSOR: KEVIN SHINPAUGH

PROJECT SPONSOR: ZETA ASSOCIATES: MICHAEL DRESCHER, STEPHEN KRALICK

PROJECT SPONSOR: VIRGINIA TECH GRADO DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING (VT ISE): ANDREA L'AFFLITTO

Agenda

3:00	Registration & Poster Session/Networking
3:10	Welcome – Fall 2020 Virtual MDE Expo
	Poster Sessions & Networking (Ongoing Throughout)
3:30-5:15	Team Project Presentations

3:30	SIMformation sponsored by General Motors
3:45	Passive Range Finder sponsored by Army Night Vision Lab
4:00	Vibration Monitoring System sponsored by Altria
4:15	Factory Robotics
4:30	Small Satellite Navigation Sensor by The Aerospace Corporation
4:45	Personal Locator Beacons System by Zeta Associates
5:00	NASA Big Idea

5:30	Final Voting & Tabulation
5:45	Awards Announcement
6:00	Celebrate MDE student teams' success!!!

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)
Altria, Richmond, VA	Brian Cramer	Vibration Monitoring System	Lynn Abbott
Army Night Vision Lab, Ft. Belvoir, VA	Clint Farrell	Passive Range Finder	Peter Han
General Motors, Detroit, MI	Keith Van Houten	SIMforation	Tim Talty
NASA	Kevin Shinpaugh	Big Idea	Greg Earle
The Aerospace Corporation	John A Janeski, Howard Ge, Hannah Weiher	Small Satellite Navigation Sensor	Greg Earle
Virginia Tech ECE & Virginia Tech ISE	Matt Earnest	Factory Robotics	Andrea L'Afflitto
Zeta Associates, Fairfax, VA	Michael Dresher, Stephen Kralick	Personal Locator Beacons System	Louis Beex

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

Director of Instructional Labs
Design Studio Safety Training and Material Procurement Instruction

Grant Brewer

Virginia Tech - LINK | The Center for Advancing Industry Partnerships

Executive Director of LICENSE
Office of the Vice President for Research and Innovation

Vibration Monitoring System

CHALLENGE

Develop a multi-sensor array for collecting vibrational data from factory machinery and, through analysis of this data, identify anomalies in the vibrational patterns.

LEFT TO RIGHT: Derik Arone, Shuhao Hu, Fengpei Gao, Stefan Moritz | **SME:** A. Lynn Abbott

Derik Rangel Arone

Shawsville, VA

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

Aspirations: My career aspiration is to work as a project engineer at a manufacturing company.

Class comment: I appreciated the experience of working with a real customer on a product that they could actually use as well as the opportunity to work with a team to reach that goal.

Shuhao Hu

Changchun, Jilin, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: My goal is to work in the field of power electronics.

Class comment: This class gave me a chance to solve a real-world problem and gain experiences from the professor and our customer. I am also glad to have had the chance to work in a team and improve my skills throughout the project.

Fengpei Gao

Kunming, Yunnan, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: After I graduate, I want to keep studying to earn a masters degree and find a job as an electrical engineer.

Class comment: I appreciated the professional experience provided by this course, which gave me a chance to work with a team on a real-world problem. Additionally, this course helped me learn some useful and important skills like how to write proposals, customer reports and progress reports; moreover, the course gave me good experience dealing with customers and teammates.

Stefan Moritz

Roanoke, VA

Bachelor of Science in Computer Engineering and Bachelor of Science in Electrical Engineering
Machine Learning

Aspirations: I hope to help solve the issues associated with embedded machine learning systems, including overcoming the constraints of time and space realized by many devices.

Class comment: This class showed us the difficulties we will encounter in a project in the real world, from bidding to delivery. It also made clear my own shortcomings and has inspired me to be better.

PROJECT SPONSOR: BRIAN WALTER

Altria

Army Passive Range Finder

CHALLENGE

Design and develop a product capable of determining the range of a target using passive techniques that do not emit radiation. The product must be operable for ranges up to two kilometers and be able to perform at least one range measurement per second.

LEFT TO RIGHT: Cyrus Unvala, Kevin Phelps, Jason Tran | **SME:** Peter Han

Kevin Phelps

Williamsburg, VA

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to pursue a career in the power systems industry. I am most interested in the implementation of renewable energy and distributed energy resources.

Class comment: I appreciated the experience provided by this course that allows students to conduct a real-world project from start to finish.

Cyrus Unvala

San Francisco, CA

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: Upon graduation, I will attend the United States Navy's Officer Candidate School with the intention to commission as a student naval aviator.

Class comment: It was incredible getting experience working with an actual customer and trying to solve a problem by delivering a requested product. It gave me experiences and skills I did not acquire while at internships.

Jason Tran

Falls Church, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: Upon graduation, I wish to delve into the workforce and discover more about the many areas of electrical engineering.

Class comment: I appreciated how this class provided a real-world work setting. This course gave me insight on the interactions that take place in a team environment underneath a company directive.

PROJECT SPONSOR: ARMY NIGHT VISION: CLINTON FARRELL

U.S.ARMY

SIMformation

CHALLENGE

The SIMformation team aims to develop a system for tracking and performance monitoring of General Motor's active safety and automated driving embedded control systems. The system will seamlessly integrate into GM's existing hardware-in-the-loop testing infrastructure.

LEFT TO RIGHT: Mitchell Gerhardt, Ellen Sawitzki, Norm Aaron, Colin Hancock, Ashlyn Pugh | **SME:** Tim Talty

Norm Aaron

Herndon, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to work as an electrical hardware engineer.

Class comment: I found the chance to use what I have learned to solve an actual engineering problem meaningful.

Mitchell Gerhardt

Saratoga Springs, NY

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to leverage my autonomy and robotics experiences to work on sustainable systems that will define how we interact with and shape our planet.

Class comment: This class granted me the opportunity to discuss and employ engineering ethics and social responsibility in a holistic, non-academic manner.

Colin Hancock

North Tazewell, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: My career aspirations are to make a difference in society and have a positive impact. I want to make life easier for others through technology — it could be as simple as wiring a house for someone.

Class comment: This class allowed us to experience real-world problems, and we got to work with a company that provided a professional experience.

Ashlyn Pugh

Salem, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to do meaningful engineering work while also challenging myself and pushing technological boundaries.

Class comment: I appreciated the exposure to real-world problems and valued the guidance from industry leaders and Virginia Tech mentors.

Ellen Sawitzki

Richmond, VA

Bachelor of Science in Computer Engineering,
Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I intend to work in the power engineering field, specifically with renewable energies.

Class comment: I appreciated that this design course sources projects from outside companies, as the format makes the work feel more interesting and worthwhile.

PROJECT SPONSOR: GENERAL MOTORS, KEITH VAN HOUTEN

NASA Big Idea

CHALLENGE

Proof of concept for a laser power transmission system. This project involves the development of an effective method of remotely delivering power to the rover and any additional systems necessary for the operation of the transmission such as tracking or communications.

LEFT TO RIGHT: Mina Shawky, Amir Bigdeli, Hillman Shiner, Ceren Demirayak, Emily Tardell | **SME:** Greg Earle

Amir Bigdeli

Fairfax, VA

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I am a senior electrical engineering student with huge interest in circuit design and power electronics. I will pursue my passion for electronics in the space industry where there is no limit to learn and excel.

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

Nebahat Ceren Demirayak

Ankara, Turkey

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to pursue a career in which I can learn and experience more.

Class comment: I appreciated the opportunity to work on a real-world problem as a team and apply what I learned in my classes at Virginia Tech while developing my problem-solving skills.

Mina Shawky

Centreville, VA

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: Launch a startup focused on energy sustainability and then sell it to Elon Musk.

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

Hillman Shiner

Palmyra, VA

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I am looking for a job in the power systems sector, ideally with renewable energy sources.

Class comment: The experience I gained working in a truly professional environment with a very professional group will be extremely valuable in my career.

Emily Tardell

Cooksville, MD

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

Aspirations: I aspire to one day have a fulfilling, full-time career in robotics working for a company that believes that no ideas are too big. I hope to make a difference with the work I do, using my degree to provide solutions to problems people once found impossible.

Class comment: I appreciated the meetings my team and I had with our subject matter expert and customer during the early stages of the project. We were able to discuss all of our ideas, and receive usable and valuable input from professionals.

PROJECT SPONSOR: KEVIN SHINPAUGH

Small Satellite Navigation Sensor

CHALLENGE

Design and characterize a sensor suite that, when integrated, will provide a navigation solution through orbital maneuvers in a 1U size CubeSat. The sensor suite blends outputs from sensors into a navigation algorithm to predict attitude and orientation.

LEFT TO RIGHT: Zach Olson, Michael Rask, Daniel Montgomery, Sam Zabel | **SME:** Greg Earle

Daniel Montgomery

Yorktown, VA

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: I want to use my knowledge of optics and electrical engineering to develop scientific instruments for the good of mankind.

Class comment: I enjoyed applying my knowledge to a real engineering problem and learning the project management to make it happen.

Michael Rask

Shoreham, NY

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I aspire to work on the hardware design side of products or technology for areas such as aerospace and defense.

Class comment: I really enjoyed the type of work that I was able to produce for this project. I have gained a lot of experience here that helped me prepare for my career. I am proud to have produced tangible things to show people in the professional world.

Zach Olson

Manassas, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to pursue a career in the analog field and use my knowledge to design hardware for audio applications.

Class comment: I found it very interesting to design a system that operates in the space environment. The scope of this project showed me how complex real-world engineering solutions can be.

Sam Zabel

Chattanooga, TN

Bachelor of Science in Computer Engineering
and Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I would like to continue down a more software-oriented path in my career. My dream would be to design different software applications for a company.

Class comment: I enjoyed being able to utilize my software skills in a group that consisted of primarily hardware-oriented members.

PROJECT SPONSOR: THE AEROSPACE CORPORATION: JOHN JANESKI, HANNAH WEIHER, HOWARD GE

AEROSPACE

Factory Robotics

CHALLENGE

Implement an autonomous robotic system that interfaces with a ground vehicle and a microcontroller to deliver parts within an Industry 4.0 environment.

LEFT TO RIGHT: Yuqing Liu, Seth Rose, Teddy Gizachew, Robert Velasco, Steve Kim | **SME:** Andrea L'Afflitto

Tewodros Gizachew

Alexandria, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: After graduation, I want to work with high-voltage and control systems.

Class comment: I appreciate the knowledge I got from the hands-on project.

Steve Kim

Centreville, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to do meaningful work and to be able to use what I learned at Virginia Tech to solve real-life problems.

Class comment: The class pushed me to work beyond my comfort zone and adapt to a changing environment that cannot be experienced in a typical class.

Yuqing Liu

Baoding, Hebei, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: My current research direction is computer architecture and computer systems.

Class comment: I was able to work with great teammates.

Seth Rose

Somerset, PA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I aspire to have a career with a company that allows me to travel all over the world and make a difference.

Class comment: This class is the culmination of everything I've experienced at Virginia Tech. Conducting professional conversations, working hand-in-hand with teammates with various skills, memorable experiences, and demanding but invaluable work.

Robert Velasco

Arlington, VA

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

Aspirations: I aspire to work with autonomous robotic systems in my career, applying both my electrical and computer engineering skills to solve problems.

Class comment: I am most grateful for the real-world problems that we faced in this project and that we were introduced to in this class. The design process and many written assignments prepared me well for the business world.

PROJECT SPONSOR: VIRGINIA TECH GRADO DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING (VT ISE): ANDREA L'AFFLITTO

Personal Locator Beacon System

CHALLENGE

Our goal was to design and create two small lightweight beacons that, when activated, will be able to send out their current position using the industrial, scientific and medical (ISM) band and no more than 1 milliwatt of power. Simultaneously, a receiver will be able to pick up the signal from at least one hundred meters away.

LEFT TO RIGHT: Donald Zimmerman, Hanna Kim, Connor Schutte, Brian Lam | **SME:** Louis Beex

Ha Young Kim

Centreville, VA

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I want to apply what I've learned throughout my education to better the technology we have.

Class comment: I appreciated the insight on real-world processes this project has brought to my attention. It really opened my eyes to how long and difficult a project can be from start to finish. Zeta provided good feedback on how we were handling our issues and successes, which motivated me to want to do more and be greater.

Brian Lam

Manassas Park, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: Upon graduation, my career aspiration is to become a patent examiner in the field of electrical engineering for the United States Patent and Trademark Office. I hope to fulfill the Office's mission to lead the nation and the world in intellectual property protection and policy.

Class comment: The whole Major Design Experience was meaningful in the sense that it taught me to take everything I've learned at Virginia Tech, both technical and personal experience, and apply it to a real-world issue. The course has also taught me to be ready to adapt to challenges that cannot be taken on alone and that teamwork can solve even the most difficult challenges.

Connor Schutte

Aldie, VA

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to work with electronics and electrical circuit design in the consumer product field.

Class comment: I appreciated the chance to apply what I've learned in my curriculum to a real-world project.

Donald Zimmerman

Ellicott City, MD

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: My current goal is to become a pilot in the marine corps. Further down the road, I am striving to become an astronaut and apply what I learned in school to other sectors.

Class comment: I enjoyed the behind-the-scenes knowledge I gained from this class. You never really hear of work breakdowns, budget sheets, or customer reports in the classroom, and it is valuable knowledge that can translate to many other fields.

PROJECT SPONSOR: ZETA ASSOCIATES: MICHAEL DRESCHER, STEPHEN KRALICK

ZETA ASSOCIATES

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.

Toby Meadows and Ken Schulz
for being our assistant instructors, mentoring teams, and making the class better.

Greg Atkins
for developing an outstanding class website.

Mary Brewer, Nicole Gholston, Kimberly Johnston, JoAnna Lewis, 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 integrating the master's students into our class and providing them with ongoing guidance.

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 and printing the poster papers in quick time.

Special thanks to Amrita Chakraborty
teaching assistant specializing in semiconductor projects, for providing excellent safety, tool, semiconductor processing, and mask design training.

Project posters

Vibration Monitoring System

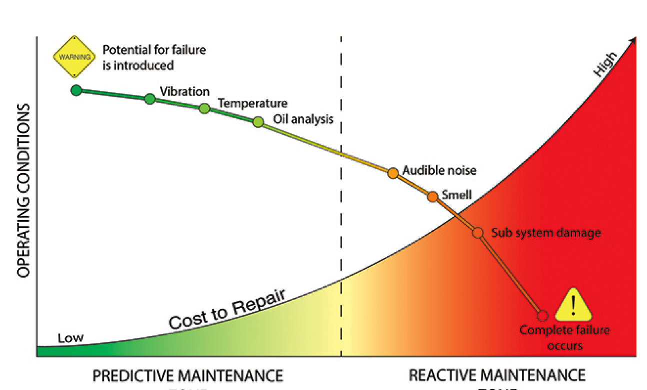
Team Members: Derik Arone, Shuhao Hu, Fengpei Gao, Stefan Moritz
Customer: Brian Cramer, Altria; Mentor: Prof. Kenneth Schulz; SME: Prof. Lynn Abbott

Background

- Vibration is a physical phenomenon that presents itself in any rotating machines and moving structures regardless of the machine's health. Moving parts, such as gears, rolling bearings, and rotating shafts will cause vibration. Vibration can be represented in different forms, including displacement, velocity, and acceleration. To analyze vibration more accurately it is highly desirable to use frequency spectrum analysis. A complex machine will generate a mixture of vibrations; thus, making more difficult to use time domain to examine the condition of the critical components. Frequency analysis decomposes time waveforms and describes the repetitiveness of vibration patterns.

  Vibration is one of the earliest indicator of machinery malfunction (see graph below). For instance, a crack that has developed on a roller bearing outer race will lead to periodic collisions with bearing rollers, which can be hidden to human perception for several months before breaking more critical parts causing downtime for a longer period of time than asserting the issue early.

  As any other manufacturer Altria run numerous machines constantly, which results in machinery malfunction over time. To solve problems earlier and therefore, saving money and reducing downtime, the best method of maintenance is predictive maintenance because it analysis when the next maintenance is needed. Our vibration system will help their staff to predict machine failure early so putting them one step closer to a better maintenance procedure.

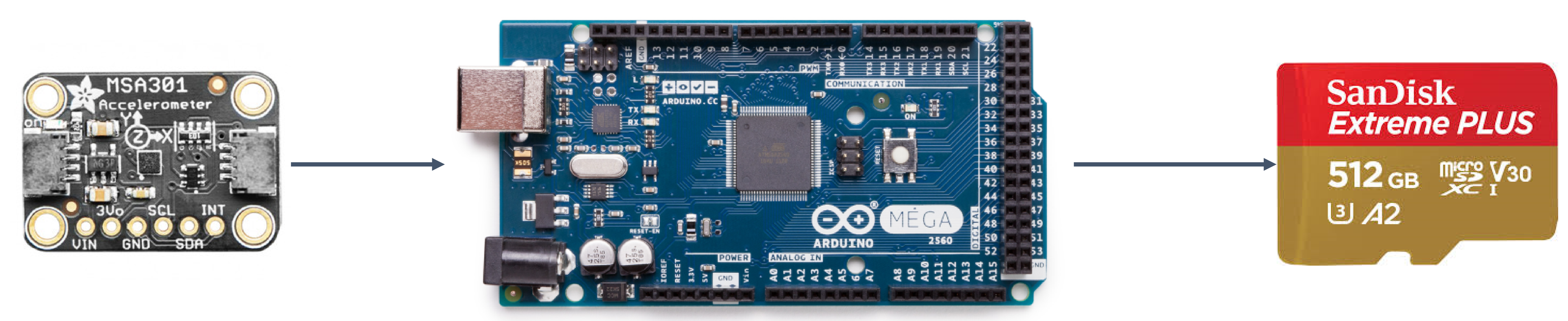


Objectives

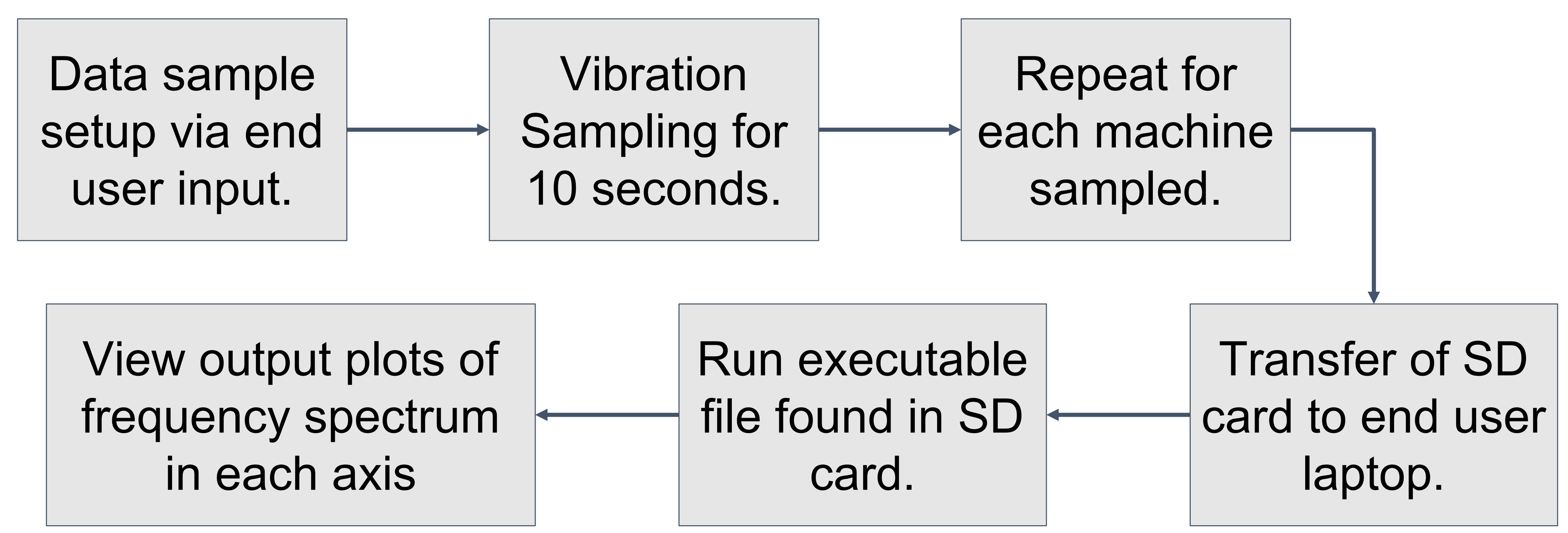
- Vibration sensors will collect data for 10 seconds in a collection frequency determined by the user.
- The system will collect data from the sensor into Arduino Uno, and transfer the data to the SD card.
- There is an MATLAB executable saved in the SD card, which will analyse the data using Fast Fourier Transform (FFT) and output spectrum graphs for the three axis (x,y,z).
- The system is important because it could be used to determine management practice to prepare equipment maintenance.

Data Collection Unit

The physical system consists of an Arduino Mega reading analog data from a 3-axis accelerometer and writing this data into text files on an SD card.



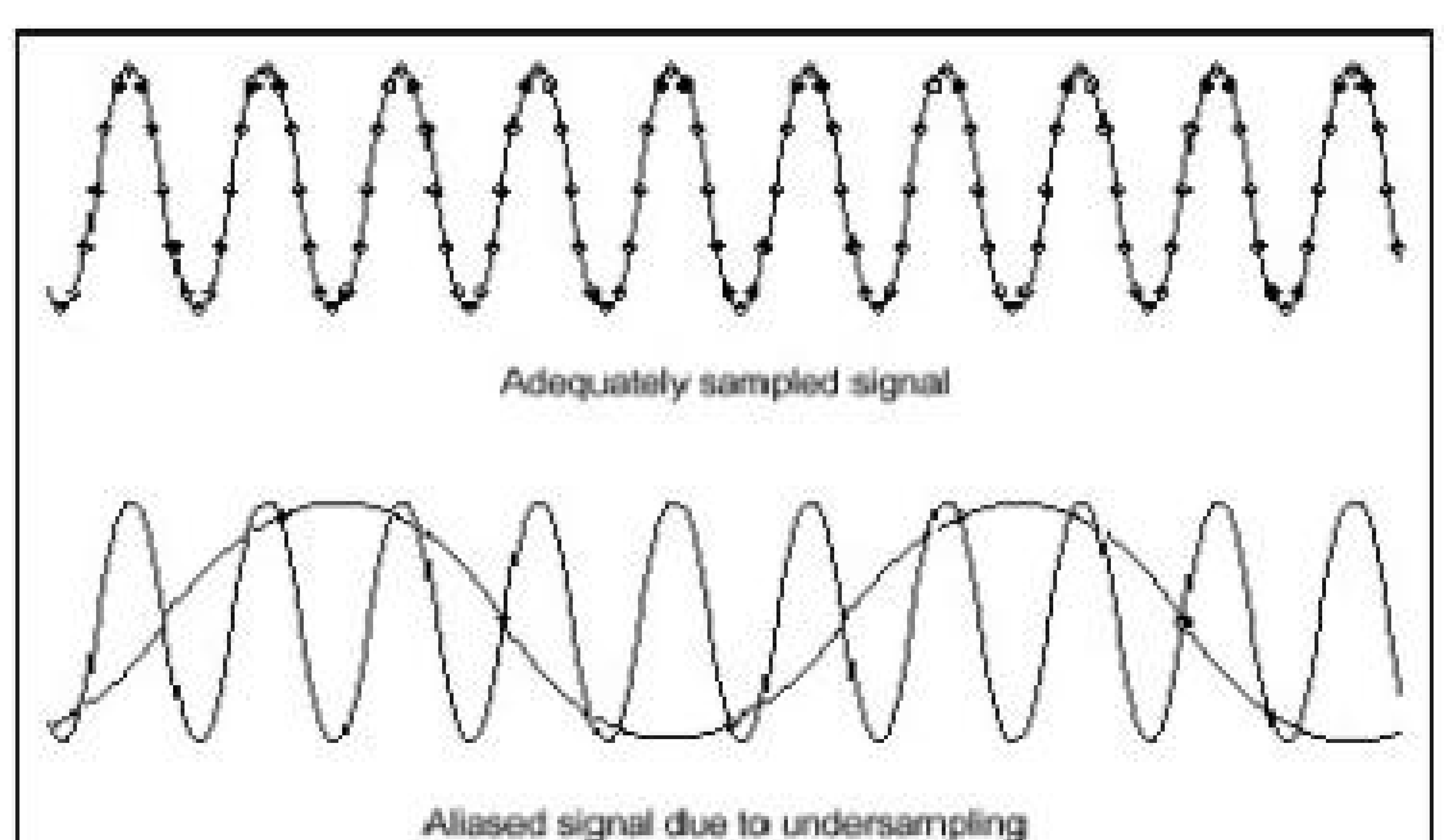
Collection and Analysis Procedure



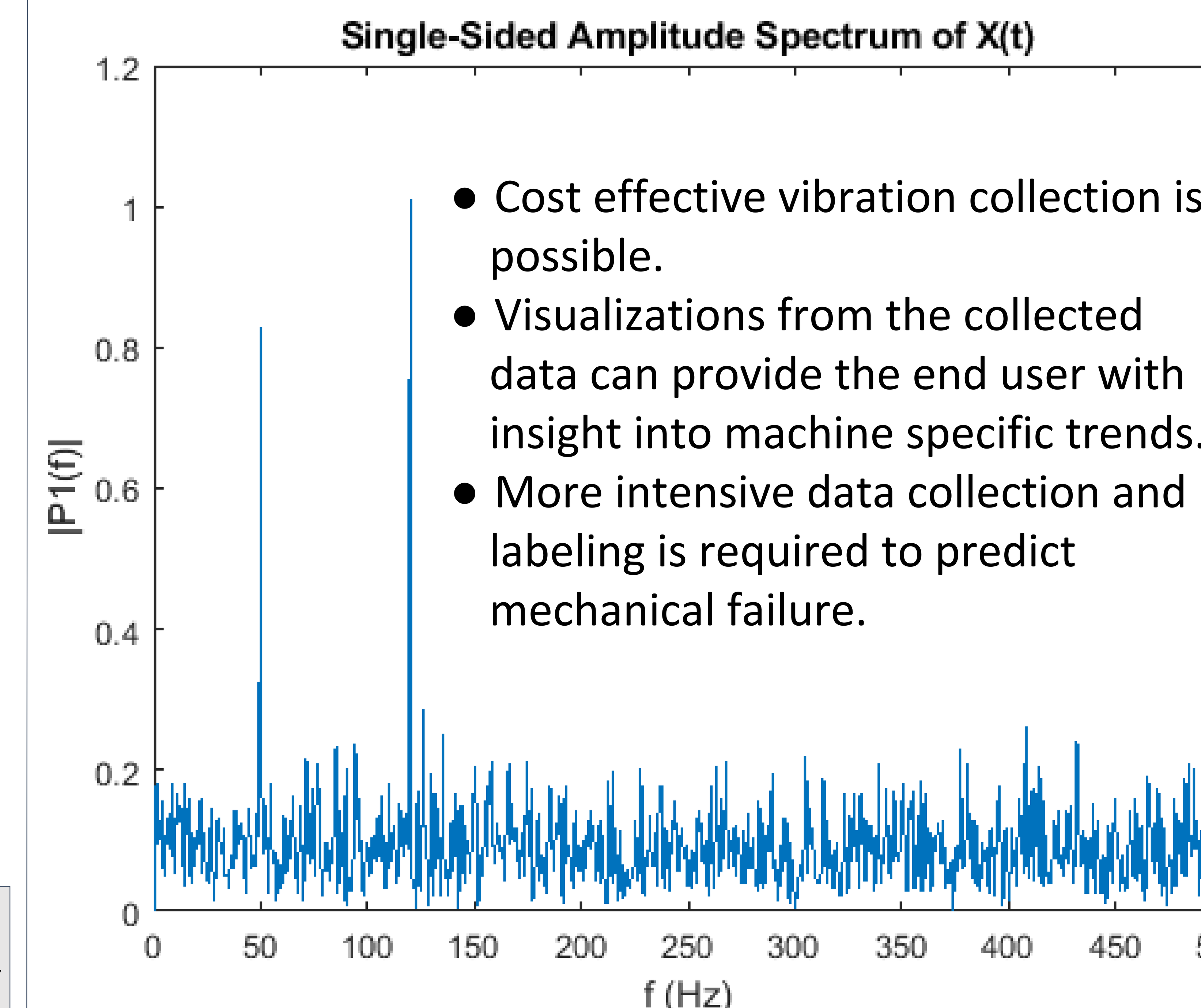
Sampling Rate and Intuition

Through application of the Nyquist-Shannon sampling theorem, underfitting can be prevented by sampling at greater than 2x the frequency of interest.

$$x(t) = \sum_{n=-\infty}^{\infty} x_n \frac{\sin \pi(2Bt - n)}{\pi(2Bt - n)}.$$



Conclusions



- Cost effective vibration collection is possible.
- Visualizations from the collected data can provide the end user with insight into machine specific trends.
- More intensive data collection and labeling is required to predict mechanical failure.

Future Plans

- Test our system at the manufacturing center.
- Analyze the best way to mount the vibration sensor on the modules.
- Develop predictive models using collected data.

Acknowledgments

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

- Altria for sponsoring this project.
- Chris Minor and Brian Cramer for giving their time and sharing their knowledge.
- The VT ECE Department for structuring this course and working within unusual restrictions this semester.
- Prof. Schulz for mentoring us through this process.
- Prof. Abbott for providing insight into potential technical problems we face.
- Prof. Ransbottom for organizing these interactions into a learning environment.

Passive Range Finding Through Application of Pixel Counting & Processing

Team Members: Kevin Phelps, Jason Tran, Cyrus Unvala   **SME:** Dr. Peter Han

Introduction

Problem: Current range weapon systems utilized by the U.S. government employ the use of active range finders (ARV). ARVs are effective in yielding accurate range findings but are susceptible to the following issues:

- ❑ Dependency on functioning lasers
- ❑ High susceptibility to detection by adversaries
- ❑ Failure to be applicable in all environments

Solution: Passive range finding addresses the above issues by utilizing heat signature reading rather than laser.

Objectives

Develop a passive range finder capable of determining the distance between the user and assigned target.

Target Assumptions:

- ❑ Target is an average human male with a height of 1.5 meters
- ❑ Target shall be centered within the captured image by the FLIR Boson 640 Camera.

Key requirements to be met:

- ❑ Range finding accuracy shall not exceed an error margin of ±2 meter
- ❑ Range finder shall update at a minimum of 1 range measurement per second
- ❑ Range finder shall operate from a minimum range of 25 meters to 2 kilometers

Analysis of Alternative Methods

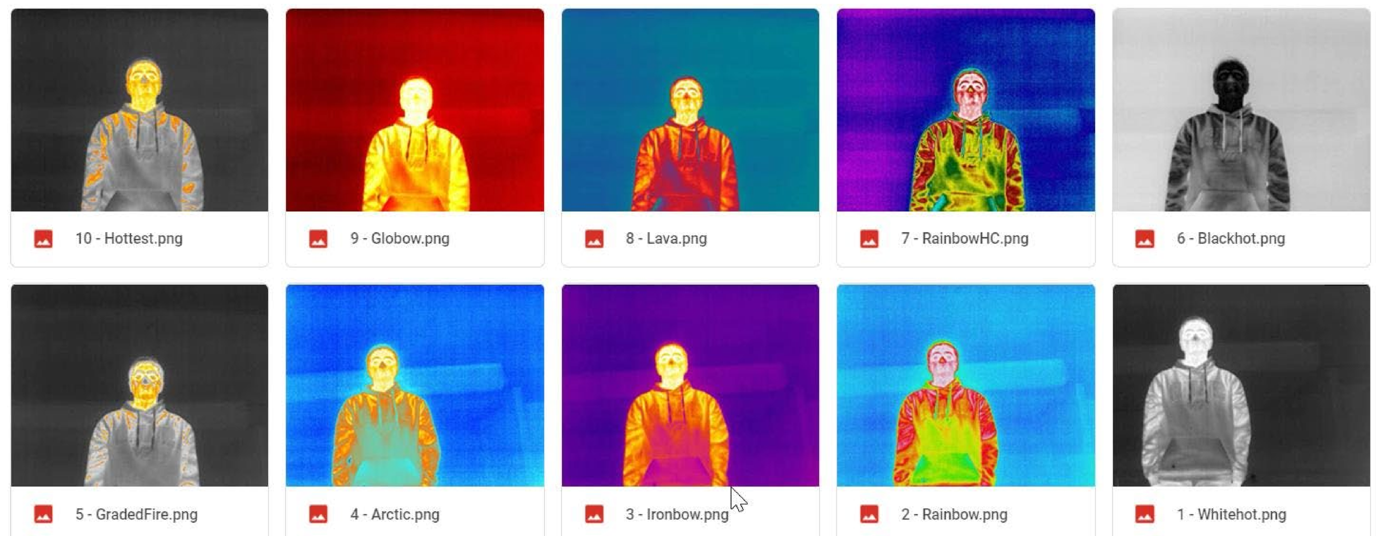
Three Primary Methods Researched for Passive Range Finding:

1. Stadiametric Rangefinding
2. Global Positioning Method
3. Stereoscopic Vision

Reasons for Stadiametric Rangefinding Approach:

- ❑ Global Positioning requires Inertial Measurement Devices (IMDs) to account for variables such as weather, elevation and accurate terrain mapping.
- ❑ Stereoscopic vision concept is triangulation of a min. of two reference points and a communications system.
- ❑ Stadiametric Rangefinding offers a direct approach where apparent size in relation to distance measured.

Ten Thermal Settings able to be Recorded by Boson Camera



Thermal Setting Whitehot chosen as binary color format is easy to view and the outline of a target is easily discernible compared to other settings

Methodology

To achieve the objective a python algorithm processes the target image captured by the FLIR Boson 640, 50 degrees FOV, 8.7mm Camera Lens and calculates the distance between user and target.

Image Capture Process:

- ❑ Capture the target image on the FLIR Boson 640, 50 degrees FOV, 8.7mm Camera Lens
- ❑ FLIR Boson camera is interfaced with a laptop computer for image recording and capturing
- ❑ Captured photo is cropped to focus on centered target
- ❑ Image is filtered by the python algorithm against a set brightness threshold
- ❑ Any pixels set below the target threshold is blacked out
- ❑ Through image processing the outline & pixels for the body of target are illuminated & recorded

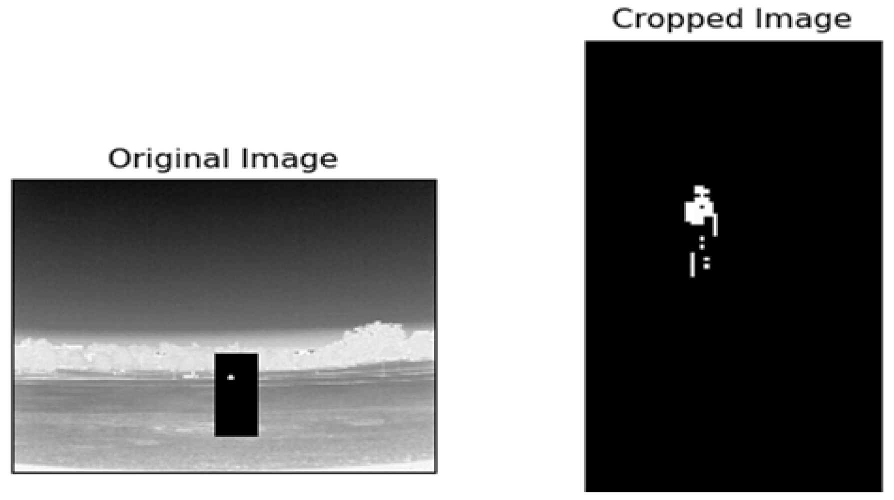


Image Processing of Captured Photo of Target at 100 meters

Range Calculation Process:

- ❑ Algorithm employs concept of pixel counting
- ❑ Takes in the highest and lowest pixel points of the illuminated target
- ❑ The difference of the target's height is recorded
- ❑ Change in height value is inputted into the best fitted exponential curve relationship
- ❑ Python algorithm outputs range value between the user and target

Acknowledgments

The team would like to thank the following individuals for their efforts and assistance through this project:

- Customer: Clint Farrell & Jie Gao
- SME: Dr. Peter Han
- Mentor: Toby Meadows

References

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Tomas Novotny 4, et al. "How to Do Exponential and Logarithmic Curve Fitting in Python? I Found Only Polynomial Fitting." Stack Overflow, 1 Nov. 1959, stackoverflow.com/questions/3433486/how-to-do-exponential-and-logarithmic-curve-fitting-in-python-i-found-only-poly.

Contact

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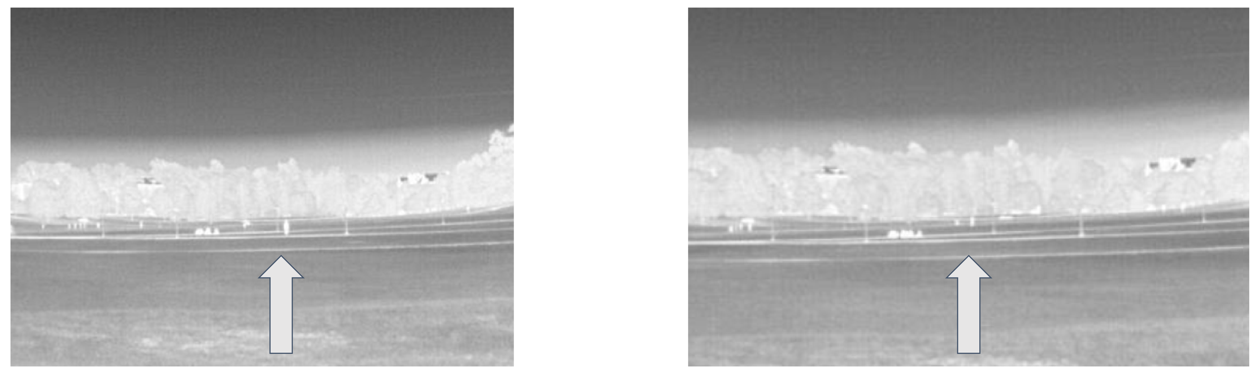
Jason Tran: jasont25@vt.edu
Cyrus Unvala: cyrusu@vt.edu

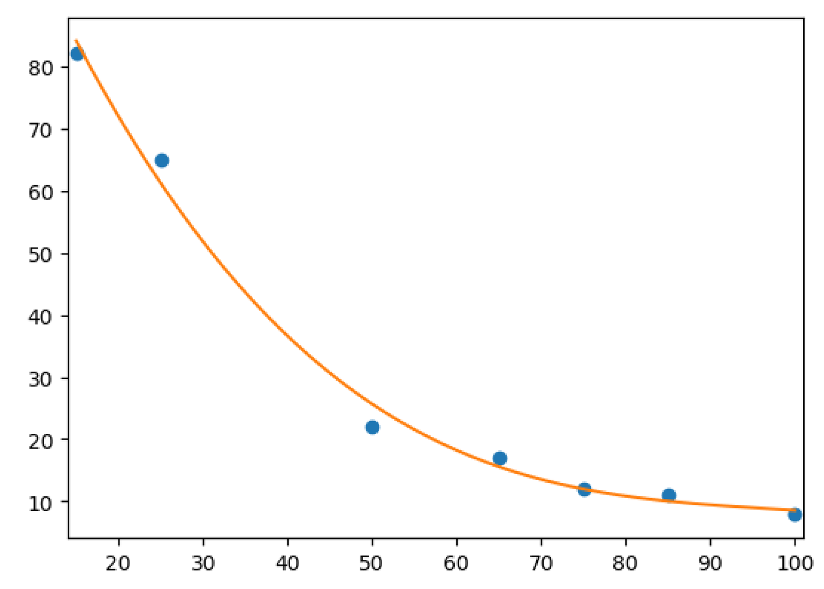
Test Results

The rangefinder yields acceptable range values when calculating for distances between 25 to 100 meters, but as the target strays farther from the user the detection of the target becomes much more difficult.



Captured Photo of Range Finder Target at 100 meters (left) compared to 175 meters (right)

Key Requirements	Success Rate		
Range Finding Accuracy			Green: Realized
Range Finder Update			Yellow: Partial Success
Range Finder Range			Red: Failed to Meet



Exponential Relationship found between Captured Pixels & Target Distance

Conclusions

The specifications of the FLIR Boson 640, 50 degrees FOV, 8.7mm Camera Lens limits performance

Thermal Sensitivity: <40 mK (Industrial); <50 mK (Professional); <60 mK (Consumer)
Full Frame Rate: 60Hz baseline; 30 Hz runtime selectable
Lens Options: 640 x 512 50° (HFOV) 8.7 mm (EFL)
Spectral Range: Longwave infrared; 7.5 μm – 13.5 μm
Pixel Pitch: 12 μm

General Motors SIMformation

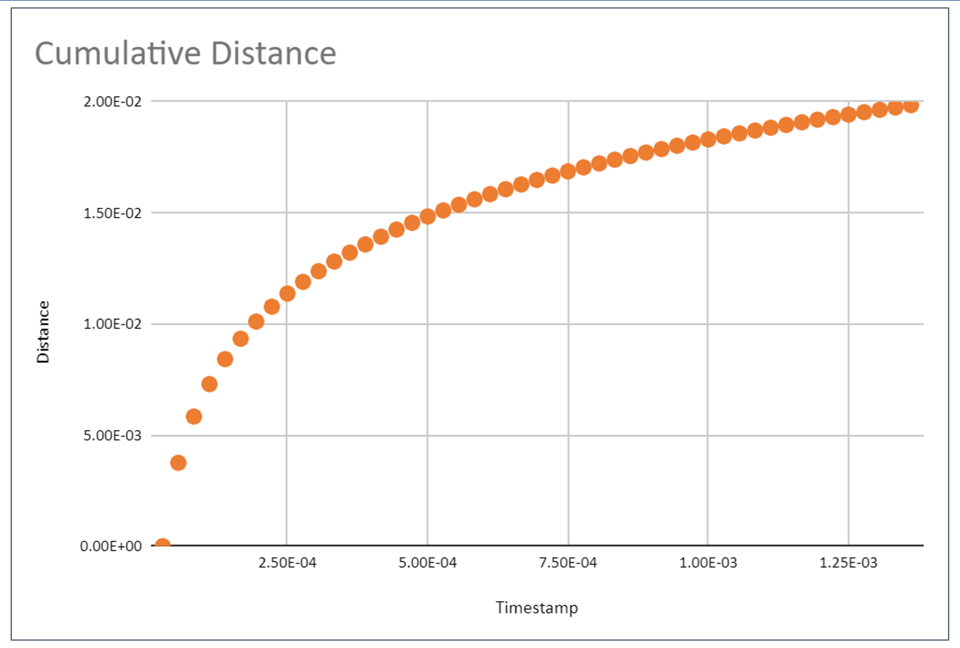
Team Members: Ellen Sawitski, Mitch Gerhardt, Daniel Aaron, Colin Hancock, Ashlyn Pugh **Customer:** Keith Van Houten, General Motors
SME: Dr. Tim Talty **Mentor:** Prof. Kenneth Schulz

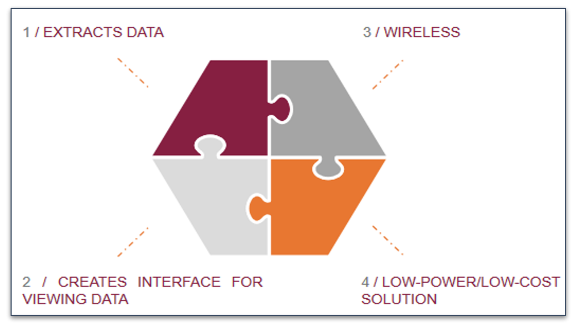
Project Statement

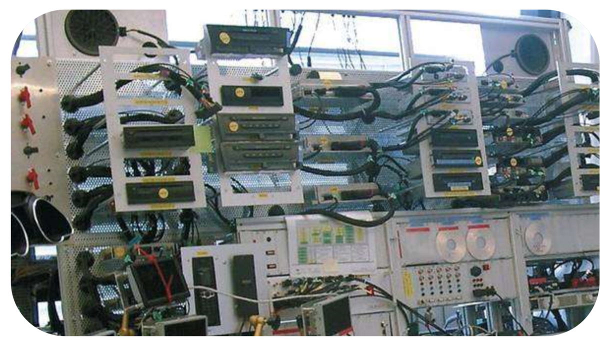
The SIMformation team aims to develop a modular system to wirelessly interface with GM's hardware-in-the-loop [HIL] setups so employees can accurately and reliably monitor the status and performance metrics associated with each bench.

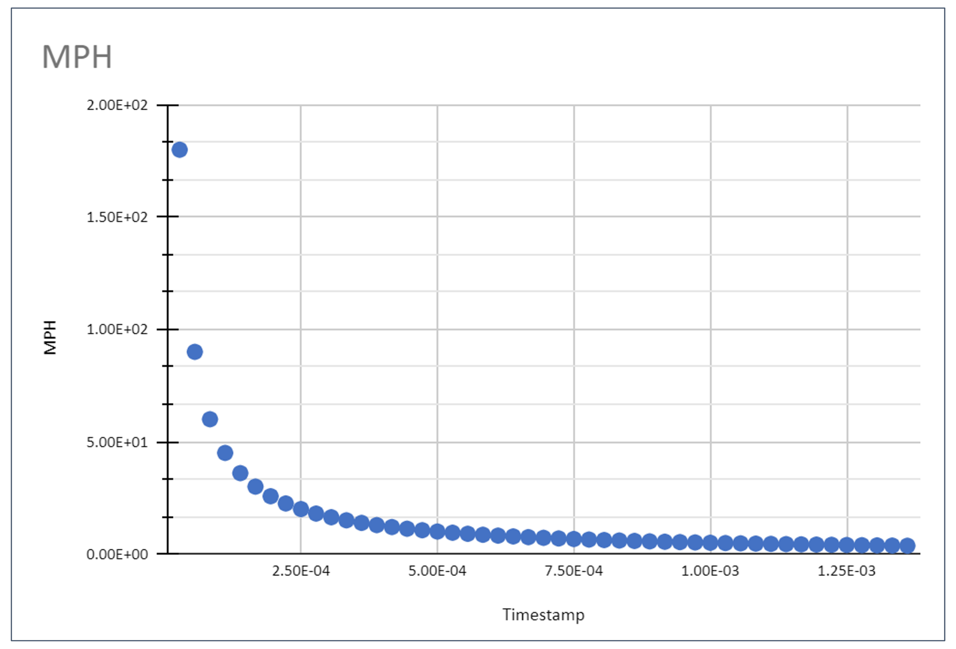
Currently, there exists no single monitoring system, which is hampering the testing, update, and progress of these setups. Left unresolved, the HIL benches overall readability and application will be limited.

We shall use a combination of CAN port methodology in tandem with wireless transmission signals, specifically Bluetooth, to extract, translate, and display performance metrics to help improve the system's efficiency and impact.







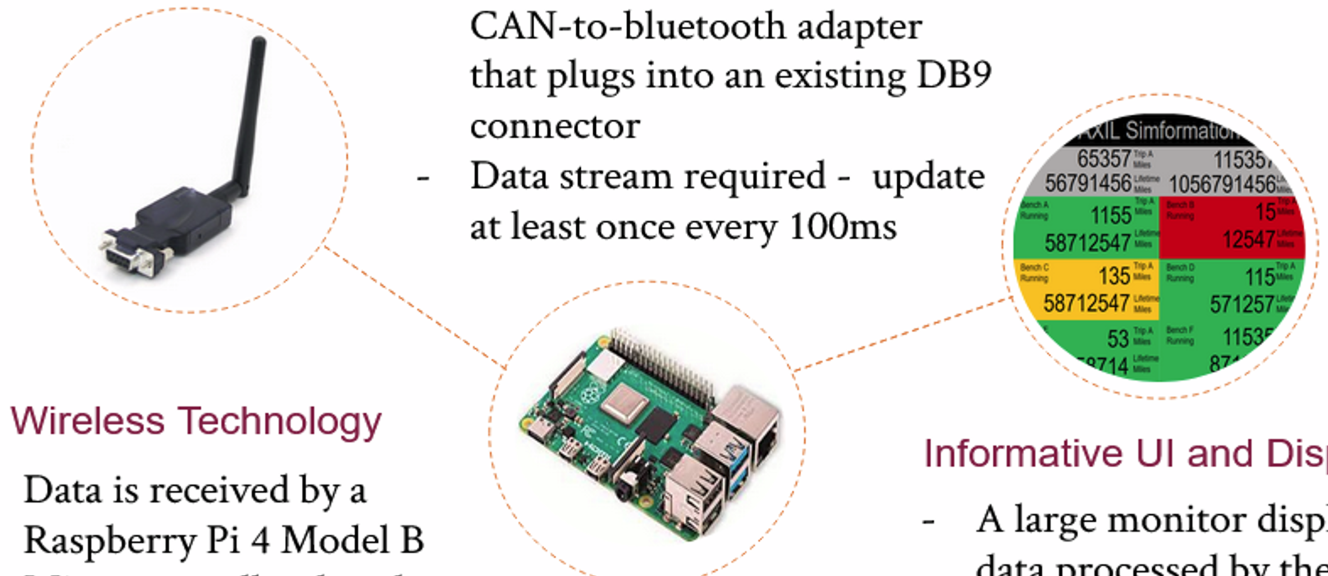


Project Deliverables

- A complete system that:
  - Wirelessly transmits data from six HILs
    - HIL Data Collected:
      - Test state (running vs. idle)
      - Current and lifetime miles and hours
      - Current speed
      - Current test number
    - Lifetime miles and hours for all HILs
  - GUI display is large monitor capable
- Project budget of $1000

Methods and Materials

CONCEPT OF OPERATIONS



Data Extraction

- Each HIL setup requires a CAN-to-bluetooth adapter that plugs into an existing DB9 connector
- Data stream required - update at least once every 100ms

Wireless Technology

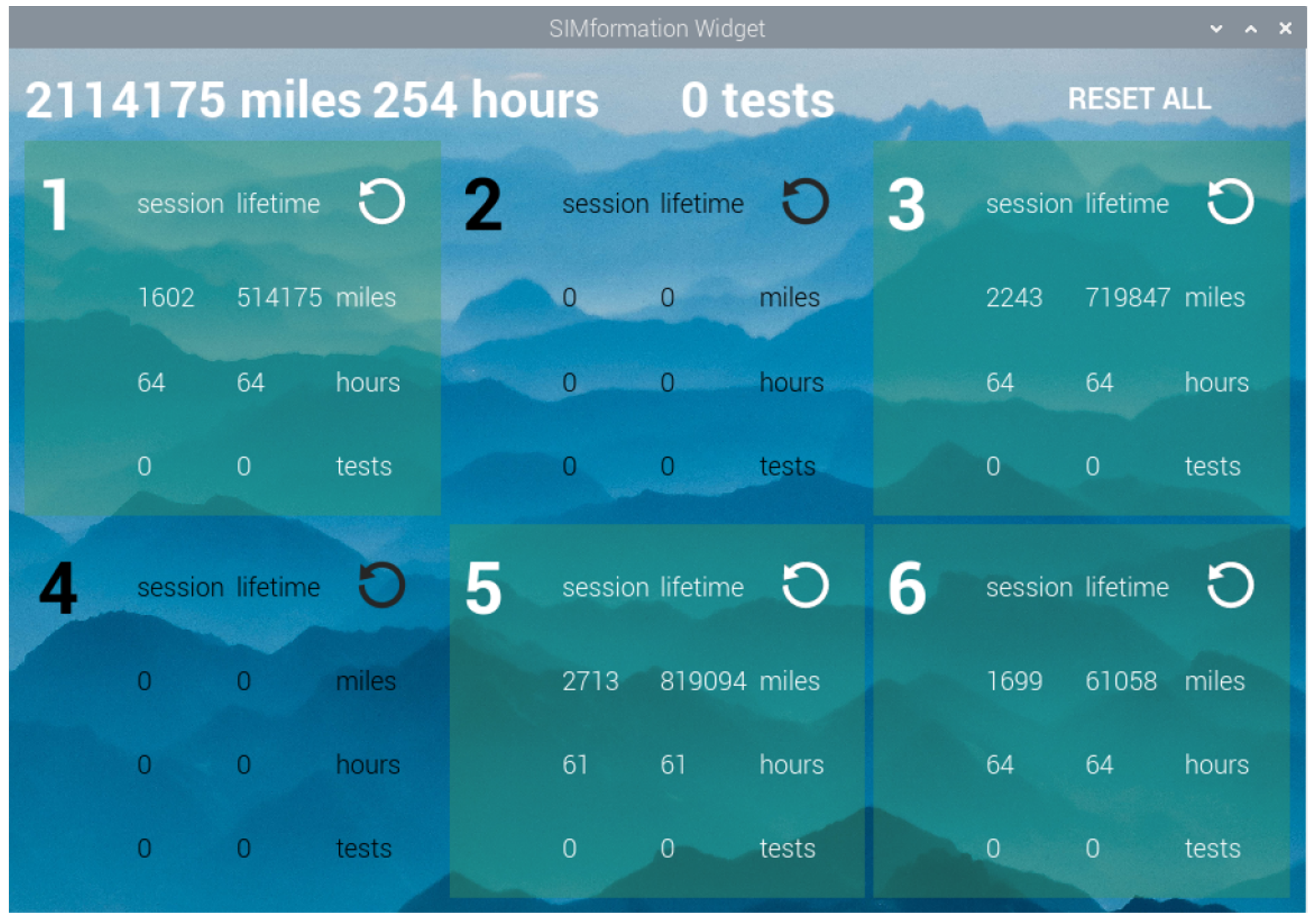
- Data is received by a Raspberry Pi 4 Model B
- Microcontroller decodes the data from the CAN buses and stores pertinent data

Informative UI and Display

- A large monitor displays data processed by the Raspberry Pi
- Individual HILs can be reset

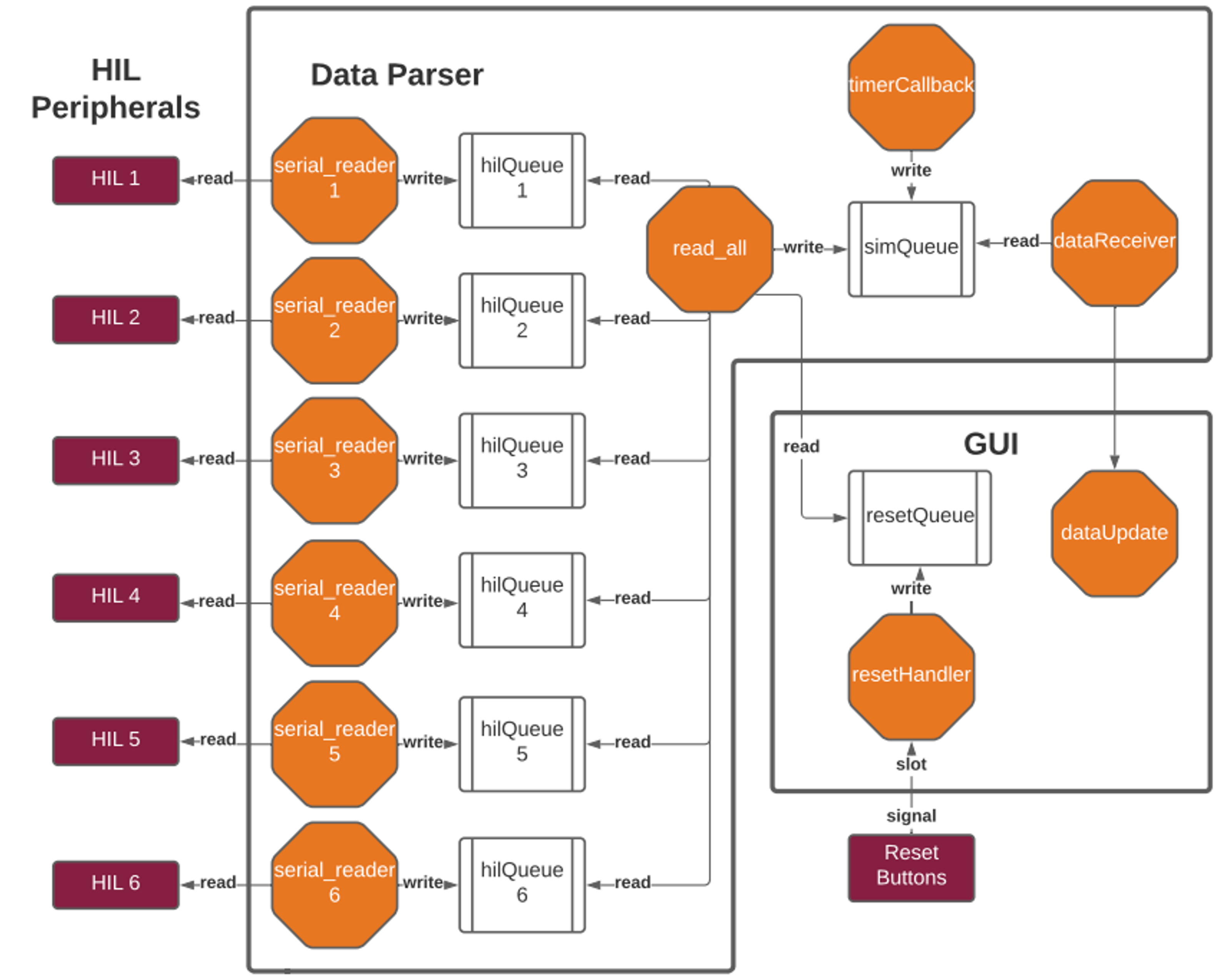
Results

- Able to transmit sample CAN data to the microcontroller
- Generated sample CAN data for testing locally
- Developed proprietary Qt GUI to display HIL data to users in different colors depending on HIL status
- Created transmitter setup document for documentation



Challenges

- COVID-19 made both communication and access to resources difficult
- Developing the communication between the data processing and GUI display portions of our code in different threads on the Raspberry Pi
- The adapter we purchased would only connect with one other adapter. We needed to find another Bluetooth receiver to connect with multiple devices



Conclusions

The results obtained from the test simulations demonstrate the following:

- The ability to receive CAN signals from each HIL
- The ability to process data into required formats
- The ability to display all required data in a user friendly format
- The ability to update the test state, current and lifetime miles and hours, current speed, and test number
- The ability to reset the program through use of GUI button
- Integration of all six HIL setups
- The project was completed on time and under budget.

References

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Acknowledgements

Keith Van Houten - Customer Contact
Kim Medley - Virginia Tech Purchase Order Contact
John Sopoci - GM Contact
Thomas Legg - GM Intern

Autonomous Laser Power Transmission System For Lunar Exploration

Team Members: Amir Bigdeli, Ceren Demirayak, Emily Tardell, Hillman Shiner, Mina Shawky
SME: Dr. Greg Earle **Mentor:** Prof. Toby Meadows **Customer:** Dr. Kevin Shinpaugh

Motivation

Some craters at the lunar poles never receive direct sunlight. These permanently shadowed regions may have underground water-ice, making them desirable for future manned lunar missions. However, the extremely cold, dark environment makes it hard to power the equipment necessary for exploration. Here we present our research focused on a possible solution to this important problem.

Objectives

Design and implement a complete Laser Power Transmission System (LPT) that works by using an autonomous tracking, targeting, and communications system to direct laser power to a solar cell. The LPT is determined to be the preferred transmission method due to its higher-power efficiency at longer distances compared to other wireless power transmission methods.

Concept of Operations

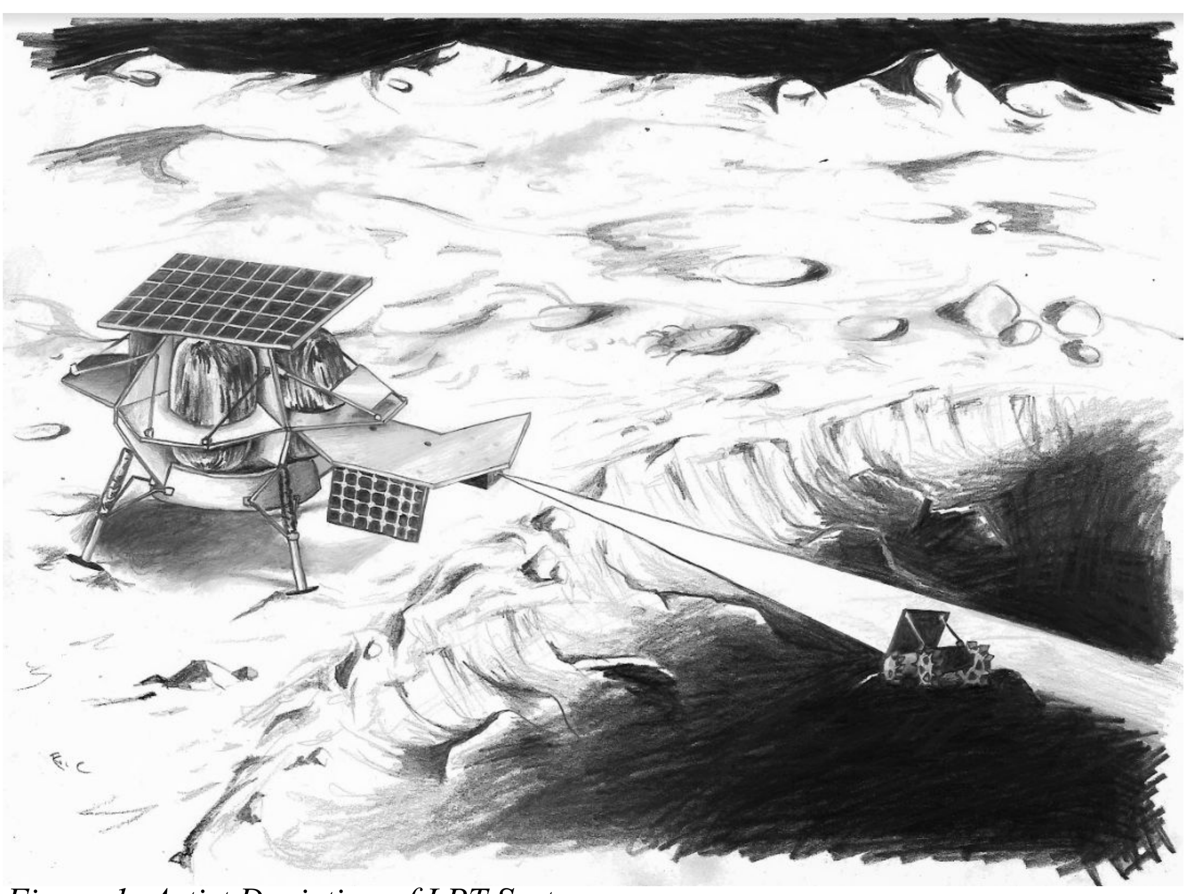


Figure 1: Artist Depiction of LPT System

Overall System Diagram

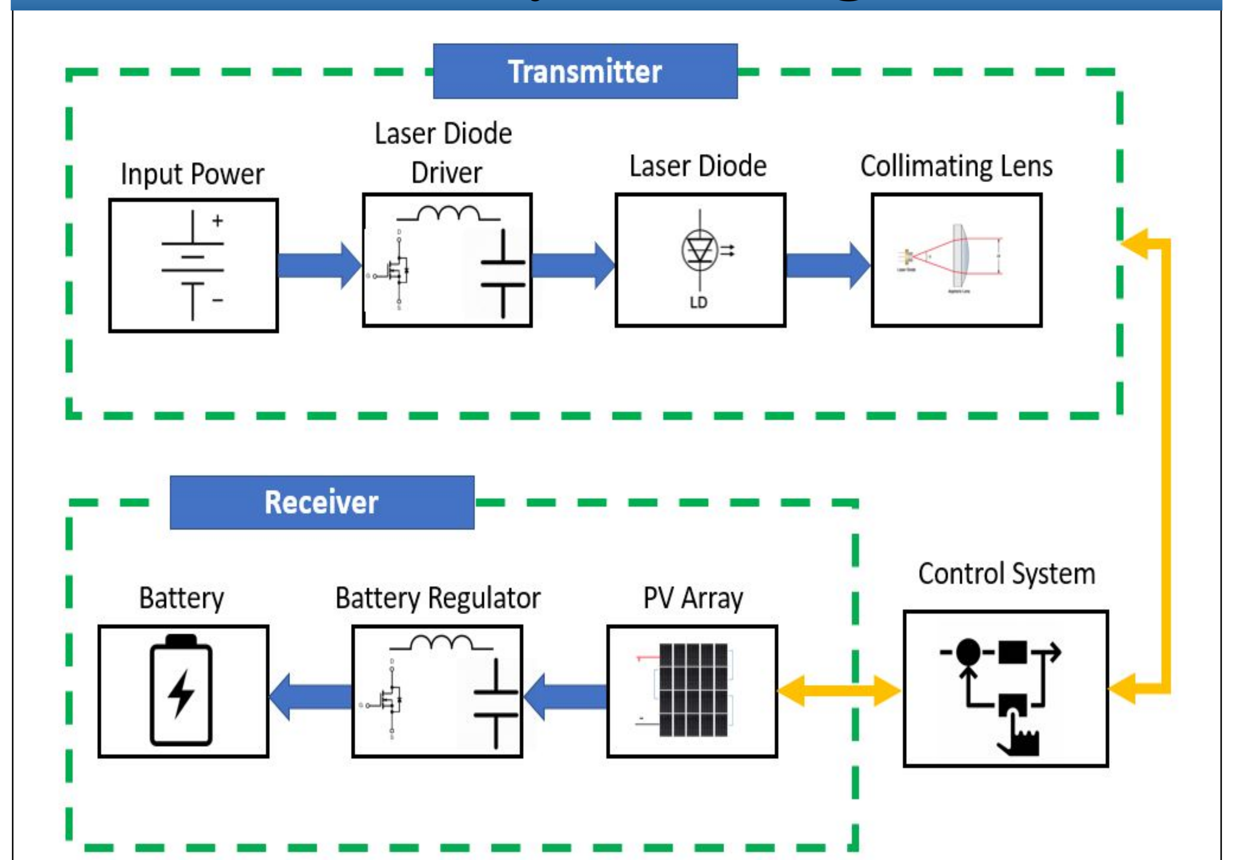


Figure 2: Overall System Block Diagram

Lens System

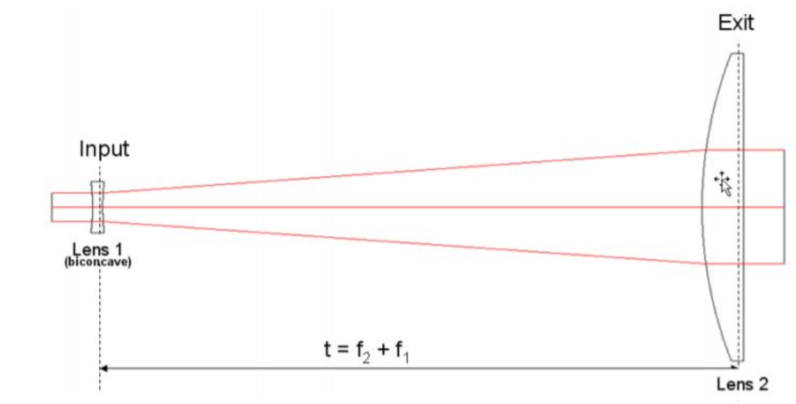


Figure 3: Beam Expander Diagram

- Beam expander reduces beam divergence
- Distance between lens is the sum of the focal lengths of the lens which is 7.5 cm
- Anti-Reflective coating on lenses reduces reflectance

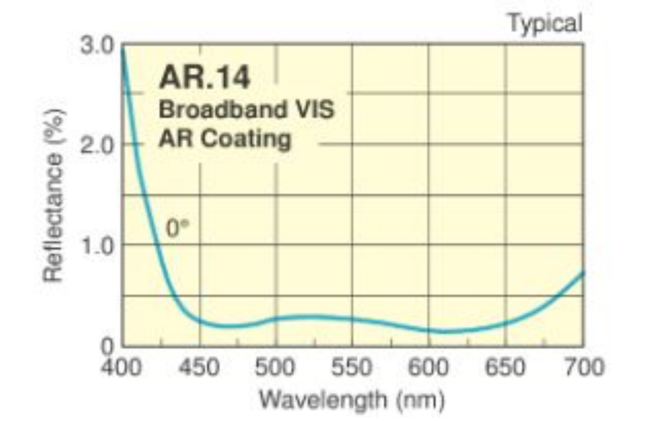


Figure 4: Effectiveness of Anti-Reflective Coating

Electronic Power System (EPS)

- EnduroSat 1U solar panel consists of two triple junction solar cells which allows for up to 30% efficiency and solar energy conversion
- EPS is used to regulate the changing input power from the solar panel, regulate the power lines across the rover, provide stable 5V and 12V rails, and charge up the onboard battery.

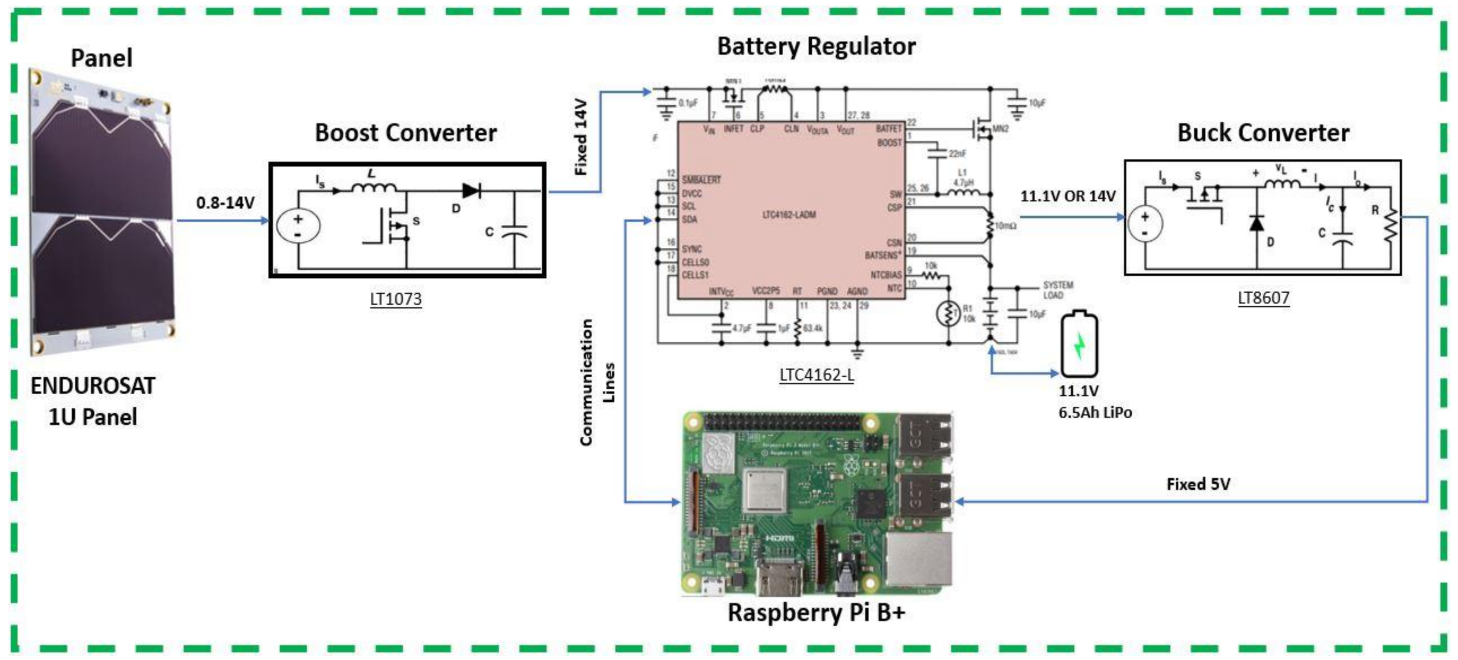
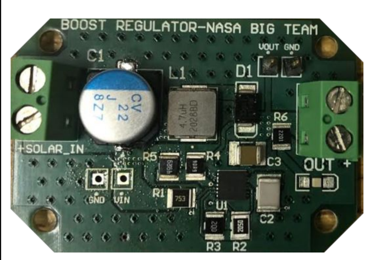
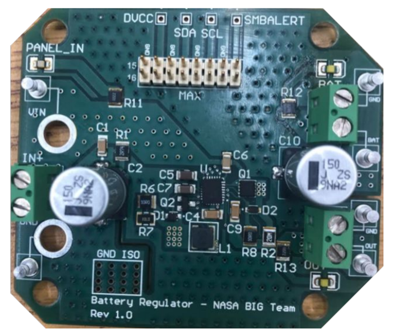


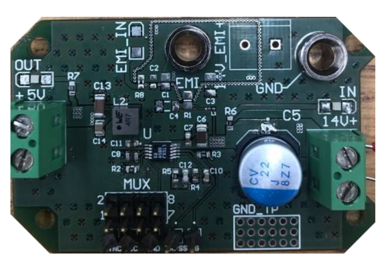
Figure 5: Electronic Power System Block Diagram



* Figure 6



** Figure 7



*** Figure 8

** Figure 6: Boost Converter PCB – Steps Up 1V Input to 14V Output*

*** Figure 7: Battery Regulator PCB – Monitors and Regulates Battery Voltage*

**** Figure 8: Buck Converter PCB – Steps Down 14V Input to 5V Output*

Laser Diode System

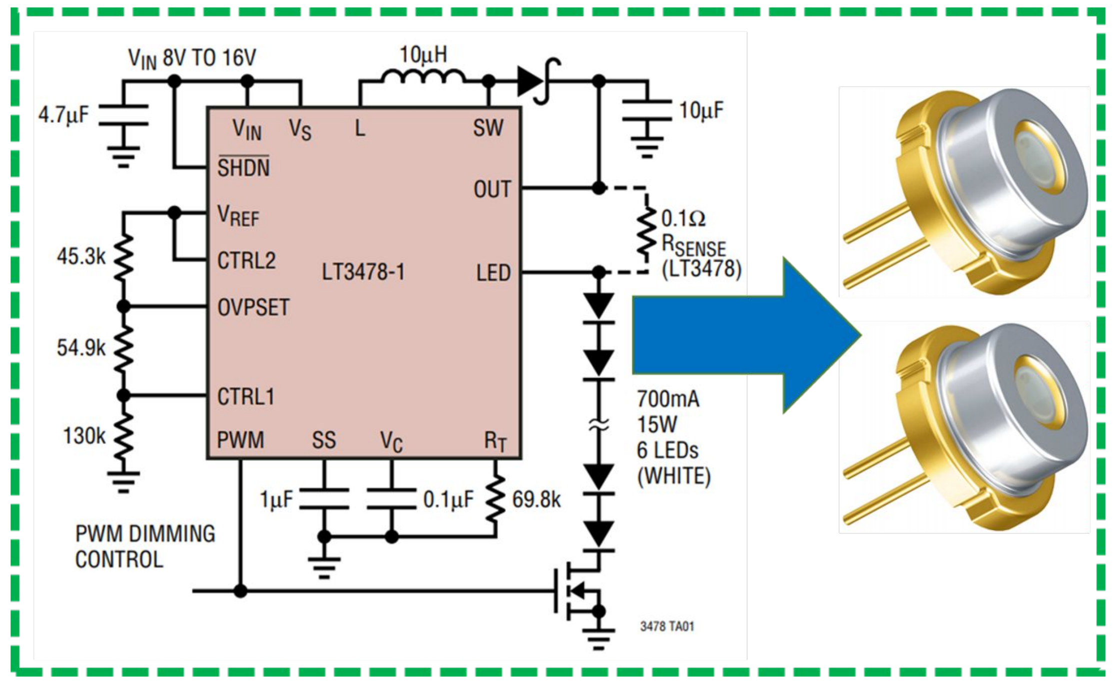


Figure 9: Laser Driver System Block Diagram

LT3478: Laser driver chip with high current driving capability, high efficiency, and ability to drive six laser diodes in series
PLPT9: Constant wave (CW) 3W laser diode

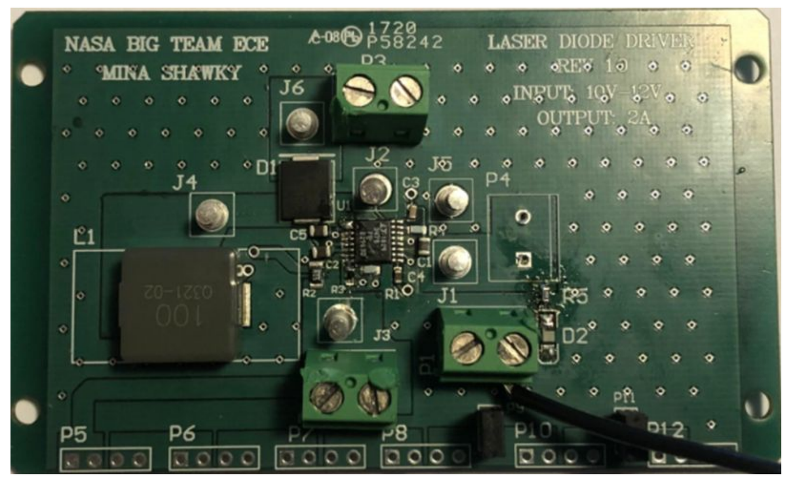


Figure 10: LT3478 Laser Driver PCB

Tracking & Communications System

Transmission System:

- Handles the communications protocol
- Targets the IR LED beacon using an IR camera and pan-tilt unit
- Triggers the Laser Power Transmission System when the receiving system reports a battery level less than 30%

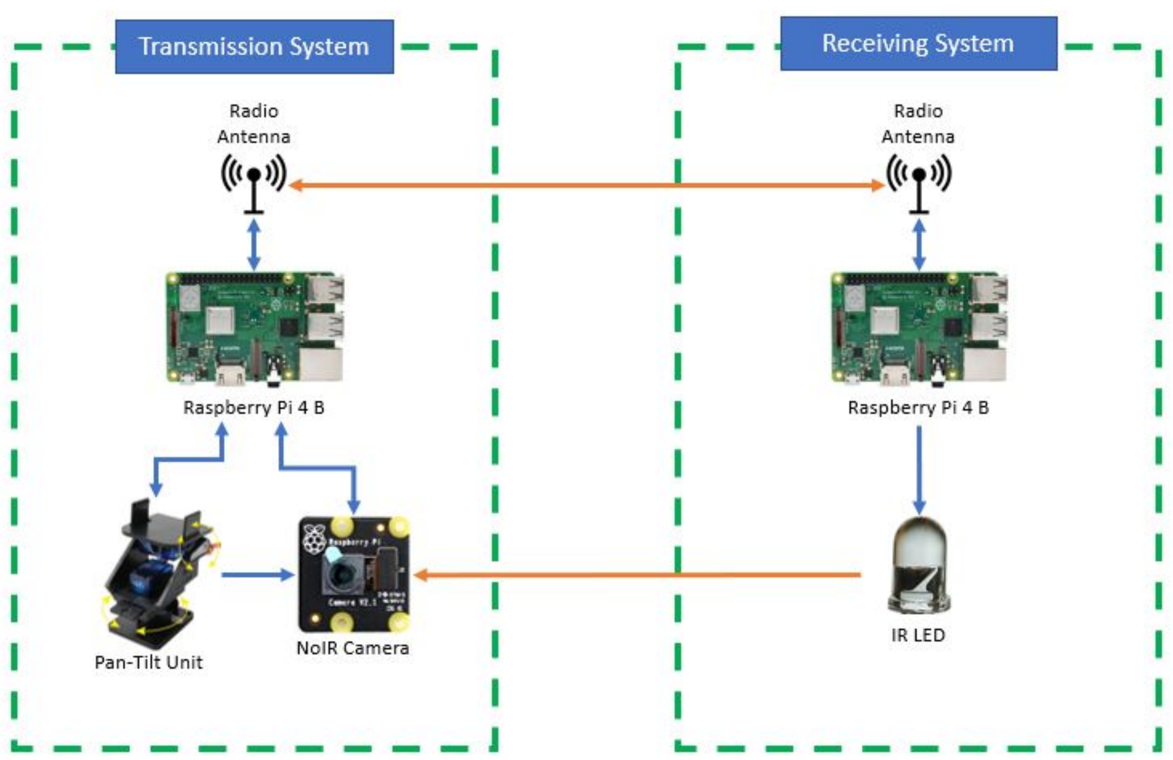


Figure 11: Tracking and Communication Block Diagram

Receiving System:

- Handles the communication of the remote exploring system, battery level, and power reception level
- Reports errors in the system operations
- Transmits state information to the transmission system

Test Results & Analysis

Subsystem	Subtask	Success	Changes/ Issues
Laser Diode System			
	Laser Diode Driver	80%	• Move from protoboard to PCB
Laser-Lens-Solar Cells Integration			
	Laser Diode	20%	• Lab equipment unavailable for safe testing
	Lens	80%	• Integration with laser diodes halted due to lab access issues
	Solar Cells	80%	• Does not provide enough amperage to turn on boost switching mechanism
Electrical Power System			
	Boost Converter	80%	• Move from protoboard to PCB
	Battery Regulator	50%	• Replace broken IC on PCB
	Buck Converter	100%	• Successful testing
Tracking and Communication			
	Tracking	80%	• Have autonomy when battery hits 30% charge
	Communication	100%	• Successful testing

Figure 12: Test Result Analysis Chart – Success Column is a Self- Assessment on Team Progress

System Prototype Videos

SCAN ME

- Scan this QR code with any mobile device to see videos of our system prototypes. Open the camera app on your device and point at the code.

Conclusion and Future Work

Simulations, theoretical calculations and subsystem demonstrations show that the system is promising as a technique for providing power to lunar systems operating in dark lunar craters, but COVID-19 and other challenges have hindered full-scale testing. Future work required to advance the technical readiness level of this system include:

- Further subsystem testing using space-rated parts;
- Use of a solar cell that will match the laser wavelength to improve efficiency;
- Comparative experimentation with a switching mode power supply for the laser diode driver;
- Further integration of subsystems into a completely autonomous prototype;
- Memory and storage analysis of code to cut down on power consumption
- Environmental testing to ensure functionality and assess lifetime limitations in cold, dark, and radiation rich environments.

Acknowledgements

The NASA Big Idea team would like to give a special thanks to our Subject Matter Expert (SME), Dr. Greg Earle, our customer, Dr. Kevin Shinpaugh, and our Mentor, Prof. Toby Meadows for their valuable time, advice, and enthusiasm throughout the entire scope of this project.

Satellite Navigation Sensor Suite

Team Members: Michael Rask, Zach Olson, Daniel Montgomery, Samuel Zabel
Sponsored by Aerospace Corp.

Motivation

During initialization and orbital maneuvers, satellites can lose their GPS signals. An on-board position and navigation solution that does not rely on GPS will allow the mission to continue even during signal outage.

Objectives

The objective is to determine the attitude and location of a satellite in orbit, utilizing an algorithm on a microcontroller that blends sensor measurement outputs.

Sensor Selection

The system consists of three magnetometers, one gyroscope and one accelerometer. The gyroscope provides very accurate angular rate over a short period of time, and then is subject to integration error over time due to noise. As a result, magnetometers and accelerometers provide measurements that correct the gyro. Three magnetometers were used in order to form a voting system: if two out of three sensors measurements are closer, the system will use the average of those two values.

Sensor Type	Signal	Units	Function
Accelerometer	Acceleration	m/s^2	Position
Gyroscope	Angular Rate	deg/s	Attitude
Magnetometer	Geomagnetic Field	Tesla	Position/Attitude

Sensor Characterization

All types of sensor will produce some kind of error. To account for that, the sensors were characterized in order to obtain any noise and biases in the measurements. The gyroscope was characterized with using an Allan Variance analysis and the magnetometer was calibrated to account for any magnetic interferences. These values will be used within the extended Kalman filter.

Figure 1: Gyroscope noise model

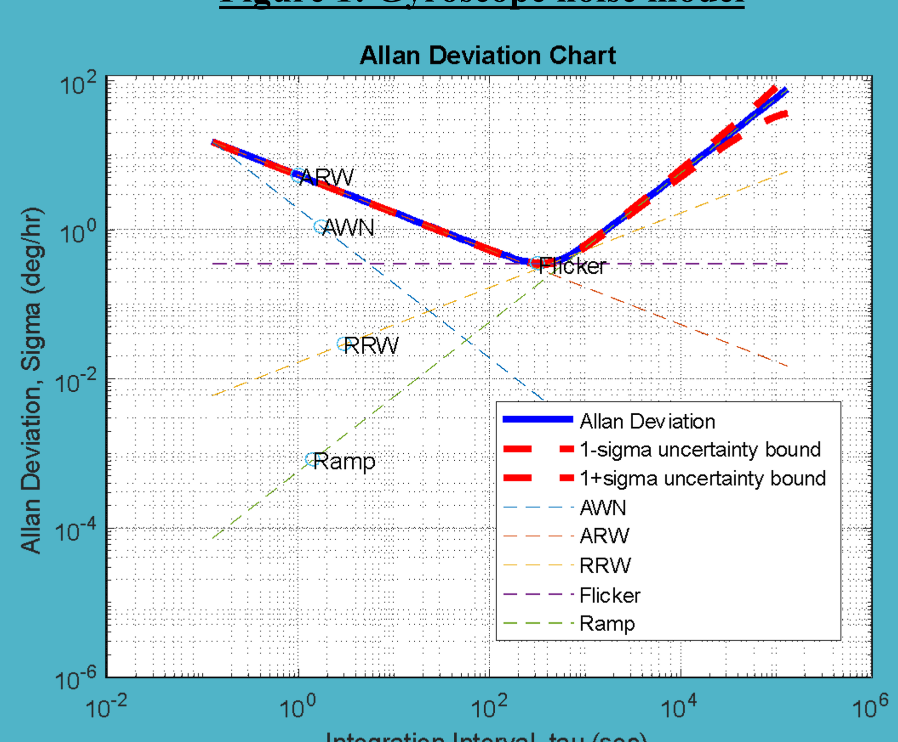
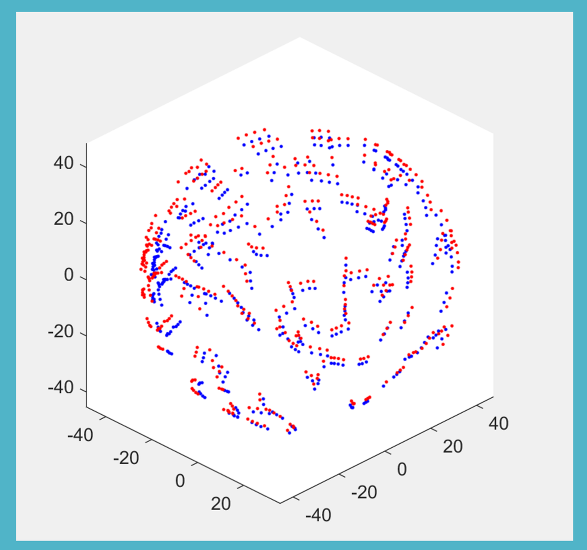


Figure 2: 3D magnetometer model. Blue is calibrated, red is not.



Sensor Fusion

In order to obtain an accurate attitude and location, a gyroscope, accelerometer, and magnetometer were used. The measurements from the accelerometer and magnetometer are used to correct the measurement drift from the gyroscope. This is done through the use of an extended Kalman filter by "predicting" the next state and "updating" the state with measurements with the equations below.

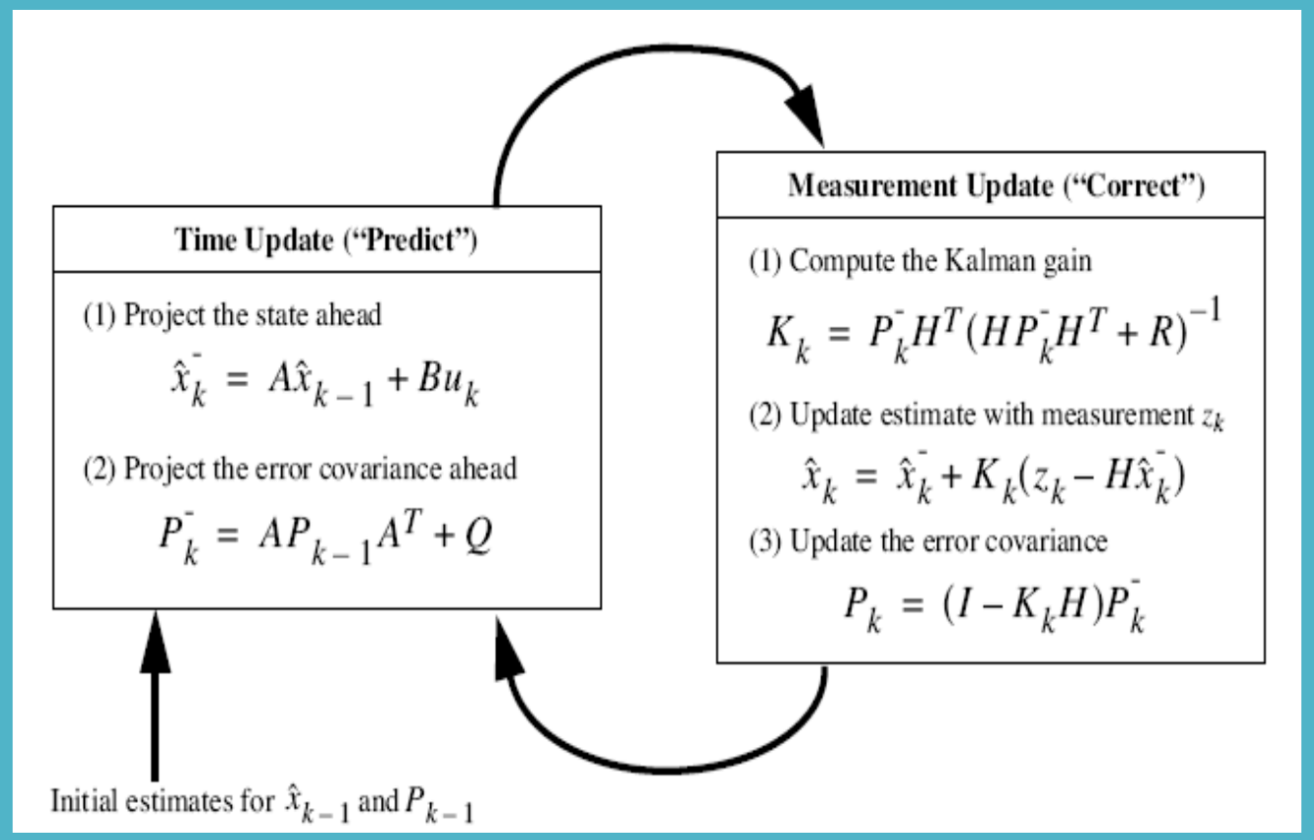


Figure 3: Kalman filter equations

Position, Navigation, and Timing Solution

Data gathered from the sensor suite populates state-space vectors to propagate the position and attitude over time. An Extended Kalman Filter blends inertial data and magnetic field measurements to increase confidence and reduce error propagation. In addition, an accelerometer can give us pitch and roll, but requires a magnetometer to give us yaw. The graph in test results show how those values compare with the gyro without the Kalman filter.

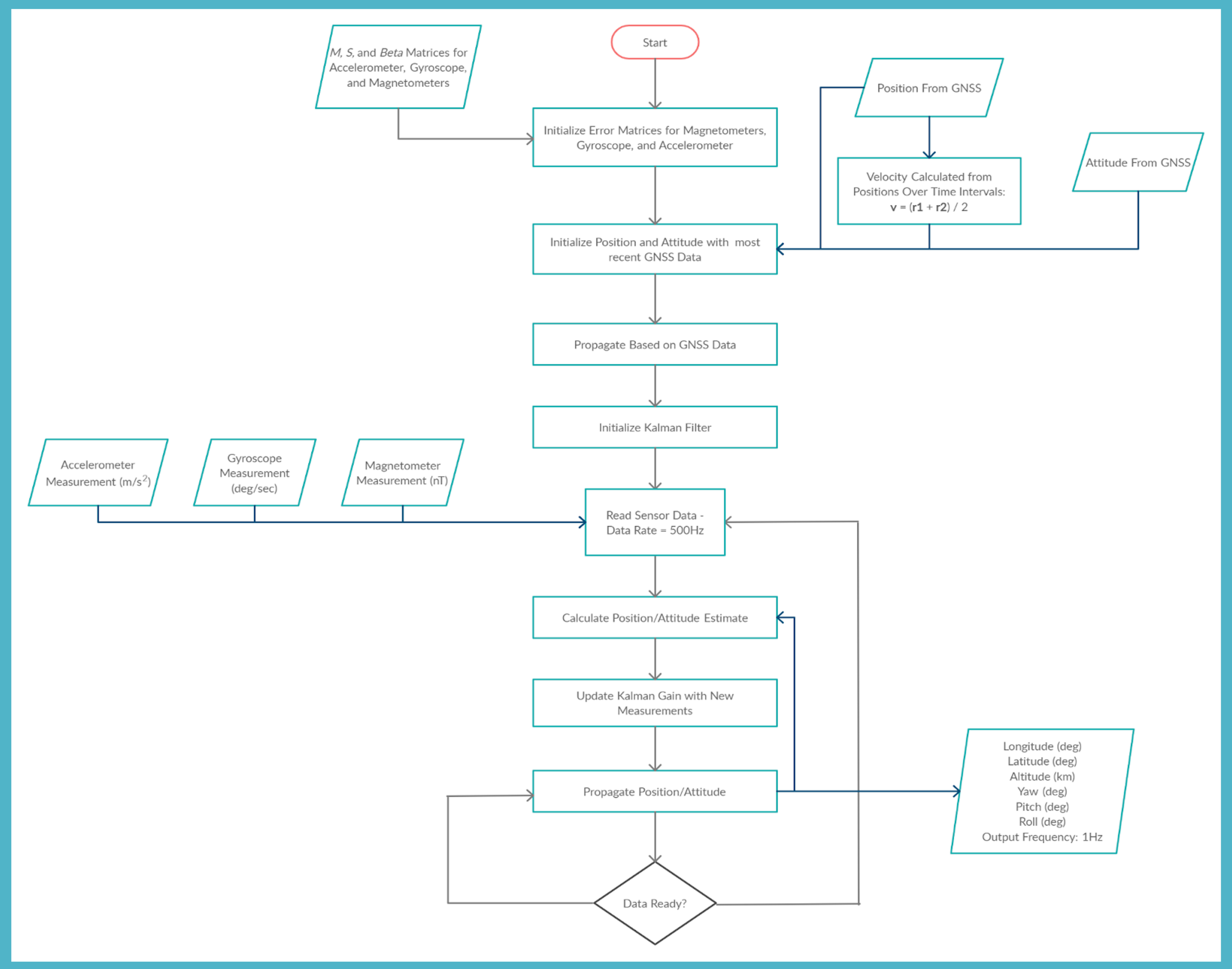


Figure 3: Algorithm system overview

System Hardware

The entire system must fit inside a 1U of CubeSat space ($10cm^3$). There were two PCBs designed to interface with the MSP432 microcontroller in a stacking fashion.

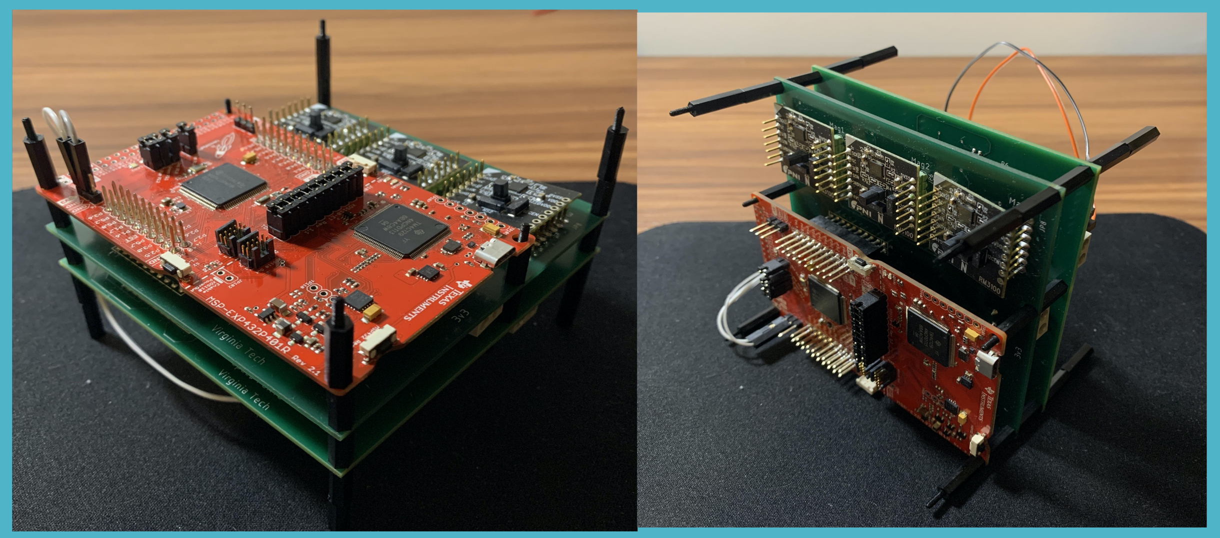


Figure 4: Picture of overall system

Test Results

Right now the system can produce the attitude (pitch, roll, and yaw values) utilizing the gyroscope, accelerometer and magnetometers. The Kalman filter needs to be optimized in order to produce more accurate results. Below are graphs for a yaw and pitch test. The blue lines are the angles obtained from the magnetometer/accelerometer and compared with the gyro angle. Similar graphs will be generated to show more filtered results.

Figure 4: Full yaw and pitch test for gyroscope and magnetometer/accelerometer

Analysis and Conclusion

The system can provide the correct attitude and location utilizing the sensor blend, however needs the Kalman filter to be optimized in order to provide a more accurate solution. A complementary filter will be used in substitution.

Challenges

Some challenges include:

- Design of extended Kalman filter
- Characterizing sensors

Future Plans

The next steps for this system include performing more tests with the optimized Kalman filter and utilizing data collected from STK orbit software to simulate an orbit on the system.

Acknowledgements

- Dr. John Janeski
- Hannah Weiher
- Dr. Howard Ge
- Dr. Earle
- Professor Ransbottom

BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING VIRGINIA TECH

VT ISE – Factory Robotics

Team Members: Seth Rose, Robert Velasco, Teddy Gizachew, Yuqing Liu, Steve Kim

SME & Customer: Dr. Andrea L'Afflitto **Mentor:** Prof. Scot Ransbottom **GTA:** Amrita Chakraborty

GRADO DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING VIRGINIA TECH

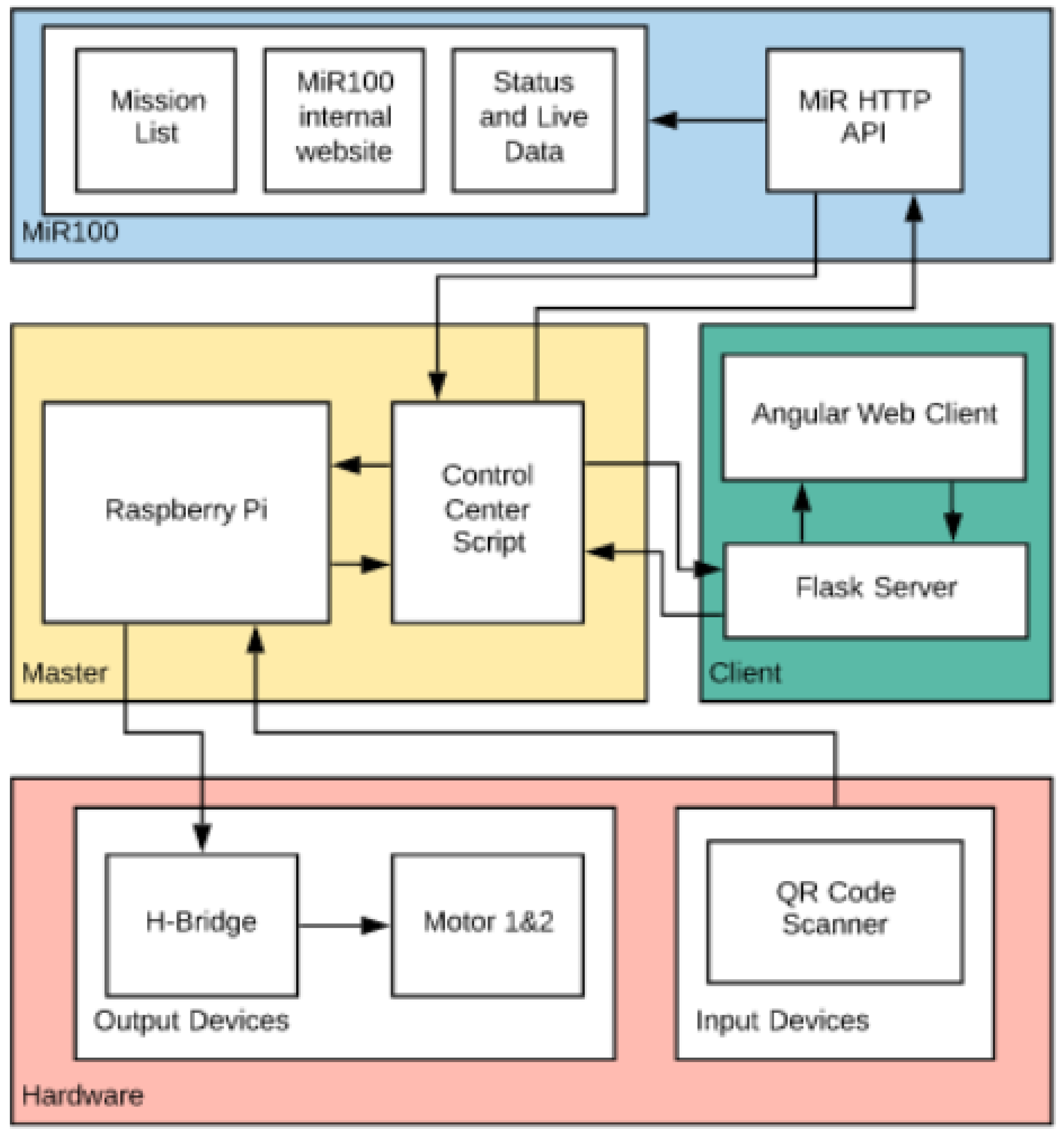
Motivation

To implement an autonomous robotic system which interfaces with a ground vehicle and a microcontroller to deliver parts within an Industry 4.0 environment.

Objectives

- Interpret QR codes to perform five functions
- Create three position coordinates accessible to the ground vehicle
- Build a conveyor belt controlled by a motor
- Integrate entire system with Raspberry Pi being the central point of control
- Create user interface to start/stop missions and display status messages

System Block Diagram



Voice Over Demo Videos

- User Interface
- Ideal Case
- Object Avoidance
- Obstacle Blocking Position
- Path Retry Error
- Resume from Error Position

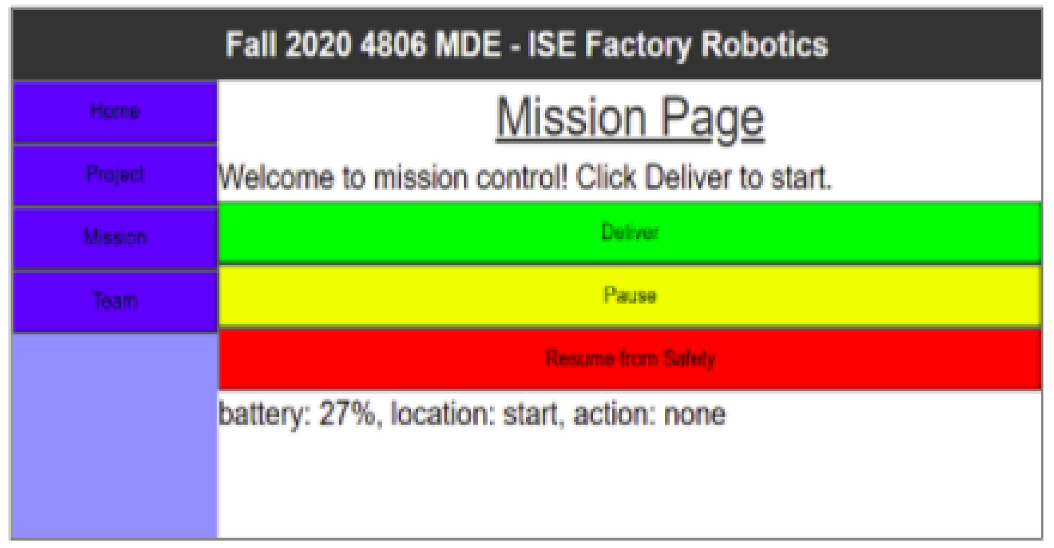
QR Code Functions

- Dock
  - Signal that MiR has arrived
- Unload
  - Conveyor belt spins backward
- Stop
  - Conveyor Belt Stops
- Load
  - Conveyor belt spins forward
- Undock
  - MiR begins to move towards final position

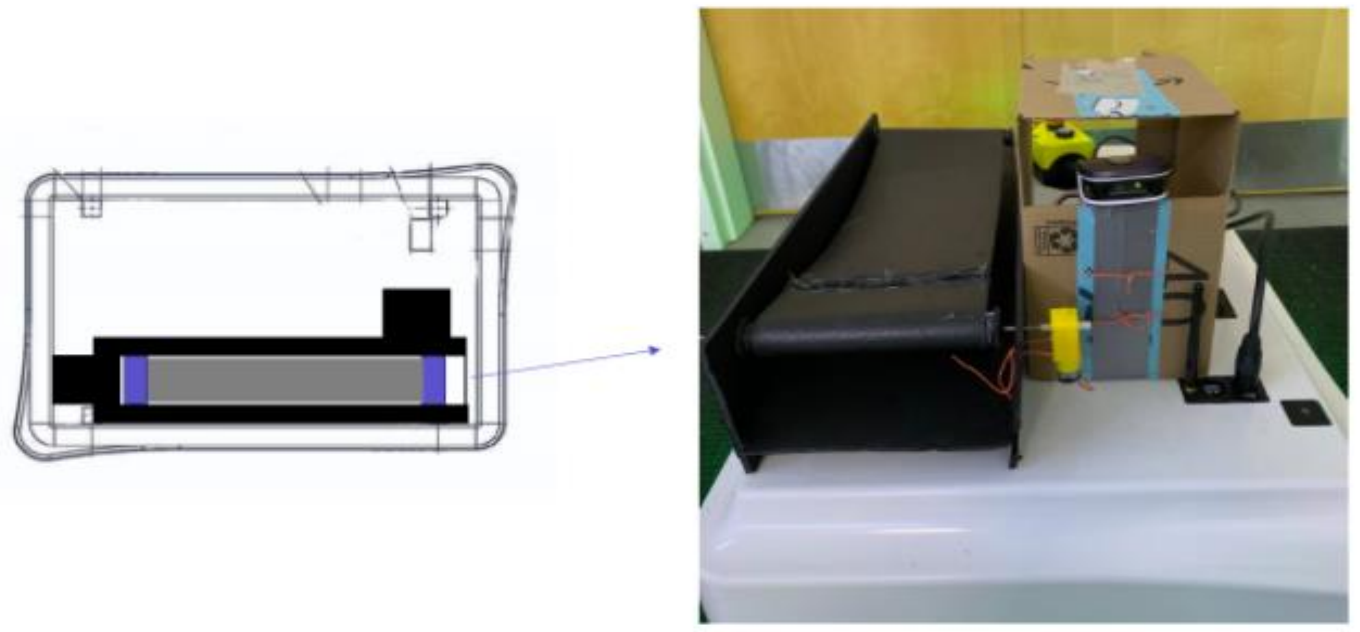
unload

User Interface

- Allows user to:
  - Start Mission
  - Pause Mission
  - Resume Mission after an error has occurred
- Hosted on the Raspberry Pi
- Accessible via local WiFi

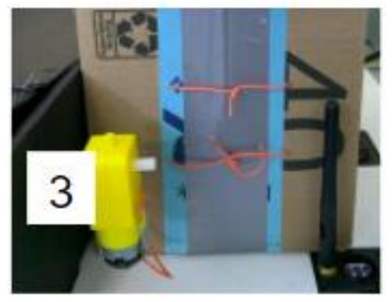


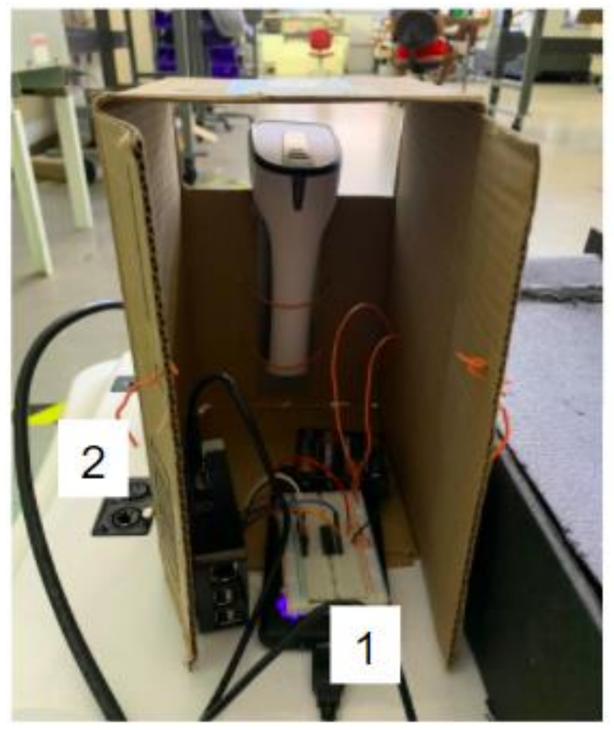
Conveyor Belt



Electrical Components

1. Power Bank: 5V/2A Output
2. Raspberry Pi 3
   a. 6V power supply
   b. H-Bridge
3. 6V DC Motor





Future Improvements

- Autonomous delivery to stations with varying heights
- Weight sensors to determine the exact part being delivered
- Storing the data of past missions
  - Success/Fall, parts being delivered, path taken
- Addition of multiple delivery stations

Acknowledgements

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

- Dr. Andrea L'Afflitto (Customer Contact and Subject Matter Expert)
- Madison "Matt" Earnest (Director of Learning Factory)
- Kim Medley (ECE Department Accountant)

Personal Locator Beacon System

Team Members: Brian Lam, Connor Schutte, Donald Zimmerman, Ha Young Kim
SME: Dr. Louis A. Beex   Mentor: Prof. Kenneth Schulz

Background

Objectives

- Create a beacon that can send and receive a uniquely programed ID
- Must be portable (fit within 30 in cubed)
- Follow health and safety guidelines created by the government for sending signals

Process

GPS module receives location data

↓

Use high level programming language to generate unique I.D

↓

Use high level programming language to code microcontroller to encode the signal

↓

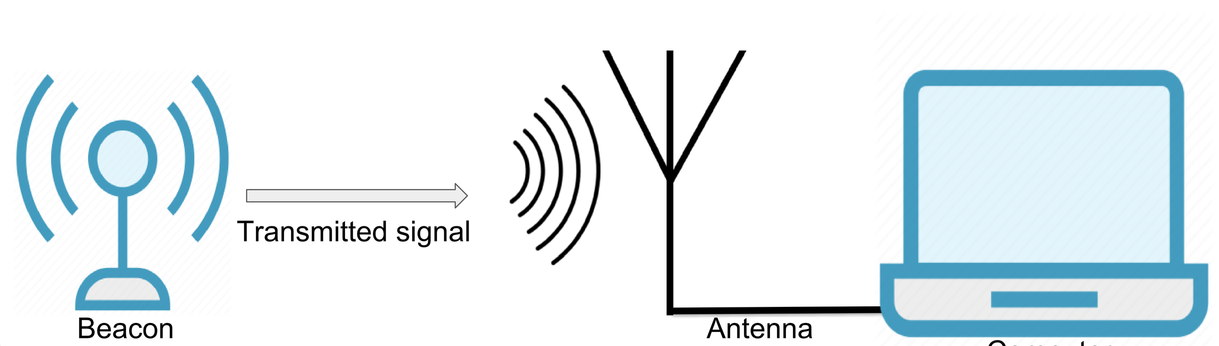
Send encoded signal to software-defined radio (SDR)

↓

Data is recorded on computer

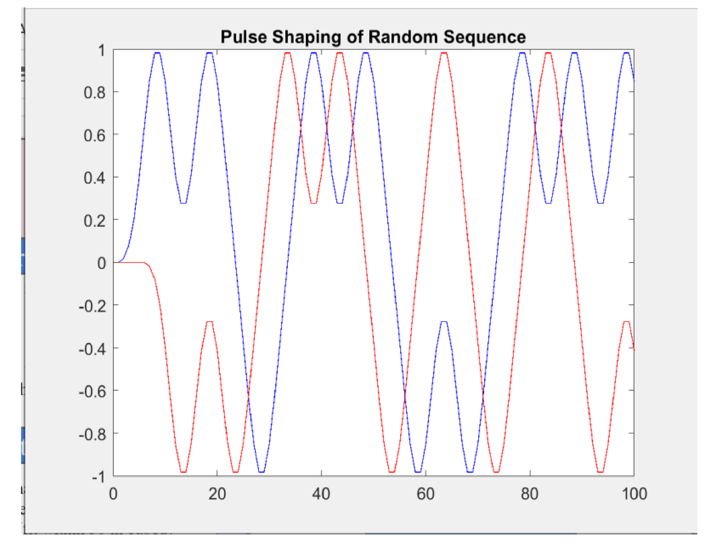
↓

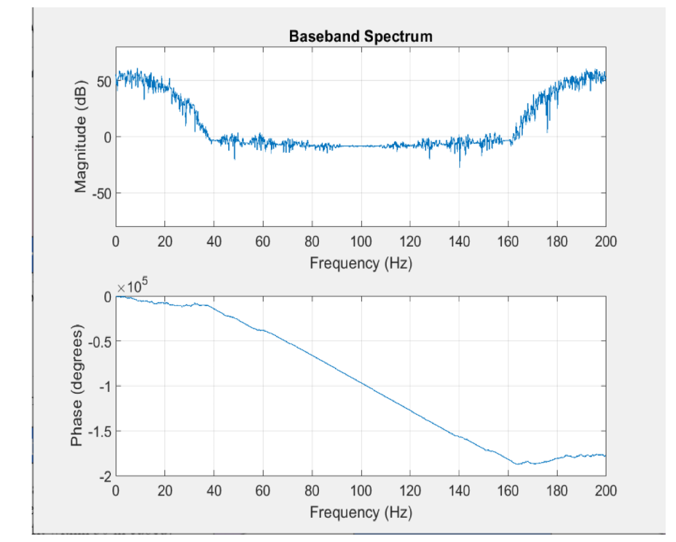
Use MATLAB to decode the signal and conduct analysis



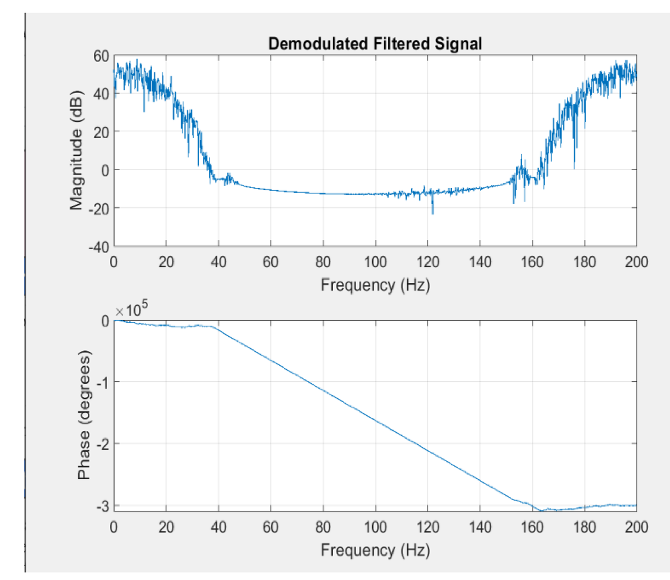
Simulation

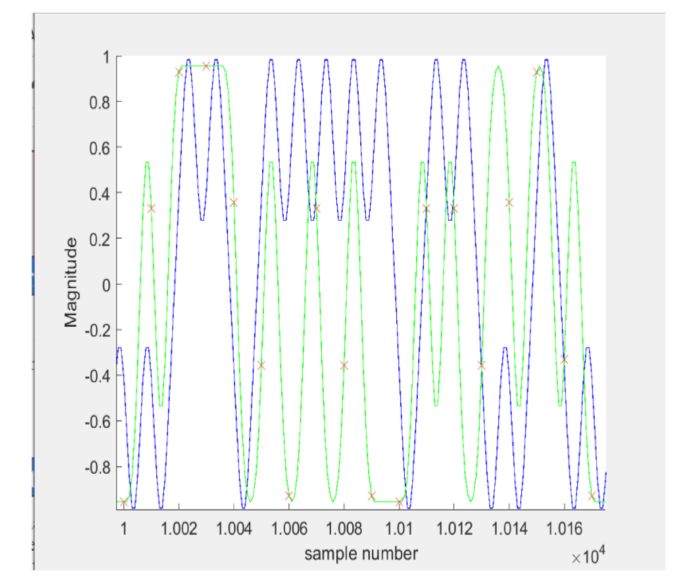
Modulation:
Pulse shaped and baseband modulated signal



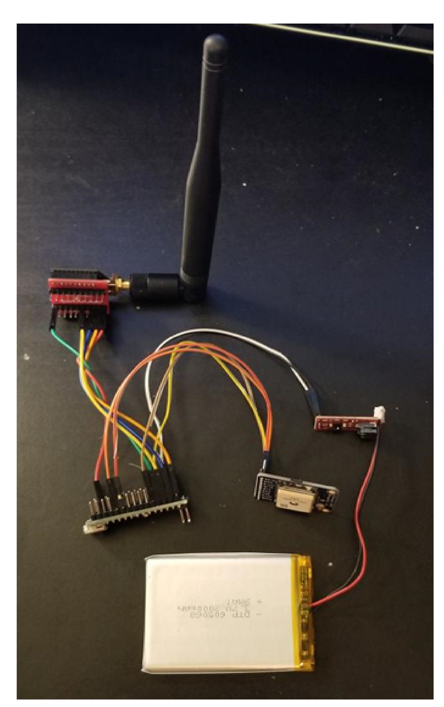


Demodulation:
Filtered baseband signal and Q component of received signal

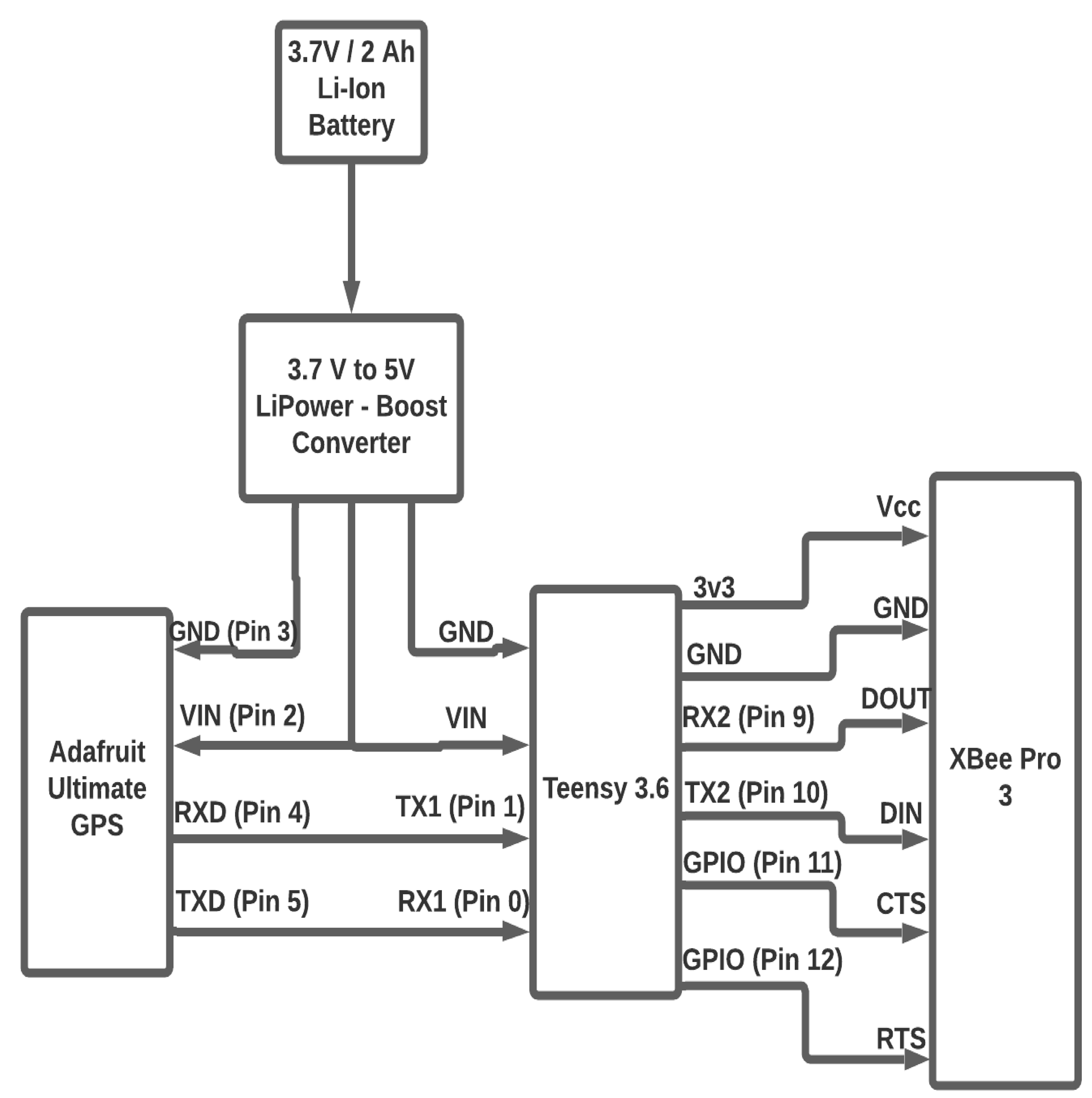




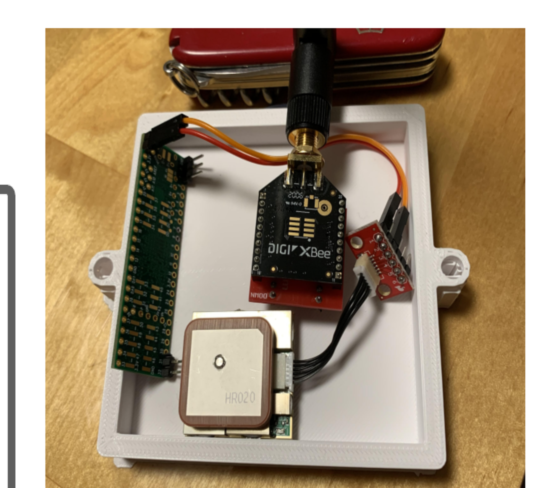
Hardware



Hardware Implementation of Beacon



Connection Diagram for Beacon



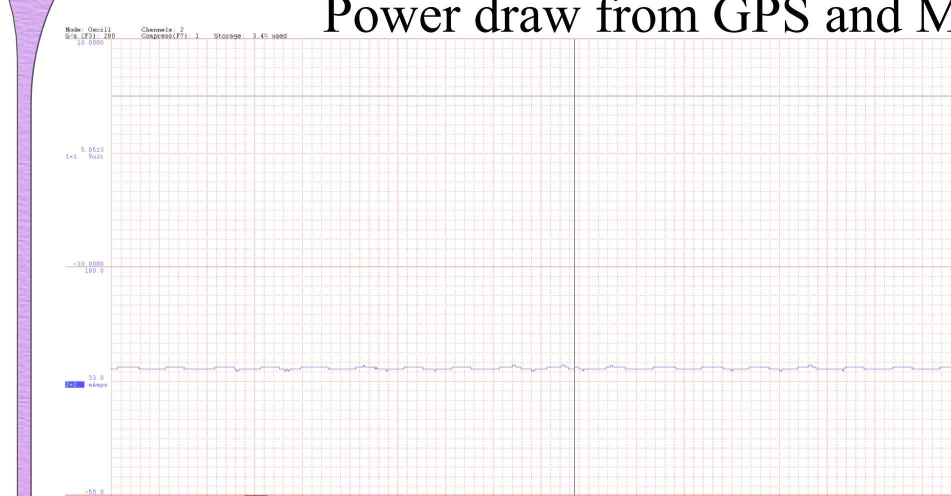
Components within Case Prototype

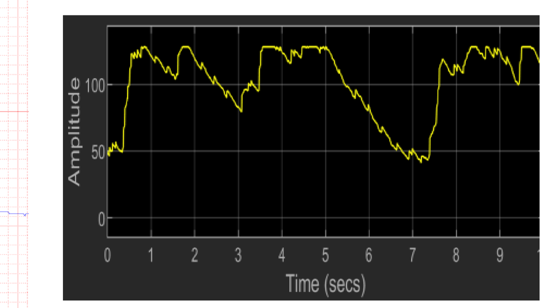
Challenges

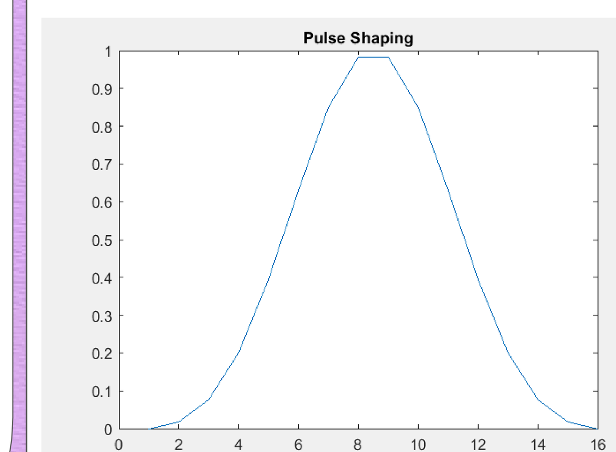
- Shipping delays/transmission to remote work due to Covid-19
- Reading in signals to a MATLAB code
- Shortened working period due to Covid-19

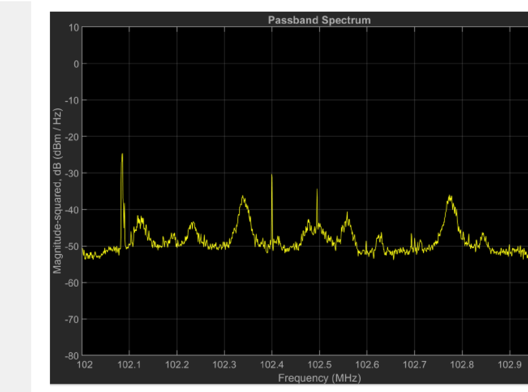
Analysis

Power draw from GPS and Microcontroller









MATLAB Spectrum Analysis SDR

The equation for our Blackman Window Filter:

$$w[n] = a_0 - a_1 cos\left(\frac{2\pi n}{N}\right) + a_2 cos\left(\frac{4\pi n}{N}\right)$$

$$a_0 = \frac{1-\alpha}{2};\ a_1 = \frac{1}{2};\ a_2 = \frac{\alpha}{2}$$

Conclusion

Building a set of beacons provided the team with a great sense of real world problem solving. It gave us experience with simulating, prototyping, real world logistical problems and signal processing under suboptimal conditions.

Acknowledgements

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

- Dr. Louis Beex (SME)
- Kim Medley (Purchasing)
- Ben Beasley, Stephen Kralick and Michael Drescher (Zeta associates)

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