ECE

MAJOR DESIGN EXPERIENCE EXPO

November 20, 2024
The Inn at Virginia Tech

COLLEGE OF ENGINEERING
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

Agenda

Registration	9:30am–10:15am
Welcome	10:15am–10:30am
Tracks	10:45am–12:45pm
Posters and Pizza	1:00pm–3:00pm
Awards	3:00pm–3:30pm

Presentation Tracks

Welcome to our Fall 2024 ECE Major Design Experience (MDE) Exposition. Each semester, we come together and take a few hours to review and celebrate the accomplishments of our undergraduate student teams. The MDE is intended to be the culmination of the students' entire undergraduate engineering educational journey. Today's MDE Expo showcases the results of 82 students, each working and learning together as a member of a design team finishing their second semester of work on their teams' unique projects.

Today, 19 exciting projects are showcased and each is a unique, open-ended, technical challenge defined by our industry partners. Each student team has engineered their own solution to their project with facilitation from our faculty subject matter experts (SMEs). Whether a student's career takes them to work in industry, to continue towards an advanced degree, or to pursue roles in our national labs, their MDE capstone will impact much of their approach to making contributions to their technical communities and, more broadly, throughout society.

Today's ECE MDE Expo offers us an opportunity to examine and celebrate each project team's outcomes and results. Once you've seen today's demonstrations, posters, and technical presentations, I think you will agree that all our students have learned much and most have delivered some very inspiring and useful projects.

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 is evidenced in these 19 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.

Harpreep Dhillon
W. Martin Johnson Professor & Interim Department Head
Bradley Department of Electrical and Computer Engineering

Sponsors

We greatly appreciate their support.

PARSONS

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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	Customer	Project	Subject Matter Expert (SME)
Aerospace Corp Arlington, Virginia	John Janeski	Sensor Fusion for Autonomous Navigation	Dan Stilwell
Boeing Blacksburg, Virginia	John D. Williams	Exploiting Bluetooth Vulnerabilities in the Nordic Thingy	Paul Plassmann
Boeing Blacksburg, Virginia	John D. Williams and Michael Mitchell	Bluetooth Low Energy (BLE) Based Mesh Network	Scott Midkiff
NAWCAD, NAS Patuxent River, Maryland	Israel Jordan and Andrian Jordan	Infrared Friend-Or-Foe Identification Sensor Design and Vision System for Lightweight UAV	Yizheng Zhu
Parsons Centreville, Virginia	Craig Vieth	Project LLM: An Offline Chatbot Memory Solution	Wenjie Xiong
Parsons Centreville, Virginia	Craig Vieth	Interactive Digital Twin for Dynamic Building Management	Richard Johnston
Parsons Centreville, Virginia	Peter Rochford	Blue Sentinel: Tactical Decision Aid	Peter Rochford
Parsons Centreville, Virginia	Bill Roman	Bluetooth Asset Tracker	Walid Saad
Parsons Centreville, Virginia	Bill Roman	Sub-1-GHz Direction Finder	Jeff Walling
Prime Vision Technology Richmond, Virginia	Timo Thans	Robotic Motion Planning	Ryan Williams
Psionic Hampton, Virginia	Rob Fleishauer	LiDAR Field of Regard Expansion System	TC Poon
Virginia Cyber Range	Tom Weeks	Network Portscan Display Panel Challenge	Thomas "Tweeks" Weeks

Sponsor	Customer	Project	Subject Matter Expert (SME)
Virginia Tech, ECE Blacksburg, Virginia	Ken Schulz	Optic Sensor and Vision System for Lightweight UAV	Peter Han
Virginia Tech, ECE Blacksburg, Virginia	Jeff Walling	Inverse Design of Passive RF Components	Jeff Walling
Virginia Tech, ECE Blacksburg, Virginia	Daniel Connors	Autonomous Water Monitoring System for Remote Creek Management	Daniel Connors
Virginia Tech, ECE Blacksburg, Virginia	Daniel Connors	Fabricating Microneedle-Based Medical Delivery Patches	Ashana Puri
Virginia Tech, ECE Blacksburg, Virginia	Joe Adams	Swarm Robots for Disaster Response	Dan Stilwell
Virginia Tech, ECE Wireless@VT Blacksburg, Virginia	Carl Dietrich	Portable Transmitter Location System	Carl Dietrich
VT College of Natural Resources Blacksburg, Virginia	Laszlo Horvath	Wooden Pallet Life-Cycle Tracking	Majid Manteghi

Project Teams and Posters

Interactive Digital Twin for Dynamic Building Management

LEFT to RIGHT: Alexander Tolochkov, Donovan Jones, Riya Parikh, Thomas Campbell, Riker Wilson

CHALLENGE

To develop a digital twin platform for a building on campus that consolidates data, offers 3D visualization, and provides real-time insights that will empower building managers to make more informed decisions. The solution should be user-friendly, utilize sensors to track building metrics, and store geolocated equipment documentation.

PARSONS

SME: Richard Johnston

Customer: Craig Vieth

Thomas Campbell Springfield, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I look forward to going into the software industry and further developing my skills. Studying Computer Engineering has given me the confidence to learn more about cybersecurity and jump headfirst into my career after graduation.

Course Comment: Our Digital Twin project has given me the unique opportunity to create software that solves a real-world problem. This practical experience has been the most helpful and rewarding class in my college career.

Donovan Jones Burke, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I hope to enhance my software development skills and begin my professional career with a company that makes a difference in people's lives.

Course Comment: Throughout this project I was able to put everything I've learned to practice, and continued to expand the breadth of my knowledge. This experience also helped me develop a lot of skills necessary for professional environments.

Riya Parikh Niagara Falls, Canada

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I plan on pursuing a masters degree in systems engineering. I will be working in the field of process automation and will use the knowledge I have gained at Virginia Tech throughout my career. I hope that my chosen career path keeps me challenged and motivated.

Course Comment: This project has helped me immensely with my problem solving skills. It has been a highly rewarding experience that I will always value.

Alexander Tolochkov Southampton, Pennsylvania

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I envision building software that solves important problems with simple, effective solutions. I aim to create positive change and make a real difference.

Course Comment: This project allowed me to apply my technical skills in a collaborative environment while tackling a complex, real-world challenge.

Riker Wilson McLean, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I want to create software that enhances people's lives and makes work processes more efficient, with the goal of leading my own team someday.

Course Comment: Working on the Digital Twin project has been a valuable and rewarding experience. Senior Design provides a great opportunity to integrate everything you've learned throughout your ECE courses and apply it to a comprehensive, large project that solves a real-world challenge.

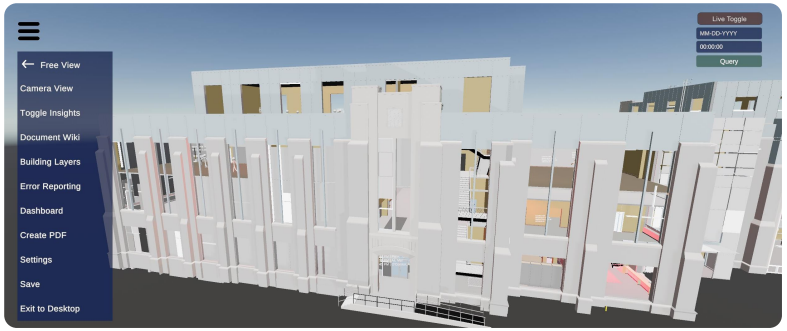
Interactive Digital Twin for Dynamic Building Management

Sponsor: Craig Veith **Mentor:** Dr. Joe Adams
Team: Thomas Campbell, Donovan Jones, Riya Parikh, Alexander Tolochkov, Riker Wilson

Background

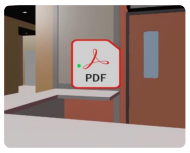
Managing campus buildings involves analyzing data from multiple sources. This fragmented approach makes it difficult for facility managers to gain a comprehensive understanding of building performance, leading to missed opportunities for optimization.

A digital twin will consolidate this data into a unified platform with 3D visualization, enabling managers to make more informed, intuitive decisions, and improve efficiency.



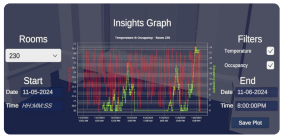
Features

- Visualize real-time temperature, humidity, and occupancy data
- View previously recorded data
- Built-in email functionality exports data to external users
- Show geolocated PDFs of manuals for various appliances
- Allows user to add and modify manuals
- View different building subsystems in isolation
- Intuitive, accessible camera controls
- Robust cloud data management system



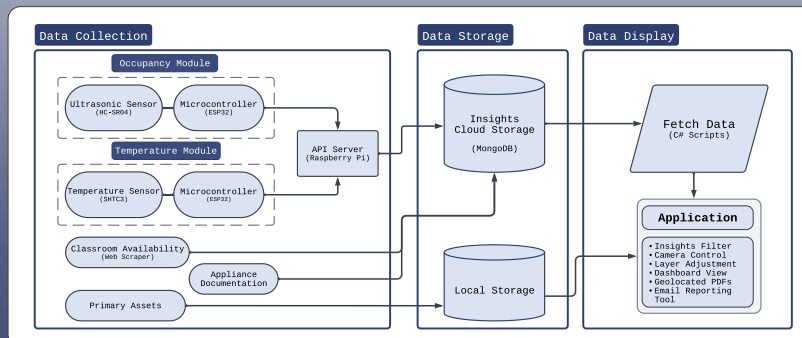
Appliance Documentation Sprite

Email Reporting Tool



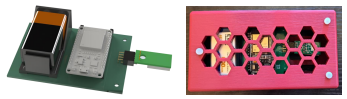
Data Dashboard

Historical View Input and Toggle



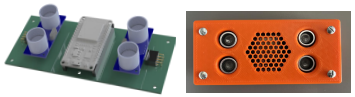
Data Collection

Temperature



- Collects temperature and humidity data
- Connects to Wi-Fi (eduroam)
- Sends data and timestamp to API Server

Occupancy



- Collects occupancy data
- Dual ultrasonic sensors detect directional movement

Data Display

- Humanoid sprites represent the number of individuals in a room
- Room color changes based on ambient temperature
- Text shows classroom availability information
- Card swipe information shows recent access to restricted areas

Classroom Availability

Web Scraper extracts data from Virginia Tech Classroom website

Conclusion

This solution provides user-friendly building management with real-time data, location-based appliance manuals, and cloud storage, allowing users to make quicker, more informed decisions

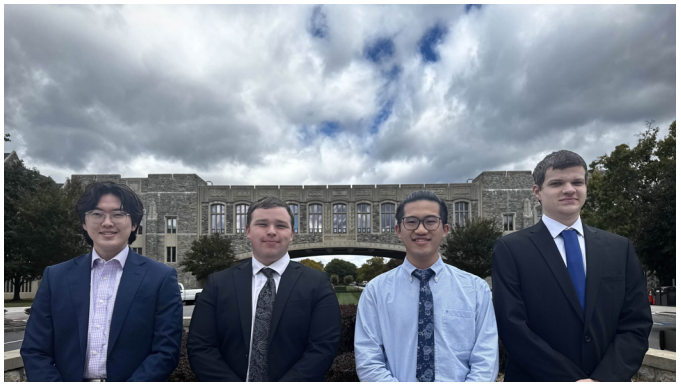
Next Steps

- Enhance immersion with AR/VR
- Additional insights including energy usage

Acknowledgements

We would like to thank Dr. Joe Adams, Craig Vieth, and Rick Johnston, for advising and supporting us throughout the project. Special thanks to the Myers-Lawson School of Construction for providing part of the Hitt Hall model.

Blue Sentinel: Tactical Decision Aid



LEFT to RIGHT: Forrest Meng, Jakob Ford, Alex Lee, Sam Macy

CHALLENGE

Our team was tasked with the development of a user GUI, radar track data parsing, and packaging the entire application into a standalone application.

PARSONS

SME: Peter Rochford

Customer: Peter Rochford

Jakob Ford Virginia Beach, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: Planning to develop embedded systems within the aerospace sector for aircarft and space systems. Hope to eventually contribute to a system that makes it to space.

Course Comment: MDE course provided invaluable hands on experience working on a product that has real world applications. During the course I also developed skills in project management, working within a team, and translating requirements to technical implementations.

Alexander Lee Herndon, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Looking forward to designing embedded system solutions in portable devices. After graduating, I hope to make an impact in fields that include robotics, smart home technology, and or accessibility devices.

Course Comment: Senior MDE provided an exceptional learning environment for students to experience workplace readiness skills with a customer. The course encourages effective communication, risk assessment, and project management skills preparing the students for future jobs.

Sam Macy Lovettsville, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Further research and development of real-world AI and ML for applications such as interpersonal records and cirminal investigation.

Course Comment: The course was a good introduction to what planning, communcation, and work for "real-world" projects and teams are like.

Forrest Meng Fairfax, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Hoping to work in startups related to fintech and high performance/low latency systems. Additionally, hoping to build out personal research in ML and compiler optimizations.

Course Comment: The MDE course helped provide light into how to do in depth planning for larger projects, as well as how having task organization is useful in case of bottlenecks from third parties.

Blue Sentinel: Tactical Decision Aid

Alex Lee, Forrest Meng, Jakob Ford, Sam Macy
Sponsor and Subject Matter Expert: Dr. Peter Rochford, Parsons Corporation
Mentor: Dr. Joe Adams, Virginia Tech

Background

Small Unmanned Aircraft Systems (sUAS) pose a significant threat on the modern battlefield because of their infiltration, attack, and information gathering ability. The Blue Sentinel: Tactical Decision Aid (TDA) aims to **assist the operator with identifying sUAS threats** through **autonomous data processing and threat classification.**

Impact

- Reduce response time to potential threats
- Reduce stress on operators
- Clearly display threats to operator
- Process data to make autonomous threat determinations

Objectives

- Interactable graphical user interface
- Schema for varying data formats
- Bridge frontend with the backend
- File server for data streaming
- Package into standalone application

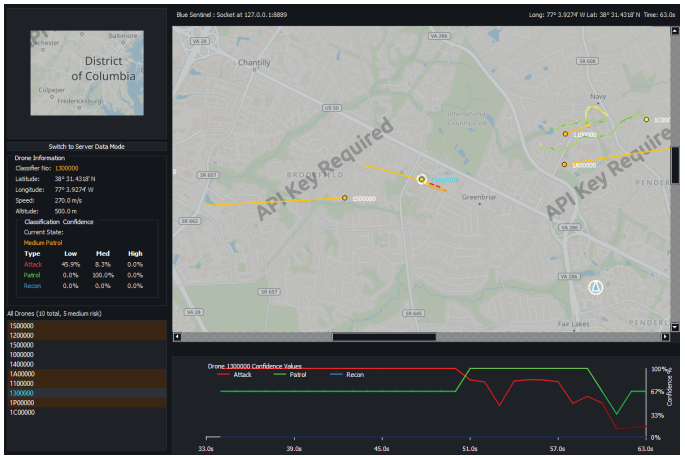


Fig 1. Graphic User Interface for the Blue Sentinel Software Application

Frontend

- Multi-threaded Java backend allows simultaneous data processing and frontend access
- C++ frontend with Qt5 Library for UI components and geographic visuals via Map QML APIs
- Java Native Interface (JNI) used to bridge the codebases and pass information between them

File Server

- Utilizes REST architecture built in Python 3.10 with open-source Flask library
- Portable and scalable for any operation required
- 2 GET Request queries to retrieve “all” files and only newly posted “updated” files.
- POST request to upload JSON files onto server

Schema

- Developed a streamlined interface for formatting varying input data
- Inputs from JSON files are currently supported
- Flexible parameters to support future JSON formats

Standalone Application

- Built with Maven (Java backend) and CMake (C++ client) for cross-platform compatibility
- Single executable and JAR file
- Run locally or connect to a server for data access
- Designed for flexibility, backend configurations can be modified directly from the client

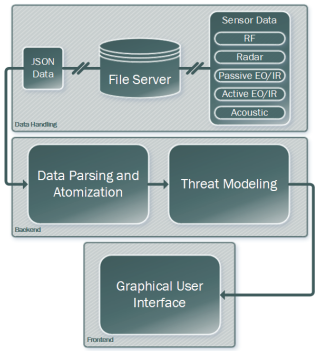


Fig 2. High level diagram for system and dataflow

Results

- Local file server for data streaming
- Integrated C++ frontend GUI
- Process tracks from field data
- Frontend and backend packageable as a standalone application

Future Work

- Improve threat classification via tuning or advanced ML algorithms
- Allow triggering of responses to threats via GUI interaction
- Improve efficiency and structure of backend
- Add layers of cyber security onto file-server

Acknowledgements

A special thank you for those who assisted is throughout this project
Dr. Peter Rochford
Dr. Joe Adams
Dr. Daniel Connors

Bluetooth Asset Tracker

LEFT to RIGHT: Dustin Mazza, Kyle Adams, Zach Santoni, Neil Baptiste

CHALLENGE

This project develops a new innovative Search and Rescue (SAR) tracking device that uses Bluetooth 5.4 Direction Finding technology with Constant Tone Extension (CTE) signals to monitor and locate workers in hazardous environments. The portable, battery-powered device uses an antenna array and BG22 board to calculate Angle of Arrival (AoA) for precise location tracking, providing real-time feedback to rescue personnel when conventional communication methods fail or are infeasible. By integrating custom hardware, asset tag tracking, and a user-friendly interface, this solution helps ensure the safety of emergency responders and workers by enabling continuous monitoring in unstable conditions.

PARSONS

SME: Walid Saad

Customer: Bill Roman

Kyle Adams West Babylon, New York

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems
Bachelor of Arts in Foreign Languages
Russian

Aspirations: I am hoping to leverage my degree and experience here at Virginia Tech to start a career in power systems, and make a positive impact on society.

Course Comment: This course, in my opinion, was a good exercise in working on a team to tackle an engineering problem. We gained experience not only in technical aspects of our project, but also in communication and teamwork as we scheduled various meetings and tasks throughout the year, while handling deadlines and technical challenges.

Neil Baptiste Chester, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After graduating, I plan to pursue a graduate degree and continue my current research on Specific Emitter Identification (SEI). I want to further develop my expertise in this area before transitioning to industry. Once I do, my goal is to make a meaningful contribution to secure communications.

Course Comment: This course has provided invaluable experience in designing and building a product as a team, strengthening my skills in communication, research, and presenting proposals to stakeholders. I've gained a solid understanding of Bluetooth Direction v5.1+ and AoA technologies. Overall, collaborating with my teammates has been rewarding, and I'm grateful for the opportunity to learn and grow together.

Dustin Mazza Richmond, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: Aspirations are hopes for the future. My primary hope is that my Computer Engineering degree will give me greater control over my time. I entered this field later in life than most, but I was driven by the desire to spend more time with my family while working less. A career in this industry offers both high compensation and stability, which will help fulfill these aspirations. Oh, and also to be debt free in 5 years. That one is up there as well.

Course Comment: The journey from the start of ECE-4805 to the end now of ECE-4806 has been a learning experience in more ways than expected. Though I learned many things about Bluetooth Direction Finding v5.1+, the true aspect learned was the logistics behind working the project as a team. This meant regular meetings and tracking progress while simultaneously meeting our own set deadlines and milestones was more the focus. It prepared us for the parts of industry that would not be the focus of our thoughts as we enter the working world.

Zachary Santoni Newport News, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: Looking ahead, I see myself enjoying field operations, R&D, or test engineering to develop solutions advancing large-scale optical and electrical systems, where I am able to see and experience the full impact of my contributions.

Course Comment: This course taught us important criteria for managing the workload and ensuring that each part of the project was implemented in a timely manner. There was a heavy amount of teamwork required to structure our design and present the project to all of the stakeholders. I enjoyed working with my team for a full year and seeing how our ability to work together developed.

Bluetooth Asset Tracker

Team Members: Dustin Mazza, Neil Baptiste, Kyle Adams, Zach Santoni
Customer: Bill Roman, Parsons | **Mentor**: Dr. Daniel Connors, Virginia Tech | **Subject Matter Expert**: Dr. Walid Saad

Key Objectives

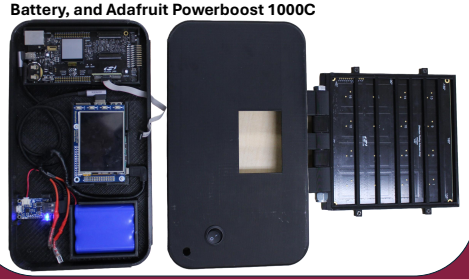
- Must be portable (carried by a person) and battery operated
- Able to provide a direction and signal strength to a detected device
- Must be able to discriminate a specific device among many

Target Application:

- Emergency Response scenarios
- Hazardous environment operations

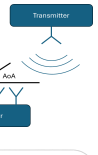
Hardware Solution

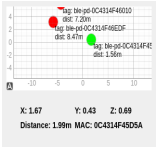
- Pictured Items: BG22 4x4 Antenna Array and Microcontroller, Raspberry Pi 4B with Display, Lithium Ion Battery, and Adafruit Powerboost 1000C

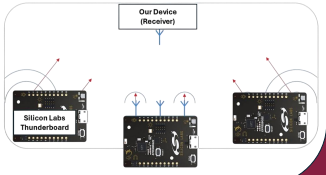


Software Solution

- Graphical User Interface (GUI)
  - Displays direction of the detected tag(s)
  - Ability to select tags and display their MAC address and distance
  - Arrow displaying direction of tag
  - Adjustable screen divider





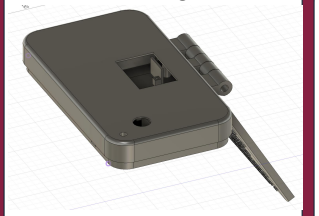


Design Overview

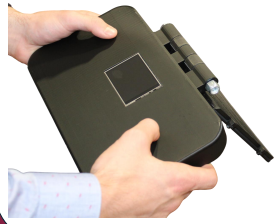
- The Bluetooth Asset Tracker (B.A.T.) leverages Bluetooth 5.4 Angle of Arrival (AoA) direction-finding technology to accurately detect and track the location of asset tags
- Constant Tone Extension (CTE) signals emitted from tags were used to calculate their direction relative to the device
- The precision-engineered, modular PLA enclosure was designed around assembly and integration

B.A.T.

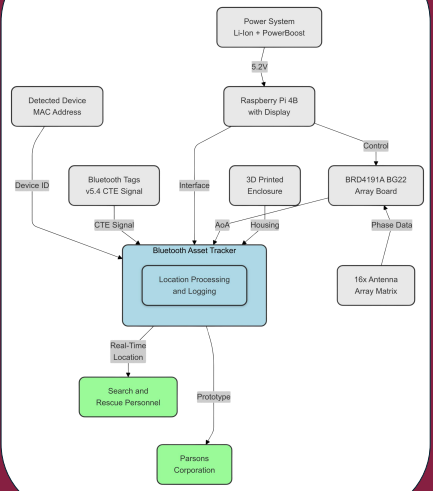
From Design



To Implementation



Block Diagram



Conclusion

- The device is innovative, as most similar implementations of AoA for Bluetooth tracking rely on a stationary receiver
- The B.A.T. is a useful tool for improving the safety of Search and Rescue personnel
- We met and surpassed the requirements of Parsons by including certain desired features

Future Work

- Improve power converter to support higher current draw
- Improve effective detection angle for direction finding
- Add weatherproofing to casing design
- Add other forms of user feedback such as audio
- Implement a recursive neural network to inform user when tag is out of antenna field of view
- Implement 3D graphics frontend for multi-level indoor direction-finding

Acknowledgment

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

- Bill Roman, Parsons (Customer)
- Dr. Walid Saad (Subject Matter Expert)
- Dr. Daniel Connors (Team Mentor)
- Kim Medley (Accountant, ECE Procurement)
- Melanie Gilmore (Conference Room Scheduling)
- Max Ofsa (Prototyping Studio Manager)
- John Hutchinson (Hacksburg)
- Max Bareiss (Hacksburg)
- Josh Eggleston (Hacksburg)

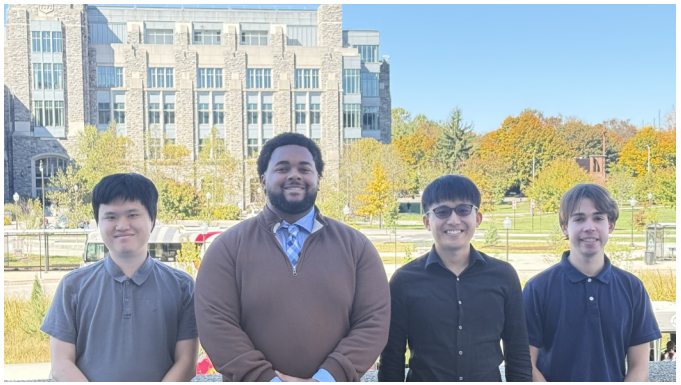
Results

- Core Functionality Achievements:
  - Successfully implemented multi-tag simultaneous detection with 5 tags minimum
  - Direction finding using AoA and Received Signal Strength Indicator (RSSI)
  - Able to discriminate specific tags using MAC address information
  - Continuous data logging with JSON format and timestamps
- Performance Metrics:
  - Material Interference Results: Non-metallic materials showed minimal impact; metal caused slight signal degradation; concrete/brick slowed updates to 1-2 seconds; functionality limited beyond two barriers.
  - Range and Detection:
    - Clear Line of Sight: 90 m
    - Through wall: 25 m
  - System Performance
    - Battery Life: 4+ hours
    - Boot Time: 20 seconds
- Physical Implementation:
  - Integrated component enclosures with raised elevations for thermal dissipation
  - Secure component mounting within enclosures using M2.5 and M3 screws
  - 3D PLA printed case from Computer Aided Design

"Must Have" Requirements	
Must be portable (carried by a person), battery operated	✓
Must be able to provide a direction and signal strength to a detected device	✓
Must be able to discriminate a specific device among many	✓

"Nice to Have" Requirements	
Rechargeable using USB	✓
Audio feedback to guide the user to the device	X
Visual feedback to guide the user to the device	✓
Simple way to select a particular device to locate, from a list of detected devices	✓
The detector should track its own location using GPS or similar	X
Keep a periodic log of device detections, RSSI, and direction and location of the detector	✓

Sub-1-GHz Direction Finder



LEFT to RIGHT: Vince Feng, Tyler Collins, Jia Xue Kow, Ethan James

CHALLENGE

Dense environments like forests and urban areas present significant challenges for RF tracking due to high levels of noise and signal reflection, which can severely compromise accuracy. We aim to develop a portable, cost-effective RF tracking system that reliably locates and tracks targets at long ranges and under a 1-Ghz frequency band, enhancing accessibility for search and rescue operations and commercial applications.

PARSONS

SME: Jeff Walling

Customer: Bill Roman

Tyler Collins Spotsylvania, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: I aspire to work on power and energy systems, where I can apply my passion for electrical engineering to develop innovative solutions that drive sustainability and efficiency in the future.

Course Comment: This course allowed for me to collaborate with three other exceptional engineers in researching, studying, and developing a product resulting in an invaluable experience.

Vince Feng Fremont, California

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I aspire to build robust computer architecture/software that provides security for future users and acts as the foundation for future innovation.

Course Comment: During this course, I got the unmatched experience of working with expert fellow engineers for the development of a product that could have a real-world impact.

Ethan James Annandale, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I will pursue ASIC (Application-Specific Integrated Circuit) design with a focus in digital signal processing.

Course Comment: This course allowed me to gain experience in a few niche areas of signal processing and improve my programming skills.

Jia Xue Kow Kuala Lumpur, Malaysia

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: I aspire to contribute to the design and development of advanced power electronics solutions that drive renewable energy innovations.

Course Comment: Working on this project gave me the opportunity to collaborate with an exceptional team, making the experience truly memorable.

Sub-1-GHz Direction Finder

Team: Ethan James, Jia Xue Kow, Tyler Collins, Vince Feng
Sponsor: Mr. Bill Roman (Parsons Corporation) SME: Dr. Jeffrey Walling Mentor: Dr. Daniel Connors

COLLEGE OF ENGINEERING
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

Problem Statement

- Efficiently locating lost people, pets, or property over long distances remains challenging, especially in outdoor settings.
- Current tracking solutions are limited by range and signal interference, making distinguishing individual devices in obstructed areas difficult.

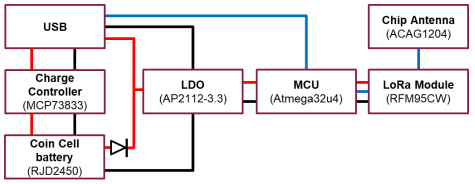
Introduction

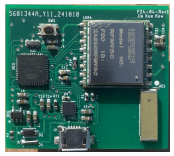
- We propose a sub-1-GHz direction-finding system to locate moving individuals or objects.
- This system is ideal for search and rescue operations, especially in challenging environments.
- Operating at 915 MHz, the system provides long-range coverage with strong penetration and minimal interference.
- Each transmitter broadcasts a unique 4-byte ID.
- The receiver displays the direction of each transmitter and uses their unique ID to distinguish between them.

Requirement

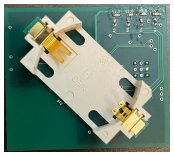
Transmitter		Receiver	
Size.	7.62 cm x 12.7 cm index card.	U.I.	Equipped with a graphical interface.
Frequency.	Operates on an unlicensed sub-1Ghz band.	S.D.R Integration.	Uses Kraken SDR for signal processing and direction finding.
Signal range.	Up to 1 km in open area and 500 m in dense local.	Transmitter Integration.	Capable of distinguishing between multiple transmitters.
Battery life.	Minimum 12 hours.	Battery life.	Minimum 3 hours.

Transmitter





Front view.
4 cm x 3.5 cm x 1.5 cm

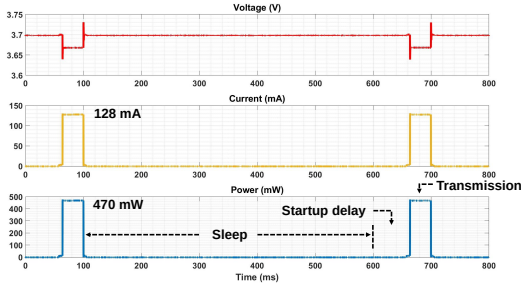


Back view.

Casing.
5 cm x 4.5 cm x 2 cm

Transmitter Power Dissipation

- One 4-byte ID transmission at +20 dBm roughly every 600 ms.
- Major operations: sleep, startup delay, and transmission.
- Data transmission dissipates the largest power.
- Average power dissipation is about 28 mW.

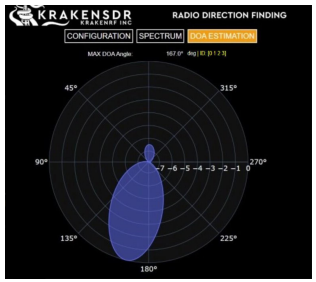


- A coin cell battery RJD2450 (with 200 mAh capacity) would power the transmitter for about 27 hours.

Receiver

- The KrakenSDR receiver uses a vehicle-mountable circular antenna array for direction-finding. The receiver interfaces with a Linux machine such as a Raspberry Pi.
- The MUSIC (MUltiple Signal Classification) Algorithm is used to predict the direction of arrival of up to 4 incoming radio signals.
- Transmitters are given a unique ID that is transmitted using LoRa modulation. The receiver uses a software demodulator to decode these IDs and identify each transmitter.
- The signal processing backend is written in Python using libraries – including numpy and scipy – this allowed us to add a software LoRa demodulator with relative ease.
- The user interface is web-based and uses a Python backend.
- A direction of arrival plot is shown on the web interface for locating transmitters, as well as a spectrogram plot for debugging and system monitoring.

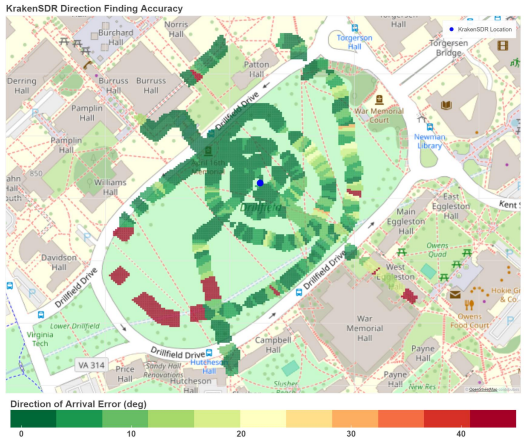
KrakenSDR.



Web Interface showing direction and unique ID.

Field Test

- We positioned the receiver on the Drillfield and walked around campus with our LoRa transmitter and a GPS logger.
- The locations we visited are overlayed with a colormap indicating the accuracy of the KrakenSDR direction of arrival predictions.



Reliable direction-finding and LoRa demodulation at 500 m.

Conclusion

- We designed a sub-1-GHz transmitter to work along with a receiver that can function in dense locales, ideal for locating lost things.
- The transmitter with its case fits in a 5 cm x 4.5 cm footprint, lasts around 27 hours, and transmits a unique ID.
- The receiver can distinguish transmitters and display their direction and unique ID on a screen.

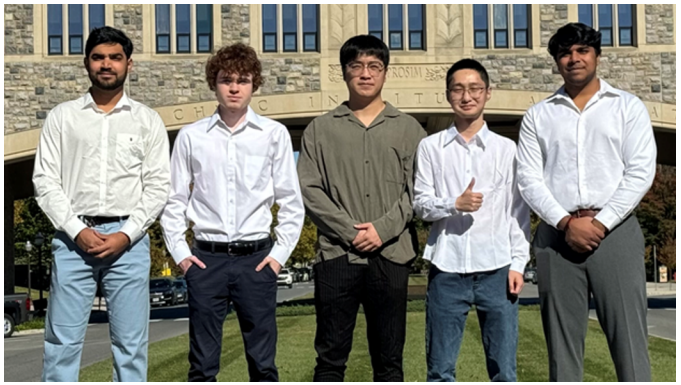
Future Work

Transmitter	Receiver
Use Semtech LoRa Transceiver chips for lower power dissipation and stronger signal.	Experiment with different frequencies and evaluate direction-finding performance.
Explore alternative antennas to extend range.	Use a beamforming algorithm to boost signal-to-noise ratio after direction finding.
Optimize PCB layout to reduce overall size.	Optimize Python data acquisition software.

Acknowledgement

- Sponsor: Mr. Bill Roman (Parsons Corporation)
- Mentor: Dr. Daniel Connors
- SME: Dr. Jeffrey Walling

Project LLM: An Offline Chatbot Memory Solution



LEFT to RIGHT: Abhinav Vemuri, Jacob Bell, Zhanhong Wang, Pengcheng Su, Sanjiv Rao

SME: Wenjie Xiong

CHALLENGE

Our project is an offline chatbot powered by a large language model (LLM) designed to offer efficient and personalized assistance to users. The system includes a user-friendly web interface, a backend for AI responses, and flexible model selection, allowing users to upload files and receive context-based responses. This setup enables users to interact with the LLM offline, ensuring privacy and reliability in information retrieval.

PARSONS

Customer: Craig Vieth

Jacob Bell Austin, Texas

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: To create impactful, reliable software that drives advancements to improve lives and empower the future as a software engineer.

Course Comment: This project has deepened my understanding of AI and natural language processing by guiding me through the complete design and development process for an offline LLM chatbot website. Collaborating closely with my team to create a functional, user-centered interface has not only improved my technical skills in web development but also highlighted the value of adaptability and iterative design in tackling complex challenges. This experience has prepared me well for real-world engineering, emphasizing teamwork, effective communication, and the creation of solutions that meet diverse user needs.

Sanjiv Rao Richmond, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: My goal is to become a machine learning engineer, applying the many skills I have garnered over the course of my degree to designing and deploying AI systems.

Course Comment: This project has been an eye opening experience for me in experiencing the trials and tribulations regarding the development of a solution from the ground up. Being able to work on this project in a team-based environment, alongside the corporate aspects of working with Parsons, has allowed me to grow more as an engineer than any other class. Facing obstacles and changes to our requirements provided an opportunity for the team and I to reach past our initial goals and develop the best possible solution for the customer.

Pengcheng Su Fuyang, China

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: My aspiration is to become an embedded systems engineer, capable of designing and developing software and hardware for embedded systems.

Course Comment: The one year project made me realize the importance of teamwork. Our projects are challenging from planning, modification, implementation and testing. But teamwork makes me realize that the lack of individual ability can be made up by the team. This course allows me to realize my shortcomings in the process of realizing the LLM project and to continuously learn from myself. I am glad to have these teammates and they really help me a lot.

Abhinav Vemuri Detroit, Michigan

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: My aspiration is to become a succesful entrepreneur in the future, who has made strides in the AI/ML field.

Course Comment: This project has been an eye-opening experience, giving me firsthand insight into the challenges and rewards of developing a solution from the ground up. Serving as team leader in a collaborative, real-world environment with Parsons allowed me to grow more as an engineer than any previous class experience. Leading the team through obstacles and adapting to changing requirements provided invaluable lessons in leadership, communication, and problem-solving, pushing us beyond our initial goals to create the best possible solution for the client.

Zhanhong Wang Changde, China

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: My career goal is to become a software design engineer, and this project really helps me learn a lot from different aspects.

Course Comment: This project has strengthened my understanding of the core principles behind natural language processing and AI-driven communication. Working collaboratively with my team has allowed me to develop both my technical skills and my ability to integrate diverse ideas and solutions. Industry sponsorship and guidance from mentors have been instrumental in guiding our project toward practical, real-world applications.

Project LLM: An Offline Chatbot Memory Solution

Team: Abhinav Vemuri, Sanjiv Rao, Pengcheng Su, Jacob Bell, Zhanhong Wang
Customer: Mr. Craig Vieth - Parsons
Mentor: Dr. Joe Adams | Subject Matter Expert: Dr. Wenjie Xiong

VIRGINIA TECH

PARSONS

Problem Statement

- How can we develop a fully functioning LLM chatbot, with memory capabilities, in an offline environment
- A scalable offline solution is highly desirable across many industries that manage large data sets, ensuring data security and privacy.

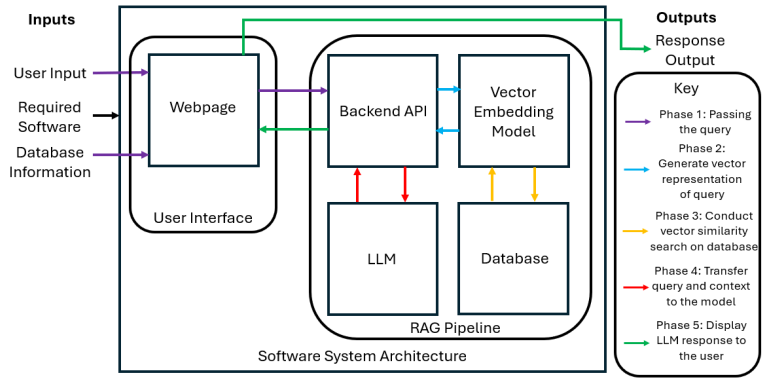
Requirements

- Completely offline solution, requiring no internet connection
- Pluggable API interface
- React SPA
- C# Back-End (ASP.NET Core Web API)
- PostgreSQL Database storing documents for comparison

Sub-Goals

- Must build the API from scratch
- Chatbot should have model switching capabilities
- UI should reflect ParsonsGPT UI as closely as possible

High-Level System Diagram



User Interface

- Provides a simple interface for a user to interact with the chatbot
- Allows uploading documents for context
- Provides capabilities to view past conversations
- Provides user access to alternative models

API / Model Hosting

- Facilitates communication from backend to model
- Models loaded through Ollama Docker image
- Containers are utilized for hosting the models
- Follows OpenAI API REST-based terminology

Document Retrieval System(DRS)

- Information uploaded to the webpage is stored as vectors within the database (pgvector)
- Retrieval Augmented Generation (RAG) system that leverages cosine similarity search for comparison of queries
- Context generated by the database is passed alongside the query to the LLM

Results

Chatbot Response Generation Time

Model	# of Parameters	Speed Of Response Generation (s)
llama3.1	8B	38.16
llama3.2	1B	32.27
llama3.2	3B	24.98
gemma2	2B	37.48
gemma2	9B	30.88
Phi3.5	3.8B	32.49

- System Hardware
  - GPU:NVIDIA RTX
  - CPU: Intel 13th Gen i5-13500H
  - RAM: Available (16GB), Allocated (9.5GB)
- Results largely dependent on system capabilities
- Embedding and database retrieval process averaged <0.5s per query, with a testing average of 0.143

Future Implementations

- Authentication/ User Management
- Filtering Relevant Information with a Scoring Mechanism
- Memory System for users to tailor the model to specific data
- Add possible plugins with configuration such as Wolfram Alpha

Acknowledgements

The team would like to thank these individuals for their support:

- **Dr. Joe Adams** (Mentor)
- **Dr. Wenjie Xiong** (SME)
- **Mr. Craig Vieth** (Parsons)

LiDAR Field of Regard Expansion System

LEFT to RIGHT: John Lucas, Josh Mitchell, Christian De Chiaro, Nii Laryea

CHALLENGE

Psionic's Navigational Doppler LiDAR (NDL) scanning system had a limited field of regard, which restricted its navigational responsiveness for applications like land vehicles, boats, and spacecraft. To address this, the company challenged our team to expand the field of regard by at least +/- 10° while maintaining precise angle measurements. Specifically, Psionic sought to explore techniques for synchronizing slow-bandwidth scanners with high-bandwidth motion platforms and to develop a reliable verification and communication framework for accurate system operation.

PSIONIC

SME: TC Poon

Customer: Rob Fleishauer

Christian De Chiaro Freehold, New Jersey

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: To work in the field of optics and photonics, particularly in laser based fusion energy generation (Intertial confinement fusion).

Course Comment: This course was great I enjoyed it very much. Through this course I discovered my deep interest for optics and photonics. Also, I enjoyed how it simulated real world engineering experience.

Nii Laryea Middletown, Delaware

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I hope to work on and continue to learn about innovative solutions related to embedded systems and hardware design.

Course Comment: This course provided an opportunity to work alongside other talented students and professionals, allowing me to obtain practical skills that I hope to carry with me as I transition to working in industry.

John Lucas Marblehead, Massachusetts

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: To design and manage projects relating to LiDAR, sonar, and radar sensing technology in marine or space environments.

Course Comment: This course is a great way of introducing design work for real customers simulating work after college for engineers.

Joshua Mitchell Clifton Park, New York

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: I hope to work in the field of digital design, as well as extend my interests to analog electronics.

Course Comment: I enjoyed going through a long term project having a customer, subject matter expert, and project mentor. I've never done anything like this and it gave me a lot of experience I hope to translate to my post-college career.

LiDAR Field of Regard Expansion System

Team Members: Christian DeChiaro, Josh Mitchell, Nii Laryea, John Lucas
Customer: Rob Fleishauer, Sanjee Abeytunge, Jeff Monaco, Jamie Lane, Psionic LLC.
SME: Dr. Ting-Chung Poon **Mentor:** Professor Shelly Stover

Motivation

The Navigational Doppler Lidar (NDL) System by Psionic enables effective autonomous navigation across diverse terrains including, land air, sea, and space. However, the system's current field of regard (FOR) is limited, restricting the ability to detect and respond to obstacles, potentially compromising vehicle safety and mission success. **By increasing the FOR, the NDL system can better support vehicles in avoiding obstacles and responding to navigation challenges in real time.** This improvement is crucial for Psionic, as a more capable NDL system will increase autonomous navigation reliability with it in use.

Objectives

- Develop a system that expands the FOR of a Lidar scanning system by at least +/- 10° mechanically (+/- 20° optical).
- Implement a low-bandwidth motion platform with a high-bandwidth scanner to expand the system's FOR.
- Create a verification subsystem to ensure accurate angle measurements of Lidar scanning.
- Record and collect data from conducted test plans.

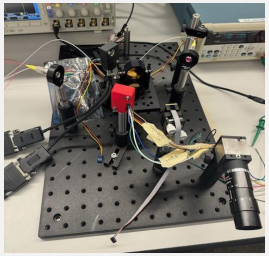
System Breakdown

Software
- Software Development Kits were used to create C++ test scripts for each scanner, with one script per test plan.

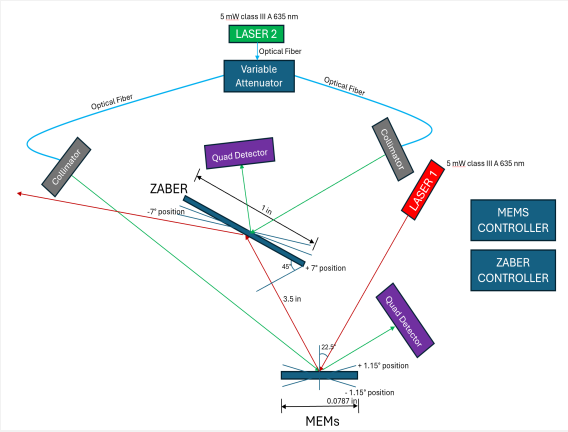
Communication
- All scanner communication occurs through designated controllers, each connected to a laptop.

Primary Laser
- The primary 635 nm red 5mW laser targets both scanners to achieve the desired scanning field of regard.

Verification Subsystem
- A secondary 635 nm red 5mW laser, split through a fiber optic splitter and attenuator, is collimated towards each scanner. The reflected beams hit a quad detector, producing analog voltage based on beam positions. A camera then captures precise beam images on the wall.

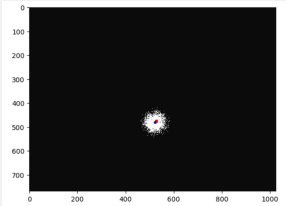


Design Implementation



This is an overview of the overall system including the main scanning and verification subsystems

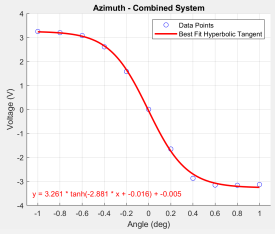
Test Results



Distance ≈ 7.07 pixels or 0.936 mm
Note: 1 pixel ≈ 0.1324 mm

	Measured FOR			
	Azi-	Azi+	Ele-	Ele+
Trial 1	15.72307	15.89603	14.27046	14.27046
Trial 2	15.43413	15.89603	14.15341	14.15341
Trial 3	15.43413	15.89603	14.15341	14.15341

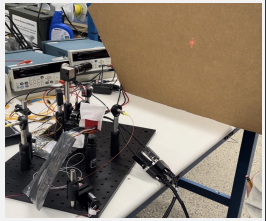
- Above Data shows total measured FOR across three trials



- Figure on the right displays a sample S-plot
- Observe the non-linearity which is expected
- This plot proves the angle doubling becomes non-linear the further it gets from zero
- This plot also allows for error analysis of the beam movements

Conclusion

- Accurate measurements are attainable using a combined system that involved a slow-bandwidth motion platform with a high-bandwidth scanner.
- Further steps can be taken to expand the FOR of the scanning system using other slow-bandwidth motion platform
- Small vibration and excess noise can cause adverse effects on affected results



Challenges

Challenges the team ran into over the project's timeline include:
- Fixing a noise problem in the data collected from our third test plan.
- Sourcing parts for the system and staying within the $500 budget
- Troubleshooting and replacing the high-bandwidth mirror after finding it was broken

Future Plans

Changes in the Future that can improve the functionality of the system include:
- Implement a slow-bandwidth mirror with a wider scanning capability in place of the Mirrorcle MEMS devices.
- Implement a more automatic data acquisition software

Acknowledgements

The F24-07 Team thanks the following people for support out project. We would have never done this without you all!

- Professor Shelly Stover
- Dr. Ting-Chung Poon
- Jamie Lane
- Sanjee Abeytunge
- Rob Fleishauer
- Jeff Monaco

Infrared Friend-Or-Foe Identification Sensor Design and Vision System for Lightweight UAV

Track 2 Winner

LEFT to RIGHT: Niloy Neogi, Andres Peñafiel, Austin Jobin, Benjamin Bush

CHALLENGE

A piece of equipment that would be mounted on an unmanned aerial vehicle in a battlefield scenario. This piece of equipment would be used in tandem with a handheld device that is safe from jamming and spoofing attacks. The handheld device would utilize eye-safe Infrared to determine the friend or foe status of a drone from at least 25 feet.

SME: Yizheng Zhu

Customers: Andrian Jordan and Israel Jordan

Benjamin Bush Reston, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Substation Engineer

Course Comment: Combines all the aspects of learning into a practical project

Austin Jobin Virginia Beach, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: Robotics Engineer

Course Comment: great project experience

Niloy Neogi Andover, Massachusetts

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I aspire to become a hardware engineer.

Course Comment: This course was a proper culmination of all the classes taught to undergraduate ECE students.

Andres Peñafiel Annandale, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Firmware/FPGA Engineer

Course Comment: good opportunity to use technical knowledge for practical applications

Infrared Friend-Or-Foe Identification Sensor Design and Vision System for Lightweight UAV

Team: Benjamin Bush, Austin Jobin, Niloy Neogi, Andres Peñafiel
Customers: Andrian Jordan, Israel Jordan, NAVAIR
Subject Matter Expert: Dr. Yizheng Zhu | **Mentor:** Professor Kelley Andrews

Problem Statement

A piece of equipment that would be mounted on an unmanned aerial vehicle in a battlefield scenario. This piece of equipment would be used in tandem with a handheld device that is safe from jamming and spoofing attacks. The handheld device would utilize eye-safe Infrared to determine the friend or foe status of a drone from at least 25 feet.

Requirements

1. System functions at a minimum range of 25 feet. Operating distance of 50 feet is "Nice to Have".
2. Must be mountable to any Navy lightweight UAV.
3. Eye-Safe Design (IR LED emits power at less than 1 mW from an arm's length distance from bulb)
4. Low power draw from the system's batteries.
5. Resistant to jamming and spoofing from enemies.

Final Product

Hand Unit
(140 g)

Drone Unit
(47 g)

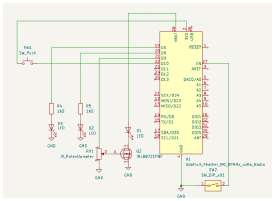
Testing Procedures

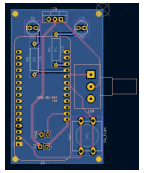
Newport 1936-C Power Meter
(Used for IR LED power testing)

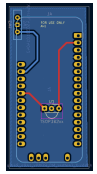
DJI Mini 2 SE Drone with Mounted Drone Unit

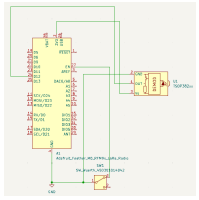
Hardware Architecture

Hand Unit Circuit Schematic **Drone Unit Circuit Schematic**



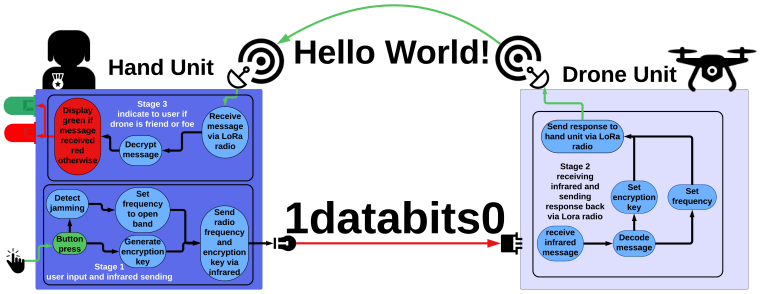




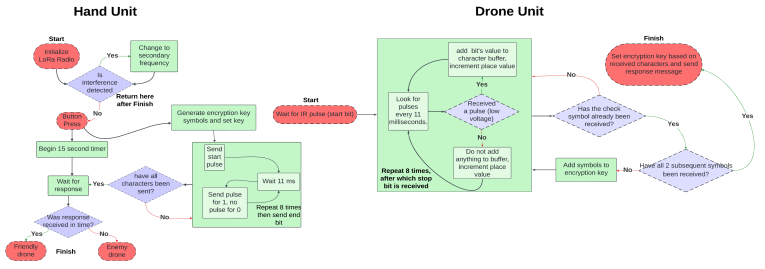


(PCBs)

High-level Design



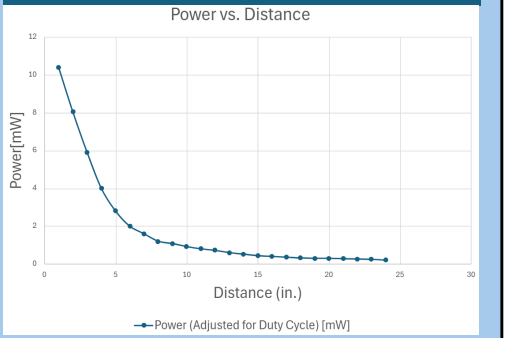
Software Architecture



Results (scan me)

- Maximum Range Attained: 188.5 feet
- Can detect mobile drones at over 100 feet
- Frequency hopping: 900 and 905MHz
- Experimentally determined the eye-safety values

IR Power Meter Measurements



Next Steps

- Modify Drone Unit design to strengthen reception of IR signal against sunlight and other weather factors.
- Research more sophisticated frequency hopping solutions for proper real-world application.
- Strategically implement additional IR receivers onto the mounted drone unit (360° of accessibility) for drastically improved reception at greater ranges.
- Hand off design to NAVAIR for further development.

Acknowledgements

We would like to thank the following individuals who helped make this project possible:

- Professor Kelley Andrews (Mentor)
- Dr. Yizheng Zhu (SME)
- Israel and Andrian Jordan of NAVAIR (Customers)

Exploiting Bluetooth Vulnerabilities in the Nordic Thingy

LEFT to RIGHT: Ryan Funkhouser, Antonio Dominguez, Dominic Deverse, Nabeel Syed

SME: Paul Plassmann

CHALLENGE

Our objective is to exploit the security vulnerabilities of the Nordic Semiconductor's Thingy sensors against both physical and remote BLE-based attacks by simulating real-world threat scenarios, identifying security gaps, and implementing mitigation strategies to safeguard against firmware manipulation, data interception, and other potential BLE vulnerabilities.

Customer: John D. Williams

Dominic Deverse Purcellville, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I aspire to increase my skills in software development and cybersecurity to devolop a deep understanding of offensive and defensive security practices, allowing me to identify vulnerabilites and design resilliant software.

Course Comment: By taking part in this course, I was able to acquire invaluable experience in the field I am pursuing, and also meet like-minded teammates that were able to motivate me to do my best.

Antonio Dominguez West Chester, Pennsylvania

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I aim to deepen my knowledge in penetration testing and IoT data security by focusing on reverse engineering, analyzing security features to assess vulnerabilities in embedded devices, alongside developing strategies to enhance protection.

Course Comment: This course offered a valuable opportunity to engage with the challenging material. I am extremely grateful to work alongside a dedicated and focused team that consistently pushed me to achieve a deeper understanding of the subject.

Ryan Funkhouser Strasburg, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I aspire to deepen my understanding of cyber security vulnerabilities in IoT devices by analyzing the strengths and weaknesses by setting up software countermeasures from plausible attack vectors.

Course Comment: This course offered a unique and valuable challenge within a deeply interesting path. My team has pushed myself to achieve and understand more in the subject, and I will be forever grateful.

Nabeel Syed Herndon, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I aspire to strengthen my skills in cybersecurity to accurately prevent attacks on software and hardware components while also expanding my knowledge in other threat detection tactics.

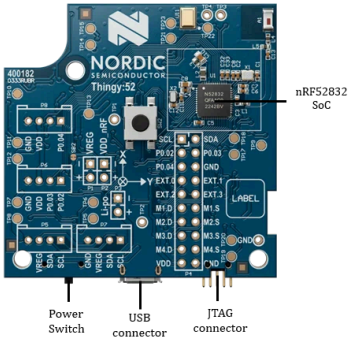
Course Comment: This course has allowed me work collaboratively with a team of high skills individual and share ideas and plan projects as well as how to pitch a product to a customer in the engineering world

Exploiting Bluetooth Vulnerabilities in the Nordic Thingy

Team Members: Nabeel Syed, Antonio Dominguez, Dominic Deverse, Ryan Funkhouser
Sponsor: Dr.John Williams - Boeing
Subject Matter Expert: Dr. Paul Plassmann - Virginia Tech

Background

Thingy Sensors: An IoT device from Nordic Semiconductor, used for environmental sensing, motion tracking, and BLE communication



Mitigating Threats: Protecting against reprogramming attacks and DoS by securing firmware access, and ensuring strong encryption communication.

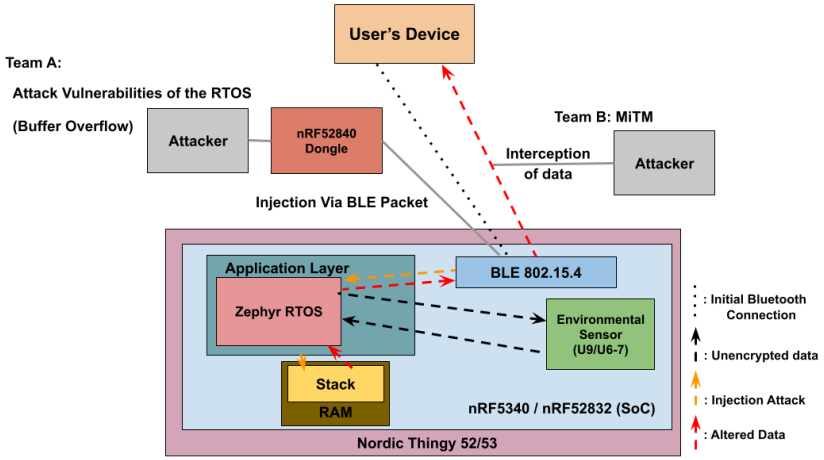
Objectives

Vulnerability Exploitation: Find various vulnerabilities and use attack methods to test the severity.

Buffer Overflow Attack on SoC: The BLE injection packet contains an oversized string parameter to exceed the size of the destination's memory.

Man-in-the-Middle: Extract Bluetooth packets using Btlejuice framework and manipulate packet data.

High-Level Diagram

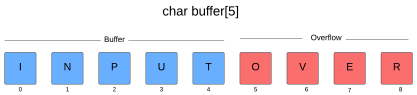


Team A

Attack vulnerabilities on SoC via BLE:

CVE-2023-4264 Vulnerability

- Severity: HIGH
- Versions Affected: 0 through 3.4
- Method: Sends a BLE response with an oversized string parameter that exceeds the buffer's size, leading to a buffer overflow
- Impact: Ranges from DoS to Remote Code Execution



Team B

Man-in-the-Middle attack over BLE

CVE-2020-26558 Vulnerability

- Effects Bluetooth Core Specification 2.1 through 5.2
- Allows attacker to imitate Passkey during pairing of BLE device
- Method: Intercept BLE packets connected to VM running Btlejuice framework and manipulate its data to perform the Man-in-the-middle attack.
- Impact: Once the packet is received, sensitive data is able to be read and altered and sent back to device.

How To Mitigate Attacks

Team A:

- Outdated C libraries in the RTOS, using functions like strcpy() don't have bounds checking. Switching to safer functions like strncpy() helps prevent buffer overflows.

Team B:

- Improving data encryption and Bluetooth connection security will render a man-in-the-middle attack obsolete.

Moving Forward

Future work includes:

- Further research firmware extraction reverse engineering attack vector started by Team A
- Expand Bluetooth Attack Vectors to exploit
- Exploit Wi-fi vulnerabilities in the Nordic Thingy

Acknowledgements

We want to thank the following for helping us over the past year:

- Dr. Joe Adams (Mentor)
- Dr. Michael Mitchell (Customer)
- Dr. Paul Plassmann (Subject Matter Expert)

Bluetooth Low Energy (BLE) Based Mesh Network

LEFT to RIGHT: Timothy Palamarchuk, Martin Weiss, Yigit Kaya, Gabriel Rivas

CHALLENGE

Warehouse tracking systems today lack precise and affordable localization and implementation that aren't able to balance real-time updates with power efficiency at a large scale. Our project aims to implement a BLE mesh network to track equipment and efficiently propagate sensor data through any warehouse, providing a lower-cost and power efficient alternative using existing technology.

SME: Scott Midkiff

Customer: John D. Williams

Yigit Kaya Delray Beach, Florida

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: As a soon to be graduate, I aspire to be a part of large-scale tech company as a software developer, where I can continue to grow by working on innovative and challenging projects.

Course Comment: This course gave me hands-on experience with the full life cycle of a long term engineering project, while collaborating with industry engineers from Boeing.

Timothy Palamarchuk Clifton, Virginia

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: I want to be driving the direction of cutting edge and evolve electronics from how we know them today

Course Comment: The team that I worked with in this class made it a very enjoyable experience

Gabriel Rivas Dumfries, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: After graduation, I aim to build a meaningful career in Network and Cybersecurity, contributing impactful solutions to advance my team and organization.

Course Comment: This course provided valuable experience in collaborating within an engineering team, handling the responsibilities that come with it, and recognizing the true impact of working with a skilled and cohesive team

Martin Weiss Potomac, Maryland

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I want to use machine learning to find new cures in oncology and rare disease.

Course Comment: I gained experience working with a great team.

Bluetooth Low Energy (BLE) Based Mesh Network

Timothy Palamarchuk, Martin Weiss, Yigit Kaya, Gabriel Rivas
Sponsor: Boeing

Objective

- Implement a BLE mesh network to efficiently track warehouse equipment and propagate sensor data in real-time
- Establish a scalable, flexible tracking system that can expand to meet future warehouse requirements
- Streamline monitoring processes to reduce tracking time and minimize manual labor

Impact

- Boost operational efficiency by reducing search time and optimizing equipment usage
- Lower costs with energy-efficient tracking and reduced downtime
- Enhance safety and scalability with real-time location data and flexible network expansion

Requirements

- Mesh network should contain at least five nodes
- Each node should last at least six months on battery power
- Mesh network should be easily expandable
- Node locations should be accurate and update in near real-time

Approach

- Set up fixed nodes at key points in the warehouse
- Use base station to estimate equipment location by triangulating Received Signal Strength Indicator (RSSI) from multiple nodes
- Utilize nearby nodes as repeaters to enhance signal coverage across the network
- Filter BLE advertisements based on the Nordic manufacturer ID to ensure only relevant signals are used for RSSI distance calculations

Signal Strength

- Below is the RSSI plot for a single moving node in the BLE mesh
- Blue dots represent stronger signal strength, indicating the BLE node is close to the base station
- Yellow dots indicate weaker signal strength as the node moves farther away

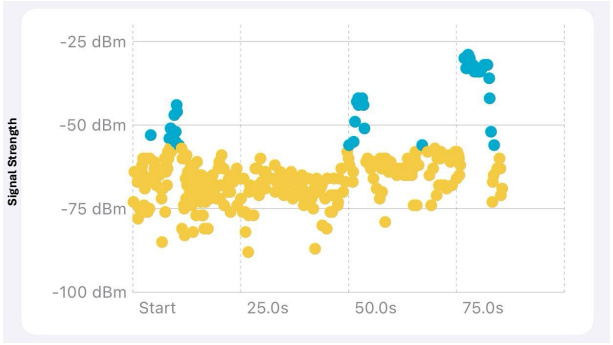


Fig. 1. RSSI Plot

Sample Application

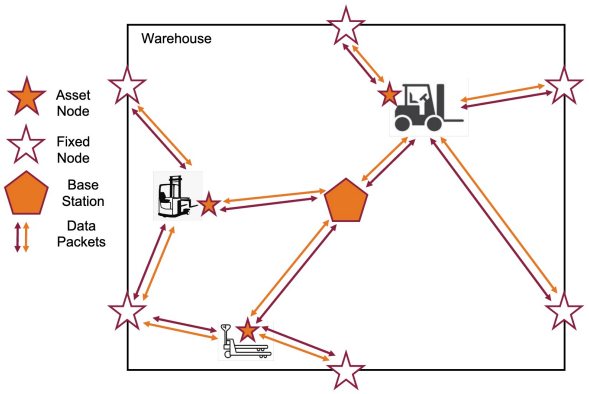


Fig. 2. Mesh Network

Sample Output

```
Device List

Node 0: D1:61:26:07:2E:11
RSSI: -46 dBm
Distance: 0.45 meters

Node 1: C3:DF:C7:39:33:10
RSSI: -73 dBm
Distance: 4.19 meters

Node 2: E1:19:6F:1A:57:16
RSSI: -69 dBm
Distance: 2.13 meters
```

Solution

- Developed a mesh network utilizing BLE nodes while also assigning extra roles to certain nodes to function as beacon advertisers or receivers
- Receiving nodes filter BLE advertisements to extract an RSSI value which is used to calculate the distance to the advertising node
- Measured the RSSI at a reference distance of 1 meter from the base node (A value) and filtered beacon signals for the Nordic manufacturer ID

Conclusions

- Successfully created a BLE mesh network
- Calculated the distance (m) from the RSSI value (dBm) from a node in the mesh relative to the base station (DevKit)

Future Work

- Further expand on using RSSI and investigate using ToF in a 3D setting
- Work on implementing the DevKits and the nodes into one cohesive mesh

Acknowledgments

Customers: Dr. Mike Mitchell & Dr. John Williams
Mentor: Dr. Daniel Connors
SME: Dr. Scott Midkiff

Network Portscan Display Panel Challenge

LEFT to RIGHT: Jimmy Mislay, Aarushi Jain, Aditya Kulkarni

CHALLENGE

The goal of this project is to develop a portable, battery-powered ``challenge in a box'' for the 2025 Cyberfusion Cybersecurity CTF competition. This device will feature a 64x128 RGB LED matrix display controlled by a networked microcontroller/embedded PC, where each pixel represents port scan data from a WiFi client. Participants must establish a session and complete a timed port scan to match displayed patterns, unlocking a flag if successful.

VIRGINIA CYBER RANGE

SME: Thomas "Tweeks" Weeks

Customer: Tom Weeks

Aarushi Jain Charlotte, North Carolina

Bachelor of Science in Electrical Engineering
Micro/Nano Systems

Aspirations: As a micro-nano electrical engineer, I aspire to drive innovation and advance technology, focusing on sustainable solutions that can make a positive impact on the world. My passion for sustainability fuels my desire to work on environmentally conscious technologies, especially within robotics and chip development. I am eager to contribute to projects that are not only technically advanced but also aimed at creating a better, more sustainable future for generations to come.

Course Comment: This course has given me the opportunity to learn valuable skills in project management, effective customer interactions, teamwork, and real-world problem-solving, all of which have prepared me to confidently tackle professional challenges. I would like to thank our customer, SME, and our mentor for their instrumental support and guidance.

Aditya Sunil Kulkarni Mumbai, India

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I aspire to keep on learning about the field of computer software, in various areas and domains, till I can call myself a master in the field

Course Comment: This course, apart from the obvious hard skills it taught me, has also taught me about various soft skills in project management, presentation and interactions with other professionals, and especially how to tackle with problems with no clear answer

James Mislay Novelty, Ohio

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I hope to continue learning about system design in the industry. With an eventual goal of being able to architect the software systems.

Course Comment: This course has been a good exercise in professionalism and project management. I hope to utilize the skills learned in the industry.

Network Portscan Display Panel Challenge

Team Members: Aarushi Jain, Aditya Kulkarni, Jimmy Mislay
Sponsor/SME: Thomas Weeks
Mentor: Dr. Joe Adams

VIRGINIA TECH

VIRGINIA CYBER RANGE

Impact

- Cyberthreats increasingly become more pervasive and sophisticated
- Understanding network vulnerabilities is essential to safeguarding sensitive data
- Port scanning - fundamental technique used by both ethical and malicious hackers to assess and exploit system weaknesses
  - Participants can use this challenge to learn how to identify misconfigurations and potential points of attacks
    - Learn skills to strength network defenses
- Showcases need for proactive cybersecurity measures
  - Prepares future professionals to address the growing demand in securing digital landscapes against ever-evolving threats

Challenge Overview

- Connect to provided network
- Execute portscans on defined ports
- LED matrix responds to port scans in real time and displays them via red LEDs
- Players match portscans to pattern on LED
- Timed challenge to get correct scan to get Challenge Flag

Objectives

- Design a portable, battery-powered "challenge in a box" for the Virginia Cyber Range's 2025 Cyberfusion Cybersecurity CTF competition.
- Must be able to visualize a portscan on a network onto the LED matrix of at least 64 x 128 full color pixels
- A correct portscan will lead to the team completing the challenge
- Documentation for teams and admins must be created

High Level Overview

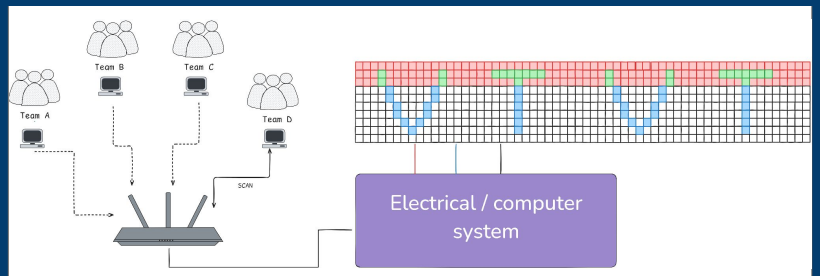


Figure 1: Participating teams connect to and scan the system, viewing feedback on the LED Matrix Display Panel

Design Implementation

Software Design

- Participants are able to establish a Session with the device
- Port Scans are mapped to the LED Matrix
- Participants are timed-out after a session and blacklisted after Success
- Participant is able to send commands to the Pi, such as refresh and able to receive challenge information

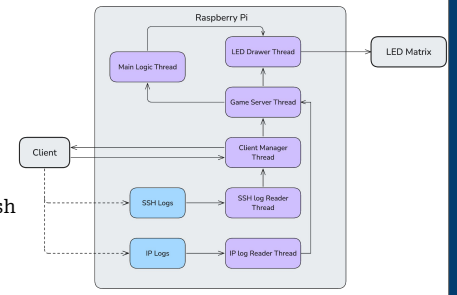


Figure 2: High Level Overview of Software Design

Hardware Design

- 2 daisy-chained 32x64 LED matrices to provide a visual representation of port scans
- Portable, rugged custom 3D printed enclosure to house electronics
  - Provide a “challenge in the box”

Network Design

- Provide wireless network for challenge
- Support Minimum of WPA2 protocol

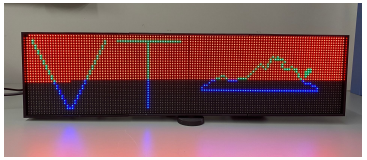


Figure 3: Example design and portscan

Hardware Setup

Figure 4: Hardware setup that will be used at competition

Future of the Project

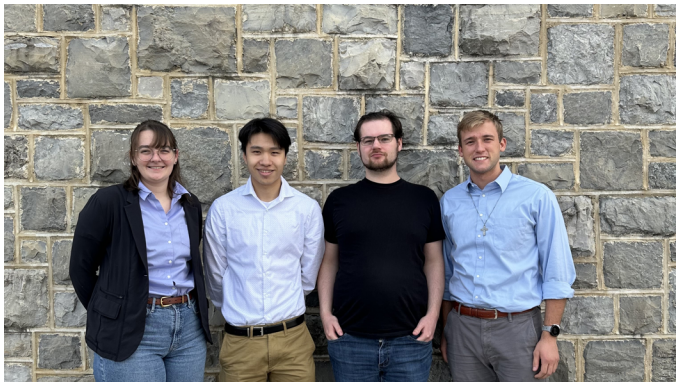
This project will be used by Virginia Cyber Range in the **2025 Cyberfusion Cybersecurity CTF Competition** to provide a Network Portmap Billboard Hacking Challenge to competitors.

Acknowledgement

The team would like to express our heartfelt gratitude to the following people:

- **Dr. Joe Adams** for his mentorship & guidance throughout this project
- **Tom Weeks**, our SME & customer for his support and guidance throughout
- **Stephen Moyer** for PCB verification
- **CRO Labs (Integrated Design Studio)** for providing us with our 3D printed needs

Robotic Motion Planning



LEFT To RIGHT: Haley Rindfleisch, Mitchell Huynh, Nic Ciccarella, Nick Eastman

CHALLENGE

Prime Vision tasked us with investigating methods to improve their robot sorting speeds. To do this we had to implement cutting-edge, multi-agent path planning algorithms in order to make recommendations based on quantitative data and simulations. For this project we had to conduct research on novel developments in this field, create a custom simulation environment that replicates the function of their robots, and create and simulate our own algorithms.

primevision
technology US, inc.

SME: Ryan Williams

Customer: Timo Thans

Nicolaus Ciccarella Roanoke, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: To work on cutting edge technology in the fields of machine learning and cybersecurity.

Course Comment: Working on a real-world problem in a team setting for a company gave me practical experience in applying theoretical knowledge to tangible challenges. Collaborating with peers and industry representatives enhanced my teamwork and communication skills, crucial for professional success.

Nicholas Eastman Hillsboro, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: After college I will continue to discern my future both in and out of electrical engineering by pursuing full time mission and service for a year. Through this I hope to have a better understanding of my long term goals before continuing into graduate education or industry.

Course Comment: This course was definitely filled with challenges and rewards. It was really good practice on how work with a team, tackle a large project, and meet project requriments. Addtionally it was benefical becasue it gave me the freedom to learn new things, specifically web development.

Mitchell Huynh Annandale, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I would like to work on some innovative technology, specifically in the field of robotics or automations. I also, hope to have a real positive impact on peoples lives.

Course Comment: I liked that this course provided a real industry environment. I also like that the projects were solutions to real-world problems. Overall the course has taught me a lot of things that I will take into the future.

Haley Rindfleisch Dubuque, Iowa

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I would like to work on the control systems of robots. Specifically, controlling the movements of the robots so that they are smooth and precise.

Course Comment: From my internship experience this course is the only one to require materials like what would be required in industry. The experiences working on a team of engineers is enlightening for working in industry.

Industry Sponsor: primevision

Robotic Motion Planning

By: Nic Ciccerella, Haley Rindfleisch, Mitchell Huynh, Nick Eastman
Mentor: Prof. Kelley Andrews | SME: Dr. Ryan Williams

VIRGINIA TECH

Problem Statement

Investigate methods to improve the sorting speeds of the customer's robots by developing more sophisticated multi-agent pathing algorithms.

Key Project Objectives

- Create a **simulation environment** to model the robot's real-world behavior
- Research and **implement multi-agent pathing algorithms** to **optimize route planning**
- Create a **web application** to showcase our results
- Create **helpful graphics** to show key findings in data

Project Background

Prime Vision operate fleets of package sorting robots to automatically deliver packages to drop off locations.

Current pathing is inefficient

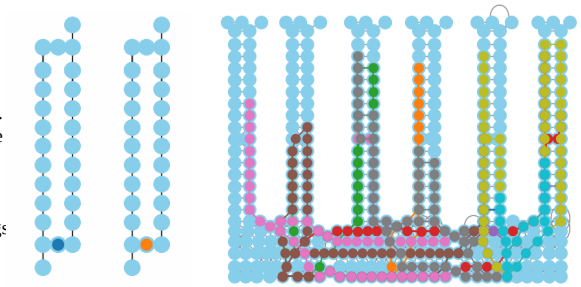
1. Other robot's positions and routes are not considered when paths are being created,
2. There is no obstacle avoidance.
3. Robots do not route around each other

More efficient path planning could increase the number of packages that can be processed or decrease the number of robots needed, thus saving money.

Our Solution

Simulation Environment

- Challenges were faced with the customer's simulation environment, so we were forced to create our own.
- Uses real floor plans provided by the customer to create a map of the warehouse.
- We can upload our algorithms to the environment to create simulation logs



Algorithm Development

A*

- Well researched and explored algorithm
- Best algorithm to find the shortest path on a graph
- Limitations include static paths and no consideration of additional agents

D*

- The dynamic A* algorithm uses priority lists and time values to find the least cost path
- Real time improvement of A* allowing for obstacle detection
- Limitations include no consideration of additional agents

A* Multi

- A* algorithm with additional conflict checking and resolution between agents
- Allows for more flexibility and free movement of robots
- Useful solution for a large amount of robots

Web Application

Development Environment
- Streamlined developing and testing
- Possess all features

→

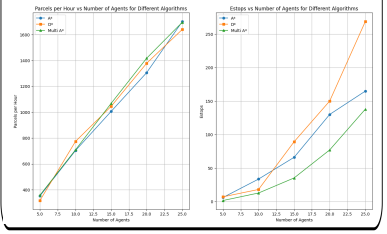
Local Deployment
- Deployed on Dell Precision 3260
- Log onto its local network to access full application

→

Cloud Deployment
- Hosted by AWS Linux EC2 instance
- Available via the QR Code

Results

- Parcels/hour is found by dividing the number of packages by the average time
- There was no significant difference in parcels/hour between algorithms
- There is a noticeable difference in the number of emergency stops as the number of agents increases
- Multi-A* has a much slower increase as the number of agents increases, making it the preferred method for larger number of agents



Future Work

- Regional rerouting on encountering an obstacle
- Dynamic node resolution to create more detailed pathing around high traffic or dynamic areas
- Implement Machine Learning to optimize node placement.
- Algorithm to choose optimal pick-up location

Conclusions

- Working with other parties' technology, permission requirements and onboarding can take up a lot of time.
- Backup plans are always necessary in case unexpected complications arise. For example, it was helpful that we were already developing or own simulation environment while waiting to get access to Prime Vision's as it allowed us to swivel quicker when the scope of the project increased
- Clear communication between the team, customer, mentor and SME can save a lot of time and headaches later in the project.

Acknowledgements

We would like to thank our **customer Prime Vision**, our **SME Dr. Ryan Williams**, and our **mentor Prof. Kelley Andrews** for their continuous support on this project!

Sensor Fusion for Autonomous Navigation

LEFT to RIGHT: Sugnan Suresh, Nick Fillo, Yohannes Zena, Yahia Tawfik

CHALLENGE

This project focuses on developing a robust navigation solution that ensures accurate positioning and orientation even when GPS signals are unreliable, such as in space missions. The system integrates data from accelerometers, gyroscopes, and magnetometers, using Madgwick and Kalman Filters to reduce noise, refine orientation, and deliver reliable state estimation. This approach ensures continuous navigation capability, even under challenging conditions, enhancing the reliability of aerial and space vehicle missions.

AEROSPACE

SME: Dan Stilwell

Customer: John Janeski

Nicholas Fillo Blacksburg, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: As an engineer, I aspire to learn as much as I can about my field of expertise while also remaining diligent in my work habits. I plan to enter industry workin on low level solutions such as embedded systems, digital design, or even electrical engineering.

Course Comment: I think this course was very beneficial to me an the people I worked with. It gave me an oppurtunity to work on a team of people with different backgrounds as well as communicate with people from industry to see how projects are executed in a work environment.

Sugnan Suresh Irvine, California

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: I aspire to develop my engineering fundamentals early on through direct application towards the industry. In the future, my goal is to lean on my fundamentals and work with teams to solve problems and work towards being in engineering management. I feel that my experience with electrical fundamentals combined with my love for working with people will allow me to engage and drive innovation.

Course Comment: This course gave us the opportunity to work with an industry project and utilize our developed skills towards a problem that emulates what we would see in our future careers. It gave me some vital preparation in understanding how to translate any of the things learned in the academic setting towards an environment and set of issues more commonly seen in an engineering company.

Yahia Tawfik Cairo, Egypt

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: As a Computer Engineering student passionate about Embedded Systems, I had the opportunity to work on exciting projects as an undergraduate, including rockets and self-driving cars. I will be attending graduate school next to deepen my knowledge in these topics

Course Comment: This course provided us with professional experience similar to that of the industry. I developed strong time management skills, as there were many stakeholders involved and numerous technical tasks to perform.

Yohannes Zena Herndon, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: As a computer engineer, I realized that my passions are ASIC/FPGA Design and Embedded Systems. After graduating, I will be extending my knowledge of these topics as an ASIC Design Engineer at BAE Systems.

Course Comment: This course provided hands-on skills and knowledge of devices that I never would have worked with had I not taken it. It also better prepared me for industry by improving my communication skills in an industry-like environment.

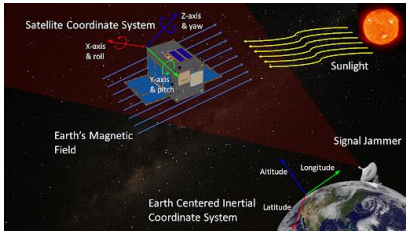
Sensor Fusion For Autonomous Navigation

Customer: John A. Janeski | Aerospace Corporation
Subject Matter Expert: Dr. Daniel Stilwell | Virginia Tech
Mentor: Prof. Kenneth Schulz | Virginia Tech
Team Members: Nicky Fillo, Sugnan Suresh, Yahia Tawfik, Yohannes Zena | ECE, Virginia Tech

Problem Statement

In space, knowing exactly where you are and which way you're facing is super important, especially for moving around safely. Usually, we can use the Global Positioning System (GPS), but out in space, GPS signals can be extremely weak or not work at all.

The picture below shows how a satellite's communication with Earth can be disrupted. A signal jammer can block signals, solar storms from the sun can add interference, which makes knowing a satellites exact position and orientation difficult.

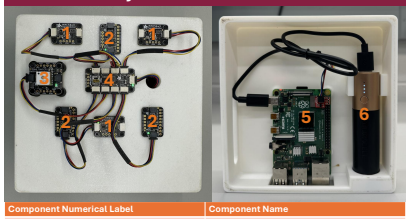


This project aims to develop a sensor fusion algorithm by combining GPS data and different sensor data to keep track of the location and direction of a satellite even if GPS signal is lost. This way, the system will can reliable positional and orientation awareness , and it can help make sure there is guidance and control even in areas where the GPS is inaccessible.

Key Requirements

- System must accurately predict both its Position and Orientation in space.
- Physical Requirements
  - An Inertial Measurement Unit (IMU) must be present to implement Sensor Fusion.
  - The sensor fusion algorithm must be run on a Raspberry Pi.
  - 1U in size and less than 1.5 kg in weight
- Angular rate dynamic range > ± 50 deg/s.

System Overview

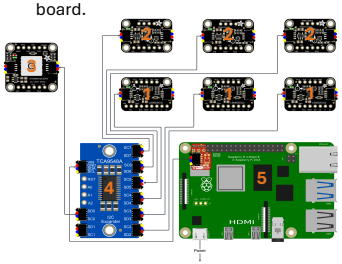


Component Numerical Label	Component Name
1	Magnetometer
2	IMU
3	GPS
4	Multiplexer
5	Raspberry Pi Board
6	Portable Battery

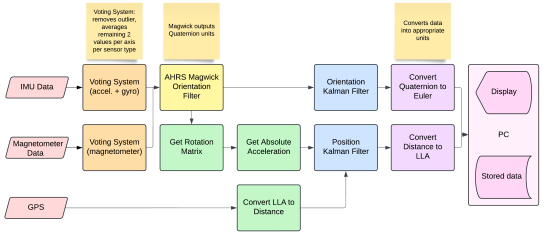
Complete System Design w/ All Hardware Components

Operations Overview

1. Sensor data is taken and processed through a voting system to remove the outlier and average the remaining two values.
2. Data is analyzed using a Madgwick Filter to derive the system's attitude, in reference to the magnetic field, represented as a quaternion.
   - Resulting quaternion is then converted into a rotation matrix to derive system's Absolute Acceleration relative to the North East Up (NEU) frame (a world reference frame).
   - At the same time, GPS coordinates are converted from Latitude, Longitude, Altitude (LLA) to distance (Meters).
3. An Orientation Kalman Filter uses the Madgwick quaternion output as measurements to estimate the system's orientation, while a Position Kalman Filter utilizes the system's Absolute Acceleration and GPS data as measurements to estimate its current position.
4. Outputs from Orientation Kalman filter are converted to Euler angles, outputs from Position Kalman filter are transformed back to LLA.
5. Processed outputs are then displayed in a user-friendly format for monitoring and testing, and saved in a text file on the board.

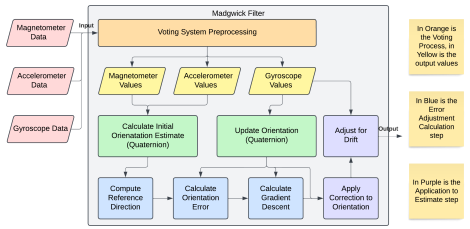


Hardware Diagram (see table in System Overview)



Software System Block Diagram

Madgwick Filter Implementation

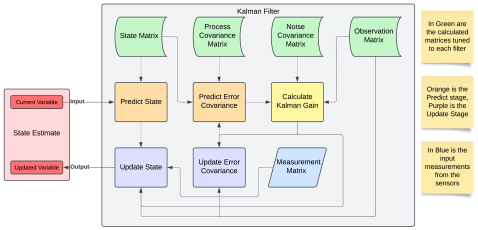


Madgwick Filter Block Diagram

- The Madgwick Filter uses a quaternion representation to avoid gimbal lock, a phenomenon that causes singularity in orientation axes which results in errors.
- The Madgwick Filter algorithm mainly consists of two steps:
  - Error Correction Step – estimates gravitation and magnetic vectors by comparing measured values from the gyroscope and magnetometer to calculate an orientation error based on the difference and align it to the Earth's magnetic field.
  - Updating Quaternion Step – calculates quaternion derivative which is then combined with orientation error calculated from earlier to update the quaternion estimate. The quaternion provides a corrected and adjusted orientation estimate that uses a gradient descent weight to control the amount the estimation is adjusted based off of the amount of error the filter calculates.

Kalman Filter Implementation

- The state of a dynamic system can be uncertain due to noisy sensor measurements over time. A Kalman Filter is widely used in navigation to combat the uncertainty of the state. It predicts the state of system based on current estimate, calculated covariance matrices, and inputs from the sensors.
- The Kalman Filter algorithm mainly consists of two steps:
  - Predict Step – uses the current estimate and a state model to predict the next state of the system. Also uses the current state to update the error covariance matrix.
  - Update Step – calculates the Kalman Gain based off of the calculated error covariance and noise covariance to weight the adjustment on the output. Then uses the predicted error covariance to update the state with a new estimate.
- The Orientation and Position Kalman Filters both follow the same structure, shown below.



Kalman Filter Block Diagram

Conclusions

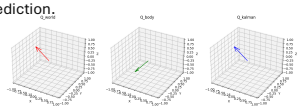
Actual results show the position algorithm output is displayed in three different scenarios:

- The first figure displays the pathing when the GPS signal is spotty, and our position algorithm is relied on
- The second displays the actual path traversed on Google Maps
- The third image shows the performance of the position algorithm by showing how the RMSE for the predicted Latitude and Longitude change over time

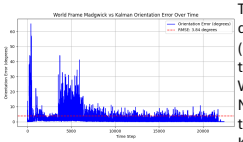
Position Estimate and RMS Error Over Time

The orientation algorithm output is displayed in three different situations:

- First figure represents orientation in the world frame, the orientation relative to the Earth.
- Second figure is orientation in the body frame, which is representation of orientation relative to itself.
- Third figure is the Kalman Filter's orientation prediction.



Orientation From Different Frames

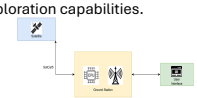


Madgwick vs Kalman Error

The image to the left details the difference (in degrees) between the output of the World Frame Madgwick Filter and the Orientation Kalman Filter, along with the RMS Error.

Future Works

Looking ahead, the establishment of a dedicated command station equipped to communicate with the navigation system via SatCat5 protocol would be a valuable next step as it would enhance the robust and private data exchange and could improve the project's range and exploration capabilities.

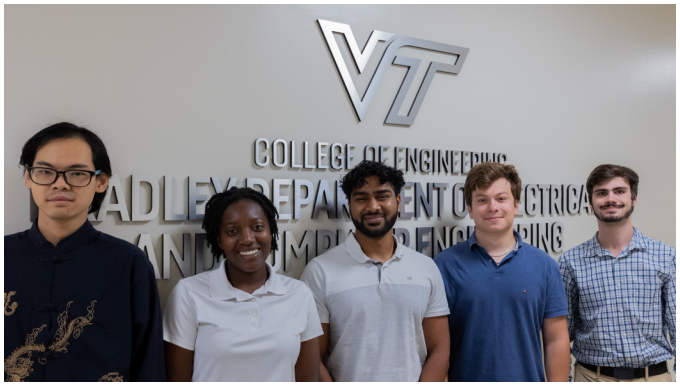


SatCat5 Protocol Block Diagram

Acknowledgements

We extend our deepest gratitude to Aerospace Corporation, our client and guiding entity, as well as our mentor and SME, whose insights have been invaluable. We also appreciate the professors at Virginia Tech, who provide us with resources and support to succeed in this class.

Wooden Pallet Life-Cycle Tracking



LEFT to RIGHT: Wenxaun Wang, Rashelle Amao, Kiran Gouttumukkala, Garret Detter, Domenic Marcelli

CHALLENGE

To design and build a system capable of quantifying the number of times a pallet has been repaired throughout its lifetime. This device will be used in a research project to help pallet manufactures collect data on different types of pallets so they can improve pallet design and application.

National Wooden Pallet & Container Association
Pallets Move the World®

College of Natural Resources and Environment
Sustainable Biomaterials
Virginia Tech
Center for Packaging and Unit Load Design

SME: Majid Manteghi

Customer: Laszlo Horvath

Rashelle Amao — Omaha, Nebraska

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: After graduation, I will be working full-time as a FPGA verification engineer while pursuing an advanced degree in systems engineering part-time. In the future, I aim to lead a team of engineers, where I can combine technical expertise with leadership skills.

Course Comment: This course was a great learning experience. It made me realize that I really enjoy the logistical, non-technical aspect of the project like writing up the requirements, presenting our findings, and preparing our documentation.

Garrett Detter — Mclean, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: I am interested in controlling automotive systems with electronics. Additionally, I want to work in real estate development.

Course Comment: This course was challenging, engaging, and offered creative direction in implementing and designing a solution.

Kiran Gouttumukkala — Moorpark, California

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I am planning on working with autonomous systems, specifically with artificial intelligence.

Course Comment: This course gave me an eye-opening experience into the how industry works. The knowledge I gained will help me for years to come.

Domenic Marcelli — Troy, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I am interested desigining and implmenting high preformance autonomous systems using FPGAs. Later in life I hope to have a second career in teaching topics in Electrical and Computer Engineering.

Course Comment: This course was really challenged me. I encountered problems that I never thought I would encounter and had to adapt my approach and my perspective to overcome those challenges! It was a worthwhile experience and I am excited to take the lessons I have learned to industry.

Wenxuan Wang — Hohhot, China

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Bachelor of Arts
Music

Aspirations: I want to become an engineer designing motors for RC car companies in the future. I've loved electric remote control cars since I was a child, and that might be one reason why I chose ECE. At the same time, becoming a music teacher is also one of my dreams. Pursuing a degree for my dreams is something I find incredibly fulfilling.

Course Comment: Although this course is challenging, we have a very responsible team, and everyone is eager to help.

Wooden Pallet Life-Cycle Tracking

National Wooden Pallet & Container Association
Pallets Move the World®

Customer: The Center for Packaging and Unit Load Design
Mentor: Dr. Daniel Connors | SME: Dr. Majid Manteghi

COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
SUSTAINABLE BIOMATERIALS
VIRGINIA TECH
CENTER FOR PACKAGING AND UNIT LOAD DESIGN

VIRGINIA TECH

Team Members: Rashelle Amao, Garret Detter, Kiran Gouttumukkala, Domenic Marcelli, Wenxaun Wang

Background

- The National Wooden Pallet & Container Association is innovating and researching in pallet durability.
- This project is especially important because the lifecycle of pallet has never been tracked before.
- The goal of the project is to record the number of trips a pallet makes across the mainland United States.
  - We were asked to store this data in a central cloud server for easy analysis.
- We were asked for a proof of concept.

System Prototype

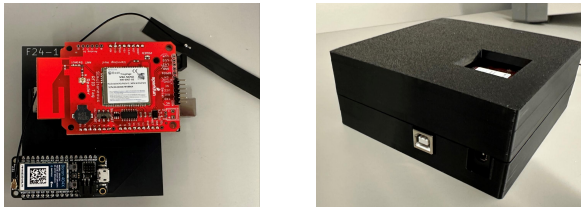


Fig 3.
This figure shows the prototype of our complete system for ECE 4806. This prototype is enclosed in our 3D printed case and contains the RFID reader, microcontroller, PCB, and antenna.

Results & Conclusions

Testing Results

- The device can scan pallets up to 16 feet away using an external antenna.
- The housing of the scanner is weather resistant.
- Passive components on each pallet are weatherproof and non-toxic.

Conclusions

- Tracking the lifecycle of a pallet is feasible without tracking each individual pallet via GPS solutions.
- Power BI is a reliable application for data visualization.

Technical Requirements

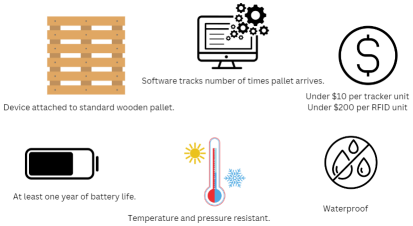


Fig 1.
This figure shows the project technical requirements. All of these requirements have been met.

Hardware

Computer Aided Design

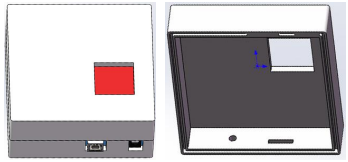


Fig 4.
This figure shows the final iteration of the waterproofed enclosure design of our product.

Printed Circuit Board

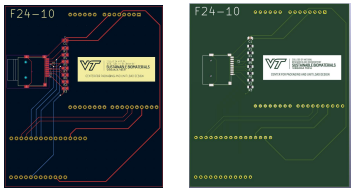


Fig 5.
This figure shows the PCB we designed specifically to connect whole system.

Future Improvements

- **Budgeting improvements**
  - Placing the hardware directly on the printed circuit board would reduce the cost of the system.
- **Verification performance**
  - Waterproof and heat dissipation performance.
- **Hardware alternatives**
  - Exploring alterative ways to assemble as the current build is not scalable.
  - Use updated versions of hardware whenever they become available.

Proposed Solution

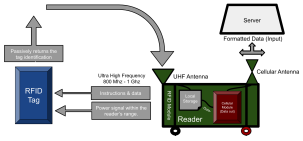


Fig 2.
This figure shows the top-level system diagram of our proposed solution .

- Waterproof, ultra-high frequency tags attached to the middle stringer of pallets.
- RFID reader system placed above conveyor belt inside repair facility. It is attached to wall power within the facility.
  - Each reader will transfer read tag data to an Azure cloud server.
  - As a backup, each reader will also have an SD card for locally stored data.

Software

Cloud Server

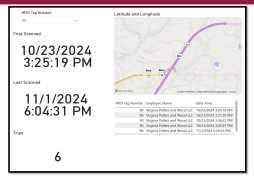


Fig 6. This figure shows the Power BI user interface. This interface shows the tag number, UTC date and time, number of trips, and latitude and longitude of the facility.

Embedded Software

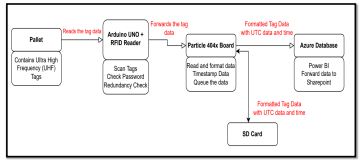


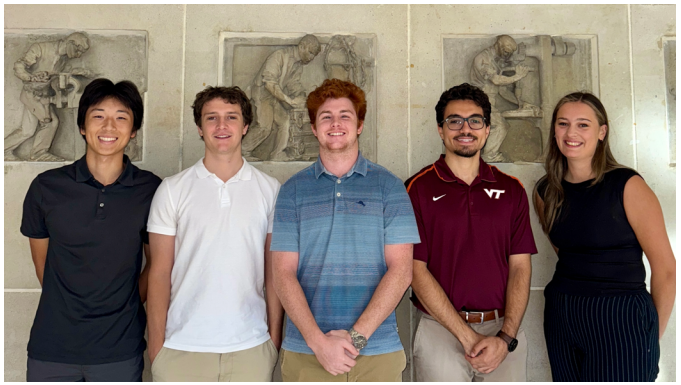
Fig 7. This figure shows the embedded software flow diagram. The three major software components are the RFID reader system, microcontroller, and cloud server.

Acknowledgments

We would like to thank the following people for their support of our project.

Mentor: Dr. Daniel Connors
SME: Dr. Majid Manteghi
Customer: Dr. Laszlo Horvath at The Center for Packing and Unit Load Design
External Sponsor: Brad Gething at the National Wooden Pallet and Container Association

Swarm Robots for Disaster Response



LEFT to RIGHT: Eric Ton, Patrick Howard, Hershel Rinker, Marc-Anthony Barsoum, Sarah Fox

CHALLENGE

Design and implement a swarm robotic system for disaster relief capable of autonomously sweeping and searching floor spaces for human presence, using a coordinated team of low-cost, durable robots. Each robot will detect and report human presence back to a base station, using light bulbs as simulated human heat signatures in testing, and will operate efficiently. The project involves end-to-end development, including fabrication of the robots and custom code creation, to ensure reliability, scalability, and ease of deployment in disaster response scenarios.

COLLEGE OF ENGINEERING
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

SME: Dan Stilwell

Customer: Joe Adams

Marc-Anthony Barsoum Springfield, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Working on hardware design through logic synthesis and iterratation for improved optimization is my dream goal.

Course Comment: Working with a diverse team over a long period is invaluable experience for my future in engineering.

Sarah Fox Calvert County, Maryland

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: As a future computer engineer, during my time at Virginia Tech I have been able to see how truly versatile this degree is. I hope to apply not only the technical skills that I have learned here but the work ethic to create a wide variety of solutions to critical problems to better the lives of others.

Course Comment: MDE has given us the best example of working on a diverse team for an extended period of time. I am thankful for such a well working team, and hopefully that is evident in our project!

Patrick Howard Scotch Plains, New Jersey

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: To pursue a career in computer engineering with a focus on embedded systems while contributing to impactful technological advancements.

Course Comment: MDE has taught me to collaborate and communicate effectively within a larger team, providing work-like experiences through regular meetings with a customer and mentor. It also emphasized the importance of managing deadlines and setting milestones.

Hershel Rinker Warrenton, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: Working in the cyber field learning the ins and outs of the trade

Course Comment: Working with different people and skill sets to accomplish a similar goal

Eric Ton Fairfax, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: My aspiration is to be a hard working and ethical engineer.

Course Comment: I enjoyed the ability to gain a hands-on experiencene while being able to apply what we have learned in classes to the real world.

Swarm Robots for Disaster Response

COLLEGE OF ENGINEERING
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

Customer: Dr. Joe Adams
Mentor: Dr. Daniel Connors
Subject Matter Expert: Dr. Daniel J. Stilwell
Team Members: Marc-Anthony Barsoum, Sarah Fox, Patrick Howard, Hershel Rinker, Eric Ton

VIRGINIA TECH

Problem Statement

In disaster scenarios, emergency response teams face hazardous and unstable environments that put their safety at risk. Checking rooms for victims, also known as room clearing, is essential but challenging due to potential structural collapses and aftershocks.

Key Requirements

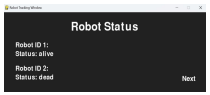
- **Fully Autonomous**: Operates with minimal user input.
- **Swarm Coordination**: Robots working in collaboration.
- **Room Clearing Capability**: Confirms if a room is clear of obstacles or victims.
- **Low Cost**: Designed within budget of less than $50 per robot.
- **Compact Size**: Small enough for maneuverability in tight spaces.
- **Battery Life**: Ensures operation for at least 5 hours.

Objectives

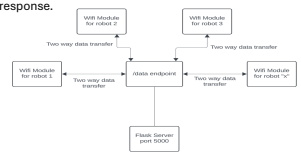
- **Wall Following**: Robot can navigate by following walls, allowing for movements in confined spaces.
- **Human Detection**: Identifies potential victims within disaster zones.
- **Doorway Detection**: Identifies doorways where potential victims may be present.
- **Room Clearing**: Navigates and clears rooms to ensure safety for responders.
- **Re-entry Detection**: Monitors and ensures safe re-entry points for rescue teams.

Communication

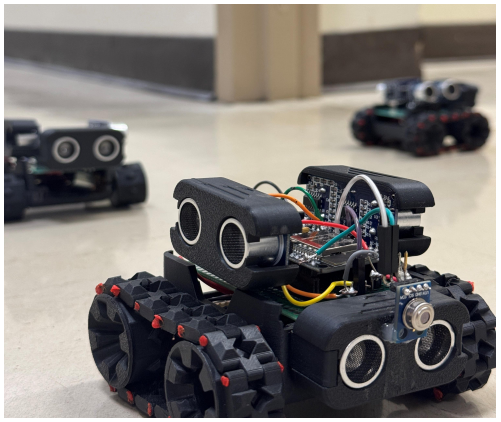
- **Robot Status**: Each robot sends regular updates on location, battery level, and room clearance status.



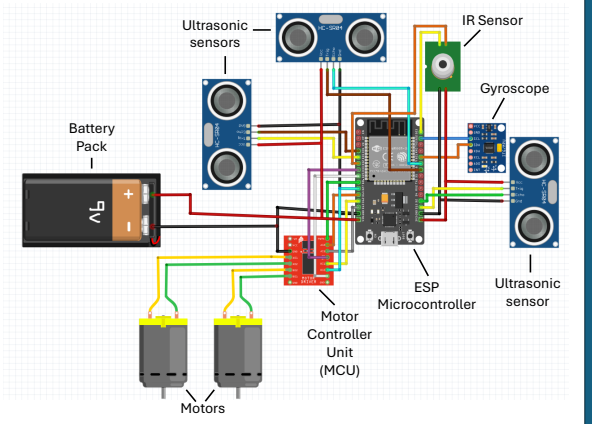
- **Data Processing**: Robots process and send data to a central system for real-time monitoring and coordination.
- **User Interface**: A GUI displays the robot swarm's positions and statuses, allowing responders to track progress and receive alerts.
This system ensures reliable, efficient management of the swarm, supporting coordination and effective disaster response.



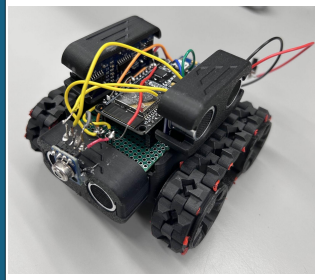
Swarm Unit



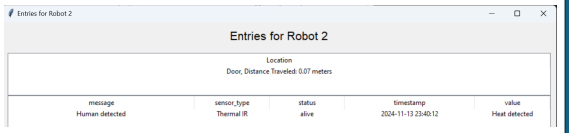
Electrical Design



Results

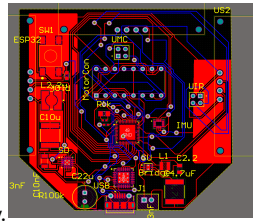


- **Communication:** Fast and uninterrupted exchange with base station.
- **Algorithm:** Able to adjust distance from wall and turn autonomously.
- **Sensing:** Detects the wall within a few centimeters and can also detect latent heat of a human hand.
- **Locomotion:** Smooth and fluid motion when moving straight or turning with minimal interruption.



Future Work

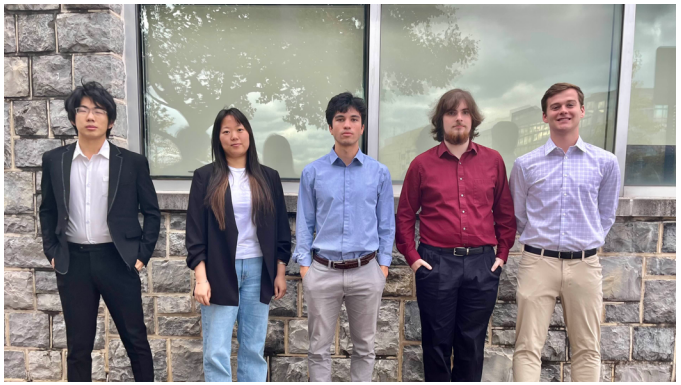
- **Enhanced Room Sweep Capabilities**: Improve sensor accuracy to ensure complete room coverage and obstacle detection.
- **Bot-to-Bot Recognition**: Implement recognition features for better swarm coordination and scalability.



- **PCB**: Implementation of PCB to reduce wiring complexity and optimize reliability.

Acknowledgments:
The team would like to express their gratitude to Dr. Daniel Connors, Dr. Joe Adams, Dr. Daniel J. Stilwell and Dr. Thinh Doan.

Optic Sensor and Vision System for Lightweight UAV



LEFT to RIGHT: Guancheng Huang, Meiyu Zheng, Georges Richard, Jamie Jaworski, Erik Honaker

CHALLENGE

For this project, we developed a device that can be fit onto any lightweight UAV, on which is fitted with a camera and processing chip. Using computer vision techniques, this device is capable of performing shape detection from an embedded, lightweight application, and relay the live video back in real-time.

COLLEGE OF ENGINEERING
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

SME: Peter Han

Customer: Ken Schulz

Erik Honaker Clifton Forge, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I am currently pursuing a masters degree from Virginia Tech, while looking forward to a future career in the fields of Machine Learning and Artificial Intelligence, with the goal of solving real-world problems and make a meaningful impact to others.

Course Comment: This project has given me the opportunity to explore an industry-like project where I got to collaborate with other engineers for a common goal. I have enjoyed being able to explore computer vision applications and how to implement these methods.

Guancheng Huang Jinan, China

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I am looking forward to a future career in circuit board design and product development, intending to create innovative electronic products that can improve everyday life.

Course Comment: This project allowed me to work on a real-world, industry-oriented task, where I collaborated closely with other engineers to achieve a shared objective. This project has allowed me to gain insights into the development process and overall architecture of image recognition devices.

James Jaworski Spotsylvania, Virginia

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I am looking forward to my career as a DOD Engineer and to getting my masters degree in the near future

Course Comment: This project allowed me to explore a realistic problem to serve industry while managing and communicating with a team of like minded engineers while applying knowledge learned on several of our previous classes.

Georges Richard Fairfax, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: I aspire to become a distinguished engineer, capable of developing and leading projects that make a positive difference.

Course Comment: This course provided me with experience working on a multi-faceted, long contract, design project for a customer through requirements to deliverables of the engineering process.

Meiyu Zheng Harbin, China

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: I aim to become a digital design engineer focused on FPGA development and VLSI design, and I plan to pursue a master's degree at Virginia Tech to further my expertise in these areas.

Course Comment: This senior design project simulated real-world company processes. We focused on meeting customer needs, minimizing costs, and emphasizing teamwork throughout, which has been invaluable preparation for future professional work.

Optic Sensor and Vision System for Lightweight UAV

Sponsor: NAVAIR

Team Members: Georges Richard, Jamie Jaworski, Erik Honaker, Meiyu Zheng, Guancheng Huang

Mentor: Kelley Andrews | **Customer:** Ken Schulz | **SME:** Peter Han

Background

- Search and Rescue teams often struggle to survey large areas due to constraints of time, resources, and treacherous terrain.
- Many military applications require quick and accurate detection and identification of different objects for a variety of mission critical operations
- Much of the technology currently available requires an expensive UAV (Unmanned Aerial Vehicle) or requires extremely costly components.

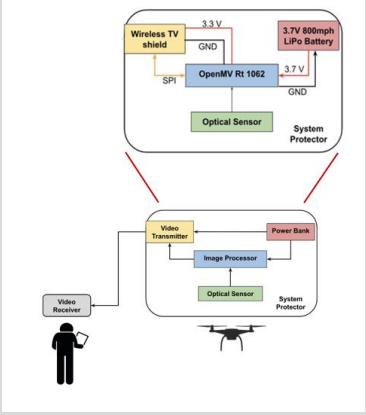
Objectives

- Develop and implement a drone mount that features the technology capable of performing vision detection of basic circles and shapes
- The device should differ from most solutions in this space by performing the vision detection through an embedded application.
- Important factors considered should be cost, upgradability, weight, and power usage.
- The user should be able to see the results in real-time.

System Overview

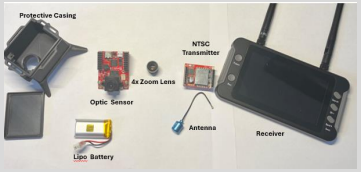
Design Overview

- Optic Sensor used to gather image frames of the ground below
- Microcontroller board that performs the image processing
- Onboard transmitter, featuring a long-distance antenna
- Battery located on the mount powers the optic sensor, computing chip, and transmitter.
- Vision System output is transmitted back to a receiver located on the ground.



Hardware

- Image processor board with interchangeable lens
- 5.8 GHz analog NTSC transmission module with swappable antenna
- 800mAh LiPo battery
- Battery charger
- FPV (First Person View) Receiver
- 3D printed, protective casing

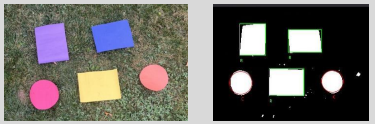


Software

- Use of LAB color system in conjunction with thresholding to filter out green from images.
- Gaussian and an unsharp filter are then used to clean up the image, results in decreased noise.
- Areas of possible interest are then left in the images, shown in white.
- Mathematical methods of the Hough Transform and Quad Threshold Detection are then used to identify circles and rectangles from the images.

Results

- In our testing, 100% accurate from 5-50ft.
- Accuracy falls off as height is further increased.
- Met weight specification of less than 100 grams and over 30 minutes of operating time.



Challenges

- Issues with increasing height due to unexpected glare present in images using an 8x zoom lens.
- Decreased FPS from optic sensor when doing intense computer vision work.

Future Work

- Future work on this project could include implementing a blob detection algorithm that features a trained AI model for detecting specific objects, such as Humans.
- Other work could include making hardware upgrades for increased computational capability.

Acknowledgement

We'd like to thank Kelley Andrews and Ken Schulz for their guidance on this project.

Autonomous Water Monitoring System for Remote Creek Management

LEFT to RIGHT: Noah Lockard, Brandan Allen, Akshara Ravi, Ayia Ismael, Cesar Bautista

SME: Daniel Connors

Customer: Daniel Connors

CHALLENGE

Our challenge was to develop an autonomous remote water measuring system for continuous water level monitoring of remote creeks. Aimed at flood damage mitigation and water management for cultural and environmental purposes, the system must collect and either transmit data via SMS or conserve data during signal loss without human interaction. The designed system includes sensors, a waterproof enclosure, power management, and a programmed microcontroller to ensure proper operation under varying environmental conditions.

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Brandan Allen Bumpass, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After graduation, I hope to work as a software engineer for an environmental agency. This would allow me to combine my interest in environmental conservation with the skill set I have developed throughout my computer engineering career at Virginia Tech.

Course Comment: This course has taught me how a team-based project needs to function in order to be successful. I've learned how workloads should be distributed, how issues should be handled, how to overcome challenges, and how to deal with adversity. The lessons I've learned from this course will benefit me in my professional career moving forward.

Cesar Bautista Puno, Peru

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After graduation, I plan on working at a smart grenhouse as a tech manager and doing some research on autonomous greenhouse management focusing on controling the amount of nutrients in the water solution, its pH levels, as well as controlling the amount and type of light that each plant requires.

Course Comment: This class helped me to understand more about the process involved in a team project by taking into account multiple standards to follow and to provide different solutions or alternatives that meet the customer requirements.

Ayia Ismael Alexandria, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After I graduate, I plan to attend graduate school in Computer Engineering. While I'm still not certain about which industry I'll work in, I have a strong interest in working on embedded systems or FPGAs within the space and aviation industry.

Course Comment: This course has helped contextualize various engineering concepts and teambuilding skills throughout the two semesters we've been working on our project. It was really fun to be able to get more experience with PCB design and soldering, as well as all the research that goes into engineering a solution to a problem.

Noah Lockard Fredericksburg, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: As I get ready to graduate, I'm excited to start my career as a project engineer. It's a role that will let me put everything I have learned to good use and allow me to continue to grow both technically and as a leader. While engineering is my immediate focus, I plan to eventually pursue a career in aviation.

Course Comment: The hands-on experience in this course has given me a deeper understanding of how to apply engineering concepts to real-world problems. Overall, this course helped me grow as an engineer by strengthening my critical thinking and building my confidence in tackling complex challenges.

Akshara Ravi Exton, Pennsylvania

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After Graduation, I plan on starting my career in the computer engineering or computer science fields and attending Graduate school after a few years in the industry. I would like to obtain hands-on experience in the work field to further my knowledge and experience and move up the corporate ladder.

Course Comment: This course has provided me with valuable experience in terms of how the industry works and how to manage a project with a team of engineers. I was able to gain valuable experience in various subjects like PCB designs, 3D printing, and other Electrical and Computer Engineering technical skills.

Autonomous Water Monitoring System for Remote Creek Management

Team: Akshara Ravi, Brandan Allen, Cesar Bautista, Noah Lockard, Ayia Ismael

Sponsor: Bradley Department of Electrical and Computer Engineering Virginia Tech

Subject Matter Expert/Customer: Dr. Daniel Connors | Mentor: Dr. Shelly Stover

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DEPARTMENT of GEOSCIENCES
College of Arts & Sciences
EAST TENNESSEE STATE UNIVERSITY

Introduction

Effectively managing the risk of flooding requires continuous, remote water level monitoring. An autonomous water level measurement system delivers real-time creek level data, empowering environmental agencies, local communities, and the agricultural sector to take proactive measures. By providing a dependable and sustainable monitoring solution, this project ensures the availability of critical real-time data, enhancing flood prediction and management, public safety, and water resource planning.

Impact

Current U.S. Methods for Monitoring Water Bodies & Predicting Flooding :

1. USGS Stream Gauges
2. Weather & Hydrological Models
3. Satellite Imagery (SAR)
4. Flood Inundation Mapping

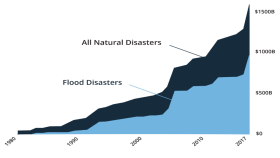

Figure 1: US Budget for Floods
Photo Credits: Flood defenders

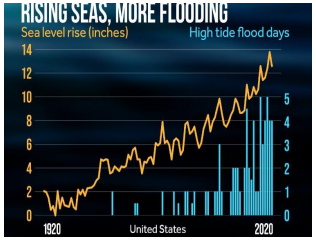

Figure 2: Rise in Floods in the US
Photo Credits: Climate Central

Predecessor Work

We received a prototype and project report of a remote creek monitoring system from East Tennessee State University, coded by Dr. Connors. Our goal was to enhance the design and create a PCB for efficient deployment. We assessed the existing design for compatibility with our location, rewrote the code, and built a new circuit to verify the PCB before production. We added a heartbeat circuit for system reboot, if necessary, resulting in a reliable, low-cost solution that's easy to deploy and replicate.

System Overview

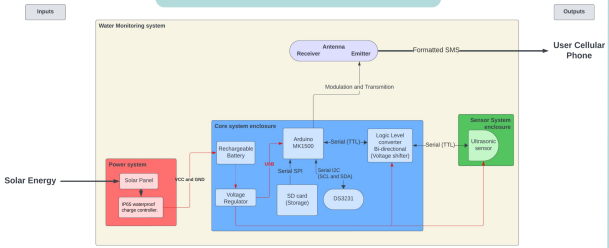

Figure 3: Overall System Diagram

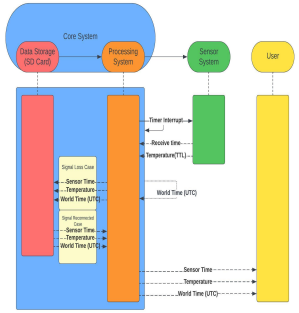

Figure 4: System Sequence Diagram

Technical Requirements

1. Register water levels remotely without physical presence.
2. Collect and transmit real-time, accurate data autonomously.
3. Maintain constant cellular communication for timely alerts.
4. Use sustainable solar power with efficient energy management.
5. Format and send data in a specific structure via SMS.
6. Record and save data during signal or power loss.
7. Maintain operational accuracy and functionality in all weather conditions.
8. Compact, transportable, "plug-and-play" design.

Hardware Solution

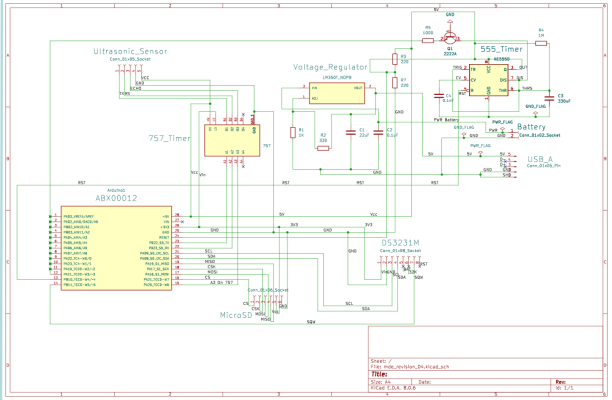

Figure 5: PCB Schematic

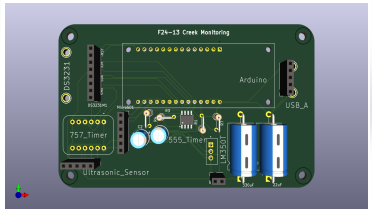

Figure 6: Core System

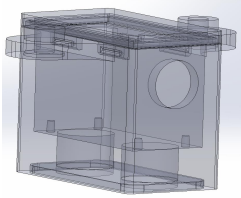

Figure 7: Sensor Enclosure

Software Solution

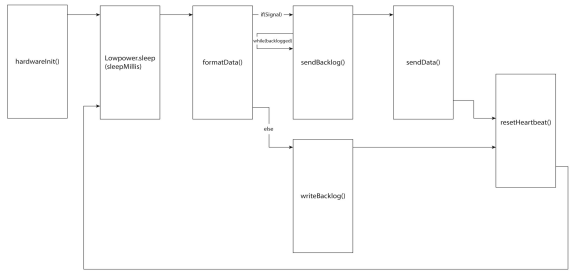

Figure 8: Software Solution

Final Product and Results

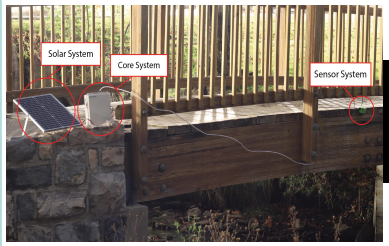

Figure 9: Assembled System

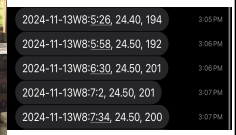

Figure 10: SMS Results

Conclusion and Future Work

All project files—code, PCB designs, component lists, and deployment instructions—are available on a public GitHub repository. This enables anyone to build and use this system for effective local water monitoring. We gained valuable experience through this project and aimed to make it accessible for anyone interested in creating their own water monitoring system.
GitHub Repository: https://github.com/aksharar25/CreekMonitoring.git

Acknowledgements

We extend our gratitude to our customer and subject matter expert, Dr. Connors, for his invaluable guidance throughout this project, Professor Shelly Stover for her mentorship and support in overseeing our work, and the Virginia Tech ECE Department for sponsoring this project.

Fabricating Microneedle-Based Medical Delivery Patches

LEFT TO RIGHT: Vivan Chopra, Michael Maley, Sun Lee, Drew Hopkins

CHALLENGE

The drug Naloxone is critical to help overdose victims and save their lives if administered to them while EMTs are on their way to the scene. Currently, microneedle patches don't deliver the drug quickly enough to have it be effective on the victim, but recent discoveries have shown that heat and constant current can drive the drug through the patch at a faster rate. Our device is a drug delivery system that utilizes heat and constant current to deliver the drug to overdose victims through a microneedle patch; the device is small, portable, and easy to use, which is ideal for situations before EMTs are able to reach the scene, and therefore nobody with medical knowledge is yet available to administer the drug via traditional needle.

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VIRGINIA TECH

SME: Ashana Puri

Customer: Daniel Connors

Vivan Chopra Springfield, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I would like to work in the field of Software Design and work in creating defense systems for organizations

Course Comment: The course structure enabled us to work on multiple engineering disicplines and learn from the challenges that come with a structured engineering project.

Drew Hopkins Henrico, Virginia

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: I would like to work in the defense field, focusing on FPGA testing and verification.

Course Comment: This course was a first venture in the full engineering process for me, from analyzing requirements to developing and testing verification tests.

Seonmin Lee Seoul, Republic of Korea

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: I aspire to develop an effective microneedle patch by integrating computer engineering and electronics, contributing to innovative healthcare solutions. As a future engineer, I aim to become a skilled professional at the intersection of computer and bioengineering.

Course Comment: In the Senior Design course, I applied theoretical knowledge to practical engineering challenges, strengthening my skills in teamwork and problem-solving. This experience was essential in preparing me for a career in computer engineering innovation.

Michael Maley Mount Vernon, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I want to develop security and network functionality for applications.

Course Comment: This project was a lot of fun! I loved working with my groupmates and making our way through the challenges we faced.

Fabricating Microneedle-Based Medical Delivery Patches

Vivan Chopra, Drew Hopkins, Sun Lee, Michael Maley
Sponsors: Virginia Tech ECE department and ETSU College of Pharmacy
SME: Ashana Puri

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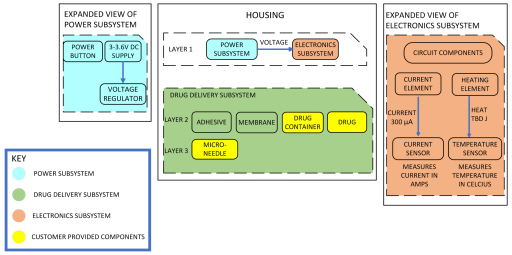
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

BILL GATTON COLLEGE of PHARMACY
EAST TENNESSEE STATE UNIVERSITY

Background/Objectives

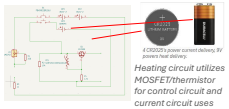
- Patients who undergo drug overdose are often kept alive through administration of a drug called "Naloxone".
- Currently, the options for administration of Naloxone are through traditional needles and nasal sprays: traditional needles are unsafe for use by the public and nasal sprays are ineffective on some people due to drug users commonly having damaged nasal cavities. Microneedle patches are currently considered too slow to administer the drug, but recent research has shown that providing heat and current to the microneedle patch can speed up drug administration.
- This project aims to develop a wearable, easy-to-use patch that will deliver heat and current to a microneedle which will supply Naloxone to a patient undergoing drug overdose.

Top-Level Diagram



Approach

- Microneedle patch uses integrated circuits which generate current and heat using small, portable DC batteries.
- Current circuit makes use of LM334 constant current source.
- Heating circuit uses MOSFET control circuit and powers a nichrome wire heating element.
- Two circuits integrated on one PCB with batteries on board, which takes little room inside housing environment.
- Housing environment stores drugs and begins delivery and power with a simple push of a button.

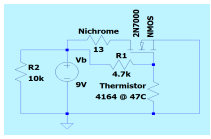


Heating circuit utilizes MOSFET/thermistor for control circuit and current circuit uses LM334 to generate current.

System Integration

Heating

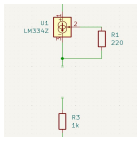
- Heating Circuit integrated into PCB alongside current circuit
- Heating circuit makes use of a MOSFET to control temperature, with a thermistor sensing the temperature of the patch and adjusting the MOSFET gate voltage accordingly.
- Average power delivered to the 13 Ω nichrome wire load is 2.33W, which is needed to heat the patch and create a 10° C difference between the patch and the skin.



Heating Circuit before current circuit integration

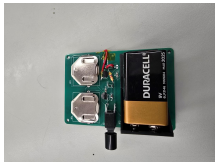
Current

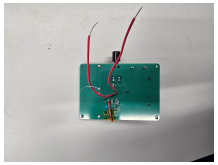
- Implemented using an LM334 and 220 Ω resistor
- Needed at least 10 V, this was supplied using 4 3 V coin batteries



Current Circuit before heating circuit integration

PCB





Test Results

Heating

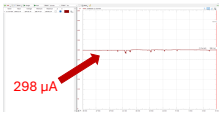
- Tested using heated pig ears as a surrogate for live human skin
- Heat measured using Infrared thermometer for accurate reading
- Patch is heated to ~10 degrees above surface of skin
- Battery lasts around 30 minutes: 9V battery for heating lasts a shorter amount of time than current battery

IR thermometer used to read temperature of patch in Fahrenheit

IR Thermometer used to read temperature of pig ear in Fahrenheit

Current

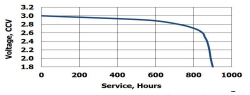
- Ran current through microneedle provided by sponsor
- Measured using an AD2 over the course of 30 minutes
- Provided constant 298 µA of current as seen on the graph to the right



Average current applied to patch over 30 min

Battery

- To test the capacity of the CR 2025 coin battery a load resistance of 15k Ohms was applied to produce a constant discharge current of 0.193mA
- The voltage drain would be at a much lower rate, ensuring that the device functions for the duration of the procedure



CR 2025 Battery voltage drain over time

Housing

Conclusion

- Drug overdose is a very serious. Naloxone is a drug that can pull people out of overdoses, and our product will make it much easier to get this lifesaving drug to people in a timely manner.
- Typical methods of delivering Naloxone require medical experience or require the user to have their nasal passages intact. With the micro-needle patch, the user will be able to provide the treatment without any prior medical experience.

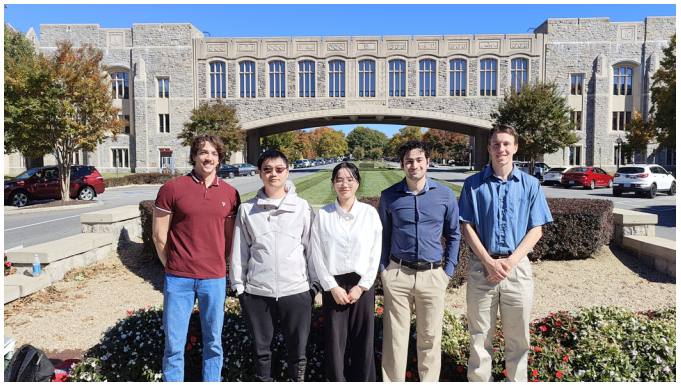
Future work

- Biocompatibility and Clinical Trials
- Expansion to Various Drugs and Applications
- Integration of Smart Features
- Miniaturized and Comfort Enhancement

Acknowledgments

The team would like to extend our heartfelt gratitude to our sponsors, the Virginia Tech ECE department and ETSU College of Pharmacy. Our team also sincerely thanks our SME and Mentor, Daniel Connors and Shelley Stover, for their guidance and expertise.

Portable Transmitter Location System



LEFT to RIGHT: Kris Schueller, Rui Peng, Stephanie Chen, Ramzy Saffarini, Tyler Eric Herod

CHALLENGE

Our device is a portable transmitter location system, engineered for tracking drones in rugged outdoor environments. Designed with a user-friendly interface, it offers seamless operation and versatility, allowing for the tracking of various frequencies as needed.

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BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
VIRGINIA TECH

WIRELESS@VIRGINIATECH

SME: Carl Dietrich

Customer: Carl Dietrich

Xi Chen Guangdong, China

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: I am driven by a commitment to innovation and precision in computer engineering and computer science, aspiring to contribute meaningfully to technology advancements, especially in fields bridging software and hardware integration.

Course Comment: The Senior Design Project has been an invaluable course that brings together students from across the ECE department to collaboratively plan and achieve project goals. It offers a unique opportunity to gain experience in client communication, understanding client requirements, and working cooperatively in a team environment to deliver a successful project outcome. This course has significantly enhanced my skills in teamwork, project management, and client-focused communication.

Tyler Herod Yorktown, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I will be a Officer in the U.S. Army. I hope to use my skills as a signal officer before transitioning to the FA26A Functional area, where I can best use my technical network knowledge.

Course Comment: The class has been a unique experience into how the engineering world works. The nature of the military will make this a little less important to me in the immediate, but I still find the process very rewarding. I believe it will be a increasingly important class to pull from further down my career.

Rui Peng Wuhan, China

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: I hope to make a career working with embedded system .

Course Comment: The class has been a great working experience.

Ramzy Saffarini Chantilly, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I will be working as a Software Development Engineer at Amazon Web Services upon graduation, on the Ground Station team. I am excited to take the skills I have learned throughout my undergrad into a fast-paced environment in industry.

Course Comment: The breadth of knowledge I have gained in RF & antennas, software development, design, and long-term project management have been invaluable for my future career. I was lucky to be surrounded by an intelligent group of self-starters.

Kris Schueller La Plata, Maryland

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: I would like to work on satellites and rockets to help explore space and push the limits of what we know.

Course Comment: This course has been a great opportunity to utilize and show off some of the skills I have gained throughout my learning career at this school. It has also given us access to some great resources which stimulate further learning.

Portable Transmitter Location System

Dr. Carl Dietrich (SME, Sponsor), Prof. Kenneth Schulz (Mentor)
By Rui Peng, Ramzy Saffarini, Stephanie Chen, Kris Schueller, Tyler Herod

VIRGINIA TECH

Wireless @ Virginia Tech

Situation

- Develop a portable device optimized for the tracking of electromagnetic transmitters.
- Balance effectiveness, usability, and durability in outdoor conditions.
- Ensure a design that allows for portable usage
- Design with a focus on the tracking of commercial drones.
- Optimize for potential mass production, including through the reduction of cost as possible.

Usage

This device was designed with the purpose to be a general transmitter location system; however, current research has focused on the usage in the detection of drones. Below is a list of potential usages.

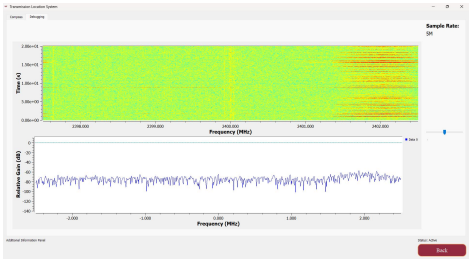
- Real-time detection of unauthorized drones
- Search and rescue
- Wildlife tagging initiatives
- Law enforcement
- Radio Direction Finding (RDF) competitions

Targets

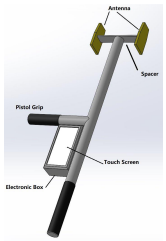
Requirement	Priority	Target Minimum
Range	4	1 Km
Frequencies	5	2.4, 5.8 GHz 915, 433 MHz
Accuracy	4	10 Degrees
Waterproof	2	IPX1 +
Battery Life	2	2 hours

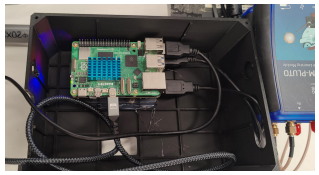
Product Design

GUI Design

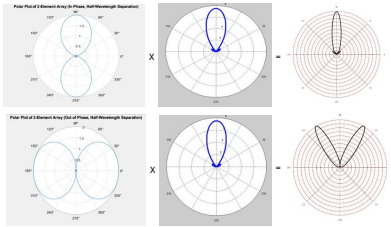


Physical Design

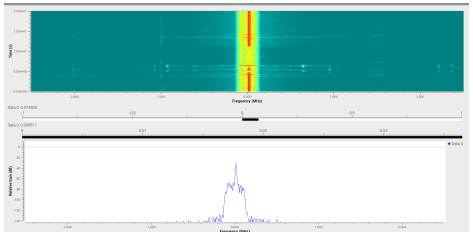




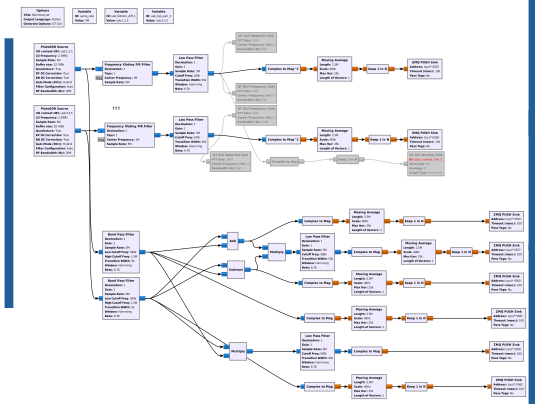
Antenna Design



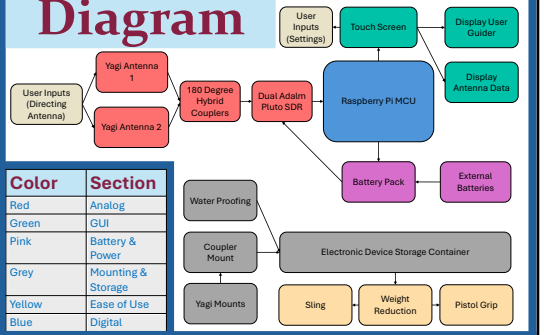
Output Diagram



GNU Radio



Diagram



Color	Section
Red	Analog
Green	GUI
Pink	Battery & Power
Grey	Mounting & Storage
Yellow	Ease of Use
Blue	Digital

Conclusion

- Capable of detecting the presence of drones and other emitters sources.
- The graphical user interface (GUI) accommodates both experienced and novice users, incorporating a straightforward compass system and a debug menu, demonstrated here in the center top-left section.
- Features include a lightweight construction, ergonomic pistol grip, and an optional sling for enhanced portability and ease of use.
- As demonstrated in the GNU section, the design is divided into two distinct portions. The upper portion is dedicated to tracking emitters, while the lower portion enhances processing accuracy and maximizes operational efficiency.

Future Research

- Expand frequency options
- Lower design cost, sourcing new materials
- Redesign Yagi mounts for motorized frequency shifts

Acknowledgment

Our team wishes to express deep gratitude to the following individuals:
Dr. Carl Dietrich
Prof. Kenneth Schulz

Inverse Design of Passive RF Components

Track 4 Winner

LEFT to RIGHT: Eddie Pritchard, Felipe Quintero, Calvin Jeter, Thomas Boris

CHALLENGE

As the Radio Frequency (RF) spectrum for wireless communication becomes more congested, effective filtering techniques are essential for mitigating undesirable interference. Our response to this is the manipulation of S-parameters with the incorporation of an accurate convolutional neural network model in order to flip pixels, either copper or dielectric, on a grid which in turn creates a filter circuit. We also seek to create a graphical user interface for unfamiliar researchers to utilize a specific electromagnetics simulator tool without the use of a command line.

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VIRGINIA TECH

SME: Jeff Walling

Customer: Jeff Walling

Thomas Boris Leesburg, Virginia

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: My aspiration is to work in the telecommuncations field and develop new communication systems.

Course Comment: This course gave me a chance to learn new topics while working on an open-ended problem.

Calvin Jeter Richmond, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: My aspiration is to research and develop technologies that will benefit people's lives.

Course Comment: This course taught me about project managment and how to plan engineering projects

Eddie Pritchard Ruckersville, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Test engineer

Course Comment: Senior design taught me about teamwork.

Felipe Quintero Washington, District of Columbia

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

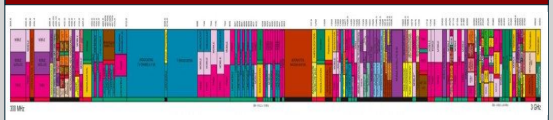
Aspirations: My aspirations are to apply what I've learned to newer or overlooked technology

Course Comment: The course has offered plenty of insight on real world engineering scenarios

Inverse Design of Passive RF Components

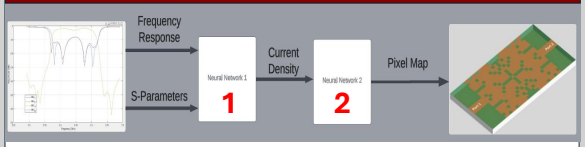
Customer and Subject Matter Expert: Dr. Walling – MICS at Virginia Tech
Mentor: Professor Kenneth Schulz
Team: Felipe Quintero, Henry Pritchard, Thomas Boris, Calvin Jeter

Background



• Increasing congestion in the RF spectrum leads to interference
•A pixelated structure may be rendered to service as a filter, discriminating between frequencies
•Using software, a tool can be devised to produce a pixelated filter with desired frequency characteristics upon demand

Block Diagram



• During testing, it was discovered that two models were required to retain information during s-param to pixel mapping
• Intermediate current density data is used to retain filter information
• Models use that data to calculate a pixel map with a similar frequency response

Accelerated Computing

- CNN Model training occurred on the VT ARC Tinkercliffs2 compute cluster on NVIDIA GPUs
- GPUs were utilized to accelerate training epoch time from:

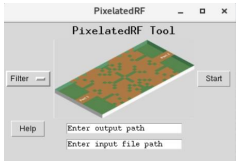
3 minutes / epoch to **3 seconds / epoch**

- Use of compute cluster allowed our team to train models on datasets exceeding 30Gb of training data!

ADVANCED RESEARCH COMPUTING

Objective

- Develop a **machine learning** tool where user inputs s-parameters receives a pixel grid
- Develop a GUI for the tool geared towards condensing technical trivialities
- Increase speed at which an engineer may manufacture a desired filter

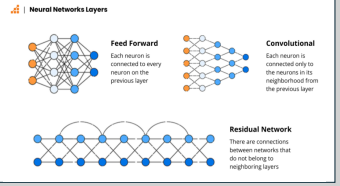


Pictured above: **GUI**

What is a Neural Network?

Neural Networks (NN) that we've considered include Convolutional Neural Networks, Recurring NN, Residual, and Generative Adversarial Networks

We've implemented a Convolutional Neural Network using Tensorflow and Keras utilizing CUDA programming

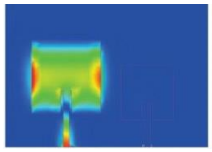


Conclusion

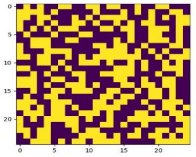
- Developed a current density to pixel map machine learning model with a 70% accuracy
- Developed a frontend GUI for our tool
- In conclusion, this project has successfully demonstrated the potential of utilizing advanced computational techniques, specifically through the integration of neural networks and multithreading, to address the challenges of RF component design in the context of an increasingly cluttered spectrum

Objective

- Sequential convolutional neural networks must be trained to relate s-parameters and current density to pixelated filter structure



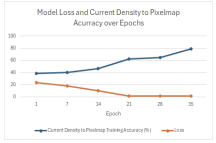
Pictured above: **CURRENT DENSITY**



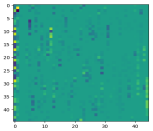
Pictured above: **A PIXELATED GRID**

Training Results

- Adding more epochs increased model accuracy up to 80 percent.
- Losses minimized to less than one.
- Improvements plateaued around 35 epochs.



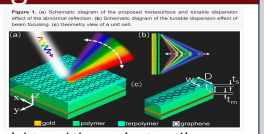
Pictured above: **LOSS per EPOCH**



Pictured above: **Sample CURRENT DENSITY**

Future Implementation & Acknowledgements

- Increase dataset size from 10000, to 50000+
- Open-source executable
- Meta surface implementation



- **Dr. Walling** for providing technical insight and the project outline
- **Professor Schulz** for mentoring us and keeping us on track
- **Woojun Lee** and **Jungmin Lee** for providing data for model training
- **Dr. Connors**, **Dr. Adams**, and **Dr. Ransbottom** for designing a course which has been demanding to complete and has prepared us with many life skills required to join the workforce

Project Contributor Acknowledgements

We want to acknowledge and thank the many people who contributed to this program:

Dr. Luke Lester and Dr. Harpreet Dhillon
for their vision and continued unyielding support to prepare our students for the future.

Joe Adams, Kelley Andrews, Daniel Connors, Ken Schulz and Shelly Stover
for mentoring the teams and making the course and all involved with it better.

Mary Brewer, Susan Broniak, Nicole Gholston, Kimberly Johnston, Alicia Sutherland, Minerva Sanabria-Padilla, Jaime De La Ree, Virgilio Centano, Scott Dunning, Paul Plassmann and Laura Villada
for watching over and advising each and every ECE student through the many challenges on the rocky road to becoming an engineer.

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

Afroze Mohammed
for being our partner and diligently working to nurture our industry relationships and to secure those critical sponsorships.

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

Kathy Atkins and Melanie Gilmore
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Donald Leber
for providing cleanroom access and training for students

Niki Hazuda and Ben Murphy
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for solving our IT issues

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for helping plan, cater and secure all arrangements to make the Major Design Experience Expo so great.

Special thanks to Rutwik Joshi
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Patty Tatro
of VTLink, License, and Launch for helping to maintain and grow our external partnerships.

Samik Bhinge, Prajwal Keshave Murthy, Jiaze Cheng and Matasir Madi
for helping run tracks and registration at the day of the Expo

The MDE Expo Judges
for judging the MDE presentations and posters.

Best in Course Recognition for Base Course Performance

Spring 2024

ECE 1004–Introduction to ECE Concepts

- Noah Chin
- Colton Fox

ECE 2024–Circuits and Devices

- Joshua Long
- Kyle Walker

ECE 2214–Physical Electronics

- Connor Balint
- Won Jae Chung
- Abhinav Terapalli

ECE 2514–Computational Engineering

- Eric Louis Bagtas
- Dowon Lee
- Shane Wyman

ECE 2544–Fundamentals of Digital Systems

- Walker Berndt
- Makeda Solomon

ECE 2564–Embedded Systems

- Pete Downey
- Theodore Moss

ECE 2714–Signals and Systems

- Connor Balint
- Charles Early

ECE 2804–Integrated Design Project

- Sachel Jetly
- Max Linville
- Molly Shear
- Samuel Thompson
- Christopher Wiencko

Infrared Radioteletype Design Project

LEFT to RIGHT: Samuel Thompson, Sachel Jetly

CHALLENGE

Design and implement an IR based wireless communication system capable of transmitting and receiving text-based messages.

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Sachel Jetly San Diego, California

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: After graduating, I plan to pursue an MS and build a career in industry, focusing on embedded systems.

Course Comment: ECE 2804 was such a fun class because it focused on hands-on learning through a semester-long project. It gave me the chance to apply what I'd learned in a way that felt engaging and practical, making it one of my favorite courses so far.

Samuel Thompson Amissville, Virginia

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: In industry, I'd like to acquire an FPGA Engineering role and be able to work on DSP projects.

Course Comment: ECE 2804 was my favorite sophomore year spring semester course. It provided an excellent opportunity to apply the knowledge and skills acquired from other courses to a semester-long project, giving a worthwhile undergraduate experience.

Infrared Radioteletype Design Project

Sachel Jetly, Samuel Thompson

Instructor: Dr. William Baumann

VIRGINIA TECH

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VIRGINIA TECH

Project Background

Designed and implemented a modern radioteletype system utilizing IR-based wireless communication to transmit and receive text messages, modernizing traditional teletype technology.

- Implemented IR transmitter and receiver modules.
- Transmitted string data as IR light pulse signals.
- Captured, amplified, filtered, and decoded IR signals into text.

This design required precise signal processing, analog circuit design, and embedded programming skills to achieve a 13-foot transmission distance.

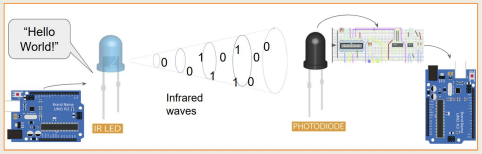


Figure 1: High-Level System Design

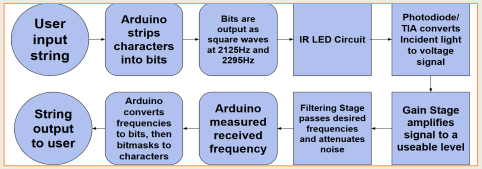


Figure 2: Mid-Level System Design

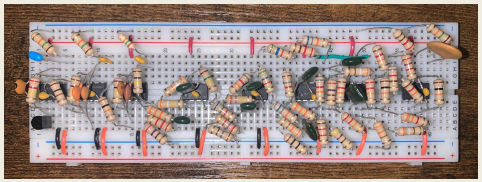


Figure 3: Final Receiver Circuit

Receiver Hardware Design

The receiver circuit needed to receive low-amplitude IR signals, attenuate noise, and distinguish 2125 Hz and 2295 Hz signals.

- **Conversion stage** consisted of the IR photodiode and transimpedance amplifier to turn IR signals to voltage signals.
- **Amplifying stage** raised received signals to measurable amplitudes without adding extra noise from op-amp saturation. Each amplifier was paired with a high-pass filter to mitigate op-amp input offset voltages.
- **Filtering stage** consisted of a 250 Hz BPF in serial with two parallel 100 Hz BPFs, connected with a summing amplifier, to achieve a 'notch' in the passband.

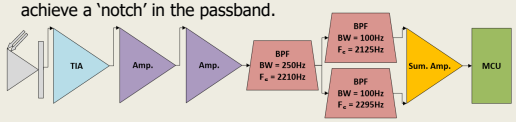
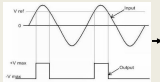


Figure 4: Receiver Circuit Block Diagram

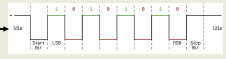
Receiver Software Design

The receiver software uses Arduino's internal comparator, set to trigger on rising edges, to convert filtered signals into binary form. An interrupt-driven FSM captures each period, distinguishing 2125 Hz ("0") from 2295 Hz ("1"). The FSM then assembles bits into ASCII characters, outputting the decoded data to the serial monitor for end-to-end transmission.



Comparator Output (Vref = 0V)

At each rising edge of the PWM, the interrupt service routine is triggered calculating the period



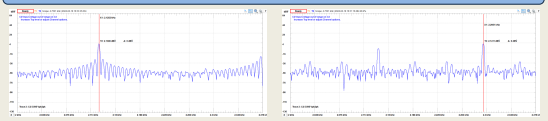
The FSM is designed to handle the UART data frame states (start, data, stop, idle)

Transmitter Design

- MCU was programmed to encode string data as desired frequency using hardware timers to pulse the IR LED with current limiting resistors.
- Hardware timers generated 2125 Hz and 2295 Hz PWMs, toggling every 22 ms for bitwise data, achieving 45.45 Baud.

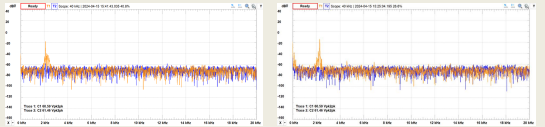
Performance Results

Transmitter Output Signal FFT Wave



The transmitter successfully produced the desired 2125 Hz (left) and 2295 Hz (right) signals, well within the required ±2 Hz tolerance. Each signal achieved ± <1 Hz within the target frequencies.

Receiver Output FFT Wave, 10-Foot Transmission



The receiver circuit effectively processed the signals at transmission distances of 10 feet. Minimal noise is present on the output, with strong frequency amplitudes of 2125 Hz (left) and 2295 Hz (right).

Receiver Filter Frequency Response

The receiver's frequency response achieved strong noise attenuation while effectively passing desired signals, exhibiting the expected 'notched' BPF characteristic to suppress noise within the system's bandwidth.

End-To-End 10-Foot Transmission

```
char str1[] = "Hello World!";
```

Transmitted Word

```
Hello World!Hello World!Hello World!
```

Received Word

Project Constraints

- **Transmitter Power:** 1 mA max current driving IR LED
- **Receiver Supplies:** max-min +5 / -5 operating voltage
- **Data Correspondence:** 2125 Hz ± 2 Hz as a binary 0
  2295 Hz ± 2 Hz as a binary 1
- **Transmission Protocol:** 45.45 Baud UART
- **Target Distance:** 10-foot transmission

Design Alternatives

- **Replace parallel filter setup with serial filter configuration.** The parallel filter configuration generated a beat frequency at the receiver output, adding extra noise to the circuit. Switching to a serial configuration would remove the beat frequency but would also require additional amplifier gain to achieve the same signal amplitude with the current filters.
- **Add parity bit in the UART data frame for error detection.**

SpO_2 System Design Project

LEFT to RIGHT: Molly Shear, Chris Wiencko

CHALLENGE

The goal of our semester-long project was to create a pulse oximeter that could calculate heart rate and SpO_2. The circuit reads in current data from a red and an infrared LED on the finger sensor. Those currents are converted to voltages and then filtered to better isolate the AC and DC components of the signals. The outputs of the filters are fed into an Arduino Uno that translates the ratio of inputs to SpO_2 using coefficients derived from a weighted quadratic regression. A representation of the heartbeat and the patient's data are shown on an external display.

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Molly Shear Chantilly, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After graduating, I hope to work on embedded systems in industry.

Course Comment: IDP was a very useful course that allowed students to practice for both senior design and real-world engineering projects.

Christopher Wiencko Winchester, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Bachelor of Science
Mathematics

Aspirations: After completing my Bachelor's degrees, I hope to work as an Embedded or Software Engineer.

Course Comment: IDP has been the most rewarding hands-on engineering course I've taken at Virginia Tech. Through this class, I gained valuable experience in signal filtering, data acquisition, and embedded system design-skills I'd like to apply to future projects in the field.

SpO_2 System Design Project

Team: Molly Shear & Chris Wiencko
Instructor: Tyler Milburn

VIRGINIA TECH

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VIRGINIA TECH

Background

Pulse oximeters are commonly used medical devices that measure oxygen saturation in the blood. This generally indicates lung performance and is used to identify the severity of conditions such as asthma or Covid-19.

Blood absorbs wavelengths of light differently depending on oxygen saturation. Utilizing this, these devices measure the absorption of light from red and infrared LEDs before and after each heartbeat to calculate blood-oxygen levels.

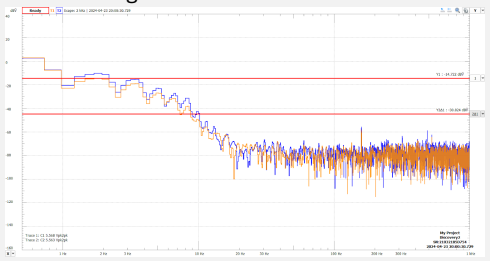
Provided image of Nellcor Ds-100A compatible finger sensor

Objectives

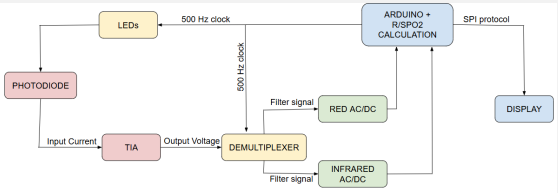
In this project, we built a pulse oximeter, consisting of a finger clamp, several hardware filters, a signal control system, and an Arduino Uno connected to a display.

Our goals for the project were to:

- ❖ Accept heartbeats from 40-120 BPM
- ❖ Keep all relevant harmonics of the heartbeat signal
- ❖ **30dB suppression at 60Hz (power line noise)**
- ❖ Validate heart rate and SpO_2 calculation using known test signals

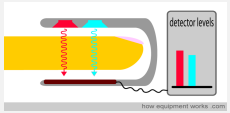


System Design



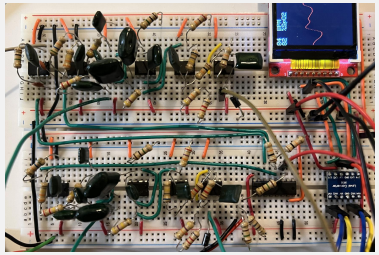
Signal Control

- **Problem:** Read light intensity from red and infrared LEDs near-simultaneously
- **Solution:**
  - Use a 490Hz PWM signal to switch between the LEDs
  - Use a demultiplexer that switches at the same rate to decode the information from the TIA to two signal filtering paths, isolating each red/infrared signal.



Signal Filtering

- Low Pass filter suppresses 60Hz noise from power sources
- High Pass filter removes the DC offset and amplifies the AC component



- Shift up the signal to be safe and readable to the Arduino

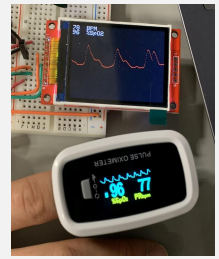
$$R = \frac{AC_{red}}{DC_{red}} \Big/ \frac{AC_{ired}}{DC_{ired}}$$

Arduino Functionality

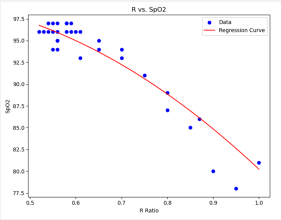
- Calculates the R ratio based on the outputs of the filters
- Translates the R value to SpO_2 using a weighted quadratic regression with gradient descent
- Draws the heartbeat on an external display

Results

- Achieved accurate heartrate readings between 40-120 BPM
- Measured SpO_2 values within 3% of a commercial sensor for SpO_2 values within the normal range.
- Under ideal conditions, our construction worked within 2% of the expected SpO_2 value, down to 87% SpO_2.



Quadratic Regression for Device Calibration



- Unclear relationship between calculated R value and SpO_2. To calibrate our device, we fitted R values to reliable SpO2 measurements.
- Biased the regression to R values between 0.5-0.6 to align with collected data.

Future Steps

Given the opportunity to continue this project, we would:

- ❖ Add more robust calibration to adjust for the patient's skin tone. We noticed that varying skin tone greatly affected our results, due to a lack of variety in our calibration data.
- ❖ Improve our construction's resilience to movement. We noticed that perturbations in the sensor possibly affected both heartrate and SpO_2 readings.
- ❖ Reduce time needed to obtain an accurate SpO2 reading thus improving response time of the circuit.
- ❖ Create a PCB to increase the reliability of connections in our circuit.

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