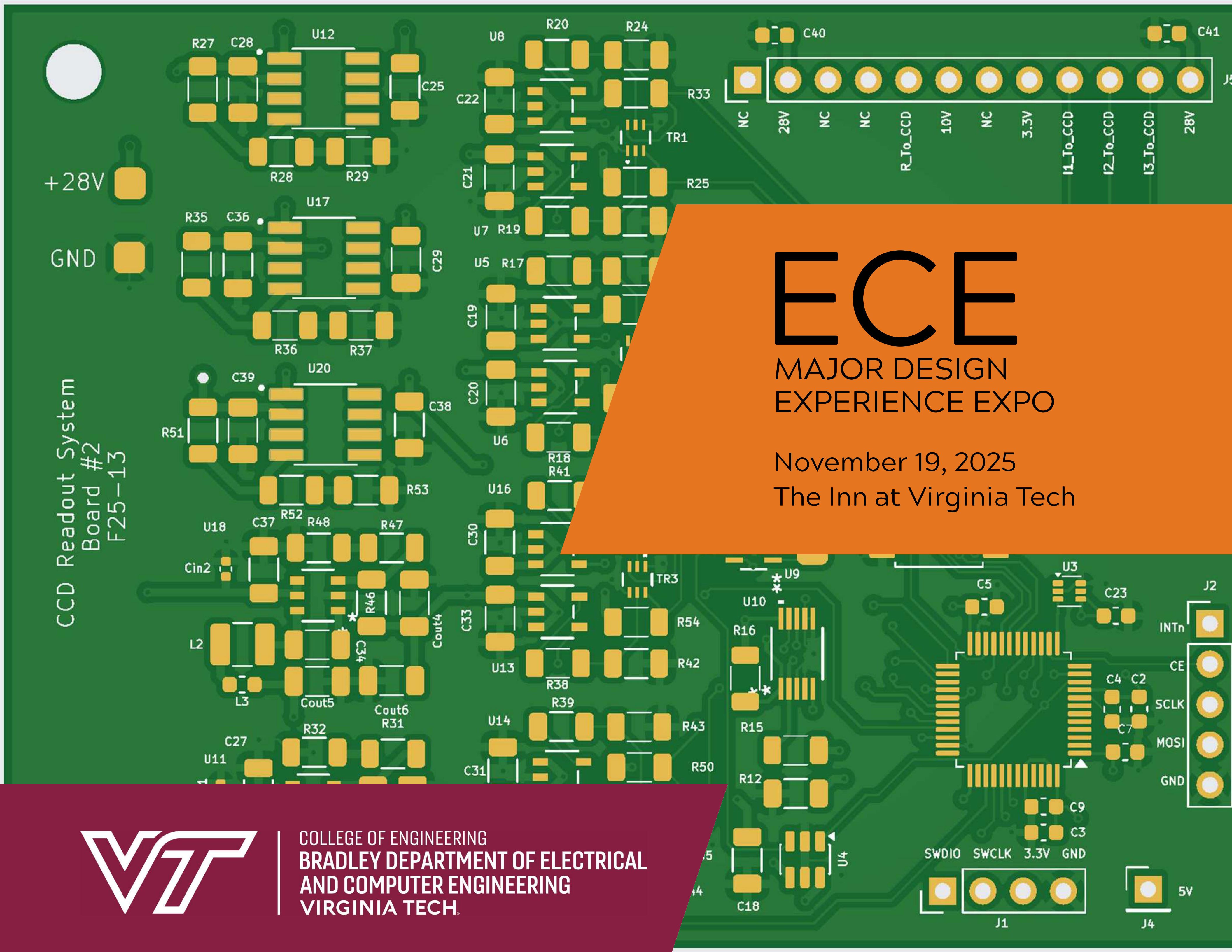


ECE

MAJOR DESIGN EXPERIENCE EXPO

November 19, 2025

The Inn at Virginia Tech

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

Agenda

Registration	9:30am–10:00am
Welcome	10:00am–10:15am
Tracks	10:30am–12:15pm
Posters and Pizza	12:30pm–2:00pm
Awards	2:00pm–2:30pm

Presentation Tracks

Welcome to our Fall 2025 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 60 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, 14 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 14 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.

Rose Hu
Department Head
Bradley Department of Electrical and Computer Engineering

Sponsors

We greatly appreciate their support.

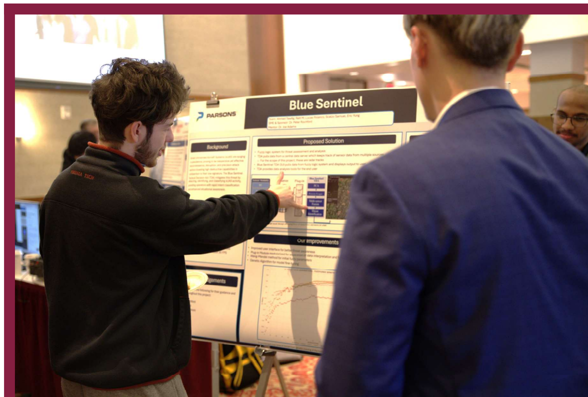
Project Leadership

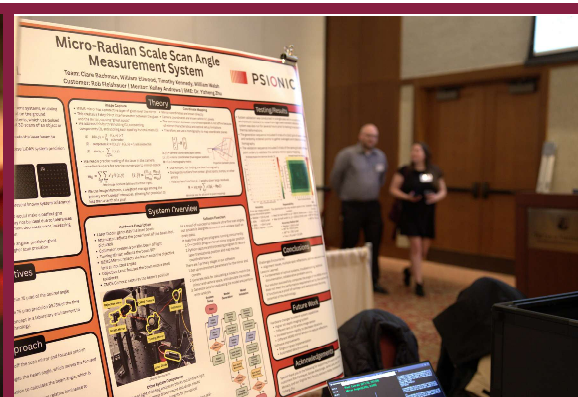
This class is only possible because of the commitment, dedication, and spirit of the following Customers and Subject Matter Experts. Thank you!

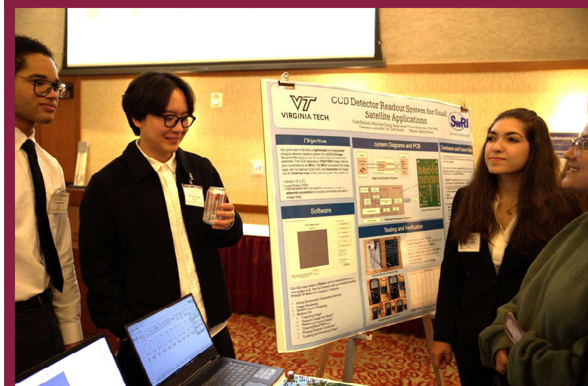
Sponsor	Customer	Project	Subject Matter Expert (SME)
Dominion Energy Electric Transmission	Anastasios karles	Virtual Phasor Measurement Units	Virgilio Centeno
Epiq Solutions	Lucas Vickers	Low Cost Portable Antenna Range	Carl Dietrich
Intellectus	Chris Watson and Owen Sullivan	Real-Time Fraud Detection	Nagender Aneja
Lenovo	Patrick Caporale and Scott Faasse	Open-Source Hardware-Based Trusted Platform Module	Jason Thweatt Christiana Garcia
MITRE	Andy Thompson, Will Flathers, Matt Ware and Connor Mahoney	Self-Contained Multi-Platform Radar System	Andy Thompson Will Flathers Matt Ware Connor Mahoney
NAWC **Patuxent River, Maryland**	Andrian Jordan and Israel Jordan	Autonomous UAV Landing	Ryan Williams Andrian Jordan Israel Jordan
Parsons **Centreville, Virginia**	Peter Rochford	Blue Sentinel	Peter Rochford
Psionic **Hampton, Virginia**	Rob Fleishauer	Micro-Radian Scale Scan Angle Measurement System	Yizheng Zhu
Southwest Research Institute	Todd Veach	CCD Detector Readout System for Small Satellite Applications	
Union Dynamic	Ames Evans and Lucie McMinn	Portable Low-Power Drone Detection System With Edge AI Accelerator	Ames Evans Lucie McMinn
Union Dynamic	Ames Evans and Lucie McMinn	Dynamic Steerable Polymer Embedded Antenna Array (DS-PEAA)	Ames Evans
Virginia Tech, ECE **Blacksburg, Virginia**	Igor Grebnev	Stylus Testing System with Positional and Force Control	Igor Grebnev

Sponsor	Customer	Project	Subject Matter Expert (SME)
Virginia Tech, ECE Blacksburg, Virginia	Creed Jones	Automated Coin Grader	Creed Jones
Virginia Tech, VTTI	Zeb Bowden	Drive Secure: Teaching Automotive Cybersecurity with RAMN	Tim Talty

Project Teams and Posters







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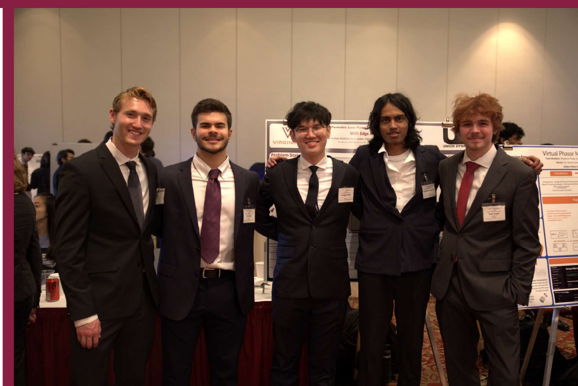

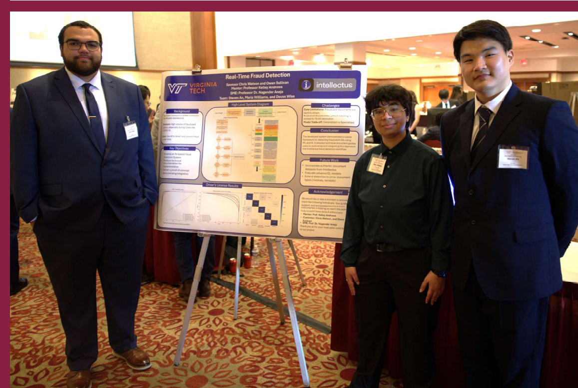

Drive Secure: Teaching Automotive Cybersecurity with RAMN

LEFT to RIGHT: William Min, Colton Smith, Jonas von Stein, Brooks O'Hanlan

CHALLENGE

The Virginia Tech Transportation Institute (VTTI) has tasked our team with designing cybersecurity challenges and a lesson plan for the RAMN (Resistant Automotive Miniature Network). The RAMN was designed as a test bed for automotive ECUs (Electronic Control Units), and VTTI has tasked our group to create cybersecurity challenges and a lesson plan that will serve as an educational tool for automotive cybersecurity. There is currently no entry-level lesson plan for automotive cybersecurity, so beginner level cybersecurity challenges and a lesson plan for students is a step towards increasing cybersecurity education. The cybersecurity challenges can provide insights about the vulnerabilities of the control units in vehicles.

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SME: Tim Talty

Customer: Zeb Bowden

William Min Bristow, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: To work with autonomous vehicles or cybersecurity and one day make projects with close friends.

Course Comment: This course helped me understand more about what it will look like when working in a team, and it gave me a better understanding of cybersecurity in automotive vehicles.

Brooks O'Hanlan Greenville, South Carolina

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I intend to pursue a master's degree in computer engineering and then start a career in the sports industry.

Course Comment: This course provided a valuable opportunity to apply engineering concepts in a team setting. I am grateful for our project because it expanded my knowledge of automotive cybersecurity and improved my skills in embedded programming.

Colton Smith Appomattox, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I want to pursue homesteading and possibly open a small family owned business in the future.

Course Comment: This course was an excellent practice of teamwork and modeled working in a technical role well.

Jonas von Stein Alexandria, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: I plan to enter the workforce and hope to build a career that contributes to improving people's lives.

Course Comment: This course provided a great experience with how to manage a project from start to finish. The project enhanced my skills in embedded systems and deepened my understanding of automotive cybersecurity.

Drive Secure: Teaching Automotive Cybersecurity with RAMN

Brooks O'Hanlan, Colton Smith, Jonas von Stein, William Min

Customer: Dr. Zeb Bowden at VTTI   Mentor: Dr. Joe Adams

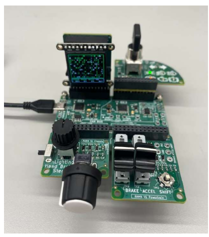
VIRGINIA TECH

VIRGINIA TECH TRANSPORTATION INSTITUTE

What is RAMN?

The Resistant Automotive Miniature Network (RAMN):

- Is a cost-effective and portable solution to teaching cybersecurity on modern vehicles
- Utilizes four open-source STM32 microcontrollers
- Simulates the function of Electronic Control Units (ECUs) in the automotive industry



Consists Of:

- Main board (center)
- LCD Screen Pod (top left)
- Chassis Pod (bottom left)
- Powertrain Pod (bottom right)
- Body Pod (top right)

Figure 1. RAMN system

Why?

As cars become more advanced, they face the same cybersecurity risks as computers. Our challenges use RAMN to help participants uncover vulnerabilities, develop defenses, and advance the future of secure automotive systems.

Project Overview

Our Challenges:

- Entry-Level Capture the Flag Challenge
  - Use Unified Diagnostic Service (UDS) commands to find the flag
- "Brute Force" Password Identifier
  - Attempt every password combination to identify the answer
- ECU Manipulation:
  - Interact at data layer instead of physical layer

System Architecture

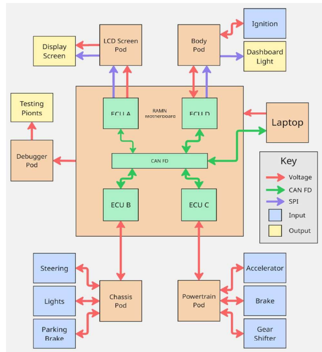


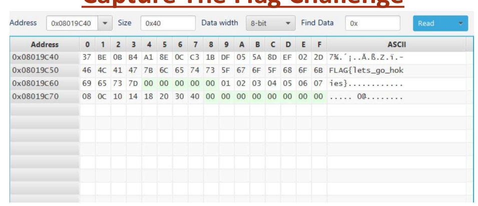
Figure 2. RAMN System architecture

Brute Force Scripting

```
&27741 -> Wrong Password
&27742 -> Wrong Password
&27743 -> Wrong Password
&27744 -> Wrong Password
&27745 -> Wrong Password
&27746 -> Wrong Password
&27747 -> Wrong Password
&27748 -> Wrong Password
&27749 -> Wrong Password
&27750 -> Wrong Password
&27751 -> Wrong Password
&27752 -> Wrong Password
&27753 -> Wrong Password
&27754 -> Wrong Password
&27755 -> Wrong Password
&27756 -> Wrong Password
&27757 -> Wrong Password
&27758 -> Wrong Password
&27759 -> Wrong Password
&27760 -> Wrong Password
&27761 -> Wrong Password
&27762 -> flag{USB_BRUTEFORCE}
FOUND: &27762 -> flag{USB_BRUTEFORCE}
```

Figure 3. Brute Force Challenge

Capture The Flag Challenge



Address 0x08019C40 Size 0x40 Data width 8-bit Find Data 0x Read

Address	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	ASCII
0x08019C40	37	BE	0B	B4	A1	8E	0C	C3	1B	DF	05	5A	8D	EF	02	2D	7¾.´¡..Ã.ß.Z.ï.-
0x08019C50	46	4C	41	47	7B	6C	65	74	73	5F	67	6F	5F	68	6F	6B	FLAG{lets_go_hok
0x08019C60	69	65	73	7D	00	00	00	00	00	01	02	03	04	05	06	07	ies}............
0x08019C70	08	0C	10	14	18	20	30	40	00	00	00	00	00	00	00	00	..... 0@........

Figure 4. CTF Challenge

ECU Manipulation

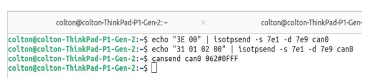


Figure 5. Commands sent to RAMN board via CAN-UTILS after all set-up steps are complete. Set-up steps can be found in our documentation.

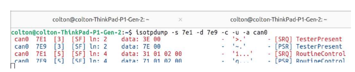


Figure 6. Response messages from RAMN to send commands in Figure X.

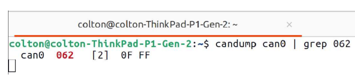


Figure 7. CAN frame changed by using cansend command in Figure X, HEX 0F FF is 100% right steering.

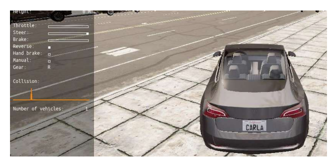


Figure 8. Visual output of cansend command to turn steering 100% right, observed by the white square on the steering value in CARLA.

RAMN/Challenge Documentation

A website for the RAMN already exists, but it was more useful for experienced users.

Our documentation:

- Step-by-step instructions
- Resources (hyperlinks)
- Debugging instructions
- Entry-level Oriented

SCAN ME

Conclusion

Our solution provides VTTI with three beginner level cybersecurity challenges and documentation to better help students understand automotive cybersecurity. This serves as foundation for future cybersecurity challenges.

Future Plans

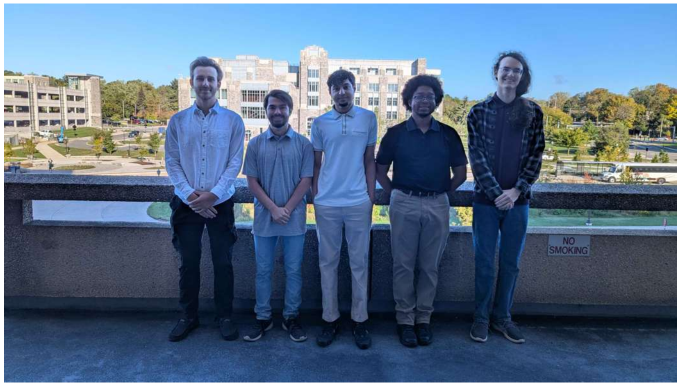
- Increase cybersecurity challenge difficulty
- Design new expansion pods i.e. wireless connectivity
- Host a competition with our challenges
- Teach automotive cybersecurity in classes

Acknowledgements

Special thank you to the following for supporting this work:

- Dr. Joe Adams (Project Mentor)
- Dr. Tim Talty (SME)
- Dr. Zeb Bowden (Customer)
- Camille Gay, Toyota (RAMN Creator)
- Kim Medley (ECE Purchasing)
- Rusty Stewart (For Soldering Training)

Automated Coin Grader



LEFT to RIGHT: Luke Graham, John Anthony Kadian, Rafay Hai, Devyn Hopkins, Eric Morley

SME: Creed Jones

CHALLENGE

Our task is to take a product-oriented approach that makes coin grading intuitive and accessible to all users. Our project integrates and refines prior grading models as complementary components within a newly developed end-to-end system that identifies and grades coins based on the Sheldon Scale. The ultimate goal is to create a reliable, user-friendly tool that brings professional-level coin grading to everyday collectors.

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Customer: Creed Jones

Eric Morley Sterling, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I look forward to making a career out of computer engineering, a field that feels like real-world magic with things that are possible. I'm excited to explore how far I can take my skills and creativity in a professional setting.

Course Comment: The MDE provides a good first splash into the deep end of the professional design setting. Allowing room for error and opportunities to learn. While still delivring an authentic experience at tackling a problem.

Luke Graham Fairlawn, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I want to work as hard as physically possible in order to succeed in a Computer Engineering job or start something of my own that will set me up to take care of my wife, have a ton of kids, and give all of my life to serving Jesus Christ.

Course Comment: The Project we received for Senior Design is a good fit for the kind of things I would like to do in the future with Computer Engineering. I like the idea of making new useful things for people even if they seem a bit obscure.

John Anthony Kadian Smithtown, New York

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I aim to use my Machine Learning degree to develop practical, impactful solutions in the field of AI and data science, either through my own startup or within the industry.

Course Comment: This Senior Design Project is well aligned with my technical focus and provided me with a profound introduction to the expectations of real-world team development.

Devyn Hopkins Fairfax, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Post graduation, I want to be able to continue learning about machine learning algorithms, data analytics, and/or embedded systems through graduate school at Virginia Tech. After achieving my masters, I want to use what I learned for defense or possibly in research

Course Comment: ECE 4805 & 4806 has proven to be an incredibly insightful course, and provided an introductory look at how we should be performing as engineers. Despite having worked in groups in other classes, MDE takes that everything to an elevated level that teaches an in-depth level of research, cooperation, and time management in order to meet deadlines and producing a good product. In spite of how hard and frustrating the work gets, I'm glad I am able to be a part of MDE and be on a project that relates to my interests.

Rafay Hai Sterling, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: In my professional career, I plan to use my Computer Engineering and Machine Learning background to pursue innovative work that pushes the technological goalpost of human innovation, driving forward the boundaries between human creativity and intelligent technology.

Course Comment: ECE 4805 & ECE 4806 provide an eye-opening experience into the professional world. This course immerses students in an environment where they tackle real-world engineering projects as part of a team, with the vision and path to success determined by the students themselves. The open-ended structure mirrors a true engineering workplace, supported by professional mentors who guide development while emphasizing effective communication, teamwork, leadership, persistence, and the ability to perform under deadlines. Overall, this course serves as a crucial bridge for students transitioning into their careers, preparing them to succeed as new graduates entering the engineering industry.

Automated Coin Grader

Sponsor – Dr. Creed Jones Mentor – Dr. Daniel Connors
Team – Luke Graham, John Anthony Kadian, Rafay Hai, Devyn Hopkins, Eric Morley

VIRGINIA TECH
ece BRADLEY DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

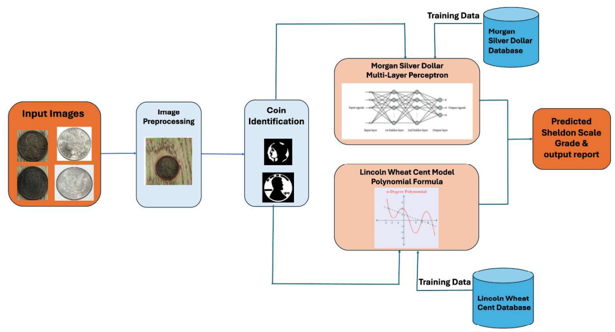
Problem Statement

Coin grading today is expensive, subjective, and time-consuming, leaving many collectors unsure whether their coins are worth professional evaluation.

Our goal is to make grading intuitive and accessible by developing a product-oriented, end-to-end system building upon prior models.

The system will deliver fast, reliable Sheldon Scale grades, giving users professional-level insight without the traditional costs or delays.

System Architecture Pipeline

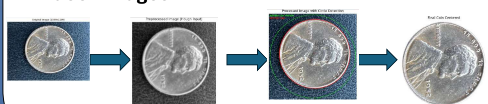


System Features

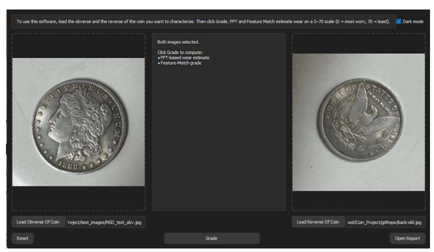
- Extracts coin automatically from raw image
- Identifies the type of coin (from supported coins)
- Produces a Sheldon Scale grade for the coin
- Output a confidence score for each grade
- Provides detailed report highlighting key elements that went into grading
- User-Friendly GUI for uploading coin images / getting grade

Image Preprocessing

- Refactoring: crops and rescales to 1000x1000
- Gaussian Blur: removes small-scale noise
- Bilateral Filter: smooths similar pixels without losing edges
- Hough Circles: isolates coin boundaries
- Anomaly Detection: reports extraneous user images



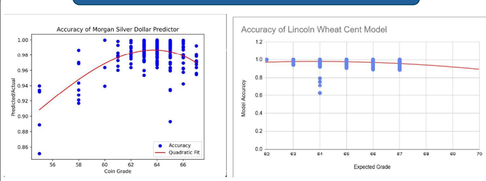
GUI & Detailed Report



Results/Conclusion

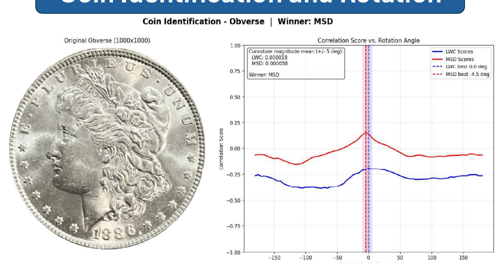
- Coin Grader Accuracy (80% Req, ±3 Sheldon points):
  - 82.23% within 3 Sheldon points
  - 45.92% within 1 Sheldon point
  - Mean Absolute Error: 1.74 Sheldon Points
  - Validated against ~1500 Pre-graded MSD and LWC coins
- Coin Type Identifier Accuracy (90% Req):
  - Correctly identified 241/250 (~96.4%) using random assorted sample of LWC and MSD obverse / reverse images
- Grading Speed (≤5 sec Req):
  - 4.91 sec average grading model runtime
- Developed a central algorithm that identifies and grades 2 distinct coin types under 5 seconds
- Designed and created a phone application for ease of use by everyday users

Machine Learning Model



Accuracy of Coin Grading Models – To determine how accurate the models were, we plotted the percent error of coins from our test database on a scatterplot. Then we graphed the line of best fit to use as the predicted accuracy score. On the left is the plot for the Morgan Silver Dollar model, and the right is for the Lincoln Wheat Cent.

Coin Identification and Rotation



Next Steps

- Add more supported coin types
- Create new quality of life features
  - "Similarly Graded" coins feature
  - Cost estimation feature

Acknowledgements

Our team would like to extend our gratitude to:
Mentor: Dr. Daniel Connors
SME & Customer: Dr. Creed Jones

Blue Sentinel

Track 1 Winner

LEFT to RIGHT: Eric Yung, Samuel Scalzo, Rett M, Lucas Polanco, Ahmed Tawfig

CHALLENGE

Design and implement a Tactical Decision Aid (TDA), a self-governing software analysis tool that utilizes fuzzy logic and a machine-learning framework, to evaluate multi-sensor data of small Unmanned Aircraft Systems (sUAS). The TDA should assess the dynamic behavior of sUAS swarms simultaneously and provide short-term threat identification and prioritization, displayed on a user interface. The resultant consequence should be lower false positive hostility rates; thus, reducing the strain on watch operators and improving overall response time.

PARSONS

SME: Peter Rochford

Customer: Peter Rochford

Rett M Cape Cod, Massachusetts

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After graduation, I plan to dedicate my career to leading my organization with the goal to America's domestic manufacturing base, with a particular focus on the defense sector.

Course Comment: Of all the design and project related courses I have taken thus far, this course has provided me with the most insight into efficient teamwork and project management. It's been incredibly valuable to gain industry experience with real requirements and deadlines, all while furthering my education.

Lucas Polanco Aldie, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I would like to further my education and pursue a career in chip-scale design.

Course Comment: This course has been a valuable place to learn about working with customers to create project specifications and road maps that allow a small team to succeed in creating a tangible product.

Samuel Scalzo Reston, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I am entering a career in software engineering after graduation.

Course Comment: This course has allowed me to gain great industry experience and learn how to build a complex product in a large team.

Ahmed Tawfig Alexandria, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I stepped into the field of Computer Engineering to further my passion for hardware and software systems. My advancement through my undergraduate courses led to my desire to pursue a focus in machine learning. It is now my goal practice the knowledge and experience I gathered at Virginia Tech, and practically apply it in the industry.

Course Comment: This course is uniquely structured in the independence it gives the students. There's value in tailoring an environment to mimic what a team project would look like in the work force. It is especially beneficial to have a client/server dynamic to condition students to appropriately interact with potential customers in the future.

Eric Yung Vienna, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: Whatever industry I end up in the end, I aspire to solving interesting and difficult problems and learning about computers, engineering, and networking.

Course Comment: This course has been a great exercise in project management, leadership, team coordination and communication over a timescale that is very rare for a normal course. It has been a unique and valuable experience.

Blue Sentinel

Team: Ahmed Tawfig, Rett M, Lucas Polanco, Scalzo Samuel, Eric Yung
SME & Sponsor: Dr. Peter Rochford
Mentor: Dr. Joe Adams

Background

Small Unmanned Aircraft Systems (sUAS) are surging in prevalence, proving to be inexpensive yet effective reconnaissance, disruption, and precision attack vectors boasting high destructive capabilities in comparison to their low signature. The Blue Sentinel Tactical Decision Aid (TDA) mitigates this threat by detecting, identifying, and classifying sUAS activity, providing operators with rapid intent classification and enhanced situational awareness.

Objectives

- Refactor user interface in Python
- Increase ease of installation and portability
- Improve accuracy of threat assessment
- Implement tools to minimize operator fatigue and cognitive load
- Fuzzy Logic false positive rate of 5% or lower
- End-to-end response time of 50 ms or less
- GUI update frequency of at least 30 FPS

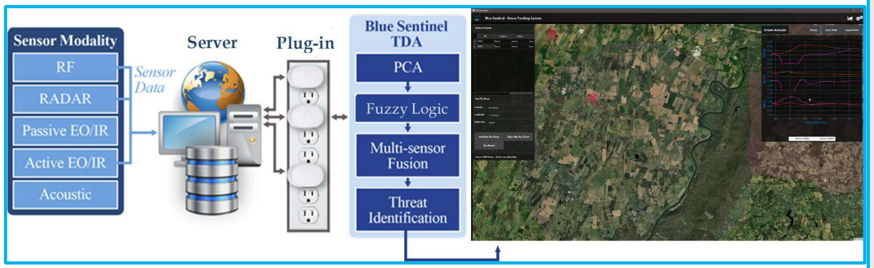
Acknowledgements

Special thanks to the following for their guidance and support throughout this project:

Dr. Peter Rochford
Dr. Joe Adams
Dr. Daniel Connors

Proposed Solution

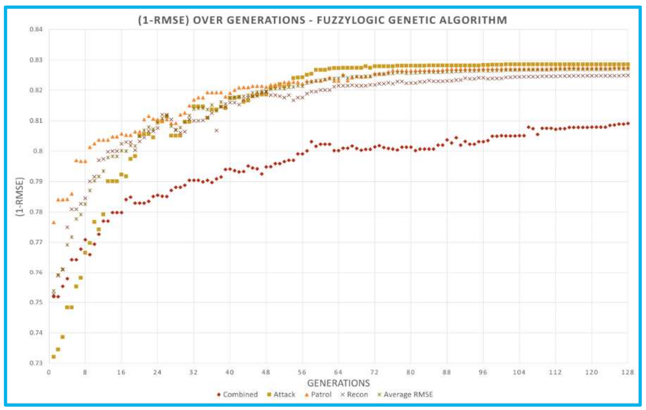
- Fuzzy logic system for threat assessment and analysis
- TDA pulls data from a central data server which keeps track of sensor data from multiple sources
  - For the scope of this project, these are radar tracks
- Blue Sentinel TDA GUI pulls data from fuzzy logic system and displays output to user
- TDA provides data analysis tools for the end user



Blue Sentinel TDA High level design showing flow of data from sensors to User

Our Improvements

- Improved user interface for better threat awareness
- Plug-in Module modularized for separation of data interpretation and fuzzy logic
- Wang-Mendel method for initial fuzzy parameters
- Genetic Algorithm for model fine-tuning



Improvement over time of model from genetic training of the fuzzy logic module

Results

- Improved Fuzzy Logic threat classification model
  - 4.8% False positive rate for attack classifications
  - ~85% classification accuracy
- Improved awareness and reduced fatigue features
  - sUAS whitelisting capabilities
  - Off-screen directional warning indicators
  - Altitude cue ring
  - Configure defense location and no-fly zone
  - Operational risk profile tool
- Latency
  - Old System: 1034.04 ms
  - Our System: 2830.35 ms

Conclusion

- Blue Sentinel TDA successfully identifies and classifies sUAS activity in a defense context
- Our testing indicates reliable intent classification and warning to the operator
- Current design provides a foundation for future expansion within capability and accuracy

Next Steps

- Continue Fuzzy Logic training to improve accuracy and decrease false positive rate
- Offload Fuzzy Logic computation to GPU for more efficient training
- Integrate additional sensor modalities for enhanced classification and situational awareness
- Optimize model for improved speed and latency

Portable Low-Power Drone Detection System With Edge AI Accelerator

LEFT to RIGHT: Yuri Braga, Youngjoon Park, Nash Gober, Andrew Bickford, Vikram Muruganandam

SME: Ames Evans and Lucie McMinn

CHALLENGE

Our team has been tasked with developing a low-power, audio-based event detection system using an embedded AI accelerator. Our challenge is to design, train, and deploy an AI model on embedded hardware capable of detecting drone presence and direction in real time using multi-channel acoustic data. This project demonstrates the feasibility of embedded low-power AI hardware for reliable offline event detection in a compact and energy-efficient package.

UNION DYNAMIC

Customers: Ames Evans and Lucie McMinn

Vikram Muruganandam Tokyo, Japan

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I intend to pursue a master's degree in Machine Learning while engaging in impactful real-world AI/ML projects within the industry to gain hands-on experience and deepen my understanding of practical applications. Upon completing my master's degree, my goal is to work on advanced research in AI/ML to solve complex real-world issues contributing positively to society through innovative solutions and advancements in the field.

Course Comment: This course provided hands-on experience for the skills we learnt throughout our degree. Additionally, it offered opportunities to work with stakeholders in industry, collaborate as a team, manage projects effectively, and deliver a final product by its deadline. As the project manager, I exercised leadership skills by clarifying objectives, setting priorities, and driving towards successful outcomes. I consider these experiences an invaluable part of my degree.

Youngjoon Park Seoul, South Korea

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I aspire to pursue a career in machine learning and artificial intelligence applications bridging hardware and software to develop efficient, low-power AI systems for real-world use. I plan to pursue a Master's program to deepen my knowledge of advanced machine learning techniques and real-time inference. One day, I hope to contribute my knowledge to create a positive impact in areas such as agriculture and autonomous systems.

Course Comment: This course provided a valuable opportunity to apply my knowledge to a real-world project. Working on drone detection through audio input allowed me to combine my interests in signal processing, embedded systems, and machine learning. I especially enjoyed collecting data, training models, and collaborating with a dedicated team. Overall, this experience strengthened both my technical and teamwork skills while giving me insight into applying my knowledge to real engineering challenges.

Andrew Bickford McLean, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: I want to go into venture capital with a national security focus and start/join an early stage startup where I am surrounded with innovative ideas enabling me to bring them into reality as something useful.

Course Comment: I've enjoyed the freedom we've had in this course to design a system using modern and state-of-the-art technology.

Nash Gober Richmond, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: My aspirations are to enter the field of AI and ML to help move it towards a more ethical future, as lots of the current applications ride the lines between ethical and unethical. Some specifics would be areas concerning data collection/use, and generative AI, both of which have huge impacts on the way we function in today's world, and both containing many areas of ethical concern.

Course Comment: The course content was not entertaining, but it taught the important aspects of being an engineer in the real world, which is arguably more valuable than any other class we've taken. Aside from that we got the freedom to choose our projects from a list and solve real world issues all while working with real companies, which is an opportunity I think most college student's would give anything for.

Yuri Braga Salvador, Brazil

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I founded a startup that used AI to predict orthopedic procedure outcomes. My short-term goal is to pitch to investors, gather resources, and build a team. In the longer term, I want to be providing software solutions to health care providers and payers to optimize value-based care.

Course Comment: The class was entertaining and a great way to learn how to handle long-term group projects. It taught me valuable lessons on collaboration and time management. I also learned about edge AI and low-power AI applications.

Portable Low-Power Drone Detection System With Edge AI Accelerator

Team: Andrew Bickford, Nash Gober, Vikram Muruganandam, Youngjoon Park, Yuri Braga

Customer/SME: Ames Evans, Michael McMinn, Lucie McMinn

Mentor: Kelley Andrews

VIRGINIA TECH

UNION DYNAMIC

Problem Statement

Given the increasing number of drones in our airspace, along with the current power consumption, capabilities, and price of market detection systems, we've been tasked with creating a solution that has the following attributes:

- Low-Power & Low-Cost
- Real-time
- Able to handle audio noise
- Able to perform in various environments

Impact

Proves that **AI** can **run fully offline** – no cloud, no internet

Reduces cost and power usage, making AI systems practical in the field

Portable and fast to deploy, perfect for real-time security operations

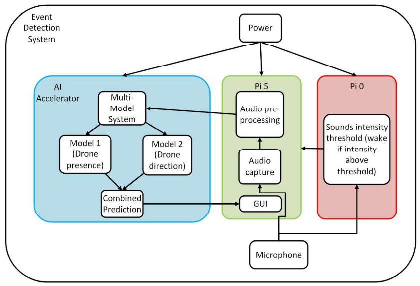
Enhances safety by continuously monitoring environments for threats

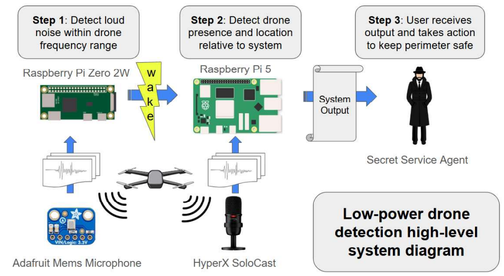
Expands access to drone detection technology through affordable design

Challenges

- **A large dataset is required to achieve high accuracy**
  - Data collection and balancing first and third-party data weights when training model
- **Differences in microphone quality**
  - Utilizing different mics for training and real-time validation could introduce drop in accuracy
- **Uneven Microphone pickup pattern**
  - The HyperX microphone being used is designed for human voice, and is therefore more sensitive to sounds directly in front of it.
- **Fine-Tuning pre-trained Models**
  - Adapting pretrained models to 4-channel drone data requires careful tuning of parameters to maintain learned features and prevent overfitting.

System Diagrams





Low-power drone detection high-level system diagram

Detailed Implementation

Hardware

Hardware:
- Raspberry Pi 5, 8 GB RAM
  - Powered by USB-C 5V
  - 128 GB SD card for storage
- Hailo 8L AI Accelerator
  - Connected through PCIe 3
- Sterio Microphone
  - Connected through USB
- LCD Touch Display
  - Connected through HDMI, USB

Networking and Communication:
- Portable networking through WiFi (Standardized SSID and Password)
- Development networking through Ethernet
- CLI Access through SSH and SCP
- GUI Access through X-RDP (X Remote Desktop Protocol)

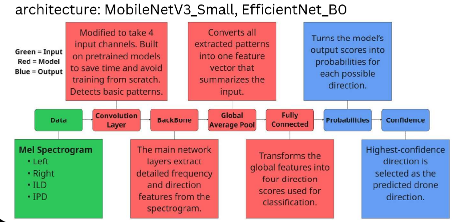
Hardware Specific Model Pipeline:
- **Model:**
  - Parse:
    - Convert .ONNX model weights to .HAR format.
  - Optimize:
    - Quantize floating points model weights to discrete integers.
    - Use "possible inputs" dataset to fine tune optimization
  - Compile:
    - Map model layers to hardware blocks 'contexts'
    - Interactively optimize hardware performance
  - Run
    - Convert .npy spectrogram data to binary

Software

Preprocessing:
- Preprocessed collected Audio to Mel-Spectrogram.
- Stored data into 4-Channels:
  - Left & Right
  - Interaural Level Difference (ILD): Difference in sound intensity between left and right channels: indicates direction.
  - Interaural Phase Difference (IPD): Difference in phase arrival time between channels: captures angle and distance cues.

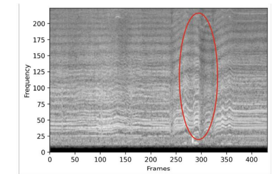
Data Augmentation:
- Augmented Data Using Concept of
  - **CutMix**: Combines two spectrograms by cutting and pasting random patches from one onto another.
  - **SpecMix**: Mixes frequency-time regions between different audio samples.
  - **MixUp**: Blends two spectrograms and their labels together by averaging them

Model Construction
- Used pretrained models to build a custom 4-channel convolutional architecture: MobileNetV3_Small, EfficientNet_B0



Data Collection

- **Zoom H6/H5 + Zoom F4 field recorders**
  - High-fidelity, omnidirectional
- **Data diversity:**
  - Hovering at different altitudes (10-60 ft)
  - Fly-by from all 4 cardinal points
  - Open field and closed room recordings
- **Negative data collection**
  - Drone-like noises used to train the system on similar but non-drone noises



Mel-Spectrogram

Conclusion

Union Dynamic now has a drone detection system that is:
- **portable**, allowing easy transportation and deployment
- **low-power,** utilizing edge AI running on a TPU
- **accurate**, distinguishing with high accuracy the presence and location of a nearby drone

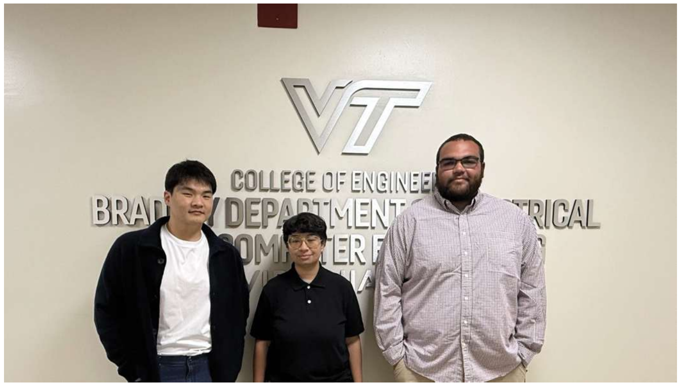
Future Work

- **Multiclass Classification**, where rather than just saying yes or no for drone presence, if yes classify what type of drone is detected
- **Improving model** accuracy with more first party data and tuning
- **Expand direction classes to include diagonal** angles for finer localization

Acknowledgements

We would like to thank the following people for all of their help and support throughout our project:
- **Kelley Andrews**, *Mentor*
- **Ames Evans**, *SME and Customer*
- **Lucie McMinn**, *SME and Customer*
- **Michael McMinn**, *SME and Customer*

Real-Time Fraud Detection



LEFT to RIGHT: Steven An, Maria Williams, Devon Wise

CHALLENGE

Our goal is to develop an AI-driven fraud detection system that automatically identifies fraudulent documents within disaster relief claims. By leveraging machine learning techniques, the system will help streamline the claim verification process, reduce manual review time, and improve the accuracy and efficiency of large-scale disaster response operations.

intellectus

SME: Nagender Aneja

Customers: Owen Sullivan and Chris Watson

Steven An Anyang, South Korea

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I aspire to contribute to the development of modern, innovative solutions that enhance the quality of life for others and create a positive impact in today's world. I am passionate about using technology and creativity to solve real-world problems, ultimately making meaningful changes. In the future, I plan to pursue a master's degree to further deepen my knowledge and expand my ability to make significant contributions in my field.

Course Comment: This course has provided valuable insights into working in a professional environment alongside industry experts. It has strengthened my understanding of how to meet customer expectations and deliver results that align with client needs. Through this experience, I have developed strong time management skills and learned to adapt effectively to evolving project requirements. Overall, this course has helped me grow both professionally and personally, preparing me for future challenges in my career.

Maria Williams Sandston, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I hope to contribute to creative software improvements that positively impact the lives of others.

Course Comment: This course has been instrumental in helping me gain an understanding of how to handle long-term software group project in a professional setting. This course has taught me to adapt and manage changes a customer may need that differ from the initial goal.

Devon Wise King George, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I want to contribute to our warfighters by bringing new technology that can aid them on the front lines and save lives.

Course Comment: This course has help me gain an understanding of what real-world software group projects consist of. While there may be a simple solution on paper, it isn't always that simple in reality

Real-Time Fraud Detection

Sponsor Chris Watson and Owen Sullivan
Mentor: Professor Kelley Andrews
SME: Professor Dr. Nagender Aneja
Team: Steven An, Maria Williams, and Devon Wise

Background

Sponsor: Intellectus (FEMA contractor for disaster assistance)

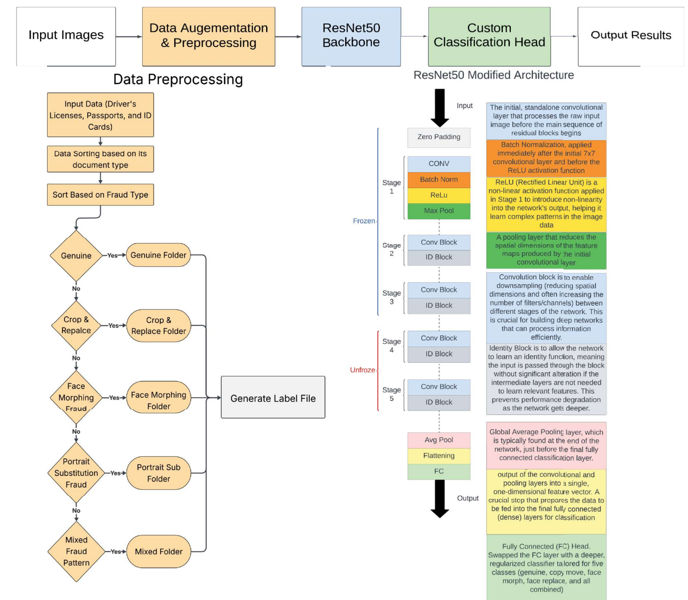
Problem: High volume of fraudulent claims, especially during crises like COVID-19.

Goal: Use AI to detect and prevent fraud in real-time.

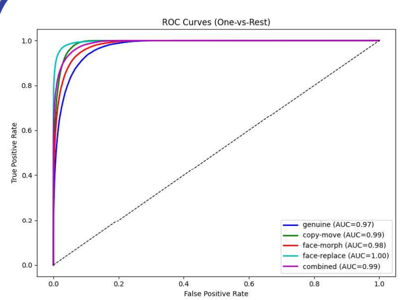
Key Objectives

- Develop an AI-based Fraud Detection System
- Produce technical documentation for implementation
- Deliver a proof-of-concept demonstrating integration

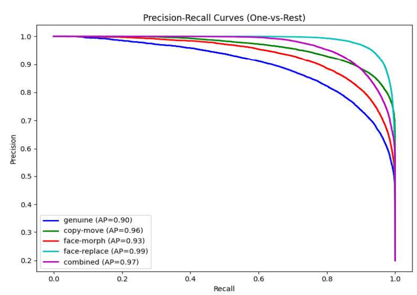
High Level System Diagram

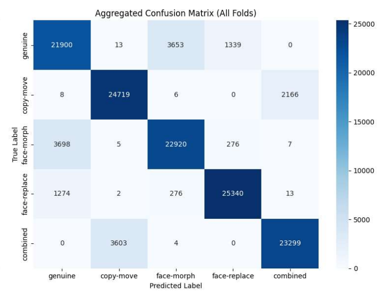


Driver's License Results



Receiver Operating Characteristic Curve (ROC)





Challenges

Data Limitations: Fraudulent documents are hard to obtain
Technical Constraints: pHash labeling is limited to 16-bit resolution
Model Trade-off: Generalized vs Specialized

Conclusion

The developed system demonstrates a viable framework for detecting fraudulent IDs using ML and AI. A detailed technical document guides users in replicating and integrating this approach into Intellectus fraud detection workflow.

Future Work

- Incorporate authentic document datasets from Intellectus
- Evaluate advance DL models
- Extend detection to other document types (invoices, receipts)

Acknowledgement

We would like to take a moment to sincerely thank the following individuals. Your guidance, support, and encouragement have been instrumental in helping us reach this point. We truly couldn't have done it without you:

- **Mentor: Prof. Kelley Andrews**
- **Customer: Chris Watson, and Owen Sullivan**
- **SME: Prof. Dr. Nagender Aneja**

Thank you all for your invaluable contributions to our project

Dynamic Steerable Polymer Embedded Antenna Array (DS-PEAA)

Track 2 Winner

LEFT to RIGHT: Jeffrey Aryeetey, Jenna Wilsher, Guadalupe Santiago, Tanner Casto

CHALLENGE

Union Dynamic has tasked our team with designing a circular antenna capable of 360° azimuthal beam steering, embedded within a polymer that exhibits minimal RF interference and can withstand extreme Arctic temperatures. This antenna will support node-mesh network applications by providing a lightweight, durable alternative to mechanically steered systems, while the polymer offers the mechanical rigidity and insulation necessary for reliable field deployment.

UNION DYNAMIC

SME: Ames Evans

Customers: Ames Evans and Lucie McMinn

Jeffrey Aryeetey Fredericksburg, Virginia

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I aim to build a career in controls and automation engineering, applying system design and integration skills to real-world applications. Working as a test engineer will allow me to apply my understanding of system design to evaluate performance and improve product quality. I enjoyed learning about LTI systems and compensating for instability in them.

Course Comment: The Senior Design course provided hands-on design experience similar to an industry-style process. I learnt how to apply knowledge from theory to practical systems work and collaborate effectively within a team to meet scheduled goals and deadlines. This course encouraged me to learn subject areas I was not previously familiar with.

Tanner Casto Kansas City, Missouri

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: Upon graduation, I intend to thru-hike the Appalachian Trail 2,198 mile Appalachian Trail. After finishing, I will be working at Raytheon as an Antenna and Microwave Engineer developing AESA radars. At Virginia Tech, I've been a member and Vice President of the Virginia Tech Amateur Radio Association, where I've learned a lot about radio/HF propagation, antenna design, and RF circuits and systems. Ham radio is what first sparked my love for RF engineering and continues to keep me inspired and motivated.

Course Comment: ECE MDE has been an influential course that encouraged self-motivated learning, problem-solving, and teamwork. It provided an accurate representation of real-world engineering and design, helping prepare students for their first experiences in industry.

Guadalupe Santiago Danville, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: As I've gone through my EE courses, I've been especially drawn to power systems and electronics, particularly in transmission and conversion. I hope to keep exploring this field in my career, working on projects that improve how we generate and transmit power, and eventually get involved with renewable energy systems. I also plan to earn my professional engineer license and possibly pursue a master's degree in the future.

Course Comment: This course has shown me what real teamwork in engineering looks like. Every step, from brainstorming to testing, involved constant collaboration and decision-making to meet our project's needs. It's been a challenging but satisfying experience learning how research, design, and teamwork come together to move a project forward.

Jenna Wilsher Stafford, Virginia

Bachelor of Science in Electrical Engineering
Applied Electromagnetics

Aspirations: Since taking my first Electromagnetic courses, I've contracted a deep interest in learning more about wave application whether that be in communication, optics, or remote sensing. In upcoming years I hope to continue exploring this interest on a quantum level in VT's graduate program and eventually pursue a career combining my knowledge of electrical theory with my passion, and minor focus, biomedical physiology to research or develop diagnostic imaging devices.

Course Comment: In Senior Design I was encouraged to learn more regarding subjects I may have not even thought to before and have been given opportunities to share my opinions contributing to major parts of team organization and prototype milestones.

Dynamic Steerable Polymer Embedded Antenna Array (DS-PEAA)

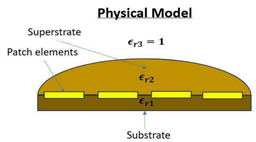
Team Members: Tanner Casto, Jeffrey Aryeetey, Guadalupe Santiago, Jenna Wilsher
Customer Sponsor: Michael McMinn
Subject Matter Expert: Ames Evans
Mentor: Shelley Stover

Key Objectives

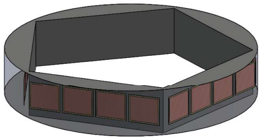
- Provide a proof of concept for an antenna array capable of 360° steering in the azimuthal direction
- Provide a lightweight and durable alternative to mechanically steered systems
- Determine antenna substrate and embedding polymer dielectric constraints that will minimize reflection radiation and maximize power transmission
- Simulate and test individual subsystem functionality

Design Overview

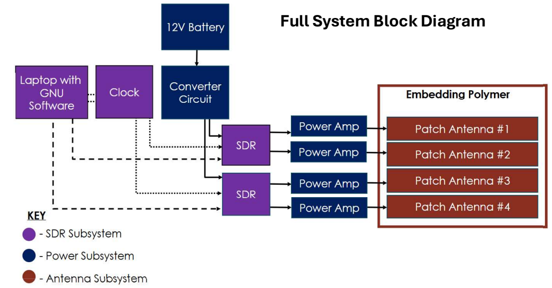
- Polymer characteristics selected using quarter-wave conditions and dielectric compatibility simulation

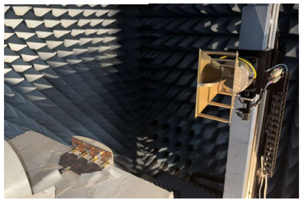


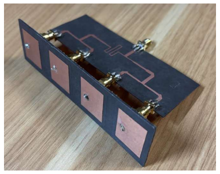
- User inputs steering angle to transmit into GNU Radio Software
- **GNU Radio** handles signal preprocessing using SDRs, converts steering angle into signal phase delay and selects subarray best suited for angle
- **SDRs** output phase delayed signals into **amplifiers** for propagation strength
- Amplified signal is transmitted from **uniform-linear subarray** encapsulated in protective polymer



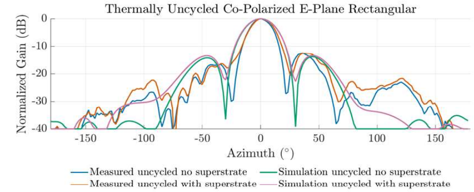
System Overview

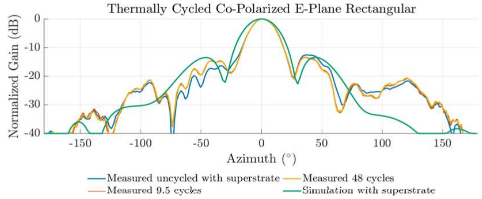



Anechoic Chamber Testing


Array With Power Divider

Results





Conclusion

Boresight Gain
- No gain enhancement observed with polymer.
- Measured and simulated patterns (cycled & uncycled) show equal normalized boresight gain at 0 dB.

Sidelobe & Null Behavior
- Uncycled array: SLL consistent with/without polymer (Sim: −13.4 dB, Meas: −12.6 dB).
- Polymer reduces null depth near ±30°.
- After thermal cycling: measured SLL improves to −13.4 dB, matching simulation.
- Null depth stable → improved dielectric uniformity & reduced phase error.

Beam Steering Stability
- Minor ~5° beam shift in measured traces.
- Likely due to phase mismatch in power divider outputs, not material effects.

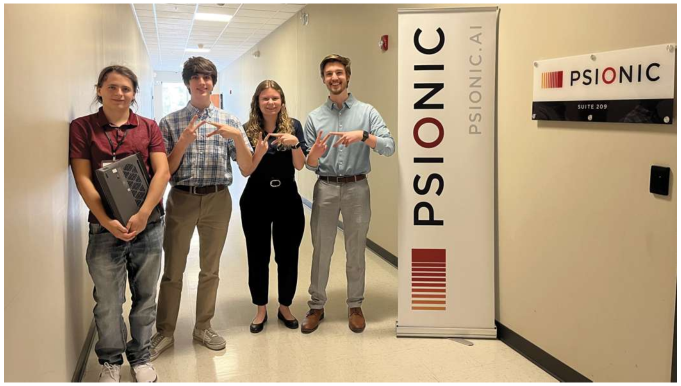
Future Work

- Implement adaptive signal tracking to determine location oof stationary receivers without user input
- Expand from single subarray prototype to full five-subarray configuration to achieve complete angular coverage
- Integrate software currently running on a laptop onto a portable microcontroller platform

Acknowledgements

Ames Evans and Chris McMinn for encouraging all our thought processes and providing valued solution insight.
Shelley Stover for introducing us to industry-level product expectations and professional resource planning.

Micro-Radian Scale Scan Angle Measurement System



LEFT to RIGHT: Timothy Kennedy, William Ellwood, Clare Bachman, William Walsh

CHALLENGE

Our team was tasked with improving Psionic's current NDL (Navigation Doppler LiDAR) technology. Their system provides precise navigation for ground, space, and landing vehicles by using a laser and scan-mirror to measure position and velocity. To enhance this technology, we developed a direct angular measurement system that uses a laser, lens, scan-mirror, and CMOS camera to track the scan-mirror's movement and verify its angle with 75-microradian accuracy at a 99.7% confidence level.

SME: Yizheng Zhu

Customer: Rob Fleishauer

Clare Bachman Stafford, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: Following graduation, I would like to use my degree in Electrical Engineering to work hands-on in electronic fabrication. I am particularly interested in designing and prototyping electronic systems, including circuit and PCB design, manufacturing, soldering, wiring, and testing. I look forward to collaborating with other engineers to develop efficient, reliable, and well-crafted electronic solutions.

Course Comment: This course does an excellent job of preparing students for their future careers. I learned a lot about Electrical Engineering as a profession, which involves not just technical skills but project management as well. This course taught me better communication, time management, teamwork, and presentation skills that I will continue to use throughout my career.

William Ellwood Charlottesville, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I want to work on intelligent software solutions that make a positive impact on the world. Working in a team setting to provide tools that improve people's day-to-day lives either directly or by way of their environment would be deeply fulfilling.

Course Comment: This course provided a great opportunity to work with industry engineers on real-world problems. The project our team worked on was challenging, but interesting. I've learned so much and discovered many interesting topics as a result of this capstone.

Timothy Kennedy Easton, Pennsylvania

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I wish to work in software development. I care little about the ends other than having enough to live off, I simply enjoy design and find programing a direct way to interact with it. I hope my creations are effective and simple.

Course Comment: I enjoyed the opportunity to interact with control software for industry software. Creation of test focused software for hardware similarly was interesting. The experience of section off and working together on a larger project.

William Walsh Roanoke, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: I aspire to continue my education by obtaining a master's degree in electrical engineering, then pursue a career in engineering design. I am interested in analog electronics, control systems, embedded systems, and robotics, and would like to find a position related to those fields. Eventually, I would like to start my own engineering firm, where I can lead innovative projects that contribute meaningful solutions to society's needs.

Course Comment: This course has provided an excellent opportunity to apply the technical and problem-solving skills I have developed throughout my degree. As a team, we have strengthened our abilities in trouble shooting, project management, and technical communication while experiencing the value of patience and collaboration. It has been challenging but rewarding and is valuable preparation for real-world engineering.

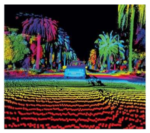
Micro-Radian Scale Scan Angle Measurement System

VIRGINIA TECH
PSIONIC

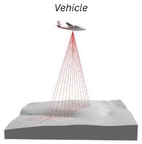
Team: Clare Bachman, William Ellwood, Timothy Kennedy, William Walsh
Customer: Rob Fleishauer | Mentor: Kelley Andrews | SME: Dr. Yizheng Zhu

Motivation

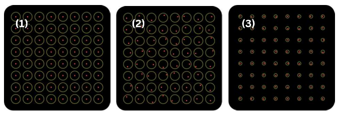
- We developed a new method for scan-angle measurement systems, enabling ultra-precise vehicle navigation in space, in the air, and on the ground
- Our system enables increased precision for LiDAR systems, which use pulsed laser light to measure distance and create high-detail 3D scans of an object or environment
- LiDAR systems contain a scanning mirror, which directs the laser beam to different positions
- We measure the scan mirror angle directly to increase LiDAR system precision



LiDAR Scan from Autonomous Vehicle



LiDAR Aerial Mapping



The yellow circles represent known system tolerance

1. Ideal scan output would make a perfect grid
2. Actual output may not be ideal due to tolerances
3. Direct measurement decreases error, increasing system precision

→ Higher angular precision gives higher scan precision

Objectives

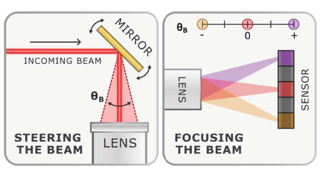
Calculate the scan mirror's angle with:

- 75 μrad precision
  - the measured angle must be within 75 μrad of the desired angle
- 3σ (99.73%) confidence interval
  - our measured angles must have 75 μrad precision 99.73% of the time

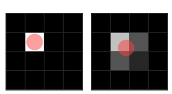
Our system will serve as a proof-of-concept in a laboratory environment to demonstrate the potential of the technology.

Approach

- The incoming beam is reflected off the scan mirror and focused onto an image sensor
- Changing the mirror angle changes the beam angle, which moves the focused spot location on the sensor
- We use the measured spot location to calculate the beam angle, which is used to find the mirror angle
- If the spot lands on multiple pixels, we measure relative luminance to determine location on a sub-pixel level



Angle Measurement Approach



Example of relative luminance for sub-pixel measurement

Theory

Image Capture

- MEMS mirror has a protective layer of glass over the mirror
- This creates a Fabry-Pérot interferometer between the glass and the mirror, causing "ghost spots"
- We address this by thresholding (1), connecting components (2), and scoring each spot by its total mass (3)

$$(1)\quad B(x,y) = \begin{cases} 1 & I(x,y) > T \\ 0 & otherwise \end{cases}$$

$$(2)\quad \text{component } k = \{(x,y) : B(x,y) = 1 \text{ and connected}$$

$$(3)\quad \text{score}_k = \sum_{(x,y)\in k} I(x,y)$$

- We need a precise reading of the laser in the camera coordinate space for precise conversion to mirror-space

$$m_{ij} = \sum_x \sum_y x^i y^j I(x,y) \qquad \{\bar{x},\bar{y}\} = \left\{\frac{m_{10}}{m_{00}}, \frac{m_{01}}{m_{00}}\right\}$$

Raw image moment (left) and Centroid (right).

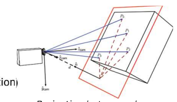
- We use Image Moments, a weighted average among the primary spot's pixels' intensities, allowing for precision to less than a tenth of a pixel

Coordinate Mapping

- Mirror coordinates are known directly
- Camera coordinates are known within 0.1 pixels
- The conversion between coordinate spaces is not affine because of mirror characteristics and optical setup limitations
- Therefore, we use a homography to map coordinate planes

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} \sim \mathbf{H} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

(x, y) = camera coordinates (spot center)
(x', y') = mirror coordinates (true angular position)
$\mathbf{H} = 3 \times 3$ homography matrix



Projection between planes.

- Use RANSAC for finding the best homography
- Disregards outliers from smear, ghost spots, bumps, or other errors
- Robust loss function $\rho(\ldots)$ weighs down large residuals

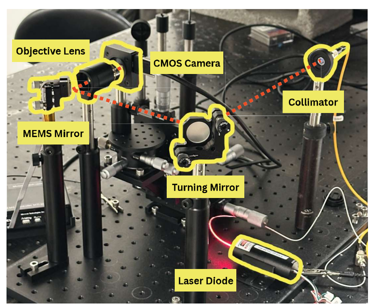
$$\mathbf{H} = \arg\min_{\mathbf{H}} \sum_i \rho(\|\mathbf{p}_i' - \mathbf{H}\mathbf{p}_i\|)$$

Minimize loss for all point-to-point mappings

System Overview

Hardware Description

- Laser Diode: generates the laser beam
- Attenuator: adjusts the power level of the beam (not pictured)
- Collimator: creates a parallel beam of light
- Turning Mirror: reflects the beam 90°
- MEMS Mirror: reflects the beam onto the objective lens at inputted angles
- Objective Lens: focuses the beam onto a small spot/area
- CMOS Camera: captures the beam's position



Labeled Components

Other System Components

- 3D printed light shielding enclosure blocks out ambient light
- 3D printed MEMS mirror driver mount and diode mount securely attach the loose components to the optical breadboard
- Graphical user interface controls the system and displays real-time system output
- 3D printed alignment targets for increased alignment ease and precision
- 6 axis mount adjusts the x, y, z, pitch, roll, and yaw of the CMOS camera

Software Flowchart

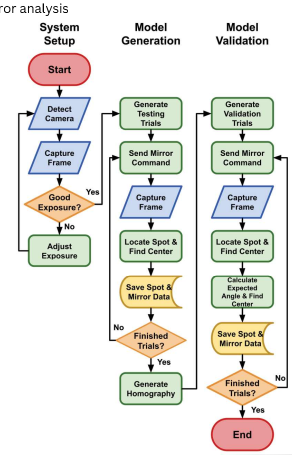
As a proof-of-concept to measure ultra-fine scan angles, our system is designed to control and validate itself on every pass.

It does this using two programs running concurrently:

1. C++ control program to set mirror angular position
2. Python capture and processing program to record laser translational position and map the two coordinate spaces

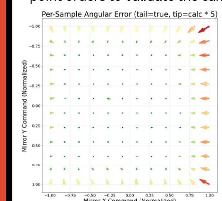
There are 3 primary stages in our software:

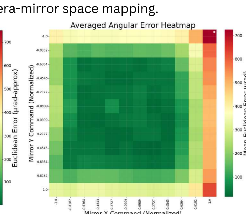
1. Set up environment parameters for the mirror and camera
2. Generate data for calculating a model to match the mirror and camera space, and calculate the model
3. Generate data for evaluating the model and perform error analysis



Testing/Results

- System validation was conducted in a single pass and in a controlled environment resistant to noise from light and transient vibration. The system was also run for several hours prior to testing to account for thermal deformations.
- The generation sequence included 5 trials of a 12x12 grid of evenly spaced and randomly ordered points to gather averaged point data to create a homography.
- The validation sequence included 5 trials of the same grid with different point orders to validate the camera-mirror space mapping.





Accuracy

Error per measurement across the entire system:

- Median = 122.8 μrad
- 95% = 523.9 μrad
- 99% = 634.3 μrad
- Frac ≤ 75μrad = 41.67%

Repeatability

The distribution for any random point in the system:

- Med 3σ half-width (x, y) = (65.57, 19.92) μrad
- Max 3σ half-width (x, y) = (230.8, 67.42) μrad

Accuracy Radius (3σ)

- Median = 150.0 μrad
- 95^{th} % = 515.4 μrad
- 99^{th} % = 728.7 μrad
- Frac ≤ 75 μrad = 22.22%

Bias

Systematic component of the error:

- Median = 126.6 μrad
- 95^{th} % = 505.0 μrad
- 99^{th} % = 725.4 μrad

Conclusions

Challenges Encountered

- Alignment issues, multiple spot reflections, optical calculation issues

Lessons Learned

- Fundamentals of optical systems, troubleshooting, technical documentation, collaborative problem solving

Our solution successfully computes the angle of the MEMs mirror, but does not meet the performance requirement set by the customer. Still, it functions as a proof of concept and demonstrates the strong potential of the technology.

Future Work

Hardware changes to extend system capabilities

- Higher bit-depth imaging system
- Different lens to fill entire image sensor
- Increase system rigidity to decrease vibrations
- Different MEMS mirror window to reduce reflections

Software improvements

- Single program implementation
- Automated data processing

Acknowledgements

Special thank you to the following for supporting this work: our Psionic customers Rob Fleishauer, Sanjee Abeytunge, Jamie Lane, and Jeff Monaco, and our Virginia Tech faculty advisors Kelley Andrews and Yizheng Zhu.

Self-Contained Multi-Platform Radar System

LEFT to RIGHT: Jennine Faruque, Alex Stoffelmayr, Amr Eldessouky, Anouar Rafai, Aemiliana Cruz

SME: Will Flathers, Connor Mahoney, Andy Thompson and Matt Ware

CHALLENGE

Our goal is to develop a self-contained, platform-agnostic radar system using commercial off-the-shelf components. We will optimize the system's size, weight, and power (SWAP) without compromising radar image quality. We will also deliver a feasibility study evaluating the system's capabilities and performance.

MITRE

Customers: Will Flathers, Connor Mahoney, Andy Thompson and Matt Ware

Aemiliana Cruz Alexandria, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: To pursue a Master's Degree in Computer Engineering

Course Comment: A great course that prepares students for the workforce by developing skills like critical thinking, communication, and problem-solving

Amr Eldessouky Woodbridge, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Project managment

Course Comment: Great for getting students ready for the proffesional work environment

Jennine Faruque Warrenton, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: After completing my undergraduate degree, I plan to pursue a Master's in Computer Engineering with a focus in networking and cybersecurity. I hope to build expertise in network security, threat detection, and secure system design before transitioning into industry.

Course Comment: This course was a great experience to mimic the industry-like atmosphere before we go out into the real world. We got hands-on experience with project management, teamwork, and technical problem-solving in a realistic setting.

Anouar Rafai Boyds, Maryland

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: Gain hands-on experience in RF engineering before applying to graduate school.

Course Comment: This course provided valuable experience in teamwork, accountability, and professional communication. It strengthened my ability to manage responsibilities collaboratively and apply engineering principles effectively in group settings.

Alex Stoffelmayr Chicago, IL

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: A career in computer hardware and/or hardware design

Course Comment: This class is a really unique course because you learn to plan and execute a project on a very long time frame

SELF-CONTAINED MULTI-PLATFORM RADAR SYSTEM

Sponsor: MITRE Corporation, Mentor: Dr. Adams
Team F25-08: Aemiliana Cruz, Amr Eldessouky, Jennine Faruque, Anouar Rafai, Alex Stoffelmayr

INTRODUCTION

- Our aim is to determine the feasibility of creating a multi-platform radar system by assessing the size, weight, and power constraints.
- We developed a self-contained and platform agnostic system capable of producing a high-quality radar image without external support.
- A major implication of this system is its integration onto a small Unmanned Aircraft System (sUAS), and our efforts are to understand the practicality of doing so.

APPROACH

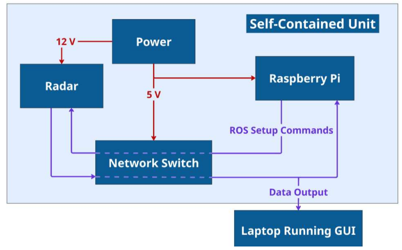
- Subsystems
  - Power provides appropriate voltage to each component.
  - SIMRAD Halo 20+ marine radar with shell removed.
  - Raspberry Pi 5 interfaces with the radar sending command bytes via an ethernet connection
- The Raspberry Pi sends control messages to the radar, turning it on, changing operation mode, or viewing range using ROS running on a docker container.
- Both the Raspberry Pi and an external computer running the GUI can receive image data returned by the radar and display it.

Radar Submodule

Power Submodule

Raspberry Pi Submodule

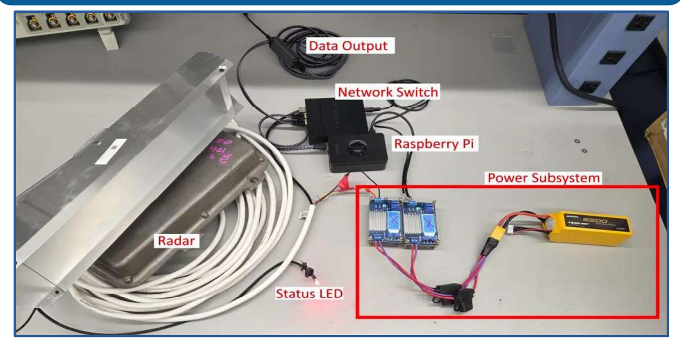
HIGH-LEVEL SYSTEM DIAGRAM



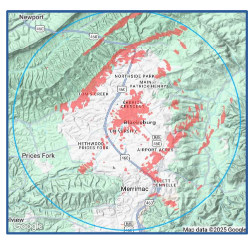
High-level system architectural design

- The power module supplies 12 V to the radar and 5 V to the Raspberry Pi and Network Switch.
- The Raspberry Pi sends commands over the network switch to the radar.
- The radar data is received and visualized on a laptop running the GUI.

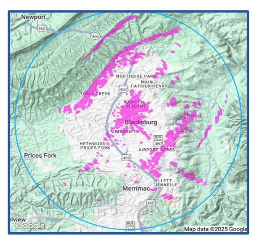
SELF-CONTAINED RADAR SYSTEM



TESTING RESULTS



Unmodified Radar Image (7.5 Kilometers)



Final System Image (7.5 Kilometers)

Results from system testing from the Roof of Whittemore hall (26-meter elevation) shows no image degradation compared to initial testing of the unmodified radar. received and visualized on a laptop running the GUI.

CONCLUSIONS

- "Commercially Available Off-the-Shelf" (COTS) marine radars can be run using very simple consumer components to meet lightweight SWAP requirements
- These systems maintain good image quality despite modification.
- Power draw requirements are low enough that relatively small batteries can provide long operation times.

FUTURE WORK

- Develop software or algorithms to run locally on the Raspberry Pi. Image analysis algorithms or machine learning could enable autonomous systems to act on radar readings.
- Introduce a wireless connection between radar module and GUI computer to enhance usability.
- More in depth testing of the radar's abilities in adverse conditions.
- Weather proofing

ACKNOWLEDGEMENTS

Thank you to our mentor, Dr. Joe Adams for his advice and support throughout this project. Also, thank you to our customers at MITRE: Will Flathers, Steve Lash, Grant Showalter, and Dasith Gunawardhana for their guidance and feedback. And shoutout to Jake Keller, our subject matter expert at MITRE, for helping us through the initial setup of this project as well as many technical challenges.

Low Cost Portable Antenna Range

LEFT to RIGHT: Jabari Simpson, Trey McDearmon, Anthony Yakubovich, Brandon Ordoobadi

SME: Carl Dietrich

CHALLENGE

Design, test, and iteratively solve the best techniques for antenna measurements in non-ideal environments. Through development of noise subtraction techniques using time-gating methods to quantify and show the electromagnetic spectrums of antenna in any environment, we were able to reveal the unseen world of electromagnetics in an open-source development so that anyone is able to access and learn of the world of RF. Additionally, the development of an FPGA for quickly embedding the system on any solution shows promise in EMI testing for a wide realm of commercial electronics in enclosed spaces that were impossible to measure and test beforehand.

Customer: **Lucas Vickers**

Trey McDearmon Roanoke, Virginia

Bachelor of Science in Electrical Engineering
Applied Electromagnetics

Aspirations: I aim to learn as much as I can to engineer better solutions for the people I work with and for.

Course Comment: This design course helped outline and define a lot of standard industry practices that helped me through internships and will set myself above others in the workplace as I move forward in my career.

Brandon Ordoobadi Bristow, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: I aim to learn new topics and ideas from each subsection within electrical engineering so I can deepen my passions within the field and find the niche that I truly belong in.

Course Comment: This design experience has taught me a lot of valuable skills, both technical and practical. I have learned more about myself, especially regarding where my interests lie within the field, which will stick with me for the rest of my life.

Jabari Simpson Fredericksburg, Virginia

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I aspire to use my undergrad experience to pursue a career as a controls engineer, devloping intelligent systems that integrate hardware and software. My goal is to design robust control algorithms for embedded systems that improve performance, reliablilty and real-world adaptability.

Course Comment: This MDE experience has given me a great understanding of what it means to be an engineer. Throughout this year, I have learned what it is like to plan and execute a plan as a team. I have learned both soft skills and technical skills that should help me succeed in my career path.

Anthony Yakubovich San Francisco, California

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: I plan to begin my career in power engineering, where i can contribute to improving the electrical grid and advancing the integration of sustainable, energy-efficient technologies.

Course Comment: This course provided valuable insight into how the engineering industry operates, from technical development to project management. It strengthened my ability to lead a team, coordinate tasks, and communicate effectively with customers and managers.

Low-Cost Portable Antenna Range

Project Members: Anthony Yakubovich, Brandon Ordoobadi, Jabari Simpson, Trey McDearmon

Mentor: Shelly Stover SME: Carl Dietrich

Customer: Epiq Solutions, Engineers: Lucas Vickers & Andrew Gobien

WEBER STATE UNIVERSITY

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

EPIQ

Abstract

- The low-cost portable antenna range is a solution for antenna characterization in everyday environments. Traditional anechoic chambers (figure 1) can cost upwards of $100,000, while ours would cost around $1,000
- Measurements occur in any environment and cancel unwanted noise and multipath reflections using time-gating and denoising algorithms
- The entire system is open source, anyone with a little know how can set up and run the system showing educational/research viability
- This system will feature a Field programmable gate array (FPGA) that can perform the time-gating algorithm

Fig 1: VTAG's Anechoic Chamber

Background

- Due to the high cost of components antenna characterization is hard to access
- Our solution provides a way to cancel out unwanted noise or reflections from the environment in any space
- By taking what is done in an anechoic chamber being a noise isolated space to generate the plot of the radiation pattern we determine a baseline for our measurements
- The envisioned future of this technology is to provide Electromagnetic Interference (EMI) testing in existing hardware within confined spaces. This would provide a new testing/diagnostic capability for previously inaccessible hardware

Fig 3: Anechoic Chamber compared to LCPAR within our lab

Theory

- Simulation of multipath reflection and cancellation of those signals to return to the baseline anechoic measurement was performed (Fig 2)
- The method of cancellation was time-gating using a Tukey Window and a Wavelet Denoise algorithm to smooth the final signal
- This method was then tested in the real world within the system and improved upon to reach requirements of ± 3 dB at peaks and ± 15 dB
- This computation is then implemented in an FPGA (field programmable gate array) for an ease of deployment approach

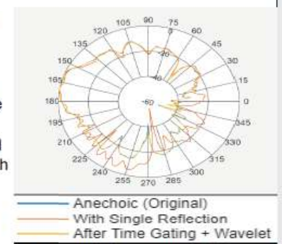
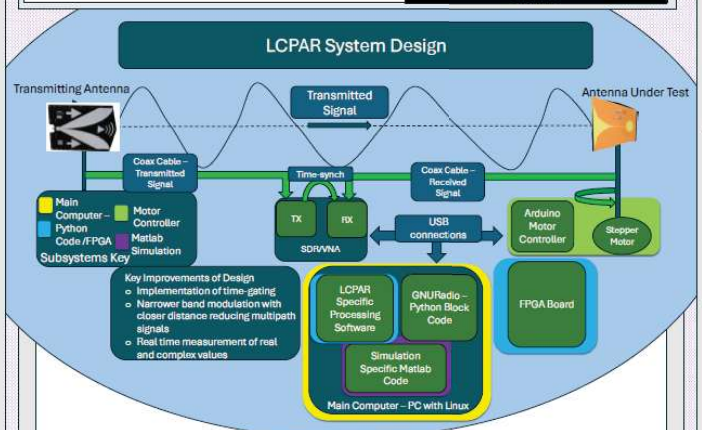


Fig 2: Radiation Patterns of Various Signals



Implementation

- The first phase utilized Matlab for simulation.
  - This featured proof of concept through subtraction of simulated multipath signal with time-gating and wavelet denoise algorithms
- The second phase implemented the system in Python
  - Offers testing in different environments, meets our 3 dB requirements, and shows proof of concept of time-gating
- The third phase deploys the algorithms onto an FPGA
  - Through design we showed ability to employ this method of analysis within an embedded system

Features

- Sends and receives a user selected spectrum of signals.
- Gates the received signal.
- Removes background noise from signal.
- Removes multipath from signal
- Presents user with a polar plot of their characterized antenna.
- Provides user with a raw data file with real and imaginary data for S11 and S21 parameters.
- FPGA based time gating option.

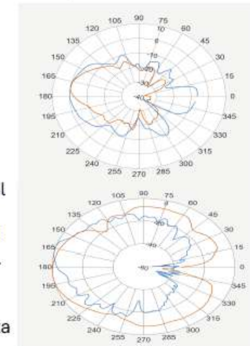


Fig 4: Results compared to anechoic in orange, measured in blue & time-gated output (bottom)

Conclusions

The LCPAR is a user-friendly tool that can be used in both characterizing basic antennas as well as an educational tool for teaching students the basics of RF and polar plotting. The novel time-gating methods implemented show a great promise towards future testing.

Next Steps

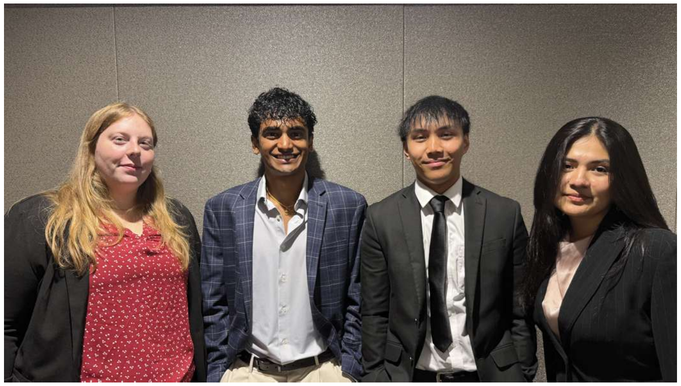
For next steps, the LCPAR's time gating algorithms can be improved to provide the user with a more accurate antenna characterization. The LCPAR's portability can be improved thereby enhancing user experience. The LCPAR's time gating methodology can also be integrated into a standalone SDR.

Acknowledgement & thanks

- SME: Dr. Dietrich – Supporting us as a resourceful SME
- Mentor: Shelly Stover – for guiding our project
- Shashank Chinnakkagari - helping us with antenna characterization
- Epiq Solutions Engineers: Lucas & Andrew
- Dr. Polys – for providing lab space and fundamental coding help
- Dr. Hearn – for the origination of this project in its first iterations
- Dr. Bekasiewicz; For the many papers written on time-gating methods

Virtual Phasor Measurement Units

Track 3 Winner



LEFT to RIGHT: Sara Mosley, Rahul Palani, Michael Naval, Stephanie Rodas

CHALLENGE

Power systems rely on Phasor Measurement Units (PMUs) to monitor and control the grid, but physical units are costly and challenging to deploy at scale. Our challenge is to develop a modular virtual PMU that replicates the capabilities of traditional devices by integrating data acquisition, signal processing, and network communication, while ensuring all measurements remain perfectly synchronized. Our solution aims to enable both accurate and reliable simulation as well as scalable, practical deployment without the limitations of hardware.

Dominion Energy® Electric Transmission

SME: Virgilio Centeno

Customer: Anastasios karles

Sara Mosley Smithfield, VA

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: After graduation, I hope to work as a photonics engineer in a cleanroom. After many years of experience in a cleanroom, I hope to transition into a technical leadership role, utilizing my deep fabrication expertise to guide the development of next-generation optical devices and sustainable semiconductor processes.

Course Comment: Through hands-on engagement, this course solidified my ability to apply engineering concepts directly to real-world problems. It was key in using my critical thinking and building the confidence required to successfully manage complex challenges.

Michael Naval Fredericksburg, VA

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: I envision building my career in the power systems industry specializing in Protection and Control. I want to build skills in designing and create systems that provide safe operations of the electric grid. Over time, I want to advance into project management roles where I can lead multiple engineering projects.

Course Comment: The Virtual Phasor Measurement Unit (PMU) project improved my understanding of power system monitoring. It strengthened my skills in signal analysis, Python programming, and client interaction.

Rahul Palani Richmond, VA

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I aspire to build intelligent, scalable software systems that bridge the gap between data-driven machine learning and real-world applications. After graduation, I will be continuing as a Software Development Engineer at Amazon Web Services full-time. I aim to leverage my background in computer engineering and AI to develop solutions that enhance cloud performance, automation, and accessibility for global users.

Course Comment: This course was a great insight into what my future as a software engineer will look like. Working as a small team, tackling a major project of this caliber, was not only a fantastic learning opportunity, but also an incredibly interesting and exciting endeavor

Stephanie Rodas Arias Huancayo, Peru

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: My career goal after graduation is to deepen my expertise in electrical engineering, particularly in power systems or MEP design. I intend to strengthen my technical foundation and gain the hands-on experience needed to transition into project management for large-scale projects. Ultimately, I aspire to establish my own engineering firm or work as a specialized contractor for leading companies.

Course Comment: This project was a fantastic opportunity to advance my skills. I strengthened my technical abilities in Python, hardware integration (GPS), and applying IEEE standards, while also developing key professional skills in project management, including client communication, stakeholder coordination, and team organization.

Virtual Phasor Measurement Units

Dominion Energy
Electric Transmission

VIRGINIA TECH.

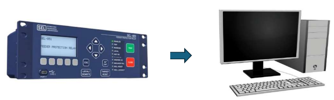
Team Members: Stephanie Rodas Arias, Michael Naval, Rahul Palani, Sara Mosley

Mentor: Dr. Daniel Connors | **Customer:** Anastasios Karles

Subject Matter Expert: Dr. Virgilio Centeno

Motivation

- The **2003 Northeast Blackout** left **55 million people** without power and caused **$6–10 billion** in losses, exposing the need for faster, synchronized grid monitoring.
- Utilities adopted **Phasor Measurement Units (PMUs)** for real-time visibility, but physical PMUs are costly and hard to scale for testing.
- This project develops a **Virtual PMU, a modular, software-based alternative** that replicates real PMU functionality.

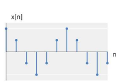


Objective

- Support **Dominion Energy's Automation & Event Analysis Team** by developing a **Virtual Phasor Measurement Unit (PMU)** that replicates physical PMU functionality through software.
- It enables engineers to:
  - **Simulate grid events**
  - **Expand testing and research** without hardware
  - **Reuse modular components** for flexible, scalable development across projects.

Solution

Data Processing: Reads COMTRADE analog and digital channels, filters noise and estimates the nominal frequency (f_o) using zero-crossing detection.



$$X(k) = \sum_{n=0}^{N-1} x(n)e^{-j2\pi kn/N}$$

Phasor Computation: Calculates magnitude and phase via a non-recursive DFT and determines the RMS value for signal strength.

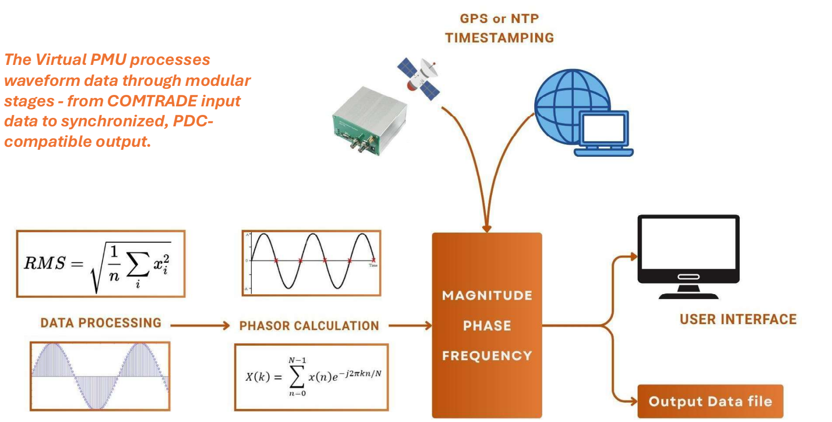
Time Synchronization & Output: Timestamps data with GPS/NTP for precise alignment and formats results for PDC-compatible analysis.

Hardware → Software

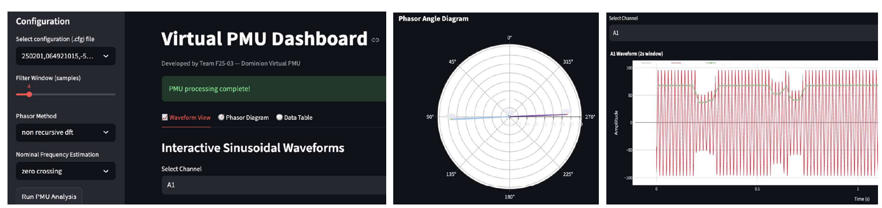
Hardware	Software
•Analog Inputs : Voltage and Current Measurement •Signal Processing Hardware : Filtering & amplification •ADC + DSP processor •GPS receiver •Communication interface	•COMTRADE waveform data import •Digital filtering & normalization •Non-recursive DFT phasor computation •GPS/NTP-based time synchronization •PDC-compatible CSV output & UI

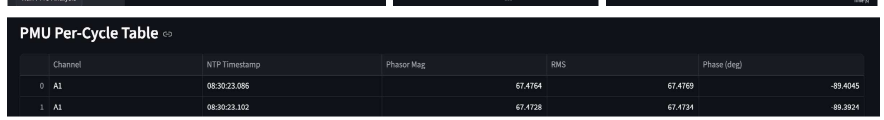
High Level Diagram

The Virtual PMU processes waveform data through modular stages - from COMTRADE input data to synchronized, PDC-compatible output.



Results



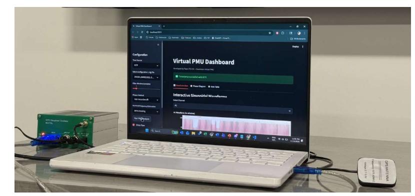


PMU Per-Cycle Table

	Channel	NTP Timestamp	Phasor Mag	RMS	Phase (deg)
0	A1	08:30:23.086	67.4764	67.4769	-89.4045
1	A1	08:30:23.102	67.4728	67.4734	-89.3924

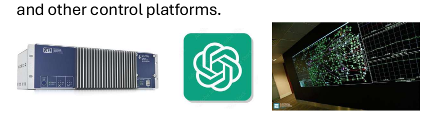
Conclusion

- ✓ In conclusion, the **Virtual PMU** accurately replicates physical PMU functionality, extracting synchronized phasors from COMTRADE waveform data.
- ✓ Testing with **Dominion Energy, we** achieved **<1% magnitude/phase error.**
- ✓ This modular software offers a **scalable, low-cost platform** for training, research, and event analysis.



Next Steps

- •Integrate **real-time data streaming** to Phasor Data Concentrators (PDCs).
- •Implement **Kalman filtering** and advanced algorithms for improved noise rejection.
- •Develop **AI-driven analytics** for real-time anomaly detection and grid monitoring.
- •Enhance **system interoperability** with SCADA, DMS, and other control platforms.



Acknowledgments

We would like to express our sincere gratitude to our Subject Matter Expert, Dr. Virgilio Centeno, our customer, Tassos Karles, and our mentor, Dr. Daniel Connors, for their invaluable guidance and support throughout the course of this project.

Open-Source Hardware-Based Trusted Platform Module

LEFT to RIGHT: Emma Wallace, Ian Sizemore, Michael Doyle, Eitan Pupkin

CHALLENGE

This project establishes an open-source framework for a Trusted Platform Module (TPM) on an FPGA, addressing the need for a verifiable, hardware-based security TPM for data centers. By providing open-source Verilog code, this offers Lenovo, its partners, and the public a mass-testable and modifiable platform to enhance server reliability and security.

Lenovo

SME: Christiana Garcia and Jason Thweatt

Customers: Patrick Caporale and Scott Faasse

Michael Doyle Martinsville, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: I want to work in power engineering, designing electrical systems that help improve energy infrastructure and sustainability.

Course Comment: In this course, I learned how to communicate with customers to understand their needs and apply that to make informed design decisions.

Eitan Pupkin Charlotte, North Carolina

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I hope to make an impact in peoples lives by becoming a respected computer engineer.

Course Comment: Through this course, I gained experience with the real-world engineering design process, which has reshaped my understanding of what it means to be an engineer in industry.

Ian Sizemore King George, Virginia

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: I look forward to working with hardware design in industry.

Course Comment: This course gave me essential experience of being part of a larger-scale engineering project.

Emma Wallace Annapolis, Maryland

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I intend on working in hardware development and maintenance. I hope to help create accessible and innovative interactive entertainment technology.

Course Comment: In this course, I have gained practice in working with industry professionals and a team to create an open-source design. This project gave me the opportunity to further develop my skills of formal documentation, Github version control, quality control, and communication, invaluable skills for working in the industry.

Open-Source Hardware-Based Trusted Platform Module

VIRGINIA TECH

Customer: Lenovo **Mentor:** Dr. Joe Adams **SME:** Dr. Jason Thweatt

Team: Emma Wallace, Eitan Pupkin, Ian Sizemore, Michael Doyle

Lenovo

Background

- Trusted Platform Modules (TPMs) are security devices used in systems that use CPUs and must keep information secure. This includes laptops, servers, cash registers, etc.
- Hardware TPMs are increasingly being considered more secure than software TPMs due to being a physical, rather than virtual, implementation.
- There are currently no open-source hardware TPMs available.
  - All hardware TPMs are proprietary black-box devices:
  - Customers unable to validate TPM meets their security needs and standards
  - Customers unable to personally make security updates as new cryptographic features are developed

Objectives and Requirements

Objective: To create a TPM framework capable of analyzing data and managing the communication of it throughout the submodules of the system.

Key Requirements:

- Implementation must be hardware based.
- Code must be open-source and fully accessible via GitHub.
- Solution must follow the TPM 2.0 specification.

I/O Interface

- Controls the communications between the TPM and the Host System. This includes:
  - Communicating basic implementation/configuration information to/from the Host,
  - Managing interrupts to the Host,
  - Reserving priority of TPM usage to secure processes (i.e., a kernel process will have priority over a user process),
  - Sending TPM command data, receiving responses from TPM.
- Interfaces to Host over SPI at 24 MHz.

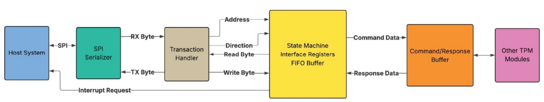


Fig. 1 Summarized modular view of I/O Interface, showcasing data flow

- Communications over SPI take the form of transactions: a read/write of 1 to 64 bytes of data to an addressed interface register.
  - A set of addresses alias to the command/response FIFO buffer.
- An internal state machine keeps track of command processing:
  - Idle, Command Reception, Command Execution, Send Response.
  - The state of this process is controlled and observed by the Host through an interface register.
  - Through this interface register and the FIFO buffer, TPM commands and responses are sent to/from the TPM.
- Manages command data parsing for Management / Execution.

Management Module

- Manages the TPM's operational state: a security measure to force proper value initialization and prevent execution of commands dangerous to TPM when in incorrect system state.
  - Note: The operational state machine is activated by the de-assertion of the _TPM_Init signal (active-low reset) and all states may be left by asserting _TPM_Init.

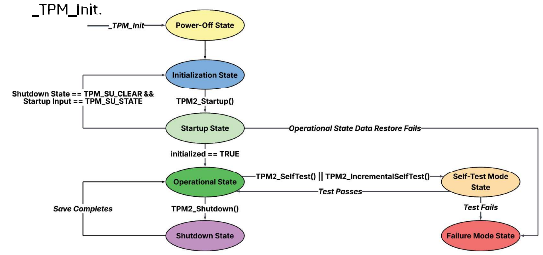


Fig. 2 TPM Operational State Machine

- Sets the control domain enable switches
  - Gives the host different ranges of control in the system
  - Initially set by the management module in the startup state based on the startup type. Can be changed by the TPM_CC_HierarchyControl command after startup procedures in the operational state.
- TPM operational state stops the execution engine from processing invalid commands in the wrong state

Execution Engine

- Manages the execution of commands: pre-processing, command execution, post-processing/response assembly
  - Pre-processing: composed of seven unique states that each make a series of 7 checks on the command data to make sure it is valid. The command fails any test a response is assembled along with an appropriate response code.

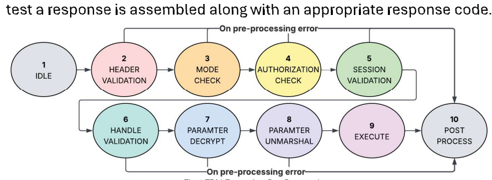
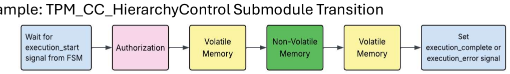


Fig.3 TPM Execution Pre-Processing

  - Command execution: Carries out the execution of commands by establishing a data-path through submodules, e.g key generation, hash engine, symmetric engine.

Example: TPM_CC_HierarchyControl Submodule Transition



  - Post-processing: assembles appropriate output data, currently only is used for generating a response code as no data is manipulated by cryptographic sub-modules.

Conclusions

Work completed:

- I/O Interface
  - Parses SPI Input for TPM, from host, and converted TPM response to SPI output
- Management Module
  - Manages TPM operational state and control domains.
- Execution Engine
  - Runs preprocessing of command inputs before sending commands through to cryptographic and memory submodules.

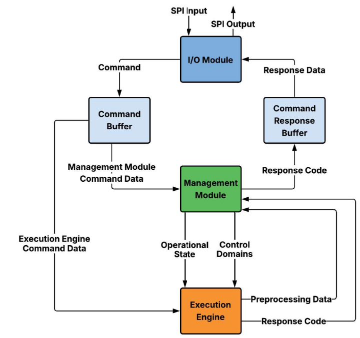


Fig.4 High Level Diagram of TPM Framework

- Framework Integration:
  - I/O module gives input command information to management module and execution engine, who use the data to manage commands and system states

Overall, the work completed in this phase of the project will support further work by a future team by implementing the basic structure of the TPM. This includes parsing of command data, outputting TPM responses, communication with submodules, and executing startup procedures.

Future Work

Our design focused on the framework of a TPM, future teams will develop:

- Cryptographic submodules
- Authentication submodule
- Non-Volatile memory and RAM components, memory management
- Entropy-Sourced Random Number Generation (RNG) module

The next team will also choose a specific FPGA to use for the implementation. This stage of the project focused on setting up the structure of a TPM that could work on any board.

- This TPM is to be used in a Data Center Security Control Module (DC-SCM) in a server or datacenter. A future team will work to ensure that it can be integrated in a DC-SCM.

Acknowledgements

Our team would like to thank our SMEs Dr. Christiana Garcia and Dr. Jason Thweatt for their support in the development of this project. We would also like to thank Patrick Caporale, Scott Faasse, and Clifton Kerr, for advising and supporting us throughout our solution.

Stylus Testing System with Positional and Force Control

Best Overall

Popular Vote

LEFT to RIGHT: Eduardo Briceno-Saez, Ashley Leister, Ella Chandan, Jiyoon Paik, Ahmed Yousif

SME: Igor Grebnev

CHALLENGE

Our challenge was to develop a stylus testing system that integrated force and positional control. We had to consolidate the three separate pen-testing setups that our client was using into one closed-loop stage with force feedback. The system we developed significantly improves efficiency and minimizes the opportunity for human error that comes with manual input.

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

Customer: Igor Grebnev

Eduardo Briceno-Saez Miami, FL

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I hope to one day have my work contribute to the future explorations of humanity and to one day have that work reach the stars both metaphorically and literally. I aspire to improve my knowledge in engineering and create devices to make the lives of people more joyful. I wish to challenege my abilities and continue to grow as an engineer.

Course Comment: This course has given me the experience of working with amazing teammates at an amazing opportuninty. Being able to practice my abilities in a real life environment has given me the chance to see what I am capable of and what I still need to improve. I have enjoyed my time here with my team and here at Virginia Tech which I will never forget.

Ella Chandan Great Falls, Virginia

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

Aspirations: I hope to use the knowedge I have gained to have a positive impact on the world.

Course Comment: Participating in this course has been a great opportunity to gain experience that models that of a full time job. I have thoughroughly enjoyed working with my team and having the opportunity to work with them on a project that uses the knowledge I acquired throughout my education.

Ashley Leister Christiansburg, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: The conclusion of my academic career will not be the end of my learning; my goal is to continue bettering my skills and knowledge through a career as a hardware design engineer. I aspire to produce the most optimized designs and meaningful products. Working on a design team in the future with innovative coworkers is something I eagerly look forward to.

Course Comment: This course has proven to be a valuable platform for the knowledge gained during the computer engineering degree. Being able to practice the full-scale design process and partner with industry leaders was highly advantageous.

Jiyoon Paik Newport News, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I hope to use innovation and data to solve meaningful challenges and enhance efficiency.

Course Comment: This course has taught me how to develop a solution to a client-presented problem, especially in a team environment with freedom in solution design.

Ahmed Yousif Brambleton, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: My aspirations are to work on many projects that have impact on peoples lives. Expanding my horizions to learn and implment and be an affective engineer through inpiration and accomplishments. I hope to continue to develop not only in Engineering, but also other aspects of life with an Engineers vision.

Course Comment: This course has been a great experience, working with a talented group of engineering students and gaining an outlook on real world prospects. The course lectures and how we were able to apply our own engineering methods into our project was very exciting. Our mentors and SME were great resources to refer to and helped us through the process of meeting our project objectives.

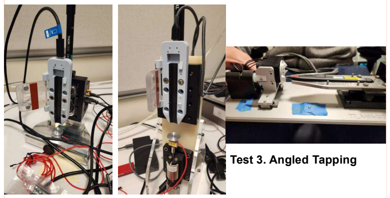
Stylus Testing System with Positional and Force Control

Team F25-10 · Virginia Tech, Problem Provided by Microsoft
Eduardo Briceno-Saez, Ella Chandan, Ashley Leister, Jiyoon Paik, Ahmed Yousif

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

Problem & Goal

- Microsoft currently uses **three separate stylus test setups**: static load, tapping (no angle), and angled tapping.
- These are hard to reproduce and manually intensive.
- **Goal**: A **single, closed-loop** linear-stage platform that can run all tests with **position and force control** and minimal human intervention.



Test 3. Angled Tapping

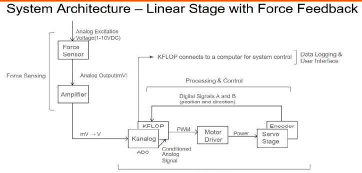
Test 1. Static Load. Test 2. Tapping.

System Requirements

- Position-controlled linear motion.
- Closed-loop **force control** with live feedback.
- Run **three test modes within one system**: static load, tapping, angled tapping.
- Terminal based user interface for controls and data monitoring.
- Modular, swappable pen-holder and fixtures.
- Requirements are met when the system
  - moves to commanded positions
  - applies commanded forces within tolerance
  - displays time-aligned position/force data.

Overall Architecture

System Architecture – Linear Stage with Force Feedback



Closed loops:

- **Position loop:** Encoder → KFLOP PID → PWM → Stage.
- **Force loop:** Force sensor → Amplifier → Kanalog ADC → KFLOP PID → PWM.

Swap-in tests: Static load / Tapping / Angled (with stepper-driven angle fixture).

Design & Construction Highlights

Mechanical

- **Single integrated platform** replaces three legacy setups (static load, tapping at no angle, tapping at angle) with quick-swap pen holder and compact layout.
- **Rigid linear stage** for precise positioning; **acrylic enclosure** promotes airflow and protects components.

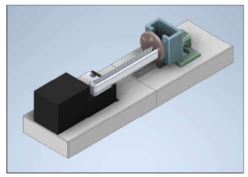


Figure A: System CAD

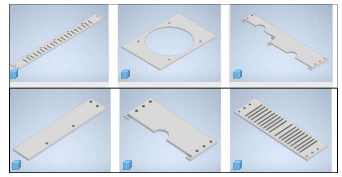


Figure B: Acrylic enclosure design

Electronics & Sensing

- **Controller:** KFLOP (motion/PID) with **Kanalog** (ADC/DAC & I/O).
- **Feedback:** Optical encoder for position; **load cell** for force.
- **Signal chain:** Custom **~1000× amplifier** PCB → Kanalog ADC for clean digitization.

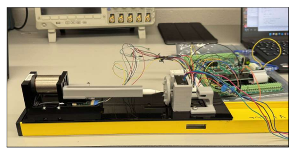


Figure C: System Setup

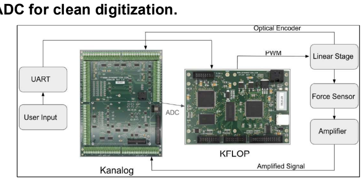


Figure D: Control electronics (KFLOP/Kanalog)

Firmware / Software

- **Closed-loop control** of position and force with **programmable tests** (static load, tap, angled tap).
- Terminal-based **user interface**; UART (and KMotion) for **PID tuning** via user parameters; PWM drive to motor.

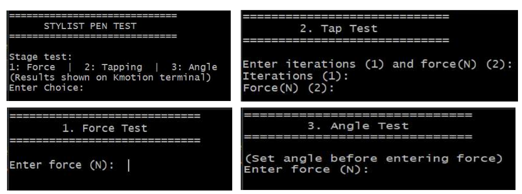


Figure E: Terminal-style user interface test parameters

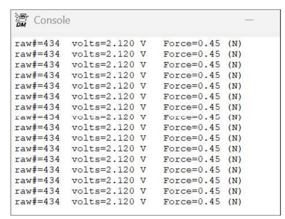


Figure D: Force data readings on Kmotion software

System Integration

- Open-slot pen holder eases tool changes; sensor mounted behind actuator logging force input throughout tests.
- **Data path:** Sensor → Amplifier → Kanalog → KFLOP → output logging (time-aligned position & force).

Data path: Sensor → Amplifier → Kanalog → KFLOP → output logging (time-aligned position & force).

System Specs and Verification

The three testing stages to encompass original setup:

- The first test is for constant force application.
- The second test taps at a chosen force.
- The third test applies force at different angles.

System Specifications:

- Measures up to 2 lbs (907g) of force.
- Linear stage movement speed adjustment via duty cycle of PWM.
- Specific angle selection through stepper motor.
- Software integrated feedback loop pausing linear stage when desired force reached.

Results and Conclusions

- Our product is able to conduct all tests within the built system
- The user control input is more refined using the UART capabilities that can be adjusted within the system to provide the needed commands.
- All system is connected via hardware and software and integrated in code to share data and feedback commands.
- Tests and functionality in the system can be adjusted based on the desired functionality through the code.

Future Work/Next Steps

- The KFLOP/Kanalog boards will allow for more user configuration or added functionality to the system, through the Kanalog that has many I/O pins that can be configured for different purposes.
- The system will be used at Microsoft for their styli testing.

Acknowledgements

Subject Matter Expert: Igor Grebnev
Customer: Igor Grebnev
Mentor: Daniel Connors

Glossary

KFLOP: Motion controller board (runs C code; generates PWM).
Kanalog: KFLOP expansion for analog/digital I/O (ADC/DAC).
PWM: Pulse-width modulation to drive stage

Contact Information

Eduardo Briceno-Saez: eduardo19@vt.edu
Ella Chandan: ellachandan@vt.edu
Ashley Leister: ashley1941@vt.edu
Jiyoon Paik: jiyoonp@vt.edu
Ahmed Yousif: ahmedyousif@vt.edu

CCD Detector Readout System for Small Satellite Applications

LEFT to RIGHT: Cody Bullock, Javier Torres, Jae Chung, Yifu Yang

CHALLENGE

Our goal is to develop an imaging detector readout system using a CCD (Charge-Coupled Device) sensor designed for small orbital and suborbital satellite applications. For use by the Southwest Research Institute, this system must be compact, low power, and able to withstand the harsh temperatures and high radiation levels of a space environment.

SwRI®
SOUTHWEST RESEARCH INSTITUTE

Customer: Todd Veach

Cody Bullock Spotsylvania, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Pursuing a Master's Degree in Computer Engineering focused on microelectronics and integrated circuit design.

Course Comment: This course offers a great opportunity to learn past what classes here teach, and to apply what we've already learned to real-world applications.

Jae Chung Suwon, South Korea

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: Pursuing a Master's Degree in Robotics

Course Comment: This course is a great opportunity to apply what they've learned in ECE, and grasp the feeling of how working in the industry feels like.

Javier Torres Quinones Newport News, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: Firmware/Embedded Systems engineer

Course Comment: This course really gave me some good experience on being on a diverse team, coordinating, and overcoming challenges when they seem incredibly hard to overcome

Yifu Yang Chongqing, China

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Pursuing a Master's Degree in Machine Learning related fields and eventually serve my own country.

Course Comment: This course is good in terms of connecting students from academic works to industrial applications, but it needs to be able to offer more flexibilities on project choices.

CCD Detector Readout System for Small Satellite Applications

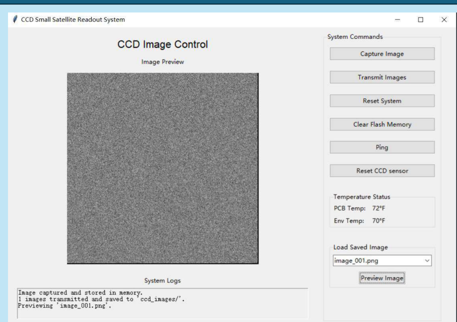
Cody Bullock, Won Jae Chung, Javier Angel Torres Quinones, Yifu Yang
Customer and SME: Dr. Todd Veach   Mentor: Shelly Stover

Objective

Our goal was to develop a **lightweight** and **low-power** imaging detector readout system for a **CCD (Charge-Coupled Device)** sensor for small orbital and suborbital satellites. The CCD captures a **1024×1024** image, with its pins controlled by an **MCU**. The **MCU** processes the image data with its internal 12-bit ADC and **transmits** the image via an **Ethernet chip** to the host computer. Our system is:

- Small (~3" x 2")
- Low-Power (<5W)
- Interfaceable with the satellite computer through an **ethernet connection** to accept commands and send image data.

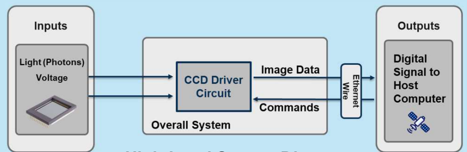
Software



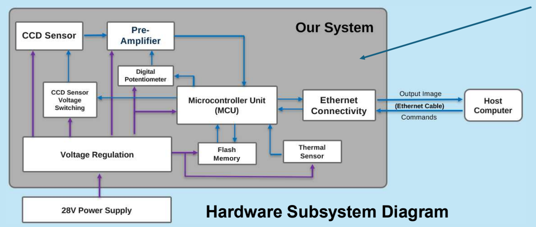
Our GUI was written in **Python**, and our embedded software was written in **C**. The GUI interacts with our embedded system through an **ethernet** connection. It features:

- Active Environment Temperature Sensing
- Image Previewing
- System Log for Monitoring
- Buttons For:
  - "Capturing Image"
  - "Transmit Image from Board"
  - "Resetting Board to Default"
  - "Clearing Board Memory"
  - "Pinging Ethernet Connection"
  - "Loading and Previewing Image"

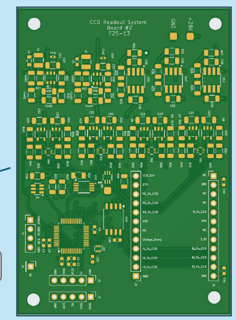
System Diagrams and PCB



High-Level System Diagram

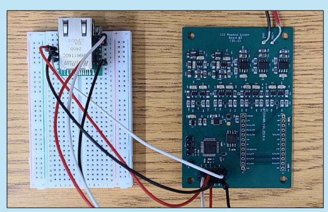


Hardware Subsystem Diagram



Custom PCB Driver Circuit

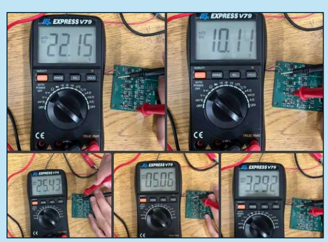
Testing and Verification



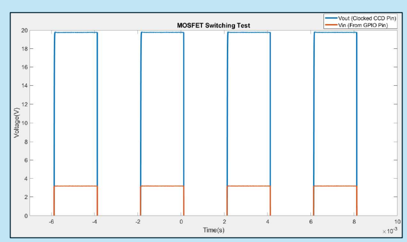
PCB and Ethernet Connection Setup

Our custom driver circuit PCB has:

- **Voltage Regulation** (25V, 22V, 10V, 5V, 3.3V)
- Environment **Temperature Sensing**
- **SPI** Connections for **Ethernet**
- **MOSFET Switching** controlled by the **MCU**
- A **Pre-Amplifier** for the CCD output with **Adjustable Gain**
- **Flash Memory** for **Image Storage**



Voltage Regulation Verification



MOSFET Switching Testing (Input GPIO, Output Clocked Pin)

Conclusion and Future Work

Our goal was to design an image detector readout system using a CCD sensor for image capture in small orbital and suborbital satellites.

Our solution combines a **custom PCB** driver circuit and an **ethernet chip** than connects to our MCU through SPI connections. Our **custom PCB** has:

- **MOSFET Switching** for CCD pin clocking
- **Low Power Voltage Regulation (<1.5W at 28V)**
- Environment **Temperature Sensing**
- Image storage through **Flash Memory**
- A **Pre-Amplifier** for the CCD output with **Adjustable Gain**
- **SPI** Ethernet Interface

Our **embedded software** controls:

- **Memory Management**
- **Analog-to-Digital** Conversion **of CCD Output**
- CCD Pin **Clocking Scheme**
- **Pre-Amplifier** Gain through **I2C** Communication
- **Ethernet** Communication

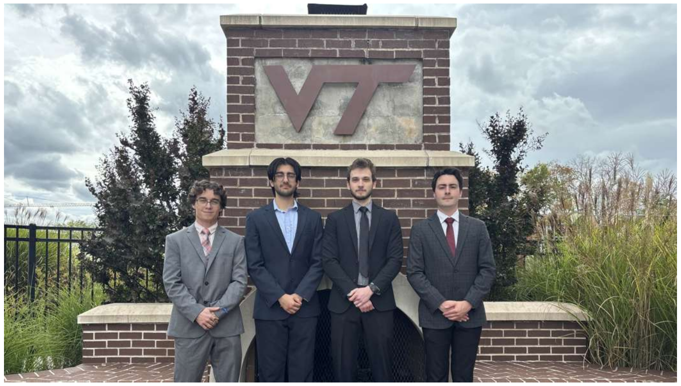
The first thing we'd like to test in the **future** is how our board works with an actual CCD sensor. We weren't able to test with one this semester, but our design should be fully functional assuming we did have a sensor. Other work would be:

- **Thermal Vacuum Chamber Testing**
- **Space-Grade PCB Design**
- **On-Board Ethernet Implementation**
- **More Efficient Power Design**

Acknowledgement

We'd like the thank our mentor Shelly Stover for always keeping us on track and giving very constructive feedback, and our customer and SME Dr. Todd Veach for giving clear and actionable objectives. We'd also like to thank AMP Lab students Shane and Alek for soldering training and PCB design tips.

Autonomous UAV Landing



LEFT to RIGHT: Alexander Anderson, Kunal Kapoor, Michael Malast, Isaac Tucker

SME: Ryan Williams

CHALLENGE

Pilots and operators at the Naval Air Warfare Center Aircraft Division (NAWCAD) often encounter challenging conditions such as low visibility, uneven terrain, and time-sensitive missions that make manual UAV landings difficult and risky. This project aims to develop an autonomous UAV landing system that increases safety and precision by enabling unmanned aircraft to identify suitable landing zones, avoid obstacles, and perform controlled descents without human input. By improving reliability and reducing pilot workload, this system supports NAWCAD's mission to advance autonomous flight capabilities for defense, research, and field operations.

Customers: Andrian Jordan and Israel Jordan

Alex Anderson Chesterfield, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: I want to implement solutions to problems affecting the U.S. armed forces, and acquire the leadership experience to manage these projects. I am hopeful that the work I will do can save and improve lives for those in the greatest danger.

Course Comment: This course allowed me to gain hands-on experience working on a long-term project in a field outside of my expertise. Navigating a foreign problem has helped me understand barriers which may create difficulties in my career, and how to overcome them.

Kunal Kapoor Robbinsville, New Jersey

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Design modern semiconductor and superconducting technologies

Course Comment: This course was a transformative experience, giving me the chance to work on a complex, long-term project with real industry impact. It pushed me beyond the classroom, sharpening my ability to navigate unfamiliar problems, integrate diverse systems, and make high-level design decisions as part of a team.

Michael Malast St. Louis, Missouri

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: My immediate goal is to launch my career within the defense/naval engineering sector following graduation. I'm drawn to the stability and importance of work in this field, and I look forward to contributing to mission-critical systems. My aspiration is to ensure my career path provides a rewarding and meaningful professional trajectory.

Course Comment: This course was a welcome change of pace from traditional academics, allowing us to dedicate a full year to a single, industry-sponsored project. The experience provided a taste of professional engineering, giving us the opportunity to develop a solution for an actual company. I particularly valued the high degree of team autonomy we were granted in determining the best approach to solving the problem.

Isaac Tucker Smithfield, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I aspire to develop software that integrates with real-world systems to deliver practical solutions for everyday challenges. My interests lie in automation and low-level design, particularly within embedded systems, robotics, and FPGA technologies.

Course Comment: This course has outlined challenges that aren't present within the classroom. Having to start from scratch on a project has shown the necessity for informed design at a macro level and it has highlighted common roadblocks to integating separate systems together. The issues we've encountered have pulled me out of my comfort zone and forced me to adapt to situations that were not obvious within the initial design process.

Autonomous UAV Landing

Sponsor: NAWCAD **Mentor:** Dr. Daniel Connors
Team Members: Kunal Kapoor, Alexander Anderson, Isaac Tucker, Michael Malast

VIRGINIA TECH

NAWC Aircraft Division NAVAL AIR WARFARE CENTER

Background

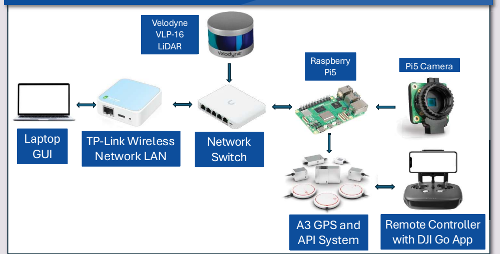
The Naval Air Warfare Center Aircraft Division (NAWCAD) wants to develop an autonomous landing aid because:

- Navy UAV pilots often need to land in adverse conditions
- Rain, fog, or other weather conditions can impact visibility
- The landing target may be a moving object, like a ship

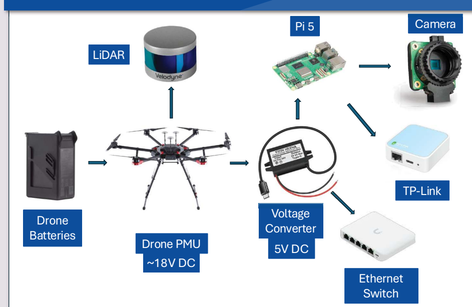
Such a system could:

- Improve landing safety
- Prevent damage or injury to Navy property and personnel
- Prevent delays during critical operations

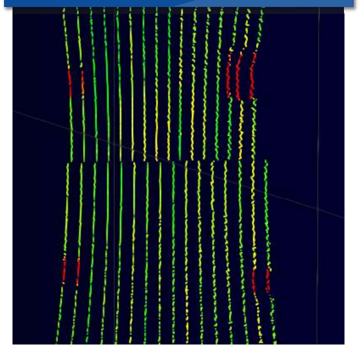
System Design & Hardware



Power Distribution



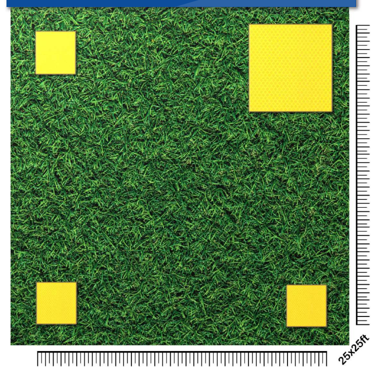
LiDAR 3D Point Cloud



Snapshot of the LiDAR's 3D point cloud in flight.

- Cool colors represent low return, warm colors represent high return
- Our landing zone markers appear as a red dots as seen above
- Retroreflective tape's microscopic prisms concentrate and return LiDAR lasers directly to the source, producing a strong signal.

Landing Zone Mockup



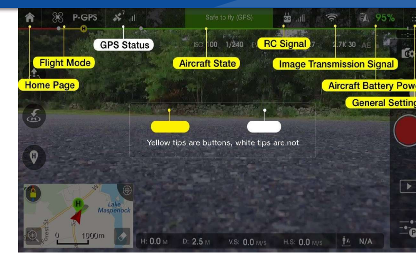
A bird's-eye view of the landing zone.

- Corners of the landing zone are marked by large "islands" of tape
- This method is easier to detect than a thin line of tape marking the entire perimeter at larger distances
- The distance between the farthest edges of each marker is 25ft
- The larger square provides directionality for pathfinding efficiency

Methodology

- **Platform**: Our system is implemented on a commercial drone (DJI Matrice 600 Pro), utilizing the existing GPS and Inertial Measurement Units (IMUs), as well as DJI's Onboard SDK API to issue movement commands.
- **On-Board Processing**: A Raspberry Pi5 microcontroller handles sensor data from the LiDAR and Camera, performing calculations, and issuing commands to the drone via a UART connection.
- **Landing Zone Acquisition**: Our landing zone is a 25x25ft square marked at its corners by yellow retroreflective tape, allowing the system to calculate the center of the four markers to find the desired landing point.
- **Sensor Integration**:
  - **LiDAR**: The primary sensor that maps the environment into a 3D point cloud allowing the system to identify the landing zone.
  - **Camera**: Provides a live video feed to the operator for supervised landing on the remote controller. The microcontroller also logs recordings and saves it for easy access.
- **Power Solution**: To supply on-board power, we draw from the drone itself (approx. ~18V DC). This is sufficient for our LiDAR, but we need to down-convert to 5V for our other components: Microcontroller & Network Switch.
- **Control Loop**: When the operator switches to "Flight" mode on the remote controller, the autonomous landing sequence initiates with operator supervision.

DJI Go App User Interface



Conclusion

Our supervised Autonomous UAV Landing System successfully integrates commercial off-the-shelf components (LiDAR, Camera, Raspberry Pi 5) into a flight-capable platform. This project has addressed NAWCAD's need to develop an autonomous landing assistant to aid UAV pilots.

The system provides a proof-of-concept for:

- **Accurate Navigation** by leveraging the Velodyne VLP-16 LiDAR to navigate and identify a marked landing zone.
- **Reduced Risk** by improving landing safety and efficiency, potentially preventing incidents during time-critical operations and reducing the chance of damage or injury to Navy property and personnel.

Next Steps

Future work may include:

- A SLAM map for accurate object detection
- Pathfinding optimization for object avoidance

Acknowledgements

The F25-17 team would like to thank:

- **NAWCAD** For sponsoring the project
- **Andrian Jordan** & **Israel Jordan** for proposing the project
- **Dr. Ryan Williams** for lending equipment and assistance as project Subject Matter Expert
- **Dr. Daniel Connors** for project guidance

Project Contributor Acknowledgements

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

Dr. Rose Hu
for her vision and continued unyielding support to prepare our students for the future.

Joe Adams, Kelley Andrews, Daniel Connors and Shelley 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, 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 Toby Meadows
for allowing us complete access to the design studio and conference room and providing assistance to students in need.

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

Dr. Tim Talty and Dr. Creed Jones
for speaking to the students about graduate school.

Kim Medley, Rowan Al-ghafafi and Dakshita Bansal
for ordering our materials, helping us solve supplier issues and managing conference rooms.

Christine Absher, Kathy Atkins and Melanie Gilmore
for tirelessly providing financial guidance and support.

The SMEs
for providing technical expertise in guiding the teams.

Niki Hazuda and Ben Murphy
for helping to share the amazing message of our students' successes and for great support on our website.

Bruce Buskill, Pouya Faeghi, Rick Johnston and Brandon Russell
for solving our IT and building facility issues.

Bianca Norton and Virginia Tech Inn Staff
for helping plan, cater and secure all arrangements to make the Major Design Experience Expo so great.

Muntasir Mahdi, Prajwal Keshava, Ibrahim Eshera, Mohammedreza Saghafi, Anthony Buchman and Henry Forsyth
for being great teaching assistants in support of these MDE students.

Eric Louis Bagtas and MD Azfarhasan
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

Spring 2025

ECE 1004–Introduction to ECE Concepts

- Isla Carlson
- Luke Coughenour
- Shelby Owed

ECE 2024–Circuits and Devices

- Vince Hoepfner
- Kyla Luby

ECE 2214–Physical Electronics

- Kemper Brown
- Marina Yamamoto Borges

ECE 2514–Computational Engineering

- Zachary Petro
- Nathan Roberts
- Joaquin Tuckett

ECE 2544–Fundamentals of Digital Systems

- Jijun Niu
- Rafael Serrano, Jr.

ECE 2564–Embedded Systems

- Scott Armand
- Noah Chin
- Gael Gael Garcia
- Luke Heller
- Ryan Jeronimus
- Justin Justin Santana
- Luke Tighe
- Jesse Ulfres

ECE 2714–Signals and Systems

- Jake Gerken
- Ryan Lauderdale

ECE 2804–Integrated Design Project

- Edward Cornette
- Phuc Doan
- Chris Nassif
- Aurlun Nelson
- Bryce Pollak
- Aaditya Sharma
- Arjab Sinha
- Cameron Williams

Blood Pressure Cuff Project

Cameron Williams (left), Christopher Nassif (right)

CHALLENGE

To create an easy-to-use blood pressure monitor that is about as accurate as a commercial monitor using a pressure sensor, arm cuff, and air pump.

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VIRGINIA TECH.

Chris Nassif Arlington, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Use control theory and machine learning to design reliable, robust, and effective autonomous robots; additionally, I also aspire to write the hyper performant code and design the computing hardware required to run autonomous robots on the edge.

Course Comment: IDP aided in developing my skills of effectively combining simulation and real validation as well as using well designed interfaces to streamline the integration of multiple hardware and software systems.

Cameron Williams Hurricane, West Virginia

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: Work in the robotics industry creating reliable autonomous software.

Course Comment: IDP helped me learn the value of simulations and well communicated interfaces in design.

Blood Pressure Cuff Project

Team: Cameron Williams & Chris Nassif

Instructor: William Baumann

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Background

High Blood Pressure increases risk of heart attacks, stroke, and heart failure almost ½ of Americans suffer from High Blood Pressure.

Blood pressure cuffs are devices that allow doctors to read what your blood pressure is in order to address early signs of heart problems. They are generally made of a pressurized cuff that squeezes down on your arm, and then a pressure sensor that reads oscillations in pressure in your arm, which can then be processed to give the systolic, diastolic, and mean arterial blood pressure readings.

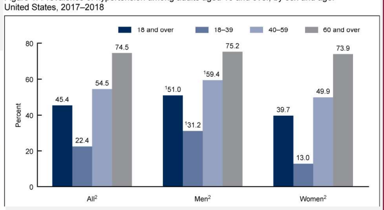


Figure 1. Prevalence of hypertension among adults aged 18 and over, by sex and age: United States, 2017–2018

Objectives

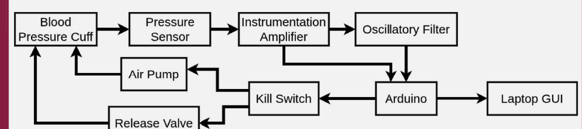
We were tasked with creating a blood pressure reading system from scratch that can just as accurately read the blood pressure of a patient as a commercial blood pressure cuff. We also had to create a desktop app to interact with the blood pressure cuff and start/ collect readings. This app should also store the blood pressure readings in a database to allow the user to view their past blood pressure readings.

Design Criteria:

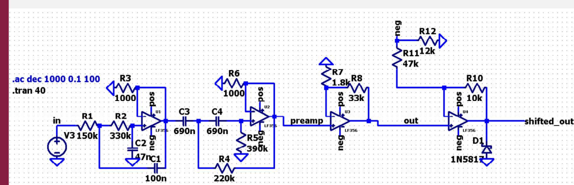
- Operate optimally from 60-100 BPM heartbeat
- -30 dB attenuation on 60Hz powerline noise
- Operate at similar if not better accuracy than a comercial blood pressure reader

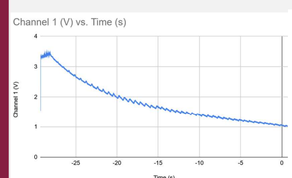
System Design

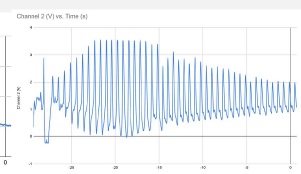
High Level System Diagram



We designed a bandpass filter to effectively isolate the oscilatory signals from the raw blood pressure reading. This signal captures how hard the patient's heartrate is pressing on the blood pressure cuff as it tightens and expands. From the shape of this curve we can determine the blood pressure for a patient. The bandpass filter to isolate the heart rate signal can be found below.

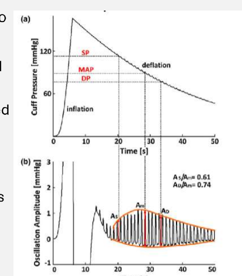






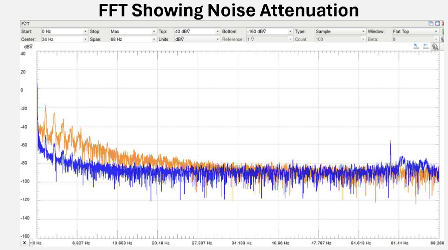
We then processed this data using an arduino by using the fixed ratio method

The fixed ratio method is widely used in blood pressure monitoring and approximates the systolic and diastolic blood pressure as a fixed ratio of the maximum amplitude value of the oscillation waveform exemplified to the right. This waveform is created by taking the derivative of the cuff pressure. The fixed ratios are created as population averages through testing on large groups of people.

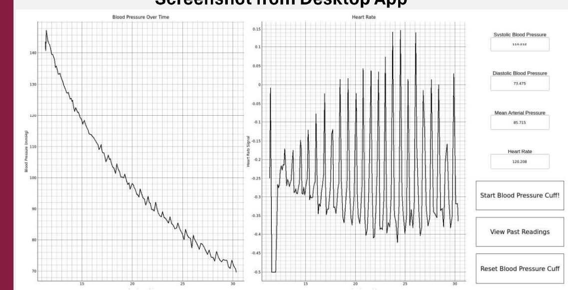


Results

FFT Showing Noise Attenuation



Screenshot from Desktop App



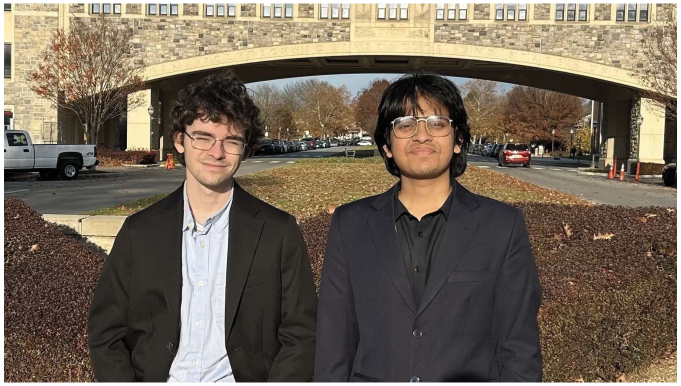
Accuracy of Measurements vs a Commercial Monitor

Person	Commercial Systolic	Commercial Diastolic	Commercial BPM	Our Systolic	Our Diastolic	Our BPM	Systolic % error	Diastolic % error	BPM % error
Dr. Baumman	129	71	67	121	73	69	6.20%	2.82%	2.99%
Cameron	113	63	84	109	63	83	3.54%	0.00%	1.19%
Chris	117	64	86	114	66	87	2.56%	3.13%	1.16%

Future Steps

- Implement automatic rejection of impossible readings
- Test on a larger population to obtain better population averages
- Improve the GUI readouts with better sampling
- Implement the circuitry on a PCB to make the device more robust and compact

Home Audio System Project



Edward Cornette (left), Arjab Sinha (right)

CHALLENGE

The objective of this project was to create a home audio system that allows the user to adjust the bass, mid, and treble of an audio signal, and the outputs the signal to a speaker. To achieve this the project requires a graphic equalizer, spectrogram, and class d amplifier. The graphic equalizer uses filters to separate bass, mid, and treble, and allows the gain for each band to be adjusted individually using potentiometers. The effect of the equalizer is visualized using the spectrogram, which displays the equalized audios current levels of bass, mid, and treble on an OLED screen. A class d amplifier is used to amplify the equalized audio, driving the speaker with high power efficiency. The complete system must minimize dB ripple for neutral equalizer settings, prevent shoot through current, and minimize the harmonic distortion.

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Edward Cornette Falls Church, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After graduation I plan to complete a master's degree and pursue a career working with hardware design and signal processing.

Course Comment: This course provided real design experience. It allowed me to apply my theoretical knowledge, improving my understanding of analog design and signals and systems.

Arjab Sinha Bangalore, India

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: After graduation I am eager to explore opportunities in digital design, embedded systems, and VLSI.

Course Comment: Integrated design project gave me an opportunity to get adept at doing large-scale analog design and debugging circuits, and there are valuable takeaways from the course.

Home Audio System Project

Team: Edward Cornette & Arjab Sinha
Instructor: Shuxiang Yu

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Objective

The goal of this project was to create a complete home audio system with the three following subsystems:

- Graphic Equalizer to boost or cut bass, mid, and treble frequency ranges independently
- Class-D Amplifier to amplify signals to audible levels with high efficiency and low distortion
- Spectrogram to show the current levels of bass, mid, and treble in the filtered audio signal

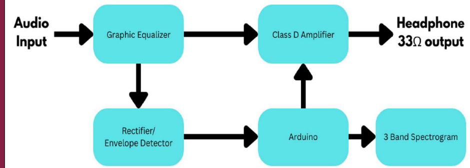
Requirements

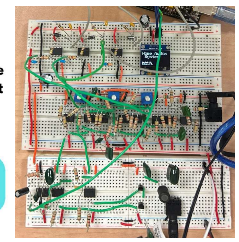
We were tasked with designing a home audio system to meet the following minimum requirements:

- The equalizer has three frequency bands spanning 100 Hz to 8 kHz, and can achieve negative, positive, and 0 dB on each band.
- Equal potentiometer settings within 30% - 70% range result in <2 dB ripple over the equalizers frequency range.
- The class-D amplifier uses a carrier frequency of 80 kHz or greater
- The switching stage of the class-D amplifier must add deadtime to prevent shoot through current
- The output to the headphones must have less than 50 mV ripple and minimal total harmonic distortion.
- The spectrogram must update smoothly and display the level of each frequency ranges amplitude.

System Design

Overall Design and Completed Circuit:

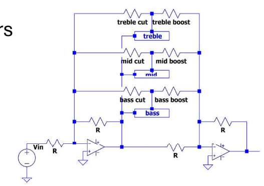




We designed the three major subsystems as follows:

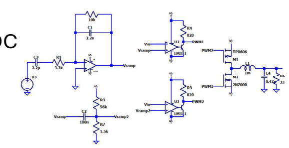
Graphic Equalizer:

- Three 2nd-order Butterworth bandpass filters
- bass: 82–300 Hz
- mid: 300 Hz–3 kHz
- treble: 3–8 kHz.
- Potentiometers control gain per band.
- Addition of series resistors prevent saturation at extreme settings.



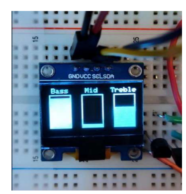
Class-D Amplifier:

- Arduino generates 80 kHz carrier square wave, converted to triangle wave via integrator.
- Two comparators convert audio to PWM. DC offset difference results in deadtime.
- Half-bridge switching stage's RLC filter (8 kHz cutoff) achieves -41 dB attenuation at carrier frequency.

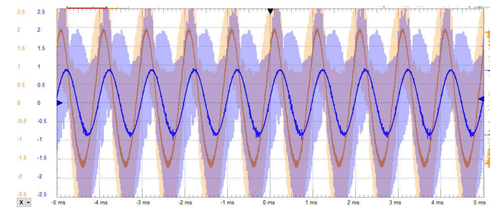


Spectrogram Display:

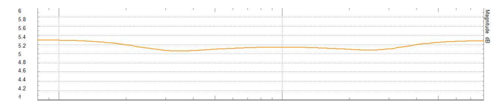
- Envelope detectors convert AC band signals to DC levels (100x gain, 100 ms time constant).
- Arduino samples three inputs and displays real-time bars for bass, mid, and treble strength.
- Welcome screen shows for 3 seconds on startup.



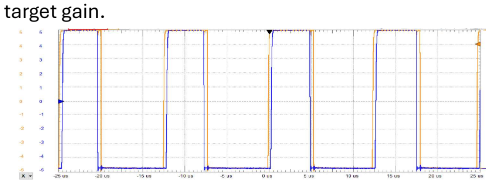
Results



1 kHz audio signal before (blue) and after (orange) being passed through complete audio system



~0.3 dB ripple using equal potentiometer settings at target gain.



PWM output for 1 kHz signal. 12.5 us period (80 kHz) with ~340 ns added deadtime

Future Steps

- Increase carrier frequency to 200–500 kHz for improved output filtering.
- Add more frequency bands for finer equalizer control.
- Implement PCB design to reduce noise and improve reliability.
- Optimize deadtime to reduce total harmonic distortion while preventing shoot-through.

Infrared Radioteletype Project

Phuc Doan (left), Aurlun Nelson (right)

CHALLENGE

The goal of the RTTY project is to design a transmitter and receiver circuit that can reliably transfer data up to at least 5 feet using a single infrared LED (with max current of 0.4 mA) and a single photodiode. No optical tricks like lenses or reflectors allowed; just pure analog circuit design and signal processing using an Arduino.

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Phuc Doan Chesapeake, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I'm likely going to find myself doing some PCB engineering work as I find the mix of theory, practice, and art to be enjoyable and important. This is despite my background being in computer programming, but perhaps one day I can combine both worlds to make software that can promote educational and productive goals in the space of PCB design.

Course Comment: This course has helped me be more confident in myself as an engineer; specifically, it demanded me to push my abilities further into technical writing, communication, problem-solving, and understanding in ways that I otherwise wouldn't have been able to had I not taken the course. It's a trial-by-fire I would do again.

Aurlun Nelson Springfield, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I intend to continue pursuing renewable and nuclear energy solutions within a team after graduation.

Course Comment: ECE 2804 prepared me for future AC circuit labs, as it contributed to my skills in rapid iteration and structuring circuits in a way to quickly replace components or isolate problems–notably in filter design.

Infrared Radioteletype Project

Team - Phuc Doan & Aurlun Nelson
Instructor - Dr. William T. Baumann

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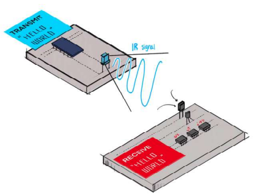
VIRGINIA TECH

Overview

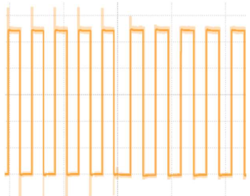
A radio teletype (RTTY) is a device circa late 1800s that uses radio waves to transmit and/or receive text over long distances wirelessly. This project is a reincarnation of such a device, but instead of using radio waves, we use an infrared LED to transmit and a corresponding infrared photodiode to receive. Using only 0.4 mA of current for the IR LED, we were able to achieve 13 ft of separation between the transmitter and receiver (while maintaining stable transmission) without resorting to optical enhancements such as lenses or parabolic reflectors.

Requirements

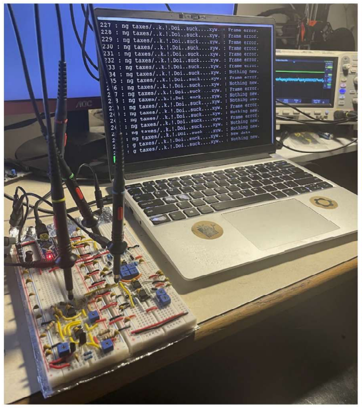
- ATmega328P as the main MCU for both transmitter and receiver circuit.
- LTR-516AD as the IR photodiode for the receiver and IR1503 as the IR LED for the transmitter.
- Max current of 0.4 [mA] through the transmitter's IR LED.
- No optical enhancements such as lenses or parabolic reflectors.
- IR LED to pulse 2125 ± 2 Hz and 2295 ± 2 Hz to designate a space (0) and mark (1).
- Protocol of UART 8N1at a transmission rate of 45.45 baud.
- Use a single BJT rather than a transimpedance amplifier as has been done in past years.
- No negative voltage supply; all opamps are in unipolar configuration.
- Minimize amount of amplification and filtering stages needed.



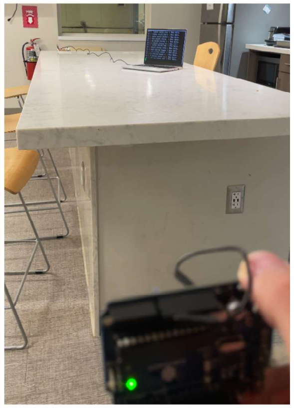
Graphic of RTTY transmitter and receiver.



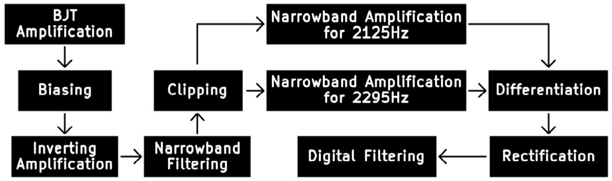
Square wave of 2295 Hz (left) and 2125 Hz (right).



Receiver circuit and the serial output.



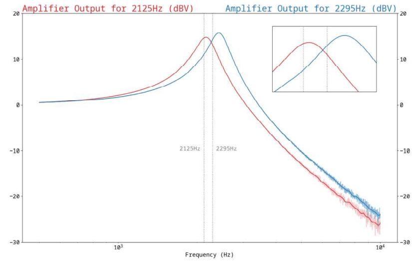
Receiver and transmitter 13 ft apart.



Receiver block diagram.

Narrowband Amplification

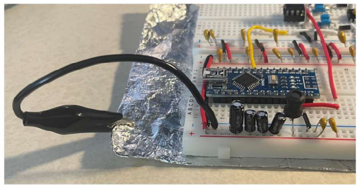
To differentiate between the 2125 Hz and 2295 Hz signals, two low-pass Sallen-Key filters were used in such a way that they were tuned to exaggerate the "ripple" in the roll-off, resulting in amplification at the desired frequencies. The advantage of this approach is that these filters have unity-gain, so no reference voltage was needed.



Frequency response of the two low-pass Sallen-Key filters.

"Ground Plane"

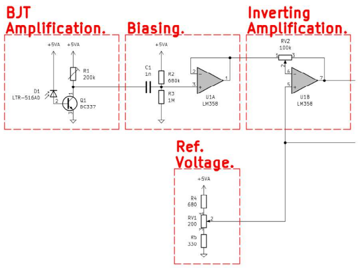
By having a sheet of aluminum placed below the breadboard and grounding it, most of the noise within the circuit can be eliminated. This is because the aluminum acts as a ground plane and helps direct the flow of the switching electrical energy within the circuit (wave-guide); without the plane, high frequency energy is radiated and induces cross-talk between the rails of the breadboard.



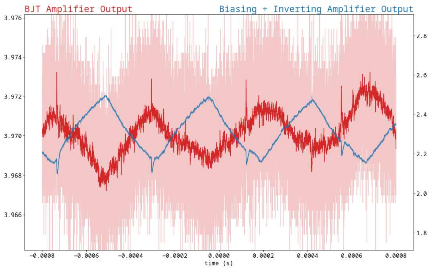
Aluminum sheet with an alligator clip to tie it to the circuit's ground.

Receiver Frontend

Most RTTY implementations use a transimpedance amplifier (TIA) in order to amplify the weak current signal of the IR photodiode, but we instead used the approach of a BJT in common-emitter configuration. Through careful tuning, the BJT provided equivalent performance to TIA but with a much simpler setup. The output is then biased to a known voltage and then amplified; this results in a gain of ~0.85 V/nA.



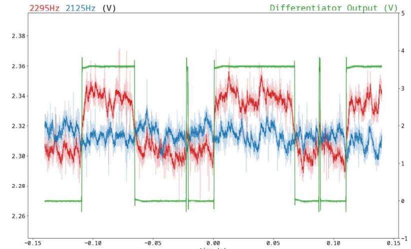
Schematic of the receiver frontend.



Output of the receiver frontend at ~3 ft.

Differentiation

By having two narrowband amplifiers to amplify one frequency more than the other, the amplifiers' outputs can be compared to determine the input signal's frequency; any switching noise in the comparison output is handled through a custom software filter on the ATmega328P.



Differentiation of the two narrowband amplifier's outputs at ~10 ft.

Further Improvements

The circuit as-is is capable of achieving 13 ft of separation between receiver and transmitter. To push this distance even further, tighter restriction on noise is needed. This can be achieved in several ways while still satisfying the original project's specification:

- Use a proper comparator IC instead of an opamp for differentiation.
- Use a soldered protoboard to remove breadboard parasitics.
- Transfer to a PCB design to have a proper ground plane.
- Use an LDO power supply topology to isolate from USB VBUS noise.

Wireless Sensor Node

Bryce Pollak (left), Aaditya Sharma (right)

CHALLENGE

Early-stage wildfire detection in remote regions is hindered by the lack of reliable, low-maintenance monitoring systems. To address this, we designed a wireless sensor node (WSN) capable of measuring temperature and transmitting data via Bluetooth, powered by a solar-charged 9 V battery with an integrated DC/DC boost converter and low-power operation mode to maintain at least five days of continuous functionality on a full charge.

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

Bryce Pollak Winchester, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I aspire to pursue my master's degree at Virginia Tech focusing on machine perception, with the goal of advancing autonomous aerial vehicle technology through intelligent sensing and decision-making systems.

Course Comment: This course was invaluable in allowing me to produce a tangible engineering product, collaborate on a long-term team project, and experience the complete design life cycle from concept to final implementation.

Aaditya Sharma Chandigarh, India

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: To ensure the machines rise with us, not against us.

Course Comment: I really enjoyed this course – it was hands-on and gave us the opportunity to actually build something and solve problems independently. It also allowed me to apply many of the concepts I'd learned in other classes in a practical way.

Wireless Sensor Node

Challenge

Early-stage wildfire detection in remote regions is hindered by the lack of reliable, low-maintenance monitoring systems. To address this, we designed a wireless sensor node (WSN) capable of measuring temperature and transmitting data via Bluetooth, powered by a solar-charged 9 V battery with an integrated DC/DC boost converter and low-power operation mode to maintain at least five days of continuous functionality on a full charge.

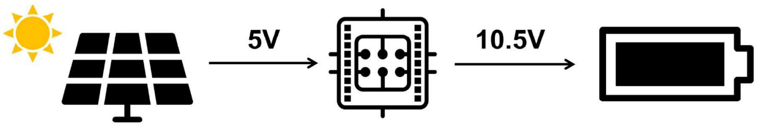
Design Requirements

- Operate continuously for at least five days on a fully charged 9 V rechargeable battery.
- Maintain greater than 80% efficiency in the DC/DC boost converter while charging the battery from a 4–5 V solar input.
- Measure and transmit temperature data via Bluetooth to a remote receiver or computer interface.
- Implement power-saving modes when solar input is unavailable, minimizing current consumption below 1.25 mA average.
- Utilize a standalone ATmega328P microcontroller for control, PWM regulation, and data processing.
- Stabilize output voltage of the boost converter using closed-loop feedback control.
- Accurately sense temperature using a calibrated thermistor circuit.
- Provide autonomous functionality with no wired connections other than the solar power input.

Innovations

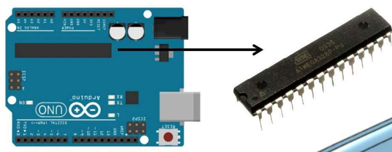
Beyond the core project requirements, several enhancements were implemented to expand system capability and usability

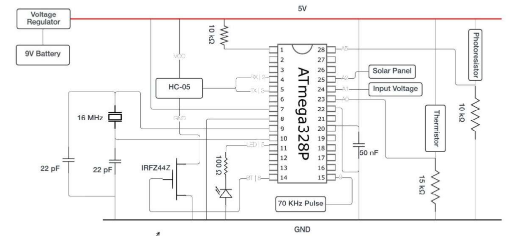
- Smoke Detection: Added a photoresistor-based smoke sensing module for early fire identification.
- Graphical User Interface (GUI): Custom Python interface for real-time data visualization and control.
- Automated Email Alerts: Integrated alert system to notify users when temperature or smoke thresholds are exceeded.
- 3D-Printed Enclosure: Designed a custom housing for environmental protection and portability.

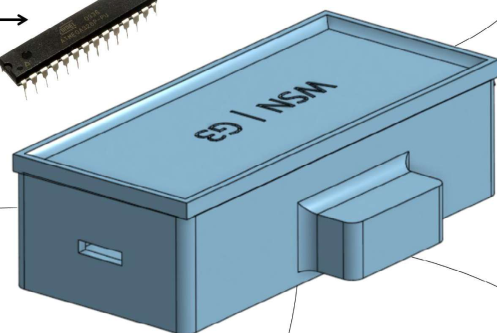


Charges at 125 – 150 mA | Efficiency ≈ 85%

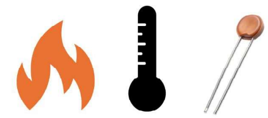
Runtime ≈ 6.5 days





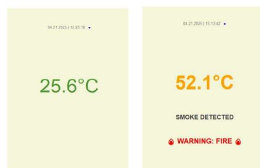


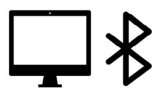
- Standalone ATMega328P
- On Demand Bluetooth Activation
- Meaningful Data Transfer
- Selective ADC activation
- Sleep mode with WDT as Wake Source
- PWM Optimization

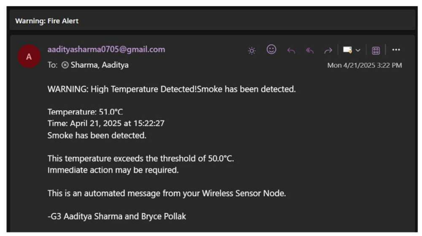


Steinhart Approximation Optimized for 40° - 60°

$$\frac{1}{T}=\frac{1}{T_0}+\frac{1}{\beta}\ln\left(\frac{R}{R_0}\right)$$






Warning: Fire Alert

aadityasharma0705@gmail.com

To: Sharma, Aaditya

Mon 4/21/2025 3:22 PM

WARNING: High Temperature Detected!Smoke has been detected.

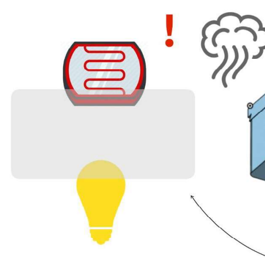
Temperature: 51.0°C
Time: April 21, 2025 at 15:22:27
Smoke has been detected.

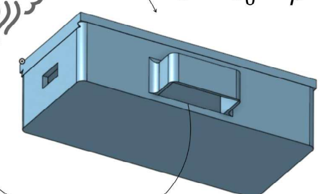
This temperature exceeds the threshold of 50.0°C.
Immediate action may be required.

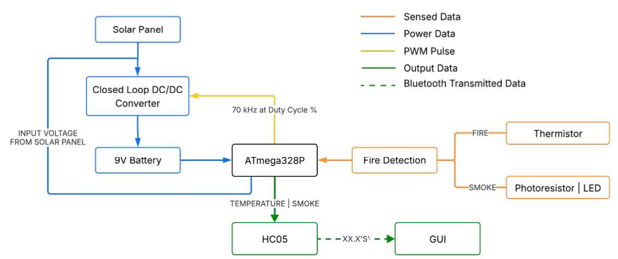
This is an automated message from your Wireless Sensor Node.

-G3 Aaditya Sharma and Bryce Pollak

Custom Smoke Detection







Feature	Implementation	Specification
Inductor Current	Triangle Shaped Acceptable Current Ripple Non-Saturating	Meets Specifications
DC/DC Closed Loop Converter	Converter outputs desired voltage accurately from 3V to 5V PI Controller Implemented	Exceed Specifications
Converter Efficiency	83% - 85% Efficient at battery charging current	Exceed Specifications
Battery Charge and Discharge	Waveforms show 150 mAh supplied into and draw out of the battery	Meets Specifications
Temperature Detection	Steinhart Approximation used for accurate temperature detection Optimized at 50°C Verified with commercial thermometer	Exceed Specifications
Power Saving Mode and Efficiency	Switches to Power Saving Mode when input voltage drops below threshold Current draw falls below 1.25 mA Runs for 6.5 days on a full charge	Exceed Specifications
Data Transmission and Display	Transmits data through HC-05 successfully Custom GUI reads and displays received data	Exceed Specifications

Aaditya Sharma, Bryce Pollak | IDP Spring 2025 Best in Course | Dr. Baumann

Best in Track

Track 1: Blue Sentinel

Track 2: Dynamic Steerable Polymer Embedded Antenna Array

Track 3: Virtual Phasor Measurement Units

Best by Popular Vote and Best Overall

Stylus Testing System with Positional and Force Control