ECE

MAJOR DESIGN EXPERIENCE EXPO

November 14, 2023
The Inn at Virginia Tech

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

Agenda

Registration	10:00–11:00am
Welcome	11:00am
Tracks	11:30am–1:00pm
Posters and Pizza	1:00–2:15pm
Awards	2:15pm–3:00pm

Presentation Tracks

Welcome to our Fall 2023 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 64 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, 13 exciting projects, each is a unique, open-ended, technical challenge defined by our industry partners; and 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 are evidenced in these 13 projects. On behalf of these students, and from me personally, thanks again to our industry sponsors, our subject matter experts, and our MDE faculty for their tremendous support in developing our next generation of engineers.

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

Sponsors

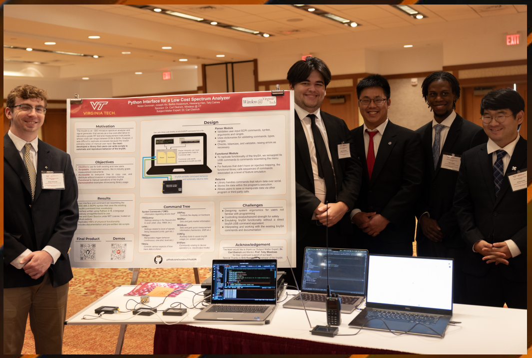
We greatly appreciate their support.

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	Customers	Project	Subject Matter Experts (SME)
Aerospace	John Janeski	Sensor Fusion for Autonomous Navigation	John Janeski
Breeze-Eastern	Thomas Aldhizer	Swing Stabilization for MEDEVAC Rescues	Mary Lanzerotti and Walter Lacarbonara
DEVCOM and ASPIRE	Creed Jones	Object Detection with Computer Vision and Machine Learning	Creed Jones
Interstellar Dreams Space Center	Robin McDougal	Interstellar Dreams Space Center Simulation Project	John Ghra
Northrop Grumman	Carl Dietrich	Measurement and Test Automation using Low Cost Instruments	Carl Dietrich
Parsons, Centreville, VA	Jordan Scott and Wes Rose	Multipath Router Implementation	Tim Talty
Parsons, Centreville, VA	Wes Rose and Anthony Kempka	2.4 GHz Energy Detection Device	Ryan Gerdes
Parsons, Centreville, VA	Brent Goodwin	String Obfuscation Software	Sook Ha
Parsons, Centreville, VA	Brent Goodwin	Secure Python Compiler and Bytecode Interpreter	Paul Plassmann
Virginia Tech, CPES, Blacksburg, VA	Dushan Boroyevich and Richard Zhang	Communication Interface Development for Power Converters in Microgrids	Haris Bin Ashraf and Vladimir Mitrovic
Virginia Tech, CPES, Blacksburg, VA	Richard Zhang	Programmable Impedance Network	Jiaxiong Yu
Virginia Tech, ECE NSF-SWIFT-IC, Blacksburg, VA	Steve Ellingson	L-Band Satellite Tracking and Characterization System	Steve Ellingson

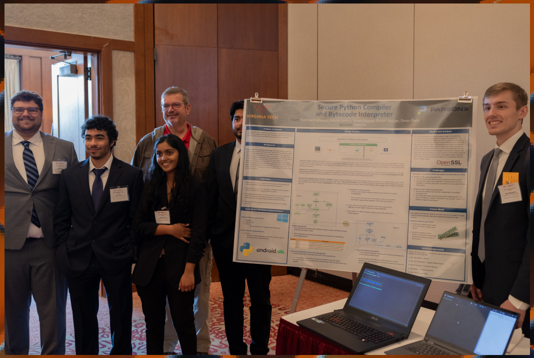


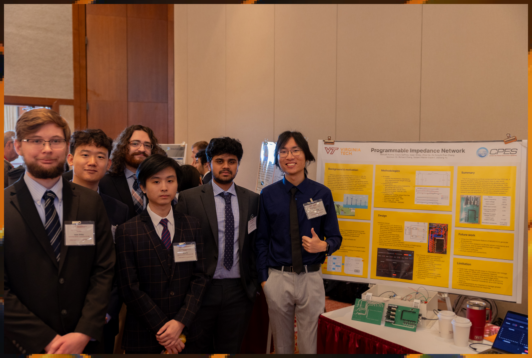


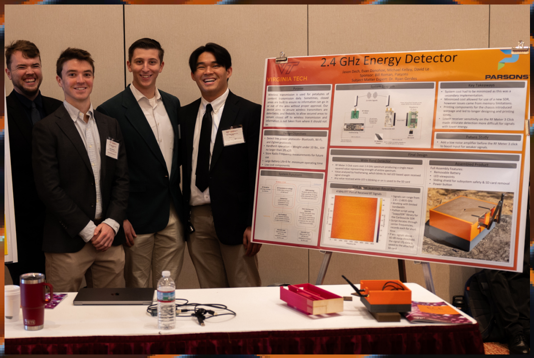


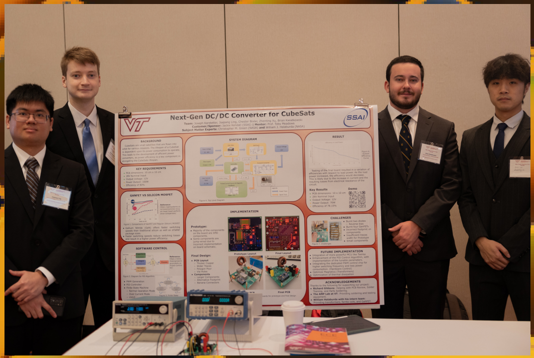



QA Environment
OS Identification
Lightweight
Versatile
Extensive
Requires CMake

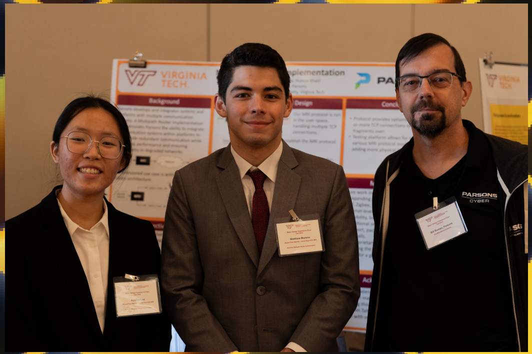








Project Teams and Posters



String Obfuscation Software

LEFT TO RIGHT: Pierre Chaux, Tyler Tran, Vishakh Subramanian, David Ron, Michael Lundquist, William Stadtlander

SME: Sook Ha

CHALLENGE

In most cases, software owners do not want their software to be replicated by external parties. The replication process is known as reverse engineering, which this project aims to prevent.

Customer: Brent Goodwin

Pierre Chaux Englewood Cliffs, New Jersey

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I'm excited to collaborate on projects with teams and dive into the design process. I enjoy balancing creativity and practicality, adapting designs to make them more effiecient, and working towards imeplemting smooth UX/UI. I want to keep learning, expanding my knowledge base and improving my problem solving skills.

Course Comment: This project has been a valuable learning experience, providing insights into containerization, collaborative code integration, and data manipulation within executables. As a software-focused student, I believe these skills will greatly benefit my work on both large-scale projects and new endeavors.

Michael Lundquist Georgetown, Massachusetts

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I'm excited to continue learning different software and languages in order to make a difference in the world.

Course Comment: This project has been extremely valuable in giving experience working with a team, and creating a project from scratch. I think this experience will help in the workforce and work with coworkers throughout my career.

David Ron Centreville, Virginia

Bachelor of Science in Electrical Engineering
Micro/Nano Systems
Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: To become an industry leader in integrating software into new technology (FPGA, nano-ICs, new microcontrollers, etc).

Course Comment: This project grew my leadership skills and taught me how to develop cross-platform software systems.

William Stadtlander Davie, Florida

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I'm excited to graduate and work on developing software that improves people's quality of life.

Course Comment: This project has been an interesting insight into software development. I'm excited to ship the software to the customer and present to peers and faculty.

Vishakh Subramanian Haymarket, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I am excited to continue my studies in Machine Learning and back-end software development. My career aspirations are to create software solutions for industries and work with engineers to make positive impact in the world.

Course Comment: This project has given me an opportunity to learn about the design process, take an idea for a product, and continue through all of the steps that it would take in industry to push our product to production.

Tyler Tran Fairfax, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I want to be able to create unique solutions and products that help many people. I became an engineer to see people use products that I created and appreciate.

Course Comment: This course allowed us to experience how real software teams research and implement products, with a safety net of having school professors assist and help where we need.

Constant String Obfuscation Software

David Ron, Michael Lundquist, Pierre Chaux, Tyler Tran, William Stadtlander, Vishakh Subramanian

Customer: Mr. Brent Goodwin SME: Dr. Sook Shin Ha Mentor: Dr. Joe Adams

PARSONS

VIRGINIA TECH

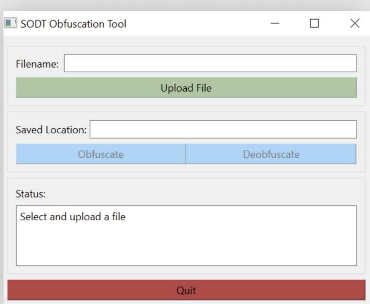
Background

The need for cyber-security is rapidly growing, as hackers are becoming more prevalent and the world's reliance on the internet is growing. Parsons Corporation requested a software that obfuscates constant strings contained within executable files to protect sensitive information contained in source code.

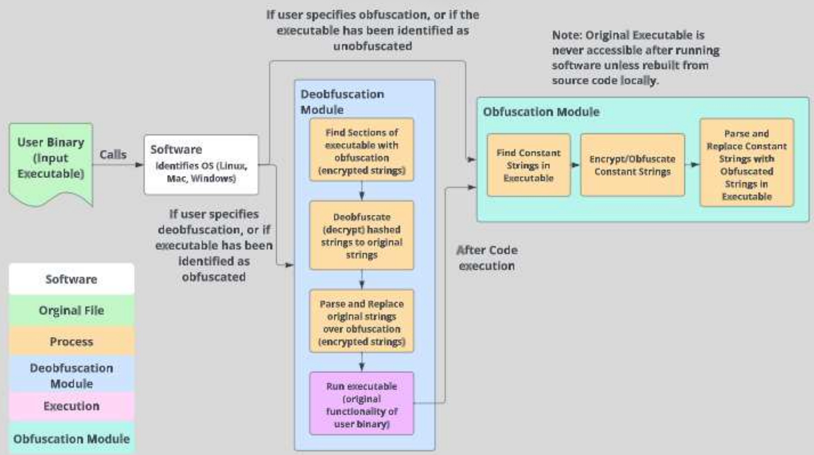
Objectives

- Portable across operating systems
- Computationally inexpensive
- Irreversible obfuscation
- Simplistic UI/UX design

Demo



Design



Obfuscation Implementation

- Find location of constant strings.
- Add the memory address and value into map.
- Remove strings and encrypt map.
- Insert map into a custom header.

Deobfuscation Implementation

- Find location of custom header that was inserted.
- Decrypt the contents and read in the data.
- Insert the original strings to correct address.
- Run the program as normal.
- Remove the strings once done with the program.

Integration

- OS Identification
- Copy relevant files for OS implementation
- Run Dockerfile(s)
- Run with the same command line Interface (CLI)
- Run GUI using correct implementation

QA Testing

- Create test executable
- Compare strings before obfuscation (match)
- Compare strings after obfuscation (NO match)
- Compare strings during deobfuscation (match)
- Compare strings after deobfuscation (NO match)

Final Product

The ultimate product of the CSOS exhibits portability across multiple operating systems, specifically Linux, MacOS, and Windows. It offers a versatile means of operation, accessible via a command line interface (CLI) or a graphical user interface (GUI).

Within the CLI, two distinct flags have been implemented to facilitate the processes of obfuscation and deobfuscation, denoted as follows: ./csos -ob <executable> ./csos -deob <executable>

```
Contents of section __DATA,__data:
 100008000 48656c6c 6f20776f 726c6421 0a00476f  Hello world!..Go
 100008010 6f646279 6520776f 726c6421 0a004d61  odbye world!..Ma
 100008020 79626520 776f726c 64210a00           ybe world!..
```

```
Contents of section __DATA,__data:
 100008000 83838aa7 8098cf80 ce8b839d 80a8efe5  ................
 100008010 968d8b80 8098cf8a ce8b839d 8ea2efe5  ................
 100008020 cf8a8d96 839d8098 efe5ce8b           ............
```

Strings as seen in executable data section (Before and after obfuscation)

Executable Format	String Storage
PE (Portable Executable)	Stored in the .rdata section or the .data section. Can also be in the .rsrc section for resources.
ELF (Executable and Linkable Format)	Stored in various sections like .rodata for read-only data, .data for initialized data, and .text for code.
Mach-O (Mach Object)	Stored in __TEXT segment for code and __DATA segment for initialized data.

Difference between string storage of three executable formats

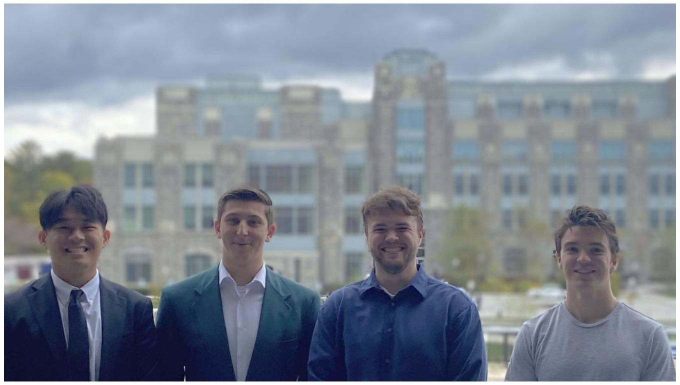
Lessons Learned

- Make time for unexpected delays
- Keep good documentation
- Write good code
- Test early and often

Acknowledgments

The CSOS team would like to give a special thanks to our customer, Mr. Brent Goodwin of Parsons Corporation, our Subject Matter Expert (SME), Dr. Sook Shin Ha and our Mentor, Prof. Joe Adams for their valuable time, advice, and enthusiasm throughout the entire scope of this project.

2.4 GHz Energy Detection Device



LEFT TO RIGHT: David Le, Jason Dech, Michael Kelley, Evan Donohoe

CHALLENGE

To design a device that can detect other devices transmitting via Wi-Fi, Bluetooth, Zigbee, or other protocols that utilize the 2.4 GHz band. The detector could be deployed to a field agent needing to protect themselves in an unknown environment or at the entrance to a SCIF to prevent unwanted devices from entering.

PARSONS

SME: Ryan Gerdes

Customers: Anthony Kempka and Wes Rose

Jason Dech Charlottesville, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: My plan is to begin my career as a network engineer, with a long-term goal of advancing to the role of a systems or network administrator.

Course Comment: Participating in this major design experience has provided me with invaluable insights into the practical aspects of product development, fostering substantial growth in my communication and teamwork abilities.

Evan Donohoe McLean, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: As I step into the world of machine learning, my goal is to work on exciting AI projects, push the boundaries of technology, and work in roles like a data scientist or machine learning engineer.

Course Comment: In this class, I've gained hands-on experience working collaboratively in teams, tackling real-world challenges for actual customers, and benefiting from the guidance of subject matter experts, all of which have enriched my learning by making it more practical and closely aligned with the demands of a future career in the field.

Michael Kelley New Bern, North Carolina

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: My career goal is to design, implement, and test the next phase of secure and robust communication links for robust information delivery

Course Comment: I appreciate the chance to work with peers in a team environment to get a real feel for peer leadership on a project that means something and to give me a better taste for what engineering will be like professionally.

David Le Springfield, Virginia

Bachelor of Science in Electrical Engineering
Micro/Nano Systems

Aspirations: My career goal is to start as a Design Engineer and advance into analog IC design with the hopes of working on newer circuits

Course Comment: Taking part in a project of this longevity has given me an invaluable experience! It's allowed me to build on my communication, teamwork, and technical skills while also learning more about RF engineering.

2.4 GHz Energy Detector

Jason Dech, Evan Donohoe, Michael Kelley, David Le
Sponsor: Bill Roman, Parsons
Subject Matter Expert: Dr. Ryan Gerdes

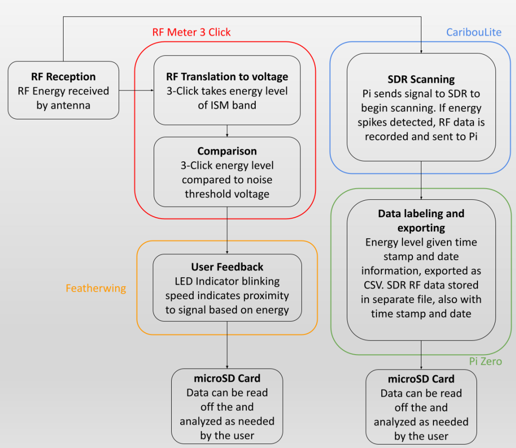
Purpose

Wireless transmission is used for petabytes of content transmission daily. Sometimes, closed areas are built to ensure no information can go in or out of the area without proper approval. Our device aims to ensure wireless transmitters are detectable, and findable, to allow secured areas to remain closed off to wireless transmission and information is not taken from where it should not be.

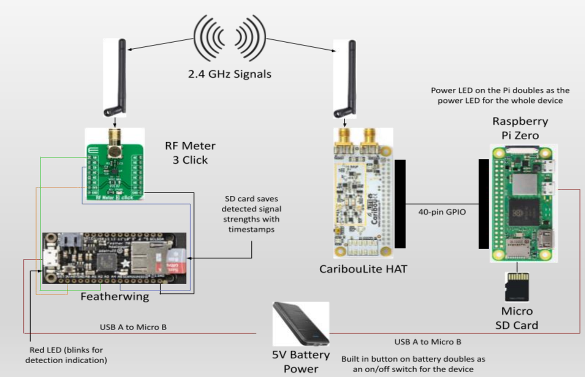
Design Objectives

- Detect low power protocols– Bluetooth, Wi-Fi, and Zigbee protocols
- Handheld operation – Weight under 10 lbs., size no larger than 1ft x1ft
- Store Radio Frequency measurements for future use
- Large Battery Life-6 hr. minimum operating time
- Low-cost components

System Functions



System Diagram



Key Takeaways

- System cost had to be minimized as this was a secondary implementation.
- Minimized cost allowed for use of a new SDR, however issues came from memory limitations.
- Printing components for the chassis introduced warpage and led to longer designing and printing times.
- Lower receiver sensitivity on the RF Meter 3 Click made accurate detection more difficult for signals with lower energy.

Future Study

- Add a low noise amplifier before the RF Meter 3 click to boost input for weaker signals.

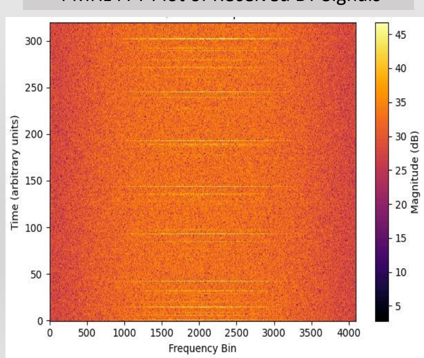
Final Design

Wide Band Detector

- RF Meter 3 Click scans over 2.4 GHz spectrum producing a single mean squared value representing strength of entire spectrum.
- Value analyzed by Featherwing, which blinks its red LED based upon received signal strength
- Any value received while LED is blinking or on is saved to the SD card

SDR Signal Scanner-Recorder

4 MHz FFT Plot of Received BT Signals

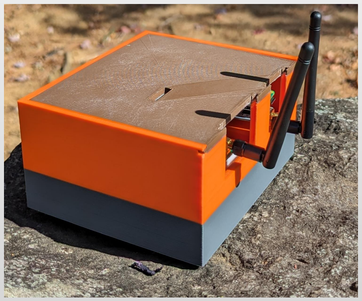


- Signals can range from 2.4 – 2.4835 GHz
- Working with limited bandwidth
- Python script using "SoapySDR" library for the CaribouLite SDR
- Script iterates through center frequencies, records each for short time
- If any signals above -60 dB noise threshold, the signal I/Q data is saved to the attached SD card

Assembled Product

Full Assembly Features:

- Removable Battery
- LED viewpoints
- Sliding shield for subsystem safety & SD card removal
- Power button



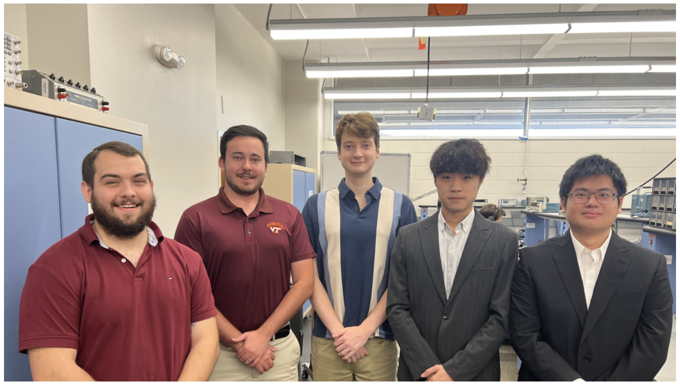
SPECIAL THANKS TO:

Our Sponsor, Bill Romans from Parsons who gave us our challenging and interesting project and joined us on the journey.

Dr. Ryan Gerdes, our SME, for their patience and technical guidance.

Track 1 Winner

Next Gen DC/DC Converter for CubeSats



LEFT TO RIGHT: Chester Bixler, Brian Kwiatkowski, Joseph Karstetter, Zhenting Xu, Jiaqiang Ling

SME: Chris Green

CHALLENGE

Design and implemented an isolated, high-efficiency DC/DC Converter that brings down 28V to 12V to power up the CubeSats which are small, compact satellites that serve as miniature payloads for rocket missions. These systems have an increasing need for more electrical power, and a more efficient DC/DC converter is a promising way to provide said power. The converter is designed based on the Forward Converter topology that meet the criteria of isolation and could have better efficiency performance under high power. The system uses an Arduino as a controller for generating a PWM signal with a specific duty cycle.

Customer: Jackie Kendall

Chester Bixler Sebring, Florida

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: I would like to pursure my PhD in power systems protection and become an Electrical Engineering professor at Tech.

Course Comment: I am excited to create my second converter! This course has given me so much insight into building and designing power converters. I am looking forward to using this knowledge in industry.

Joseph Karstetter Culpeper, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: I'm looking forward to applying my degree in whatever job I settle on. Although I currently enjoy PCB design and Controls, there are so many other aspects of Electrical Engineering that I am equally looking forward to learning about.

Course Comment: This project taught me a lot: soldering, PCB design, circuit analysis and testing, and everything else. Very glad to have been apart of this project and I hope our customers liked what we built for them!

Brian Kwiatkowski Virginia Beach, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: My career goal is to design inverter-based control systems that may be used to further the integration of renewables into our electrical grid.

Course Comment: The project was an incredible accomplishment for myself and this team. Being able to work on a real project for a real customer was an incredible experience and I learned a significant amount about real-world engineering in the process.

Jiaqiang Ling Shenzhen, China

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I want to contribute to the VLSI related industry with the integration of Machine Learning.

Course Comment: This course gave me a good platform to apply my knowledges to a real-world, industry-like problem. I have gained experiences like PCB Design and Soldering that would not be taught in class.

Zhenting Xu Suzhou, China

Bachelor of Science in Electrical Engineering
Micro/Nano Systems

Aspirations: I aim to contribute to the development in microsystem technology in order to help solve practical engineering problems with my degree in Electrical Engineering.

Course Comment: This project gives me a platform to collaborate engineers with different background to solve real-world problems which makes my preparations for future challenge.

Track 1 Winner

Next-Gen DC/DC Converter for CubeSats

Team: Joseph Karstetter, Jiaqiang Ling, Chester Bixler, Zhenting Xu, Brian Kwiatkowski
Customer/Sponsor: Jackie Kendall (SSAI) | **Mentor:** Prof. Toby Meadows
Subject Matter Experts: Christopher M. Green (NASA) **and** William J. Halaburda (NASA)

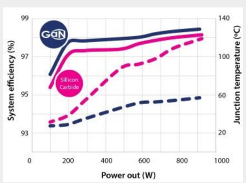
BACKGROUND

CubeSats are small satellites that are flown into orbit for various missions. The lifespan of a CubeSat is dependent upon its power consumption to operate. This leads to the development of efficient power converters, as power efficiency is a key component in elongating the CubeSats lifespan.

KEY REQUIREMENTS

- PCB dimensions: 10 cm x 10 cm
- 28V Nominal Input
- Output Voltage: 12V
- Power Output: 100W
- Efficiency of 90%

GANFET VS SILICON MOSFET

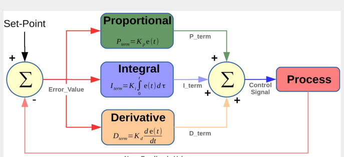


Reference: https://gansystems.com/newsroom/sic-vs-gan-head-head-performance-comparison/

Figure 1. Comparisons of GanFET and Regular (Silicon) MOSFET

- Gallium Nitride (GaN) offers faster switching speeds than traditional silicon as well as smaller package sizes.
- Faster switching speeds reduce switching losses and result in a higher power efficiency.

SOFTWARE CONTROL



Reference: https://www.theengineeringconcepts.com/pid-controller/

Figure 2. Diagram for PID Algorithm

- PWM Generation
- PID Controller
- Finite State Machine
  - Normal Operation Mode
  - Over Current Mode
  - UVLO
- User defined output voltage

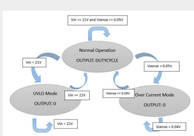


Figure 3. Finite State Machine for Operation Mode Control

SYSTEM DIAGRAM

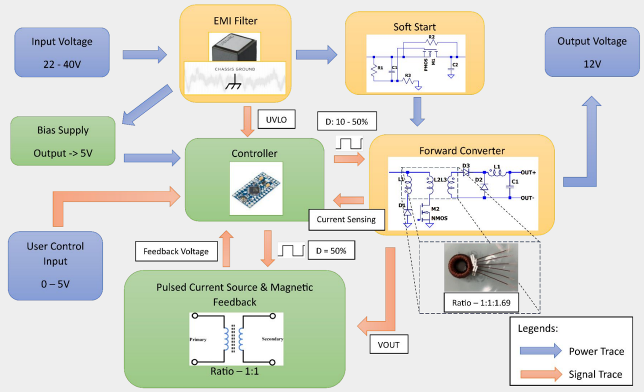


Figure 4. Top Level Diagram

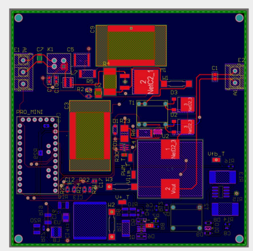
IMPLEMENTATION

Prototype:

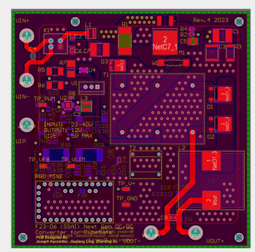
- Majority of the components on the board are SMD components.
- Some components are jump-wired due to incorrect implementation on board schematic.

Final Design:

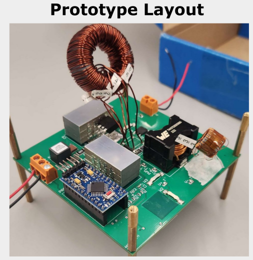
- **PCB Layout**
  - Thicker Copper
  - Wider Traces
  - Polygon Pour
  - Via Holes
- **Components**
  - Larger Components
  - Alternative Footprint
  - Banana Connectors



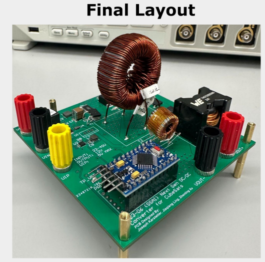
Prototype Layout



Final Layout



Prototype PCB



Final PCB

Figure 5. Layouts and Assembled Boards for prototype and final design

RESULT

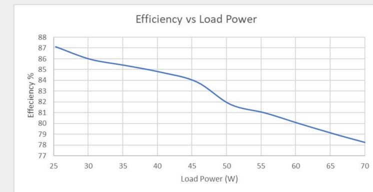


Figure 6. System Efficiency Curve

Testing of the final board resulted in a variation of efficiencies with respect to load power. As the load power increased, the efficiency would decrease. This is likely due to the increase in current and the resulting losses from electrical resistance of the circuit.

Key Results

- PCB dimensions: 10 x 10 cm
- 28V Nominal Input
- Output Voltage: 12V
- Power Output: 70W
- Efficiency of 78.15%

Demo

CHALLENGES

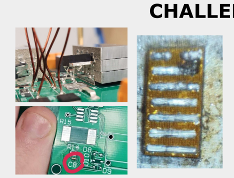


Figure 7. Challenges

- Burnt two diodes
  - Reverse bias
- Burnt four GanFETs
- Incorrect footprint on components
- Insufficient traces width for Prototype
- Small components

FUTURE IMPLEMENTATION

- Integration of more powerful MCU like Teensy
- Enhancement of the PID Control Algorithm, with implementation of the tunable parameters.
- Integrating the dedicated PWM control chip for higher switching frequency and less power consumption. (Hardware Control)
- Optimize Magnetics (Transformers)
- Optimization of thermal dissipation

ACKNOWLEDGEMENTS

Thanks to the following for supporting our project:

- **Richard Gibbons**: Helping with PCB Review, Solder Training, and Parts Soldering.
- **The AMP Lab at VT**: Providing soldering and testing equipment.
- **William Halaburda with his intern team**: Providing transformers, ferrite coils, and GaNFET.

Multipath Router Implementation

LEFT TO RIGHT: Adaline Lee, Matthew Moreno

CHALLENGE

Design a multipath communications router with the focus to enhance redundant communication data flows. The multipath router provides functionality in degraded networks by allocating paths for secondary channels for increased reliability and performance.

SME: Tim Talty

Customers: Wes Rose and Jordan Scott

Adaline Lee Chantilly , Virginia

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I hope to contribute to the telecommunications field which allows for a better connected world.

Course Comment: This project allowed me to work with networking protocols and their implementations on embedded systems.

Matthew Moreno Long Beach, New York

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I aspire to serve a career as a USN Maritime Cyber Warfare Officer, dedicated to safeguarding our nation's critical cyber infrastructure and enhancing its security.

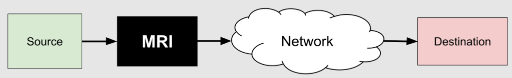
Course Comment: This course provided invaluable insights into the challenges of collaborative teamwork and equipped me with the experience and skills to learn from such challenges and proactively address such issues, empowering me to be a more effective team member in the future.

Multipath Router Implementation

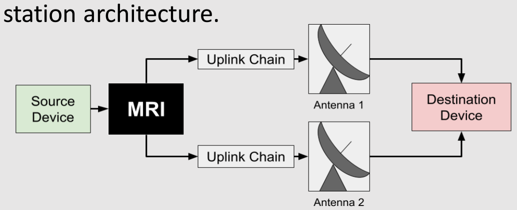
Matthew Moreno, Adaline Lee, Humza Khalil
Sponsor: Jordan Scott, Parsons
Subject Matter Expert: Dr. Tim Talty, Virginia Tech

Background

Parsons develops and integrates systems and platforms with multiple communication systems. A Multipath Router Implementation (MRI) provides Parsons the ability to integrate communication systems within platforms to consolidate redundant communication while optimizing performance and ensuring functionality in degraded networks.



The envisioned use case is within a ground station architecture.

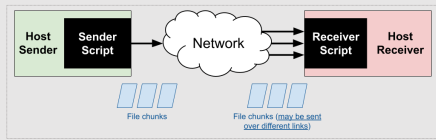


Objectives

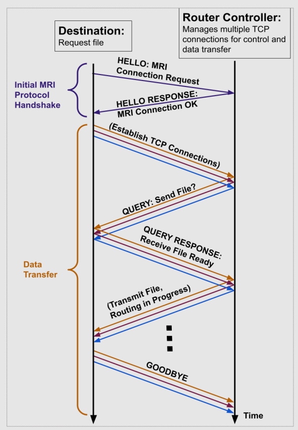
Implement, test, and deliver a simple multi-path communications router capable of routing over multiple links.

- Design a protocol to package existing communication data that requires minimum modifications to existing protocols.
- This protocol should be adaptable enough to change how data is routed based on network conditions.
- Provide performance data of the system, regarding how long it takes to switch routes, limitations on data that can pass through the system, and rates of errors or data loss.

Software & Protocol Design



Our MRI protocol is run in the user-space, handling multiple TCP connections.

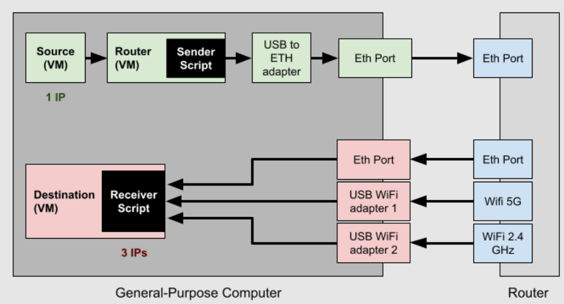


First, we establish the MRI protocol connection.

Then, consider a large file transfer:

1. The file would be split up.
2. Using the MRI protocol, the sender may send the data fragments over multiple TCP connections.
3. Using the MRI protocol, the receiver can reassemble the data fragmented across the multiple TCP connections.

Testing Architecture



We tested this system by transferring large data files. The source and destination are run on one general-purpose computing device, simulated across multiple VMs. The generic router acts as an access point to a generalized network.

Conclusion

- Protocol provides options for selecting one or more TCP connections to send data fragments over.
- Testing platform allows for quick testing of various MRI protocol modes, in addition to adding more physical links.

Moving Forward

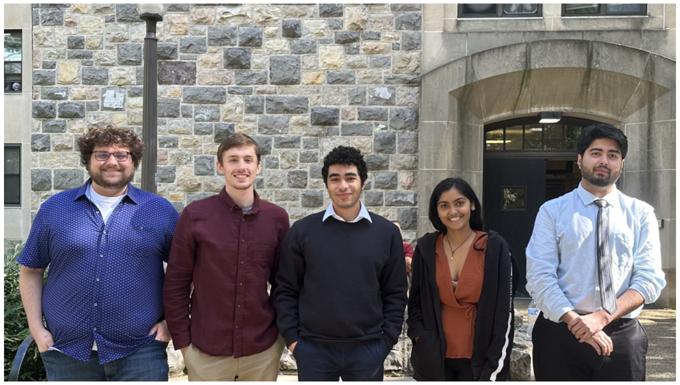
Future work includes:

- Expanding physical layer options: Bluetooth, RF, Zigbee, fiber-optics, etc.
- Kernel-level implementation for greater flexibility, bandwidth, and optimization.
- Additional security measures such as VPN support, packet inspection, and secondary firewalls.
- A proprietary device strictly tasked with housing the routing software, alleviating the need for a general-purpose computer.

Acknowledgement

Our team extends our gratitude to our sponsor and subject matter expert. Thank you, Parsons, for funding this project. Thank you, Jordan Scott and Dr. Tim Talty, for the assistance, advice, and support with our project.

Secure Python Compiler and Bytecode Interpreter



LEFT TO RIGHT: Daniel Santos, Ryan Bellinghoven, Omar Owis, Shefali Ranjan, Sirash Phuyal

SME: Paul Plassmann

CHALLENGE

To develop an extension to the Python language compiler and bytecode interpreter which allows Python to encrypt the application sources. The extension should have the ability to decrypt files using a decryption key. The decryption key is concealed from the user for more secure encryption. The extension executes the decrypted files without writing to the disk beforehand.

PARSONS

Customer: Brent Goodwin

Ryan Bellinghoven Virginia Beach, Virginia

Bachelor of Science in Electrical Engineering
Electrical Engineering
Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I'm happy to aim for something simple. I aspire to find a career I can do for the rest of my life. Right now, that is software development for digital communication security.

Course Comment: I'd like to thank Virginia Tech and Parsons for the opportunity to get introduced to the intricacies of Python. I'm glad to have the lessons from this course to help me become a better engineer.

Omar Owis Cairo, Egypt

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: My aspiration is to become a Cybersecurity professional and innovate new technologies to protect against hackers.

Course Comment: MDE gave me valuable hands-on experience in planning, designing and managing a real life engineering project.

Sirash Phuyal Sterling, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I see myself working in the industry for a couple of years, and then returning to get my Master's. My aspiration is to work with state-of-the-art tools, and assist individuals in seamlessly incorporating emerging technologies into their daily lives.

Course Comment: I had the opportunity to get hands-on experience working with industry-standard encryption tools, identifying and addressing abstract problems and collaborating with multiple teammates to deliver a working product.

Shefali Ranjan Johns Creek, Georgia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: After graduation, I aim to work as a Data Scientist within the fields of Cybersecurity and Machine Learning. I want to work on creating Machine Learning Models that use Cyber Security data to help find vulnerabilities in applications.

Course Comment: I am very grateful to be given the oppurtunity to work with other team members to coordinate and work on a real-world project. This project has given me the oppurtunity to learn about the intricacies of encryption and decryption.

Daniel Santos Alexandria, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: My goals as an engineer are to find interesting opportunities and to see what I can as an individual can accomplish. I want to work on as large of a variety of systems possible so that I can experience all that my degree can offer.

Course Comment: I am very happy to have been able to interact and work in a team environment especially on a more real-world opportunity. This project has enriched my ability to interact and coordinate with others in a work environment.

Secure Python Compiler and Bytecode Interpreter

Team: Ryan Bellinghoven, Daniel Santos, Sirash Phuyal, Shefali Ranjan, Omar Owis
Sponsors: Brent Goodwin & Wes Rose, Parsons

Problem Statement

Our objective was to research and develop an innovative extension to the Python compiler and bytecode interpreter which allows Python to securely create, load, and execute encrypted python bytecode.

Background

Parsons delivers innovative technology-driven solutions in defense, intelligence, and critical infrastructure. Some of these solutions come from third parties and are run on a client's machine. By running the solution on a client's machine, there is a security vulnerability that is introduced. Because the application bytecode has touched the disk of the client machine there is a chance that even after the source application is deleted from the client's machine that the application bytecode could be retrieved and the application could be recreated. To keep possible applications safe from being reverse engineered, our project looks into the idea of running the application in the memory of the client machine.

Objectives

- Application sources will need to be compiled and encrypted prior to being deployed to the host where they will execute.
- Encrypted bytecode that's deployed to different hosts should be unique, verifiable by comparing their SHA 256
- The design should adhere to use established encryption standards while also incorporating robust measures to safeguard the discovery of the encryption key/IV used to decrypt the files.
- The decrypted files should not be written to disk prior to being executed.

Android and Windows Implementation

Required Software and Libraries:

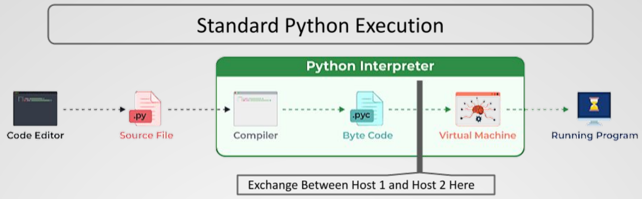
- OpenSSL
- Vagrant VM
- Python 3
  - We use the CPython compiler and interpreter

Android Specific Implementation:

- Termux
  - Terminal window application that lets us have a way to use Python on an android device

android

Design Process

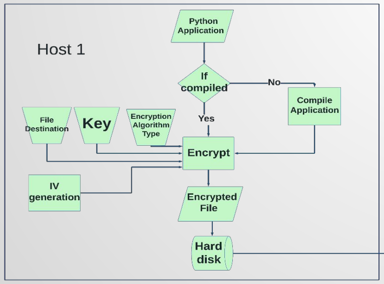


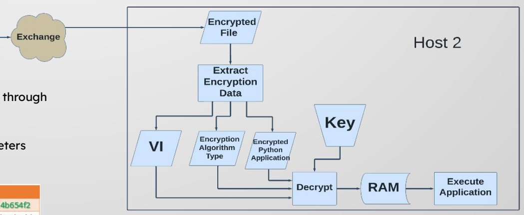
PROTECT CODE AT REST. We needed a solution that did not decrypt into a file on disk while simultaneously delivering that decrypted code to Python for execution. Our team chose to use a design that **overrides Python's "import"** statement because it's responsible for doing just that. It delivers files on disk to the Python interpreter, so the design just modifies how that happens. We dismissed another design that we touch on in the Future Work section of this poster.

PREVENT KEY DISCOVERY. The whole philosophy of modern encryption places all responsibility of security on the key. Practically speaking, if the **key is discovered, security is lost**. Key management escapes the scope of this project, however our project does use it, so should **avoid leaking the key**. We keep the key on disk in a file protected by root user access, so only the owner of the computer can use it.

EFFECTS OF OVERRIDING PYTHON'S "IMPORT." Python's import statement can still use regular unencrypted files, but it needs to know which ones are encrypted. For this reason, each encrypted file must have a **".pyce" file extension**. Due to implementation of the override, the encrypted files must be compiled Python files. A known **vulnerability** of this design is code leaks onto disk when the decrypted code is larger than available computer memory.

- **Compilation and Encryption:**
  - Using a user-friendly interface, Python source files are compiled into bytecode.
  - The compiled bytecode can be encrypted using any algorithms and modes supported by OpenSSL 3.0.8, allowing flexibility.
- Works with any encryption algorithm and mode supported by OpenSSL and can support any key for those methods.
- Each section of code is entirely modular so as to be usable with current systems





- **Unique Deployment:**
  - Encrypted bytecode deployed to different hosts is unique, verifiable through SHA-256 hash digest values.
  - This uniqueness is achieved by randomness of encryption IV parameters across deployments.

Bytecode : encrypted_primesum.pyc	SHA-256 hash
Round 1	862538f228ff467965b21882121e56b4d5449204b4a6333303a0613414b654f2
Round 2	04b24a006d950df5ece650b025c456ae7cd9bd81946991a02792e06bd94d61bb
Round 3	26e096f9ab138d31aab88c1ad1a392e50081fca12f698f43f728b9c060db5d1d
Round 4	d40661d2bcc130aa8a9992e3bbb2bdaa543e21c0e25d08826088f66121a88b8a
Round 5	8ae4ff4271325656ff090b2100cb17b243fcaf40b2957422e88e468c6d7e23d5

- **Key and Initialization Vector (IV) Management:**
  - The encryption key is securely read from a user-specified file.
  - IVs are randomly generated, ensuring compatibility with the chosen encryption mode, and encoded before prepending to the encrypted file using base64.
- **Execution Without Disk Write:**
  - The encrypted bytecode is decrypted in memory and executed without being written to disk.
  - We are limited by the size of available memory and if it extends past real memory and attempts to page swap security becomes riskier

Results and Analysis

Our final prototype encryption module is able to successfully encrypt a file using any algorithm supported by OpenSSL. The encryption module also makes use of IV's in order to ensure that our encrypted bytecode is unique across different hosts. The final decryption module is able to successfully run without saving any code to disk. We also take steps to secure our key by limiting our references to the key itself during runtime. We were able to make sure that the decryption and encryption are entirely modular and able to be interchanged with current systems with minimal work on integration. We had to limit the size of the applications to be less than or equal to the size of the available ram to prevent memory failure or page swaps.

OpenSSL
Cryptography and SSL/TLS Toolkit

Challenges

Encryption architecture limits decryption to entire files at a time

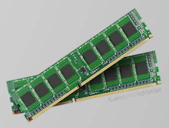
- Problems with single encrypted files
  - Q How do we decrypt files without putting the result on disk?
  - A We pipe the output of an OpenSSL command line call into a variable in memory. From that, we extract an executable Python Code Object
- Problems with multiple encrypted files
  - Q How do we handle when one file is dependent on another encrypted file?
  - A Two dependent files cannot be executed independently; they must use Python's "import" statement. We override "import" to perform single-file decryption

Future Work

Our project is limited by memory as when we run our project it would have to all fit in memory. We have 2 potential solutions to this problem:

Potential Memory issue fixes:

- Enforce encrypted page swaps with a key from a secure web server
- Directly reimplement the CPython compiler & interpreter to decrypt individual program instructions



Acknowledgements

Thank you to our sponsor Parsons as well as the following people who helped us on our journey:

- Dr. Joe Adams - Mentor
- Dr. Paul Plassmann - Subject Matter Expert
- Brent Goodwin - Company Sponsor
- Wes Rose - Company Sponsor
- Our friends and family

L-Band Satellite Tracking and Characterization System

Track 2 Winner

Popular Vote

LEFT TO RIGHT: Jared Jamison, Samuel Taliaferro, Charles Van Horn, Justin Daigle, Ethan Duval

SME: Steve Ellingson

CHALLENGE

The L-Band Satellite Tracking and Characterization System is a portable device designed for use in radio telescope interference research. It consists of a high-gain antenna on a motorized two-axis mount, a sensitive receiver, and continuous Nyquist-rate sampling and streaming to local storage. The system is capable of capturing and displaying the spectrum of Iridium satellite signals with a tuning range of 1550-1700 MHz, maximum gain, and a noise temperature of less than 200 K.

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

Customer: Steve Ellingson

Justin Daigle Montclair, Virginia

Bachelor of Science in Electrical Engineering
Communications & Networking

Aspirations: I intend to gain hands-on experience with hardware development and implementation in an electrical research and development department. Additionally, I'm plan to work towards a Master's Degree in Engineering Management.

Course Comment: I was given the opportunity to work on both systems and electrical engineering, and learned the benefits of efficient organization on the production of a project.

Ethan Duval George Town, Cayman Islands

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: Driven by a passion for cybersecurity, I aspire to deepen my expertise and, in time, establish a pioneering company in the Cayman Islands dedicated to advancing research and fortifying the digital landscape of my country

Course Comment: Working with Dr. Ellingson and Dr. Stover was a great experience, their remarkable expertise enriched my learning experience. The hands-on exposure to hardware and software integration was extremely valuable and greatly enhanced my understanding of the subject matter.

Jared Jamison Callaway, Virginia

Bachelor of Science in Electrical Engineering
Controls, Robotics & Autonomy

Aspirations: I want to build, test, and repair electrical hardware for a technology company, preferably working for the United States Government. In the long-term, my goal is to get a job building and testing robots, which has been a passion of mine since high school.

Course Comment: This course has helped me get real world experience and tackle challenging goals while working individually and as a team.

Samuel Taliaferro Boquete, Panama

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I have a strong desire to work as a software developer in a prominent tech company, where I can learn from the best and enhance my skills. In the long run, my goal is to start my own business, focusing on creating innovative AI tools that can bring change to the industry.

Course Comment: This course gave me hands-on experience developing complex back-end for a software system that interacts with multiple hardware subsystems.

Charles Van Horn Sterling, Virginia

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I aspire to get my master's here at Virginia Tech to enhance my understanding of electromagnetics, and take that understanding to industry where I can work with RF front end components such as antennas and radomes, as well as other applications of electromagnetics.

Course Comment: I am glad I was able to work closely with experts to get more experience with RF front end design as well as system level design working with a skilled team.

Track 2 Winner

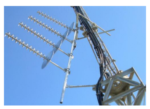
Popular Vote

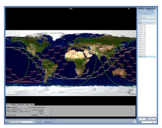
L-Band Satellite Tracking and Characterization System

Team Members: Charles Van Horn, Justin Daigle, Samuel Taliaferro, Jared Jamison, Ethan Duval
Customer / SME: Dr. Steven Ellingson Mentor: Prof. Shelley Stover GTA: Richard Gibbons III

Motivation

Design and develop a portable L-band radio interference research device with a high gain antenna operating with wireless control through a two-axis mount and a frequency sensitive receiver. Other functions include continuous Nyquist-rate sampling and streaming to local storage, two line element (TLE) data conversion into Az/El rotational commands, and queue-based wireless tracking of LEO satellites.





This has applications in the field of RF communication and Signal Processing used in antenna development, analog and digital signal processing, and RF communications.

Objectives

- Deploy an autonomous system to continuously track low earth orbit satellites.
- Develop a central computer system interfaced with a two-dimensional rotator.
- Design a high gain antenna system capable of capturing and displaying the spectrum of satellite signals with a tuning range of 1550 - 1700 MHz.
- Locally store captured satellite spectrum and metadata.

Theory Of Operations

- Activation of the system is performed during calibration by powering on the 12V DC battery, converting to alternating current through a DC / AC converter, and then performing initial rotational / antenna adjustment to ensure accuracy during measurement.
- The onboard computer system then receives a list of TLE commands from the wireless user control unit and sends these commands to the Raspberry Pi to get converted into a schedule for tracking.
- The rotator then adjusts to the required angle, after which the antenna and receiver samples the iridium satellite spectrum and stores this information into the system's local storage.

Sample Operation

1. Assemble system
2. Turn the system on.
3. Input a list of commands for the system to track.
4. The system automatically collects the requested spectral data
5. Return to system at any time and wirelessly connect to the device.
6. Download the desired data to your external device.
7. Power down the system.
8. Disassemble the system and recharge the battery for the next deployment.

System Model & Schematic

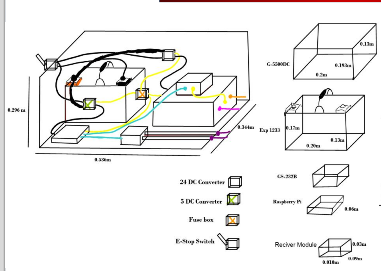


Fig 1. V-1 of Sys. Enclosure (Computer Interface)

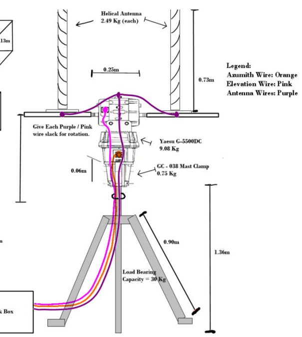


Fig 2. V-1 Schematic of the System

Testing Results

Fig 3. Graph of Antenna S11 Parameter

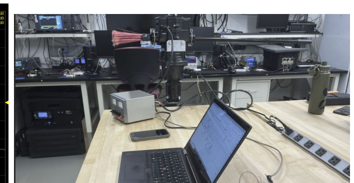


Fig 4. V-1 Rotator & Software System Integration Test

Fabrication Process

The fabrication process for the L-Band Satellite Tracking System involves the assembly of physical components and software. The Raspberry Pi, serving as the central processing unit, is integrated with the Adafruit Feather for precise motor control of the antenna mount and connected to the RSPDuo SDR for satellite signal capture. Python is utilized for backend programming, alongside Arduino code for interfacing with hardware. The system leverages the SGP4 algorithm for automated tracking schedule generation, ensuring autonomous operation post-initial TLE data input via Bluetooth. Thorough testing phases, including comparison with established satellite tracking software and live demonstrations, are conducted to validate the system's performance. The entire setup process is meticulously documented, ensuring ease of understanding and replicability for the client, resulting in a reliable and efficient system.

Future Plans

Some ideas that could improve the functionality of the system as a whole could be:

- Add a camera to the system in order to record it while in operation. This would improve operations by allowing the user to determine if the system is knocked over or out of operation to some degree.
- Increase the battery life. This would increase the lifetime of the system in the field. It would also allow the user to install further upgrades to the system without affecting the total 18 hour lifetime of the system.
- Add an internal charger to the system. This would have the benefit of being able to charge the system without having to partially disassemble the box. This would also have the benefit of the user not having to potentially deal with the crossed wires of partial disassembly.

Sensor Fusion for Autonomous Navigation

LEFT TO RIGHT: Marlin Spears, Carl Nicklas, Rishi Mantha, Mert Kaner, Hayden Craun, Adam Lahouar

SME: John Janeski

CHALLENGE

The project involves developing a sensor suite for Position, Navigation, and Timing (PNT) systems, which are used by autonomous vehicles (e.g. self-driving cars, satellites, UAVs) to determine their current position, desired position, and necessary corrections to get there. The focus of this design effort is to create a low Size, Weight, and Power (SWaP) sensor suite that can help a vehicle navigate in short periods where its primary PNT system does not have access to Global Navigation Satellite System (GNSS) signals.

AEROSPACE

Customer: John Janeski

Hayden Craun Glade Hill, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I desire to use my skills in hardware and software to pursue a career in the embedded systems industry.

Course Comment: This course taught me how to work with a team of engineers to develop a full system while overcoming numerous challenges.

Mert Kaner Guttenberg, New Jersey

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I want to make sure I push my engineering skills to the limit, challenging myself and continue learning while also enjoying life!

Course Comment: This course has helped me get real world experience and tackle challengings goals while working individually and as a team.

Adam Lahouar Blacksburg, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I hope to develop software at a small, quiet company.

Course Comment: This course has reinforced the idea that modern engineering is a team effort above all else.

Rishi Mantha Clarksburg, Maryland

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: My career aspirations are to work on the cutting edge of AI and ML to develop products that make life easier for the common man.

Course Comment: This course has been a great insight into what it's like to work on a real engineering team on a long-term project.

Carl Nicklas West Hartford, Connecticut

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I want to be able to open more time in my life for helping people and hope to volunteer at the Blacksburg Fire Department after graduating.

Course Comment: This course has provided invaluable experience on how to quickly integrate and collaborate with new people. It has improved my ability to communicate in a team project setting and taught me patience when dealing with external challenges.

Marlin Spears Chesapeake, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: My aspiration is to become a software engineer who has extensive knowledge. One who can solve any problem. I also wish to become someone who can help everyone around me with my developer prowess.

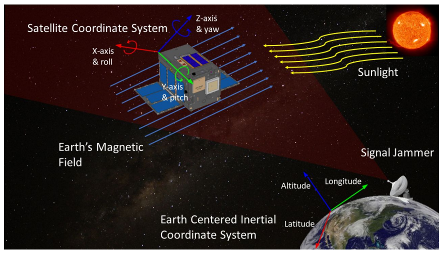
Course Comment: I would say that I learned to understand the need to develop a plan. This class made me more meticulous and taught me the importance of the engineering process.

Sensor Fusion for Autonomous Navigation

Team: Hayden Craun, Adam Lahouar, Marlin Spears, Carl Nicklas, Rishi Mantha, Mert Kaner
Customer / Subject Matter Expert: Dr. John Janeski, Aerospace Corp

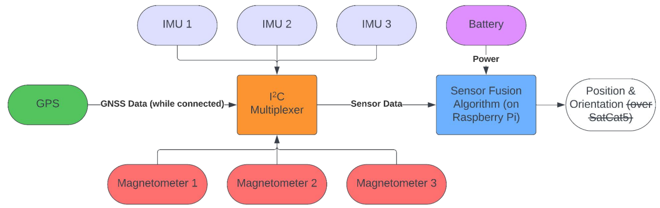
Problem Overview

Create a low SWaP (Size, Weight, and Power) sensor suite to help an autonomous vehicle navigate when GNSS (Global Navigation Satellite System) signals are unavailable to the primary Position, Navigation, and Timing (PNT) system.



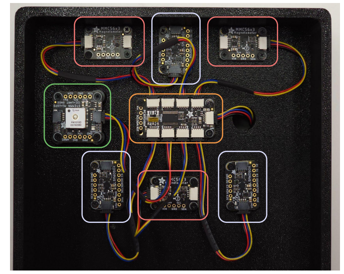
Navigation System Operation Diagram

Top-Level Design

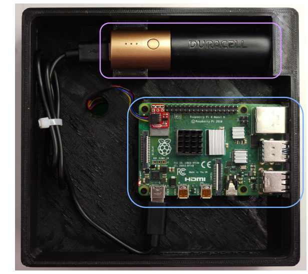


The enclosure is 3D-printed using polylactic acid plastic. On the top face, the I^2C multiplexer is flanked by 3 inertial measurement units and 3 magnetometers, placed in staggered order. The Raspberry Pi and battery power source are housed underneath.

The sensor fusion algorithm uses the last signal from the GPS as the last-known position. The IMUs and magnetometers feed data to the multiplexer, which relays the data to the Raspberry Pi. A new PNT update is then calculated by the algorithm.



Top View

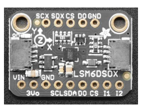


Bottom View

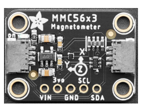
Adafruit PA1010D GPS	Adafruit PCA9548 Multiplexer	Adafruit MMC5603 Magnetometer
Adafruit LSM6DSOX IMU	Duracell 3350 mAh Power Bank	Raspberry Pi 4 Model B

Hardware Used

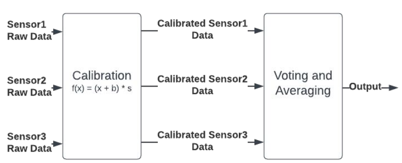
Sensors



IMU



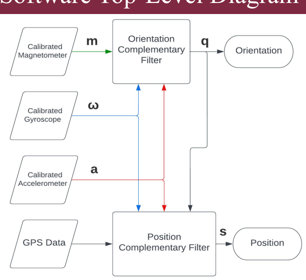
Magnetometer



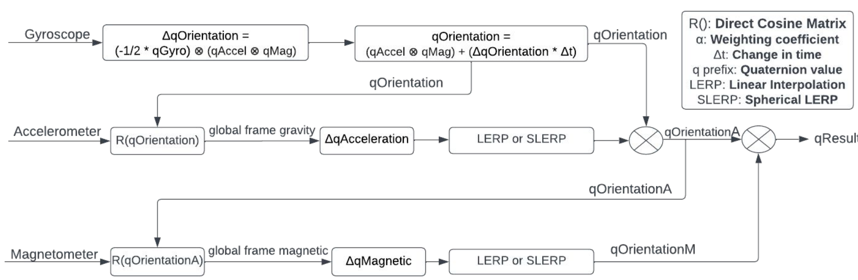
Sensor Calibration/Filtering Diagram

All sensors undergo calibration and filtering procedures before being utilized in the sensor fusion algorithm.

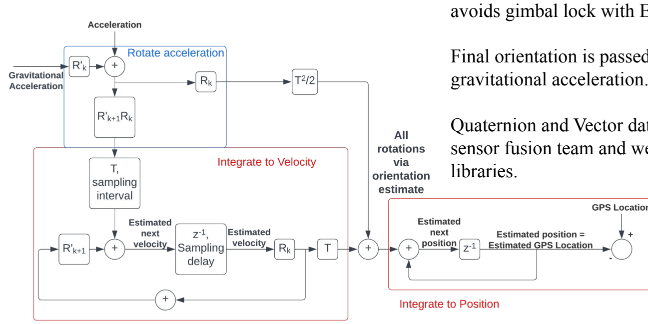
Software Top-Level Diagram



Sensor Fusion



Orientation Complementary Filter



Position Complementary Filter

Quaternions are used to represent the system's attitude. This avoids gimbal lock with Euler angles.

Final orientation is passed to the position filter to obtain the gravitational acceleration.

Quaternion and Vector data structures were written by the sensor fusion team and were more efficient than imported libraries.

Results

Requirement	Value	Test Result
System Size	≤ 10cm x 10cm x 10cm (1U)	15.6cm x 15.1cm x 7.0cm
System Weight	≤ 1.5kg	339g
System Operating Power	≤ 2.0W	4.1W
Runs real-time on a Raspberry Pi	N/A	Yes
Includes an IMU	N/A	Yes
Output Data Rate	≥ 200Hz	53 Hz
Measurement Bandwidth	≥ 80Hz	25 Hz
Angular Dynamic Range	± 50 deg/s	± 125 deg/s
Acceleration Dynamic Range	± 10g	± 16g

Traceability Table with Test Results

Notes on results:

- Output data rate severely bottlenecked by sensor polling rate. One output iteration takes ~20 ms:
  - Data collection: ~19 ms
  - Algorithm: < 1 ms

Future work:

- SatCat5 implementation
- Multithreaded data collection
- Kalman filtering
- Improved sensor calibration

Acknowledgments

The team would like to extend a special thanks to Dr. John Janeski, Richard Gibbons, and Professor Toby Meadows, for their invaluable advice and support throughout this project.

Interstellar Dreams Space Center Simulation Project

LEFT TO RIGHT: Hailey Thomas, Chenhao Wang, Zach Nesbit, Ploypailin Gowitwaraporn, Hanheng Zhang

SME: John Ghra

CHALLENGE

To design and create an interactive simulation demo set on the moon that provides both fun experiences and useful information with the goal to both entertain and spark STEM interest in children aged kindergarten through 12th grade. The simulation should run at least 20 minutes in length and demo different interaction types and level formats in order to provide a variety of information mediums to the client.

INTERSTELLAR DREAMS SPACE CENTER
EXPLORE • IMAGINE • DESIGN

Customer: Robin McDougal

Ploypailin Gowitwaraporn Virginia Beach, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: My goal is to become a computer engineer in the industry and expand my knowledge in game development.

Course Comment: This course provided me with hands-on experience on both the engineering and business sides. It was a great experience to be able to work with a real client. I gained a lot of confidence, knowing that I can apply what I've learned to different kinds of engineering problems before moving on to my professional career.

Zachary Nesbit Raleigh, North Carolina

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: To be a technical expert for a company and pursue research in cutting technology

Course Comment: The course gave me a lot of needed experience on how to work and communicate with clients in a business environment.

Hailey Thomas Williamsburg, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I want to become a leader in the computer engineering field and expand my knowledge of coding and game development

Course Comment: This course has given me a deeper understanding of what it is that I want to do. Being able to create what is essentially a video game, has given me a huge boost of confidence.

Chenhao Wang Henan, China

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: To become a software engineer working for a technology indusry or a game design company.

Course Comment: The course provided an environment where I worked with people on a project that we were unfamiliar with. We also learned how to work on game development. I found these experiences valuable.

Hanheng Zhang Guizhou, China

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: Master the knowledge of electrical engineering and seek opportunities to apply it to future legal work.

Course Comment: The course provided me with the opportunity to gain the experience of the simulation of an actual work and practice various skills in group work. Also, I learned the new ability of using Unreal Engine to implement the designing environment, and became more familiar with coding.

Dream Space Project

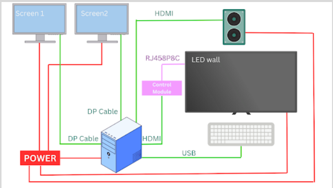
Name: Hailey Thomas, Hanheng Zhang, Zach Nesbit, Ploypailin Gowitwaraporn, Chenhao Wang
Sponsor: Interstellar Dream Space Center
Subject Matter Expert: John Ghra

INTERSTELLAR DREAMS SPACE CENTER
EXPLORE · IMAGINE · DESIGN

VIRGINIA TECH

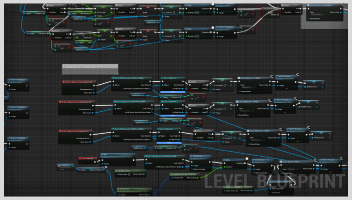
Background

The Interstellar Dreams Space Center tasked our team to engage, analyze, and cultivate an understanding of how information technology, audio-visual technology, and 3D technology are used to create a simulated learning environment made of LED Walls.



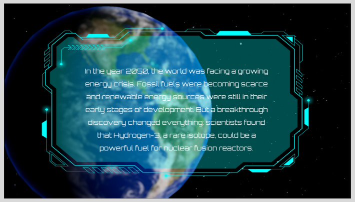
Objective

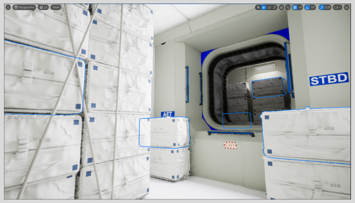
- Design and create an interactive simulation detailing the company's "planetary habitat" room.
- Model a science center on a different planet/moon
- Detail a story and experience for users k-12 to experience.
- Final Deliverables:
  - 2-hour storyboard design for the final simulation
  - Simulation demo of 5 scenes selected by the client



Design Process

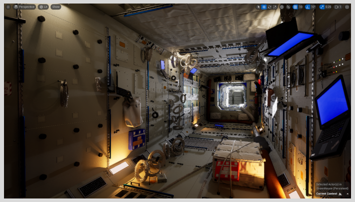
- Hardware decisions are made based on client project operation system requirements.
- Careful design of the entire simulation storyboard to meet the 2-hour time requirement.
- Presentation of the story concept to the client based on group-developed storyboard plans.
- Client selection of key elements from the storyboard.
- Individual team members are responsible for designing the selected key levels in Unreal Engine 5.
- Made the Sprints board for appropriate tasks allocation in accord with an efficient timetable.

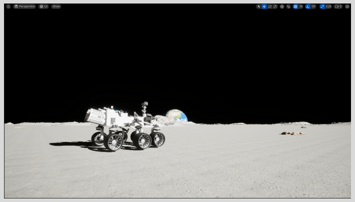




Prototype

- A Simulation menu screen, chapter select, and simulation options
- A combined 5 levels of the planetary habitat room simulation
  - Introduction and user tutorials
  - Mining Tritium on the Moon
  - Greenhouse and space food
  - Moon Exploration
  - Debris Mitigation and Waste Management





Challenges

- Language barriers
- Communication issues and misunderstandings
- Very open problem
- New form of coding/coding language

Final Product

- Interactive Simulation Demo
  - 20 minutes Simulation Demo of 5 selected scenes for the user to experience the planetary habitat room on Moon.
- Detailed Storyboard
  - 2 hour narrative that guides the user through an educational and engaging journey within the simulated space.
- QR CODE

Acknowledgements

Our team thanks...

Robin McDougal,
John Ghra,
Chimene Davis,
Kevin Taylor

Object Detection with Computer Vision and Machine Learning

LEFT TO RIGHT: Michael Kattwinkel, Jimmy Cook, Jay Yim, Jalen Neal, Hayley Wisman, Christopher Vanwinkle

CHALLENGE

Small object detection is an under-researched area within computer vision rife with real-world potential. UAV and satellite imaging often capture distant objects that appear very small and can be obscured by traditional object detection models. Detecting these features, however, can have useful applications in important fields like military reconnaissance. The goal of this project is to meet these needs by identifying and applying cutting-edge model architectures to detect small objects.

DEVCOM ARMY RESEARCH LABORATORY

ÂSPIRE CAPSTONE

SME: Creed Jones

Customer: **Creed Jones**

James Cook Falls Church, Virginia

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Upon graduation, I will be pursuing a master's degree in computer engineering. My goal is to continue learning and challenging myself within and outside of the field of engineering.

Course Comment: This course has given me the opportunity to develop my engineering skills, as well as other skills applicable to an engineering career in the corporate environment. I've learned how to better collaborate with a team as well as SMEs, mentors, and customers to work towards a final product that fully represents the needs of the customers.

Michael Kattwinkel Charlottesville, Virginia

Bachelor of Science in Computer Engineering
Software Systems

Aspirations: I want to pursue a career in Software Engineering, in various fields starting with full-stack development.

Course Comment: This course has helped me learn by experience, particularly everything that comes along with a full life-cycle engineering project, and the challenges that come along with it.

Jalen Neal Springfield, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Following graduation, I aspire to enter the field of Software Engineering, honing in on Machine Learning applications. My goal is to leverage my skills to address novel problems and contribute to cutting-edge solutions.

Course Comment: The course has provided a valuable opportunity to learn and apply skills to work on and accomplish a common goal. Working on a transdisciplinary team with SMEs, Mentors, and Customers to define and develop a final product was a valuable experience that has enhance my perspective on what is needed to succeed as an engineer

Christopher Vanwinkle San Jose, California

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: Ideally, no matter where I end up, I hope that I will continue to educate myself about topics both in and outside of engineering.

Course Comment: This course has given me insight on how team dynamics can evolve over a longer term project.

Hayley Wisman Edinburg, Virginia

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: My interests in engineering are broad, but my ultimate goal is simply to continue learning, challenging myself, and evolving to become a better person and engineer.

Course Comment: Senior design is a valuable experience that not only challenges students on their technical prowess, but also on their skills in project management and collaboration. It fosters growth by creating an environment where failure is not strictly punished, but presented as an opportunity to learn and improve.

Jiwoon Yim Fairfax, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Upon graduation, I will be commissioned into the United States Air Force as a Computer Systems Engineering Officer

Course Comment: Throughout this course, I have learned many valuable lessons from how to work in a professional team environment effectively to insights on engineering product life cycle.

Object Detection using Computer Vision & Machine Learning

Hayley Wisman, Jay Yim, James Cook, Jalen Neal, Christopher Vanwinkle, Michael Kattwinkel
Sponsor: Matthew Wilchek, Victor Villacis - US Army C5ISR
Subject Matter Expert: Dr. Creed Jones, Virginia Tech

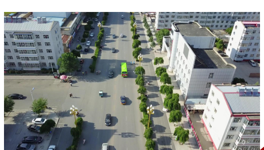
Abstract

The realm of small object detection has witnessed the release of multiple iterations of YOLO, a widely employed model for image classification and object detection. Small object detection presents a distinct set of challenges when juxtaposed with the broader field of image classification. This specialized task hinges on the model's precise classification of objects that may span only a few pixels.

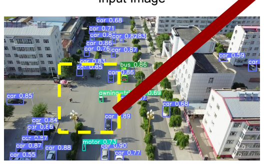
While current techniques have demonstrated impressive performance with limited input information, the integration of the latest YOLOv8 model, coupled with supplementary processes like SAHI (Slicing Aided Hyper Inference) and tiling during training, holds significant potential for elevating the efficacy of small object detection beyond the capabilities of existing models.

Background/Objective

Small object detection has been ongoing research in the field of image processing and machine learning. Due to the nature of size of these small objects, which could only be a few pixels, many existing object detection models struggle to predict and classify them in their detection approach. Often, these small objects do not get detected due to factors such as occlusion, background clutter, and variations in lighting conditions. An example prediction with these issues is below:



Input Image



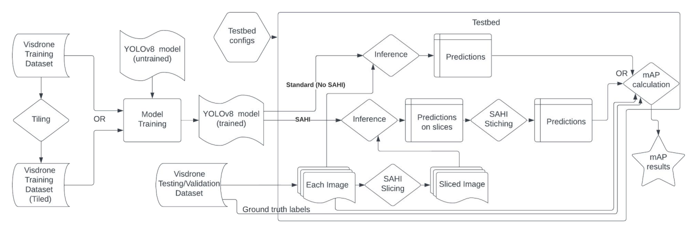
Objects Predicted (with baseline model)

Our research objectives are the following:

1. Attain a mean average precision at 0.5 IOU threshold (mAP@0.5) of no less than 0.5 on the VisDrone dataset
2. Improve model robustness, or performance on images that have suboptimal conditions

Approach

Architectural Design



Model and Dataset

We utilized YOLOv8 as the object detection model for our development effort because of it's high speed and baseline accuracy[1]. The model was trained on the VisDrone dataset, consisting of drone footage of various cities in China. For consistency, we trained our models for 100 epochs and a resolution of 640px.

Testing

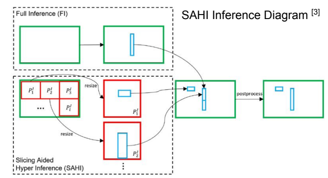
To test for mAP throughout this process, we built a testbed that quickly runs inference on the Visdrone dataset and calculates mAP (see right side of Architectural Design).
All mAP values are from the test partition of the VisDrone dataset.

Baseline model predictions vs Final model predictions

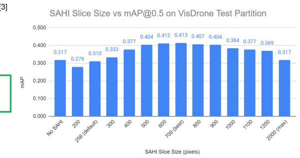
Baseline model (YOLOv8L) vs YOLOv8L trained on 640px tiles, inference with SAHI 640px slices
Our final model shows visual improvement compared to the YOLOv8 baseline, specifically with very small objects. Part of the image is focused on to highlight these additional detections.

SAHI

SAHI[2] is a library designed to improve small object detection by breaking down an image into smaller slices, running inference on each slice, and stitching together the results. It also increases the relative size of each object relative to the image, potentially affecting model accuracy. We found that with a slice size too small, there are many false detections, and with a slice size too large, it has limited benefits. We found that in our case, a slice size of around 700px performed the best.



SAHI Inference Diagram [3]



Tiling

When training a YOLO model, every image gets downsampled to 640x640 px during training, resulting in some pixel loss. We implemented a tiling method to address this. Tiling breaks up the image into 640x640 px smaller images (similar to SAHI but done before training), and trains the model on them. This eliminated loss of pixels in the training set, but will took longer to train. When this new model was ran with SAHI (slices of 640), it had great performance (see results).

Model Robustness

To handle non-ideal imaging, we trained a model on an altered dataset to improve performance on noisy images. A sample image before and after transformation is below:

Original Image

Transformed Image

Model	mAP@0.5 standard dataset	mAP@0.5 altered dataset
YOLOv8L trained on standard dataset (baseline)	0.3165	0.1410
YOLOv8L trained on altered dataset	0.3003	0.2461

Results

Model	mAP@0.5 VisDrone test partition
Yolov8L baseline	0.3165
Yolov8L + SAHI (default configs)	0.3104
Yolov8L + SAHI @ 700px	0.4130
Yolov8L trained on 640 px tiled dataset + SAHI @ 640px	0.4827

Conclusions

Processing images through methods such as SAHI has great potential to improve small object detection, but there are key considerations:

1. Object detection models use object size to aid in categorization. To offset problems this may cause,
   a. Use larger tile sizes to mitigate detection issues
   b. Train the model on pre-tiled images that replicate the SAHI slice sizes

Future work:

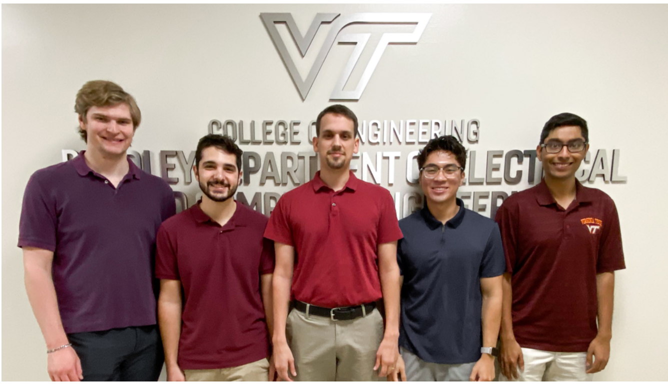
1. Vary the tile sizes based on the depth of the image to maintain the same scaling factor for objects in the foreground and background
2. Use the size of other spatially nearby objects in order to help determine if a detection could be a false positive.

References

[1] Ultralytics, Ultralytics YOLOv8 Docs, https://docs.ultralytics.com/ (accessed Oct. 26, 2023).
[2] F. C. Akyon, C. Cengiz, S. O. Altinuc, D. Cavusoglu, K. Sahin, and O. Eryuksel, "SAHI: A lightweight vision library for performing large scale object detection and instance segmentation," Nov. 2021. [Online]. Available: https://doi.org/10.5281/zenodo.5718950. doi: 10.5281/zenodo.5718950.
[3] STPM_SAHI: A Small-Target Forest Fire Detection Model Based on Swin Transformer and Slicing Aided Hyper Inference - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/The-process-of-slicing-aided-hyper-inference_fig5_364257753

Best Overall

Swing Stabilization for MEDEVAC Rescues



LEFT TO RIGHT: Ryan Gurney, Mario Termine, Hayden King, Hoan Pham, Sachin Dhiman

SME: Walter Lacarbonara and Mary Lanzerotti

CHALLENGE

Design, build and test a system that interfaces with a MEDEVAC rescue hoist in order to stabilize a swinging payload. When the payload reaches a swing angle greater than five degrees the system is turned on to stabilize the payload by adjusting cable length at specific times determined by the stablization algorithm.

Customer: Thomas Aldhizer

Sachin Dhiman Albertson, New York

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: My career goal is to work as an electrical engineer with a power utility company where I can apply the skills I have learned to solve hands-on problems.

Course Comment: This course has provided me an invaluable experience of working in a real engineering environment and solving complex problems in teams.

Ryan Gurney East Hanover, New Jersey

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

Aspirations: My career goal is to contribute to the world in a positive manner helping people or making their lives easier in some way. A way that I most immediately hope to accomplish this is through assisting in our nation's goverment.

Course Comment: The experience of working with an industry sponsor and understanding the practice and steps of completing an engineering project from start to finish.

Hayden King Kempton, Pennsylvania

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: I have always aspired to be useful and help others. I want to working in the power industry to provide electricity to peoples homes.

Course Comment: This course has taught me the importance of strong team communication and participation. There's been a lot of hurdles to overcome this year and without such a great group of engineers we would not be where we are.

Minh Pham Fairfax, Virginia

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I hope to become a competent engineer to drive the society to be a better place

Course Comment: This course showed me how to face difficult circumstances and how to overcome them.

Mario Termine Mahopac, New York

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: I want to be able to use my skills to improve sustainability and promote green energy.

Course Comment: This course gave me insight and experience on what we might expect in industry, including the aspects you can't learn without actually doing it for yourself.

Swing Stabilization for MEDEVAC Rescues

Team Members: Sachin Dhiman, Ryan Gurney, Hayden King, Hoan Pham, Mario Termine
SME: Dr. Mary Lanzerotti **Customer:** Ian Azeredo, Breeze Eastern
Mentor: Prof. Shelley Stover

Objectives

Helicopter payloads for medical evacuation are difficult to stabilize once oscillation forces during lifting cause the payload to swing. This can pose a threat to both the crew in the helicopter and the patient attached to the line.
The goal is to create a working system which can control and stabilize the hoist provided by Breeze-Eastern by using a 2-D pendulum stabilization algorithm.

System Requirements

- Utilize Breeze-Eastern Hoist
- Control hoist speed and direction by using a 0 - 10V analog signal
- Monitor the swinging angle, angle velocity, and cable length
- Stabilize the rescue swing from a starting angle of 15 degrees to 5 degrees within 30s

Algorithm

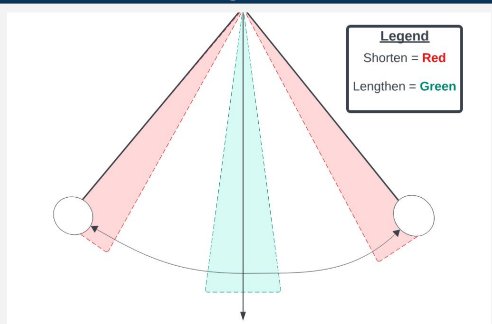


Figure 1: Algorithm Model

The algorithm stabilizes by shortening and lengthening the length of the pendulum in the defined regions above to decrease the angular amplitude. The algorithm is based and simulated on the second order differential equation of motion. This concept was provided to us by our SME.

Hardware

1. Main Processing:
   - This system is used to interface with the hoist, collect data from the payload, display and record data received, and apply the algorithm. It utilizes a Teensy 4.1 microcontroller to process all the information. STDP relays are used to disconnect pendant controls from the hoist and a MOSFET circuit to control the direction of the hoist.
2. Payload:
   - This system is located near the bottom of the cable. It utilizes a Berry IMU gyroscope to collect angle and velocity. An Arduino Nano is used to process and send the data over bluetooth to the main processing housing.

System Sequencing

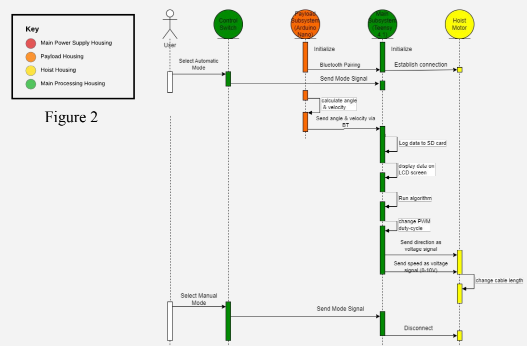


Figure 2

Test Results

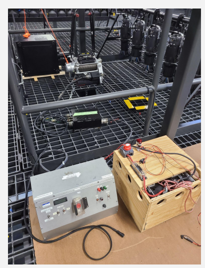


Figure 3: Test Setup

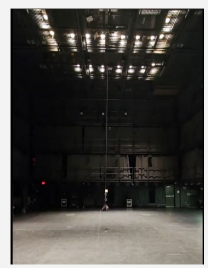


Figure 4: Hoist Payload

As seen in figure 5, the free swing data from the payload shows the measured angle and angular velocity of the 2d pendulum.

Tests were conducted at the Moss Arts Center. Due to the nature of the hoist cable, the payload spun with the cable which caused incorrect angle and angular velocity readings. Spinning was minimized during free swing, but pulling up or down using the hoist introduced a lot of unwanted movement and invalidated many of the test results.

By manually controlling the hoist to mimic the algorithm's characteristics, we were able to prove the algorithm's effectiveness in reducing the swing angle.

Figure 5: Free Swing Test with Hoist

Lessons Learned

1. Limited processing power of Teensy 4.1:
   - Restricted ability to communicate with multiple hardware devices at the same time
   - Single-core processor is incapable of meeting tasks' deadlines. Multi-core processor is recommended
2. Bluetooth communication:
   - Limited signal range
   - Connection stability (packet loss, EMI)
3. Payload housing:
   - Not a good solution for military use due to the rechargeable battery
   - Bluetooth communication is not secure
4. Hoist motor jerking:
   - Motor triggers instantly without ramping up or down
5. Gyroscope:
   - Difficult to prevent spinning on the cable which interferes with the axis readings

Future Plans

1. Further develop the algorithm:
   - The stabilization algorithm utilizes two constants for when to pull up and let down the cable. These constants are angle and angular velocity. Further development is need for these constants to be suited for the Breeze Eastern hoist.
2. Alternative sensor for angle and angular velocity.
   - The future sensor design can be seen below in figure 6 and figure 7. This design will be a mechanical design that is attached right where the cable exits the hoist drum. This would be similar to a joystick and would use potentiometers to read the angle and angular velocity. This design eliminates the need for a payload housing and would eliminate the battery, bluetooth, and unpredictable spinning of cable.

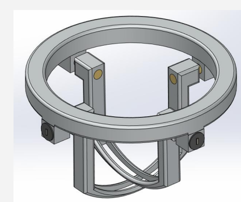


Figure 6: Gimbal Sensor (Side View)

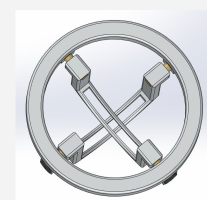


Figure 7: Gimbal Sensor (Top View)

Acknowledgements

We would like to give special thanks to the following people who made this project possible.

- Moss Arts Center Staff
  - Adam Cook (Stage and Rigging Supervisor)
  - Doug Witney (Director of Production)
- Richard Johnston (Freight Shipment Coordinator)
- Richard Gibbons (MDE Lab Manager)
- Redwan Bijoy (Breeze Eastern)
- Thomas Aldhizer (US Army)

Programmable Impedance Network

LEFT TO RIGHT: Zhiqi He, Ze Zong, Isaac Shiley, Coury Gaffney, Anirudh Kurma, Zhen Zhang

CHALLENGE

A prototype of a programmable impedance network has been developed to emulate the impedance characteristics of various offshore HVDC cable transmission lines around the world. This design provides an invaluable tool for researchers and engineers, enabling precise simulations and testing of HVDC cable transmission scenarios representative of global undersea power grids.

CPES
Center for Power Electronics Systems

SME: Jiaxiong Yu

Customer: Richard Zhang

Coury Gaffney Arlington, Virginia

Bachelor of Science in Electrical Engineering
Micro/Nano Systems

Aspirations: I hope to use what I've learned to help people, and make a positive impact on the world in any way I can.

Course Comment: An invaluable amount of information can be learned from this course. It is a phenomenal experience in learning and using engineering in a practical setting. What you learn to do, and more importantly, what not to do, will stick with you for your career.

Zhiqi He Guangzhou, China

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I aspire to become a distinguished engineer, capable of developing innovative and pioneering products that address the requirements of the modern populace.

Course Comment: This course has proven to be an invaluable learning opportunity for me. Throughout its duration, I collaborated with exceptional pre-engineering peers, diligently striving to deliver work that meets the precise requirements of the client. It is unequivocally one of the most advantageous courses an undergraduate aspiring to excel in engineering can undertake.

Anirudh Kurma Mumbai, India

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I'm dedicated to acquiring deep knowledge and honing my skills for a future where I can contribute to cutting-edge AI advancements

Course Comment: This course has been an interesting challenge in team communication and working as a unit to deliver a well engineered product

Isaac Shiley Winchester, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: My dream is to use my engineering skills to leave a positive impact on the world by making the electric grid cleaner, introducing more green energy in order to tackle climate change.

Course Comment: Throughout the year I have spent during MDE, I have had a sandbox to transform my technical knowledge into professionalism. Through all the challenges and failures along the way, I discovered what works and what doesn't, and gained a better perspective of life in industry.

Zhen Zhang Zhengzhou, China

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Contribute my efforts to the advancement of human civilization, making the world cleaner and more harmonious

Course Comment: This course is an assessment of the knowledge students have acquired, to verify whether they have become competent engineers. Before they start contributing to society, they undergo simulated real-world scenarios. Through this course, I am confident in moving into practical application.

Ze Zong Sichuan, China

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: My aspiration is to acquire knowledge and skills, that allow me to pursue a career that I am deeply passionate about.

Course Comment: This course offers an opportunity for you to enhance your teamwork skills, while also experiencing the joy that comes from collaborating with your fellow group members to tackle challenges.

Programmable Impedance Network

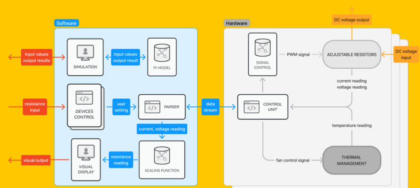
Anirudh Kurma, Coury Gaffney, Isaac Shiley, Zhiqi He, Ze Zong & Zhen Zhang
Sponsor: Dr. Richard Zhang, Subject Matter Expert: Jiaxiong Yu

Background & motivation

Offshore wind farm electricity transmission is vital. By 2040, the International Energy Agency predicts offshore wind power capacity will hit 130-180GW, making transmission lines critical. A breakdown can paralyze power systems, causing major consequences. Therefore, it's key to simulate and optimize these systems in labs. This project aims to emulate offshore transmission line characteristics and create a model network. Researchers will adjust parameters to simulate specific offshore transmission scenarios.

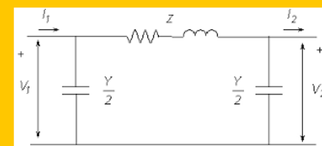
Objective

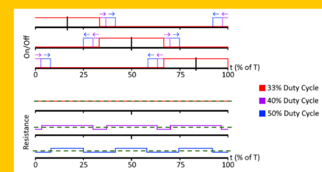
- Design a prototype of programmable impedance node that can form an impedance network for simulating real-world power transmission grid scenarios in a lab.
- Each node has dynamic impedance adjustment capability.
- Nodes are monitored through software for:
  - Resistance
  - Temperature
  - Other related values
- Nodes can be interconnected to form the Programmable Impedance Network (PIN).
- Software enables simultaneous setting of multiple nodes for simulating various scenarios.



Methodologies

- Pi-model
  - control the resistance, inductance, and capacitance per length through computer program
- Control signal
  - Altering the duty cycle of MOSFETs will change the resistance
  - Resistance MIN: 33Ω @ 100%
  - Resistance MAX: 100Ω @ 33%
- Scaling function
  - Scaling the reading values from the device to scenario range
  - Scenario range: 0.01 - 20Ω
  - Our range: 33 - 100Ω
  - F(x) = 0.298358x - 9.83582

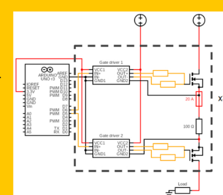


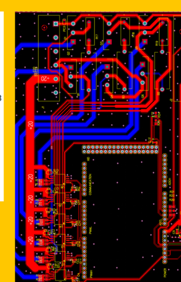


Design

Hardware design:

- Uses a control unit (Arduino) to generate the Pulse Width Modulation (PWM) signal to MOSFETs to achieve the desired R_DS(on) resistance values
- Configuration involves three parallel branches, each with a pair of MOSFETs connected drain-to-drain for bidirectional power flow, with a resistor between.
- Adjusting resistance by varying the overlap of PWM signals through duty cycle control for the three branches.



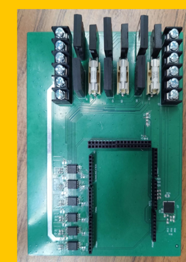


User friendly graphical interface for:

- selecting cables and required parameters for both simulation and real-world application
- user input to change simulation parameters in real-time
- displaying output in real-time as numerical and graphical representation
- quick switching between cable presets stored in local database
- multi-device selection and monitoring

Summary

The P.I.N project is a critical component for the CPES lab. It aims to emulate HVDC transmission lines in real-world systems, such as offshore wind farms by allowing users to control the resistance and impedance of the network. This project incorporates both hardware and software components to create a versatile tool for simulating and testing different transmission line scenarios, serving as a valuable asset for research and development in power electronics systems.



Name	Value
Switch frequency	10kHz
Input voltage	≤40V
Input current	≤18.2A
MAX input current	20A
Gate driver supply voltage (VCC1)	3.3V
Gate driver supply voltage (VCC2)	24V
Control unit supply voltage	7~12V
Simulated resistance	0.01~20Ω ± 0.99mΩ

Future work

- Utilize the ON resistance feature of MOSFETS to generate all resistances
- need for further research on Mosfet-driven inductance and capacitance, and on more effective high-voltage resistance control methods.
- Close loop in software
- Multiple control unit connections

Limitation

- Scale high-voltage circuits down to the Extra Low Voltage (ELV) range for safety and consistency reasons.
- Aim to model a complete transmission line, but initially only include resistance due to time and budget limits.
- Incorporate a 100Ω resistor in series with R_DS(on) to achieve higher maximum resistance, as a cost-saving measure.
- PCB enhancements are required to manage greater currents and improve thermal response.

Communication Interface Development for Power Converters in Microgrids

LEFT TO RIGHT: Ivan Torres, Rong Xiao, Bowen Zheng

CHALLENGE

Design and build a software interface that facilitates seamless communication among multiple power converters. It is designed to effectively dispatch pre-set commands to the converters, following a predetermined routine, and proficiently receive measurements, showcasing them through an intuitive Graphical User Interface (GUI).

CPES Center for Power Electronics Systems

SME: Haris Bin Ashraf and Vladimir Mitrovic

Customers: Dushan Boroyevich and Richard Zhang

Ivan Torres Woodbidge, Virginia

Bachelor of Science in Electrical Engineering
Energy & Power Electronics Systems

Aspirations: I aspire to work on renewable energy, with the aim of creating a greener future, and helping people along the way.

Course Comment: This course has provided me with the opportunity to improve not only as an engineer but also as an individual.

Rong Xiao Chengdu, Sichuan, China

Bachelor of Science in Computer Engineering
Computer Engineering

Aspirations: In my graduation project, I have a profound aspiration and ambition to develop MicroGrid software for intelligent control of power converters, thereby promoting the sustainability and efficiency of power systems. Additionally, I am keenly interested in the fields of Artificial Intelligence (AI) and Mixed Reality (MR) human-computer interaction. I hope to integrate these interests in the future, contributing to the creation of a cleaner, more efficient energy future and innovative applications of AI and MR technologies. I am confident in my ability to pursue a graduate degree to further deepen my knowledge and professional capabilities, enabling me to better realize these aspirations and ambitions.

Course Comment: This senior design course has provided me with valuable hands-on experience, bridging the gap between theoretical knowledge acquired in school and practical project execution. Through this course, I have not only solidified my academic understanding but also cultivated essential skills such as problem-solving, teamwork, and project management, which are pivotal for my career growth. Moreover, it has allowed me to integrate interests spanning various fields, setting a strong foundation for my future professional endeavors.

Bowen Zheng ZhengZhou, Henan, China

Bachelor of Science in Electrical Engineering
Electrical Engineering

Aspirations: In my future career, I aspire to apply the knowledge and skills I acquired in college to the real world.

Course Comment: This senior design experience has given me a firsthand understanding of what a real-world project entails, equipping me with the knowledge of how to initiate a project from its inception and effectively communicate with both clients and mentors.

Software Interface
For Power Converters in Microgrids

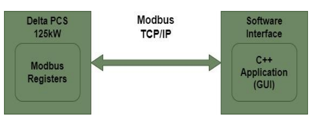
Team Members: Bowen Zheng, Ivan Torres, Rong Xiao
Sponsor: Dr.Dushan Boroyevich and Dr.Richard Zhang
SME: Haris Bin Ashraf and Vladimir Mitrovic

Background

- **Microgrids are localized energy systems that can operate independently or in conjunction with the main power grid, consisting of distributed energy sources, storage systems, and loads. To establish an efficient Microgrid, cooperation between a Power Converter is essential.**

Objectives

- **Build a Software Interface that communicates between multiple Delta PCS 125 kW Power Converter and a Graphical User Interface(GUI). The GUI shall control and operate the PCS.**

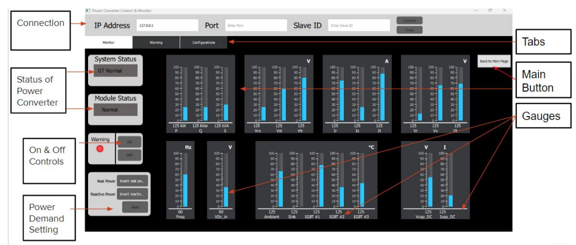


Requirements

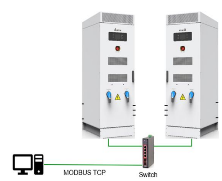
- **Control & Monitor Multiple Power Converters**
- **Display the Measured Parameters Values & Commands Through a GUI**

Solution

- **The Software interface allows users to effortlessly monitor and control, read values like voltage, power, current ect., display warnings to multiple Power Converters**
- **Regarding the hardware aspect, 2 Power Converters are connected via a network switch, utilizing the MODBUS TCP protocol for communication and data exchange.**



GUI Interface for Power Converters



Hardware Connection

Results

- **Communications between the Software Interface & Power Converters was successful**
- **Can Operate and Monitor Multiple PCS**
- **Additional Power Converter can be added to the Software Interface**

Challenges

- **Testing can be difficult without direct access to the Power Converter**
- **Internal workings of a Power Converter are difficult to know**

Future

- **Adding features such as Peak-Shaving Mode, Low/High Voltage Ride-Through and Low/High Frequency Ride-Through**
- **Be able to control more than 2 Power Converters through the GUI**
- **Adding other Power Converters than Delta 125kW PCS**

Measurement and Test Automation using Low Cost Instruments

Track 3 Winner

LEFT TO RIGHT: Joseph Ha, Tahj Caines, Nolan Donovan, Heesang Han, Barkin Keskinturk

SME: Carl Dietrich

CHALLENGE

We developed a free and open source, modular library to communicate Standard Commands for Programmable Instruments (SCPI) for the tinySA, a low cost spectrum analyzer and signal generator, used in RF testing and measurement applications. Our overall package contains our source code, documentation, and pre-written example experiments and applications to showcase the tinySA's capabilities, but through standardized commands and automated scripts.

NORTHROP GRUMMAN

Customer: Carl Dietrich

Tahj Caines Virginia Beach, Virginia

Bachelor of Science in Electrical Engineering
Micro/Nano Systems

Aspirations: I strive to pursue a career in the semiconductor industry with a focus on working with nanosystems.

Course Comment: Through this course, I have gotten a different perspective on how industries operate; thus, giving me a better grasp of what to expect post graduation.

Richard Donovan Richmond, Virginia

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I aspire to lead a team of engineers on a project that has the potential to outlive me.

Course Comment: This course has given me great insight into the life cycle of a software project and has taught me valuable lessons about operating on a software team.

Hyun Myung Ha Seoul, South Korea

Bachelor of Science in Computer Engineering
Controls, Robotics & Autonomy

Aspirations: I want to be part of a team of engineers who create products to make this world a better place, day by day.

Course Comment: MDE gave me the opportunity to connect and interact with other engineers at a level which no other class could provide.

Heesang Han Sejong, South Korea

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I strive to pursue master's and PhD degree to be a researcher in Machine Learning and Computer Vision area.

Course Comment: I strive to pursue master's and PhD degrees and become a researcher in Machine Learning and Computer Vision areas.

Barkin Keskinturk Istanbul, Turkey

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I strive to pursue projects that tackle everyday problems and make a positive difference in people's lives, while building my skills in the Machine Learning field.

Course Comment: This course has helped me identify and formulate project requirements with team members and gave me understanding of software development on a collaborative environment.

Track 3 Winner

VIRGINIA TECH

Python Interface for a Low Cost Spectrum Analyzer

Nolan Donovan, Joseph Ha, Barkin Keskinturk, Heesang Han, Tahj Caines
Sponsor: Dr. Carl Dietrich, Wireless @ VT
Subject Matter Expert: Dr. Carl Dietrich

NORTHROP GRUMMAN

Motivation

The tinySA is an ~$80 miniature spectrum analyzer and signal generator that serves as a low-cost alternative to laboratory-grade RF test and measurement instruments whose costs can range between $10k to $20k. However, it was difficult to replicate processes because the tinySA primarily relies on manual user input. **Our team developed a library that users can write scripts to automate and reproduce behavior of the tinySA.**

Objectives

1. ***Intuitive*** to use for both existing and new users
2. ***Scriptable*** / Automated actions, like in industry grade measurement instruments
3. ***Accessible*** to everyone: free to copy, use, and distribute without invasive or proprietary license
4. ***Functional*** to manual operations of the tinySA
5. ***Demonstrative*** examples showcasing library usage

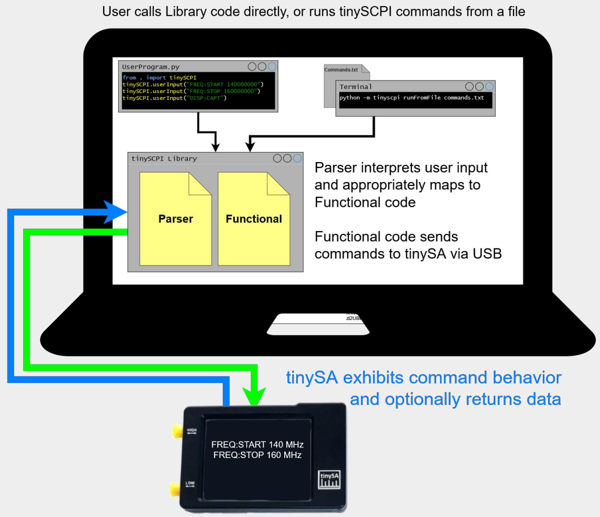
Results

1. User interface and command set resembling the **IEEE-488.2 (SCPI) syntax** that **uses the existing tinySA command tree vocabulary**
2. Interface written using **Python 3.10**, a language relatively **straightforward to use**.
3. **Free and Open Source** under MIT License, hosted on Github publicly
4. Replicates **>96% of physical functionality**
5. Includes **documentation** and **pre-written lab scripts**

Final Product

Demos

Design



Parser Module

- Validates user-input SCPI commands, syntax, arguments and ranges.
- Uses dictionaries for validating commands, types, ranges.
- Checks, tokenizes, and validates, raising errors as necessary.

Functional Module

- To replicate functionality of the tinySA, we remapped its USB commands to commands resembling the menu tree.
- For features that didn't have an injective mapping, the functional library calls sequences of commands associated as a level of feature emulation.

Returns

- Library handles commands that return data over serial.
- Stores the data within the program's execution.
- Allows users to save or manipulate data via other program or third-party calls.

Command Tree

System Commands (*CMD):
Information regarding device itself

FREQuency:
Settings relating to the frequencies to scan (start, stop, RBW, etc.)

LeVeL:
Settings related to level of signals being measured (units, gain etc.)

TRIGger:
Manipulates trigger behavior (continuous, one-shot, level etc.)

TRACe:
Controls various aspects of how trace data is shown

DISPlay:
Controls the display on hardware

MARKer:
Sets and gets marker information

MEASure:
Sets and gets quick measurement information (harmonics, SNR etc.)

CONFig
Auxiliary tools to assist tinySA usage (i.e. screen capture)

SYSTem:
Commands relating to device operation (i.e. input/output mode)

github.com/noldono/tinySCPI

Challenges

- Designing system ergonomics for users not familiar with programming
- Controlling receive/transmit strength for safety
- Emulating tinySA functionality without a direct tinySA USB command equivalent
- Interpreting and working with the existing tinySA commands and documentation

Acknowledgement

The team would like to thank our Subject Matter Expert, **Dr. Carl Dietrich** and Mentor, **Prof. Toby Meadows** for their continued support of our team.
Special Thanks to **Erik Kaashoek**, developer of the tinySA

Project Contributor Acknowledgements

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

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

Joe Adams, Kelley Andrews, Daniel Connors, Toby Meadows, Ken Schulz and Shelly Stover
for being our mentoring teams and making the class and all involved with it better.

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

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

Afroze Mohammed, Karin Clark, Megan Wallace and Lisa Young
for being our partners and diligently working to nurture our industry relationships and to secure those critical sponsorships.

Arthur Ball, Daniel Connors and Toby Meadows
for providing guidance, support and great value to our competition teams.

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

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

Donald Leber
for providing cleanroom access and training for students

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

Brandon Russell, Shrestha Agarwal and Beenaa Salian
for solving our many IT issues and printing all these posters in, literally, no time.

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

Special thanks to Rutwik Joshi and Amrita Chakraborty
for teaching, coaching and mentoring our cleanroom teams to produce great semiconductor results.

Rutwik Joshi, Richard Gibbons, Christopher Pham, Anthony Buchman and Yuezhong Xu
for being great teaching assistants in support of these MDE students.

Janice Burr, Daniel Connors, Ken Schulz, Duane Blackburn and Sam Yakulis
for supporting the MDE Expo as Panel Judges.

Joe Adams, Kelley Andrews, Toby Meadows and Shelley Stover
for serving as track Master of Ceremony during the Expo.

Karin Clark, Patty Tatro and John Ralston
of VT Link, License, and Launch for helping to maintain and grow our external partnerships.

Guest Speakers

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

Robin McDougal, CEO and Founder

Interstellar Dreams Space Center---``If you can dream it, you can do it."

Qasim Wani, CPE'22

Building to Solve the Right Problem, Entrepreneurship and Teaming Remotely

Corwin Warner, EE'23

Risk Management, Design Process

Sal Bezos, Mark Mondry and Corwin Warner

Innovation and Intellectual Property Management

Tim Talty

``What I wish I knew before starting MDE" and VT ECE Masters of Engineering Opportunities

Best in Course Recognition for Base Course Performance

Spring 2023

ECE 1004–Introduction to ECE Concepts

- Mohja Filfil
- Jonas von Stein
- Janna Weiss

ECE 2024–Circuits and Devices

- Andrew Budzynski

ECE 2214–Physical Electronics

- Aditya Bangalore
- Peter Costescu
- Abigail Dillard
- Thomas Lu
- Richard Martinez
- Benjamin Pittelkau

ECE 2514–Computational Engineering

- Nick Meier
- Daniel Reeves

ECE 2544–Fundamentals of Digital Systems

- Brianna Rodriguez
- Howard Yu

ECE 2564–Embedded Systems

- Xavier Casanova Pabon
- Peter Costescu
- Thomas Lu

ECE 2714–Signals and Systems

- Peter Costescu
- Nick Eastman
- Richard Martinez

ECE 2804–Integrated Design Project

- Tiernan Barber
- Abigail Dillard
- Haley Strong
- Charlotte Uehling
- Andrew Viola

ECE 2804 Integrated Design Project: Infrared Radioteletype

LEFT TO RIGHT: Abigail Dillard, Andrew Viola

CHALLENGE

The goal of this project is to create a modern radioteletype that communicates over an infrared optical link and maximizes the communication distance subject to a power constraint on the transmitter. The TTY and modem functions will be handled by an Arduino Uno and the transmitting radio function will be handled by pulsing an IR LED at the required frequencies, limited to just 1mA of current through the IR LED. The receiving radio function will be accomplished by using an IR photodiode and analog electronics to amplify and filter the received signal.

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

Abigail Dillard Arlington, Virginia

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

Aspirations: I aspire to have a fulfilling engineering career in my focus area: controls, robotics, and autonomy.

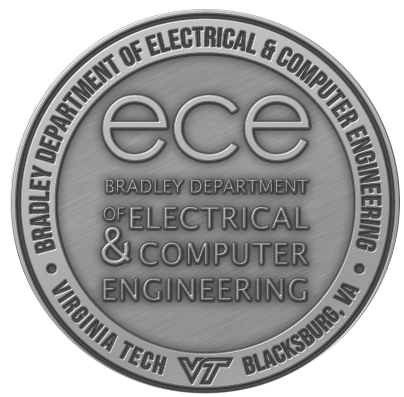
Course Comment: The integrated-design project course has provided a hands-on opportunity to apply theoretical knowledge to a real-world engineering problem. The focus of design, innovation, and collaboration has prepared me for my career aspirations.

Andrew Viola Leland, North Carolina

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: Upon completion of my bachelor's degree, I hope to further my education in the machine learning field by pursuing a master's degree.

Course Comment: Integrated Design Project has given me the wonderful opportunity to work on a challenging project within the comfort of a classroom. With this new experience, I fully expect myself to be capable of handling my major design project and any future projects that I may find myself completing.



ECE 2804 Integrated Design Project: Infrared Radioteletype

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

INFRA-RED RADIOTELETYPE

TEAM: ABIGAIL DILLARD & ANDREW VIOLA

VIRGINIA TECH.

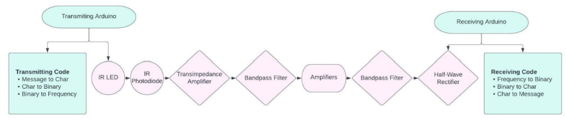
Overview

The infra-red radioteletype system (RTTY) is a modification of the teletype system. Traditionally a system that consisted of two teletypes connected by wires, this project instead utilizes an IR LED and IR photodiode for its implementation. Using this methodology, the LED turns on and off at two set frequencies to correspond to either a binary bit 1, or 0.

For transmission, the Arduino converts the user input string into its ASCII representation and sends marks (1 in binary) and spaces (0 in binary) using an IR LED.

For receiving, the IR photodiode "sees" the radiation, and the signal is processed into an Arduino where it is reconstructed to the original message. The goal of this design is to maximize the distance the transmitter and receiver work, while also keeping a consistent and accurate output. The success, validation, and precision of the results are illustrated. Furthermore, an additional twist to the project was implemented, to be explained.

Design



Digital Implementation

- Transmitter
  - User entered string is trimmed and converted to char array
  - Each char is converted into 8 bit ASCII
  - Adds start and stop bits to the 8 bit dataframe
  - Arduino's tone function is used to transmit the ASCII
- Receiver
  - analogRead() > 500 mV to remove noise
  - Uses the start bit as a reference voltage, and compares the remaining bits to assign 1's and 0's appropriately
  - Once 10 bits are established, start and stop bits are removed and the character is printed to the console

Analog Implementation

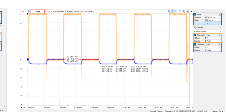
- Transimpedance Amp (TIA)
  - Converts IR photodiode current into usable voltage
- Bandpass Filter 1
  - Center frequency of 2125 Hz, bandwidth of 110 Hz
- Amplifiers
  - Increases gain for distance elongation
- Bandpass Filter 2
  - Center frequency of 2125 Hz, bandwidth of 110 Hz
  - Increased gain compared to bandpass filter 1
- Half-wave rectifier
  - Smooths the receiving signal for readable output by Arduino

Requirements

Given a photodiode and an IR LED, create a radio-teletype.

.Specification:

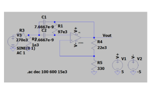
- Current on IR LED limited to 1 mA
- 2125 Hz for mark frequency
- 2295 Hz for space frequency
- Transmit message at 45.45 baud
- No Arduino libraries
- 8-bit ASCII
- 1 start bit and 1 stop bit

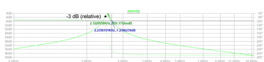


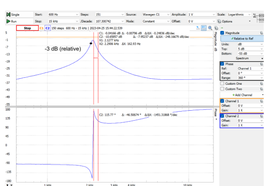
Validation

For each milestone, steps were taken to ensure each aspect of the project functioned as intended. In the pictures below, one can view the transmission and receival of the letter, 'H,' a crucial initial step.

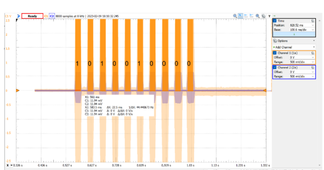
Above the transmission of the letter 'H', one can view the validation for one of the two bandpass filters. As displayed, the bandwidth and center frequency are as designed.







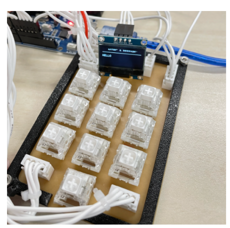
In total, two bandpass filters were included. Each were targeted for the mark or space frequency.

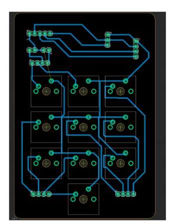


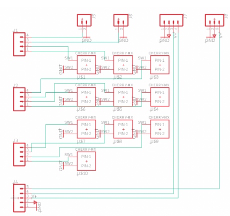
Extension - T9 Dialing Input

Inspired by old school T9 dialers found on older cell phones and hit game, Super Smash Bros, a new input was made in place of a standard string input. To send a message, the user has the joy of hitting mechanical keyboard switches multiple times to type out messages. After writing a whole message, a beautiful loading bar that is dependent on the size of the message is displayed. The features of the T9 dialer include:

- Standalone T9 Dialer
- Custom designed and milled PCB in Autodesk EAGLE
- Mechanical keyboard switches as buttons
- Small OLED screen
- Custom variable loading bars dependent on message sizes

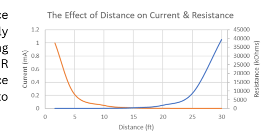


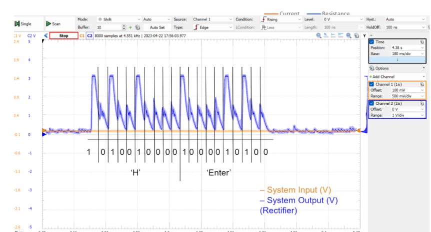




Distance

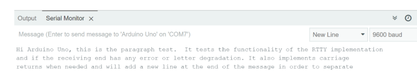
The maximum distance achieved was approximately 30 ft, simulated by adding resistance across the IR LED. The final resistance was 40 MΩ (compared to the original 3900 Ω)





Percent Error at 30 ft Simulated Distance

Character Error (%)							
Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	**Average**	**Standard Deviation**
2.27	1.95	0.65	0.97	4.22	0	**1.68**	**1.3699114**



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