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Virginia Tech ECE MDE Expo

Fall 2021

VIRGINIA TECH™

Welcome back to the Bradley Department of Electrical and Computer Engineering Major Design Experience (MDE) Exposition. We are back in person for our Fall 2021 MDE Expo. The MDE Expo is an opportunity to showcase and share the results of our students' culminating project experience. We currently have 10 project teams comprised of 49 undergraduate students focused on the design, build, test, and delivery of a realistic project for a real customer. Six industry sponsors and three Virginia Tech organizations have sponsored these projects. The sponsor serves as the customer throughout the project lifecycle.

MDE students contribute their knowledge and skills as part of an engineering project team focused on engineering their solution through a full design cycle where teamwork, communications, planning, and testing are all necessary to achieve the success you see on display. These teams were online, and many were in remote locations for the first half of their project design. Local students had access to the design studio, but all were supported by shipping parts and equipment to team members. Planning had to consider location and shipping times as well as engineering considerations. The second half of their project build was back on campus and in person but was still impacted by COVID protocols and global logistics challenges. Some delivered well beyond what we thought possible under such conditions, and some will discuss remaining work. These students represent our next generation of engineers, ready to address and overcome society's emerging global challenges.

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

Congratulations to each of the 49 students; their dedication and diligence are evidenced in these 10 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

The Major Design Experience (MDE) for Electrical and Computer Engineering is the culminating experience of the undergraduate studies for each of our students. The 2021 Fall Exposition provides us the opportunity to gather and celebrate the achievements of 49 ECE students who have come together to form 10 project teams. These students' entire MDE experience and most of their college careers are within the context of COVID. Their resilience and ability to adapt well beyond previous expectations is evidenced by their results here today. The first half of their project experience was remote online. Some teammates were in various locations across the globe and, in some cases, austere conditions. These students have truly proven their readiness to rise to world challenges and to tackle our greatest emerging issues.

The primary goal of the MDE program is to provide our ECE students a realistic engineering experience and provide them a safe, controlled environment for their first engineering project. These students developed creative strategies to build, test, and deliver their projects. This is not the MDE experience we envisioned for the students, but this class understands risk and mitigation much more directly. The students shipped equipment among sites, and they conducted planning, development, testing, and customer meetings via Zoom. They created shared collaboration sites, and many thrived...producing beyond expectations.

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

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

To our ECE students: Your culminating experience was entirely in the context of a pandemic, but you overcame so many challenges. You stand ready to become Engineers! And as VT ECE Hokie engineers, know that you are ready to invent the future in the spirit of "Ut Prosim" (That I may serve)!!!

J. Scot Ransbottom
Director of Design Projects
Bradley Department of Electrical and Computer Engineering

Sponsors

We greatly appreciate their support.

AEROSPACE

Altria

BAE SYSTEMS

LOCKHEED MARTIN

NAVAIR

VIRGINIA TECH

ZETA ASSOCIATES

VIRGINIA TECH ELECTRIC SERVICE

BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING VIRGINIA TECH

Project Leadership

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

Sponsor	Customers	Project	Subject matter expert (SME)
The Aerospace Corporation, El Segundo, CA	John Janeski	Small Satellite Navigation Sensor	Greg Earle
Altria, Richmond, VA	Brian Cramer	Vibration Monitoring and Analysis	Peter Han
BAE Systems, Manassas, VA	Bobby Bowen	Create the Power Schema for a Space-based CCA	Peter Han
Virginia Tech ECE/ISE, Blacksburg, VA	Matt Earnest, VT ISE	Learning Factory – CNC Lathe Integration	Toby Meadows
Virginia Tech ECE/ISE, Blacksburg, VA	Xiaowei Yue, Andrea L'Afflitto, VT ISE	Learning Factory – Manufacturing Robot	Ryan Williams
Lockheed Martin, Bethesda, MD	Geoffrey Kerr	UAV Telemetry Courier System	Louis Beex
NAVAIR, NAS Patuxent River, MD	Andrian Jordan, Israel Jordan	Sonobuoy Communications	Louis Beex
Virginia Tech, Blacksburg, VA	Igor Cvetkovic	Preparation of FutureHAUS for demonstration at Dubai EXPO 2021	Igor Cvetkovic
Virginia Tech, Blacksburg, VA	Scott Dunning, VT ECE	Utility Scale Power Planning Study and Initial Design	Delorean Power: Michael Herbert, Paul Duncan, & Rory Jones
Zeta Associates, Fairfax, VA	Michael Drescher, Stephen Kralick	Personal Locator Beacons System	Louis Beex

Small Satellite Navigation Sensor

Best Overall and Popular Vote

CHALLENGE

To develop a navigation sensor capable of utilizing a student-selected sensor suite to supply Position, Navigation, and Timing (PNT) data to a CubeSat when the satellite does not have access to a Global Navigation Satellite System (GNSS).

LEFT TO RIGHT: Mouad Ait Taleb Ali, Julius Hunt, Murphy Smith | **SME: Greg Earle**

Mouad Ait Taleb Ali

Blacksburg, Va.

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: As a space system engineer, my first step is to secure a job in the aerospace industry, then get a master's degree. Ultimately, I would like to start an aerospace business.

Class comment: This class was very special for me. I think we have had the best SME and mentor, who were there when we needed them. Also, as a team, we were just perfect to work with each other.

Murphy Smith

Roanoke, Va.

Bachelor of Science in Electrical Engineering
Photonics

Aspirations: During my career I hope to make advancements for the greater good in the fields of photonics and communications.

Class comment: I appreciate being partnered with an industry sponsor and exposed to novel engineering problems faced today. The systems engineering skills I have learned have already proven to be valuable outside this course.

Julius Hunt

Manassas, Va.

Bachelor of Science in Electrical Engineering
Space Systems

Aspirations: My career goal is to contribute as an electrical engineer at a company specializing in developing satellites or launch vehicles. It is my dream to watch a project to which I contributed launch successfully into space.

Class comment: I appreciate the opportunity to advance my skills and confidence in PCB design and programming. I found self-designation of team deadlines to be an important project management practice, and I learned a lot through exchanges with technical experts and stakeholders.

PROJECT SPONSOR: JOHN JANESKI

AEROSPACE

Industrial Vibration Monitoring

CHALLENGE

To make a system that monitors and records vibration data in industrial equipment. This data will be stored on a computer and compared to historical trends, tracking machine wear and predicting maintenance needs.

LEFT TO RIGHT: Yuhui Xu, Hao Quian, Dhwan Wanjara, John Curry, Philip Brewer | **SME: Peter Han**

Philip Brewer

Rustburg, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: My goal is to work in electrical building design and to obtain my PE.

Class comment: I appreciate the opportunity to work on a project that required a change of perspective from what I am accustomed to.

John Curry

Willis Wharf, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I want to work in the industrial controls or power industries.

Class comment: I learned real world leadership and project management skills.

Hao Qian

Ningbo, Zhejiang, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I plan to become an electronic mechanical engineer in hardware development.

Class comment: I learned about hardware development from the class, and learned python algorithms to achieve our goals.

Dhwan Wanjara

Edison, N.J.

Bachelor of Science in Electrical Engineering
Software Systems

Aspirations: I want to start a company that disrupts an existing industry, process, or standard. I want to work in a fast-paced, high-demand environment with tangible and meaningful results.

Class comment: I enjoyed the collaborative nature of this class. Designing a solution and solving a complex, real life problem was really rewarding.

Yuhui Xu

Nanjing, China

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: To build on my two internship experiences. First as an intern in State Grid corporation of China, second with a small company focused on power electronics.

Class comment: This class made me understand the problems I will face in my career. It will help me adapt to the environment of my future company.

PROJECT SPONSOR: BRIAN CRAMER

Altria

Space-Based CCA Power Supply Circuit

CHALLENGE

To design the power schematics for a power supply for the Kintex UltraScale Plus FPGA that will be used in space applications.

LEFT TO RIGHT: Eshi Baldano, Randal Day, Reily Snodgrass, Corey Martin, John Schafer | **SME: Peter Han**

Eshi Baldano

Mattituck, N.Y.

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I want to work in circuit design or IC design.

Class comment: I appreciate that this class allowed me to use the skills and concepts I learned in my other classes.

Randal Day

Virginia Beach, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I want to develop and improve isolated power systems such as naval vessels.

Class comment: This course provided me the opportunity to practice essential project management skills that only come through experience—such as budgeting.

Corey Martin

Bassett, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I am seeking a career in the field of industrial control systems.

Class comment: I appreciate being able to work on a real, hands-on project in order to use the concepts we learned in class.

John Schafer

Burlington, Ky.

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I am seeking a position in analog hardware design for power or space applications, and hoping to earn a Ph.D. in Analog IC transistor design.

Class comment: I appreciate having a better understanding of the work and organization that goes into coordinating a full team of engineers and managing a project from initial brainstorming to final product.

Reily Snodgrass

Timonium, Md.

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: I plan to focus on development of FPGA hardware and DSP applications of FPGA hardware.

Class comment: This course gave me hands-on experience with circuit design and troubleshooting, as well as experience with formal presentations in a professional setting. This will help me as I move from an academic setting to a professional one.

PROJECT SPONSOR: BOBBY BOWEN

BAE SYSTEMS

VT ISE Lathe Integration

CHALLENGE

To restore operation of an ECOCA flatbed lathe and network it to the Learning Factory digital infrastructure for real-time monitoring of manufacturing data. Also, to incorporate the lathe into the Learning Factory "virtual factory" as a 3D model.

LEFT TO RIGHT: Ryan Singman, Mark Bezik Jr., Luke Minton, Biruk Woldemaryam | **SME: Matt Earnest**

Mark Bezik Jr.

Virginia Beach, VA

Bachelor of Science in Electrical Engineering

Aspirations: My intent is to become the boots on the ground keeping electrical distribution systems intact. The dream is to get paid for performing maintenance and gauge calibrations for high-energy equipment.

Class comment: I appreciate the experience I've garnered in finally being able to purpose my learning here at VT towards a significant product that other students will be using here for years to come.

Luke Minton

Wytheville, Va.

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: After graduation, I will be continuing my education at Virginia Tech in the Masters of Engineering program for Computer Engineering. After that I will be working for the U.S. Department of Defense as a Computer Engineer.

Class comment: This class helped me realize all the details that make up a team dynamic. The class helped me improve my communication and teamwork to achieve an engineering design goal.

Biruk Woldemaryam

Alexandria, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: After graduation, I hope to pursue a career in power or control systems.

Class comment: I appreciate the opportunity to work on a real-world project. It has helped me apply the problem solving skills I learned in class. I also got experience in project management and working as a team.

Ryan Singman

Clifton, Va.

Bachelor of Science in Computer Engineering
Machine Learning

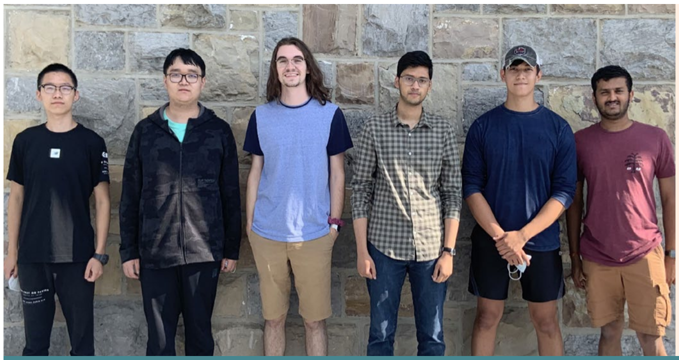
Aspirations: I hope to make an impact in the field of reinforcement learning.

Class comment: I appreciate the opportunity to practice professional communication skills, as I believe it will help me in my career.

PROJECT SPONSOR: MATT EARNEST

Learning Factory Robot

Track 2 Winner



CHALLENGE

To streamline robotic package transport, pickup, and dropoff. The packages are transported on an autonomous robot, and are identified and moved to and from the robot using computer vision.

LEFT TO RIGHT: Aoyu Yang, Shun (James) Fang, Nolan Pletcher, Aziz Shaik, Jacob Carroll, Harsh Patel | **SME: Ryan Williams**

Jacob Carroll

Midlothian, Va.

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

Aspirations: To design and implement cutting-edge control systems.

Class comment: I enjoyed learning to work in a team environment and communicating with other groups to coordinate usage of supplies and other recourses.

Shun (James) Fang

Shanghai, China

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

Aspirations: I want to be an engineer who designs control system circuits for autonomous vehicles.

Class comment: The part about Vehicle Cybersecurity Penetration Testing impressed me a lot. Since I'm fond of autonomous vehicles, I have researched the problem that control systems are affected by third parties.

Harsh Patel

Chesapeake, Va.

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I want to learn to make machine learning algorithms that can talk to humans. Siri is the main aspiration behind choosing a machine learning career.

Class comment: I appreciate the real-world problem-solving skills needed to complete this class project. I applied everything I learned in my Virginia Tech classes to this class project.

Nolan Pletcher

Mahomet, Ill.

Bachelor of Science in Computer Engineering
Networking & Cybersecurity

Aspirations: I would like to work in software engineering in a field like robotics, AI, or game development. Working in a place where I am passionate about the technology would help me reach my potential and grow as a professional in the industry.

Class comment: The senior design experience really helps put pressure on you to be independent. You get to both apply your skills in engineering and control your project's direction as you work in a team.

Aziz Shaik

Falls Church, Va.

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I hope to pursue a career related to machine learning, particularly within the domain of computer vision, and use the experiences and knowledge I've gained at VT.

Class comment: Besides the opportunity to work on a design team and use everything I've learned over the years, the constructive criticism and advice provided by the MDE mentorship was incredibly helpful in improving my technical communication skills.

Aoyu Yang

Chengdu, Sichuan, China

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

Aspirations: To always keep moving in my journey to be an electrical engineer.

Class comment: I appreciate how this class provides me a broad view about what future career experience will be like, and guides me through this transition from school to career.

PROJECT SPONSOR: XIAOWEI YUE

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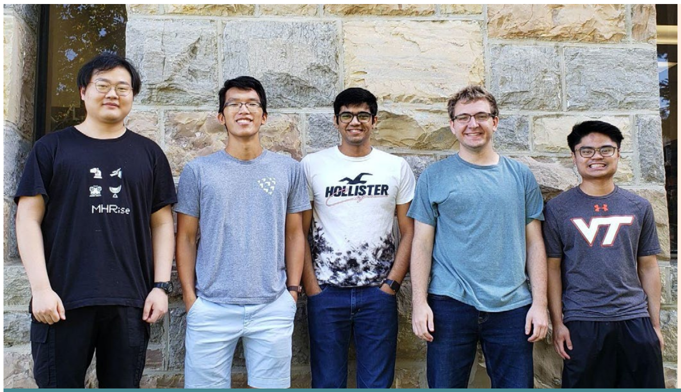
FutureHAUS



CHALLENGE

To revive the electrical system for the Future-HAUS smart home – consisting of PV panels, charge controllers, solar inverter, and batteries – and to improve its functionality by developing a power monitoring system, an augmented reality mobile application, and an energy management algorithm.

LEFT TO RIGHT: Ruiqi Zhang, Matthew Trang, Rutvik Chavda, Jonathan Borghese, John Alcantara | **SME: Igor Cvetkovic**

John Alcantara

Ashburn, Va.

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I intend to join industry so that I can apply and expand my skills in fields related to software development, automation, or AI.

Class comment: I appreciate the experience of working in a team environment and the importance of teamwork, good team atmosphere, and dealing with team conflict. I am also grateful that I could apply my skills to improve a novel idea.

Jonathan Borghese

Ashburn, Va.

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: I am looking to become a skilled data scientist working in the field of machine learning and artificial intelligence.

Class comment: This class helped me experience working in a group with different skillsets as well as applying my skills in a professional environment.

Rutvik Chavda

Rajkot, India

Bachelor of Science in Computer Engineering
Computer Engineering (general)

Aspirations: : I hope to obtain a position of responsibility that utilizes my skills and experience, and am keen to work in an environment where I can enrich my knowledge and unlock my potential.

Class comment: I appreciate the year-long experience that not only gave me a platform to apply my theoretical knowledge to real-world problems but also improve my technical and communication skills while working in a team setting.

Matthew Trang

Nokesville, Va.

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: After graduation I will be working for a government defense contractor, and will be developing Reinforcement Learning-based Artificial Intelligence for drones and fighter jets.

Class comment: I enjoyed having the opportunity to work on a complex and technical project and see the physical results of our work. The class also gave me a good experience of working with teams and collaborating with a subject matter expert.

Ruiqi Zhang

Shanghai, China

Bachelor of Science in Computer Engineering
Chip-Scale Integration

Aspirations: I hope to pursue a career in the smart home industry, and dedicate myself to the development of smart and sustainable technologies that will improve our quality of life.

Class comment: This course provided me with an opportunity to apply my knowledge to a real-world problem, and helped me gain valuable experience working on a professional level.

PROJECT SPONSOR: IGOR CVETKOVIC (CPES)

Utility Scale Power Planning Design

CHALLENGE

To create multiple design concepts for an Energy Storage System (ESS) to be implemented in tandem with Virginia Tech Electric Service. The ESS should provide backup energy for critical infrastructure, generate income/savings, and support future transition to renewable energy.

LEFT TO RIGHT: Ikram Zainal, Mahdi Alkafawi, Carlos Gil, Can Enkavi, Irdina Shahriman
SMEs (Delorean Power): Paul Duncan, Michael Herbert, Rory Jones

Mahdi Alkafawi

Ashburn, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: The energy industry needs to make a radical shift to combat the climate crisis, and after graduation I want to contribute to that radical shift.

Class comment: Our interactions with the various stakeholders involved with our project was a wonderful experience with wonderful people. They created an environment which emulates that of industry without any harshness.

Can Enkavi

Istanbul, Turkey

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like a position as a power engineer, performing tasks that focus on the generation, transmission and the distribution of power, or contributing to developments in power electronics.

Class comment: I enjoyed the process of researching, testing, confirming, and communicating between the different stakeholders to obtain a final deliverable at the end. I am grateful that I will not have to go through this for the first time in an actual work environment.

Carlos Gil

Richmond, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I want to apply the skills I learned at Virginia Tech to the renewable energy industry. One specific goal is to design a renewable energy system in Colombia, the country my family is from.

Class comment: I appreciate the opportunity to work with those in the utility-scale energy storage industry. It gave me great insight into how a project like this is designed and what criteria to consider.

Irdina Shahriman

Selangor, Malaysia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I aspire to a career in large-scale application of power engineering, and following my passion for developing renewable energy and contributing to the improvement of sustainability in the energy industry.

Class comment: This class has provided me a valuable opportunity to solve real-world engineering problems that enhance technical skills. Working as a team helps me harness my collaboration, interpersonal, and time management skills.

Ikram Zainal

Kedah, Malaysia

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

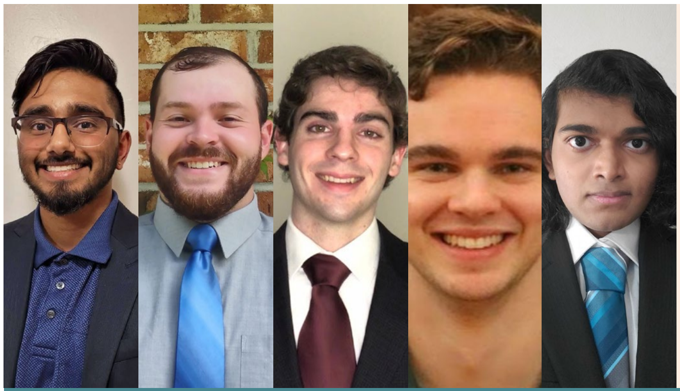
Aspirations: I aspire to be an electrical engineer who is capable of solving real-life problems to help improve the quality of life in my community.

Class comment: I really appreciate learning about the engineering process in industry, and discovering how what I learned in class is applied in the real world. I also find the exposure to the current trends in industry and how those trends are changing really meaningful.

PROJECT SPONSOR: SCOTT DUNNING

VIRGINIA TECH

UAV Telemetry Courier



CHALLENGE

To design and build an UAV system to collect data from a remote sensor via Radio Frequency transmission and deliver it to a base station. The data is modulated using an SO-QPSK-TG Modulation Schema, transmitted by a software-defined radio, and collected and demodulated on a Raspberry Pi.

LEFT TO RIGHT: Santosh Krishnan, Eric Cueva, Kevin Sauers, Stephan Muller, Rohit Selvam | **SME: Louis Beex**

Eric Cueva

Hillsville, Va.

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

Aspirations: I want to take part in innovative autonomous technologies that make the production of food and resources more efficient and sustainable in the fields of agriculture and fungiculture, and to help remove human-generated waste from land and water.

Class comment: I think the best way to learn something is with hands-on experience, and that's what this class has given me. I appreciate the taste of what it's like to work in engineering, and I feel that I'm now ready to go out and invent the future.

Santosh Krishnan

Ashburn, Va.

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

Aspirations: I aspire to be a computer engineer working in embedded systems doing both hardware and software programming. I also want to work with systems contributing to robotic systems.

Class comment: I am glad to have experienced a full, year-long design process as I learned how to work with a new team to coordinate the project. I am also grateful to have worked on a project that utilized my digital design experience.

Stephan Muller

Ashburn, Va.

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: After graduating, I would like to work within the wireless communications field, specifically on researching and designing machine learning algorithms to effectively aid in signal processing and low probability of detection systems. Later, I plan to pursue a master's degree.

Class comment: My favorite aspect of this class was the ability to work closely with a customer in industry, and being able to learn from their experience as a professional. I also enjoyed being challenged and having to research and learn new skills.

Kevin Sauers

Chesapeake, Va.

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

Aspirations: I hope to work as a software developer for a small tech company.

Class comment: I appreciated the opportunity this class provided to get a sense of what life as an engineer would be like after graduation.

Rohit Selvam

Jersey City, N.J.

Bachelor of Science in Computer Engineering
Machine Learning

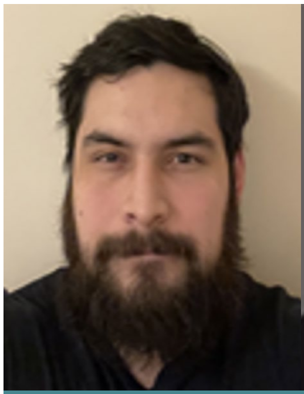
Aspirations: I plan on pursuing a career in information technology or software engineering with a focus on machine learning.

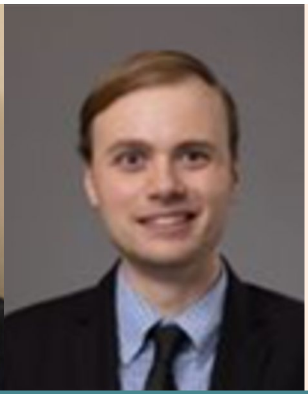
Class comment: The experience of working for a large company such as Lockheed gives us a great insight into how projects are managed and developed in industry.

PROJECT SPONSOR: GEOFFREY KERR

LOCKHEED MARTIN

NAVAIR Sonobuoy Comms





CHALLENGE

To implement the Audio and GPS data collection functionality of a DIFAR sonobuoy using a LimeSDR Mini. Data was transmitted using SOQPSK modulation, received with a NESDR Mini and processed in MATLAB.

LEFT TO RIGHT: Noel Gabino-Perez, Gavin Doering | **SME: Louis Beex**

Gavin Doering

Dumfries, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to apply my knowledge of electrical engineering to support the growth of nuclear power and other alternative energy sources.

Class comment: I enjoyed working on a team to solve a real design problem with high autonomy.

Noel Gabino-Perez

Fairfax, Va.

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I am fascinated by the unique relationship that radio-frequency engineering and national defense have, and aspire to a career at the frontier of R&D in the defense industry.

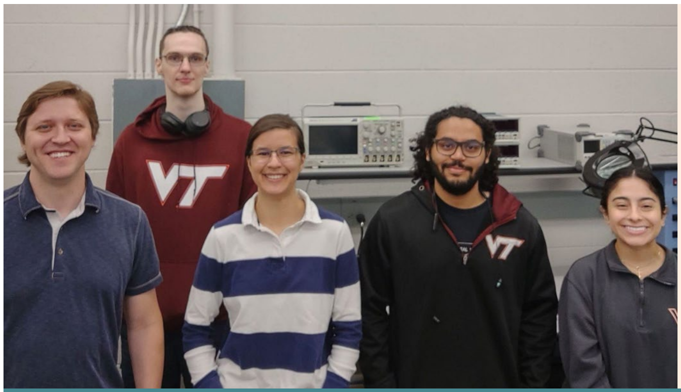
Class comment: I am extremely thankful for the immense amount of time our mentor, subject matter expert, and customers dedicated to meeting with us to provide their expertise and guidance.

Note: This was a 3 person team

PROJECT SPONSORS: ANDRIAN JORDAN, ISRAEL JORDAN

Personal Locator Beacons

Track 1 Winner



CHALLENGE

To design and build two low-power beacons that can transmit GPS location data and beacon ID, receive and decode the messages in two minutes within a 100m radius, and display the received beacon information.

LEFT TO RIGHT: Casey Latoski, Lewis Bass, Elizabeth Horley, Abdulelah Ali, Karen Perez-Serpa | **SME: Louis Beex**

Abdulelah Ali

Madina, Saudi Arabia

Bachelor of Science in Electrical Engineering
Micro-Nanosystems

Aspirations: I aspire to make the world a better place by advancing technology and creating new inventions.

Class comment: The chance to solve real world problems and work with a team has given me the experience I need to become a successful engineer.

Lewis Bass

Woodbridge, Va.

Bachelor of Science in Computer Engineering
Machine Learning

Aspirations: To increase the complexity and efficiency with which computers perceive and interact with the real world.

Class comment: I appreciated learning new skills with the help of my team members.

Elizabeth Horley

Williamsburg, Va.

Bachelor of Science in Electrical Engineering
Energy & Power Electronic Systems

Aspirations: I would like to get my Master's focusing on grid connected power electronics, and pursue a career developing that technology.

Class comment: I enjoyed breaking down a broad design problem into realizable portions, and the opportunity to gain more experience with mixed signal PCB layouts.

Casey Latoski

Alma, Mich.

Bachelor of Science in Electrical Engineering
Radio Frequency & Microwave

Aspirations: I aspire to work in areas where I can blend my passion for electromagnetics with machine learning applications.

Class comment: I experienced a full life cycle of an engineering program, and with it the lasting life lessons that come from a multiorganizational program that balanced leadership, progress, and success.

Karen Perez-Serpa

Bristow, Va.

Bachelor of Science in Electrical Engineering
Electrical Engineering (general)

Aspirations: I hope to continue learning and use the knowledge/skills acquired to inspire others and make a difference in society.

Class comment: I enjoyed working with talented people and gaining some experience in the process of engineering design.

PROJECT SPONSOR: MICHAEL DRESCHER

ZETA ASSOCIATES

Project Contributor Acknowledgements

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

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

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

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

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for providing financial guidance and support.

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for solving our many IT issues, and printing the poster papers quickly.

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for Innovation and Intellectual Property Management.

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for helping plan, cater, and secure all arrangements for the Poster Paper Event.

Special thanks to Ms. Amrita Chakraborty
Teaching Assistant specializing in Semiconductor Projects
for providing excellent safety, tool, semiconductor processing, and mask design training.

Special thanks to Mr. Alexander DeRieux
Teaching Assistant
for enhancements in course automation and individual progress reporting.

Best in Course Recognition for Base Course Performance

Spring 2021

ECE 2804 — Integrated Design Project

- Mason Ahner, Jared Beller, and John Fiorini *(Audio Direction Finder)*
- Brady Alexander and Sean Pack *(Wireless Sensor Node)*
- Danny Stover and Evan Allen *(915 MHz Communication)*
- Aaron Yang and Danielle Reale *(Smart Home)*

ECE 2714 — Signals and Systems

- Evan Allen

ECE 2544 — Fundamentals of Digital Systems

- Rufus Hinton, IV

ECE 2514 — Computational Engineering

- Ben Barber
- Greg Brinson
- Chris Maksimowicz
- Noah Sweilem
- Yuanzhi Zhang
- Jay Yim

ECE 2214 — Physical Electronics

- Nate Doggett
- William Poland

ECE 2024 — Circuits and Devices

- Nick Huy Hoang

ECE 1004 — Introduction to ECE Concepts

- Ethan Shaw

Project Posters

Best Overall and Popular Vote

Small Satellite Navigation Sensor

Team: HokieNav – Julius P. Hunt, Mouad A. T. Ali, Murphy A. S. Smith
Sponsor: Dr. John A. Janeski, The Aerospace Corporation
Subject Matter Expert: Dr. Gregory D. Earle, Virginia Tech

Introduction

Satellites generally rely on the Global Navigation Satellite System (GNSS) to provide position, navigation, and timing (PNT) data. If a satellite loses GNSS connection, it will be unable to execute its mission objectives. Our objective is to design a small-satellite navigation sensor capable of supplying PNT data when GNSS blackouts occur.

Key Requirements

- GNSS signal may not be used
- Utilize an IMU as well as other sensors
- Unit must fit within a 1U (10x10x10cm) volume
- Unit mass must be less than 1.5kg
- Average power consumption less than 2W

Concept of Operations

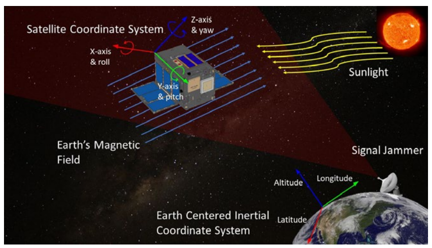
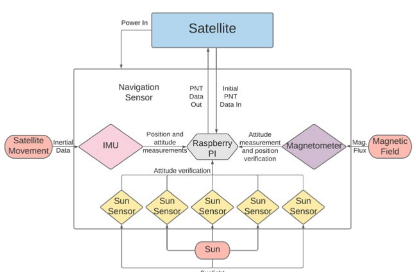


Diagram of the navigation sensor's operation

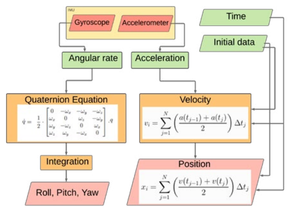
Approach



Flow chart of the full navigation sensor system

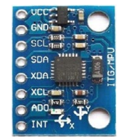
The design consists of 3 major sensory components—IMU, magnetometer, and Sun sensors. Data from all sensors are inputted to the Raspberry Pi via the I2C communications protocol and blended into a single PNT solution. This is then sent to the satellite through the SATCAT5 communications protocol.

Inertial Measurement Unit (IMU)



Flow chart of IMU algorithm

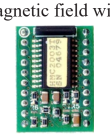
- Measures position and attitude of the satellite
- Position measured along XYZ axes
- Yaw, pitch, roll obtained from IMU's angular velocity measurement
- Yaw, pitch, roll converted to quaternion form
- IMU performance is limited by vibration, constant bias, angle random walk, bias stability, temperature effects, and calibration error
- IMU measurements must be corrected periodically in software



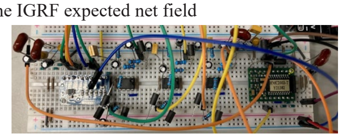
GY-521 MPU6050 IMU

Magnetometer

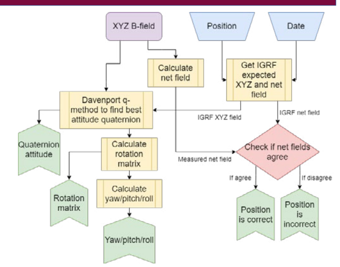
- HMC2003 magnetometer measures magnetic field in the XYZ directions
- XYZ magnetic field vector measured is compared to the reference frame XYZ field described by the IGRF model
- Optimal coordinate system rotation required to make magnetic field vectors match is calculated
- Position input is checked for accuracy by comparing the measured net magnetic field with the IGRF expected net field



HMC2003



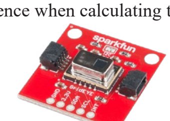
Magnetometer breadboard prototype



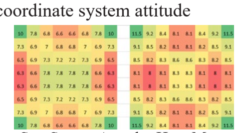
Flow chart of magnetometer algorithm

Sun Sensors

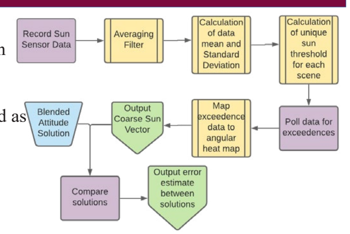
- GridEYE thermopile arrays measure heat over an 8x8 pixel array
- Test set-up used a hot halogen lightbulb to simulate the Sun's position in orbit
- Five Sun sensors are used to record light surrounding the CubeSat
- A Sun vector is computed in the spacecraft's coordinate system and used as a reference when calculating the ECI coordinate system attitude



GridEYE Thermopile Sensor

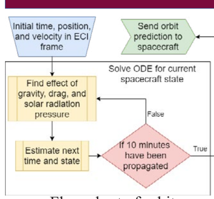


Sun Sensor Angular Heat Maps



Flow chart of Sun Sensor algorithm

Orbit Propagation

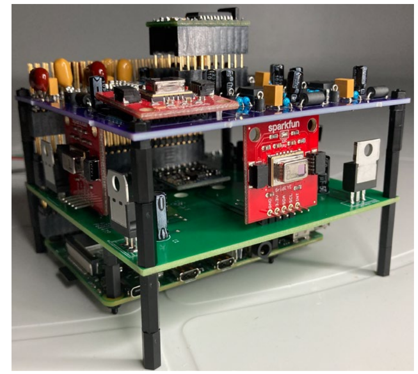


Flow chart of orbit propagation algorithm

- Orbit is predicted for the conditions of the spacecraft at the time of GNSS signal loss
  - Position, velocity, time
- Prediction is made for the estimated duration of GNSS blackout—approx. 10 min for 300km altitude
- Orbital perturbations considered:
  - Drag—NRLMSISE00 model
  - Gravity—EGM2008 model
  - Solar Radiation Pressure—Ephemeris

Sample orbit propagation result

Hardware Result



Full hardware assembly

The full assembly of the navigation sensor is shown above. The magnetometer and 1x Sun sensor PCB is placed at the top. The middle PCB is dedicated to power distribution, the IMU, and 4x Sun sensors. The Raspberry Pi is placed below.

Conclusion

Completed work:

- Full hardware assembly
- Communication with sensors
- Obtained comprehensible sensor data
- Sensor algorithms
- Orbit propagation algorithm

Future work:

- Sensor fusion algorithm
- Kalman filter
- Extensive full-system testing

Overall, most of the system design has been completed, but there are more steps required to achieve full functionality. Once full functionality has been achieved, extensive testing should be performed to characterize the performance of the navigation sensor.

Acknowledgments

HokieNav would like to extend a special thanks to Dr. Gregory Earle, Matt Werner, Dr. John Janeski, Mr. Alex Utter, Dr. Stephen Spry, Dr. Howard Ge, Dr. Brittany Chamberlain, Dr. Scott Ransbottom, Prof. Toby Meadows, and Dr. Kevin Shinpaugh for their invaluable advice and support throughout the duration of this project.

Created By: Philip Brewer, Dhwan Wanjara, John Curry, Qian Hao, Yuhui Xu

Acknowledgements

Our team would like to thank Professor Han, Brian Cramer of Altria, and ECE department for giving us the opportunity to work on this exciting project.

Purpose

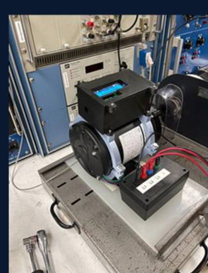
- Observing changing vibration trends can help the customer predict maintenance issues and reduce unscheduled downtime.
- This saves manufacturing customers large amounts of money.
- Plant management can plan on parts breaking by using new changes in vibrations

Project Description

- Monitors, collects, and sorts vibration data from industrial equipment
- Allows user to separate normal and abnormal behavior
- Patterns can be extrapolated and saved
- This helps predict failures, extend equipment service life and saving significant amounts of money
- No technical background needed to process data with this system

Approach

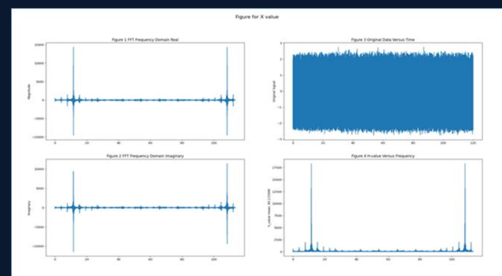
This project uses an Arduino based computer system to read the vibrations off industrial equipment. The data is processed by a Python computer program to find the frequency of the vibrations. Users can then organize and highlight anomalies in the vibrations.



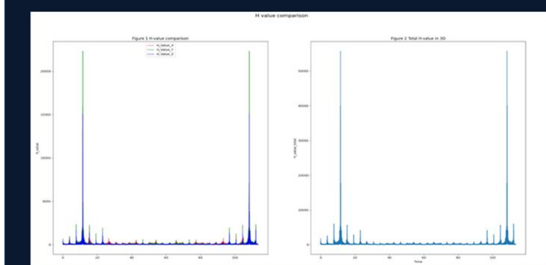
Technical Design

$$X(k) = Nc_k = \sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi kn}{N}}, k = 0,1,\ldots,N-1$$

$$H = a(k) = \sqrt{X_R^2 + X_I^2}$$

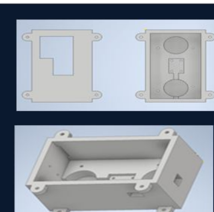


- DFT Theory
- FFT data for 3D
- Amplitude H for 3D
- Total Amplitude comparison
- Additional CSV file storage



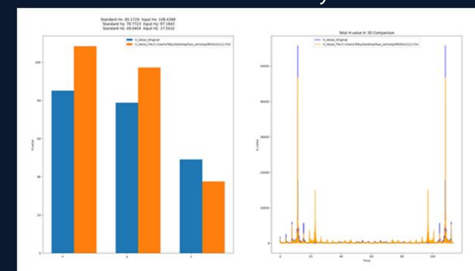
Housing

The housing for the electronics was 3D modelled using Inventor to securely mount the electronics. The system was tested in a lab using a motor at varying frequencies and load to introduce controlled distortions.



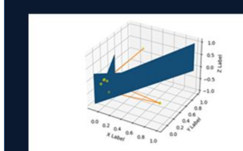
Conclusion

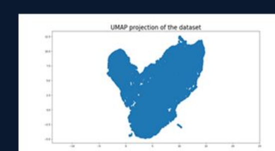
The software tool that team has delivered meets all the desired goals and objective that were proposed. The software can collect and visualize vibration data. It allows the suer to compare current data with historic data and provided metrics to quantify behavior. This information can be used to classify the behavior of the system. and The requirements of the customer are successfully met

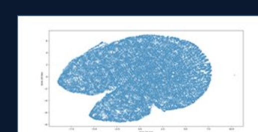


Future Study

The team tried to apply dimensionality reduction, a machine learning technique, to find patterns in vibrational data and notify the user of poor behavior. However, the approach was not successful the approach to apply machine learning to perform vibrational analysis is extremely relevant and useful. While this model failed to successfully meet the objective of classify behavior it shows that a tweaked and trained model can in fact deliver useful results.







Space-Based FPGA Power Supply Circuit

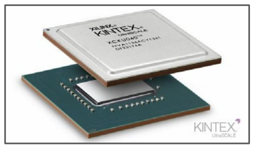
John Schafer, Reily Snodgrass, Eshi Baldano, Randal Day, Corey Martin
Sponsor: Robert Bowen, BAE Systems Inc.
Subject Matter Expert: Prof. Peter Han, Virginia Tech

VIRGINIA TECH

BAE SYSTEMS

Background

As an industry leader of space and defense solutions, BAE Systems Inc. is moving from older FPGA devices to new 20nm FPGAs, such as the Kintex Ultrascale Plus. To power these new devices, an updated power supply system must be designed to meet new voltage, current, and tolerance requirements.

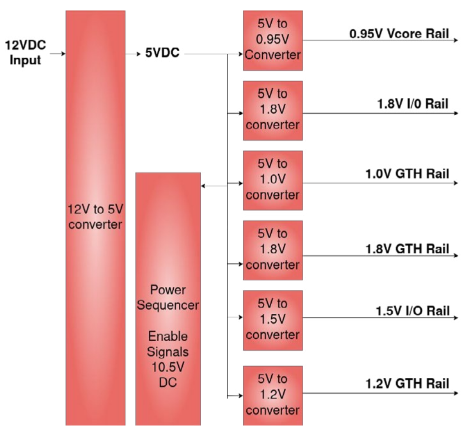


https://www.xilinx.com/products/silicon-devices/fpga/kintex-ultrascale.html

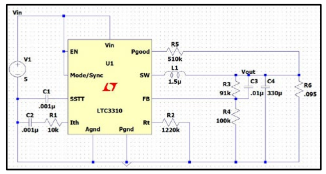
Objectives

Create a power delivery circuit with a +12V input, stepped down to six voltage and current outputs.

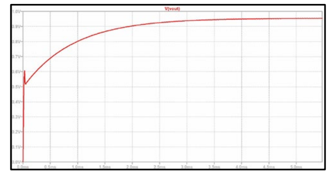
- Follow power sequencing requirements according to FPGA datasheet
- Minimize size, cost, and weight



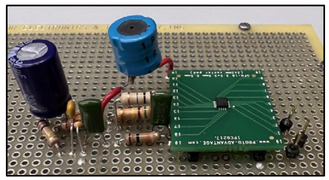
Design & Implementation



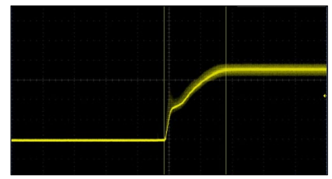
LTspice schematic of .95V rail



Transient simulation



Circuit assembled on the protoboard



Measured transient response

- Buck converters used to step down all voltages.
- Analog Sequencer chosen to handle power sequencing.
  - Microcontroller introduces too much complexity for scope of project
- Initial step down converter from 12VDC to 5VDC:
  - Increases IC choices.
  - Powers the sequencer & all subsequent rails.

$$\Delta I_L = \frac{V_{out}}{L \cdot f_{sw}} \cdot \left(1 - \frac{V_{out}}{V_{in(max)}}\right)$$

Additional Circuits

Results

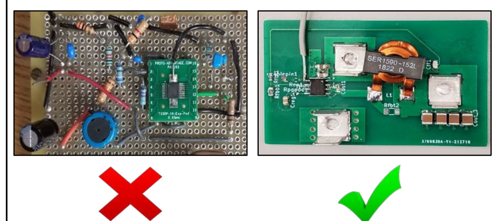
	V_{CORE}	$1.8V_{I/O}$	$1.0V_{GTH}$	$1.8V_{GTH}$	$1.5V_{I/O}$	$1.2V_{GTH}$	12V - 5V
V_{out} Mean	0.95	1.9 V	1.0 V	1.8 V	-	1.2 V	5 V
I_{out} Max	2mA	4 A	2 A	2.5 A	-	.1 A	-
Efficiency at max load	-%	74%	36.3%	51.1%	-%	-%	-%

- Sequencer enables all rails in the correct order.
- The following rails need to be improved: 12V-5V, Vccint, Vccaux.
- Some rails are unable to keep within regulation throughout all possible loads.

Conclusions

Over the course of the project, our team found that:

- Original prototyping using protoboards is unsuitable for testing power electronics.
- When prototyping, account for breaking multiple components during testing.
- Proper layout of components must be considered to minimize parasitic capacitance and inductance.



Future Considerations

Some future considerations include:

- Testing for continually changing loads.
- Overcurrent protection / Undervoltage lockout.
- Reset switch for power cycling.
- Improved heat dissipation without convection cooling.
- Substitution of consumer components to radiation hardened components.

Acknowledgements

The design team would like to acknowledge the technical and structural guidance given by:

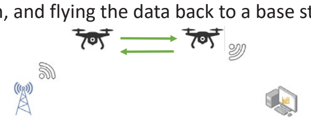
- Robert Bowen and BAE Systems Inc.
- Subject Matter Expert: Prof. Peter Han
- Mentor: Professor Kenneth Schulz

UAV Telemetry Courier

Eric Cueva, Santosh Krishnan, Stephan Muller, Rohit Selvam, Kevin Sauers
Sponsor: Geoff Kerr, Lockheed Martin   Subject Matter Expert: Dr. Louis Beex

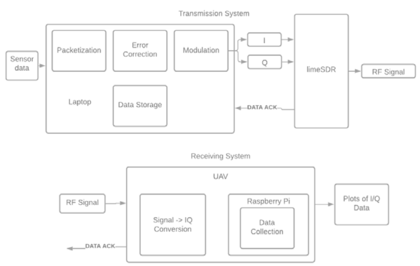
Problem Statement

Remote sensors collecting data may be located in places without any existing or secure network infrastructure. As a result, Lockheed Martin seeks a UAV Courier design capable of flying out to remote sensor(s), retrieving data via RF burst transmission, and flying the data back to a base station.



Objectives

- Packetize, apply FEC, modulate, and transmit over RF
- Receive RF Signal, convert to baseband I/Q, and (optionally) recover original data bits
- Carry hardware for up to a one-mile round trip
- Deliver the data within an hour after collection



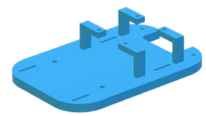
Design Process

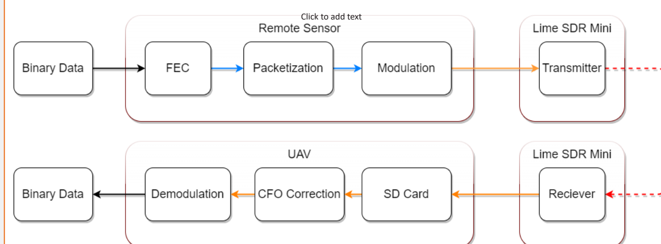
Our design process included implementations for packetization, FEC, and modulation/demodulation. A custom packetization protocol was implemented to split the data. Our modulation/demodulation is written in python and based on a theoretical solution, but with additions to improve the efficiency of the transmission. In addition to creating programs to enable transmission/reception, design decisions were made for choosing a suitable drone as well as a mount to attach our system to the drone.

DJI Inspire I

$ 1759.99 (+351.99%)

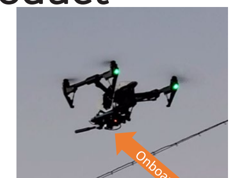
13 mins | 49 mph | Feasible*

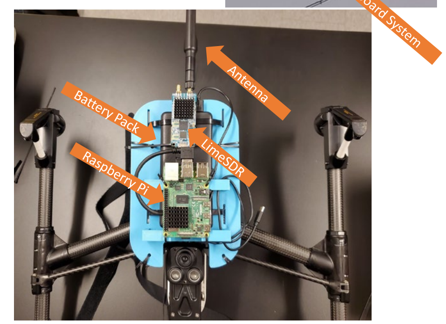




Final Product

DEMO



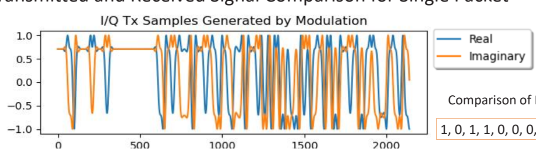


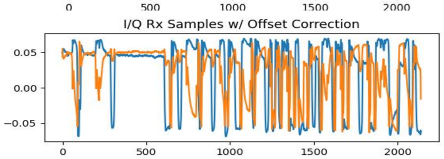
Challenges

- SOQPSK-TG is a complex, multi-step modulation scheme that was difficult to implement from scratch
- Drone models that fit within our budget struggled to reach the original round trip distance requirements
- Finding a suitable frequency and bandwidth in the RF spectrum given interference from multiple sources

Validation

Transmitted and Received Signal Comparison for Single Packet





The signals are similar in terms of real and imaginary values, but the differences are simply caused by the noise that is injected during transmission.

Comparison of Excerpt of Transmitted/Received Bits

1, 0, 1, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 1, 0, 0, 1, 1

1, 0, 1, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 1, 1

- There was one error in the excerpt of the received bits in comparison to the bits that were transmitted.
  - This was likely due to noise.

Progression of Flight Testing over Project Development

Trial	Time(mins)	Weight/Type	Range(ft)
1	11	400 g/ Mock Weight	4000
2	10	400 g/ Mock Weight	4200
3	11.5	400 g/ Mock Weight	5600
4	11.5	400 g/ Mock Weight	6000
5	11.5	316 g/ Battery + Raspberry Pi	8400

The table shows the results of our flight testing when trying to identify the constraints of the drone that was eventually chosen for this project

Conclusion

Our final design was able to make a one-mile round trip and received 127 Kilobytes of data at 3 Mbps. Comparing the transmitted and received bits at the base station revealed a 76% accuracy rating. The final per unit cost was $2303.90.

Potential Improvements

- Reduce Error Rate
- Improve Transmission Rate

Sonobuoy Communications

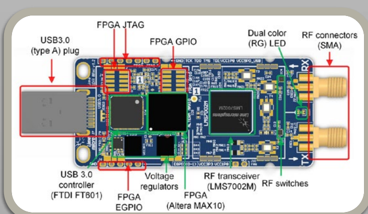
Gavin Doering, Noel Perez, Elizabeth Prevost
Major Design Experience, Virginia Tech

Background

A sonobuoy is an aircraft-delivered underwater device that measures acoustic data for the purpose of Anti-Submarine Warfare. An onboard radio transmitter takes the data collected by a hydrophone and transmits it to a nearby friendly aircraft, which then interprets the data from multiple sonobuoys to determine the presence and location of hostile submarines. There are various categories of sonobuoy (active, passive, and other specialized types). The target deployment for this project would be the passive sonobuoy. The two unique aspects of our specific implementation are the use of a novel LimeSDR Mini transceiver, and the use of a more bandwidth efficient version of Quadrature Phase Shift Keying (QPSK) modulation that can transfer both audio and GPS data. Transmitting the data is the key component of the design; the receiver is simply used to confirm the transmission.

Objectives

- Collect acoustic and GPS data
- Prepare the modulated data for burst RF transmissions
- Transmit the data using a LimeSDR Mini
- Use a second LimeSDR Mini as a receiver
- Use a Laptop to verify the information transfer is successful
- Analyze the data using MATLAB

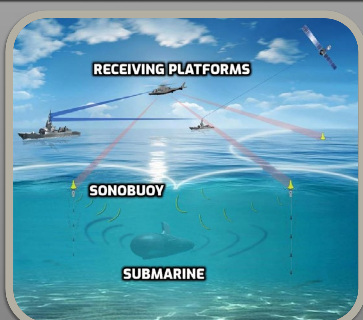


LimeSDR Mini

Challenges

A few weeks before the Fall 2021 semester, the team was informed that one of the members was not returning to Virginia Tech. The team worked with the mentor and SME to rescope the project.

Concept of Operations



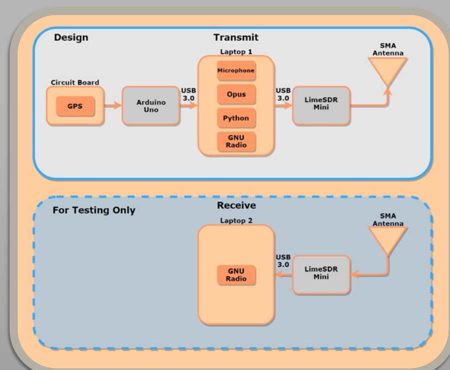
System Design

The team chose a GPS module compatible with the Arduino Uno: the Adafruit Ultimate GPS. The Arduino Uno+GPS is connected to a laptop via USB. The laptop's integrated microphone provides the audio.

Opus was used to encode the audio. Opus was chosen, because it gives a fixed bit rate at high fidelity and allows the GPS data to be added as metadata. Python was used to capture and encode the audio with GPS, to save the captured Opus files, and to transmit the Opus files as packets using ZMQ to GNU Radio. ZMQ is a popular asynchronous messaging library that has support for Python and GNU Radio. The packets contain a known header or tag that can be used to identify the packet boundaries. The python script runs on the laptop.

GNU Radio processes the Opus packets by modulating two-bit symbols, using QPSK, creating a baseband signal that is transmitted at the carrier frequency by the LimeSDR Mini.

The transmitted data is then received by a second LimeSDR Mini and demodulated by a second GNU Radio process. The recovered symbols are then analyzed in MATLAB for correctness.

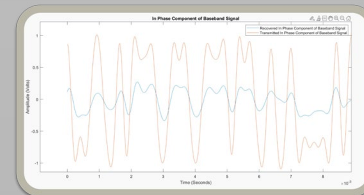


Transmission Subsystem Testing

After designing the transmitter, the system was tested with a receiver implemented in MATLAB to ensure that the data was not lost during the transmission process. Preliminary testing indicated the received baseband signal had a significant frequency offset and high amount of noise. The frequency offset could not be fully corrected and a residual offset existed due to the effect of noise. In turn, the residual frequency offset adversely affected phase and time offset correction of the received signal.

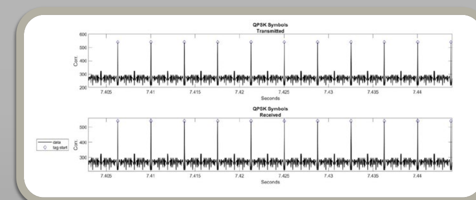
The addition of a preamble to the transmitted data and enhanced noise reduction on the receiver made the baseband signal recovery possible. From the baseband signal, the data could be recovered and full system testing using GPS and audio data could proceed.

Transmission Subsystem Testing (Continued)

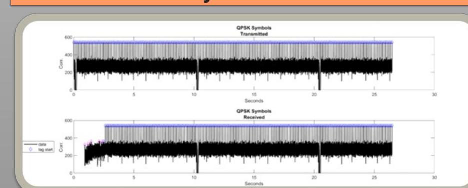


System Testing and Results

The audio was tested by recording multiple sets of 10 seconds and playing the recorded data back to ensure that there were no gaps. The GPS was verified by inspection of the saved Opus file. To prove that no data was lost in the packetization process, a single Opus file was sent to GNU Radio and the checksums were compared.
The symbols that were to be modulated were sent to a file. This was used to compare with the received samples. The received symbols were then aligned using a combination of correlation and the alignment of the packet boundaries discovered with correlation, through the tag.



Full System Results



Conclusion and Future Work

We have succeeded in transmitting a QPSK signal containing audio and GPS data.
Using our progress as a foundation, a future team could:

- Implement an SOQPSK-TG modulation scheme
- Collect acoustic data in real time using discrete analog components
- Downsize the transmission system to accommodate size constraints

Acknowledgements

The team's project was sponsored by NAVAIR. The team would like to thank Mrs. Andrian Jordan, Mr. Israel Jordan, Dr. Louis Beex, and Professor Toby Meadows for their time, knowledge, and support..

Utility Scale Power System Design

Team Members: Can Enkavi, Carlos Gil, Ikram Bin Zainal, Irdina Shahriman, Mahdi Alkafawi
Customer: Dr Scott Dunning SME: Michael Herbert, Paul Duncan, Rory Jones

Motivation

- Help Virginia Tech Electric Service reach 100% renewable energy
- Provide continuous source of backup power to critical load
- Provide an economically stable/feasible energy storage system (ESS)

High-Level Diagram

The team proposed to design a battery energy storage system that will be connected to a VTES substation. The conceptual high-level diagram shows connection to the substation and the main components that will be in the system. The system can be operated under several use cases that the team has determined to be important and beneficial to VTES.

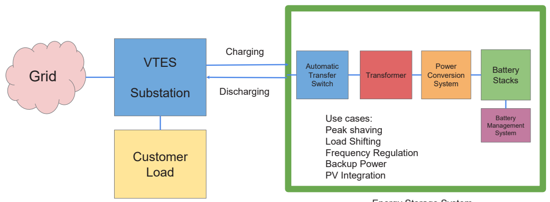


Figure 1: The conceptual high-level diagram

Key Functional Requirements

- 10 MW Power Conversion System Rating
- 20 - 40 MWh energy storage capacity at the beginning of life
- Last 10 years without augmentation
- Cost should be about 15 million USD
- Size should not exceed 5 acres
- Deliver 10% of the predicted critical load and 20 MWh for peak shaving/ load shifting at year 10

Use Cases

Load Shifting : Entails charging when energy prices are low, and discharging when energy prices are high.

Peak Shaving: Reduce the peak load of the utility by discharging the battery during peak coincident events to get savings from reduced capacity obligation and transmission charges.

Frequency Regulation: Charges and discharges the battery based on AGC (Automatic Gain Control) signal from PJM to maintain 60 Hz in the grid. Charging helps lowering the frequency and discharging helps raising the frequency.

Backup Power: Discharges the battery to critical loads when the grid fails.

***PV Integration:** Using the battery to charge from PV arrays directly and discharge into the grid.

* Given the current infrastructure in Blacksburg, we have determined that an indirect PV connection is preferable for the project, as it would:

- Involve inefficiencies after taking the distance between the locations of the panels and the battery into account
- Increase the cost of the overall system, by not providing a real stream of revenue or savings

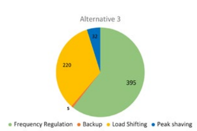


Figure 2: The distribution of number of cycles for recommended use case alternative

Analysis of Alternatives

Table 1: Comparison of Alternatives

Alternatives	Alternative 1	Alternative 2	Alternative 3
Use Cases	Backup Power Load Shifting Peak Shaving	Backup Power Frequency Regulation	Backup Power Load Shifting Peak Shaving Frequency Regulation
Usable Life	17 years	19.8 years	19.2 years
Initial Battery Capacity	29.81 MWh	27.16 MWh	36.72 MWh
Capital Cost	$ 14.7 million	$13.7 million	$17.4 million
Revenue/ year	$1.28 million/year	$1.31 million/year	$2.59 million/year
Payback period	12 years	11 years	8 years

Comparing each alternative at their optimum operation, we recommended alternative 3 since it has the least payback period, highest revenue per year, and a relatively long usable life.

Electrical & Physical Layout

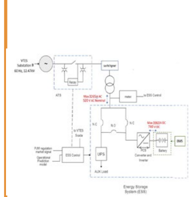


Figure 3: The Electrical High-Level Diagram

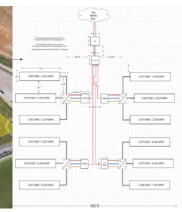


Figure 4: The Physical Layout for Alternative 3

- 4 transformers: 3 of 3 MVA, 1 of 2.5 MVA
- 10 MW capacity divided into 12 enclosures
- 4 inverters: 3 operate at approx. 2.6 MW, where 1 at 2.1 MW at full battery discharge
- The switchgear would ensure transformer, inverter and enclosure isolation for a fault in a given transformer branch
- The ATS would ensure the isolation of the entire system or the reconnection of it with the grid
- Busbars and aluminium wires providing connections between the system components
- Expected to cover an approximate area of 0.52 acres

System Operation

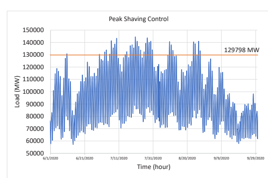


Figure 5a: Peak Shaving Operation

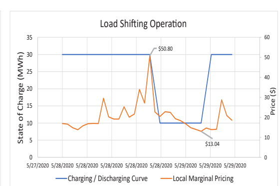


Figure 5b: Load Shifting Operation

- Want to reduce the peak load of utility by discharging the battery during peak events
- Historical peak data was used to determined a threshold to forecast when peaks occur
- Discharge battery when load is over the threshold

- Discharge when Local Marginal Pricing (LMP) is the highest for the day
- Charge When the LMP is the lowest for the day
- The savings are obtained by the difference in the maximum and minimum LMP of the day
- This is also how the indirect PV Integration use case would function for the implemented design

System Operation (cont.)

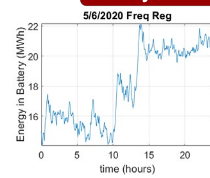


Figure 6a: Shows the state of the energy stored in the battery from an initial point of 15 MWh throughout May 6, 2020 when performing Frequency Regulation.

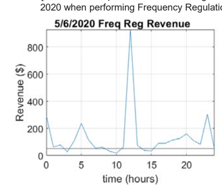


Figure 6b: Shows the hourly potential revenues associated from performing Frequency Regulation on May 6, 2020.

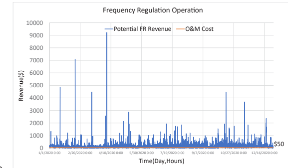


Figure 6c: Frequency Regulation Operation

- Battery will charge or discharge depending on the regulation signal sent by PJM
- Frequency Regulation operation depends on the potential revenue and the O&M cost
- When the potential revenue is higher than the cost, the battery will do FR
- The amount of enegy charged or discharged depends on the signal from PJM

Savings & Revenues

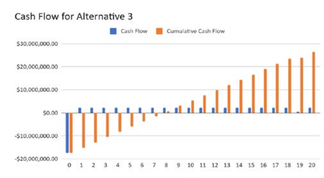


Figure 7: Cash Flow for Alternative 3

Table 2 : Details of the savings and revenue for each use cases

Use Case	Savings/Revenues
Frequency Regulation	$1,300,000
Peak Shaving	$1,160,000
Load Shifting	$120,000
Total	$2,580,000

Conclusions

The team recommends:

- Implementation of an energy storage system (ESS) with PCS rating of 10 MW and energy capacity of approximately 37 MWh;
- A battery with LFP technology and discharging rate of 1/3C;
- Utilizing a combination of use cases including: backup power, load shifting, peak shaving, and frequency regulation;
- An ESS which is predicted to reach 80% of its capacity after 19.2 years, after which an augmentation of the battery stacks is required to maintain the operation of all use cases.
- An ESS that would provide a sufficient revenue streams and savings for the utility, which will recoup the investments into the system in 8 years.

In the future our designed system could be integral to the transition to 100% renewable electricity by Virginia Tech by reducing the intermittency issues associated with renewables.

Acknowledgments

The Utility Scale Power team would like to thank the following people for their contributions and guidance for the project:

- Michael Herbert, Paul Duncan, Rory Jones (SMEs at Delorean Power)
- Dr. Scott Dunning (Customer representing ECE Dept.)
- Dr. Chen-Ching Liu (VT Power & Energy Center)
- Robert Glenn (VTES)
- Dr. Scot Ransbottom (Mentor)

MDE 22

FutureHAUS

John Alcantara, Jonathan Borghese, Rutvik Chavda, Matthew Trang, Ruiqi Zhang

Sponsor/SME: **Igor Cvetkovic**, VT Center For Power Electronics

Background

The FutureHAUS was built with the goal of creating a home design that is affordable, modular, and a blueprint for the future of housing. It was designed to explore the prefabrication process to make a modular structure that allows the house to be built in a few days, integrate smart home technologies, build and operate an energy positive solar home.

The Virginia Tech FutureHAUS was the winning prototype home design for the Solar Decathlon Middle East 2018, a worldwide design competition to make an energy positive solar home that best addresses the issues the Middle East faces. Due to the competition's success, the FutureHAUS was nominated to be displayed at the Dubai EXPO 2020, delayed to October 2021 due to COVID-19.

Figure 1. Completed FutureHAUS in Dubai during the Solar Decathlon

We were tasked to revive the existing electrical system of FutureHAUS and make improvements to the house that will be showcased at the Dubai EXPO, ranging from Augmented Reality programs for the house to improvements in the energy production of the electrical system.

Objectives

Primary Objective: Repair the electrical system for the FutureHAUS

- Electrical system comprised of state-of-the-art electrical components chosen to maximize efficiency and accessibility for its users

Figure 2. Components of the FutureHAUS Electronics Cartridge

Secondary Objective: Brainstorm and implement ideas that would improve the house

- Facial Recognition
  - A machine learning algorithm is trained to recognize a person using a camera to unlock and open the main door
- Power Monitoring System
  - Organizes power information and displays it nicely on an external display
- Energy Management Algorithms
  - Design an algorithm that will make better use of the energy provided by the solar panels
- Augmented Reality
  - Create an AR application that would allow users to gain access to the power information by pointing their phone camera at the electrical component

Design Process

Electrical System

- Validated each electrical component individually, then tested the entire electrical system of the house at once
- Started with the batteries, then the charge controllers and solar panels, and lastly the inverter
- Confirmed system was working properly before shipping house to Dubai

Figure 3. Students working on the FutureHAUS Electrical System

Facial Recognition

- Utilizes a Raspberry Pi and a USB Camera to detect faces of people
- If detected people are within a database of selected users, the Pi sends an open door request to an MQTT server

Figure 4. Facial Recognition System

Power System Testbed

- Installed solar production system in CPES lab, using the PV panels on the roof of whittemore
- The system is the testbed for new developments in power monitoring system and energy management algorithm

Power Monitoring system

- Measures the total power consumption of the house using CTs.

$$P = \left(\frac{\sum P_{inst}}{\#\ samples} - (I_{avg} * V_{avg})\right) * \alpha * \beta$$

$$\{\alpha = CT\ scaling\ factor, \beta = voltage\ scaling\ factor\}$$

- Scraps the power production data from comm-box.
- Combines both the data and publishes onto the server for the website to plot real-time graphs.

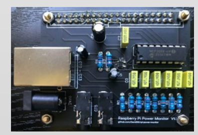


Figure 5. RPi power monitor PCB

Augmented Reality

- Used Tensorflow v2 to train a custom object identifier that detects the FutureHAUS electrical components, PV panels/charge controllers, solar inverter, and battery. This model is later converted to tfjs so that it is usable in our website.
- Used Angular to locally host a website, display a camera, and load the tfjs model used to detect trained objects from the camera.

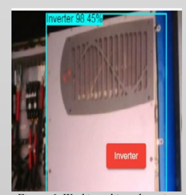


Figure 6. Working object detection classifier on web application

Energy Management Algorithm

- Linear Programming approach
- PV forecast: Using past data from NRES of PV power production and irradiance data, we trained a neural network model that predicts PV production using real-time irradiance forecast data. Using the predicted data we can optimize when and how much we can sell back to the grid.
- Consumption Model: The model that schedules daily tasks throughout the day at optimal times to maximize energy efficiency
- Simulink

Figure 7. Forecasted PV Output

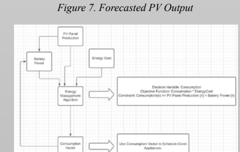


Figure 8. The Flowchart for the first design of the Energy Management Algorithm.

Final Product

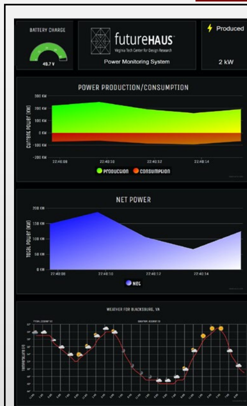


Figure 9. Power Monitoring System displaying electronic system data and forecast/temperature

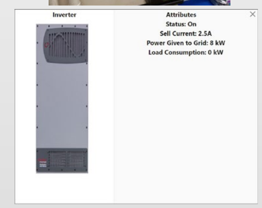


Figure 10 (top): Completed Power Electronics Testbed in CPES Lab
Figure 11 (bottom): Inverter Status page on website

Challenges

- A big challenge that we faced was that the FutureHAUS was shipped to Dubai earlier than expected. This meant that the revival and preparation of the solar production system needed to be done in a short period of time. Furthermore, due to harsh weather conditions of frequent snow and rain, installation of PV panels were postponed, giving us very little time.
- When working on the power monitoring system, we had a major time crunch towards the end. The system had to be setup in house before the expo started, giving us very little time to research, build and test the prototype.
- The display for the power monitoring system overheated when placed outside, due to the intense heat in Dubai. The display was moved inside as a result.

Conclusions

In conclusion, the work that our team did was successful in restoring functionality to the FutureHAUS, and we completed a number of additional advancements. The FutureHAUS is currently displayed at the Dubai Expo 2020 with the power monitoring system and the updated website setup.

Lessons Learned:

- We learned how to handle high voltage power electronics in safe, professional ways in a residential setting
- We learned to collaborate with a team halfway across the world, as we collaborated with other students in Dubai
- We learned how to develop machine learning algorithms to perform computer vision and consumption forecasting

ISE Learning Factory Lathe Revival and Machinery Networking

Reclaiming the Past for Industry 4.0

Grado Department of Industrial and Systems Engineering

Mark Bezik, Luke Minton, Ryan Singman, Biruk Woldemaryam

Bradley Department of Electrical and Computer Engineering

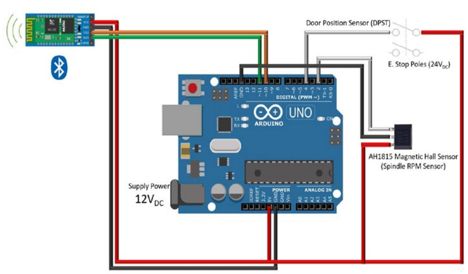
Background

The ISE Dept. Learning Factory seeks to provide a safe and effective learning environment where hands-on undergraduate education of Industry 4.0 concepts and technologies can be experienced. Such an undertaking demands an integrated network capable of data retrieval from all on-site machinery and devices to include the recently-acquired, vintage ECOCA CNC flatbed lathe.

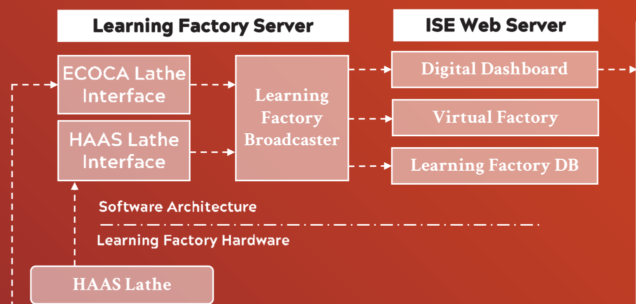
Key Requirements

- *Restore ECOCA lathe to CNC operability*
- *Establish interface for direct communications with Learning Factory server*
- *Develop and test the Learning Factory server*
- *Create, test, and host the Digital Dashboard to display detailed status information*
- *Integrate ECOCA lathe into digital framework*

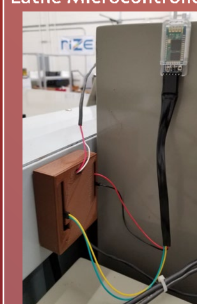
Lathe Microcontroller



An Arduino microcontroller is powered via on-board CNC. This externally-mounted device provides real-time monitoring of ECOCA lathe spindle speed and door position. The captured manufacturing data is continuously transmitted to Learning Factory servers is via Bluetooth UART protocol.



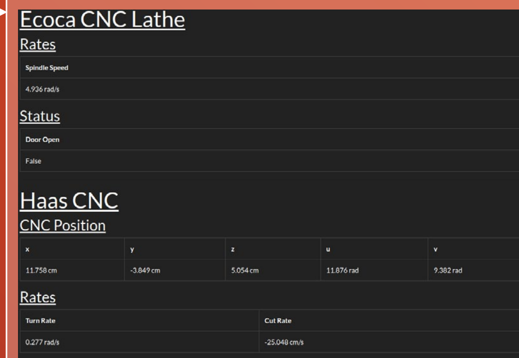
Lathe Microcontroller



Lessons Learned

- *Proprietary software with discontinued support limits the ability to integrate dated machinery with industry 4.0 concepts*
- *The more options made available from project onset significantly impact forward trajectory.*
- *Preexisting solutions are not deterministic of task complexity and may prove to be disadvantageous*
- *Alternative planning is critical to success*

Digital Dashboard



Major Obstacles

- *Absence of ECOCA documentation and delayed power install limited discernment of machine initial conditions*
- *Previous modifications left the machine in a state of CNC inoperability requiring fabrication of driver communication cables.*
- *ECOCA operating systems and proprietary applications are incompatible with modern communications standards*
- *Global pandemic limited travel and timely access of resources*
- *Complete server architecture reconstruction required on existing structure to establish secure, optimal networking solutions*

Conclusion

Modernization of industry invariably includes digitization. Data collection and processing has become a key part of Industry 4.0 because of its ability to inform and drive more efficient industrial processes. The revival and digitization of the ECOCA lathe is a case study in this, as a previously defunct piece of machinery is made useful by way of connecting it to the Digital Dashboard.

VIRGINIA TECH™

Acknowledgements

Matt Earnest, Toby Meadows, Mark Montgomery, Ben Standfield, Matt Earnest, Kim Medley, Randall Waldron, John Grha, Tom Martin, Zhenyu Kong

VIRGINIA TECH

Industrial Package Management System

Team Members: Aoyu Yang, Aziz Shaik, Harsh Patel, Jacob Carroll, James Fang, Nolan Pletcher
SME: Dr. Ryan Williams **Customer:** Dr. Xiaowei Yue

COLLEGE OF ENGINEERING
GRADO DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING
VIRGINIA TECH

Track 2 Winner

Objective

With the advent of Industry 4.0 encouraging automation and interconnected devices, the Learning Factory aims to exemplify these values in a demonstrative environment. In order to further these goals of the factory, we have been tasked by our customer to develop a package management system that can efficiently and autonomously transport packages around the factory, while providing the user with the data they need to manage the transportation of the packages.

System Overview

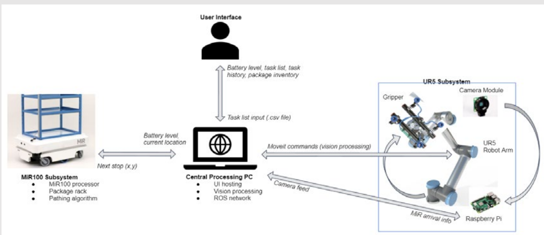


Figure 1: System Decomposition

Requirements:

1. There must be a remote interface for the user to access data about the transport robot and input data for routes.
2. The transport robot must autonomously plan its route within the facility based on the locations provided by the user.
3. The planned route must efficiently navigate between locations and avoid obstacles.
4. The transport robot navigates to charging station and pauses current task when below 10% battery.
5. The robotic arm must detect and load/unload the correct package using camera processing.

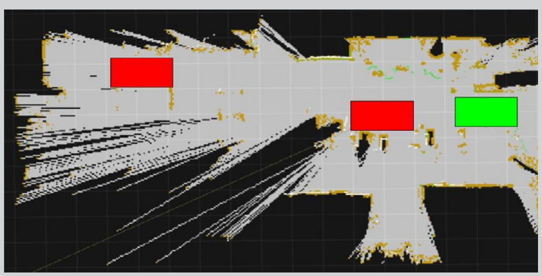


Figure 2: Facility map with load stations (red) and base station (green)

Robotics Design

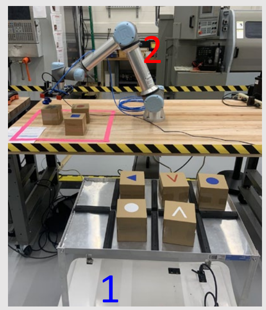


Figure 3: Package Unloading

- Robotic arm possesses 6 degrees of freedom with inverse kinematics used for computing the tooling pose
- The robotic arm calculates pose based on distance and coordinate data from computer vision processing
- Mapping made use of mobile robot's inbuilt processes, and map was developed prior to beginning the system
- Travels to set pose representing drop-off stations based on input from the user interface

- Uses ROS for data communications between subsystems, as well as external control of robotic arm (UR5e) and mobile robot (MiR100).
- Data from map in Figure 2 is forwarded to user interface for display of mobile robot position within the facility.

User Interface Design

Home Page

- Task history, package inventory, and robot data including the current location.
- Input package delivery tasks.
- Start / Stop buttons for the current delivery task.
- Monitors battery life.

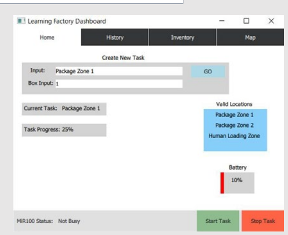


Figure 4: UI Home Page

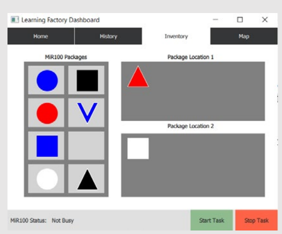


Figure 5: UI Inventory Page

Inventory Page

- Displays packages on mobile robot
- Displays packages in loading and unloading zones
- Layout of packages on mobile robot shelf

Computer Vision Design

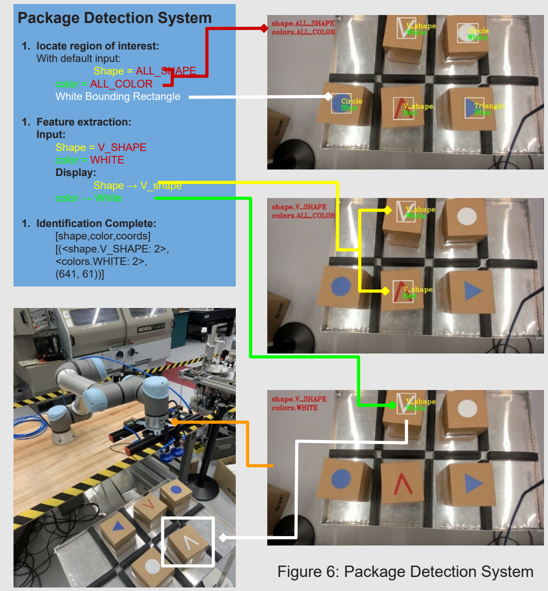
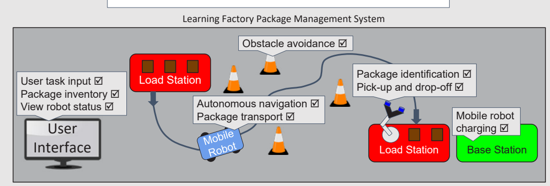


Figure 6: Package Detection System

Conclusion



Acknowledgements

For their assistance on this project, we would like to thank:

- Dr. Ryan Williams for his technical expertise
- Matt Earnest and Benjamin Standfield of the Learning Factory for presenting us with this meaningful challenge
- Dr. Andrea L'Afflitto for helping with initial design phases
- Dr. Xiaowei Yue for stepping in and guiding us to completion

ZETA ASSOCIATES
Innovative Engineering Solutions

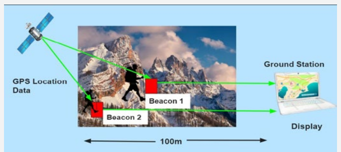
Personal Locator Beacons

Abdulelah Ali, Lewis Bass, Elizabeth Horley, Casey Latoski, Karen Perez-Serpa
Mentor and SME: Prof. Toby Meadows, Dr. Louis Beex

VIRGINIA TECH

Track 1 Winner

Background



System Concept of Operations

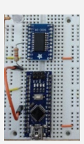
Personal Locator Beacons (PLBs) are used around the world to summon emergency search and rescue assistance. To wirelessly transmit data over long distances, data encoding or modulation is necessary for the message to be successfully received. Therefore, the PLBs can be broken into two main sections: the encoding software and RF transmission circuitry.

This project is intended to explore techniques for integrated RF and signal processing systems subject to size, weight, and power constraints.

Objectives

- Design and build two beacons that can wirelessly transmit GPS location data and ID over a 100m radius.
- Receive, decode, and display transmitted messages from both beacons on GUI within two minutes.
- Design beacons to fit within a maximum 30in³ enclosure.

ATtiny Interfacing

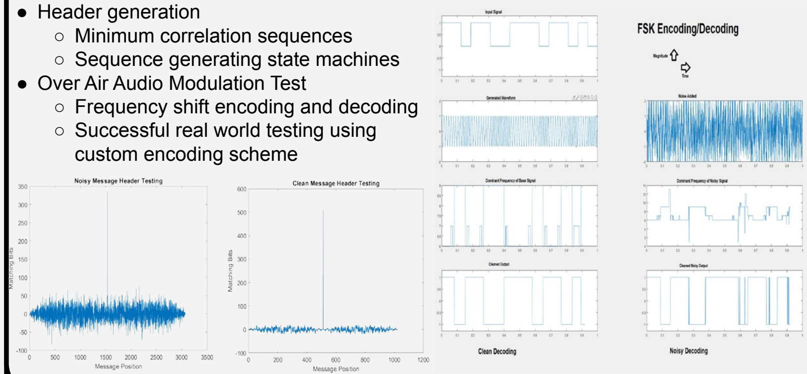


UPDI

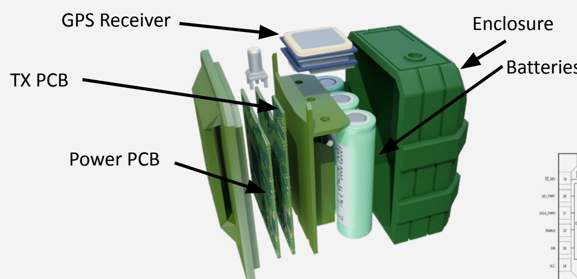
The ATtiny microprocessor controls the subsystems and acts as a communications hub. GPS location is received over UART and it controls the transmitter using SPI.

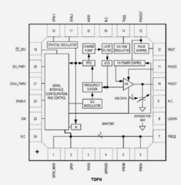
Matlab Simulations

- Header generation
  - Minimum correlation sequences
  - Sequence generating state machines
- Over Air Audio Modulation Test
  - Frequency shift encoding and decoding
  - Successful real world testing using custom encoding scheme

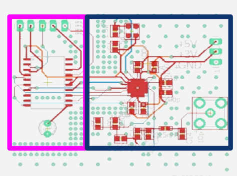


Hardware Realization

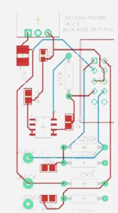




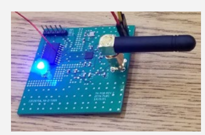
Tx-Pinout



Transmitter (TX) PCB showing Digital and Analog sections



Power PCB

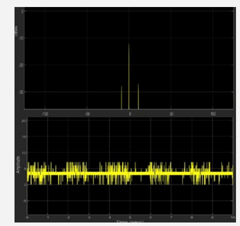


Assembled TX PCB

Analysis

QR Code to Video of Operation

The beacons successfully transmit a signal at 416.49MHz. With increased transmission power, the signal can be detected and decoded into location data.



RX 433MHz FSK Signal

Challenges

- Interference from digital signal RF emissions
- Calibrating RF circuits
- Troubleshooting crystal oscillator
- Properly programming TX IC
- Identifying beacon signal in noisy RF environment

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