



**Vertically Integrated Projects (VIP)  
Program**

**Information Packet**

Summer Quarter 2025-2026

Thank you for your interest in the Vertically Integrated Projects (VIP) Program at Drexel University!

VIP team members work as part of a multidisciplinary group of undergraduate students, graduate students, research staff, and faculty members to tackle novel research and design problems around a theme. Undergraduate students that join VIP teams earn academic credit for their participation in design/discovery efforts that assist faculty and graduate students with research and development issues in their areas of expertise.

VIP teams are:

- Multidisciplinary - drawing students from all disciplines on campus;
- Vertically-integrated - maintaining a mix of freshman through PhD students each academic term;
- Long-term - each undergraduate student may participate in a project for up to three years and each graduate student may participate for the duration of their graduate career.

The continuity, technical depth, and disciplinary breadth of these teams are intended to:

- Provide the time and context necessary for students to learn and practice many different professional skills, make substantial technical contributions to the team project(s), and experience many different roles on a large, multidisciplinary design/discovery team.
- Support long-term interaction between the graduate and undergraduate students on the team. The graduate students mentor the undergraduates as they work on the design/discovery projects embedded in the graduate students' research.
- Enable the completion of large-scale design/discovery projects that are of significant benefit to faculty members' research programs.

In the following pages you will find descriptions of the following VIP teams that are recruiting for the Summer Quarter of the 2025-2026 academic year:

- Accelerating Pharmaceutical Process Development with Robotics and Machine Learning
- An integrative approach for sustainable water management using spatial data and data-driven tools
- Artificial Intelligence and Robotics for Nondestructive Evaluation
- Astroparticle Physics in Extreme Locations
- Circular Buildings & Cities: Measuring circularity, understanding decision-making, and predicting material flows from new and existing buildings in Philadelphia
- Cognitive Neuroengineering for the Brain and Mind
- Consortium for Climate Risks in the Urban Northeast (CCRUN) Climate and Sustainability Research Team (CSRT)
- Coordination and Planning for Multi-Robot Systems
- Emergent coordinate systems for organizing massively parallel robotic swarms
- Language Models with Iterative Self Attention (LISA)
- Neuroergonomics and Neuroengineering for Brain Health and Performance Research
- Robotic Evaluation for Circular Lifecycle Assessment of Infrastructure Materials (RECLAIM)
- Robotics, Automation, and AI for Smart Agriculture
- Vision Language Models for Autonomous Driving

In order to participate in VIP, you must formally apply and be accepted to a specific team. To apply, please log into ForagerOne ([www.drexel.edu/foragerone](http://www.drexel.edu/foragerone)) and search for "VIP". This will bring up all available open positions tagged as VIP projects. When submitting an application, please be sure to have uploaded an updated résumé to your ForagerOne profile and to include a statement regarding why you are interested in working on the team to which you are applying.

Please note that VIP team participation requires registration for the accompanying VIP course section. The number of credits required per quarter is flexible and will be determined on a case-by-case basis in consultation with the team's faculty mentor and a student's academic advisor; however, most VIP team members will register for a single credit per quarter. Long-term, sustained participation in the program (three or more quarters of working on a single team) is strongly encouraged and may be required in order for earned VIP credits to count towards degree requirements. More information will be provided to all applicants that are offered a position.

Should you have any questions about a particular team, please feel free to reach out to the team's faculty mentor(s). Any questions regarding the VIP program in general should be sent to Chad Morris via email at [cam83@drexel.edu](mailto:cam83@drexel.edu). We hope you'll take the time to consider this compelling new opportunity. We look forward to receiving your application!

## Accelerating Pharmaceutical Process Development with Robotics and Machine Learning

Dr. [Matthew McDonald \(CBE\)](#) – Faculty Mentor

### GOALS

Chemical processes rarely perform the same at the lab scale and the plant scale; studying these differences is the core practice of chemical engineers. Today, miniaturization, AI, and automation are used to perform thousands of lab-scale experiments per hour, but little progress has been made accelerating implementation of these experiments at larger scale. Our goal is to use the same tools, plus the fundamentals of thermodynamics, kinetics, and transport phenomena, to increase the rate and success of scaled-up experiments.

### METHODS & TECHNOLOGIES

In our lab we use a 6-axis robot arm, x-y gantry liquid handler, and custom automation instruments to perform chemical reactions. Of particular interest are crystallization processes. Crystallization poses a significant challenge to scale up because the system has multiple independent length scales: the size of the reactor, and the size of the crystals. Slurry-to-slurry reactions are a subclass of crystallization that is ripe for development in this area. We are in the process of integrating these systems to work together for experiments. For example, the liquid handler, which operations at the  $\mu\text{L}$ -to- $\text{mL}$  scale, can perform hundreds of reactions in parallel, while the reactor, which operates at the Liter scale, can only perform a single reaction at a time. We need to analyze small scale experiments to choose the best large-scale experiment. Our current approach is to use Bayesian Optimization, but we are always exploring alternative avenues, especially those that are cutting edge or have not yet been applied for chemical systems. We need to coordinate these instruments at the same time we are teaching our models chemistry.



In addition to spanning multiple experiments, we need to develop custom hardware to perform large scale experiments. At the small scale, the Society for Laboratory Automation and Screening (SLAS) has standardized how parallel reactions are performed. But at the large scale, no such solution exists. We use 3D printing to rapidly prototype new bits of hardware, and lightweight Arduinos to automate simple mechanisms. This space may be particularly interesting to Mechanical Engineers.

Finally, we should build on centuries of work understanding chemical processes to provide our models with a sense of the theories that underly modern chemistry, as opposed to learning it again on the fly. Here, the project requires the strengths of computer scientists who can develop models and algorithms to combine theory with statistics. Our current approaches center on Neural ODEs paired with lightweight support vector machines but are highly uncertain in unexplored space and struggle to adapt existing data. Additional areas for development include uncertainty quantification and generative modeling.

## **MAJORS & AREAS OF INTEREST**

Our team is made up of students with broad interests and capabilities, reflecting the reality of drug development in the age of AI. All majors are welcome, but you may find this project particularly interesting if you are studying

- Chemical and Biological Engineering
- Chemistry, Math, or Physics
- Computer Science
- Mechanical Engineering
- Medicine

## **MENTOR CONTACT INFORMATION**

Dr. Matthew A. McDonald  
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## **PARTNERS & SPONSORS**

None

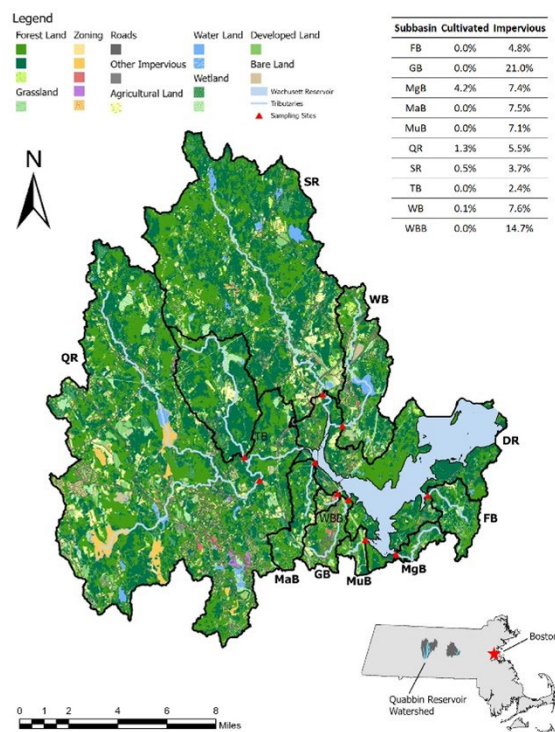
## An integrative approach for sustainable water management using spatial data and data-driven tools

[Dr. Amanda Carneiro Marques \(CAEE\)](#) – Faculty Mentor

### GOALS

Protection of waterbodies used for drinking water supply systems includes the assessment of constituent delivery within sensitive timeframes and areas of water supply watersheds in face of changes caused by land use, human practices, and climate patterns. Often, the type of land use/land cover plays a significant role in determining nutrient and sediment loading patterns to water resources. Improvements in land use planning and protection programs aim to control nonpoint source contributions. Studies have demonstrated the impact of watershed protection components to understand how programs can be balanced, effective, and sustainable.

This VIP team will focus on using Geographic Information Systems and Machine Learning to elucidate how changes in land use/land cover affect water quality trends and climate change impacts in environmental systems. The team's first major project will aim at identifying, assessing, and predicting major drivers of water pollution. This project will involve learning ArcGIS Pro as a tool to process and analyze spatial data. Additionally, it will provide an understanding of GIS principles and practices and an overview of spatial data analyses and computer systems. This project is designed to encourage team members to think more broadly about the use of spatial technologies, practices, and models and how they influence communities and the environment. Team members will gain experience working with spatial data and using spatial analysis tools to answer research questions integrating water quality and quantity assessments. The team will also assess how changes in land use/land cover affect water quality trends, including identifying the main drivers of pollutants in freshwater. Furthermore, team members will support key aspects of this research by learning how to process environmental datasets and climate records, and preparing datasets for exploratory and predictive analysis. They will gain hands-on experience with Python for data processing, ArcGIS Pro for spatial mapping, and learn the basics of supervised machine learning (e.g., Random Forest, XGBoost) for environmental modeling.



*Land use/land cover map of a drinking water supply watershed with altered drainage landscaped percentages showed by subwatershed created using ArcGIS (Marques et al, 2024)*

### METHODS & TECHNOLOGIES

1. Spatial data collection (e.g., ArcGIS)
2. Statistical data analysis (e.g., to assess water quality trends)
3. Machine learning algorithms (e.g., to identify major drivers of water pollution)

### RESEARCH, DESIGN, & TECHNICAL ISSUES

This VIP team will focus on collecting and preprocessing data from ArcGIS. Team members will learn how to use tools in ArcGIS Pro for spatial data analysis; understand what types of spatial data are available and how to access/download data from publicly available sources; investigate the impacts of changes in land

use/land cover for water quality patterns; and assess the impacts of those changes for water management by using these tools to support the development of effective mitigation strategies.

Team members will also learn how to compile spatial and tabular data across multiple datasets (USGS, NOAA, EPA, state agencies). Tasks may include processing water quality datasets, land cover and climate data, conducting seasonal trend analysis, elucidating spatial patterns and building a water quality index, and assisting with training and evaluating machine learning models. This project will give team members exposure to real-world environmental data challenges, interdisciplinary research, and a better understanding of sustainable watershed planning.

### **MAJORS & AREAS OF INTEREST**

This VIP team is interested in recruiting undergraduate students from the following majors or areas of interest:

- Civil, Architectural, and Environmental Engineering – water resources; water planning and management; water quality; stormwater management; urban flooding; environmental systems; watershed management; hydraulic modeling; sustainable systems
- Computer Engineering – big data, machine learning

Other students with a variety of interests are welcome to apply!

### **MENTOR CONTACT INFORMATION**

Dr. Amanda Carneiro Marques

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[Water, Sustainability, and Climate Research Group](#)

### **PARTNERS & SPONSORS**

[Massachusetts Department of Conservation and Recreation](#)

[Philadelphia Water Department](#)

[Pennsylvania Water Resources Research Center](#)

## Artificial Intelligence and Robotics for Nondestructive Evaluation

Drs. [Arvin Ebrahimkhanlou \(CAEE/MEM\)](#) – Faculty Mentors

### GOALS

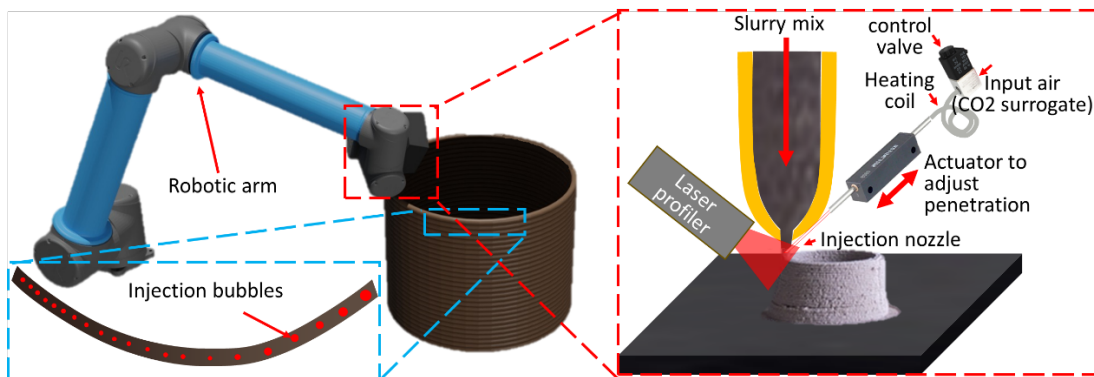
Recent advancements in artificial intelligence and robotics have created new opportunities for transforming how we evaluate and assess the condition of physical assets. Projects in this research theme leverage such opportunities to advance the field of nondestructive evaluation.

### CURRENT PROJECTS

#### PROJECT 1: DESIGN AND MANUFACTURING OF A ROBOTIC NOZZLE FOR NONDESTRUCTIVE EVALUATION OF CO<sub>2</sub> INJECTION IN 3D PRINTED CONCRETE

The construction industry faces a significant challenge in achieving net-zero carbon emissions, contributing 8% of global carbon emissions. While concrete 3D printing offers material waste reduction by eliminating formwork, it paradoxically increases embodied carbon due to higher cement content. Although concrete can naturally absorb CO<sub>2</sub> through carbonization, this process is slow and limited to external surfaces. Once saturated, the external surfaces further inhibit additional CO<sub>2</sub> uptake, limiting the net-zero benefits. Existing CO<sub>2</sub> injection methods in prefabrication, while enhancing concrete properties, suffer from the limitations of slow absorption and CO<sub>2</sub> re-release, highlighting a critical need for innovative, more efficient carbon sequestration strategies in concrete.

This project focuses on designing and manufacturing an injection nozzle to investigate the feasibility of injection-based carbon sequestration in 3D printing of cementitious materials. The idea is to use a laser profiler to nondestructively track the geometry and defects (e.g., cracks) of 3D printed concrete as a function of the amount and patterns of CO<sub>2</sub> injections. To this end, the project will utilize an existing robotic arm and instead of actual CO<sub>2</sub> gas, will experiment with air bubbles as surrogates for CO<sub>2</sub> to ensure safety and a manageable timeline.



### METHODS & TECHNOLOGIES

- 3D printing concrete
- Robotics
- Nondestructive evaluation
- Mechanical design and manufacturing

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Computer-aided design (CAD) and manufacturing of the injection nozzle.
- 2) Mechatronic implementation and integration with the robotic arm.

- 3) Sample generation with variable concrete mix, bubble sizes, spacing, injection depths, and temperatures.
- 4) Nondestructive evaluation (NDE) and time-dependent assessment of the prints. A laser surface profiler will be used to scan the geometry and map its defects, such as cracks.

## PROJECT 2: DESIGN AND CONSTRUCTION OF A CONCRETE 3D PRINTER FOR SUSTAINABLE MATERIALS RESEARCH

Concrete 3D printing is emerging as a transformative construction technology with the potential to reduce material waste, enable complex geometries, and accelerate construction timelines. However, most existing systems are expensive, closed-source, and difficult to modify for research purposes—particularly for exploring alternative, earth-based cementitious matrices and novel printing strategies. There is a strong need for flexible, research-grade concrete 3D printers that can be designed, built, and modified in-house.

This project focuses on the design and construction of a gantry-based concrete 3D printer using a CAD-driven, mechatronics-centered approach. Students will design the mechanical structure, motion system, and extrusion hardware, followed by hands-on assembly, integration, and testing. The resulting printer will serve as a research platform to support ongoing and future studies in concrete 3D printing, including printing with earth-based and low-carbon matrices, material processability, and print quality control.

Beyond system construction, the project emphasizes the integration of hardware, control, and materials research. The printer will be designed to accommodate interchangeable nozzles, adjustable printing parameters, and sensor integration, enabling experimental studies in sustainable construction materials and advanced additive manufacturing.

### METHODS & TECHNOLOGIES

- Computer-aided design (CAD) for mechanical systems
- Gantry-based motion systems and linear actuation
- Mechatronics and electromechanical integration
- Motor selection, drives, and motion control
- Hands-on assembly, wiring, and system integration
- Concrete extrusion and material handling systems
- Additive manufacturing for construction materials
- Earth-based and sustainable cementitious matrices

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) System Architecture and Requirements Definition
- 2) Mechanical Design Using CAD
- 3) Motion and Actuation System Design
- 4) Extrusion and Material Delivery System
- 5) Mechatronics and Control Integration
- 6) Hands-On Assembly and Commissioning
- 7) Printing Trials and System Validation
- 8) Support for Earth-Based Materials Research
- 9) Future Expansion and Research Enablement

### PROJECT 3: NONDESTRUCTIVE EVALUATION OF ADDITIVE MANUFACTURING FOR CIVIL INFRASTRUCTURES

Additive manufacturing (AM) is revolutionizing civil infrastructure by enabling complex geometries and accelerating construction timelines. However, ensuring structural integrity and long-term durability of AM components remains a critical challenge. Currently limited or no real-time destructive evaluation is used to monitor the printing process and provide feedback to the printer to adaptively change the print parameters and ensure a consistent process. This creates an urgent need for advanced nondestructive evaluation (NDE) techniques that can monitor and assess AM processes and products without compromising their integrity.

This project aims to develop and validate non-contact, vision-based NDE methods for additive manufacturing in civil infrastructure applications. Leveraging computer vision and machine learning, the project will focus on detecting geometric deviations, surface defects, and early-stage cracking during and after the printing process. The ultimate goal is to establish a robust framework for real-time quality assurance and predictive maintenance of AM-based structural components.

#### METHODS & TECHNOLOGIES

- Non-contact vision-based NDE
- Computer vision and image processing
- Machine learning for defect detection and pattern recognition
- Hands-on experimental validation

#### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Design and fabrication of a test rig for controlled AM experiments.
- 2) Sample preparation with varying material compositions and printing parameters.
- 3) Data collection and annotation using cameras and sensors during and after printing.
- 4) Using computer vision algorithms for geometry tracking and defect identification.
- 5) Machine learning model training and validation for automated defect classification and predictive analysis.
- 6) Data analysis and interpretation to correlate printing parameters with defect occurrence.
- 7) Drafting and submission of publications to disseminate findings in leading journals and conferences.

### PROJECT 4: BRIDGE WEIGH-IN-MOTION (B-WIM) FOR DETECTING OVERWEIGHT TRUCKS WITHOUT DISRUPTING TRAFFIC

Ensuring the safety and longevity of bridges requires continuous monitoring of traffic loads, especially overweight trucks that can accelerate structural deterioration and increase maintenance costs. Traditional weigh stations and in-road load cells disrupt traffic and capture only a subset of vehicles. Bridge Weigh-In-Motion (BWIM) systems offer a non-intrusive alternative by estimating vehicle weights from bridge responses as trucks pass at normal speeds. This project focuses on a camera- and sensor-enabled BWIM system that identifies trucks and their axle configurations using computer vision while simultaneously measuring bridge vibrations and strains with accelerometers and strain gauges. The system integrates hardware designed for decades-long operation with solar power, robust environmental packaging, and edge processing. Advanced signal processing, finite element (FE) modeling, and filtering (e.g., Kalman filters) will be used to estimate truck speed, axle weights, and gross vehicle weight (GVW) in varying lighting, temperature, and environmental conditions—without disrupting traffic.

This project aims to design, prototype, and validate a fully integrated BWIM solution for civil infrastructure. It will combine synchronized multi-sensor measurements, robust computer vision algorithms for truck and wheel detection, physics-informed numerical models, and state estimation techniques to deliver reliable, scalable, and maintainable overweight-truck detection with actionable outputs for asset management.

### METHODS & TECHNOLOGIES

- Non-contact vision-based detection (truck classification, axle/wheel detection, license plate association as applicable)
- Bridge sensors: accelerometers (vibration), strain gauges (strain), optional temperature sensors for compensation
- Hardware development: PCB design, battery selection, solar power integration, ruggedized sensor packaging
- Computer vision and machine learning (edge deployment, low-light enhancement, adverse weather robustness)
- Finite element modeling (FE) and model calibration with measured data
- Filtering and estimation (Kalman filter / extended Kalman filter for speed and weight estimation; sensor fusion)
- Hands-on experiments, field deployment, data collection, and iterative validation

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Design and prototype hardware with PCB, solar power, and rugged packaging for long-term operation.
- 2) Process and synchronize accelerometers, strain gauges, and cameras data for accurate event alignment.
- 3) Develop computer vision algorithms for truck and axle detection under varying environmental conditions.
- 4) Modify and calibrate existing finite element models to relate bridge responses to axle loads.
- 5) Implement filtering algorithms (e.g., Kalman filter) for weight and speed estimation using sensor fusion.
- 6) Drafting and submission of publications to disseminate findings in leading journals and conferences.

### PROJECT 5: GENERATIVE AI FOR EARLY-STAGE BUILDING DESIGN AND LIFE-CYCLE ASSESSMENT

Building design decisions made at the early conceptual stage have a profound impact on construction cost, energy performance, and life-cycle environmental impacts. However, early-stage designs are often schematic and lack sufficient detail to support informed sustainability assessments or performance-based decision-making. Recent advances in generative artificial intelligence (AI) offer a unique opportunity to bridge this gap by enriching early-stage building designs with plausible, data-driven details derived from existing design knowledge.

This project focuses on developing a generative AI framework for building design by compiling a curated dataset of building components—such as windows, doors, walls, and façade elements—extracted from architectural and engineering CAD drawings. The dataset will consist of labeled 2D image crops representing common building components and configurations. These data will be used to train generative AI models capable of inferring and enriching architectural details from sparse or conceptual design inputs.

The trained models will support early-stage design by automatically proposing detailed building components consistent with architectural intent and enabling preliminary life-cycle and sustainability assessments. By integrating generative design with performance-aware evaluation, this project aims to accelerate sustainable building design workflows and reduce the environmental footprint of buildings from the earliest design phases.

### METHODS & TECHNOLOGIES

- Generative AI and deep learning (e.g., diffusion models, GANs)
- Computer vision and image processing
- Dataset curation and annotation from CAD drawings
- Architectural design representation
- Life-cycle assessment (LCA) concepts for buildings
- Python-based ML frameworks and data pipelines

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Dataset Compilation
- 2) Data Preprocessing and Representation
- 3) Generative AI Model Development
- 4) Early-Stage Design Enrichment
- 5) Life-Cycle and Sustainability Assessment
- 6) Drafting and submission of publications to disseminate findings in leading journals and conferences

### PROJECT 6: MACHINE LEARNING AND DEEP LEARNING FOR ACOUSTIC EMISSION-BASED NONDESTRUCTIVE EVALUATION

Acoustic emission (AE) monitoring is a powerful nondestructive evaluation (NDE) technique that captures stress-wave signals generated by damage processes such as cracking, debonding, corrosion, and fracture. AE has been widely applied to diverse systems including concrete structures, composite materials, and batteries. However, AE data are inherently high-dimensional, noisy, and voluminous, making manual interpretation and physics-only approaches insufficient for reliable damage characterization and prognosis.

This project focuses on applying modern machine learning (ML) and deep learning (DL) techniques to acoustic emission data collected from concrete structures, batteries, and composite materials. The goal is to develop data-driven methods for automated damage detection, characterization, and progression tracking. Students will work with real experimental AE datasets and develop end-to-end pipelines including data cleaning, feature extraction, signal and image processing, unsupervised and supervised learning, and model interpretation. The outcomes of this project will directly contribute to peer-reviewed journal papers and conference presentations in the NDE, materials, and structural health monitoring communities.

### METHODS & TECHNOLOGIES

- Acoustic emission sensing and waveform analysis
- Signal processing (time, frequency, and time–frequency domains)
- Feature extraction and dimensionality reduction
- Machine learning (clustering, regression, classification)
- Deep learning (CNNs, RNNs, transformers for time-series and spectrograms)
- Anomaly detection and damage evolution modeling
- Python-based data science and ML frameworks

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Data Acquisition and Understanding
- 2) Data Cleaning and Preprocessing
- 3) Signal and Image Processing
- 4) Unsupervised Learning and Clustering
- 5) Supervised Learning and Regression
- 6) Anomaly Detection and Damage Progression
- 7) Model Validation and Interpretation

- 8) Contributing to journal papers and conference presentations

#### PROJECT 7: GENERATIVE AI FOR CAUSAL REASONING, DIAGNOSIS, AND PROGNOSIS OF STRUCTURAL CONDITION

Assessing the condition of civil and aerospace structures requires not only detecting defects, but also reasoning about their causes, progression mechanisms, and future consequences. Traditional nondestructive evaluation (NDE) methods can identify cracks, corrosion, delamination, and other damage features, but they often rely on expert interpretation and lack automated reasoning capabilities. At the same time, purely data-driven AI models struggle to generalize across structures, loading conditions, and environments when physical causality is ignored.

This project aims to develop a new generation of generative AI systems capable of causal reasoning for structural condition evaluation, by integrating visual–language models (VLMs) with mechanics-based structural models. The project will focus on automating the diagnosis (what damage exists and why) and prognosis (how damage will evolve) of defects in civil and aerospace structures using multimodal data such as images, videos, sensor measurements, and engineering models. By grounding generative AI in physics-based understanding, the project seeks to move beyond pattern recognition toward interpretable, trustworthy, and decision-relevant AI for infrastructure health monitoring.

#### METHODS & TECHNOLOGIES

- Generative AI and foundation models
- Vision–Language Models (VLMs) for multimodal reasoning
- Computer vision for defect detection and tracking
- Structural mechanics and physics-based modeling
- Physics-informed and hybrid AI models
- Causal inference and reasoning frameworks
- Nondestructive evaluation (NDE) data integration
- Python-based AI and simulation workflows

#### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Multimodal Data Integration
- 2) Visual–Language Reasoning for Damage Interpretation
- 3) Causal Modeling of Structural Damage
- 4) Integration with Mechanics-Based Structural Models
- 5) Automated Diagnosis of Structural Defects
- 6) Damage Prognosis and Scenario Generation
- 7) Interpretability and Trustworthiness
- 8) Contributing to journal publications and conference presentations

#### PROJECT 8: INTERACTIVE ROBOTIC INSPECTION AND ASSESSMENT OF CIVIL INFRASTRUCTURE

Inspection and structural assessment of civil infrastructure are traditionally performed as two largely separate processes. Field inspections are conducted on-site, often relying on visual observations and limited nondestructive testing, while structural assessment and diagnosis are performed later by engineering firms in office settings through post-processing and analysis. This separation limits the ability to interactively investigate observed damage, verify hypotheses about root causes, and adapt inspection strategies in real time.

This project aims to develop an interactive robotic inspection and assessment framework that integrates on-site inspection, nondestructive evaluation (NDE), and structural reasoning into a unified, closed-loop process. By leveraging robotic systems and AI-driven perception, the project will enable infrastructure

inspection platforms to actively search for confirmations of suspected damage mechanisms. For example, a localized reduction in stiffness may be caused by a missing connection bolt, a cracked structural member, or a deteriorated or leaking joint—each requiring different follow-up measurements. Robotic systems can autonomously approach regions of interest, collect additional sensing data, and even apply localized static or dynamic loads to directly measure structural response.

The project will involve constructing a small-scale structural testbed and using an existing mobile robotic rover to perform vision-based inspection and interactive assessment. The robot will be programmed using the Robot Operating System (ROS) and will integrate computer vision and vision–language models (VLMs) to reason about observed damage, plan follow-up actions, and guide on-site decision-making. This work aims to demonstrate how robotic and AI technologies can fundamentally transform infrastructure inspection from a passive data collection task into an active, hypothesis-driven process.

### METHODS & TECHNOLOGIES

- Mobile robotics and robotic inspection systems
- Robot Operating System (ROS)
- Computer vision for defect detection and localization
- Vision–Language Models (VLMs) for reasoning and decision support
- Nondestructive evaluation (NDE) techniques
- Structural mechanics and response measurement
- Autonomous exploration
- Small-scale experimental structural testing

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Small-Scale Structural Testbed Design
- 2) Robotic Platform Integration
- 3) Vision-Based Inspection
- 4) Interactive Assessment and Hypothesis Testing
- 5) NDE Data Collection and Structural Response Measurement
- 6) Vision–Language Action models for Inspection Planning
- 7) Closed-Loop Inspection–Assessment Workflow
- 8) Contributing to journal papers and conference presentations

### PROJECT 9: ENHANCING COMPUTATIONAL MECHANICS RESULTS USING GENERATIVE AI

Computational mechanics simulations—such as finite element (FE) models—are essential tools for predicting the behavior of structures and materials under load. However, even high-fidelity simulations often deviate from experimental observations due to modeling assumptions, uncertain material properties, idealized boundary conditions, and incomplete representation of damage mechanisms. These discrepancies can lead to unrealistic stress fields, overly smooth deformation patterns, or visualizations that fail to capture real-world damage signatures observed in experiments.

This project aims to use generative AI to enhance the realism and interpretability of computational mechanics results by learning mappings between physics-based simulation outputs and experimentally observed responses. Generative models will be trained to transform simulated fields (e.g., displacement, strain, stress, damage indicators) into realistically-looking visualizations that better reflect experimental measurements, such as crack patterns, localization, noise, and heterogeneity. Rather than replacing physics-based models, the approach seeks to augment simulations with data-driven realism while preserving physical consistency.

The project will explore hybrid workflows that combine computational mechanics, experimental data, and generative AI to improve visualization, interpretation, and downstream decision-making in civil, mechanical, and aerospace engineering applications.

### METHODS & TECHNOLOGIES

- Generative AI (e.g., GANs, diffusion models)
- Image-to-image translation and conditional generative models
- Computational mechanics (finite element modeling)
- Physics-informed and hybrid AI modeling
- Data preprocessing and visualization
- Python-based simulation and AI workflows

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Computational Simulation Data Generation
- 2) Representation and Preprocessing
- 3) Generative Model Development
- 4) Physics Awareness and Constraints
- 5) Contributing to journal papers and conference presentations in computational mechanics and AI

### PROJECT 10: EXPERIMENTAL GUIDED-WAVE–BASED CONDITION ASSESSMENT OF PRESTRESSING STRANDS, PIPES, AND RAILS

Prestressing strands, pipelines, and railway rails are critical structural components in civil and transportation infrastructure, where corrosion and material degradation can significantly reduce load-carrying capacity and service life. Early detection and characterization of corrosion damage in these elongated structural elements remain challenging due to limited accessibility, large inspection lengths, and the need for nondestructive, scalable inspection techniques.

This project focuses on experimental guided ultrasonic wave–based condition assessment of prestressing strands, pipes, and rails. Guided waves are particularly well suited for these structures because they can propagate over long distances while remaining sensitive to defects such as corrosion, section loss, and cracking. However, the interaction between corrosion damage and guided wave propagation is complex and not yet fully understood, especially under realistic damage scenarios.

The project will involve building meso-scale experimental setups and performing accelerated corrosion testing to simulate realistic corrosion damage under controlled conditions. The effects of corrosion on guided wave characteristics—such as wave velocity, attenuation, mode conversion, and scattering—will be experimentally investigated. The results will contribute to improved interpretation of guided-wave signals and more reliable condition assessment methodologies for infrastructure systems.

### METHODS & TECHNOLOGIES

- Guided ultrasonic waves for nondestructive evaluation (NDE)
- Experimental structural health monitoring (SHM)
- Ultrasonic transducers and data acquisition systems
- Signal processing and time–frequency analysis
- Accelerated corrosion testing techniques
- Meso-scale experimental design and fabrication
- Data-driven interpretation of wave–damage interactions

## RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Design of the Experimental Setup
- 2) Guided Wave Excitation and Sensing
- 3) Accelerated Corrosion Testing
- 4) Signal Processing and Feature Extraction for Wave–Damage Interaction Studies
- 5) Contributing to journal papers and conference presentations

### PROJECT 11: GENERATIVE AI FOR ENHANCING AND PREDICTING MICROSTRUCTURE EVOLUTION IN ADDITIVELY MANUFACTURED METALS

The mechanical performance, durability, and reliability of additively manufactured (AM) metals are governed by their microstructure, which is highly sensitive to printing conditions such as laser power, scan speed, layer thickness, and thermal history. Experimental characterization of microstructures is expensive, time-consuming, and often limited to a small subset of process parameters. Moreover, computational microstructure models can struggle to reproduce the complex, heterogeneous features observed in real microscopy images.

This project aims to leverage generative artificial intelligence (AI) to enhance and predict microstructure images of additively manufactured metals. Generative models will be trained on experimentally obtained microstructure images (e.g., optical microscopy, SEM, EBSD) to produce realistically enhanced microstructures and to perform conditional modifications based on changes in printing parameters. By conditioning generative AI models on process variables, the project seeks to predict how microstructures evolve when manufacturing conditions are altered—enabling rapid exploration of process–structure relationships.

Rather than replacing experiments or physics-based models, the generative AI framework will serve as a data-driven surrogate that augments microstructural analysis, supports materials design, and accelerates optimization of AM process parameters.

## METHODS & TECHNOLOGIES

- Generative AI (GANs, diffusion models, conditional generative models)
- Image-to-image translation and conditional synthesis
- Microstructure characterization (optical microscopy, SEM, EBSD as available)
- Additive manufacturing process–structure relationships
- Image processing and feature extraction
- Python-based machine learning workflows
- Data-driven materials modeling

## RESEARCH, DESIGN, & TECHNICAL ISSUES

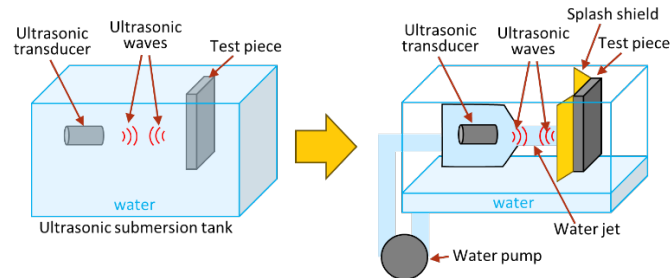
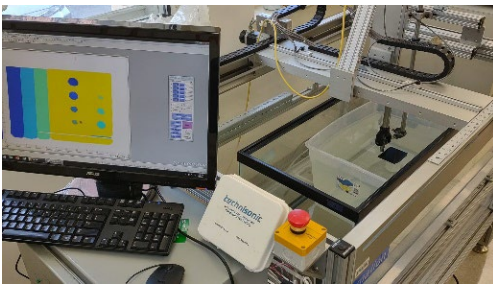
- 1) Microstructure Dataset Compilation
- 2) Image Preprocessing and Representation
- 3) Generative Model Development
- 4) Conditional Microstructure Modification and Prediction of Microstructural Evolution
- 5) Validation and Quantification of the Results using Computer Vision Methods
- 6) Contributing to journal publications and conference presentations

### PROJECT 12: DESIGN AND MANUFACTURING OF AN ULTRASONIC JET SYSTEM FOR BATTERY INSPECTION

Batteries are becoming increasingly prevalent due to the rise of electric vehicles, the growing need for renewable energy storage, and advancements in battery technology that have lowered costs and improved performance. Inspecting damaged batteries is vital for understanding their failure modes—including internal

defects and material degradation—which is crucial information for designing safer, more reliable products and refining manufacturing processes. Ultrasonic inspection stands out as a fast and reliable non-destructive evaluation (NDE) method for assessing the internal structures of batteries. This technique offers key advantages over alternative approaches, such as X-ray imaging and destructive techniques like the microscopic analysis of sectioned battery components.

This project aims to enhance Drexel University's current ultrasonic inspection capabilities by modifying an existing ultrasonic tank to incorporate a squirting (water jet) ultrasonic system. The primary goal is to enable the NDE of internal battery structures to identify defects and damage effectively. While traditional ultrasonic submersion tanks can provide high-resolution three-dimensional scans of various materials' internal structures, submerging batteries for inspection is often prohibitive due to safety concerns. Therefore, this project seeks to eliminate the need for direct submersion, ensuring the batteries are protected throughout the inspection process.



### METHODS & TECHNOLOGIES

- Nondestructive Evaluation (NDE) - Squirting Ultrasonic Testing
- Mechanical Design and Modification
- 3D Printing
- Machining
- Sensing and Data Acquisition Robotics

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Literature Review: Performing a literature review and comparing different NDE methods for inspection of batteries.
- 2) Design and Integration of Squirting Jet System: Developing and integrating a squirting ultrasonic water jet system into the existing tank system. This includes nozzle design, water flow control, and transducer placement.
- 3) Battery Protection: Designing and implementing effective measures to protect batteries from water ingress during the inspection process.
- 4) Ultrasonic Calibration: Selecting appropriate probes (frequency, aperture, focal distance), choosing the inspection mode (pulse-echo or through-transmission mode), setting ultrasonic gates, calibrating ultrasonic parameters (probe delay and wave velocity), and choosing scanning parameter (steps and speed) for effective penetration and reflection from internal battery structures.
- 5) Data Acquisition: Acquiring data from battery samples provided by Ohio University and characterizing internal defects.
- 6) Report Writing: Documenting the design and findings.

### **MAJORS & AREAS OF INTEREST**

This VIP is interested in recruiting both undergraduate and graduate students from the following majors and areas of interest:

- Civil, Architectural, and Environmental Engineering: Concrete 3D Printing, Nondestructive evaluation, Robotics, Sustainability
- Mechanical Engineering and Mechanics: Mechanical design and manufacturing, Nondestructive evaluation, Robotics, Control, Mechatronics
- Electrical and Computer Engineering: Nondestructive evaluation, Robotics, Control, Mechatronics
- Computer Science: Artificial Intelligence, Computer Vision, Robotics, Automation
- Material Engineering: Nondestructive evaluation

### **MENTOR CONTACT INFORMATION**

Dr. Arvin Ebrahimkhanlou  
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Civil, Architectural, and Environmental Engineering

### **PARTNERS & SPONSORS**

Potential for funding from the National Science Foundation and the Manufacturing PA Initiative

## **Astroparticle Physics in Extreme Locations**

Dr. Christina Love (Physics) – Faculty Mentor

### **GOALS**

Particles like cosmic rays and astrophysical neutrinos are produced throughout our Universe. This Astroparticle VIP team explores two main ways of detecting these particles: the IceCube Neutrino Observatory at the South Pole and the HERA collaboration using High Altitude Balloons (HAB). IceCube detects neutrinos using a massive array of detectors embedded in the Antarctic ice. Team members working on IceCube will specifically work with the citizen science project called Name that Neutrino. This project allows volunteers (members of the general public) to aid in data classification of events for IceCube. The HERA collaboration studies particles produced by cosmic ray air showers by using HAB to carry scientific instruments into the stratosphere.

Team members participating in Name that Neutrino will work on analyzing data, visualizing data for the next iteration, exploring ways to reach more volunteers, and actively participating in the forum talk pages to help volunteers.

Team members participating in the HERA HAB experiment will engage in all the stages of real-life research projects: literature searches, theory calculations and predictions, equipment design, prototype testing and development, logistics and deployment, data analysis, and project reporting. There should be a few opportunities to participate in the field deployment of devices on balloons.

The entire Astroparticle VIP team will focus on improving the experimental design for these two distinct detection methods to better understand the origins and properties of these elusive and astronomical particles.

### **METHODS & TECHNOLOGIES**

Computer programming, citizen science, web development, hardware with particle detectors, literature searches, communication, surveys, social media

### **MAJORS & AREAS OF INTEREST**

The Astroparticle VIP team needs a variety of skills:

- Physics and Math – astronomy, particle physics, data analysis, data visualization
- Computer Science – microprocessors for data collection for HAB, data analysis, data visualization
- Engineering – engineering payload design for HAB, data analysis, data visualization
- Education, Communication, and Sociology – design, assess, or deliver high school lessons
- Design Majors and English – explore ways to recruit volunteers through graphic design, animation, blog posts, etc
- Other students with a variety of interests are welcome to apply – this is a multidisciplinary project.

### **MENTOR CONTACT INFORMATION**

Dr. Christina Love  
Email: [love@drexel.edu](mailto:love@drexel.edu)

## **PARTNERS & SPONSORS**

Collaborators: Richard Cairncross (Chemical and Biological Engineering); Alissa Sperling (Springside Chestnut Hill Academy); Naoko Kurahashi Neilson (Physics)

Funding received from:

- NSF IceCube: [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=2209445&HistoricalAwards=false](https://www.nsf.gov/awardsearch/showAward?AWD_ID=2209445&HistoricalAwards=false)
- Nationwide Eclipse Ballooning Project (NEPB): <https://eclipse.montana.edu/>
- Pennsylvania Space Grant Consortium: <https://sites.psu.edu/paspacegrant/support/statewide-support/competitive-mini-grant-program/>
- Drexel: College of Arts and Sciences Undergraduate Research Support (ASURS) Fund



- Qualitative data collection and analysis (interviews and surveys with demolition and deconstruction contractors and experts)

### RESEARCH, DESIGN, & TECHNICAL ISSUES

The VIP team will focus on collecting and preprocessing quantitative data from ArcGIS, City databases, building codes, life cycle inventory databases, and stakeholder surveys. Students may also participate in collecting and analyzing qualitative data from stakeholder interviews. Undergraduate students will work with graduate students and professors biweekly to work on developing the building material stocks database for Philadelphia and predicting current material flows in the city.

#### PROJECT 2: Understanding complex decision-making systems through social practice theory: actors, skills, knowledge, beliefs and how they shape Circular Economy in Philadelphia

Our team will conduct and analyze interviews with key circular economy actors in Philadelphia (designers, business owners, waste management professionals, advocates, policymakers). Our goal is to understand how people make decisions in this environment and what are the challenges and opportunities to increase circularity of building products in the city. **Team members will assist in scheduling, conducting, and analyzing interviews, analyzing existing policies, writing results, and creating visual representations of their findings.**

### METHODS & TECHNOLOGIES

Team members will:

- Qualitative data collection (interviews), thematic data analysis
- Policy analysis
- Statistical data analysis

### RESEARCH, DESIGN, & TECHNICAL ISSUES

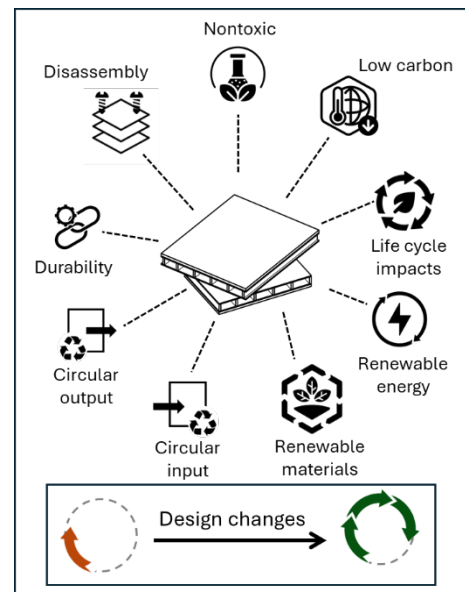
The VIP team will focus on collecting and analyzing qualitative data from stakeholder interviews.

#### PROJECT 3: Circular Prefabricated Façades: Learning Circular Economy for Building Envelope Design

This project focuses on **making building envelopes more sustainable and circular**. Students will learn how wall, window, and roof systems can be designed to reduce waste, use more recycled content, and allow for reuse or recycling at the end of their life.

The goal is to understand how circular economy concepts can be applied to **prefabricated façade systems** and how design choices affect the environmental impacts of a building.

Team members will **learn about circularity strategies and metrics** and **assist the research team** with collecting, organizing, and analyzing data on the circularity of building components, and documenting information related to circularity and design for disassembly.



## METHODS & TECHNOLOGIES

Team members will be introduced to:

1. Circularity metrics and tools: **Product Circularity Indicator (PCI) and the Circular Construction Evaluation Framework (CCEF)**
2. **Life Cycle Assessment (LCA)** basics
3. Collecting and organizing material data using **Excel**
4. Understanding how to evaluate product reuse and recyclability
5. Exploring examples of **Design for Disassembly**
6. Learning how digital tools can support circular design decisions

## RESEARCH, DESIGN, & TECHNICAL ISSUES

Team members will:

1. Help collect, organize, and analyze data about building materials
2. Learn to identify recycled and reusable components
3. Create tables and visual summaries
4. Discuss progress and new topics in weekly or biweekly meetings

This experience will give students a chance to learn by doing, while contributing to ongoing circular economy research at Drexel.

## **MAJORS & AREAS OF INTEREST**

This VIP team is interested in recruiting undergraduate students from the following majors or areas of interest:

- Civil, Architectural, and Environmental Engineering – sustainable buildings and cities, circular economy, building envelope design, life cycle assessment, material flow analysis, urban metabolism, material reuse or recycling.
- Computer Engineering – big data, machine learning, computer vision algorithms
- Architecture and urban studies – circular building design, circular cities
- Construction management – deconstruction and material reuse
- Behavioral economics, Law, Environmental Policy, and other disciplines
- Environmental Studies and Sustainability
- 

Other students with a variety of interests are welcome to apply!

## **MENTOR CONTACT INFORMATION**

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[CIRCLE Lab](#)

## **PARTNERS & SPONSORS**

None

## Cognitive Neuroengineering for the Brain and Mind

Drs. [John Medaglia \(PSY\)](#) & [Gary Friedman \(ECE\)](#) – Faculty Mentors

### GOALS

Just like any other part of the body, brains are unique to the individual and change over time. Anatomical MRIs (magnetic resonance imaging) show very clear differences in the shape and position of different landmarks, lobes, etc. in different peoples' brains. But there are also many differences that are not evident from visual inspection of anatomical images. Using fMRI (functional MRI), we are able to see which areas become more or less activated during a certain task. This allows us to make a functional connection between a behavior or performance and regions of the brain. For example, fMRI has allowed us to associate the frontal areas of the brain with executive control, which is the ability to choose between options and make plans. Like anatomy, the location of these functional areas varies across individuals. Even more, functional areas are part of greater networks throughout the brain. These networks connect and exchange information in order to execute tasks. For example, the "frontoparietal control network" (FPCN) is a network that links frontal and posterior areas of the brain and is especially important in helping us to switch between different tasks based on the context of our environment or rules. Networks vary across individuals in the same way that functional areas do.

As described above, there are individual differences at many levels within the brain. i.e. at the anatomical, functional, and network levels. Our lab uses a combination of MRI, functional MRI, diffusion MRI (which maps brain connectivity), EEG, graph theory, and network control theory to create individual-level functional maps of a person's brain. We pair these maps with TMS (transcranial magnetic stimulation) and tDCS (transcranial direct current stimulation) to stimulate the brain in order to learn about how functional networks connect and to develop and inform treatments for brain disorders. TMS and tDCS are non-invasive brain stimulation technologies, meaning that they can influence how neurons fire, harmlessly, from outside the body. TMS achieves this through the application of strong magnetic fields and tDCS achieves this through direct low-intensity electrical currents. A unique advantage of brain stimulation allows us to make causal connections between brain activation and behavioral outcomes, which was previously only possible using invasive techniques or by studying those with brain damage due to injury.

However, TMS and tDCS are often used in treatments without any information about underlying neural circuits and network organization, i.e. using anatomical landmarks. Our lab uses the fMRI methods described above to create detailed and personalized functional networks to guide stimulation to test whether we can induce improved behavioral responses. Another aspect of targeting neural stimulation is synchronizing it to the activity in the relevant networks. Our lab uses Electroencephalography (EEG) to measure what happens in subjects' brains while they complete tasks. We use extremely fast "closed-loop" systems to deliver neural stimulation that can enhance or suppress brainwaves in the targeted networks. Together, personalized targeting in space ("where" in the brain) and in time (synchronizing with ongoing brain waves from functional networks) can help us to identify optimal stimulation strategies that lead to better treatment plans and better patient outcomes.

### METHODS & TECHNOLOGIES

Many different methods and technologies are used at each step of our research. Our typical process is to design appropriate MRI tasks and scan sequences; bring the subject into the scanner; process their imaging data and create personalized stimulation targets; create cognitive/behavioral tasks that test the function of interest; noninvasively stimulate the subject at their personalized target and analyze their results. Some steps are more design-focused with an emphasis on cognitive psychology, some are more technically focused such as creating tasks and setting up equipment, some are more subject-focused, i.e. running sessions, and some are more programming-focused, such as neuroimaging data processing and analysis. In general, most of our time is spent doing processing and analysis on computers, and the rest is spent in-person running sessions. Experience with and interest in any of the following will be relevant to our research.

- Computer-guided behavioral testing of humans
- EEG (electroencephalography)
- MRI (magnetic resonance imaging)
- Transcranial magnetic stimulation (TMS)
- Transcranial direct current stimulation (tDCS)
- Statistical data analysis (Matlab, Python, R, etc.)
- Neural network models
- Any EEG or MRI preprocessing suite (FreeSurfer, SPSS, FSL, fMRI prep, EEGLab, ERPLab, FieldTrip, etc.)
- Using the Command Line
- Signal Processing
- Cloud Computing, Supercluster computing, Supercomputer computing (Azur, AWS, Google Cloud, University Clusters, regional sites) and knowledge of computing resources for research beyond Drexel
- Windows, Mac, and Linux operating systems
- Computer Hardware/Design, including adding hard drives, expansion cards, memory, etc., upgrading internal components, RAID configuration, and technical specifications such as cable shielding, data transfer rates and certifications, Monitor metrics such as ppi, refresh rate, viewing angle, motion artifacts, etc.

### **RESEARCH, DESIGN, & TECHNICAL ISSUES**

In general, VIP team members will be involved in both running in-person research sessions and in analysis, processing, and design. The lab will work closely with incoming VIP students to understand their interests and goals and align their time and efforts with appropriate projects. At any given time, the lab has multiple ongoing projects in various stages of development.

### **MAJORS & AREAS OF INTEREST**

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical Engineering - EEG and MRI signal detection and processing, modeling of field penetration into the brain, neural network models, statistical signal processing
- Computer Engineering - software for behavioral tests, implementation of testing protocols over internet, neural network modeling, statistical signal processing
- Psychology - development of behavioral tests, interpretation of EEG data, development of TMS and TDCS protocols, neural network modeling
- Biomedical Engineering - EEG and MRI signal detection and processing, modeling of field penetration into the brain, neural network models, statistical signal processing
- Computer Science - software for behavioral tests, implementation of testing protocols over internet, neural network modeling, statistical signal processing

### **MENTOR CONTACT INFORMATION**

Dr. John Medaglia  
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 Phone: 215.553.7169  
[Cognitive Neuroengineering & Wellbeing  
 Laboratory](#)

Dr. Gary Friedman  
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 Phone: 215.895.2108  
[Professional Profile](#)

### **PARTNERS & SPONSORS**

None

## **Consortium for Climate Risks in the Urban Northeast (CCRUN) Climate and Sustainability Research Team (CSRT)**

Drs. [Franco Montalto \(CAEE\)](#) & [Patrick Gurian \(CAEE\)](#) – Faculty Mentors

### **GOALS**

We invite students interested in Resource Stewardship and Sustainability, Climate Change, Climate Resilience, and related topics to join the VIP Climate and Sustainability Research Team (CSRT). As part of the [Consortium for Climate Risks in the Urban Northeast \(CCRUN\)](#), Drexel undertakes stakeholder-driven, applied research that helps our external partners cope with and plan for climate change. Working under the supervision of a research team directed by Dr. Franco Montalto and Dr. Patrick Gurian, CSRT students will be involved in all aspects of this work, including data collection, data analysis, planning studies, modeling and simulation efforts, literature reviews, interviews, surveys, and planning and organization of meetings and convenings.

Climate resilient development simultaneously addresses human well-being, sustainability, and climate action goals. Our team is developing planning, policy, and infrastructure strategies that align the various sustainability, adaptation, and emissions reduction goals of our stakeholders. This work requires that engineers work with natural, social, and applied scientists, and public health experts. The objective is to explore the various intersections between sustainability, mitigation, adaptation, and equity goals, addressing topics such as the: 1) Emissions implications of various adaptation projects (e.g., low carbon adaptation); 2) Ecological implications of adaptation strategies; 3) Social/cultural/regional implications of coastal retreat; 4) Relationship between nature-based solutions and green gentrification; and 5) Enhancement of urban land-based ecosystem services through decentralization.

### **METHODS & TECHNOLOGIES**

Team members will have the opportunity to tackle real-world projects and create deliverables for these real-world projects, including communication & outreach plans; data tools, maps, information; decision support tools; publications (book, peer-reviewed publication, and/or technical report); presentations; white papers; academic theses/dissertations; and methodologies/approaches.

### **RESEARCH, DESIGN, & TECHNICAL ISSUES**

Currently, the faculty mentors and research coordinator for this team are looking for team members interested in:

#### **Building Sustainability Techno-Economic Analysis Studio**

Technological change in areas such as heat pumps, solar energy, storage, controls, and materials is accelerating, while energy markets and sustainability expectations are changing just as rapidly. Despite this, the uptake of economically attractive, small-scale sustainability measures remains surprisingly low. This phenomenon is often referred to as the energy efficiency gap: well-documented cases in which energy efficiency or sustainability investments with positive expected economic returns are not adopted by infrastructure owners. Research suggests that this gap persists due to a combination of behavioral and structural factors, including cultural inertia, split incentives between owners and renters, limited or unreliable information, uncertain returns, and high analytical costs.

Evaluating technological options often requires specialized, bespoke engineering analysis. For many small-scale projects, the cost and effort of this analysis can rival or exceed the value of the investment itself. As a result, many potentially cost-effective sustainability measures are never seriously considered. In this sense, energy efficiency is not limited by a lack of technology or capital, but by market friction created by costly and inaccessible analysis.

This studio addresses that problem by focusing on techno-economic analysis as a design tool, not just a reporting exercise. Team members will explore how emerging technologies perform under real-world

technical, economic, and behavioral constraints, and will develop simplified, decision-relevant tools that lower the cost of evaluating sustainability investments.

The studio has three core goals:

- **Explore the technological frontier**  
Identify emerging and under-explored building sustainability technologies and design strategies that may offer favorable economic and environmental performance under current and future market conditions.
- **Reduce analytical costs**  
Develop tools, templates, and simplified models that make techno-economic analysis accessible for small-scale projects—where traditional high-fidelity modeling is often impractical.
- **Build a shared knowledge base**  
Catalogue results in a growing library of techno-economic case studies, documenting how different sustainability investments perform across infrastructure types, climates, energy prices, and behavioral assumptions.

By combining engineering fundamentals, economic reasoning, and practical modeling, the studio aims to equip team members with skills that are directly applicable to real-world sustainability challenges—while contributing to a broader effort to close the energy efficiency gap.

The team members will work on real-world infrastructure sustainability problems using simplified but decision-relevant techno-economic analysis, with an emphasis on reducing analytical barriers to adoption.

Current project opportunities include:

- **Hybrid heat pump and resistance heating systems for Philadelphia-area schools and residential buildings.**  
Heat pumps offer highly efficient heating but often come with high upfront capital costs. Pairing heat pumps with electrical resistance heating can reduce system size and installation costs, while relying on resistance heating only during the coldest periods. This project identifies economically optimal combinations of these technologies under real-world weather conditions, energy prices, and comfort requirements.
- **Hybrid automated and manual dynamic building envelope strategies.**  
Shutters, shades, night insulation, and ventilation control can significantly affect building energy performance, but they also introduce aesthetic tradeoffs and require varying levels of time and attention from building occupants. This project examines the tradeoffs between manual and automated approaches and identifies a frontier of efficient design options based on user willingness to monitor and adjust these systems.
- **Shipping container farming: conceptual basis of design.**  
Shipping containers offer low-cost, modular, and rapidly deployable space, but require substantial retrofitting to support year-round urban agriculture. This project applies fundamental heat transfer and energy balance principles to identify insulation, heating, cooling, and ventilation requirements, and evaluates the techno-economic feasibility of shipping-container-based farming concepts.

## **MAJORS & AREAS OF INTEREST**

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the following areas:

- Infrastructure and the built environment
- Nature-based strategies / green infrastructure
- Water, energy, waste
- Computer simulations
- Planning and urban design
- Other related topics

## **MENTOR CONTACT INFORMATION**

Dr. Franco Montalto  
Email: [fam26@drexel.edu](mailto:fam26@drexel.edu)

Dr. Patrick Gurian  
Email: [pgurian@drexel.edu](mailto:pgurian@drexel.edu)

## **PARTNERS & SPONSORS**

This work is sponsored by the [Consortium for Climate Risks in the Urban Northeast \(CCRUN\)](#) and the [National Oceanic and Atmospheric Administration \(NOAA\) Climate Adaptation Partnerships \(CAP\) / Regional Integrated Sciences and Assessments \(RISA\) program](#)

## Coordination and Planning for Multi-Robot Systems

[Dr. Lifeng Zhou](#) (ECE) – Faculty Mentor

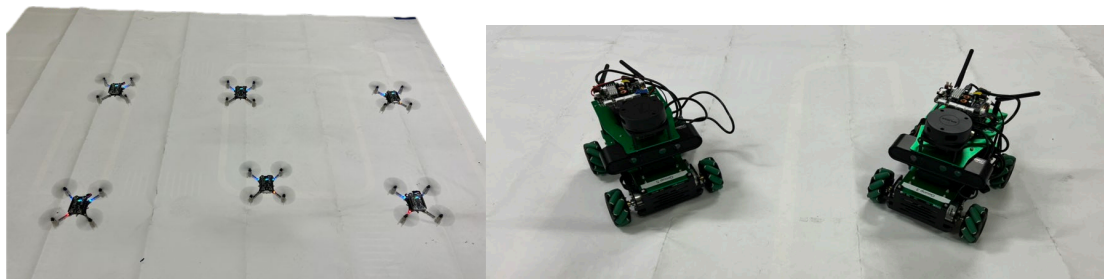
### GOALS

Robots continue to get smaller, faster, and cheaper. Robots today are equipped with sophisticated computing, communication, and sensing resources. It is becoming increasingly essential to advance robotics systems and algorithms that make full use of the robots' capabilities. The goal of this VIP team is to develop novel robotics systems and advanced coordination and planning algorithms for the resilient and long-term operation of robots in tasks such as environmental monitoring, search and rescue, target tracking, surveillance, and reconnaissance. VIP team members will work with professors and Ph.D. students and have regular meetings to discuss progress. There will be opportunities for publications at top robotics venues.

### CURRENT PROJECTS

#### PROJECT 1: HETEROGENEOUS MULTI-ROBOT TARGET TRACKING

This project focuses on developing a multi-robot target tracking system and designing coordination algorithms that enable drones to actively track dynamic ground robots. The project aims to enhance real-time tracking efficiency by optimizing drone collaboration, path planning, and target adaptation in dynamic environments



#### RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Develop a Multi-Robot Target Tracking System – Create a system where multiple drones act as trackers and multiple ground robots serve as dynamic targets, enabling real-time monitoring and pursuit.
2. AI-Powered Target Detection – Equip each drone with an AI-driven camera to detect and track ground robots accurately in varying environments.
3. Advanced AI for Target Recognition – Implement AI techniques such as Vision-Language Models (VLMs), YOLO, or DETR to recognize, classify, and track targets efficiently.
4. Multi-Drone Coordination Algorithms – Design intelligent coordination algorithms that enable drones to share perception data, communicate in real-time, and dynamically assign tracking responsibilities for optimized performance.

## PROJECT 2: COORDINATION OF HETEROGENEOUS ROBOTICS SYSTEMS

This project focuses on the coordination between a drone and a rover for outdoor information gathering. The perceptions of the drone and rover can complement each other for better data collection. In addition, when the battery of the drone is out of power, the rover should rendezvous with the drone to charge the drone.



### RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Developing a heterogeneous robotics system composed of a drone and a rover
2. Autonomous landing of the drone on the rover (the drone can be ferried by the rover)
3. Autonomous drone charging by the rover
4. Autonomous navigation of the rover using a Lidar, a camera, etc.
5. Area monitoring, coverage, exploration, target tracking of the drone using a downward facing camera
6. Real-time communication and information sharing between the drone and the rover
7. Joint perception of the drone and rover

### **METHODS & TECHNOLOGIES**

Robotics system design, unmanned aerial and ground vehicles, multi-robot coordination and communication, planning and control, perception and deep learning, reinforcement learning, GNNs, LLMs, robotics algorithm design, sensing techniques (Lidar, camera, radar, etc.).

### **MAJORS & AREAS OF INTEREST**

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical & Computer Engineering - coordination and control, motion planning, perception (Lidar, camera, etc.), LLMs, VLMs, computer vision, deep learning, reinforcement learning, robot communication, system design
- Computer Science - LLMs, VLMs, perception, computer vision, deep learning, reinforcement learning, algorithm design and analysis
- Mechanical Engineering - computer aid design (CAD) software experience, sensor design, system design, structure design

### **APPLICATION PREREQUISITES**

Prior to applying for a position on this team, prospective team members are asked to please install the Linux-Ubuntu & Robot Operating System (ROS) on their computer and go through the ROS tutorials (ROS1: <http://wiki.ros.org/noetic> or ROS2: <https://docs.ros.org/en/humble/index.html>). Prospective team members should prepare a video of the velocity control of a turtlebot in the ROS-Gazebo simulator and provide a link to this video when reaching out on ForagerOne to apply for the team.

If needed, a docker package with all the instructions for both ROS 1/2 which allows using Rviz, Gazebo, etc. is available at: <https://github.com/Zhourobotics/ros2-docker-dev> Alternatively, this software can also be utilized using a virtual machine to install Linux and ROS.

For Project 1: Try out mapping and wall-following of a Crazyflie drone in ROS-Gazebo simulator by following <https://www.bitcraze.io/2024/09/crazyflies-adventures-with-ros-2-and-gazebo/> and record a video. Try out camera calibration: [https://docs.opencv.org/4.x/dc/dbb/tutorial\\_py\\_calibration.html](https://docs.opencv.org/4.x/dc/dbb/tutorial_py_calibration.html) and document your findings. Please provide a link to this video when reaching out on ForagerOne to apply for the team.

For Project 2: Implement the autonomous navigation of a HUKSY robot in the ROS-Gazebo simulator (similar to this: <https://www.youtube.com/watch?v=F5OiuIkqxcc>) and record a video. Please provide a link to this video when reaching out on ForagerOne to apply for the team. Please also provide a demonstration of your skills in CAD design (Fusion 360 or SOLIDWORKS).

Please note that participation on this VIP team requires use of many robot hardware and software tools, which can take significant time to learn and build familiarity with; therefore, it is NOT recommended to apply for this team if one doesn't have enough time to commit to this effort (such as having a heavy courseload or participating in co-op in the same quarter). Prospective team members should indicate how much time they can commit to the team when reaching out on ForagerOne to apply for the team.

### **MENTOR CONTACT INFORMATION**

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[Drexel Zhou Robotics Lab](#)

### **PARTNERS & SPONSORS**

[Distributed and Collaborative Intelligent Systems and Technology Collaborative Research Alliance \(CRA\)](#)

[Assure - THE FAA's Center of Excellence for UAS Research](#)

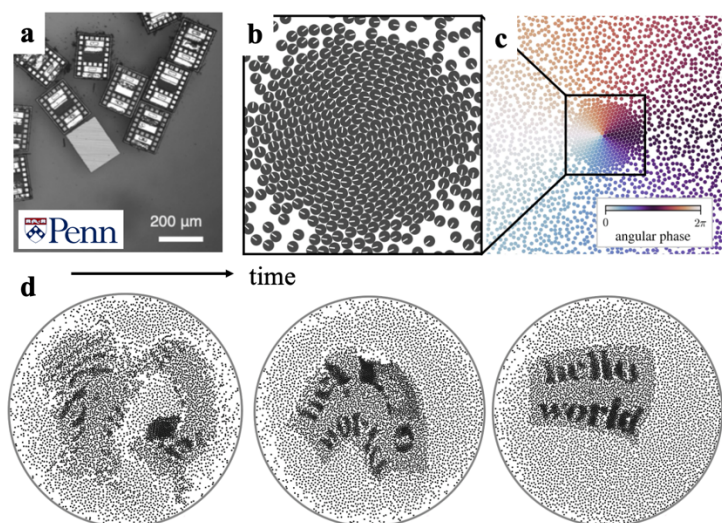
## Emergent coordinate systems for organizing massively parallel robotic swarms

[Dr. Bryan VanSaders](#) (Physics / MSE) – Faculty Mentor

### GOALS

When viewed as a material, living matter has exceptional properties. Its hierarchical organization allows it to adapt to external stresses, reconfigure its composition, and recover from damage. These properties are possible because of its massively parallel structure, composed of millions to trillions of distinct subunits (e.g. cells). However, this high degree of organization poses a riddle - how do individual cells collaborate and produce such useful emergent group behaviors? Biology provides a proof positive that such organization across scales is possible, while experimental efforts to miniaturize robots have succeeded in producing autonomous devices as small as single cells. What capabilities must such microscopic robots have so that they are capable of the same kinds of impressive feats we observe in collections of cells?

Microrobotic platforms are severely limited in their communication bandwidth, processing power, and on-board memory. Coordination strategies appropriate to large devices such as drones will not be feasible at the micro scale. Rather, we take an approach inspired by condensed matter physics to frame the coordination problem in terms of field equations and topological defects. With this foundation, we can realize highly robust coordination even for agents which cannot communicate over distances more than a few body lengths.



**a.** Microscopic robotic devices as small as single cells (courtesy of the Miskin Lab). **b.** Simulations of many simple robots carrying coupled clocks can achieve special collective states with topological defects. **c.** A zoomed out view of robots colored by the phase of their clock. **d.** Topological defects can act as an emergent reference point for group organization – here a swarm of 4000 simulated agents can spell out ‘hello world’ while only communicating with their closest neighbors.

This VIP team will focus on simulating thousands of interacting, self-propelled agents that collectively build a coordinate system and use that shared field to reconfigure themselves into desired patterns and shapes. Team members will interact with the University’s high performance compute cluster to run simulations, develop analysis code to interpret results, contribute to high-quality data visualizations, and interact with experimental collaborators. Authorship on a scientific publication is possible.

### METHODS & TECHNOLOGIES

1. Molecular dynamics simulation: [HOOMD-Blue](#) simulation package
2. High performance computing: Large scale simulation on the Picotte cluster, Slurm job scheduling
3. Dynamical systems theory: Excitable dynamics, fixed points, stability analysis
4. Data analysis and visualization: Python, matplotlib, scikit-learn, [Freud analysis](#)
5. Optimization and parameter search methods: Gradient descent, Monte Carlo, function approximation

### MAJORS & AREAS OF INTEREST

This VIP team is interested in recruiting undergraduate students from a variety of areas:

- Physics and Math – Dynamical systems, field evolution, topological states, simulation, data analysis, data visualization
- Engineering – Robotics, control, simulation, data analysis, data visualization, kinetics
- Computer Science – Optimization, parallelization, simulation, data visualization, data analysis
- Other students with a variety of interests

### **MENTOR CONTACT INFORMATION**

Dr. Bryan VanSaders  
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Department of Physics, Materials Science Engineering (affiliated)

### **PARTNERS & SPONSERS**

None

## Language Models with Iterative Self Attention (LISA)

[Dr. Anup Das \(ECE\)](#) – Faculty Mentor

### GOALS

Hardware noise, quantization errors, and real-world text imperfections degrade the performance of large language models during deployment. Our lab recently published a technique at the ACL 2026 that makes AI language models significantly more robust by redesigning how attention works inside the bidirectional encoder (BERT). The core idea draws on a concept from information theory called Shannon entropy, which measures how "spread out" or uncertain a probability distribution is. The VIP project will build on top of this foundation work. First, we will extend our technique to the class of models that powers tools like ChatGPT, so-called decoder or generative language models such as LLaMA, Mistral, and GPT-2. Extending our prior work on encoder to generative models requires rethinking how iterative attention converges when a model can only look backward in context, not forward. Second, the team will release everything into a clean, open-source library that plugs directly into HuggingFace Transformers, the most widely used AI toolkit in the world, so that any researcher or engineer can apply our robustness improvements to their own models in just a few lines of code.

Team members will work on real, publishable research, build tools that the broader AI community will use, and come away with hands-on experience in large language model internals, PyTorch, HuggingFace, and GPU computing, all skills that are in extremely high demand in both industry and graduate programs.

### METHODS & TECHNOLOGIES

- **HuggingFace Ecosystem & Open-Source Development:** Working directly with the HuggingFace Transformers library to package our research as a plug-and-play tool; publishing models to the HuggingFace Hub so the community can download and use them instantly
- **Generative (Decoder) Language Models:** Understanding how models like LLaMA and GPT-2 generate text token-by-token, and adapting our robustness technique to work with this generation process; exploring efficient fine-tuning methods such as LoRA and QLoRA to keep compute costs manageable
- **Robust Attention Mechanisms:** Extending our published attention mechanism to generative models; investigating whether the mathematical guarantees we proved for understanding models still hold when generating text; studying how eigenspectrum structure and Shannon entropy of attention layers behave differently under causal masking
- **Robustness Benchmarking:** Systematically stress-testing models with corrupted inputs such as typos, noise, and adversarial prompts, to measure how well our technique holds up compared to existing methods
- **Deep Learning & GPU Computing:** Training and evaluating models on GPUs using PyTorch; learning techniques like mixed-precision training and gradient checkpointing that make working with large models practical
- **Evaluation & Benchmarking:** Running experiments on standard AI benchmarks including HellaSwag, ARC, TruthfulQA, and GLUE; tracking accuracy, robustness, and speed across different model sizes
- **Software Engineering:** Writing clean, documented, tested Python code and contributing to a public GitHub repository, the kind of portfolio work that stands out to employers and graduate programs

### MAJORS & AREAS OF INTEREST

This VIP team is interested in undergraduate students from the following majors or areas of interest:

- Computer Science - machine learning, natural language processing, deep learning, software engineering, high-performance computing, artificial intelligence
- Computer Engineering - parallel computing, GPU programming, computer architecture, performance optimization

- Electrical & Computer Engineering - digital systems, signal processing, optimization theory, computational methods
- Data Science - statistical learning, machine learning, language modeling, experimental design, performance analysis
- Mathematics & Applied Mathematics - numerical analysis, linear algebra, optimization, statistics, mathematical modeling
- Cognitive Science - computational neuroscience, brain-inspired computing, cognitive modeling

Preferred skills: Some experience with Python is the main requirement, everything else can be learned on the team. Familiarity with PyTorch, HuggingFace, or basic machine learning concepts is a bonus. Curiosity about how AI models actually work under the hood is more important than prior research experience. No prior knowledge of our published work is expected or required!

### **MENTOR CONTACT INFORMATION**

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Phone: 215.895.2847

### **PARTNERS & SPONSORS**

None

## Neuroergonomics and Neuroengineering for Brain Health and Performance Research

[Dr. Hasan Ayaz \(BMES\)](#) – Faculty Mentor

### GOALS

Our lab studies the human brain in real-world settings using wearable neurotechnologies and computational methods. We investigate brain function across the lifespan, from children to older adults, and across both healthy and clinical populations.

As part of this VIP team, members will contribute to projects that combine wearable neuroimaging, Brain-Computer Interfaces (BCIs), physiological monitoring, and eye tracking systems. These technologies are developed with the goal of improving human health, accessibility, and performance in everyday life.

- **Project Area #1: Brain-Computer Interfaces (BCIs):** Team members will help design mobile, non-invasive BCIs (using EEG and fNIRS) that allow people to control devices with their brain activity. Applications include accessibility for patients with conditions such as ALS, healthcare technologies, and human-machine teaming in real-world environments.

BCIs translate neural activity into real-time control signals for computers, robots, and other external systems. Our work focuses on mobile, non-invasive BCIs (using EEG and fNIRS) that can be used outside the laboratory and with clinical populations such as ALS patients. We aim to design systems that adapt to users in real-world environments and support applications in accessibility, healthcare, and human-machine teaming.

- **Project Area #2: AI-Enhanced Brain Signal Processing and Analysis:** Team members will apply machine learning and deep learning methods to EEG, fNIRS, and eye-tracking data. Projects include developing real-time decoding models, creating algorithms for artifact removal and signal enhancement, and fusing multiple data sources to better understand human cognition and behavior.

Advances in artificial intelligence are transforming how we process and interpret neural data. In this project area, we focus on developing and applying machine learning and deep learning methods to extract meaningful patterns from complex, noisy brain signals such as EEG and fNIRS. Team members will work on creating models for real-time signal decoding, cognitive state classification, and adaptive feedback to improve the performance of BCIs and neuroergonomic applications. Beyond classification, AI techniques will be used to enhance artifact removal, feature extraction, and multimodal data fusion (combining brain, eye tracking, and physiological signals). The overarching goal is to build robust and generalizable algorithms that can operate effectively in real-world environments, enabling neurotechnologies that are both accurate and accessible.

- **Project Area #3: Scalable Physiological Monitoring / Eye Tracking:** Team members will develop and test affordable, camera-based eye tracking and ultra-low-cost physiological systems that monitor large number of humans simultaneously and continuously during collaborative work. These systems provide new opportunities for research and clinical use for teamwork and cooperation, and can be integrated with BCIs for multi-modal human-technology interaction.

Eye movements reveal attention, cognitive load, and decision-making. Traditional eye trackers are expensive and limited in accessibility. Our lab is utilizing camera-based eye tracking technologies that are affordable, scalable, and deployable on standard devices (e.g., webcams, tablets). These tools open up opportunities for broad research and clinical use, as well as integration with BCIs to create multi-modal human-technology interaction systems.

Together, these efforts aim to enhance human performance, health, and well-being, and to create neuroadaptive technologies that respond intelligently to the user's brain and behavior in real-world settings.

## METHODS & TECHNOLOGIES

The team's research integrates cognitive science, electrical engineering, computer engineering, biomedical engineering, and computer science. Members will gain exposure to:

- **Electroencephalography (EEG)** and **functional near-infrared spectroscopy (fNIRS)** for brain monitoring
- **Brain-Computer Interface design** for real-time neural decoding and adaptive feedback
- **Eye tracking methods** using both commercial and novel camera-based systems
- **Physiological sensing** approaches for cardiac activity (heart rate), skin response (electrodermal), etc.
- **Machine learning and AI methods** for neural and signal processing and behavioral data analysis
- **Signal processing pipelines** for EEG, fNIRS, physiological signals and eye-tracking data
- **Software development** for neurotechnology prototypes, user interfaces, and experimental paradigms
- **Human-subject experiments** in cognitive neuroscience and neuroergonomics

Depending on their skills and interests, team members may focus more on system design, programming, data analysis, or experimental research with human participants.

## MAJORS & AREAS OF INTEREST

This VIP Team is seeking both undergraduate and graduate students with diverse skill sets and interests, including but not limited to:

- Electrical Engineering – signal acquisition, signal processing, hardware interfaces
- Computer Science / Computer Engineering – software architecture, machine learning, computer vision for eye tracking
- Psychology / Cognitive Science – experimental design, cognitive testing, human–technology interaction
- Data Science / Applied Mathematics – computational modeling, neural and behavioral data analysis
- Biomedical Engineering – neuroimaging, BCI, neurotechnology

## MENTOR CONTACT INFORMATION

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[Neuroergonomics and Neuroengineering Lab](#)

## PARTNERS & SPONSORS

None

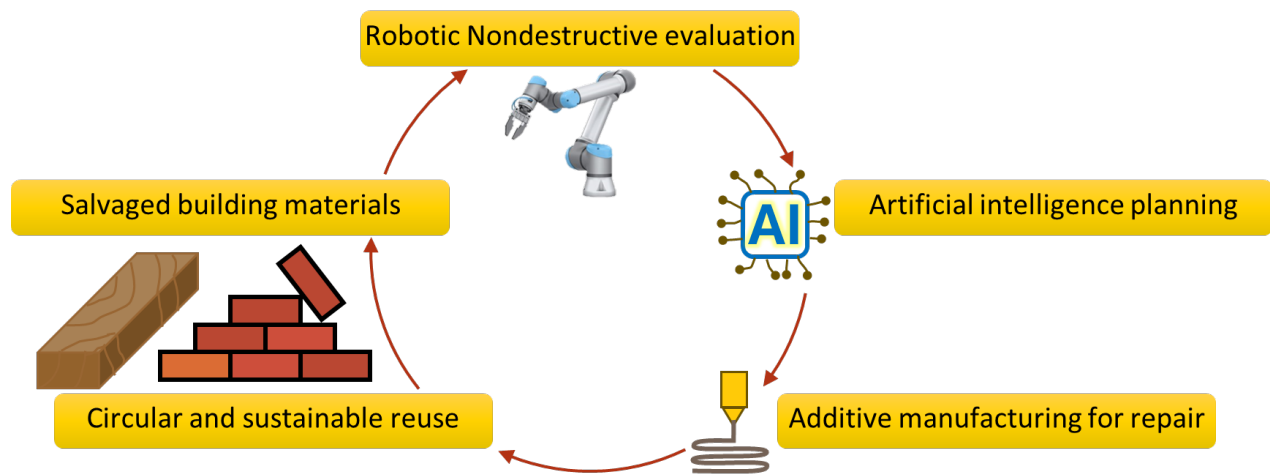
## Robotic Evaluation for Circular Lifecycle Assessment of Infrastructure Materials (RECLAIM)

Drs. [Arvin Ebrahimkhanlou \(CAEE/MEM\)](#) & [Fernanda Cruz Rios \(CAEE\)](#) – Faculty Mentors

### GOALS

In the U.S., construction and demolition waste is more than twice the volume of municipal solid waste, with approximately 90% originating from demolition activities. Every year, large volumes of potentially reusable materials from building demolitions are lost due to a lack of sorting, assessment, and reuse infrastructure. Recent research by Drexel's [CIRCLE lab](#) found that, in Philadelphia houses, the materials with the largest environmental benefits from reuse are also the materials that are more feasible to deconstruct and salvage from older buildings: brick and lumber.

**This team aims to evaluate building materials recovered from old buildings without damaging them, using nondestructive evaluations.** The goal is to find the best ways to repair and reuse these materials to reduce demolition waste, carbon emissions, and other environmental impacts at the end of a building's life. By applying circular economy principles – such as extending material lifespans, designing for reuse, and closing material loops – the project supports sustainability in the built environment. A key challenge is that sorting and testing old materials can be costly and labor-intensive. To address this, the project builds on the expertise of the [ARVIN lab](#) to use robotics, artificial intelligence (AI), and additive manufacturing (3D printing) to automate material assessment, repair, and reuse.



### METHODS & TECHNOLOGIES

Nondestructive evaluation, Load testing, Environmental testing, Robotics, Artificial intelligence, Machine learning, Building information modeling, Life cycle assessment

### RESEARCH, DESIGN, & TECHNICAL ISSUES

- 1) Nondestructive evaluation (NDE) as well as destructive load and environmental tests will be performed in the laboratory on building materials salvaged from old buildings in Philadelphia (e.g., bricks, wood beams, plaster panels, etc.).
- 2) Machine learning will be used to correlate the results of NDE and destructive tests and estimate the structural properties of the salvaged materials.
- 3) Environmental Life Cycle Assessment (LCA) will be used to quantify the environmental costs and benefits associated with recovering, testing, and reusing the materials.
- 4) A robotic arm will be programmed to automate the repetitive task of performing NDE on large quantities of building materials, and the process costs will be quantified.

- 5) Artificial intelligence (AI) and building information modeling (BIM) will be used to find the optimal and individualized reuse plan for each unit of recovered building materials.
- 6) Advanced manufacturing methods will be deployed to implement the repair plan and enhance the properties of each recovered unit for their future reuse.

### **MAJORS & AREAS OF INTEREST**

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and areas of interest:

- Civil, Architectural, and Environmental Engineering: Digital twins, Sustainability, Circular economy, Life cycle assessment, Material reuse or recycling, Nondestructive evaluation, Artificial intelligence, Robotics.
- Mechanical Engineering and Mechanics: Nondestructive evaluation, Robotics, Artificial intelligence
- Electrical and Computer Engineering: Nondestructive evaluation, Robotics, Artificial intelligence
- Computer Science: Robotics and Artificial Intelligence

### **MENTOR CONTACT INFORMATION**

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Civil, Architectural, and Environmental  
Engineering

### **PARTNERS & SPONSORS**

Potential for funding from Manufacturing PA Initiative

## Robotics, Automation, and AI for Smart Agriculture

[Dr. Lifeng Zhou](#) (ECE) – Faculty Mentor

### GOALS

This VIP team explores the integration of robotics, automation, and AI in modern agriculture, focusing on two key applications:

1. AI-driven robotic arms for intelligent packaging and autonomous soil sampling systems: VIP team members will learn how AI enhances robotic manipulation for efficient sorting and packaging of agricultural products, optimizing speed and precision
2. The design and implementation of autonomous soil sampling systems: VIP team members will gain the knowledge to develop robotic solutions for precision agriculture.

Through hands-on projects and real-world case studies, team members will gain practical expertise in AI-driven automation for agricultural efficiency and sustainability.

### CURRENT PROJECTS

#### PROJECT 1: AI-DRIVEN ROBOTIC ARM FOR INTELLIGENT PACKAGEING OF AGRICULTURAL PRODUCTS



As agriculture embraces automation, AI-powered robotic arms are revolutionizing the packaging process, improving efficiency, precision, and adaptability. This project explores the integration of robotic manipulation, computer vision, and AI-driven decision-making to automate the packaging of agricultural products such as fruits, vegetables, and grains.

VIP team members will explore how AI enhances robotic perception and control, enabling robotic arms to identify, sort, and package agricultural products while adapting to variations in size, shape, and texture. By programming and deploying AI-powered robotic solutions, team members will gain hands-on experience in developing smart, autonomous packaging systems for modern agricultural industries. Additionally, they will work with professors and Ph.D. students and have regular meetings to discuss progress. There will be opportunities for publications in top robotics and AI venues.

#### RESEARCH, DESIGN, & TECHNICAL ISSUES

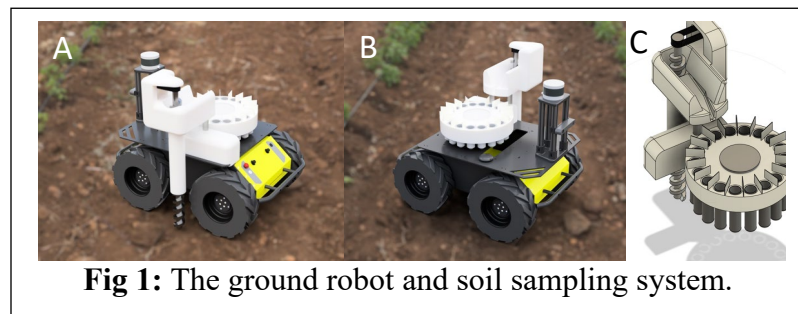
1. Camera Integration for Object Detection – Mount a camera on the robotic arm to enable real-time product identification and classification for efficient packaging.
2. Custom CAD-Designed Gripper – Design a specialized gripper for secure and delicate handling of a specific agricultural product.
3. AI-Powered Packaging Control – Train an AI model to map camera observations to robotic actions, enabling adaptive and efficient packaging.

#### METHODS & TECHNOLOGIES

Vision-language-action (VLA) model, robot kinematics, motion planning, AI-based object detection, force control for delicate handling, and real-time optimization for packaging.

## PROJECT 2: AUTONOMOUS SOIL-SAMPLING SYSTEM

This project aims to develop an autonomous robotic system for precise soil sampling from agricultural fields



**Fig 1:** The ground robot and soil sampling system.

to enable accurate soil health monitoring. The robotic system will autonomously navigate fields and collect geo-referenced soil samples at predefined depths for further analysis. The autonomous robotic system should perform automatic, consistent, efficient, and precise soil sampling across large agricultural fields, which will lead to large-scale soil sampling and accurate soil

health assessments. The VIP team members will work with professors and Ph.D. students and have regular meetings to discuss progress. There will be opportunities for publications in top robotics and AI venues.

### RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Build an autonomous soil sampling system.
2. Equip the ground robot (HUSKY) with RTK-GPS for precise geo-localization.
3. Equip the system with a soil sampling drill, a slice coated with Teflon, a shaker motor, a motorized sampling wheel with absolute position encoders, etc.
4. Develop autonomous navigation algorithms via GPS or LiDAR/camera and precise sampling/planning/control algorithms

### METHODS & TECHNOLOGIES

Robotics system design, path planning, motor control, sensing techniques (RTK-GPS, LiDAR, camera).

### **MAJORS & AREAS OF INTEREST**

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical & Computer Engineering – motion planning, robotic arm and gripper control, path planning, motor control, RTK-GPS, robot communication, system design, autonomous navigation, localization and mapping
- Computer Science - vision-language-action, perception, motion planning, autonomous navigation, reinforcement learning
- Mechanical Engineering – robot kinematics, sampling system design, structure design, computer aid design (CAD) software experience

### **APPLICATION PREREQUISITES**

Prior to applying for a position on this team, prospective team members are asked to please install the Linux-Ubuntu & Robot Operating System (ROS) on their computer and go through the ROS tutorials (ROS1: <http://wiki.ros.org/noetic> or ROS2: <https://docs.ros.org/en/humble/index.html>). Prospective team members should prepare a video of the velocity control of a turtlebot in the ROS-Gazebo simulator and provide a link to this video when reaching out on ForagerOne to apply for the team.

If needed, a docker package with all the instructions for both ROS 1/2 which allows using Rviz, Gazebo, etc. is available at: <https://github.com/Zhourobotics/ros2-docker-dev> Alternatively, this software can also be utilized using a virtual machine to install Linux and ROS.

For Project 1

1. Follow the Open Platform tutorial for the FR5 robot arm at <https://fair-documentation.readthedocs.io/en/latest/ROSGuide/index.html> and create a ROS package for it. Document your findings and questions.
2. Try out LeRobot simulation: <https://github.com/huggingface/lerobot> and PI simulation: <https://github.com/Physical-Intelligence/openpi>. Document your findings and questions.
3. If you are not a fan of ROS programming, you must demonstrate strong skills in CAD design (Fusion 360 or SOLIDWORKS).

For Project 2

1. If you plan to work on autonomous navigation of the HUSKY robot, implement the autonomous navigation of a HUKSY robot in the ROS-Gazebo simulator (similar to this: <https://www.youtube.com/watch?v=F5OiuIkqxcc>) and record a video.
2. If you plan to work on the design and control of the soil sampling system, you must demonstrate strong skills in CAD design, embedded system programming, DSP, circuit design, etc.

Please provide links to the materials prepared from the above when reaching out on ForagerOne to apply for the team.

Please note that participation on this VIP team requires use of many robot hardware and software tools, which can take significant time to learn and build familiarity with; therefore, it is NOT recommended to apply for this team if one doesn't have enough time to commit to this effort (such as having a heavy courseload or participating in co-op in the same quarter). Prospective team members should indicate how much time they can commit to the team when reaching out on ForagerOne to apply for the team.

**MENTOR CONTACT INFORMATION**

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[Drexel Zhou Robotics Lab](#)

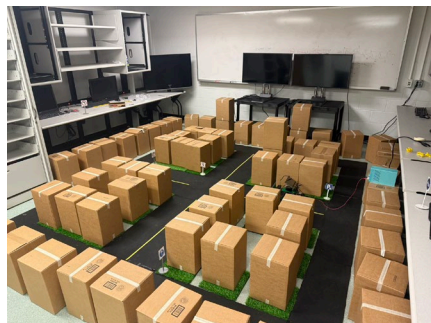
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Drexel College of Engineering Longsview Faculty Award

## Vision Language Models for Autonomous Driving

[Dr. Lifeng Zhou](#) (ECE) – Faculty Mentor

### GOALS



As autonomous systems continue to evolve, the integration of vision-language models (VLMs) is revolutionizing how autonomous cars perceive, reason, and act in dynamic environments. This course explores the intersection of computer vision, natural language processing, and robotic control, focusing on how multi-modal AI models can enhance decision-making in autonomous robot cars.

VIP team members will gain hands-on experience with state-of-the-art vision-language models (e.g., GPT-4V, Flamingo, BLIP, LLaVA) and their applications in scene understanding, trajectory planning, and real-time control. Through simulations and real-world case studies, the team will examine how these models interpret visual inputs, follow natural language commands, and make autonomous decisions in complex scenarios. Undergraduate team members will work with professors and Ph.D. students and have regular meetings to discuss progress. There will be opportunities for publications in top robotics and AI venues.

### METHODS & TECHNOLOGIES

Vision-language models (VLMs), motion planning and control for AVs, multi-modal perception (Lidar, camera, microphone, etc.).

### RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Implement and fine-tune small VLMs for real-time perception
2. Motion planning and control of AVs

### MAJORS & AREAS OF INTEREST

This VIP team is interested in recruiting both undergraduate and graduate students from the following majors and/or with a background and interest in the areas listed below.

- Electrical & Computer Engineering, Computer Science, and Mechanical Engineering – VLMs, motion planning and control, robot perception (Lidar, camera, microphone, etc.).

### APPLICATION PREREQUISITES

Prior to applying for a position on this team, prospective team members are asked to please install the Linux-Ubuntu & Robot Operating System (ROS) on their computer and go through the ROS tutorials (ROS1: <http://wiki.ros.org/noetic> or ROS2: <https://docs.ros.org/en/humble/index.html>).

If needed, a docker package with all the instructions for both ROS 1/2 which allows using Rviz, Gazebo, etc. is available at: <https://github.com/Zhourobotics/ros2-docker-dev> Alternatively, this software can also be utilized using a virtual machine to install Linux and ROS.

Prospective team members should:

1. Implement the autonomous navigation of Turtlebot in the ROS-Gazebo simulator, similar to this: <https://www.youtube.com/watch?v=IW-c88vxLRE> and record a video.
2. Go through the tutorials (Chapters 8, 11, 12, 14, 15, 16) of ROSMASTER R2: <http://www.yahboom.net/study/ROSMAS-TER-R2>. This is the robot car the team will use in the lab. Document your findings and questions.
3. Try out some small VLMs: <https://huggingface.co/blog/paligemma>. Document your findings and questions.

Please provide links to the materials prepared from the above when reaching out on ForagerOne to apply for the team.

Please note that participation on this VIP team requires use of many robot hardware and software tools, which can take significant time to learn and build familiarity with; therefore, it is NOT recommended to apply for this team if one doesn't have enough time to commit to this effort (such as having a heavy courseload or participating in co-op in the same quarter). Prospective team members should indicate how much time they can commit to the team when reaching out on ForagerOne to apply for the team.

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### **PARTNERS & SPONSORS**

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