Vertically Integrated Projects (VIP) Program

Information Packet

Fall Quarter 2026-2027

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 Fall Quarter of the 2026-2027 academic year:

- Accelerating Pharmaceutical Process Development with Robotics and Machine Learning
- AI-Driven Robotic Manipulation
- 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: Understanding decision-making in circular economy across sectors, and predicting material flows from new and existing buildings in Philadelphia
- Cognitive Neuroengineering for the Brain and Mind
- Coordination and Planning for Multi-Robot Systems
- Data-Driven Circular Economy and Robotic Evaluation for Circular Lifecycle Assessment of Infrastructure Materials (RECLAIM)
- Detecting Cyberattacks in Traffic Systems Using Data Analytics and Machine Learning
- DriveSmart, WorkSafe
- Emergent coordinate systems for organizing massively parallel robotic swarms
- Foundation Models for Autonomous Driving
- Language Models with Iterative Self Attention (LISA)
- Neuroergonomics and Neuroengineering for Brain Health and Performance Research
- Ukraine Sovereign Recovery Through a Sustainability Lens

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) 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
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.

New for the Fall Quarter 2026-2027: As our research has progressed, we are seeking specific skills to further our progress.

- A team member (preferably mechanical engineering) with CAD software experience who is comfortable with machining and 3D printing for rapid prototyping
- A team member with expert python experience to automate sample collection

We are in the process of integrating these systems to work together for experiments. For example, the liquid handler, which operations at the µL-to-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.

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
Email: mam3266@drexel.edu

PARTNERS & SPONSORS

None

AI-Driven Robotic Manipulation

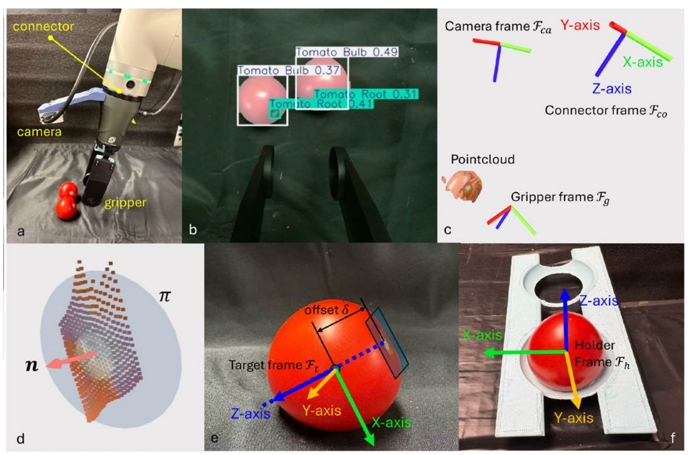
Dr. Lifeng Zhou (ECE) – Faculty Mentor

GOALS

This VIP team explores how modern AI enables robots to manipulate objects intelligently in unstructured, real-world environments. The core theme is AI-driven intelligent manipulation powered by robot foundation models, such as vision-language-action (VLA) models and world-action models, which map what a robot sees and what it is told to do directly into robot actions. Team members will work on two complementary projects: (1) intelligent processing of agricultural products with a single robot arm, and (2) long-horizon, contact-rich household tasks with a bimanual (dual-arm) robot. Across both projects, team members gain hands-on experience with the full manipulation pipeline: perception and object detection, grasping and motion planning, teleoperated demonstration collection, and finetuning and deploying learned policies on real robot hardware.

CURRENT PROJECTS

PROJECT 1: AI-DRIVEN ROBOTIC MANIPULATION FOR INTELLIGENT PROCESSING OF AGRICULTURAL PRODUCTS



Agricultural products are deformable, fragile, and highly variable in size, shape, ripeness, and texture, which makes them an excellent testbed for intelligent robotic manipulation. This project develops a single-arm robotic system that perceives, grasps, and processes agricultural products, for example detecting tomatoes and their bulbs and roots with a wrist-mounted RGB-D camera, estimating 6-DoF grasp poses from point clouds, and executing precise, force-aware picking, sorting, trimming, and packaging.

VIP team members will explore how AI enhances robotic perception and control, enabling a robot arm to identify, grasp, sort, and package agricultural products while adapting to variations in size, shape, and texture. They will finetune object detection and segmentation models on their own produce datasets, design and 3D print custom grippers, and train AI policies that map camera observations to robot actions. Additionally, 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 and AI venues.

RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Perception for Produce - Finetune object detection and segmentation models (e.g., YOLO, SAM) on a custom dataset to localize target parts such as the tomato bulb versus the root, and fuse the detections with depth data to obtain 6-DoF target poses.
2. Custom CAD-Designed Gripper - Design and 3D print a compliant gripper for secure and delicate handling of a specific agricultural product.
3. Grasping and Motion Planning - Calibrate the camera, connector, and gripper frames and compute collision-free trajectories and grasp offsets for reliable picking and placement. Learning-Based Manipulation - Collect demonstrations and finetune a vision-language-action (VLA) policy that maps camera observations to robot actions, enabling adaptive and efficient processing and packaging.

METHODS & TECHNOLOGIES

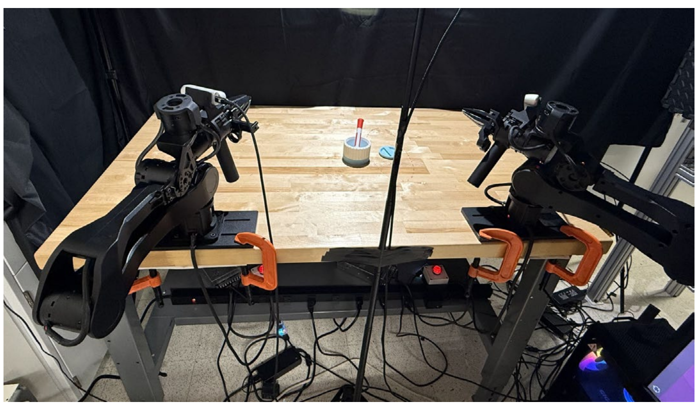
Vision-language-action (VLA) models, RGB-D perception, object detection and segmentation (YOLO, SAM), 6-DoF pose estimation and point cloud processing, robot kinematics and motion planning, compliant grasping and force control for delicate handling, imitation learning, and CAD design and 3D printing of grippers.

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, real-time and embedded systems
- Computer Science - vision-language-action models, computer vision, object detection and segmentation, imitation learning
- Mechanical Engineering - robot kinematics, gripper and structure design, CAD design and 3D printing

PROJECT 2: BIMANUAL ROBOTIC MANIPULATION FOR LONG HORIZON HOUSEHOLD TASKS



Many everyday household tasks require two arms working in close coordination over long sequences of contact-rich steps, for example folding clothes, twisting bottle caps open and closed, and plugging and unplugging a mouse cable or swapping batteries. This project builds a bimanual (dual-arm) manipulation system with leader-follower teleoperation and multi-view cameras for demonstration collection, and uses robot foundation models to perform such long-horizon tasks autonomously.

VIP team members will collect teleoperated demonstrations on the dual-arm platform, finetune robot foundation models, including vision-language-action (VLA) models and world-action models that imagine future observations before acting, and deploy them on the real robot. The project emphasizes long-horizon task decomposition, bimanual coordination, deformable object manipulation, and failure detection and recovery. Team members work with professors and Ph.D. students and have regular meetings to discuss progress. There will be opportunities for publications at top robotics and AI venues..

RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Build a bimanual teleoperation and data collection pipeline with leader-follower arms, multi-view RGB-D cameras, and synchronized recording in a standard dataset format (e.g., LeRobot).
2. Finetune and evaluate robot foundation models (VLA models and world-action models) on the collected demonstrations, in both simulation and the real world.
3. Long-Horizon Task Decomposition - use LLM/VLM high-level planners to break a task into subgoals and chain learned skills together.
4. Bimanual Coordination and Contact-Rich Control - dual-arm collision avoidance, object handover, and force and compliance control for cap twisting and connector insertion.
5. Deformable Object Manipulation - state estimation and manipulation policies for cloth folding.
6. Failure detection and recovery during long task sequences

METHODS & TECHNOLOGIES

Robot foundation models (vision-language-action models, world models and world-action models), imitation learning (e.g., ACT, diffusion policies, flow matching), teleoperation and demonstration collection, LLM/VLM task planning, bimanual motion planning and control, multi-view perception, and manipulation simulation environments.

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 - bimanual control, teleoperation systems, motion planning, real-time and embedded systems
- Computer Science - vision-language-action models, world models, imitation learning, LLM/VLM task planning, computer vision, reinforcement learning
- Mechanical Engineering - dual-arm workcell and end-effector design, robot kinematics, structure design, CAD design

APPLICATION PREREQUISITES

Prior to applying for a position on this team, prospective team members are asked to please Install Linux-Ubuntu & Robot Operating System (ROS) on your machine and go through ROS tutorials (ROS1: http://wiki.ros.org/noetic or ROS2: https://docs.ros.org/en/humble/index.html). Here is a docker package with all the instructions for both ROS 1/2 which allows using Rviz, Gazebo, etc.: https://github.com/Zhourobotics/ros2-docker-dev. Other than docker, you can also use a virtual machine to install Linux and ROS. You are also expected to be comfortable with Python and PyTorch, and to have access to a GPU (your own machine or Google Colab) for model finetuning.

Project 1
Finetune an object detection or segmentation model on your own data: collect and label a small dataset of fruits or vegetables (50-200 images is enough) and finetune a YOLO model (https://docs.ultralytics.com) or SAM 2 (https://github.com/facebookresearch/sam2). Report the training curves and mAP, and show detection results on images the model has never seen. Document your findings and questions.

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.

If you are not a fan of ROS or machine learning programming, you must demonstrate strong skills in CAD design (Fusion 360 or SOLIDWORKS), for example by designing and 3D printing a compliant gripper finger for handling a tomato, and sharing both the CAD model and the printed result.

Project 2
Try out LeRobot: https://github.com/huggingface/lerobot. Run one of its simulation environments (e.g., ALOHA sim or PushT), train or finetune a provided policy (ACT, Diffusion Policy, or SmolVLA), and record a rollout video. Document your findings and questions.

Try out a robot foundation model in simulation: openpi (pi-0 / pi-0.5) at https://github.com/Physical-Intelligence/openpi, NVIDIA Isaac GR00T at https://github.com/NVIDIA/Isaac-GR00T, or OpenVLA at https://github.com/openvla/openvla. Run inference on a sample task and document what the model does well and where it fails.

Pick one manipulation simulation environment, complete a long-horizon or bimanual task in it, and record a video. Recommended options: ManiSkill3 (https://github.com/haosulab/ManiSkill, fast GPU-parallel simulation with bimanual and dexterous tasks), RoboCasa (https://github.com/robocasa/robocasa, large-scale household kitchen tasks built on robosuite/MuJoCo), LIBERO (https://github.com/Lifelong-Robot-Learning/LIBERO, language-conditioned long-horizon manipulation benchmark), robosuite (https://robosuite.ai), MuJoCo Playground (https://github.com/google-deepmind/mujoco_playground), Isaac Lab (https://github.com/isaac-sim/IsaacLab), or Genesis (https://github.com/Genesis-Embodied-AI/Genesis). Document your findings and questions.

If you are more interested in hardware, you must demonstrate strong skills in CAD design (Fusion 360 or SOLIDWORKS), 3D printing, or embedded system programming, for example by designing a dual-arm workcell fixture or a custom end-effector.

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. Responses will only be provided after the prerequisites have been completed and the time commitment has been made.

MENTOR CONTACT INFORMATION

Dr. Lifeng Zhou
Email:lz457@drexel.edu
Phone: 215.895.1922
Drexel Zhou Robotics Lab

PARTNERS & SPONSORS

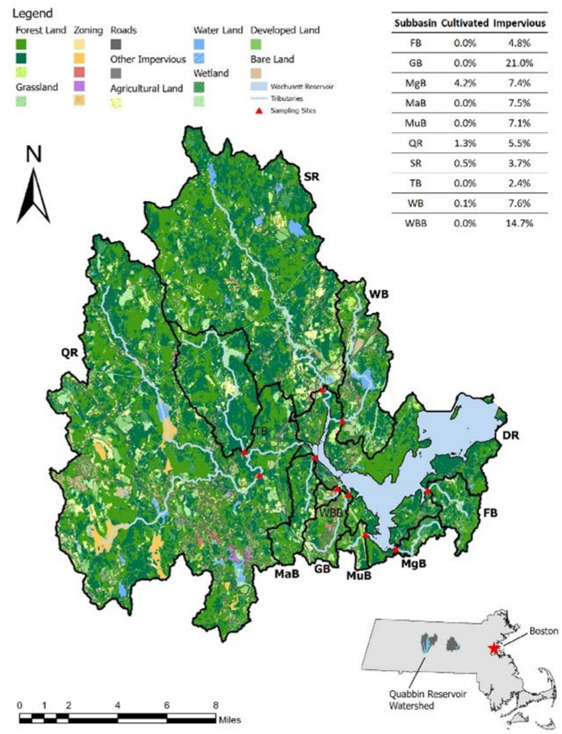
United States Department of Agriculture (USDA)

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.



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)

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.

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
Email: ac4547@drexel.edu
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

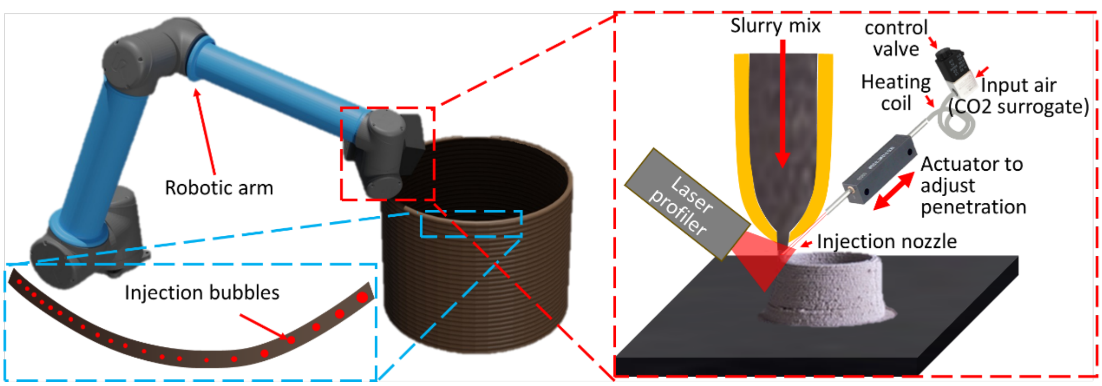
Recent advancements in artificial intelligence and robotics have created new opportunities for transforming how we evaluate and assess the condition of physical assets. Projects in this research theme leverage such opportunities to advance the field of nondestructive evaluation.

CURRENT PROJECTS

PROJECT 1: DESIGN AND MANUFACTURING OF A ROBOTIC NOZZLE FOR NONDESTRUCTIVE EVALUATION OF CO_2 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_2 through carbonization, this process is slow and limited to external surfaces. Once saturated, the external surfaces further inhibit additional CO_2 uptake, limiting the net-zero benefits. Existing CO_2 injection methods in prefabrication, while enhancing concrete properties, suffer from the limitations of slow absorption and CO_2 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_2 injections. To this end, the project will utilize an existing robotic arm and instead of actual CO_2 gas, will experiment with air bubbles as surrogates for CO_2 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 nuzzle.
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

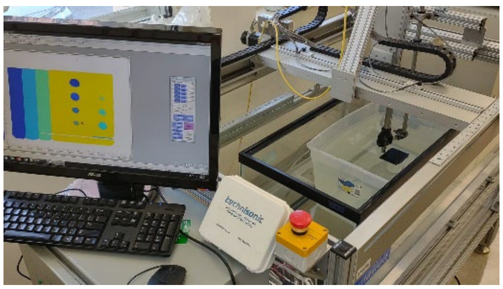
RESEARCH, DESIGN, & TECHNICAL ISSUES

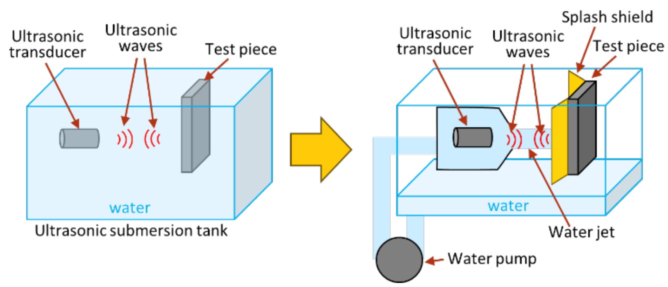
1) Microstructure Dataset Compilation
2) Image Preprocessing and Representation
3) Generative Model Development
4) Conditional Microstructure Modification and Prediction of Microstructural Evolution
5) Validation and Quantification of the Results using Computer Vision Methods
6) Contributing to journal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

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
Email: ae628@drexel.edu
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

PARTNERS & SPONSORS

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

Funding received from:

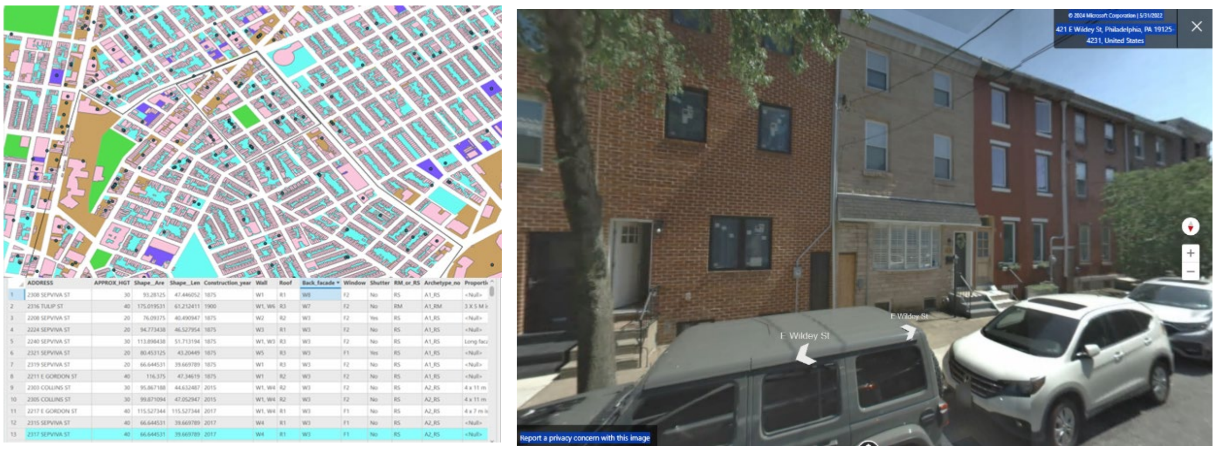
- NSF IceCube: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2209445&HistoricalAwards=false
- Nationwide Eclipse Ballooning Project (NEPB): https://eclipse.montana.edu/
- Pennsylvania Space Grant Consortium: https://sites.psu.edu/paspacegrant/support/statewide-support/competitive-mini-grant-program/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

Circular Buildings & Cities:
Understanding decision-making in circular economy across sectors, and predicting material flows from new and existing buildings in Philadelphia

Dr. Fernanda Cruz Rios (CAEE) – Faculty Mentor

GOALS

Cities are responsible for 75% of natural resource consumption and 70% of global greenhouse emissions. The circular economy has been increasingly discussed as a potential solution to climate change, resource scarcity, and pollution – problems that have been exacerbated by growing urbanization trends. In circular economy systems, products and services are traded in closed loops, and resources are recirculated into the Technosphere through sustainable strategies such as reuse, refurbishment, remanufacture, or recycling. Circular buildings and cities apply circular economy concepts in infrastructure, resources, goods, and services. At CIRCLE Lab, we have **two projects** that address this issue.



1 ArcGIS and Google Street View Fishtown, Philadelphia

PROJECT 1: Tracking and predicting material stocks and flows in Philadelphia

Our team will focus on circular economy for city infrastructure; specifically, building envelope materials from buildings that have been demolished or will be demolished (or deconstructed) in the future. To reuse or recycle building materials, first we need to understand the quantity and types of materials that are and will be available in a city. Materials that are currently being used in a building are called "material stocks", while materials that are arriving at the construction site or leaving the demolition site are called "material flows". Assessing, predicting, and tracking building material stocks and flows is key to creating economic opportunities and public policy to incentivize the recirculation of building materials. **Team members will assist in the creation of an urban database for building material stocks and flows in Philadelphia, including quantity and type of materials and their respective environmental impacts for manufacturing and end-of-life treatment (e.g., reuse, recycling, incineration, disposal in landfills).** Throughout AY 24-25, teams will focus on residential buildings in the Fishtown neighborhood.

METHODS & TECHNOLOGIES

Team members will be introduced to:

1. Spatial data collection (e.g., ArcGIS), photogrammetry (e.g., analysis and interpretation of photographic images from different sources)
2. Life cycle inventory data collection (collecting data on environmental impacts from different building materials)
3. Statistical data analysis
4. Machine learning algorithms (e.g., for predicting future material flows based on demolition trends)

5. 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:
1. Qualitative data collection (interviews), thematic data analysis
2. Policy analysis
3. Statistical data analysis

RESEARCH, DESIGN, & TECHNICAL ISSUES

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

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

Dr. Fernanda Cruz Rios
Email: fc432@drexel.edu
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 tCDS 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 tCDS 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 tCDS 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
Email: john.d.medaglia@drexel.edu
Phone: 215.553.7169
Cognitive Neuroengineering & Wellbeing Laboratory

Dr. Gary Friedman
Email: gf29@drexel.edu
Phone: 215.895.2108
Professional Profile

PARTNERS & SPONSORS

None

Coordination and Planning for Multi-Robot Systems

Dr. Lifeng Zhou (ECE) – Faculty Mentor

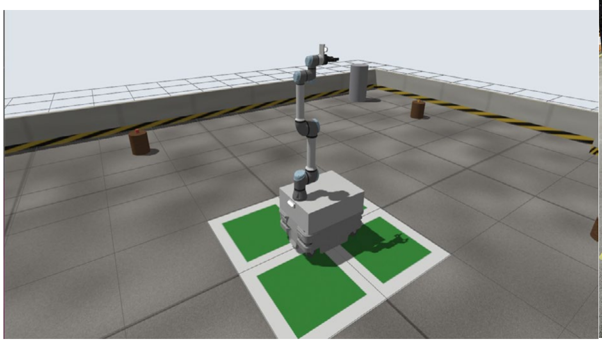
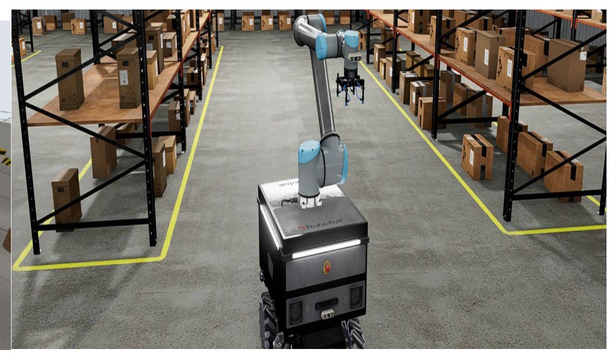
GOALS

Robots continue to get smaller, faster, and cheaper, and today they are equipped with sophisticated computing, communication, and sensing resources. At the same time, foundation models and AI agents are changing how robots perceive, reason, communicate, and cooperate. The goal of this VIP team is to develop novel robotic systems and advanced coordination and planning algorithms that combine AI agents and foundation models with classical planning and control, enabling the adaptive and long-term operation of multi-robot teams in tasks such as factory and warehouse logistics, search and rescue, foraging for resources, environmental monitoring, target tracking, surveillance, and reconnaissance. 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: COORDINATION OF MULTIPLE MOBILE MANIPULATORS

This project focuses on the coordination of multiple mobile manipulators, that is, mobile bases each equipped with a robot arm, using AI agent techniques. Each mobile manipulator is given its own onboard AI agent built with modern agent engineering: prompt engineering, context engineering, a library of reusable skills, tool calling, and harness engineering that connects the agent to the robot perception, navigation, and manipulation stacks. The agents share information and negotiate with each other in a decentralized way, so that the team can allocate tasks, resolve conflicts, and recover from failures without relying on a central coordinator. Target applications include transporting and sorting parts in a factory or warehouse, search and rescue in unknown environments, and foraging for resources such as food and supplies.

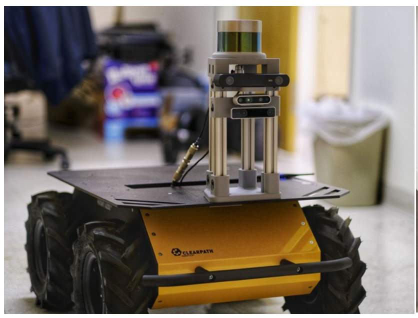
RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Build a Multi-Mobile-Manipulator System - Set up a team of mobile bases equipped with robot arms, first in simulation (e.g., NVIDIA Isaac Sim or Gazebo) and then on real hardware, with working navigation, perception, and manipulation stacks.
2. Per-Robot AI Agent - Design an onboard AI agent for each robot using prompt engineering, context engineering (what the agent remembers about the environment, the task, and its teammates), a skill library (explore, navigate, detect, pick, place, hand over), and tool calling into ROS services and action servers.
3. Harness Engineering and Safety - Build the harness that grounds agent outputs into executable robot commands, verifies preconditions, handles timeouts and failures, and keeps the robot safe when the model is wrong.
4. Decentralized Multi-Agent Coordination - Design agent-to-agent communication protocols and negotiation or auction mechanisms that let robots assign tasks, share maps and observations, and coordinate their motions without a central planner, and evaluate scalability and robustness under limited or intermittent communication.

5. Applications and Benchmarking - Evaluate the team on factory and warehouse transport, search and rescue in unknown environments, and multi-robot foraging, and compare against classical multi-robot task allocation baselines.

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 the rover complement each other for better data collection, and when the battery of the drone runs out, the rover rendezvouses with the drone so that the drone can land, be charged, and be ferried. The emphasis of this project is on integrating foundation models (LLMs, VLMs, and vision-language-action models) with classical planning and control algorithms such as A*, RRT, and model predictive control (MPC). The foundation models provide semantic understanding, high-level task decomposition, and adaptation to novel situations, while the classical algorithms provide the real-time, verifiable, and safe motion that the robots actually execute.




RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Develop a heterogeneous robotic system composed of a drone and a rover, with real-time communication and information sharing.
2. Joint Perception - Fuse the downward-facing drone camera with the rover LiDAR, camera, and RTK-GPS into a shared semantic map of the environment.
3. Autonomous Landing, Charging, and Ferrying - Land the drone on the rover using VLMs or foundation models for landing-pad and marker recognition, combined with visual servoing and MPC for the final approach, then charge and ferry the drone.
4. Foundation Models in the Planning Loop - Use LLMs and VLMs to interpret mission descriptions, decompose them into subtasks, and select semantic goals, waypoints, costs, and constraints, and then hand these to classical planners (A*, RRT/RRT*, coverage planning) and controllers (MPC, pure pursuit, PID) for safe execution.
5. Autonomous navigation of the rover using RTK-GPS, LiDAR, and camera, and area monitoring, coverage, exploration, and target tracking with the drone.
6. Benchmarking - Compare the hybrid foundation-model-plus-classical pipeline against purely classical and purely learned baselines in terms of success rate, safety, and computation time.

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 (A*, RRT, MPC), perception (LiDAR, camera, etc.), LLMs, VLMs, AI agents, computer vision, deep learning, reinforcement learning, robot communication, system design
- Computer Science - LLMs, VLMs, AI agents and tool calling, multi-agent systems, perception, computer vision, deep learning, reinforcement learning, algorithm design and analysis
- Mechanical Engineering - computer aided design (CAD) software experience, mobile manipulator and end-effector design, 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 Linux-Ubuntu & Robot Operating System (ROS) on your machine and go through ROS tutorials (ROS1: http://wiki.ros.org/noetic or ROS2: https://docs.ros.org/en/humble/index.html). Here is a docker package with all the instructions for both ROS 1/2 which allows using Rviz, Gazebo, etc.: https://github.com/Zhourobotics/ros2-docker-dev. Other than docker, you can also use virtual machine to install Linux and ROS.

Project 1.1: Set up a mobile manipulator in simulation and make it work end to end. Follow a ROS 2 navigation tutorial (Nav2: https://docs.nav2.org) to drive a mobile base in Gazebo, then add a robot arm with MoveIt 2 (https://moveit.ai) and perform a pick-and-place task. Record a video and document your findings and questions.

Project 1.2: Build a small AI agent that controls a robot through tool calling. Using any LLM API or an open model, define two or three tools (e.g., navigate_to, detect_object, pick_object), and show the agent calling them in the correct order to accomplish a simple task, in simulation or even with mock functions. Explain how you designed the prompt, what context you gave the agent, and how you handled a tool call that failed.

Project 2: Implement the autonomous navigation of a HUSKY robot in the ROS-Gazebo simulator (similar to this: https://www.youtube.com/watch?v=F5OiuIkqxcc) and record a video. In addition, implement a classical planner and controller yourself, for example A* or RRT for path planning together with an MPC or pure-pursuit controller for trajectory tracking, and demonstrate it in simulation. Demonstrating strong skills in CAD design (Fusion 360 or SOLIDWORKS) is also welcome.

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. Responses will only be provided after the prerequisites have been completed and the time commitment has been made.

MENTOR CONTACT INFORMATION

Dr. Lifeng Zhou
Email:lz457@drexel.edu
Phone: 215.895.1922
Drexel Zhou Robotics Lab

PARTNERS & SPONSORS

National Science Foundation (NSF)

Data-Driven Circular Economy and Robotic Evaluation for Circular Lifecycle Assessment of Infrastructure Materials (RECLAIM)

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

Recent advances in artificial intelligence, building information modeling, and circular economy assessment are creating new opportunities to transform how buildings are designed, deconstructed, and reused throughout their lifecycle. Projects in this research theme leverage these technologies to advance Design for Disassembly, evaluate the reuse potential of recovered building materials, and support data-driven strategies for a more circular built environment.

PROJECT 1: Design for Disassembly or Deconstruction (DfD)
Through Artificial Intelligence and Building Circularity

GOALS

The architecture, engineering, and construction (AEC) industry is one of the world's largest consumers of resources and contributors to environmental impacts. While circular economy (CE) strategies such as Design for Disassembly (DfD) and circular material selection have the potential to significantly reduce waste and carbon emissions, their implementation remains limited in practice. DfD means to design buildings and infrastructure so they can be disassembled/deconstructed in the future, and its materials can be reused. A major challenge is that circularity assessments and DfD decisions often require detailed technical information that is only available in later design stages, when architects have less flexibility to influence building outcomes.

This project aims to enable architects and engineers to assess and improve building circularity during the earliest stages of design through Design for Disassembly (DfD). The project investigates how artificial intelligence (AI), building information modeling (BIM), and data-driven decision support systems can bridge the gap between early-stage design freedom and late-stage technical detail. By automatically generating design specifications, evaluating circularity performance, and recommending optimized solutions, the project seeks to transform how buildings are designed for future reuse, adaptation, and disassembly.

This project combines the expertise of Drexel's CIRCLE Lab, which specializes in circular economy, life cycle assessment, and sustainable building design, with the expertise of the ARVIN Lab in artificial intelligence, machine learning, robotics, and advanced computational methods. Through this interdisciplinary collaboration, the project will develop novel tools that help designers make informed circularity decisions early in the design process, supporting a more sustainable and resource-efficient built environment.

METHODS & TECHNOLOGIES

Artificial Intelligence (AI), Generative AI, Machine Learning, Building Information Modeling (BIM), Design for Disassembly (DfD), Circular Economy, Building Circularity Assessment, Life Cycle Assessment (LCA), Case-Based Reasoning (CBR), Data Analytics, Sustainable Building Design, Decision Support Systems, Digital Twins.

RESEARCH, DESIGN, & TECHNICAL ISSUES

1) **Generative AI** models will be developed to automatically generate detailed material and assembly specifications from early-stage building designs using information such as building type, climate zone, and design intent.
2) **Building Information Modeling (BIM)** datasets and construction documentation from industry partners will be analyzed to train and validate AI algorithms capable of augmenting conceptual building designs with technical specifications.

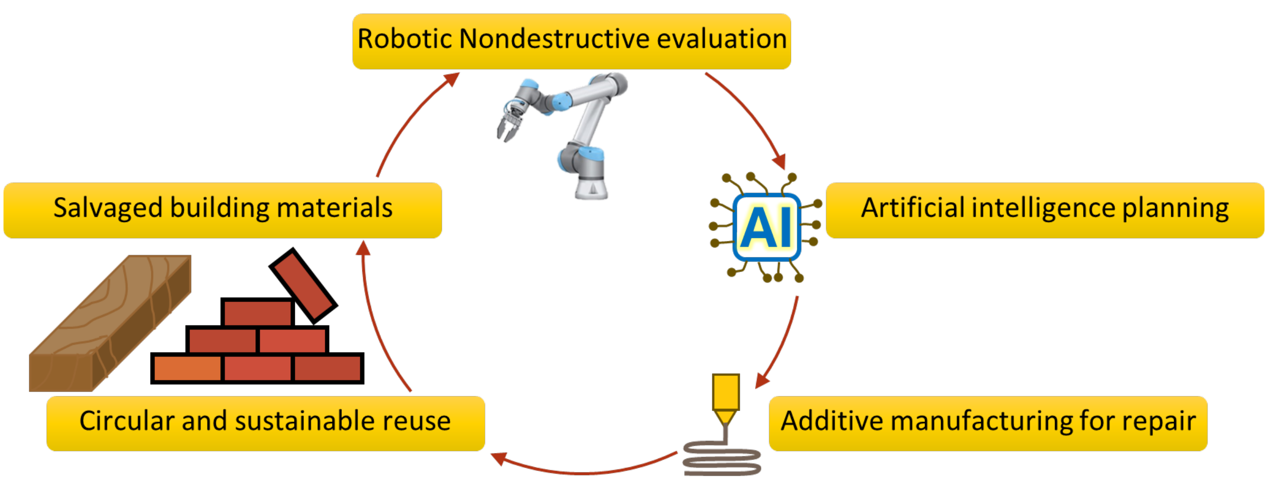
3) **Quantitative circularity assessment** methods will be used to evaluate the circular economy potential of alternative design solutions through metrics such as the Material Circularity Indicator (MCI) and Building Circularity Indicator (BCI).
4) **Life Cycle Assessment (LCA)** will be performed to quantify the environmental impacts associated with alternative building materials, assemblies, and end-of-life scenarios.
5) **A Circular Building Solutions Database (CBSD)** will be created to store building design alternatives, technical specifications, circularity metrics, and environmental performance data as a reusable knowledge repository.
6) **Case-Based Reasoning (CBR)** and AI-driven recommender systems will be developed to automatically retrieve, adapt, and recommend circular design solutions during early design, enabling architects to evaluate and improve building circularity in real time.

PROJECT 2: Robotic Evaluation for Circular Lifecycle Assessment of Infrastructure Materials (RECLAIM)

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 project 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: Sustainable design, Circular economy, Design for disassembly, Life cycle assessment, Building information modeling, Construction materials, Material reuse or recycling, Digital twins, Artificial intelligence, Nondestructive evaluation, Robotics.
- Mechanical Engineering and Mechanics: Machine learning, Generative design, Sustainable manufacturing, Artificial intelligence, Computational modeling, Artificial intelligence, Nondestructive evaluation, Robotics.
- Electrical and Computer Engineering: Artificial intelligence, Machine learning, Data analytics, Software development, Decision support systems, Nondestructive evaluation, Robotics.
- Computer Science: Artificial intelligence, Generative AI, Machine learning, Data science, Knowledge-based systems, Case-based reasoning, Database development, Robotics.

MENTOR CONTACT INFORMATION

Dr. Arvin Ebrahimkhanlou
Email: ae628@drexel.edu
Civil, Architectural, and Environmental Engineering

Dr. Fernanda Cruz Rios
Email: fc432@drexel.edu
Civil, Architectural, and Environmental Engineering

PARTNERS & SPONSORS

Potential for funding from Manufacturing PA Initiative

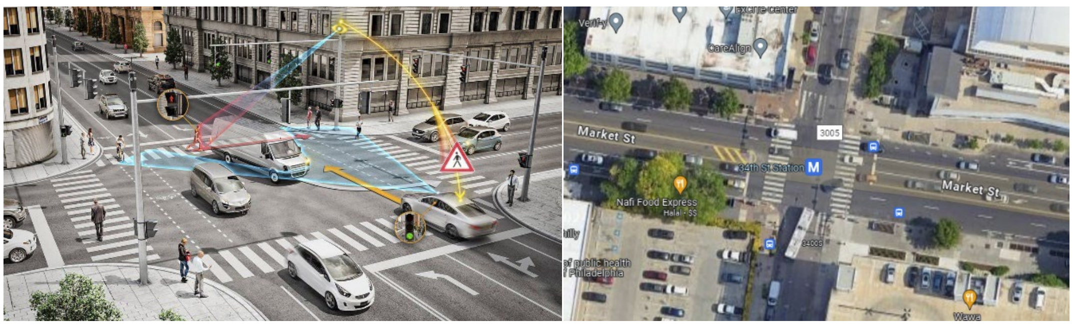
Detecting Cyberattacks in Traffic Systems Using Data Analytics and Machine Learning

Dr. Liang Zhang (ELS) – Faculty Mentor

GOALS

An Intelligent Transportation System (ITS) is a system in which real-time data is gathered and used to inform automated decisions regarding the function of traffic-related infrastructure and hardware. Although traffic communications have traditionally been hardwired, cities are increasingly looking to wireless networks for such communications. Challenges, however, could arise when adopting these sectors to smart cities. Traffic systems generate large volumes of data from sensors and controllers. Cyberattacks often leave subtle patterns in this data before major failures occur. This project focuses on using data analysis and machine learning to detect and tackle abnormal traffic behavior caused by cyber threats.

Team members will analyze traffic datasets and develop Python-based simulation models that can flag suspicious activity in intelligent transportation systems.



The VIP team will have the opportunity for publications at top systems engineering, engineering management and transportation engineering venues, such as INFORMS, ASEM, and TRB.

RESEARCH, DESIGN, & TECHNICAL ISSUES

The VIP team will mainly focus on hands on experiments, field research at signalized intersections, and writing research papers. Undergraduate team members will work with graduate students and professors biweekly on the following activities: 1) performing literature review; 2) conducting field research; 3) establishing simulation environments using SUMO or VISSIM and Python; 4) analyzing data.

METHODS & TECHNOLOGIES

1. Basic traffic flow theory, traffic control methods.
2. Machine learning algorithms (deep learning, reinforcement learning, classification methods, etc.).
3. Cybersecurity.
4. Traffic simulation software (SUMO and VISSIM), operations research software (Arena), programming language (Python and MATLAB).

MAJORS & AREAS OF INTEREST

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

- Civil, Architectural and Environmental Engineering – transportation systems, infrastructure, GIS, air pollution, data analysis.
- Systems Engineering – optimization, operations research, queue theory, game theory, graph theory.
- Computer Engineering – big data, machine learning.
- Sociology – societal impacts of smart cities.

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

MENTOR CONTACT INFORMATION

Dr. Liang Zhang
Email: lz465@drexel.edu
Telephone: 215.571.3749

DriveSmart, WorkSafe

Dr. Zhiwei Chen (CAEE) – Faculty Mentor

GOALS

DriveSmart, WorkSafe aims to develop and prototype two automation technologies for transportation systems. The “DriveSmart” thrust builds an eco-driving research testbed using robot cars to develop and evaluate motion planning and control algorithms that reduce energy use while maintaining safety and mobility performance. The “WorkSafe” thrust designs and builds small robots that support work-zone operations, with the long-term objective of reducing worker exposure to traffic crash risk.

METHODS & TECHNOLOGIES

Team members will gain hands-on experience with a full autonomy/robotics stack and transportation evaluation methods, including:

- Robotics and autonomy: ROS/ROS2, simulation-to-hardware workflows, state estimation, motion planning (trajectory optimization, MPC-style control), behavior logic, and safety constraints
- Sensing and perception (as needed by subprojects): camera/LiDAR/IMU integration, basic perception pipelines, mapping/localization, sensor calibration
- Software and experimentation: Python/C++, data logging, experiment design, reproducibility, version control (Git), documentation, and team-based development
- Transportation domain knowledge such as work zone operations, traffic flow theory.

RESEARCH, DESIGN, & TECHNICAL ISSUES

For DriveSmart, key technical challenges include integrating the robot-car platform (sensors, onboard computing, and actuators), achieving reliable wireless communication and time synchronization (packet loss/latency), and building a ROS/ROS2 software stack with repeatable, high-quality data logging. The team will implement baseline autonomy modules (state estimation and trajectory tracking), then evaluate eco-driving algorithms in standardized scenarios using metrics such as energy proxies, travel time, smoothness, and safety margins.

For WorkSafe, key challenges include selecting a feasible work-zone support task, designing robust mobility and sensing for cluttered and variable environments, and ensuring safety-by-design through conservative behaviors, geofencing, remote stop/override, and fault handling. Prototypes will be tested in staged settings and improved iteratively with clear documentation of assumptions and performance.

MAJORS & AREAS OF INTERESTS

This team is interdisciplinary. Students from many majors can contribute meaningfully, including:

- Engineering: Civil/Transportation, Mechanical, Electrical, Computer, Systems, Robotics
- Computing/Data: Computer Science, Data Science, AI/ML
- Design/Operations: Product design, human factors, technology innovation

You will be a good fit for you if you enjoy building robots, autonomy software, running experiments, working in teams, and translating real transportation problems into testable engineering solutions.

MENTOR CONTACT INFORMATION

Dr. Zhiwei Chen
Email: zc392@drexel.edu
Connected and Automated Mobility Lab

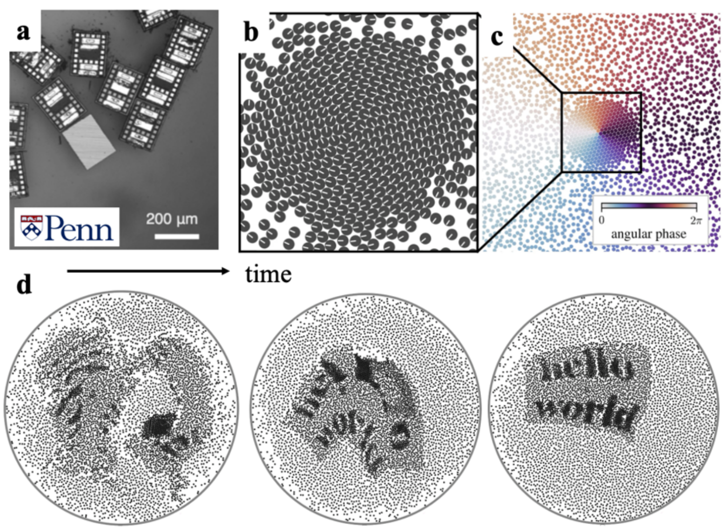
Emergent coordinate systems for organizing massively parallel robotic swarms

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
Email: vansaders@drexel.edu
Department of Physics, Materials Science Engineering (affiliated)

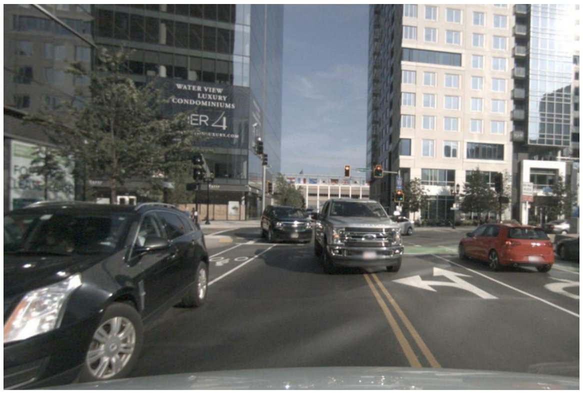
PARTNERS & SPONSERS

None

Foundation Models for Autonomous Driving

Dr. Lifeng Zhou (ECE) – Faculty Mentor

GOALS



Autonomous driving is being reshaped by large pretrained foundation models. Vision-language models (VLMs) allow a vehicle to describe and reason about what it sees; vision-language-action (VLA) models go one step further and turn camera observations and natural language instructions directly into driving trajectories and control commands; and world models learn to predict how a driving scene will evolve, so that a vehicle can imagine the consequences of an action before taking it, and so that rare, safety-critical scenarios can be generated for training and testing. This course explores the intersection of computer vision, natural language processing, generative world modeling, and robotic control, focusing on how multi-modal foundation models enhance perception, reasoning, and decision-making in autonomous robot cars.

Team members will gain hands-on experience with state-of-the-art open foundation models for driving, including VLMs (e.g., PaliGemma, LLaVA, Qwen-VL), open driving VLA and reasoning models (e.g., the NVIDIA Alpamayo family), and world foundation models (e.g., NVIDIA Cosmos), and their applications in scene understanding, risk and intent reasoning, trajectory planning, and real-time control. Through simulation, public driving datasets, and experiments on the lab robot car, we will examine how these models interpret visual inputs, follow natural language commands, explain their driving decisions, and generate driving scenarios, including rare corner cases, for closed-loop training and evaluation. 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 and AI venues.

METHODS & TECHNOLOGIES

Vision-language models (VLMs), vision-language-action (VLA) models, world models and generative driving scenario simulation, end-to-end and modular autonomy stacks, motion planning and control for AVs, multi-modal perception (LiDAR, camera, radar, microphone, etc.), parameter-efficient finetuning (LoRA/PEFT), and efficient real-time inference on embedded GPUs.

RESEARCH, DESIGN, & TECHNICAL ISSUES

1. Perception and Reasoning with VLMs - Finetune and evaluate small VLMs for scene understanding, risk and intent reasoning, and natural-language explanation of driving decisions.
2. VLA Models for Driving - Finetune open driving VLA models (e.g., NVIDIA Alpamayo) that map camera observations and language instructions to trajectories or control commands, and deploy them on the lab robot car.
3. World Models for Driving - Use world foundation models (e.g., NVIDIA Cosmos) to predict future frames, generate rare and safety-critical driving scenarios, and build closed-loop training and evaluation pipelines.
4. Real-Time Deployment - Quantize, distill, and optimize large models for real-time inference on embedded GPU hardware, and integrate them with ROS-based planning and control.

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 and control, robot perception (LiDAR, camera, radar, microphone, etc.), embedded and real-time systems, on-vehicle deployment
- Computer Science - VLMs, VLA models, world models, generative models, computer vision, natural language processing, reinforcement learning
- Mechanical Engineering - vehicle dynamics, sensor mounting and platform design, computer aided design (CAD) software experience

APPLICATION PREREQUISITES

Prior to applying for a position on this team, prospective team members are asked to please install Linux-Ubuntu & Robot Operating System (ROS) on your machine and go through ROS tutorials (ROS1: http://wiki.ros.org/noetic or ROS2: https://docs.ros.org/en/humble/index.html). Here is a docker package with all the instructions for both ROS 1/2 which allows using Rviz, Gazebo, etc.:
https://github.com/Zhourobotics/ros2-docker-dev. Other than docker, you can also use virtual machine to install Linux and ROS. Then implement the autonomous navigation of Turtlebot in the ROS-Gazebo simulator, similar to this: https://www.youtube.com/watch?v=lW-c88vxLRE and record a video.

Go through the tutorials (Chapters 8, 11, 12, 14, 15, 16) of ROSMASTER R2: http://www.yahboom.net/study/ROSMASTER-R2. This is the robot car we use in the lab. Document your findings and questions.

Try out a small VLM and run it on driving images: PaliGemma (https://huggingface.co/blog/paligemmav), LLaVA (https://github.com/haotian-liu/LLaVA), or Qwen-VL. Run it on a few frames from a public driving dataset (e.g., nuScenes: https://www.nuscenes.org) and ask it to describe the scene, identify the risks, and propose the safest next action. Document your findings and questions.

Explore the open driving foundation models from NVIDIA: the Alpamayo family of open reasoning/vision-language-action models for autonomous vehicles (https://github.com/haotian-liu/LLaVA) and the Cosmos world foundation models (https://github.com/nvidia-cosmos). Run one of the released models or example notebooks, and document what it does well and where it fails.

Optional but strongly encouraged: install the CARLA driving simulator (https://carla.org), run a simple autopilot or ROS-bridge scenario, and record a video. 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. Responses will only be provided after the prerequisites have been completed and the time commitment has been made.

MENTOR CONTACT INFORMATION

Dr. Lifeng Zhou
Email:lz457@drexel.edu
Phone: 215.895.1922
Drexel Zhou Robotics Lab

PARTNERS & SPONSORS

National Science Foundation (NSF)

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

Dr. Anup Das
Email: anup.das@drexel.edu
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

Dr. Hasan Ayaz
Email: ayaz@drexel.edu
Neuroergonomics and Neuroengineering Lab

PARTNERS & SPONSORS

None

Ukraine Sovereign Recovery Through a Sustainability Lens

Dr. Joseph Hughes (CAEE/ELS), – Faculty Mentor

GOALS

The United Nations Sustainable Development Goals (SDGs) provide a broad framework for improving human well-being, protecting the environment, strengthening institutions, and creating sustainable communities. The goals are deeply interconnected: progress in health, water, energy, education, infrastructure, economic opportunity, strong institutions, and peace depends on the performance of systems that support one another.

War places extraordinary stress on these systems. It damages housing, energy, transportation, water and sanitation, communications, agriculture, environmental systems, businesses, schools, healthcare, governance, and public safety. The consequences extend beyond the location of a damaged asset because modern societies function through networks of interdependent physical, economic, institutional, environmental, and social systems.

This VIP team will examine Ukraine as a real and consequential case study in sustainable recovery. The central question is: How can Ukraine recover in ways that restore the ability of people and communities to thrive while rebuilding national systems that are resilient, sustainable, interconnected, and capable of supporting the country's long-term sovereignty?

We will use sovereign recovery as an organizing framework. Sovereign recovery considers reconstruction as more than replacement of damaged assets; it asks how infrastructure, institutions, economic activity, security, the rule of law, environmental integrity, and civilian life can recover together as a functioning national system

Why Ukraine?

Ukraine provides team members with a living case study rather than a hypothetical exercise. The scale of destruction creates difficult technical and societal questions, while the recovery process creates opportunities to reconsider how modern systems should be designed. Reconstruction decisions made today can influence Ukraine for decades.

Examples of recovery challenges that students may investigate include:

- Housing reconstruction and the changing geography of communities created by internal displacement.
- Energy-system recovery and the dependence of water, heating, transportation, communications, and public services on reliable power.
- Water, sanitation, wastewater, and long-term environmental recovery, including contamination and altered hydrological systems.
- Transportation, rail, ports, and logistics needed to reconnect communities, move reconstruction materials, and restore trade.
- Agricultural recovery, including land access, irrigation, transportation, export logistics, landmines, and unexploded ordnance.
- War-generated debris, hazardous materials, recycling, material recovery, and the enormous waste-management requirements of reconstruction.
- Schools, healthcare, cultural institutions, governance systems, emergency services, and other social infrastructure that anchor community life.
- European integration and infrastructure interoperability, including energy, transportation, communications, environmental standards, and markets.
- Innovation in AI, geospatial analysis, drones, digital engineering, advanced construction, and infrastructure monitoring.

Work Progression

Fall Term 2026 — Build expertise. Each team member will select a specific Ukraine recovery challenge and become knowledgeable about that problem. They will learn the technical, environmental, social, economic, institutional, and sustainability dimensions of their topic; identify important stakeholders and data sources; and begin to understand how their challenge connects to the broader recovery of Ukraine.

Subsequent Terms — Build systems understanding. Team members will begin working in small teams that connect individual areas of expertise. The emphasis will shift from understanding individual recovery challenges to understanding relationships, dependencies, feedback, sequencing, tradeoffs, and opportunities for compounding benefits across systems.

The progression is deliberate: first understand a part of the problem well; then connect that knowledge with the expertise of others; then ask what becomes visible when Ukraine's recovery is viewed as a system of systems.

Expected Outcomes

The goal for AY 2026–27 is to develop work that can be shared beyond the classroom. The small teams will work toward one or more conference-quality posters or presentations suitable for a local venue such as Drexel's Celebration of Engineering or a similar university research event.

A successful year will produce more than a collection of individual studies. It will create an increasingly connected picture of Ukraine's sovereign recovery and demonstrate how students from different disciplines can contribute to understanding a complex, real-world sustainability challenge.

METHODS & TECHNOLOGIES

The VIP team will use research, systems thinking, visualization, and emerging technologies as tools for inquiry and communication. Depending on student interests and project needs, work may include literature and data analysis, GIS and geospatial analysis, systems mapping and modeling, AI-assisted research and analysis, remote sensing, visualization, and development of decision-support concepts.

Technology is a means rather than the research objective. Students will use appropriate tools to make complex recovery systems visible, test relationships, communicate uncertainty, and develop shared understanding across disciplinary boundaries.

RESEARCH, DESIGN, & TECHNICAL ISSUES

A recurring technical theme will be interdependence. Ukraine's recovery paper illustrates that damage to a single critical infrastructure node can propagate through multiple systems: loss of power can disrupt water treatment and district heating; transportation damage can constrain agriculture and humanitarian logistics; housing and population movement can create new demands on utilities, transportation, schools, healthcare, and municipal services.

Team members will therefore be encouraged to ask questions at more than one scale. What is the immediate recovery problem? What systems enable it? What systems depend on it? What environmental and human outcomes are affected? What sequence of actions creates the greatest capacity for further recovery? Where can sustainable design, interoperability, or innovation improve the long-term outcome?

Five useful design lenses drawn from the sovereign recovery framework are infrastructure functionality, environmental integrity, institutional legitimacy, equitable service delivery, and system interoperability. These lenses provide a starting point for comparing recovery choices without requiring every team member to approach the problem from the same discipline.

MAJORS & AREAS OF INTEREST

Sovereign recovery is inherently interdisciplinary. T from any major and at different stages of study are welcome. No prior knowledge of Ukraine, reconstruction, or systems modeling is required. Useful interests include:

- Sustainability and environmental systems
- Engineering and infrastructure
- Energy, water, transportation, and the built environment
- Health and public safety
- Computing, AI, data science, GIS, and visualization
- Economics, business, supply chains, and entrepreneurship
- Public policy, governance, law, and institutions
- Psychology, sociology, anthropology, and community development
- Agriculture and food systems
- Peace, conflict, international affairs, and European studies

MENTOR CONTACT INFORMATION

Dr. Joseph (Joe) Hughes
Email: jbh68@drexel.edu

PARTNERS & SPONSORS

The VIP will draw on Professor Hughes's ongoing work and professional engagement related to Ukraine sovereign recovery. Specific external collaborators and project connections may be incorporated as opportunities develop during the academic year.