Department of

Civil, Construction and Environmental Engineering

Jackie MacDonald Gibson, Ph.D.
Professor and Head

Spring 2023

NC STATE UNIVERSITY

Department of Civil, Construction, and Environmental Engineering

Established in 1895
10,700 B.S. degrees

Wallace C. Riddick
1895-1908

Carroll L. Mann
1916-48

Charles R. Bramer
1948-49; 1962-65

Ralph E. Fadum
1949-62

Donald L. Dean
1965-78

Paul Zia
1979-88

E. Downey Brill
1988-2005

George List
2005-10

Morton Barlaz
2010-22

Jackie MacDonald Gibson
2022-Present

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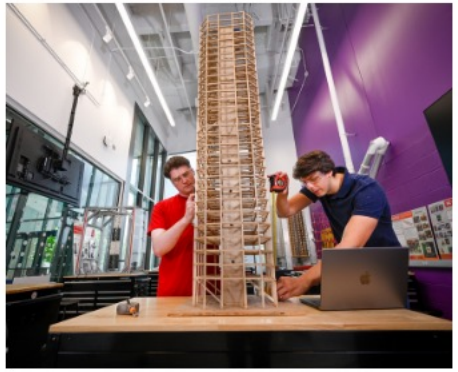
Department of Civil, Construction, and Environmental Engineering

AREAS OF EXPERTISE



- Computing and Systems
- Construction Engineering
- Environmental, Water Resources, and Coastal Engineering
- Geotechnical/GeoenvironmentalEngineering
- Mechanics and Materials
- Structural Engineering and Mechanics
- Transportation Systems and Materials

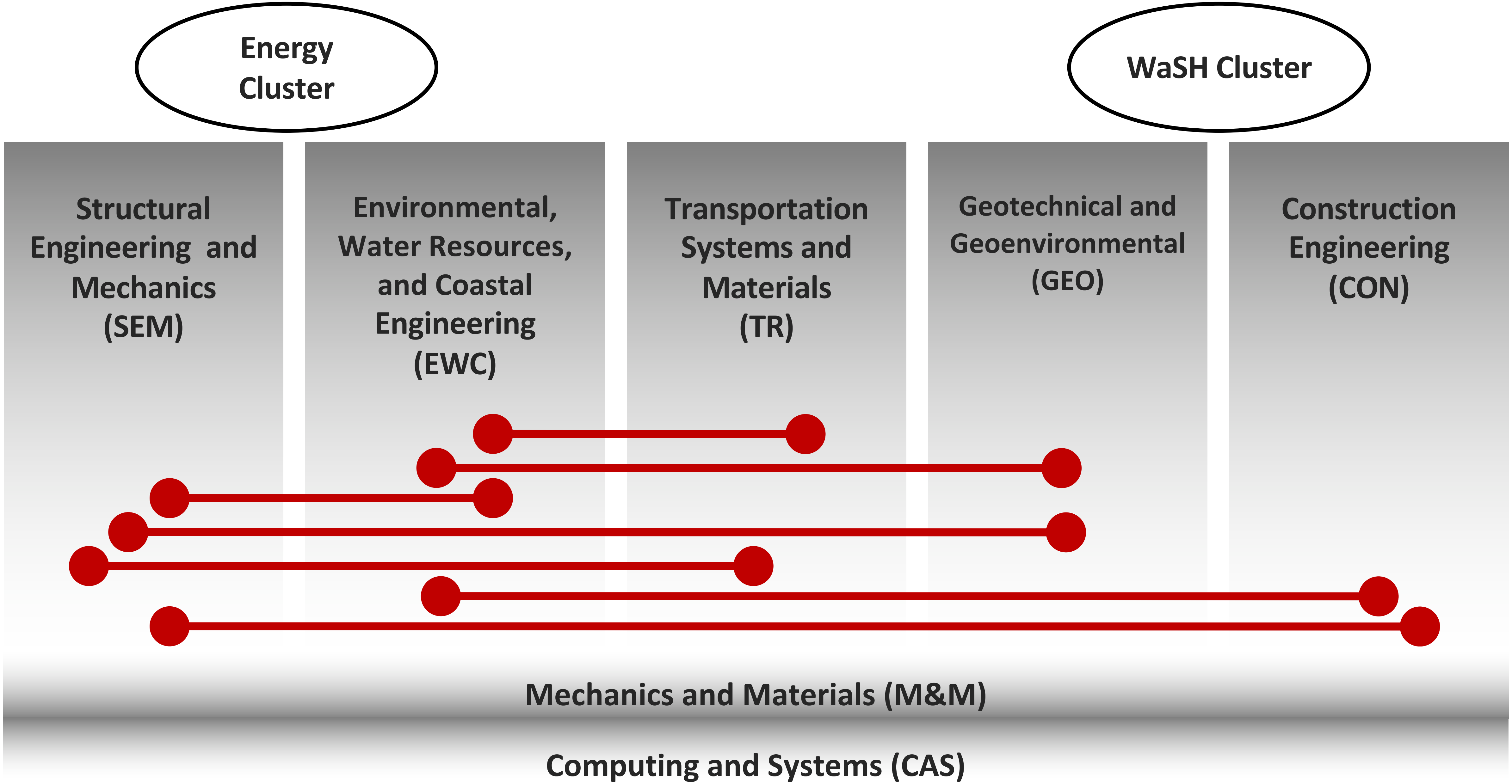
NC STATE UNIVERSITY

Department of Civil, Construction, and Environmental Engineering

WE ARE ONE OF THE LARGEST CIVIL/ENVIRONMENTAL ENGINEERING DEPARTMENTS IN THE NATION.

- 52 distinguished faculty, 17 winners of CAREER and other NSF young faculty awards
- Total research expenditures exceed $22.7 million
- 270 ongoing research projects
- Undergraduate enrollment of 739
- Graduate enrollment of 290

Who We Are?


Energy Cluster
WaSH Cluster
Structural Engineering and Mechanics (SEM)
Environmental, Water Resources, and Coastal Engineering (EWC)
Transportation Systems and Materials (TR)
Geotechnical and Geoenvironmental (GEO)
Construction Engineering (CON)
Mechanics and Materials (M&M)
Computing and Systems (CAS)

NC STATE UNIVERSITY

Department of Civil, Construction, and Environmental Engineering

STRONG UNDERGRADUATE AND GRADUATE PROGRAM RANKINGS

20th
Undergraduate Civil Engineering

21st
Undergraduate Environmental Engineering

26th
Graduate Civil Engineering

21st
Graduate Environmental Engineering

21st
Graduate Environmental Engineering

1st
Civil Distance Education

2nd
Environmental Distance Education

We Are Large

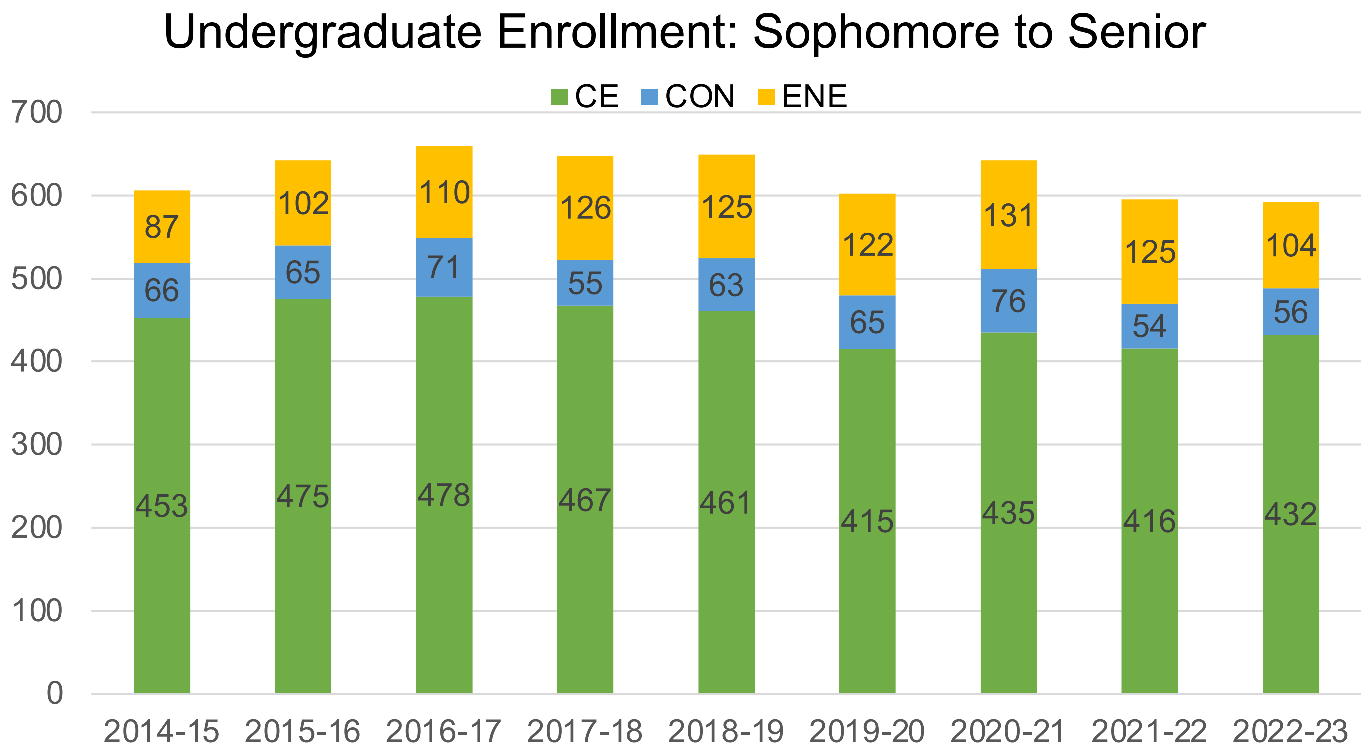
Civil Engineering Degrees Awarded By School	
1. Texas A&M University	248
2. Iowa State University	245
3. Virginia Polytechnic and State University	217
4. Purdue University	195
5. University of Illinois	180
6. The Pennsylvania State University	179
7. California State University, Long Beach	167
8. The University of Texas	160
9. The Ohio State University	158
10. California Polytechnic State Univ. San Luis Obispo	155
11. Louisiana State University	153
12. University of Buffalo, SUNY	150
13. North Carolina State University	148

- NC State is 195 including Construction and Environmental
- NC State College of Engineering ranks 9th in degrees awarded – 1,801

Academic Programs: Undergraduate

Undergraduate Degrees

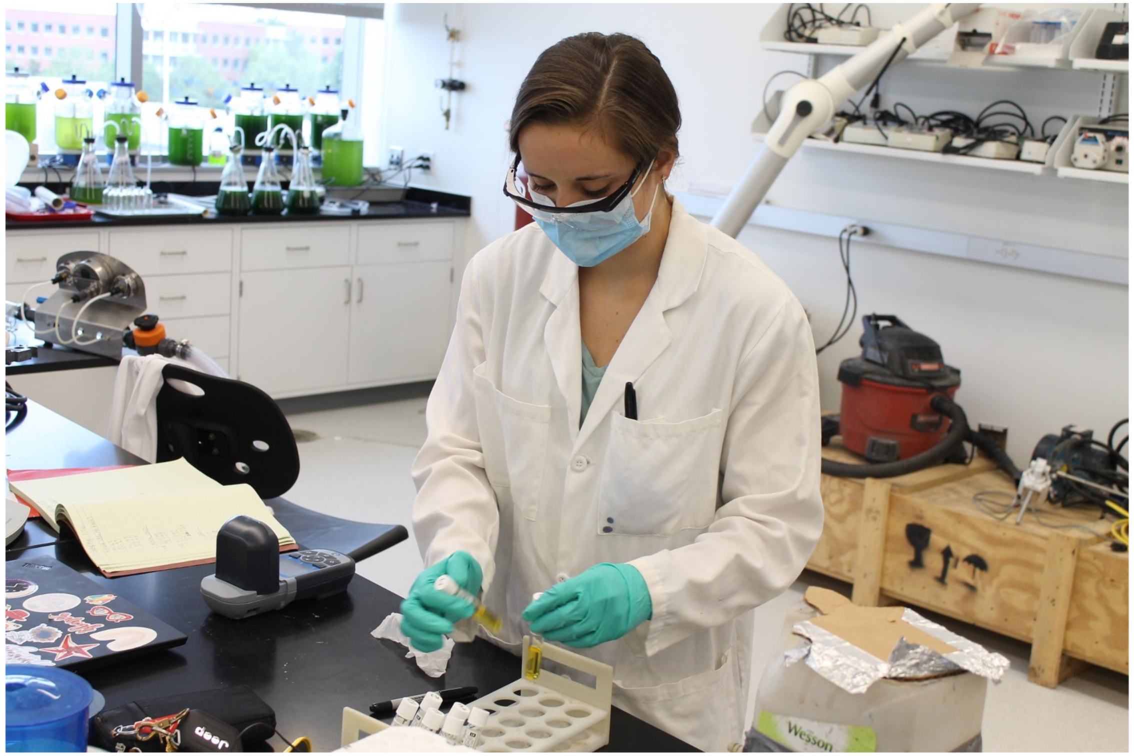
- Civil Engineering
- Construction Engineering
- Environmental Engineering
- 592 matriculated
- 810 with Engineering First Years, CE, CON, ENE Intended



MEET THE UNDERGRADUATE CCEE STUDENT AMBASSADORS

The select group of undergraduate students represents the department at a variety of academic, social and networking events throughout the academic year.

Undergraduate Research



- Undergraduates working with graduate students and faculty in a smaller setting
- Students involved in cutting edge work
- Undergraduate thesis option

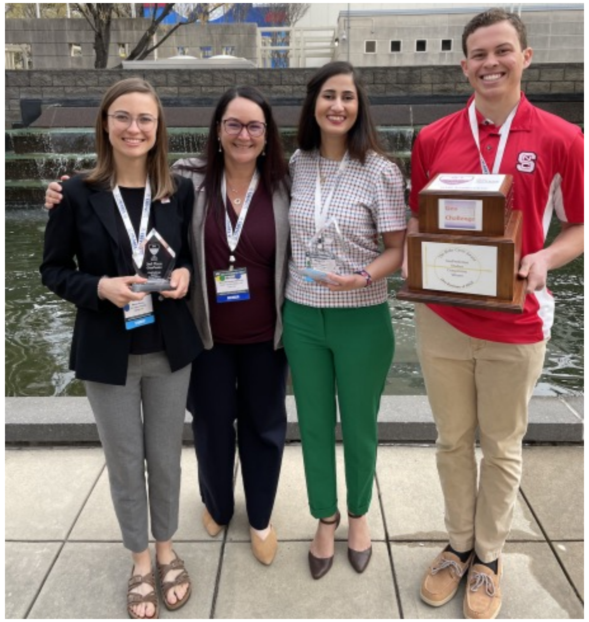
Academic Programs: Site and Conference Visits

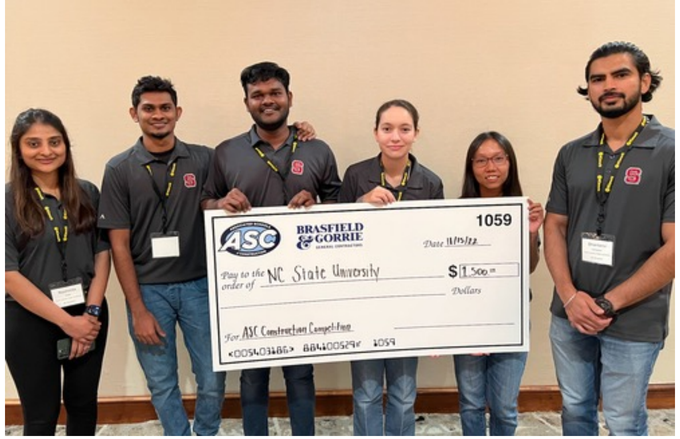
- ACI Convention, TRB Annual Meeting
- Design Competitions

Academic Programs: Site and Conference Visits

- American Concrete Institute
- Associated General Contractors
- American Society of Civil Engineers
- American Water Works Association
- Air and Waste Management Association
- Chi Epsilon
- Coasts, Oceans, Ports, and Rivers Institute

Academic Programs: Site and Conference Visits



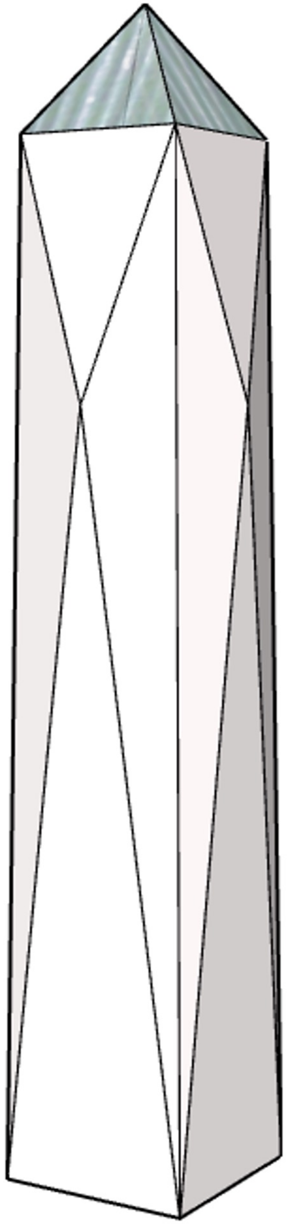


- Construction Managers Association of America
- Earthquake Engineering Research Institute
- Engineers Without Borders
- Geotechnical graduate student association
- Institute of Transportation Engineers
- National Association of Home Builders
- Professional Engineers of North Carolina

Earthquake Engineering Research Institute

Seminars to Prepare

- Introduction
- Structural Dynamics
- Seismic Design
- Seismic Analysis of Frame Buildings
- Seismic Analysis of Dual Systems
- Materials — Balsa Wood
- SAP2000 — Time History Analysis
- SAP2000 Part II



Geo-Institute Graduate Student Organization

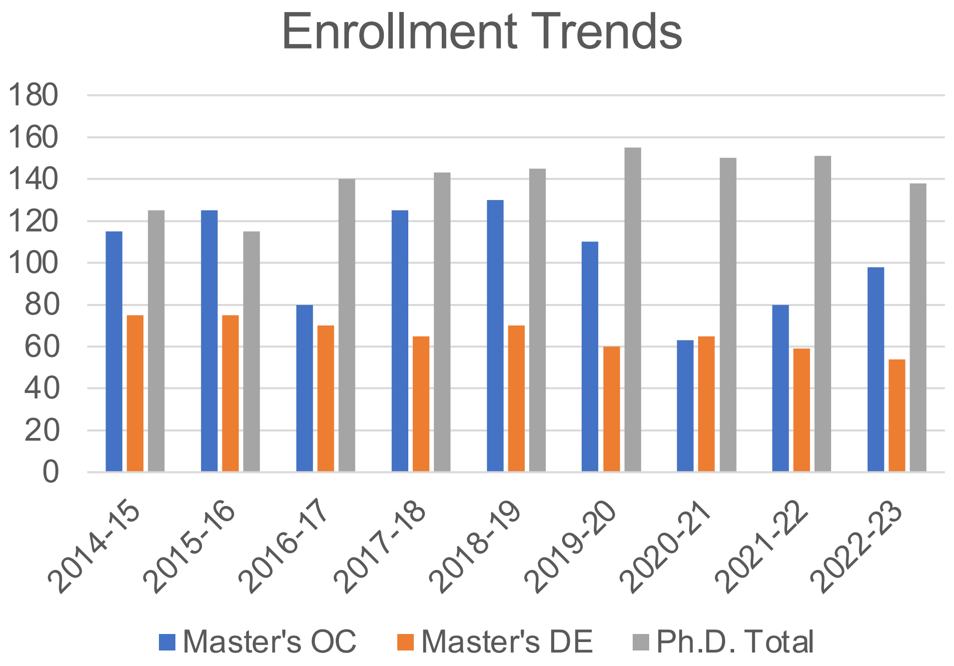
Technical Seminars

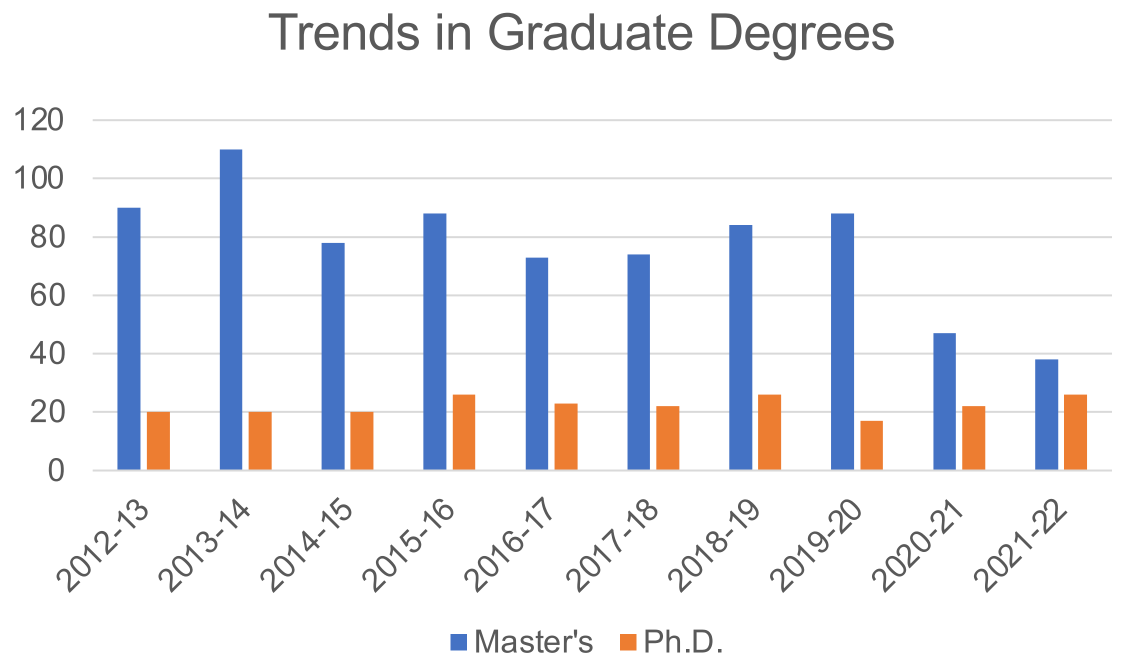
Social Events

Annual Geotechnical Engineering Conference

K-12 Outreach

Academic Programs: Graduate





- Master of:
  - Civil Engineering
  - Environmental Engineering
- Master of Science:
  - Civil Engineering
  - Environmental Engineering
- Distance Education
- Ph.D.

- Total of 290 graduate students
  - 150 students on assistantships

Academic programs: Graduate

- **Dr. Meagan Kittle Autry, director of Graduate Professional Development**

- **Ph.D. Communication, Rhetoric and Digital Media with a focus on scientific and technical communication**

    - Research Skills
    - Professional Skills
    - Career Support

- **Summer Distance Education Course**

- **Extension to undergraduates**

https://bit.ly/3zNEUKW

Graduate Programs

- **Engineering Online Degree Programs**
    - Master of Civil Engineering (MCE)
    - Master of Environmental Engineering (MENE)
- **Average age of online student: 34 years**
- **EOL students in 45 states and 21 countries**
- **We offer about 15 courses a semester**

Fall 2022 CCEE-EOL Course Offerings

Construction	CE 538	Information Technology and Modeling
	CE 590	Facilities Engineering
	CE 592	CII Best Practices
Environmental	CE 574	Chemical Principles of Environmental Engineering
	CE 578	Energy and Climate
	CE 586	Engineering Hydrology
	CE 588	Water Resrouces Engineering
Structural	CE 515	Advanced Strength of Materials
	CE 522	Theory and Design of Prestressed Concrete
	CE 523	Theory and Behavior of Steel Structures
	CE 525	Structural Analysis II
	CE 594	Nondestructive Evaluation of Concrete
	CE 723	Advanced Structural Dynamics
	CE 724	Probablistics Methods of Structural Engineering
	CE 725	Earthquake Structural Engineering
	CE 726	Advanced Theory of Concrete Structures
Transportation	CE 501	Transportation Systems Engr
	CE 502	Traffic Operations
	CE 595	Asphalt and Bituminous Materials
	CE 707	Transportation of Policy and Funding
	CE 708	Transportation Logistics Planning
	CE 755	Highway Pavement Design
Geotechnical	CE 548	Engineering Property of Soils
	CE 584	Hydrolics of Groundwater
	CE 741	Geomechanics of Stress Deformation
	CE 747	Geosynthetics in Geotechnical Engineering
Professional Developmen	CE 550	Professional Engineering Communication

CCEE-EOL Intro Videos

(https://go.ncsu.edu/ccee-eol_vids)

What's it take to earn a Masters Degree online?

Listen to real stories from our online graduates about how they balanced work and family life, while watching the lectures and completing the coursework in way that worked for them.

Watch a 3 minute video featuring former graduates. »

https://go.ncsu.edu/ccee-eol_testimonial_vid

Are you ready to engineer your career?

You can earn a Masters of Civil Engineering (MCE) or a Masters of Environmental Engineering (MENE) online thru CCEE's highly ranked program. Think about how that could enhance your career. Hear from our professors, students, and administrators about how it works.

Find out how to earn a Masters degree in the place, and at the pace, that works for you. »

https://go.ncsu.edu/ccee-eol_overview_vid

Customize your online degree to support your interest.

We have one of the most comprehensive online programs in the nation. Choosing the right Degree, the right Concentration, and the right Coursework allow you to customize your plan of study to support your Career!

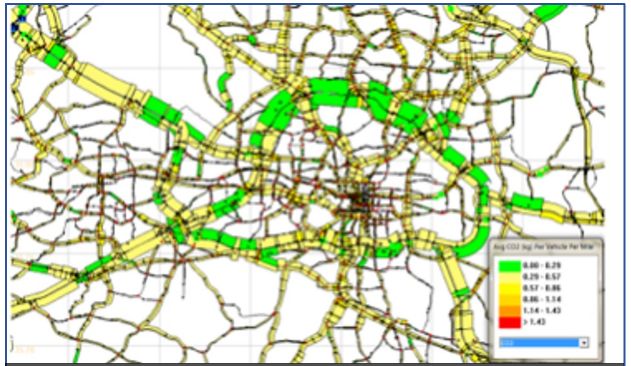
This very short animation clarifies how you can complete a degree that is just what you need. No more, no less. »

https://go.ncsu.edu/ccee-eol_custom_vid

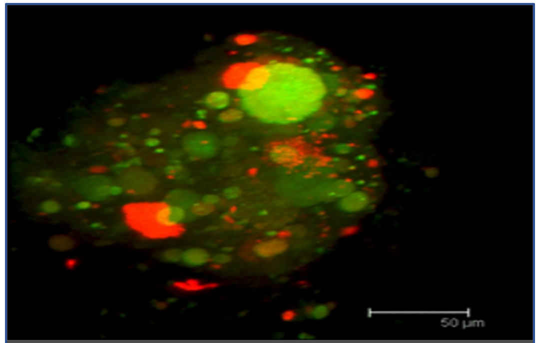
Research: Diverse in Expertise and Strengths

- We model, we test, we analyze, and we solve
- We work at scales from nano to lab to pilot to full-scale field research
- We are helping to design sustainable infrastructure for society all over the world
- Our research capabilities and methodologies span from the fundamental to the applied

Accelerated pavement testing

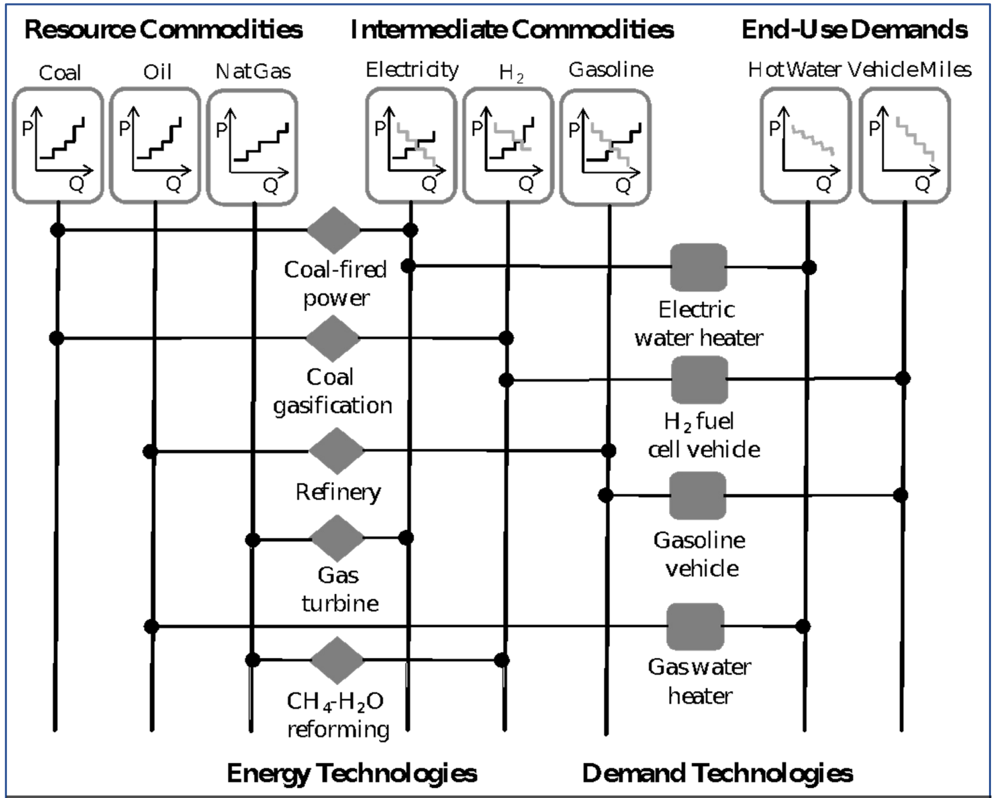


Energy efficiency and transportation



Colonies with the nirS gene

Soil flushing



U.S. Energy and Environmental Policy

Research: In the News

Dr. Detlef Knappe's PFAS research highlighted in New York Times article

The New York Times — BUSINESS — How Chemical Companies Avoid Paying for Pollution

Detlef Knappe, a researcher at North Carolina State University who has focused on PFAS, leading students to collect water samples at the William O. Huske Dam in Fayetteville. Ed Kashi for The New York Times

Research: In the News

Left: Dr. Shane Underwood. Right: Asphalt sample loaded into ovens for testing.

Underwood's asphalt research featured on CNN

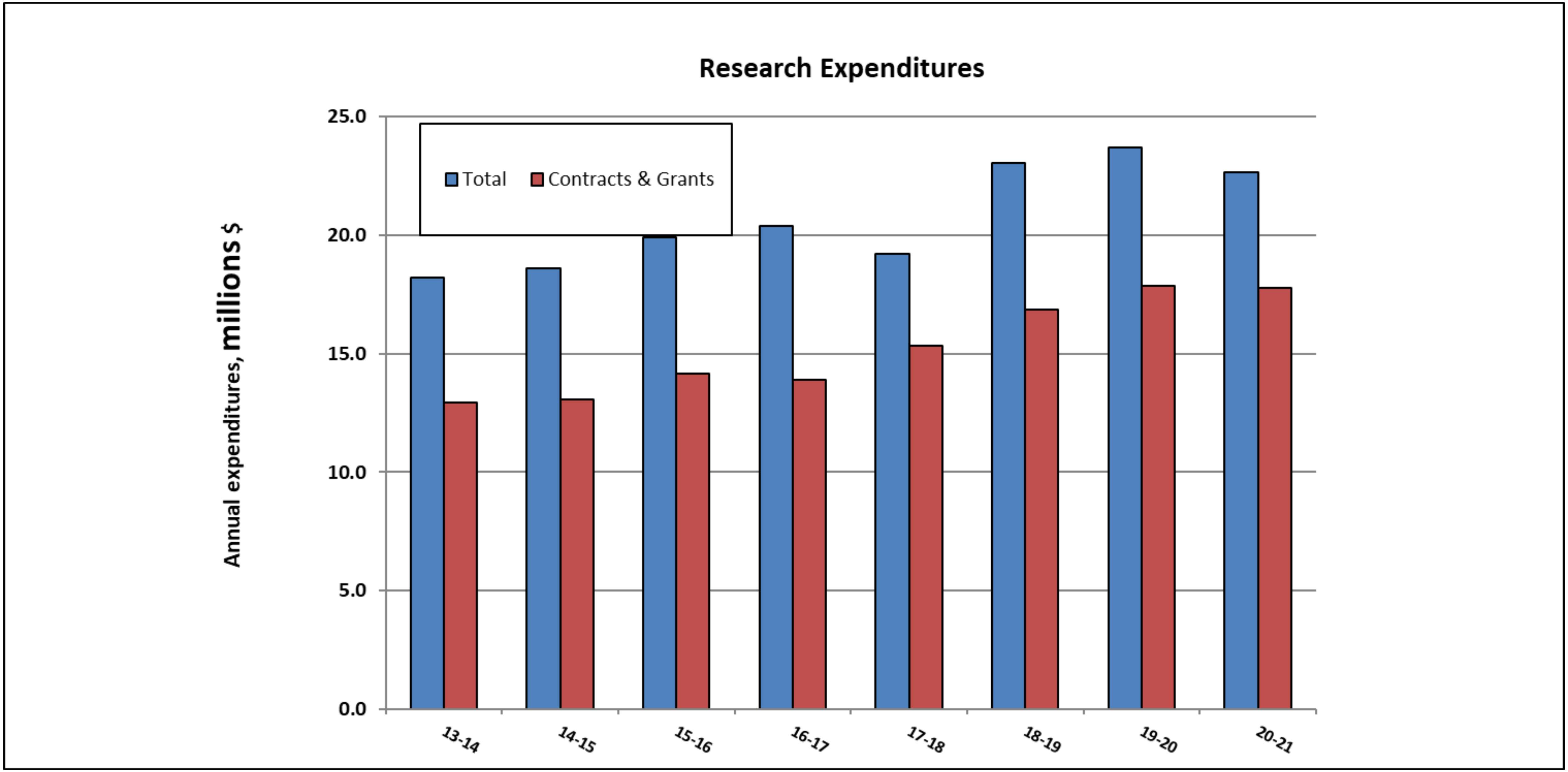
July 26, 2021

With the world getting hotter, road crews should install pavement that is more heat-resistant. CCEE's Dr. Shane Underwood leads research to understand and improve the behavior of asphalt concrete in changing climates. He was recently featured in a CNN story titled "Extreme weather events put spotlight on climate change's toll on US infrastructure" that first appeared on July 23rd. The news story examines the effects of climate change on transportation systems including public transport, and highways. The feature was spurred in part by the incidents c pavement failure that occurred in Washington state during record-breaking temperatures in early July.

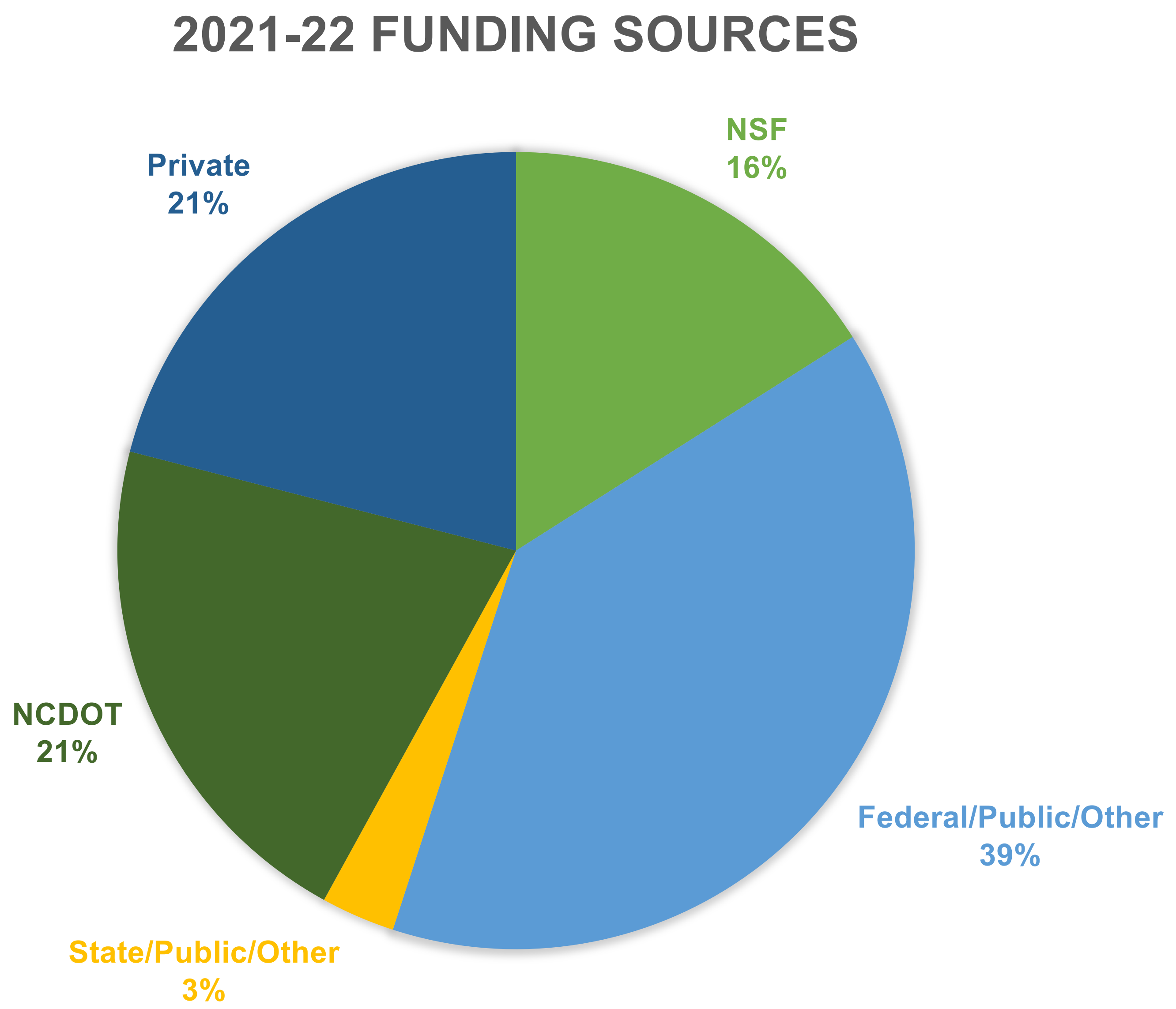
Research: In the News

Dr. Katherine Anarde's work on "Sunny Day Flooding" research featured on PBS

Trends in Funded Research



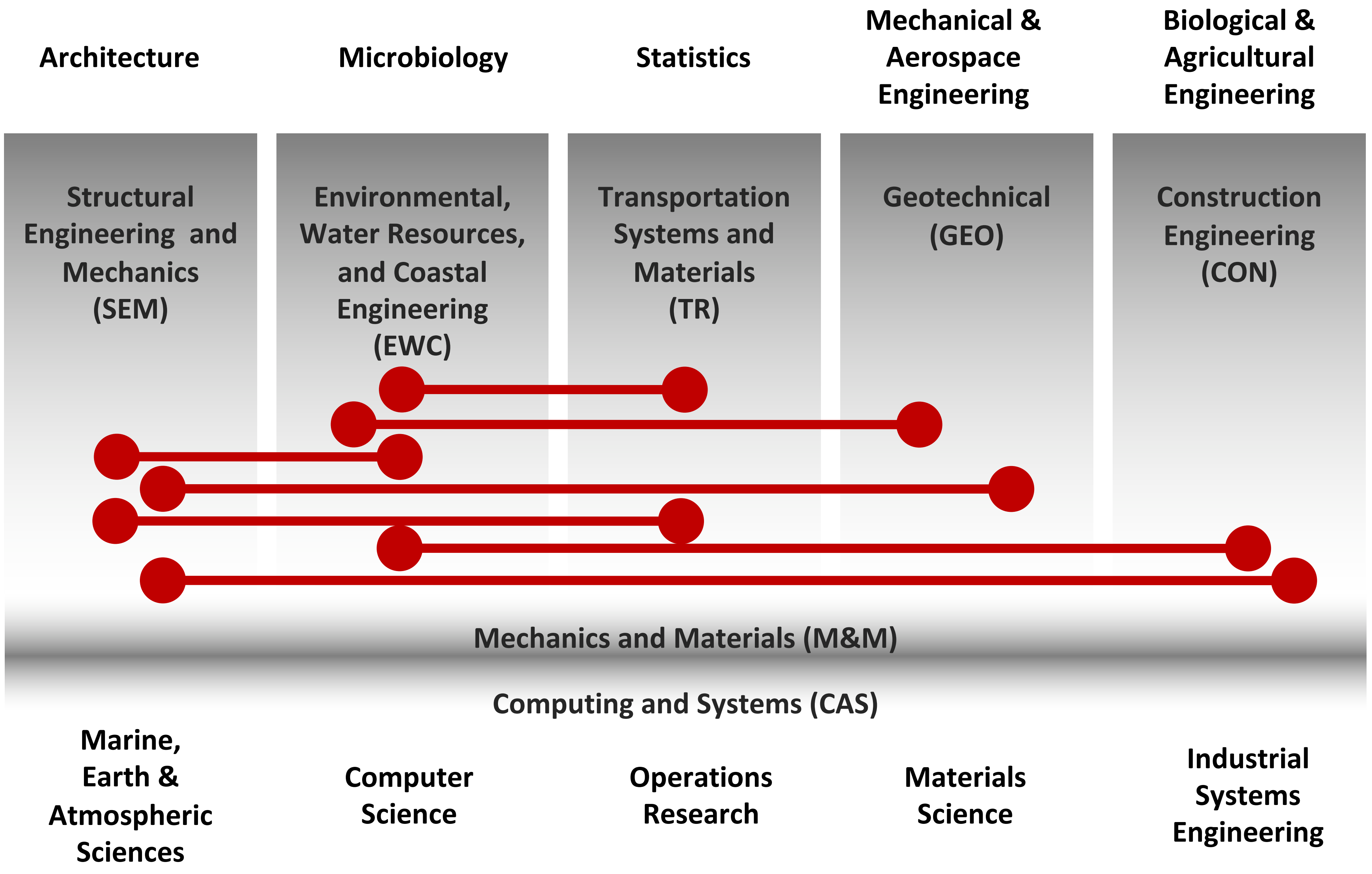
Funded Research: Funding by Source



Illustrative Funding Sources

- Army Corps of Engineers
- Bill and Melinda Gates Foundation
- Department of Defense (DOD)
- Department of Energy (DOE)
- Department of Homeland Security (DHS)
- Environmental Research and Education Foundation
- Federal Highway Administration (FHWA)
- Health Effects Institute
- National Aeronautics and Space Administration (NASA)
- N.C. Renewable Ocean Energy Program
- N.C. Policy Collaboratory
- National Science Foundation (NSF)
- National Oceanic and Atmospheric Administration (NOAA)
- N.C., C.A., A.L. and U.S. Departments of Transportation
- Sloan Foundation
- U.S. Environmental Protection Agency (U.S. EPA)
- U.S. Geological Survey

Working Across Disciplines



Chancellors Faculty Excellence Program

Vision Statement

"NC State University will emerge as a preeminent technological research university recognized around the globe for its innovative education and research addressing the grand challenges of society."

We are home to two faculty excellence clusters:

Global WaSH (Water, Sanitation, and Hygiene) (Dr. Francis De los Reyes)
Sustainable Energy Systems and Policy (Dr. Joseph DeCarolis)

Sustainable Energy Systems

The pursuit of energy sustainability represents a multigenerational challenge to deliver clean, affordable, secure and reliable energy.

Technology innovation - - - - - - **Political, social, economic, environmental dimensions** - - -> **Meeting societal grand challenges**

Our vision is to transform NC State into a preeminent and high visibility hub for transdisciplinary research that informs key energy decisions at the state, federal, and international levels.

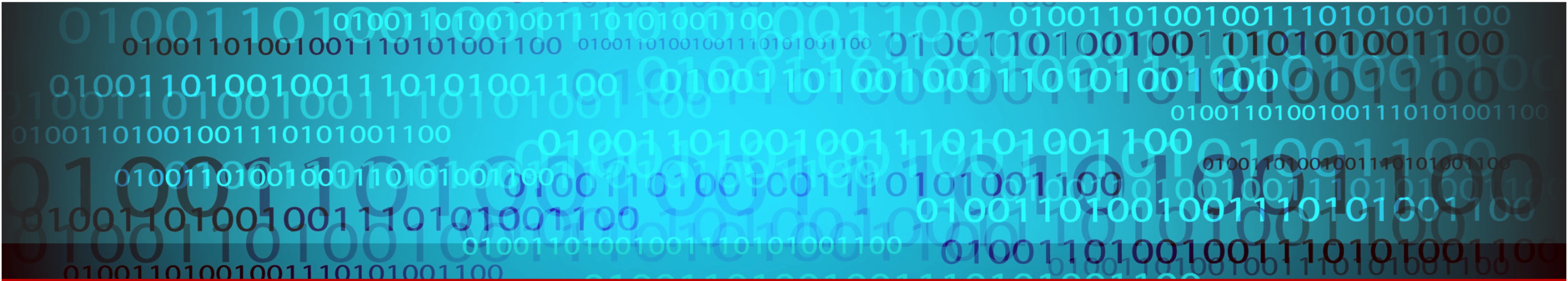
Mission

The NC State WaSH Cluster catalyzes and conducts transformational research and education to serve the water, sanitation and hygiene needs of marginalized people.

- Detection and transmission pathways of pathogens
- Creating effective indicators to track effectiveness of WaSH interventions
- Technology development for improving
  - Water quality
  - Sanitation services

NC STATE UNIVERSITY

Computing and Systems

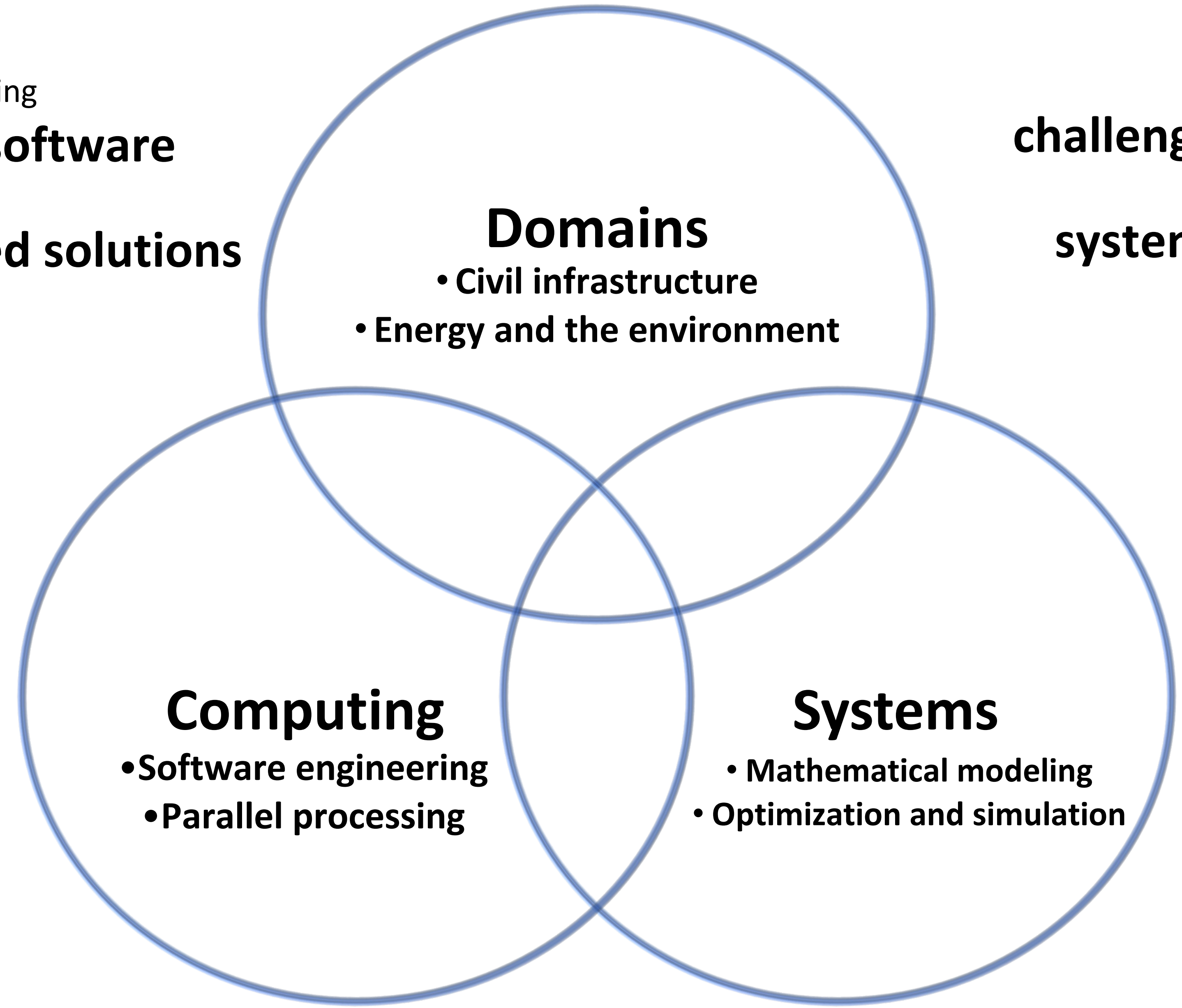


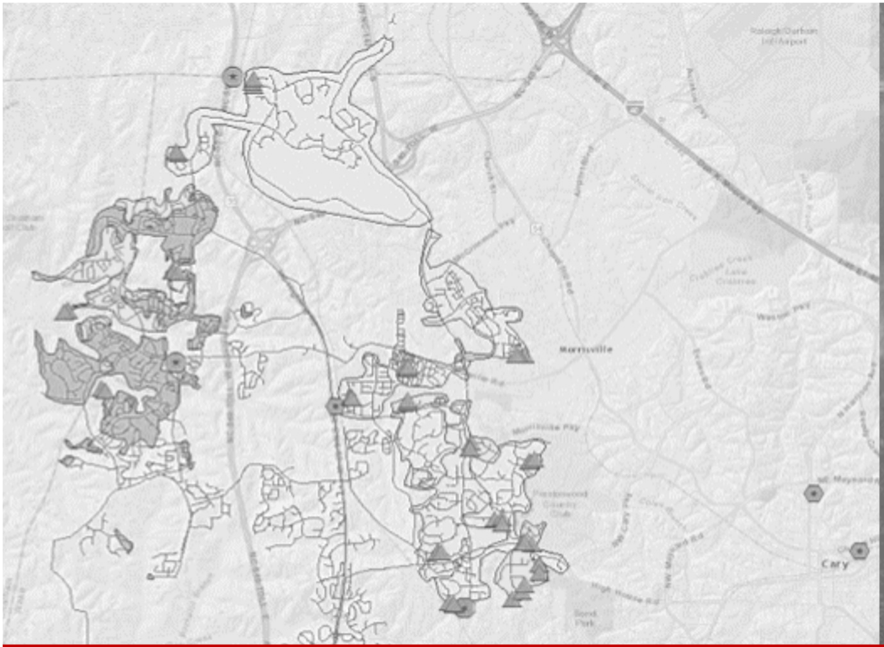
- An interdisciplinary program in civil engineering
- Faculty expertise in core computing and systems areas and traditional areas such as structures, coastal engineering and environmental engineering
- Our graduates pursue careers at traditional firms, government agencies, national laboratories and universities and others such as SAS, Cisco, IBM, Microsoft, GE and Intel
- We are working to develop new computing and methodological tools to solve critical civil engineering problems
- Programming, algorithm design and analysis, and software development play major roles in our research

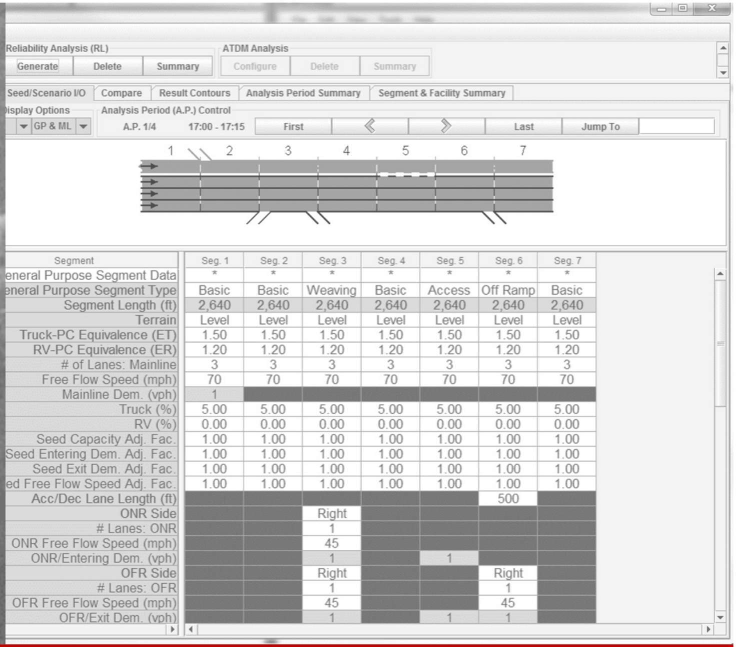
Computing and Systems

Developing
innovative software
and
computer-based solutions

Tackling
challenging problems
with
systems concepts







Four Core Areas of Strength

- **Scientific Computing**

  Numerical methods, high performance computing, algorithm development and analysis, reproducibility and correctness

- **Cyber-Physical Systems**

  Combining and integrating computation and physical components: smart cities and infrastructure, transportation, and energy systems

- **Systems Modeling & Optimization**

  Mathematical modeling, decision support systems, search algorithms, agent-based modeling, inverse problems, and multi-scale models

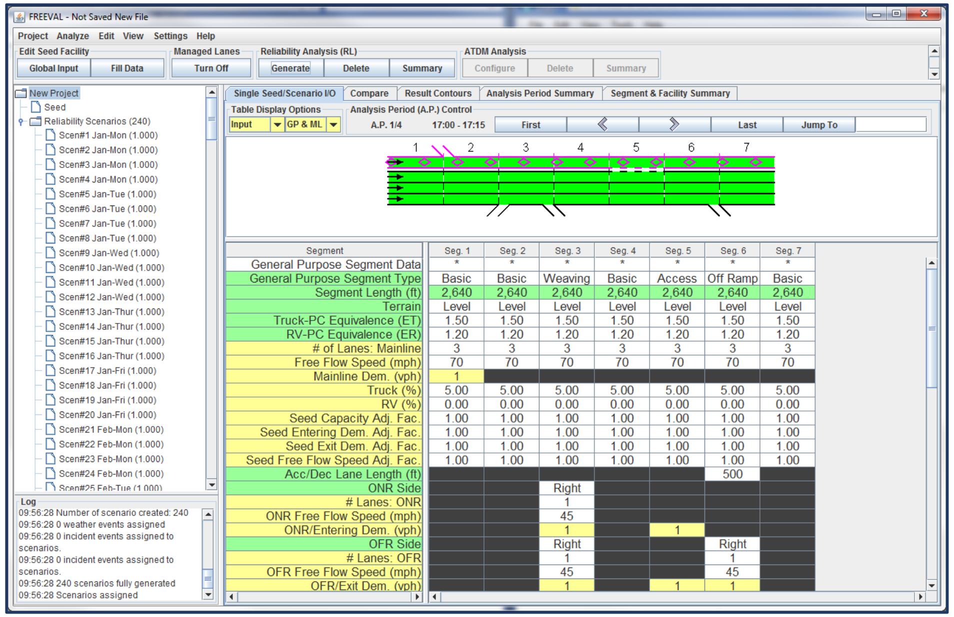
- **Data Science & Analytics**

  Machine learning and artificial intelligence, uncertainty quantification, data mining, large-scale models and data sets

Optimization of Transportation Systems

GOAL

Better decision-making tools for network design and traffic management



METHODS

Software design, mathematical optimization, integer programming and metaheuristics

APPROACH

Design a software framework for the Highway Capacity Manual (HCM) that extends simulation with optimization and decision-support features

IMPACT

An intuitive component of a workflow that:

- quantifies the effects of decisions
- finds optimal management strategies
- includes network design options

Energy-Efficient Buildings

GOAL

Increase energy efficiency of buildings

APPROACH

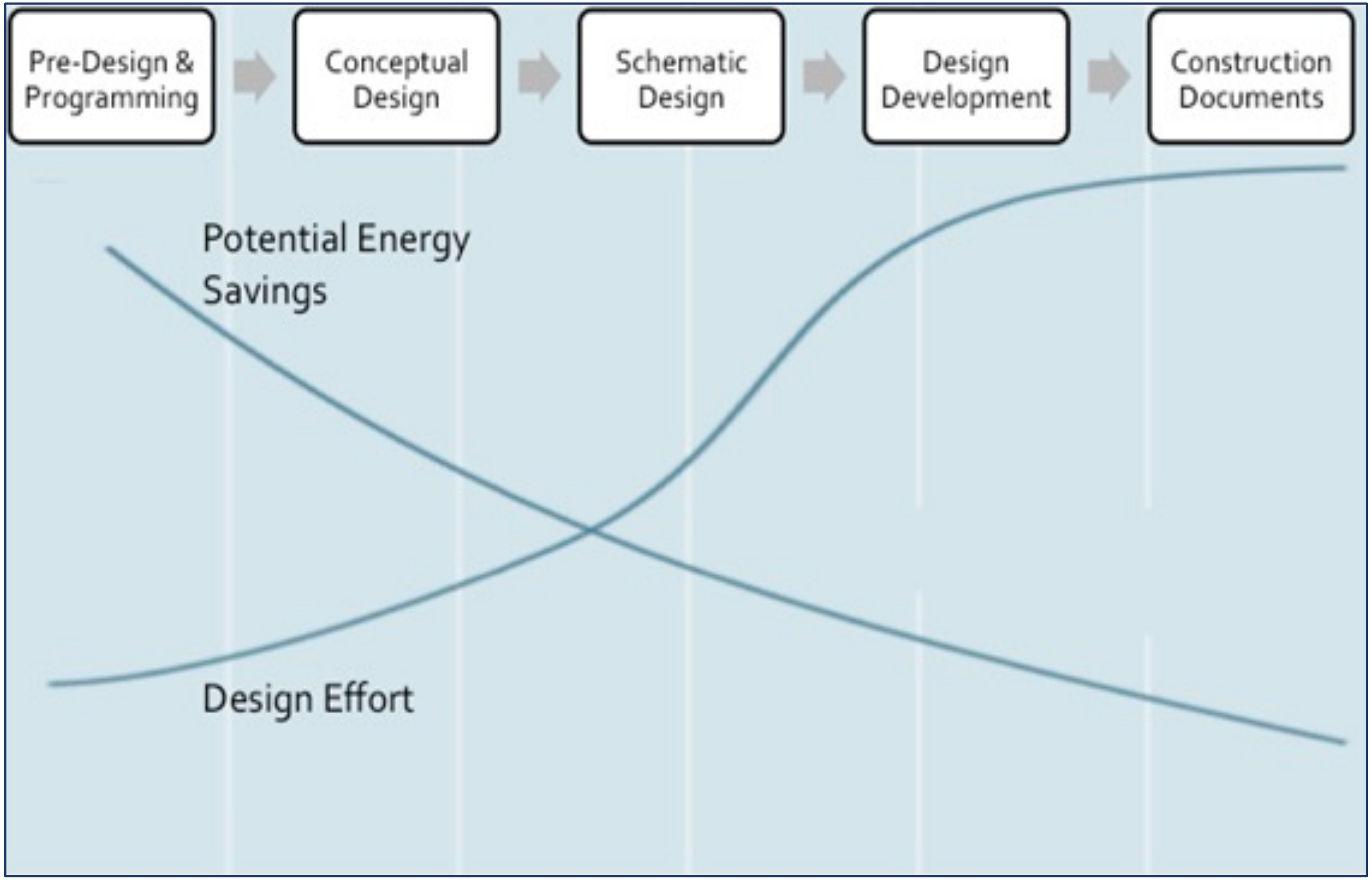
Coupling innovative optimization methods with building information models in architectural and engineering design

IMPACT

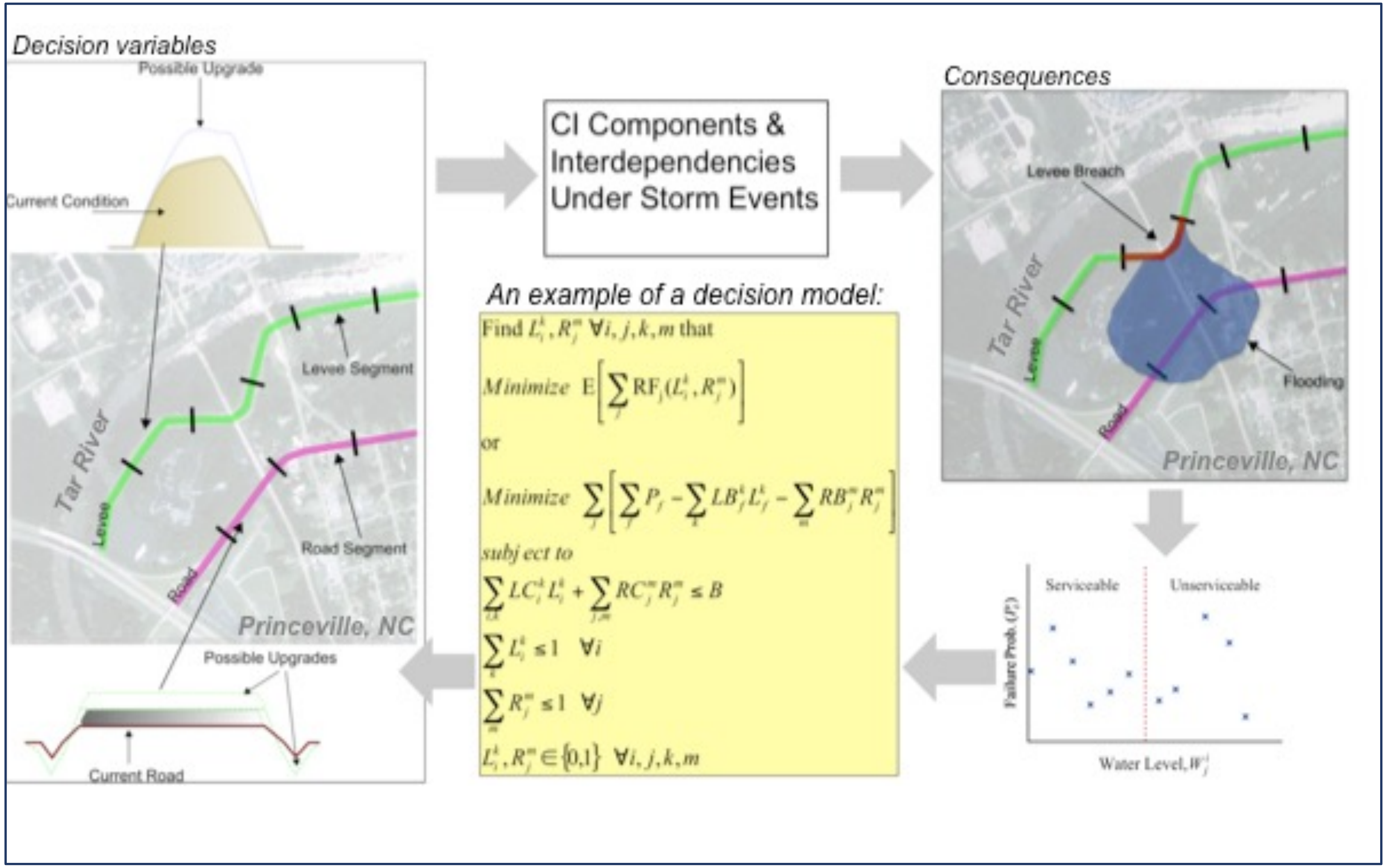
Green buildings and energy sustainability

METHODS

Optimization, simulation and modeling



Infrastructure Resilience



GOAL

Prioritize infrastructure investments to improve lifeline service resilience

APPROACH

Storm hazard impact simulation, mathematical modeling and computational procedures

IMPACT

Civil infrastructure investment prioritization to improve lifeline service resilience to storm hazards

METHODS

Optimization, simulation and modeling

Water Distribution System Management

GOAL

Computational tools for leak detection, contaminant source characterization, and risk assessment in water networks

APPROACH

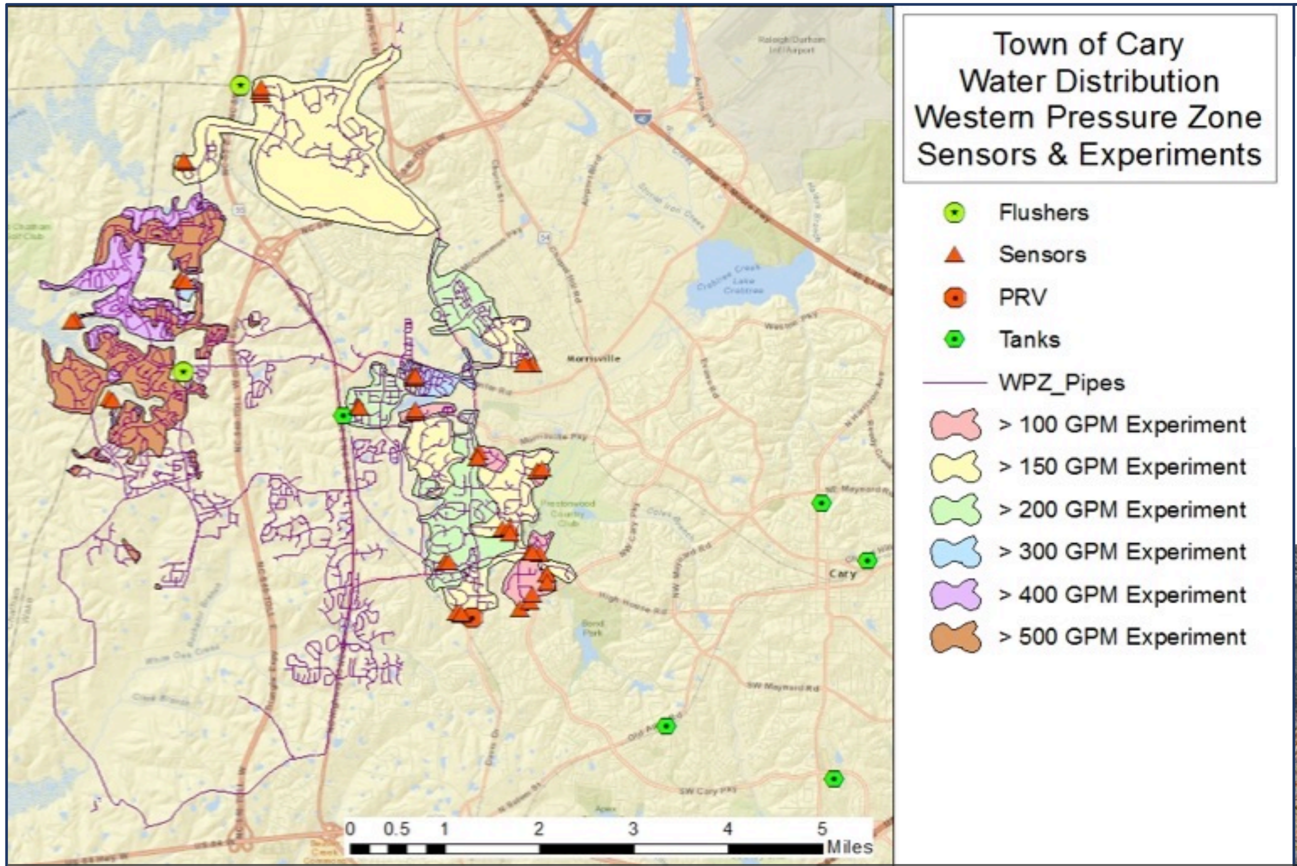
Customized optimization and statistical techniques enabled by high-performance computing; testing and deployment with Town of Cary network

IMPACT

Real-time water loss and contamination management as well as improved risk assessment

METHODS

High-performance computing, optimization, software engineering and Bayesian inference



Pressure Sensor Placement for Leak Detection

Socio-Technical Systems Analysis for Adaptive Water Resources Sustainability

GOAL

An adaptive modeling method to integrate the dynamic interactions and feedbacks between the social system and water infrastructure design and management policies

APPROACH

A novel adaptive simulation modeling procedure coupled with optimization techniques. Illustrative case applications for a large metropolitan area in Texas.

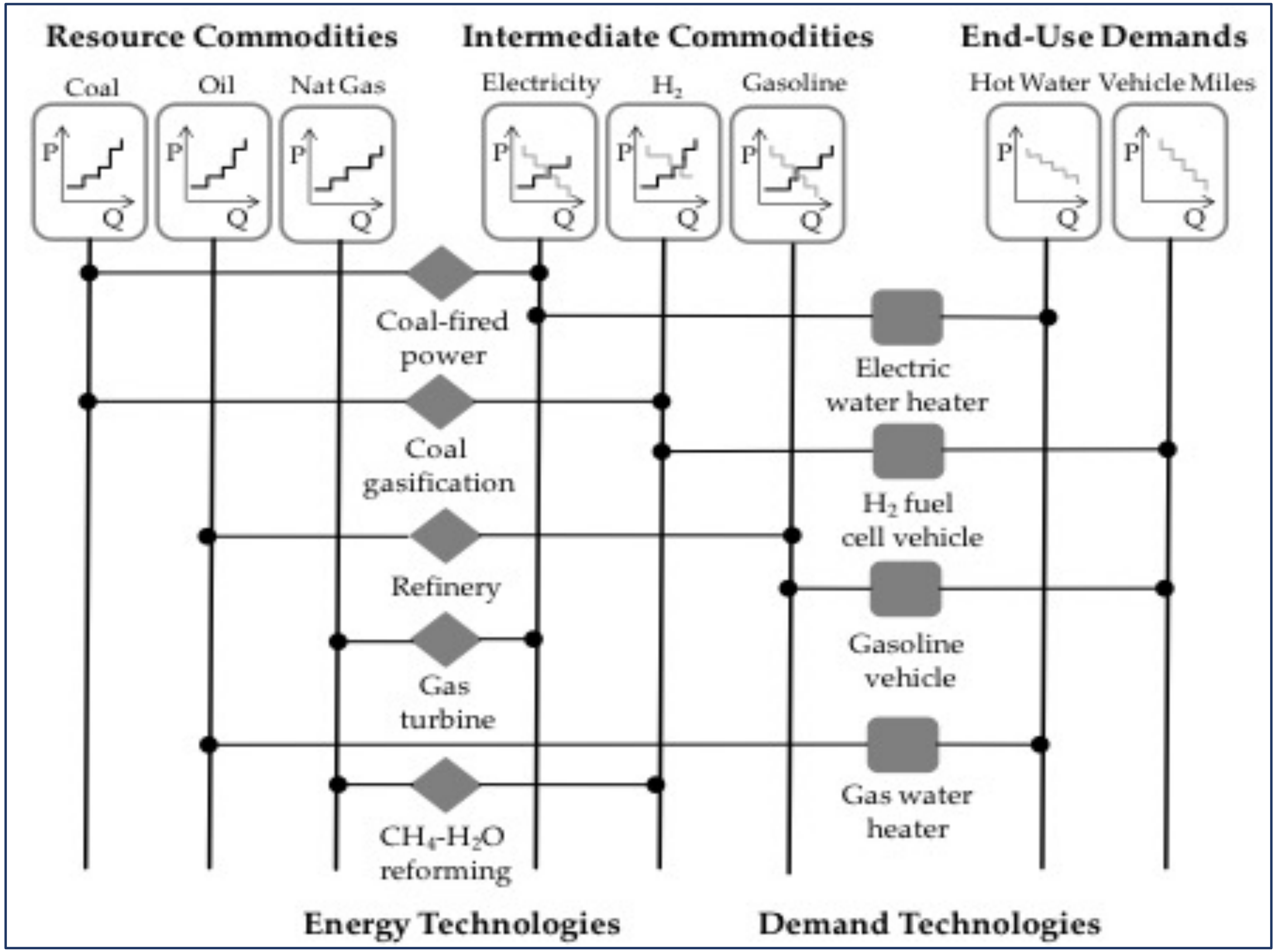
IMPACT

Adaptive water resources planning, design and operation considering social behavior

METHODS

Complex adaptive systems modeling and optimization

Energy Systems Modeling



GOAL

To perform system-level assessments of future technology deployment and public policy to inform decision-makers

APPROACH

Computational modeling of energy systems informed by technology explicit data

IMPACT

Insight relevant to U.S. energy and environmental policy

METHODS

Optimization, software engineering and high-performance computing

Integrated Solid Waste Management

GOAL

Evaluate solid waste system performance (i.e. economic, environmental) while accounting for changes to waste composition and generation, waste policy, the energy system, and potential future GHG mitigation policies

APPROACH

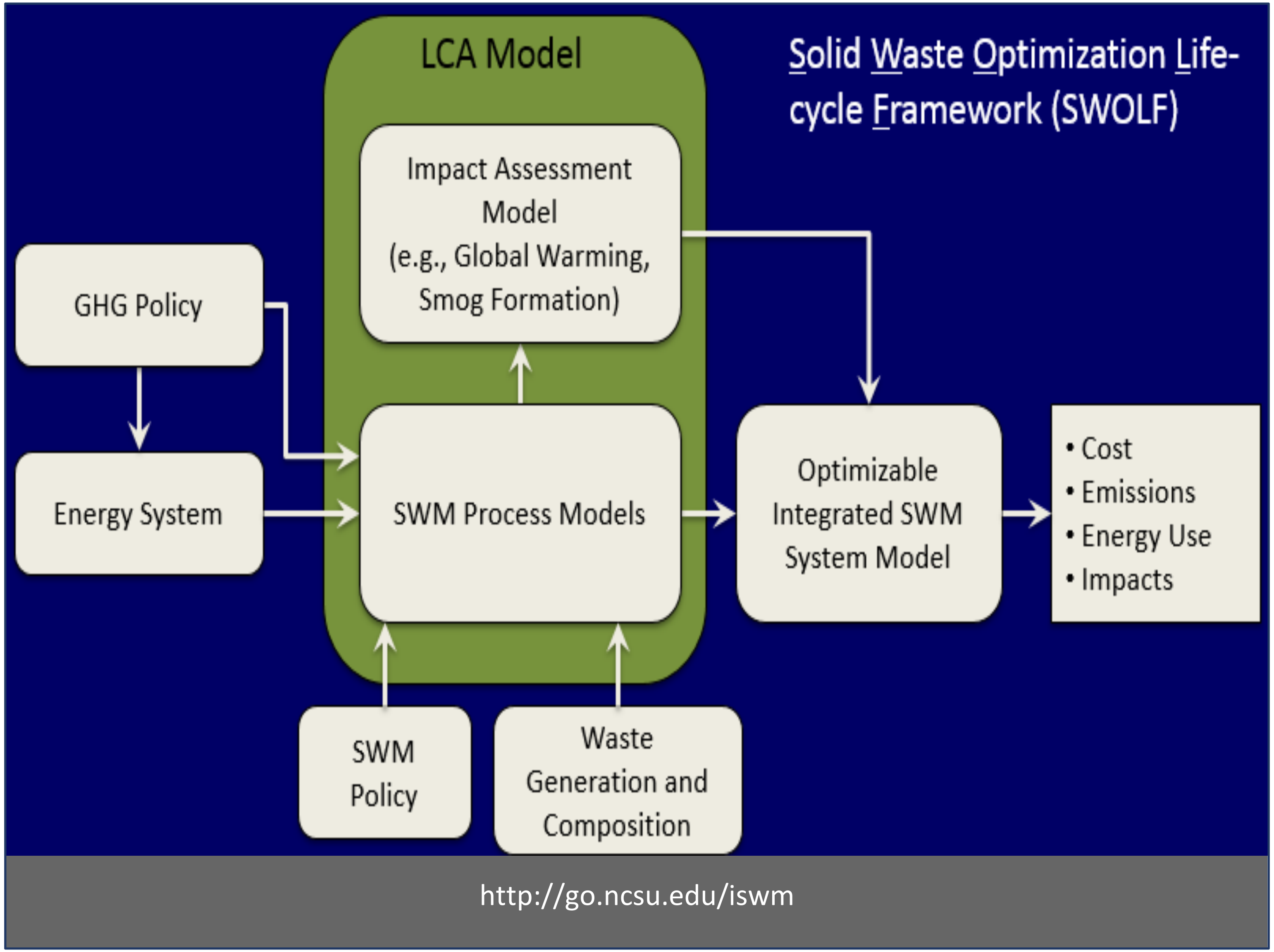
Innovative interfacing of data, measurements, analytical and decision models, and search algorithms for optimization

IMPACT

Enable integrated solid waste management by practitioners

METHODS

Process simulation modeling, optimization and software engineering



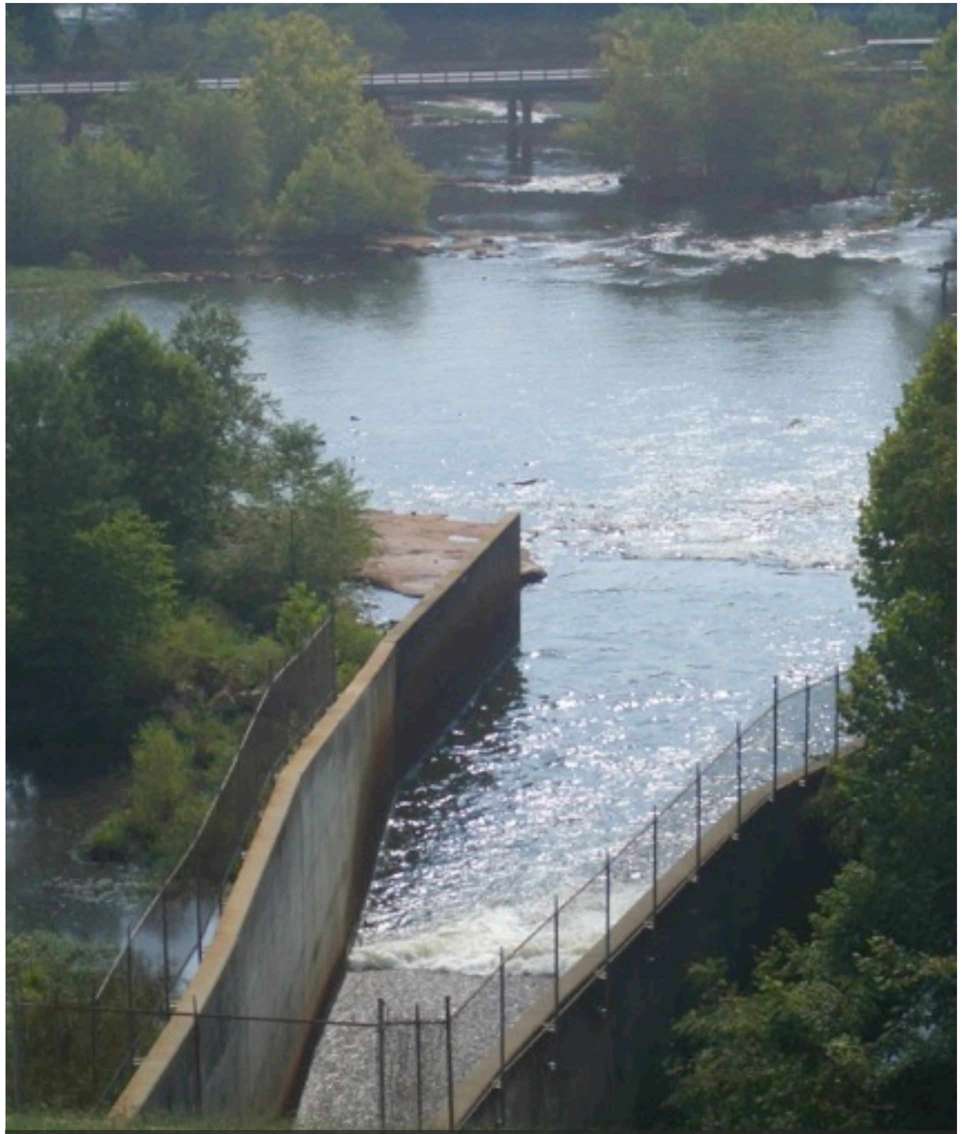
Hydroclimatology and Water Management

GOAL

Improve water-management practices by incorporating climate information

APPROACH

Innovative data fusion methods with statistical modeling and inference and optimization



Climate Informed Drought Management at Falls Lake

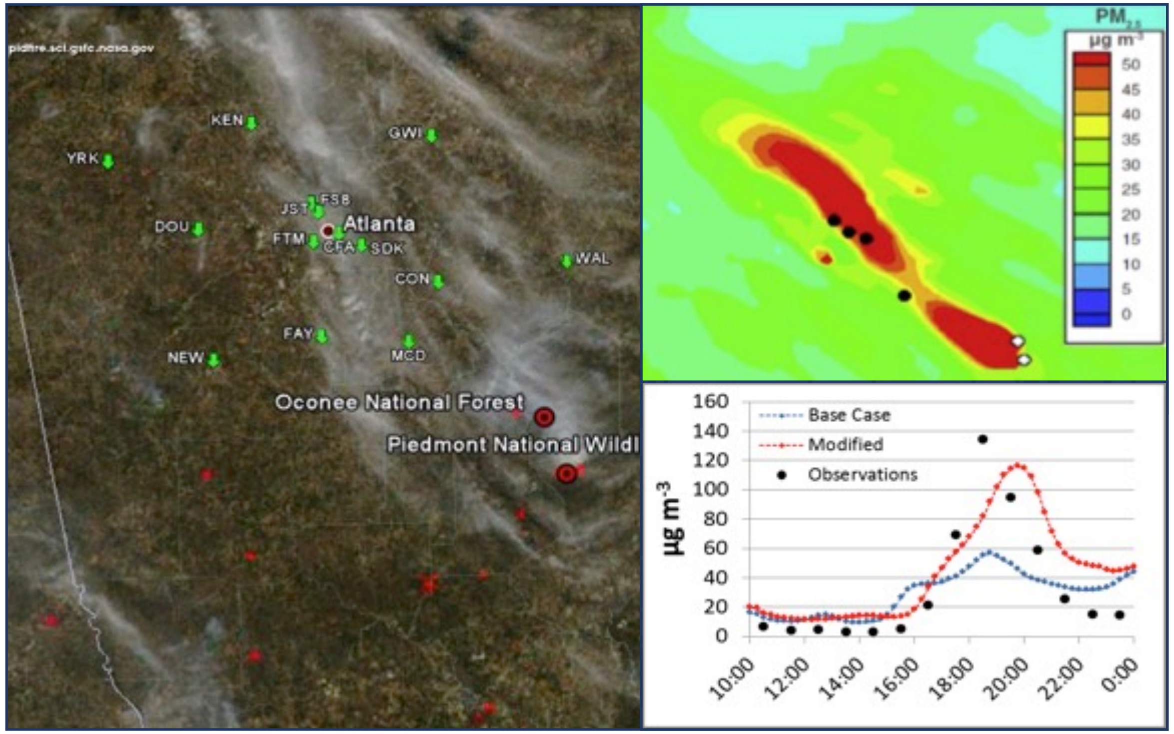
METHODS

Stochastic modeling, simulation and optimization

IMPACT

Improved water sustainability, flood and drought management, reservoir operation, hydropower management, water quality and risk management

Air-Quality Modeling



GOAL

Identify and evaluate strategies to mitigate air pollution and its impacts using computational models

APPROACH

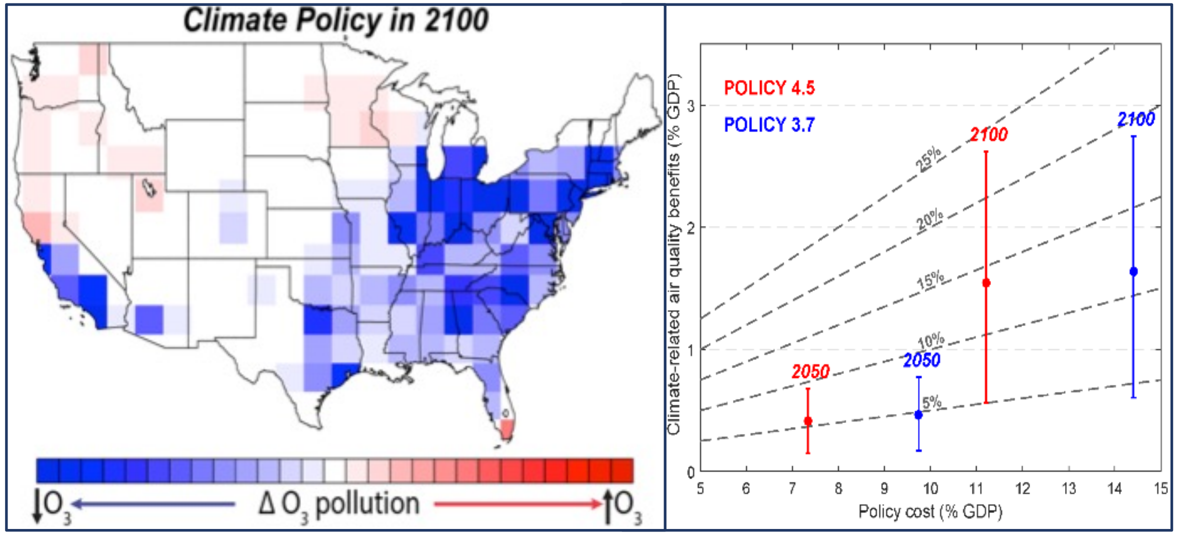
Multiscale modeling frameworks to simulate air quality and its interactions with other environmental and human systems

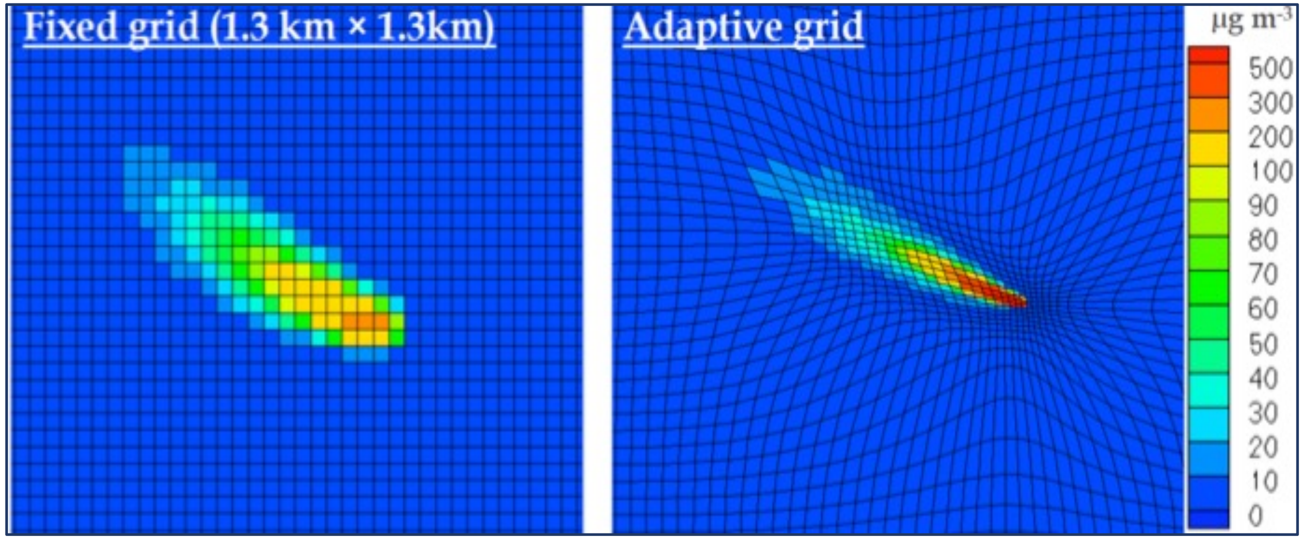
IMPACT

Improve air quality and earth systems models, guide environmental regulatory decision-making and policy

METHODS

Numerical methods, uncertainty analysis, integrated assessment modeling and high-performance computing





Decision-Making Under Uncertainty

GOAL

To create modeling and problem-solving frameworks that enable users to make consistent and robust decisions when facing uncertainty

APPROACH

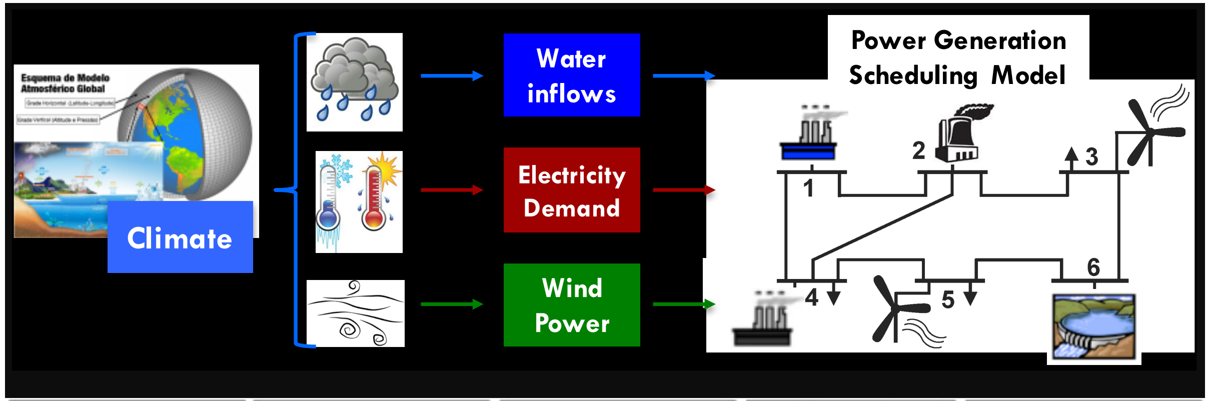
Water-Energy Nexus, Electricity Power Systems and Systems Engineering

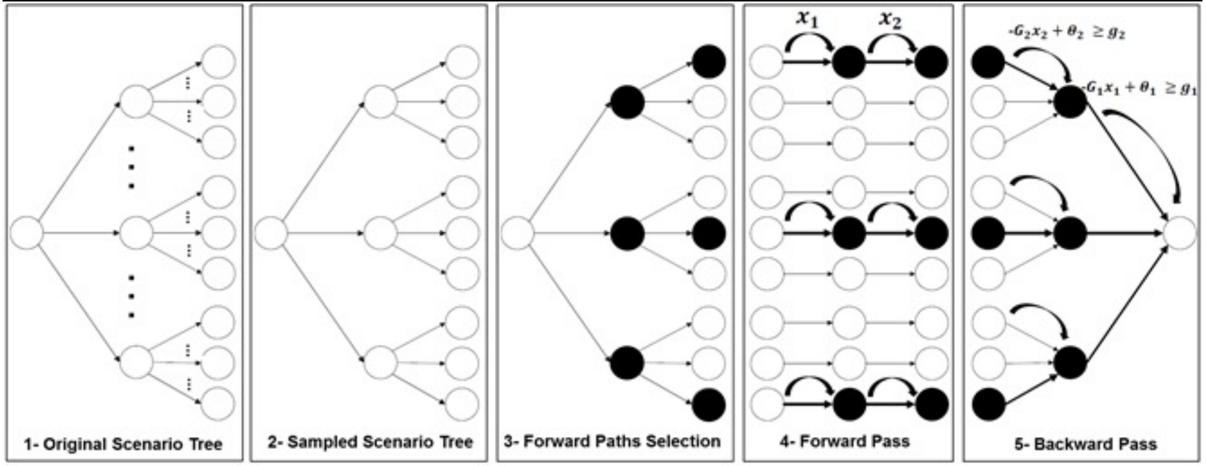
IMPACT

Insight relevant to investors, system users and policymakers

METHODS

Math programming, Stochastic optimization, decision analysis and high-performance computing





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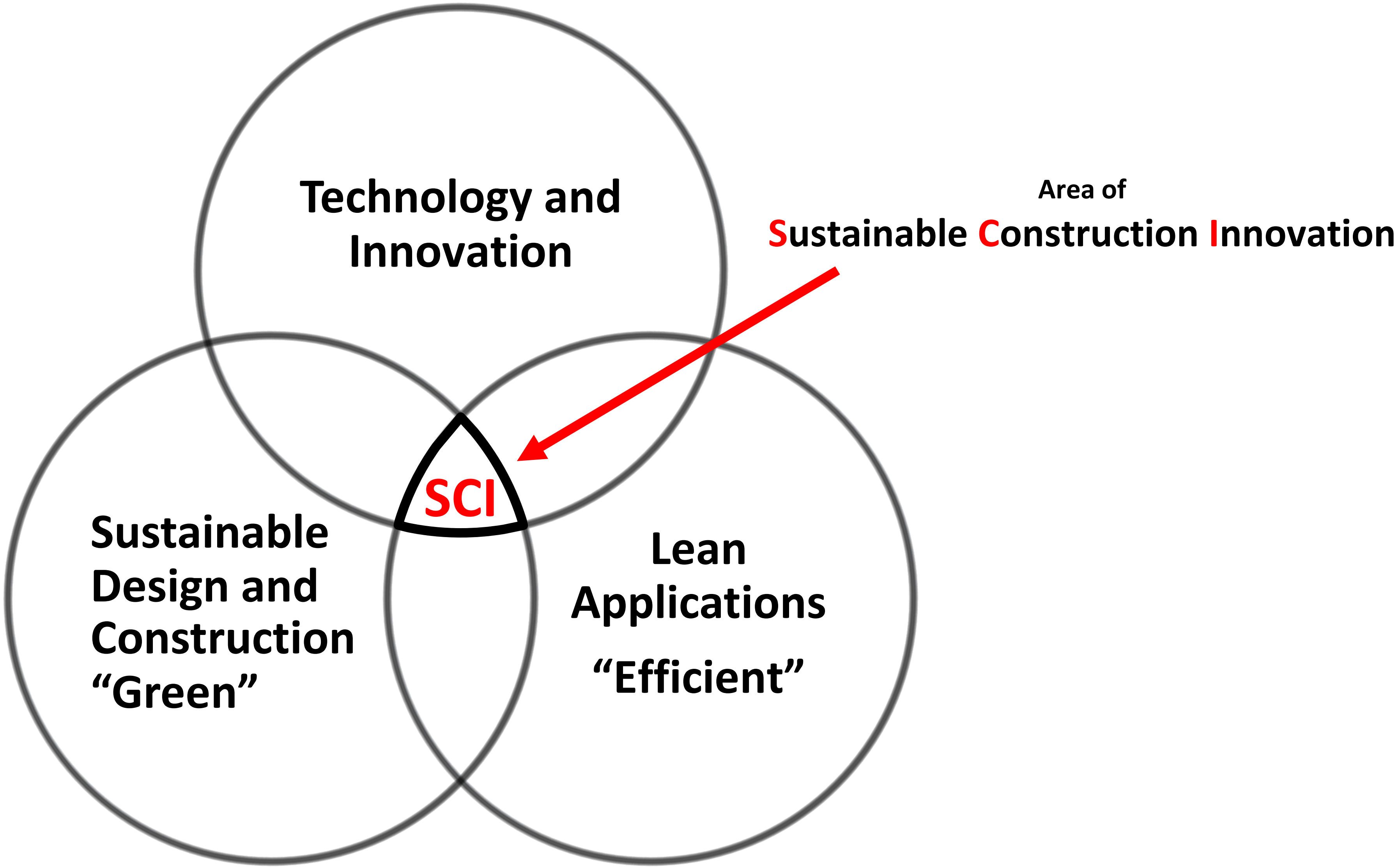
Construction Engineering

Construction Engineering: Research Framework

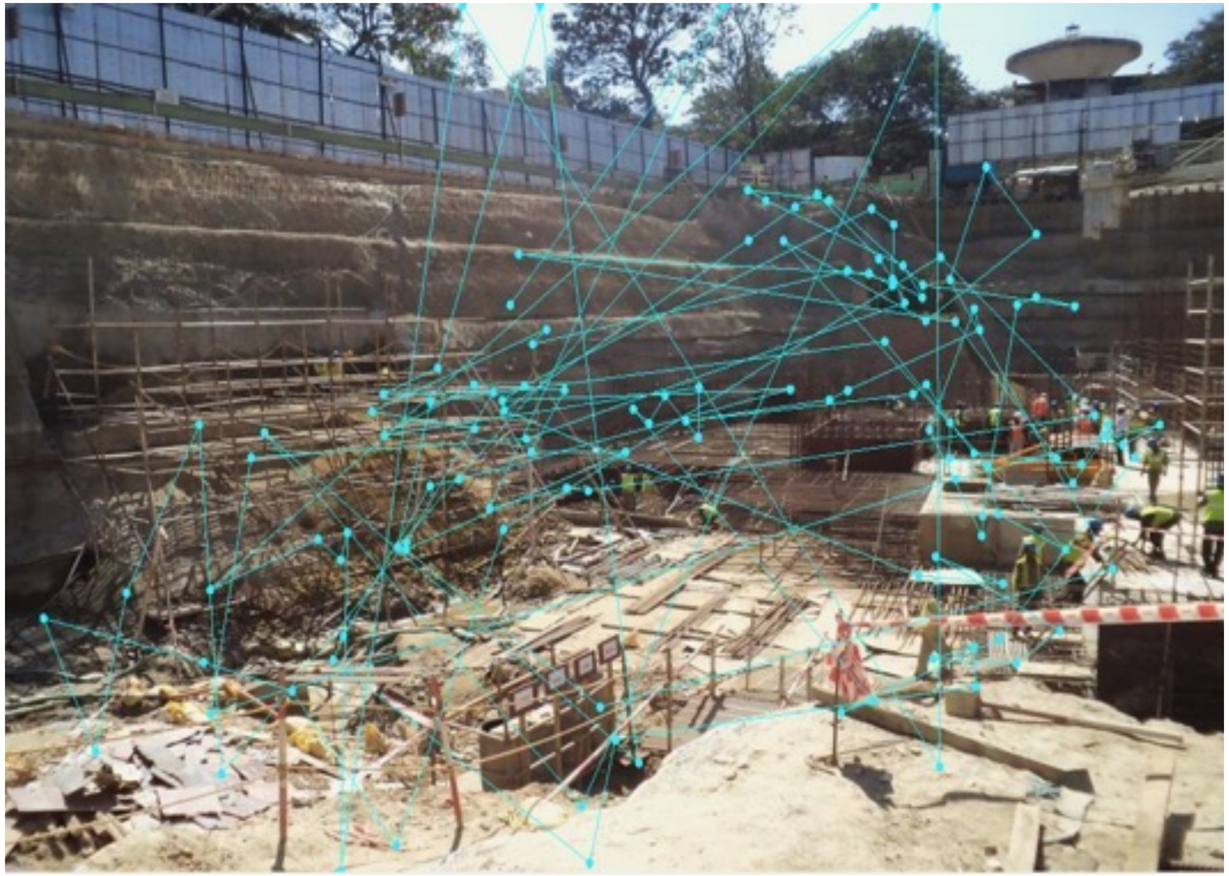


Automate and Personalize Safety Training Interventions

GOAL
Replace one-size-fits all training approach with personalized need-based training solutions

APPROACH
Leverage capabilities of eye-tracking technology, virtual reality, computer vision and machine learning

IMPACT
Improve safety performance and reduce construction injury rates

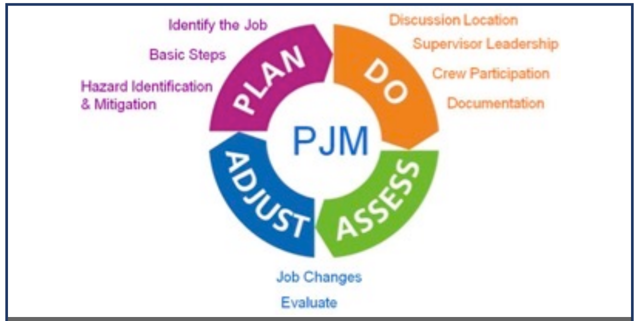


Emerging Strategies for Construction Hazard Recognition

GOAL

Develop and test strategies to improve construction hazard recognition performance

Training Strategy



Planning Strategy

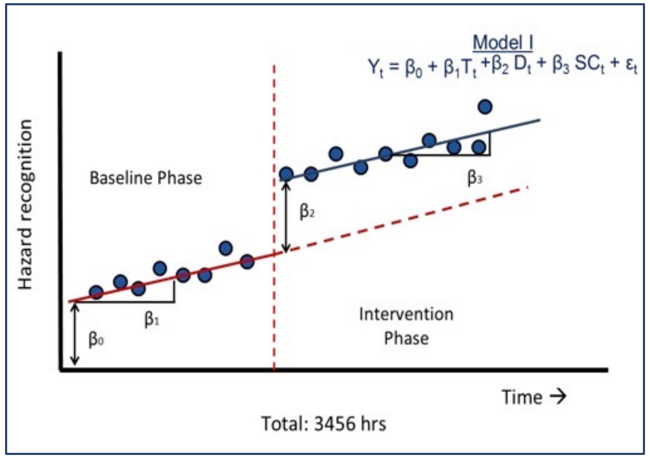
Execution Strategy

APPROACH

Integrate Visual Cues

IMPACT

> 20% hazard recognition improvement after intervention



METHOD

Multiple baseline testing

Preventing falls among bridge workers

GOAL

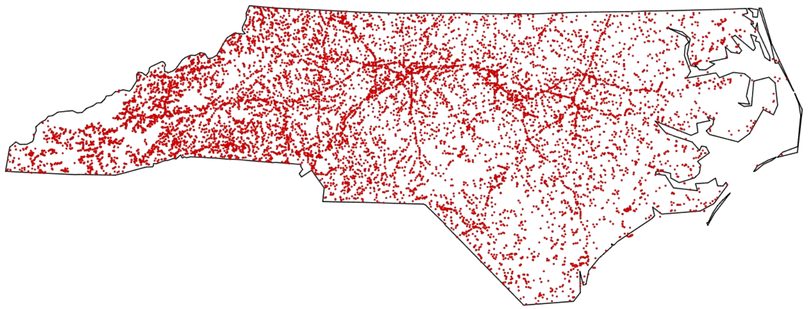
Identify compatible fall protection solutions for bridge construction and maintenance workers

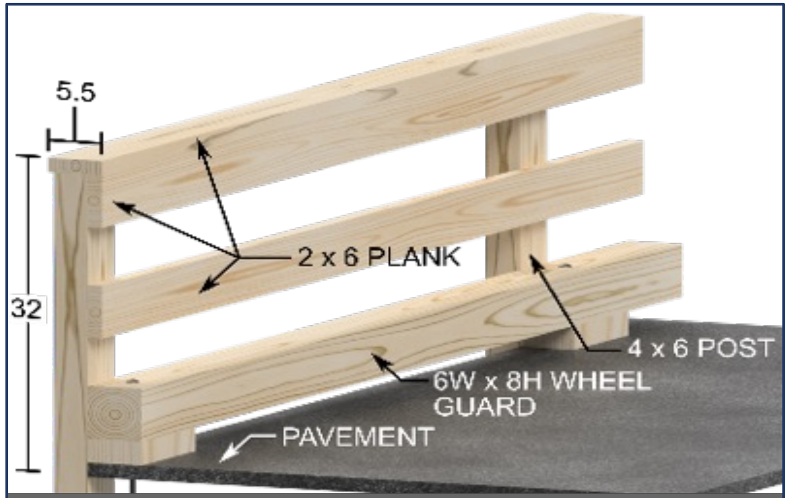
APPROACH

Leverage virtual prototyping to replace the manual trial-and-error based approach

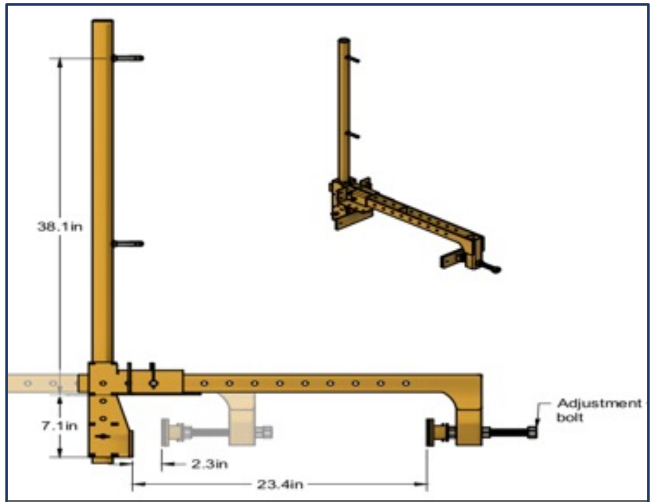
IMPACT

Identify fall protection measures for more than 22,000 guardrails across North Carolina

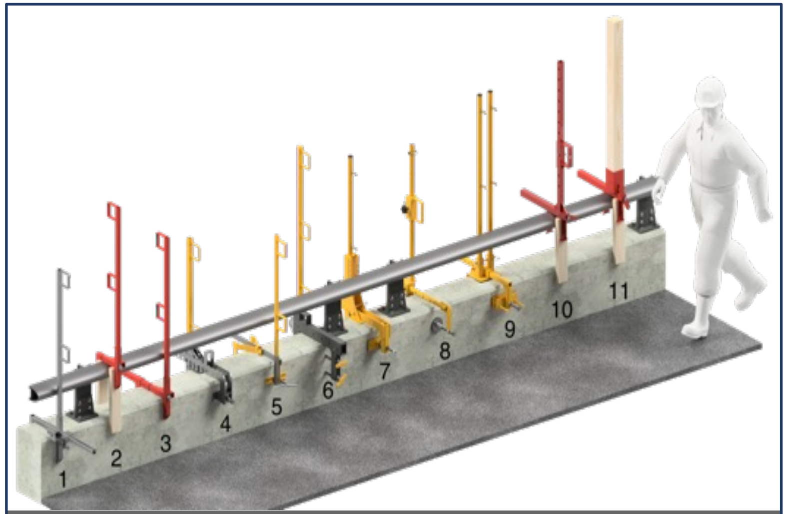




Bridge Guardrail Prototype



Fall protection system prototype



Virtual compatibility testing

Visual Data Analytics and BIM in Construction

GOAL

Automate construction management practices

APPROACH

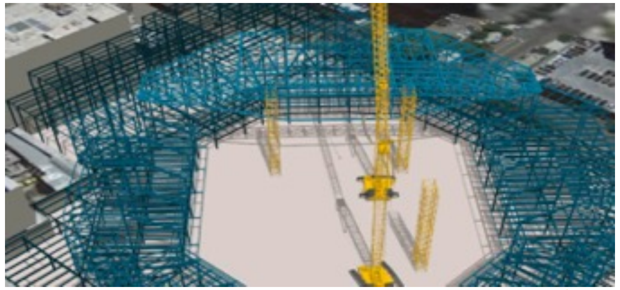
Visual data collection using unmanned aerial and ground vehicles; project controls using visual data — images, videos, and/or 3D point clouds — and BIM.

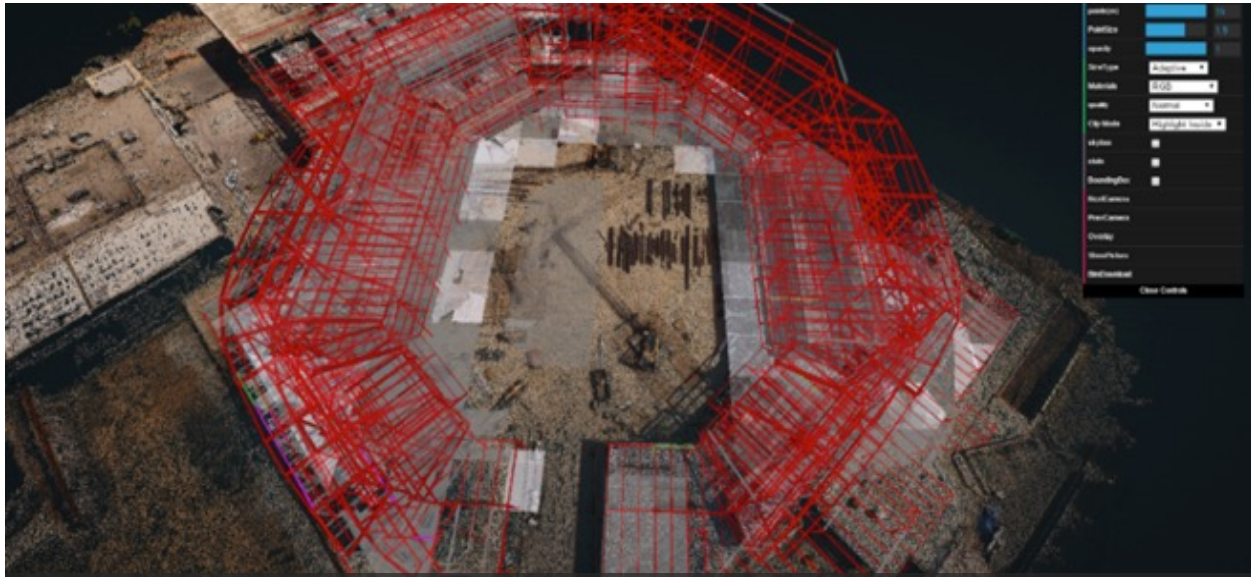
METHOD

Image processing/computer vision/machine-learning algorithm development

IMPACT

Improve project tracking and situation awareness; decentralized decision-making





As-built Documentation
Progress Monitoring

Quality Control

Safety Monitoring
Contractor Hand-Over

Construction Automation and Robotics

GOAL

Automate construction management practices through advances in robotics

APPROACH

Autonomous navigation for construction performance monitoring; multiple robots interacting with humans; automated construction tasks using a robotic arm

METHOD

Custom-built unmanned aerial and ground vehicles for autonomous navigation on construction sites, both indoor and outdoor; robotic arm manipulation; image processing/computer vision/machine-learning algorithm development

IMPACT

Improve project tracking and situation awareness; decentralized decision-making; automated construction sites

Success on Complex Projects

GOAL

Improve cost and schedule performance on large, complex construction projects.

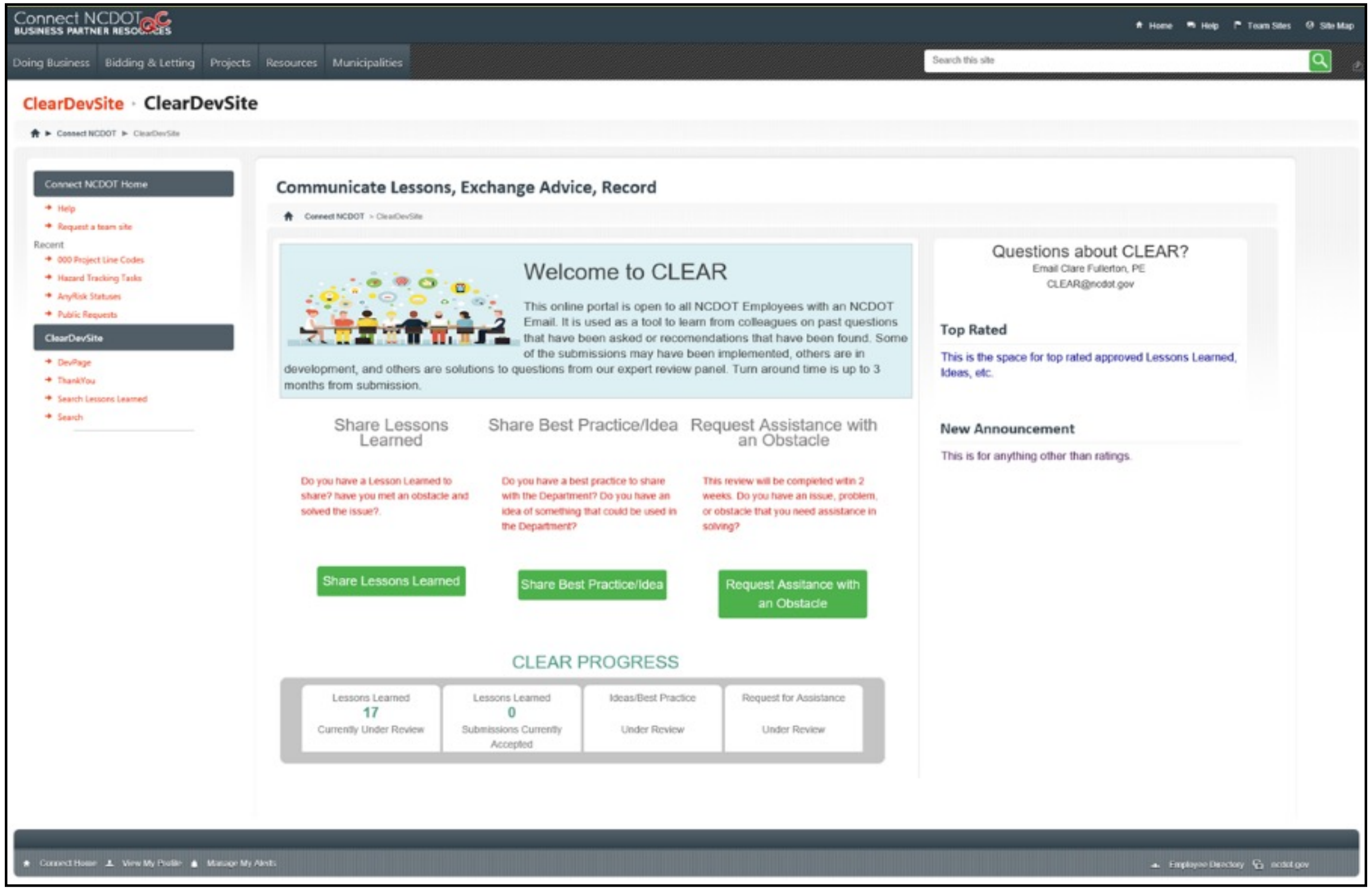
APPROACH

Understand critical success factors for improving project performance in project management, controls, technology readiness, and risk

IMPACT

Enable owners and contractors to improve chances of meeting original cost, schedule, quality, and safety target values.

Risk Management at the Project Level



GOAL

Assess, mitigate, monitor and communicate projects risks to improve project performance

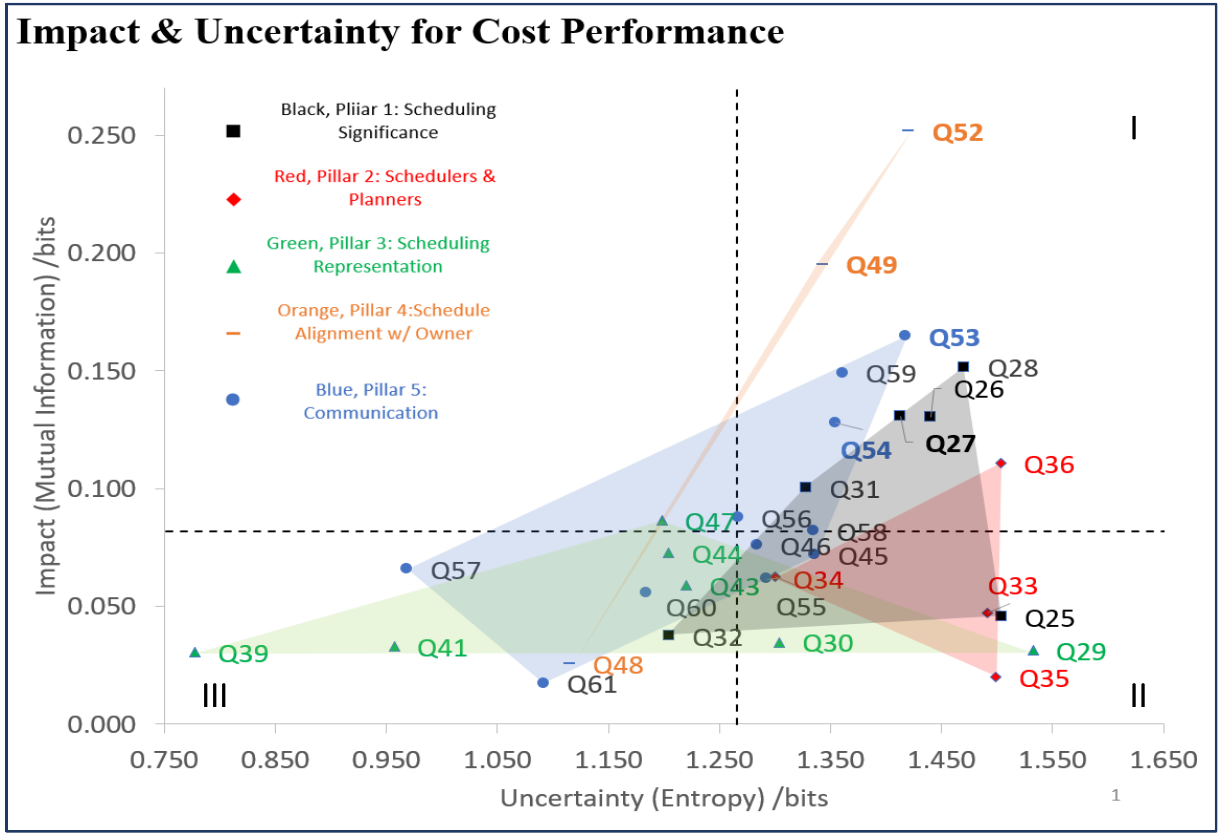
APPROACH

Understand successful risk-management procedures during all phases of a project and determine effective methods for implementation

IMPACT

Reduce negative effects of risk on projects and increase opportunities that lead to better project outcomes

Obstacles and Challenges of Collaborative Scheduling



GOAL

Maximize the benefit of Collaborative Scheduling with limited management time and efforts in construction projects

APPROACH

Use Information Theory analysis approach to identify the uncertainty and impact of various types of collaborative practices

IMPACT

Enable contractors to improve planning reliability given limited planning and management resources

Blockchain Technology for Trust Network in Construction

GOAL

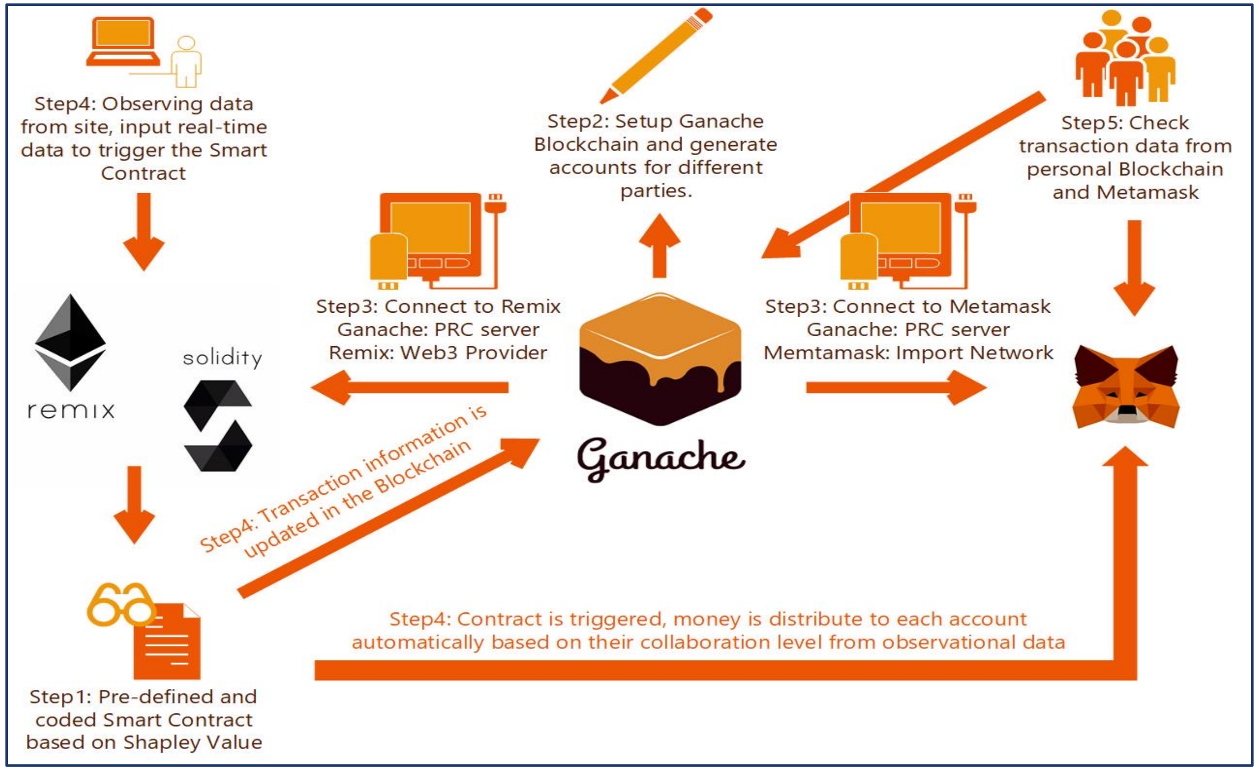
Facilitate, verify, and enforce the negotiation and performance of Smart Contract

APPROACH

Use Shapley Value method to derive fair distribution of benefits and risk in collaboration; implement Blockchain technology to execute the Smart Contract

IMPACT

Enable fair, transparent, and instant Trust management in construction collaboration



Pollutant Emission Reduction

GOAL

Quantify CO_2, NO_x, PM emissions from construction equipment

APPROACH

Model emissions using data from measurements and published data; benchmark model forecasts against measurements

IMPACT

Enable planners to forecast construction equipment emissions for future projects

Advances in Construction of Nuclear Power Plants

GOAL

Improve cost and schedule performance of nuclear construction

METHOD

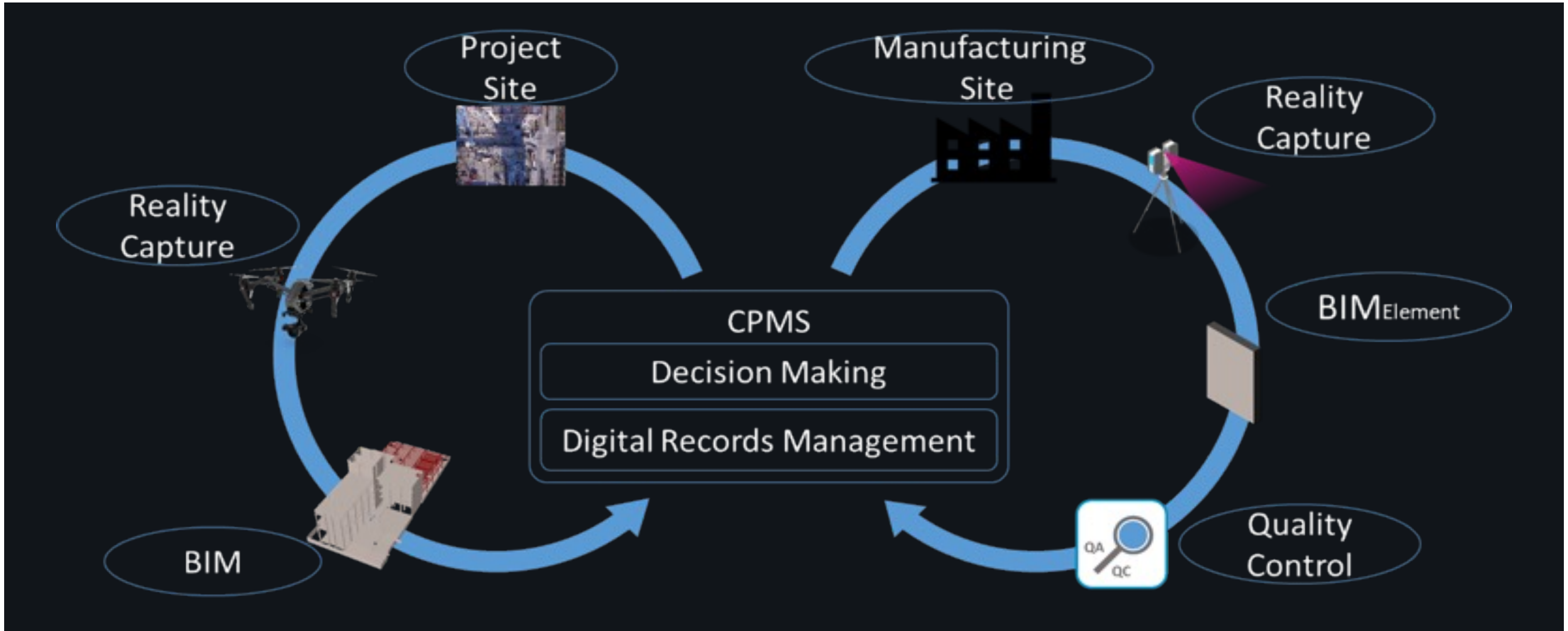
Automate and improve QA/QC process at off-site facilities; virtually connect performances at off-site facilities to the project site

APPROACH

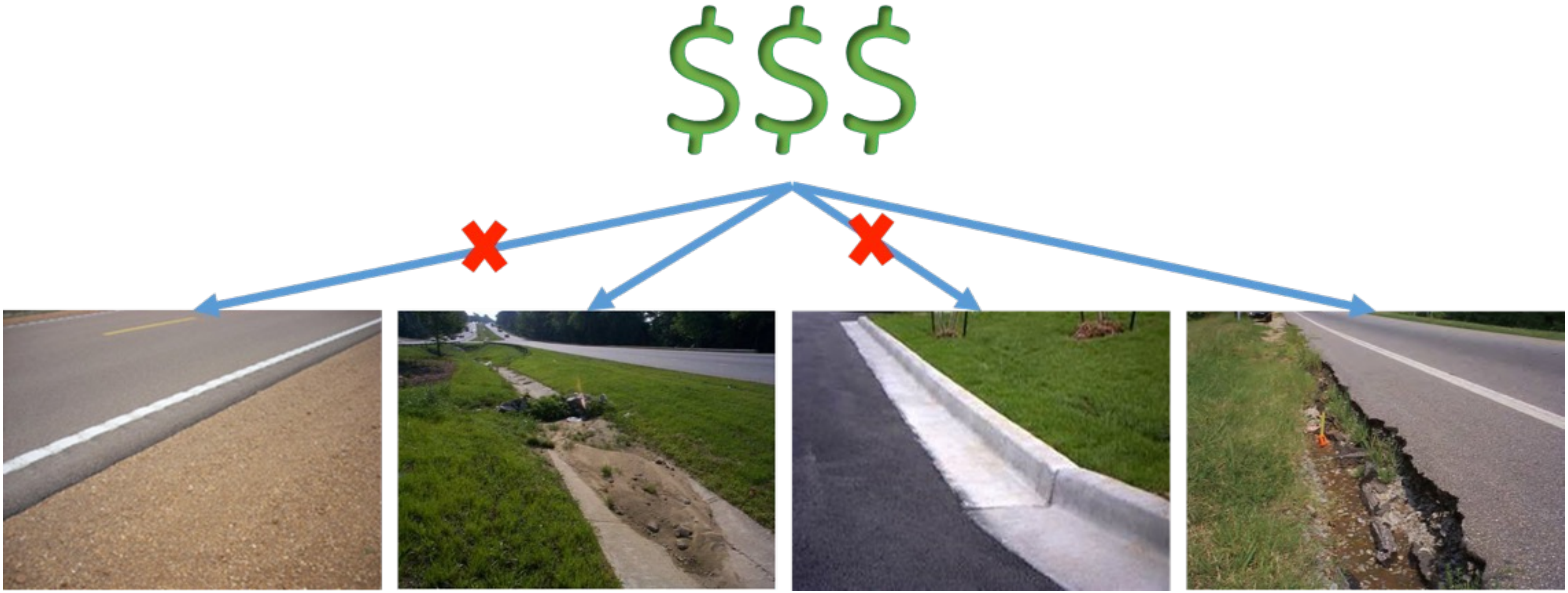
Advances in modular construction, visual data analytics and BIM

IMPACT

Improved project tracking and situation awareness even at off-site facilities; connected sites for decentralized decision making; improved capital cost and return on investment.



Balancing Highway Asset Condition Improvement with Budget Allocation



GOAL

Understand how to determine how much to spend statewide to maximize an asset's condition level of service

APPROACH

Determine a condition deterioration rate for each asset; model the relationship between deterioration and condition vs. budget allocation

IMPACT

Perform maintenance more efficiently, thereby improving condition and maximizing the impact of spending

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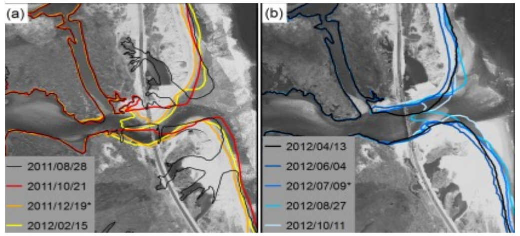
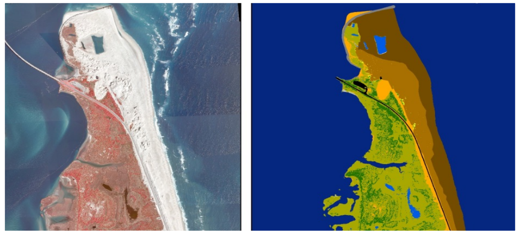
Coastal Engineering

Coastal Engineering

Landform Change
How do coastal landforms respond to natural (waves, sea level rise) and anthropogenic (beach nourishment) processes?



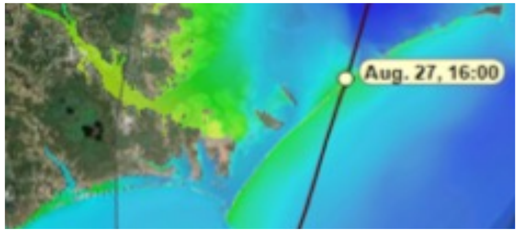
Inlet Formation & Evolution



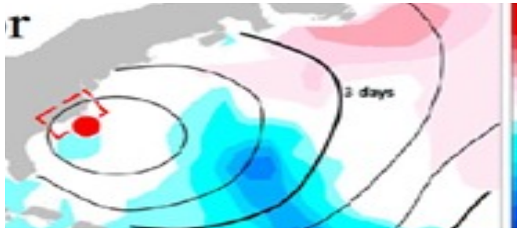
Habitat Mapping & Spatial Modeling

Applied Remote Sensing and Geospatial Modeling
How can we map and communicate impacts of coastal hazards on infrastructure?

Coastal Hazards
What are combined effects of tidal and rip currents, waves, meteotsunami, storm surge and flooding?



Flood Forecasting



Hybrid Statistical-Dynamical Models

Long-term Projections
How can we connect climate variability to aid in decision-making?

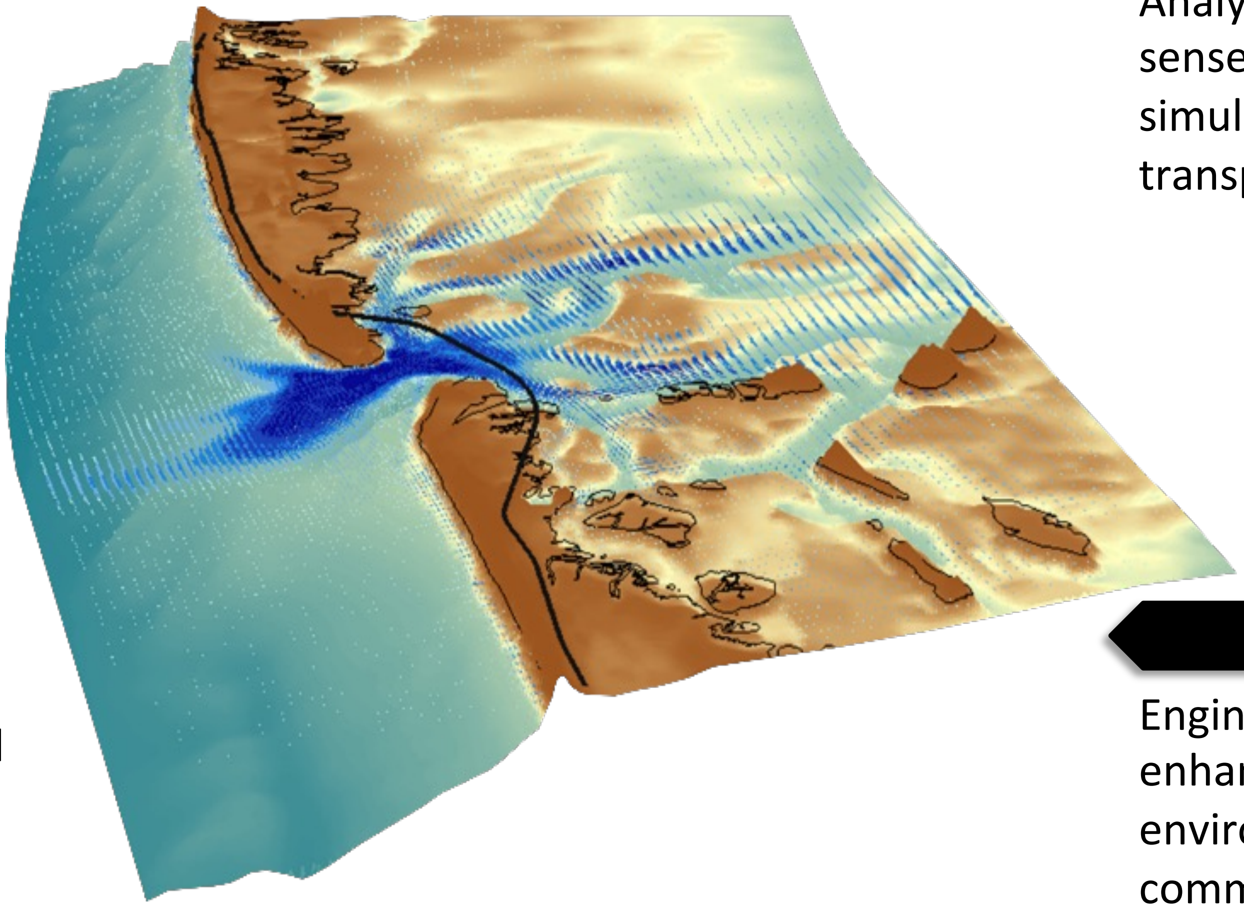
How do natural processes and human decisions change our beaches, inlets and barrier islands?

GOAL

Generate knowledge on coastal processes to inform short-term (storm) and long-term (decadal) planning for vulnerable coastal regions (e.g. deltas, marshes, barrier islands) and their infrastructure

METHODS

Analysis of field and remotely sensed data, model simulations of flow, sediment transport and morphology



APPROACH

Develop and use (1) numerical models to understand, visualize and develop solutions to coastal problems (2) geospatial techniques for multidimensional data

IMPACT

Engineering solutions to enhance resilience of coastal environments and communities

How can we process and use observations of the coastal environment?

GOAL

Assess and communicate the short- and long-term coastal hazards on vulnerable highways, communities and ecosystems

APPROACH

Develop remote sensing algorithms and spatial modeling approaches for assessing and predicting changes in coastal ecosystems

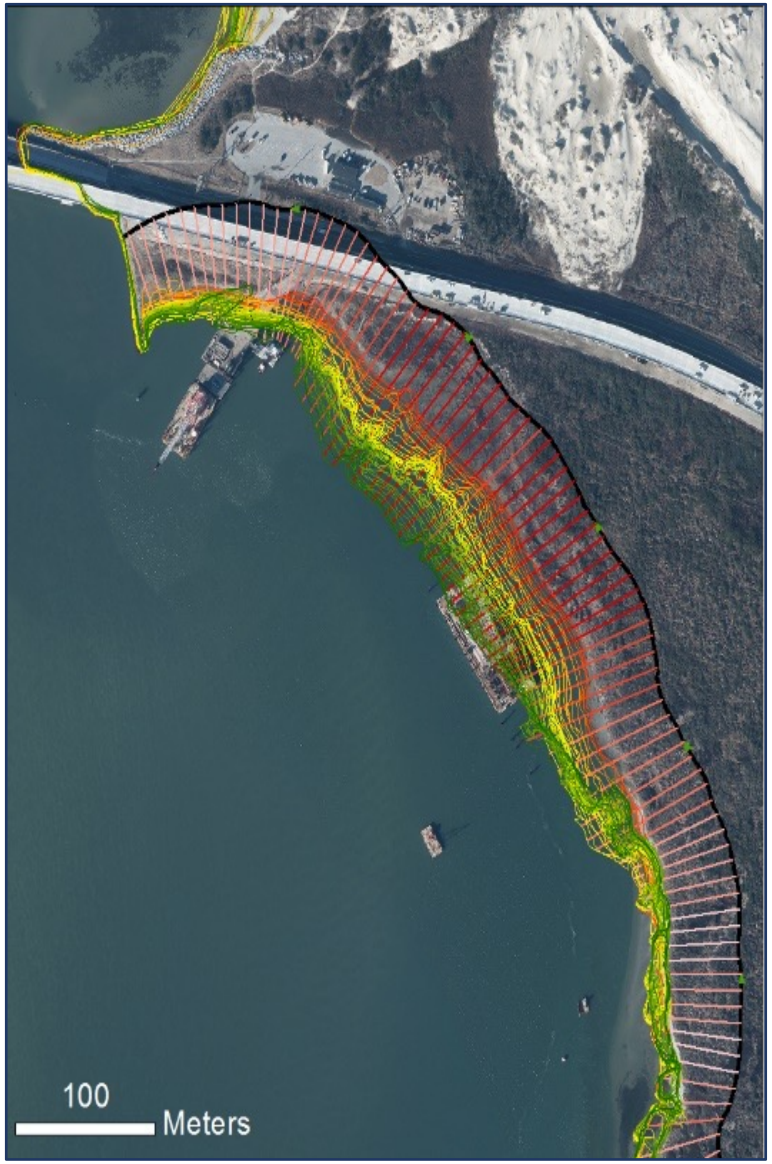
METHOD

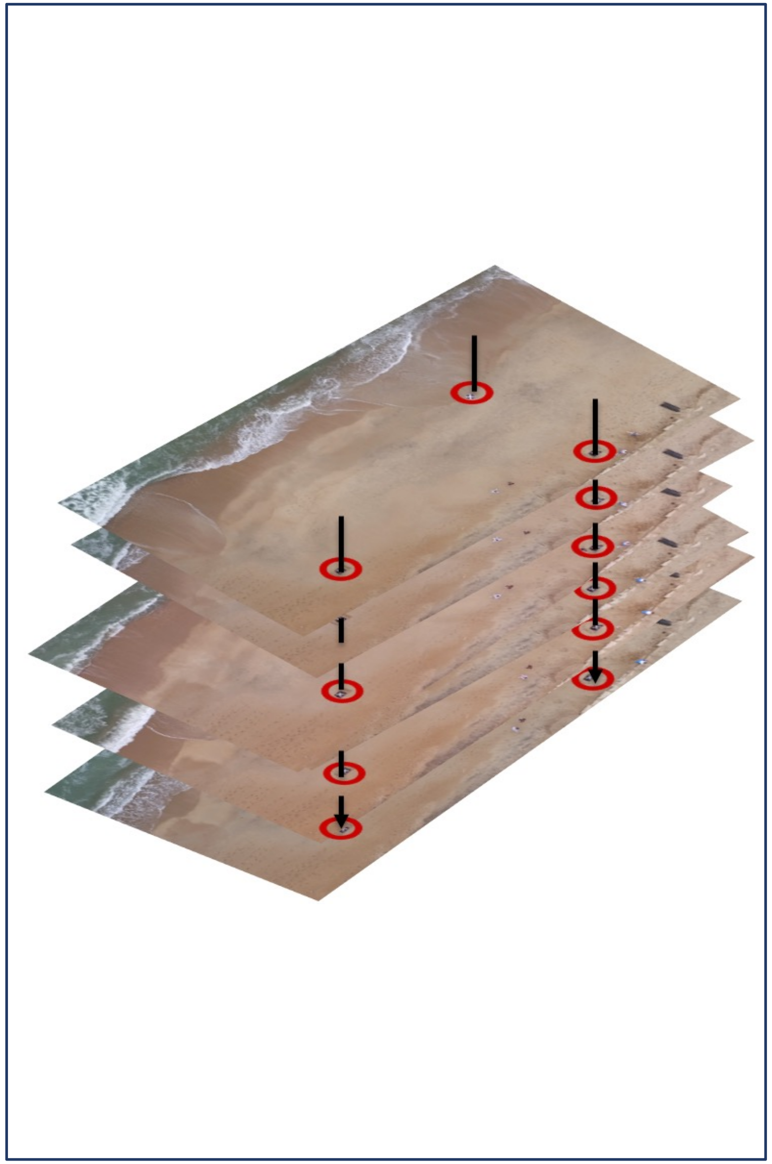
Software design, spatial algorithm development and machine learning

IMPACT

Improved understanding of physical processes to assess and predict:

- Beach, dune, and marsh response, recovery, and resilience
- Storm damage to infrastructure
- Potential adaptation pathways





Can we improve prediction of storm hazards by:
1) using flexible resolution along our coastline?

GOAL

An efficient computational approach for assessing storm surge and coastal flooding at many spatial scales:

- Ocean to shelf to floodplain to infrastructure
- Waves, circulation and coastal erosion

METHOD

Seeking advances in:

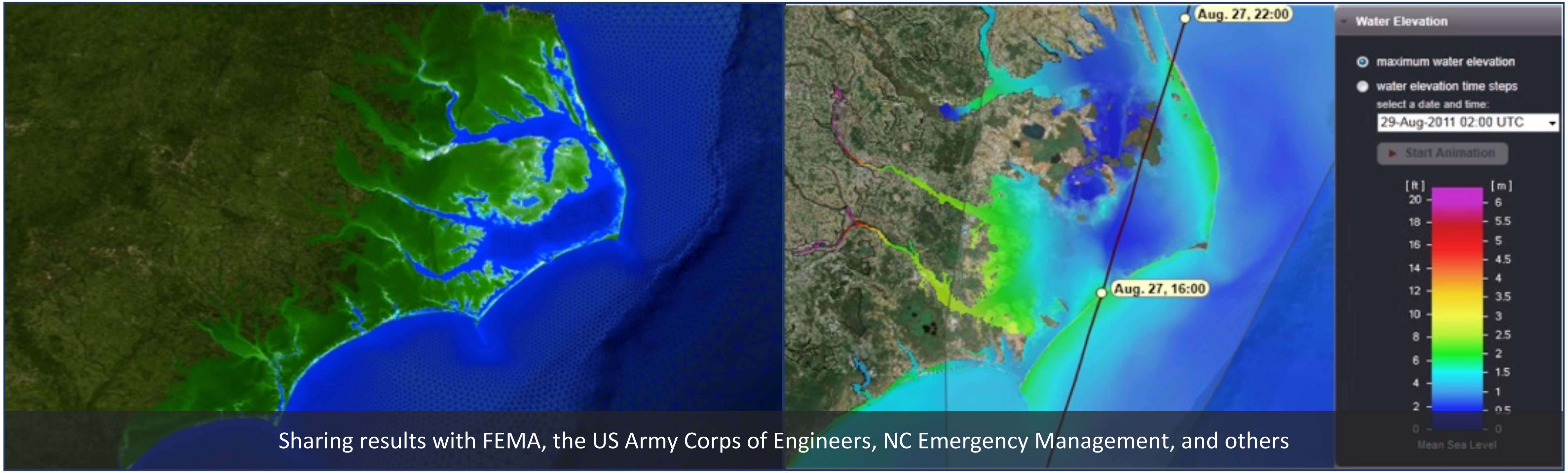
1. Computational efficiency via adaptivity, submesh corrections and improved code
2. Additional physics via coupling to erosion and density-driven circulation

APPROACH

Develop models at high resolution and solve on supercomputers

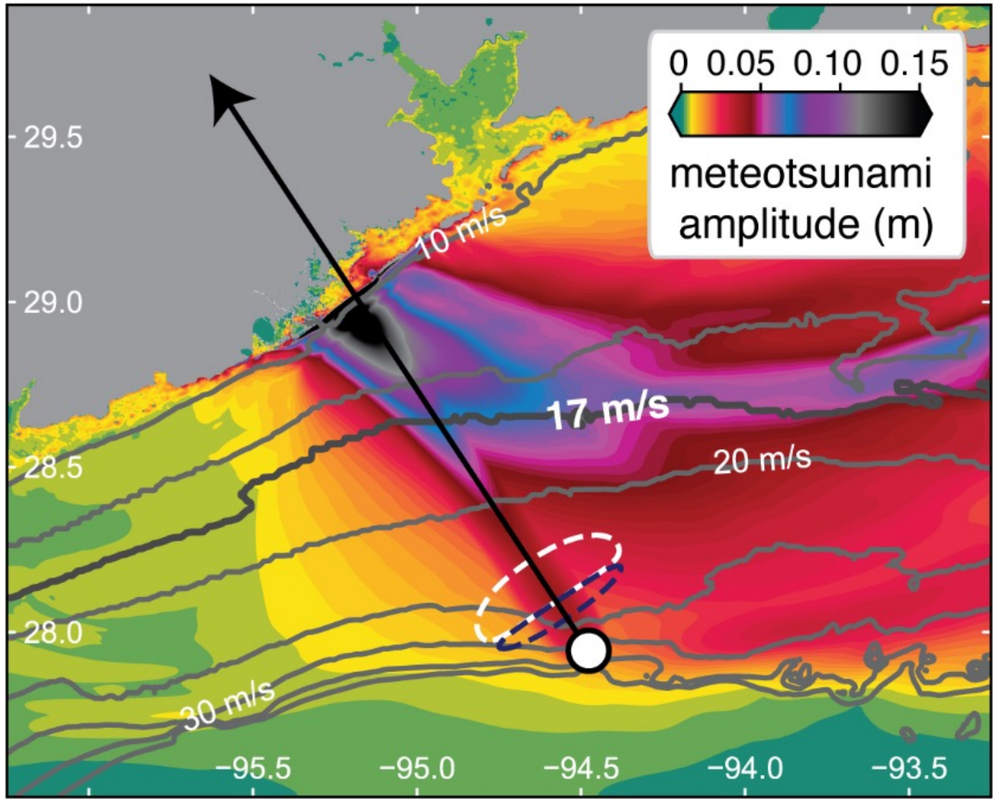
IMPACT

Connect waves and flooding to built infrastructure in real-time and long-term design



Sharing results with FEMA, the US Army Corps of Engineers, NC Emergency Management, and others

Can we improve prediction of storm hazards by:
2) capturing in situ observations of storm impact?



GOAL

Obtain perishable observations of waves, overland flow, beach morphology and loading on infrastructure during storms

IMPACT

1. Identify feedbacks between infrastructure and physical processes during storms
2. Improve understanding of relevant processes needed for predictive modeling of morphological change

METHOD

1. Develop and deploy low-cost instrumentation that can transmit data in real time
2. Integrate field measurements with numerical modeling

Can we project coastal hazards to inform decisions by our coastal managers?

GOAL

Framework for climate variability in wave, surge, and erosion predictions

- Probabilistically account for randomness of storms and large-scale climate oscillations
- Make projections of beach nourishment volume loss, nuisance flooding and surges

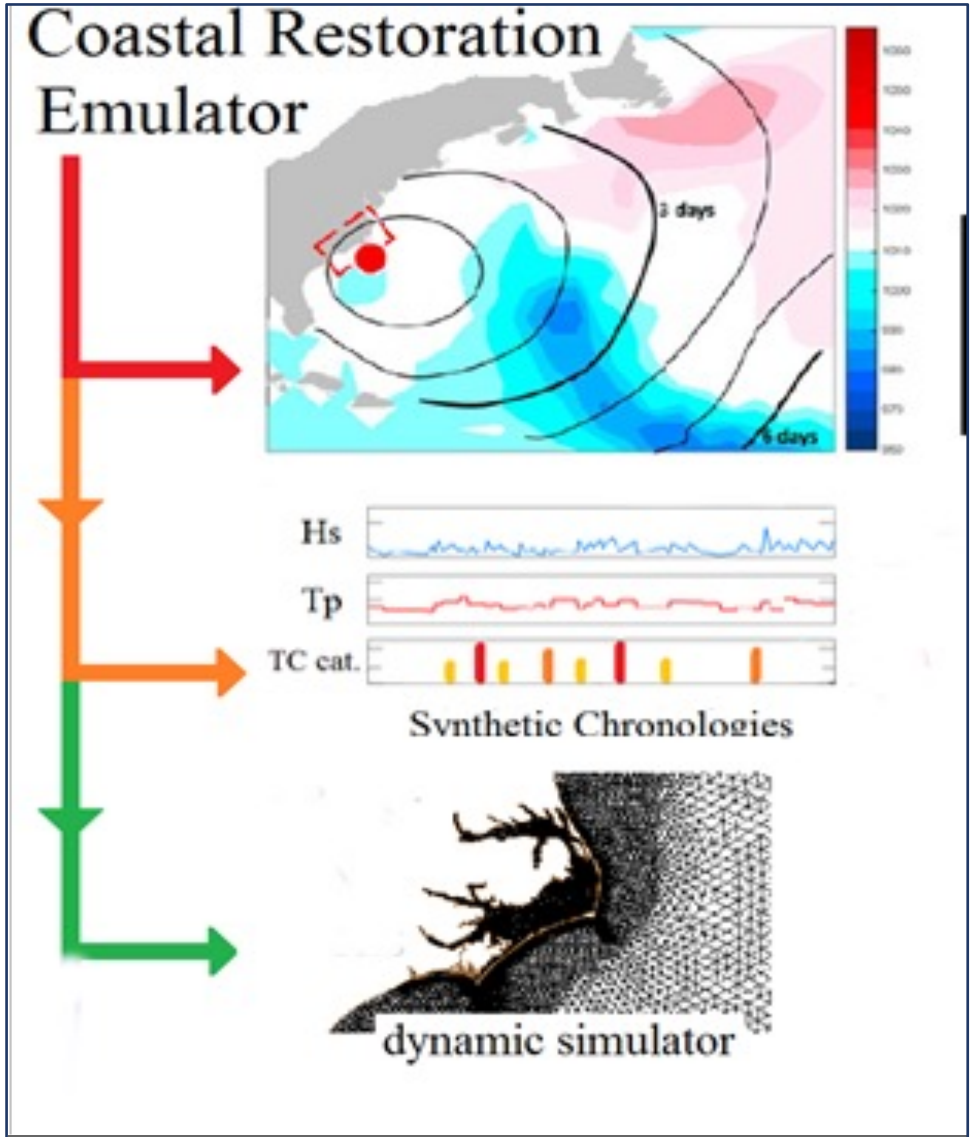
METHOD

Hybrid statistical-dynamical models

- Create synthetic chronologies of coastal storms and hurricanes via weather regimes
- Surrogate emulators of flooding and erosion
- Validate with field observations of morphology change and storm impacts
- Inputs to decadal community decision models

IMPACT

Inform local management decisions for coastal defense policies



Sharing results with Town of Nags Head, US Geological Survey, US Army Corps of Eng., and others

Field Work and Lab Facilities

METHOD

Utilize state-of-the-art technology to conduct experiments

- Real-Time Kinematic GPS
- UAV imaging and video
- LiDAR
- Current meters
- Pressure sensors
- Drifters
- Sediment grain sizer
- Sediment flume

IMPACT

Improved understanding of:

- Wave runup
- Marsh erosion
- Response of living shorelines
- Interactions between flow, vegetation and structures

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Water Resources and Environmental Engineering

Engineering for Sustainable Civilization

- **Air**
  - On-road and nonroad vehicle emissions
  - Human exposure and risk management
  - Atmospheric aerosols
  - Energy and environmental health in developing countries
- **Water**
  - Watershed development and flow alteration
  - Water supply and quality
  - Contaminant removal
  - Groundwater remediation
  - Water and wastewater treatment
  - Water Sanitation and Hygiene (WaSH) in developing countries
- **Land/Solids**
  - Biological and chemical processes in landfills, energy recovery
  - Identification of waste management alternatives
- **Energy Systems**
  - Emissions
  - Transportation fuels and operations
  - Building energy efficiency
  - Regional energy systems optimization
- **Climate**
  - Greenhouse gas emissions
  - Climate change and watershed flow impacts

Implications and Impact

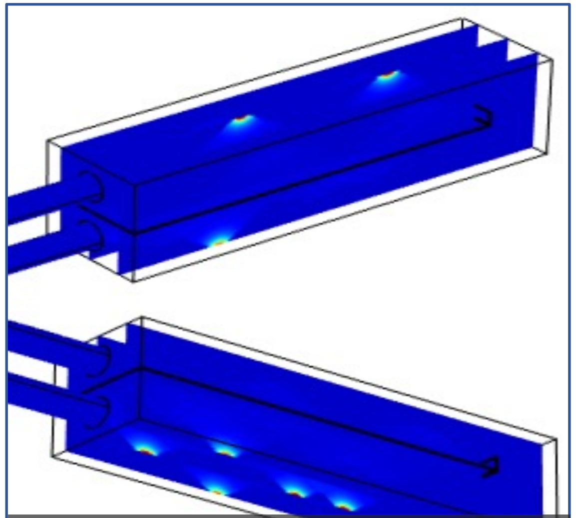
- Quantify contaminant releases and concentrations in the environment
- Process engineering for contaminant treatment and control
- Water, solid waste and air quality management
- Public and occupational health and safety
- Reduce exposure to toxic pollutants
- Emergency response (e.g., floods)
- Resource use and allocation
- Land use and environment
- Energy choices
- Water supply

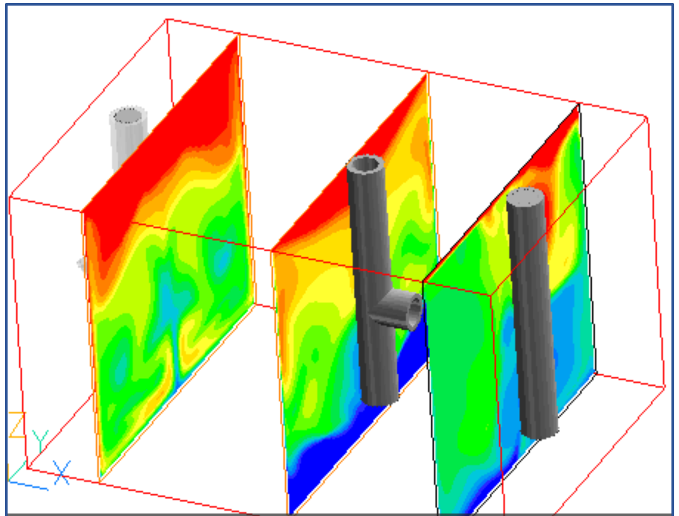
Environmental Engineering and Science

- **Physical Processes**
  - Transport and fate of contaminants
  - Process technology mass balance
  - Adsorption processes for water treatment
- **Chemical Processes**
  - Oxidation processes for water treatment
  - Contaminant sequestration
  - Air pollutant formation and control
- **Biological Processes**
  - Mechanistic understanding of wastewater treatment and landfills
  - Groundwater remediation
  - Detection and quantification of microbes
- **Decision Science**
  - Risk Assessment
  - Support and Analysis
  - Data Assimilation, Algorithm Development
  - Optimization, operations research
  - Modeling and simulation
  - Integrated system assessment

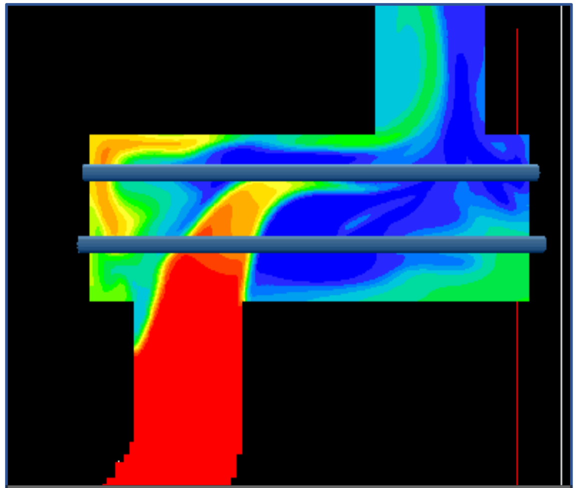
Water and Wastewater Treatment



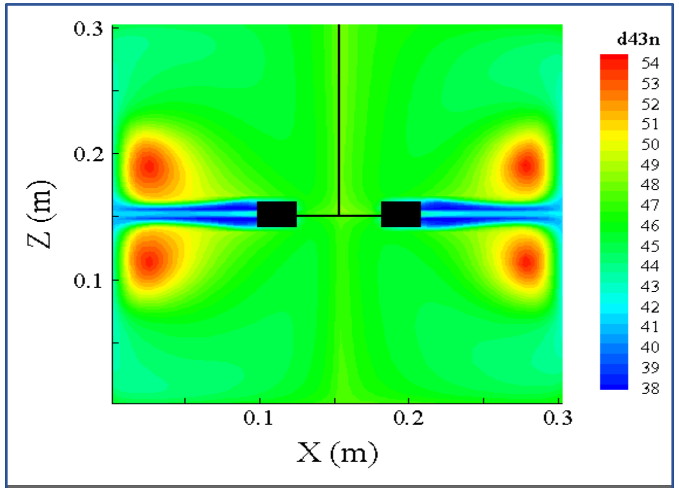
Microalgae Photobioreactor



Oil removal



UV disinfection



Impeller mixing

GOAL

Optimize the efficiency of water and wastewater treatment processes

APPROACH

Use validated numerical transport models coupled with global search optimization algorithms

METHOD

CFD, Optimization and laboratory analytical measurements

IMPACT

Efficient treatment systems that enhance pollutant removal and uses less resources

Environmental Biotechnology

GOAL

Understand fundamental microbiological processes in waste treatment, develop waste-to-energy technologies, design appropriate sanitation for developing countries, quantify risk of water reuse

APPROACH

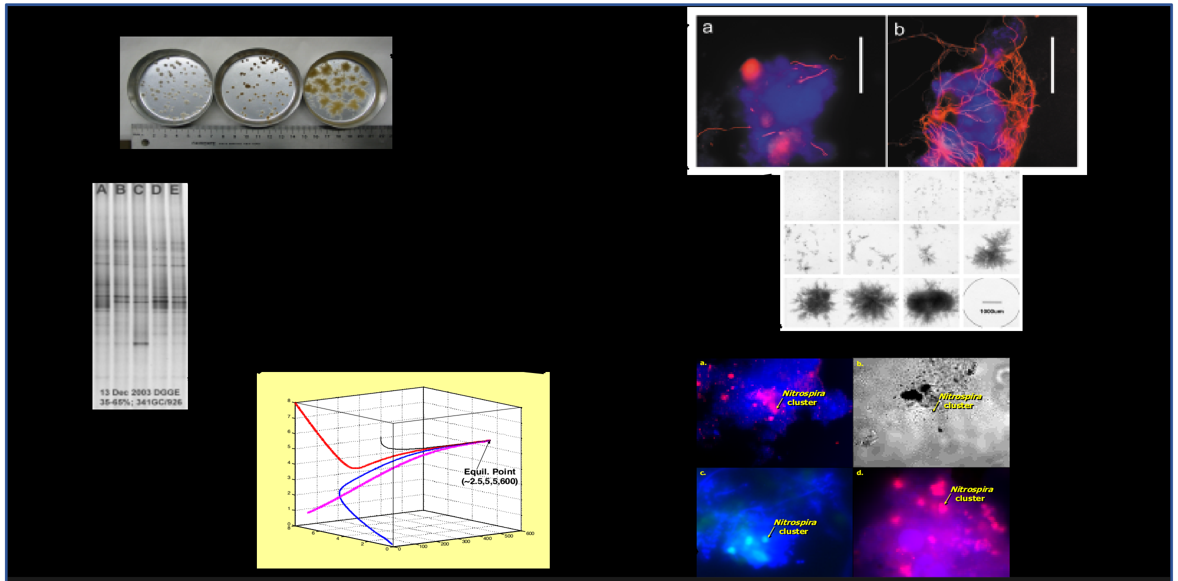
Analysis of microbial function in lab- and full-scale systems, application of ecological theory to bioreactors, detection and quantification of pathogens in water reuse systems, field testing of sanitation technologies

METHOD

Molecular (DNA/RNA) techniques, modeling, reactor studies and field testing

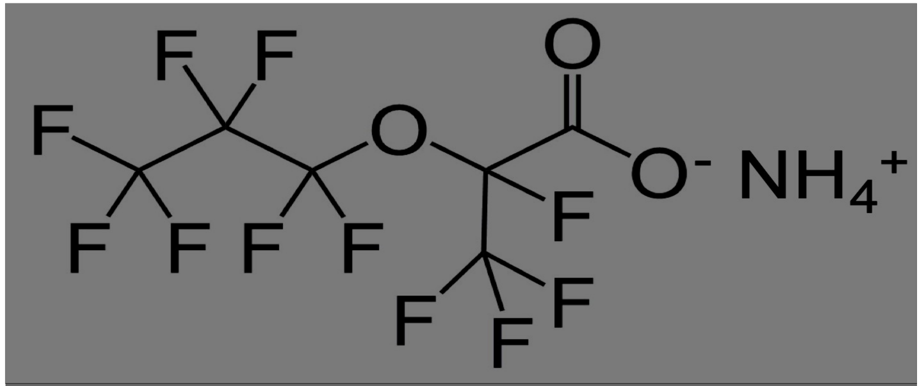
IMPACT

Improved bioreactor designs for nutrient removal, methane production, and low-cost systems; acceptable water reuse; solving the sanitation challenge for underserved areas

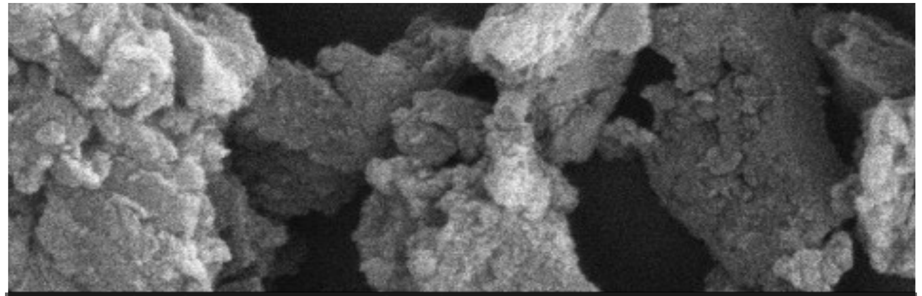


Opening the bioreactor “black box”

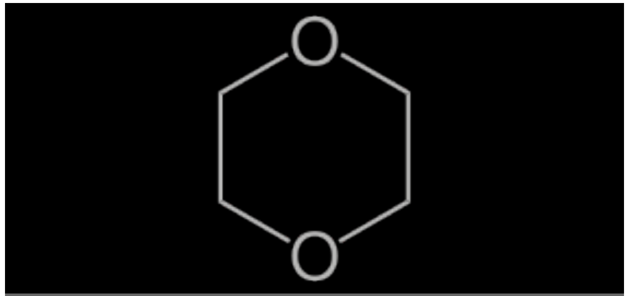
Drinking Water Treatment



GenX

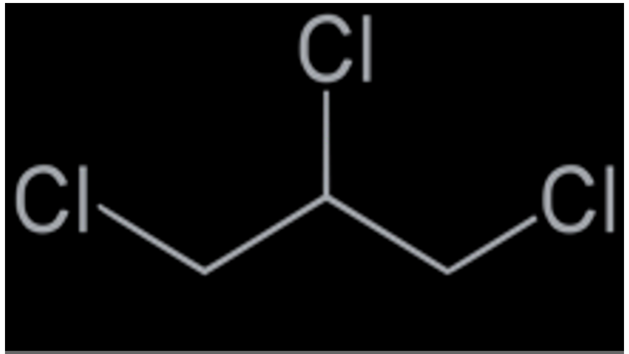


Superfine Powdered Activated Carbon



1,4-dioxane

LC-QToF-MS



1,2,3-trichloropropane

GOAL

Improve drinking water safety

APPROACH

- Develop analytical methods for unregulated organic contaminants
- Characterize the effects of wastewater contaminants on the quality of drinking water sources (e.g. Cape Fear River)
- Identify effective management and treatment approaches for controlling organic contaminant levels in drinking water

IMPACT

Inform policy decisions and treatment process selection, reduce human exposure

Renewable Electricity Generation

GOAL

Recover energy from wastewater and salinity gradients

APPROACH

Develop effective (bio)electrochemical technologies to:

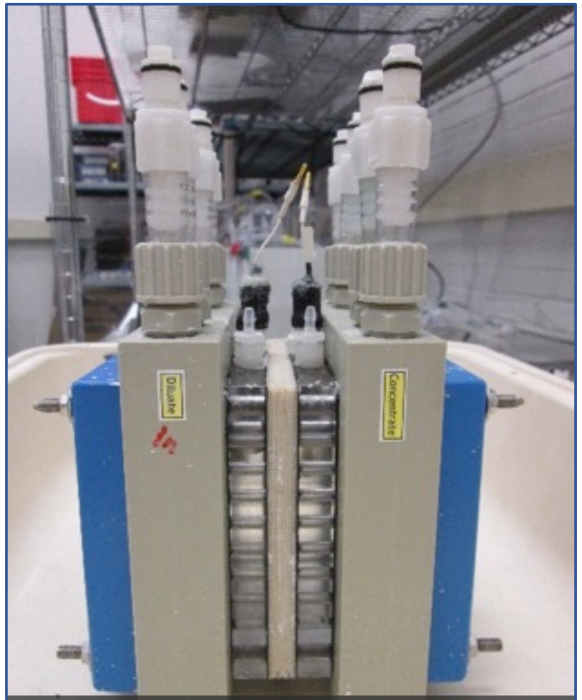
- Simultaneously recover energy and treat wastewater, and
- Generate electricity from the controlled mixing of low- and high-salt waters

METHOD

Electrochemical techniques, micro/molecular biology and reactor studies

IMPACT

Transform wastewater utilities into net-positive energy facilities and generate grid-scale electricity from coastal and inland salinity gradients



Reverse Electrodialysis Cell


Pilot-Scale Microbial Electrolysis Cell

Pathogen Detection and Transmission Pathways & Creating Effective WaSH Indicators

GOAL

Identifying fecal contamination transmission pathways

APPROACH

- Interviews and observations on local behaviors
- Field and laboratory water quality sampling

Domestic animals are often an overlooked source of fecal contamination in household settings

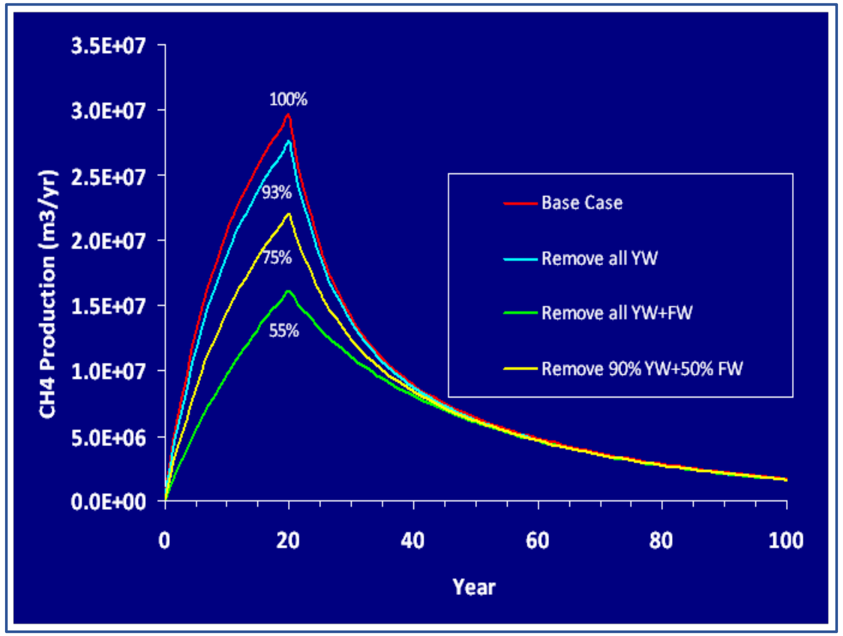
METHODS

Structured surveys, randomized controlled trials, molecular and microbiology detection and enumeration techniques

IMPACT

Recommendations for water-quality sampling and reductions to human exposure to fecal pathogens

Solid Waste Engineering



GOAL

Understand biological and chemical processes in landfills as they affect energy potential, waste decomposition and heat accumulation

APPROACH

Laboratory simulations integrated with field observation and mathematical modeling

IMPACT

Improved predictive models for methane generation, use in national emissions inventories, development of landfill waste acceptance strategies and manage elevated temperature landfills

Water Treatment in Resource Constrained Settings

GOAL

Create water treatment technologies for resource constrained settings

APPROACH

- Laboratory and field methods for detecting chemical contaminants from pesticides, industrial effluents and pharmaceutical residues
- Establish effective methods for creating and using biochar adsorbents for chemical toxin removal

METHODS

Mass spectrometry and pyrolysis

IMPACT

Increased access to safe and healthy drinking water

Improving Sanitation Services

GOAL

Develop cost-effective technologies along the sanitation chain (user interface, collection, treatment, and reuse of fecal sludge)

APPROACH

Experimental and modeling studies, field testing in Asia and Africa

METHOD

CAD, CFD Modeling, rapid prototyping, time-motion studies and field testing

IMPACT

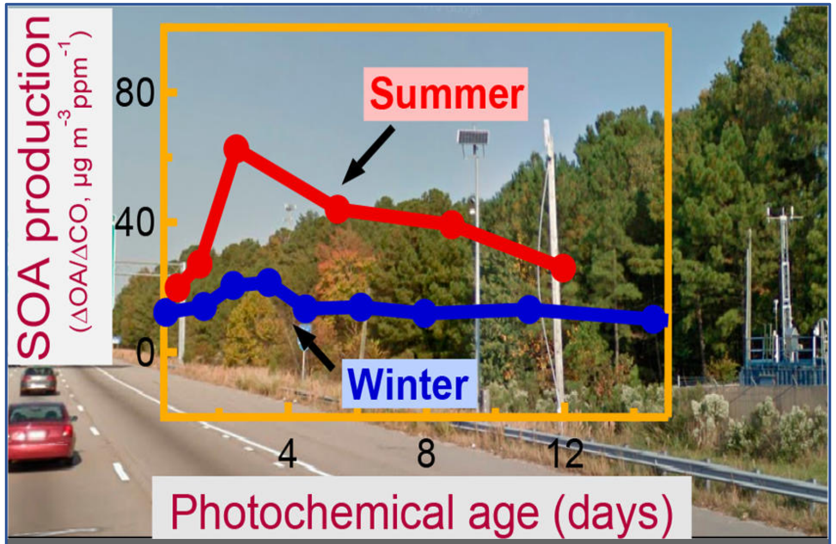
Reductions in fecal contamination; providing dignity to sanitation workers; scaling up solutions

Manual (top) vs mechanized emptying (bottom)

Understanding Atmospheric Aerosols

Low-cost sensors in rural Malawi

Solid fuel cooking in Rwanda



I-40 Study

GOAL

Reduce air emissions' health and climate impacts at home and abroad, including from indoor solid fuel use in developing countries

APPROACH

Develop data, tools and insights to improve our understanding of sources and atmospheric transformations of emissions

IMPACT

Aid in optimal selection of technologies and policies to protect health and address climate change

Transportation and Air Emissions

GOAL

Identify effective ways to reduce real-world energy use and emissions of on-road and nonroad vehicles

APPROACH

Measure vehicle activity, energy use, and emissions with portable emission measurement systems (PEMS); develop high-resolution vehicle energy use and emission models

IMPACT

Improve vehicle operations, traffic management, traffic control and infrastructure design; evaluate fuels and technologies

Measurement and Modeling of Human Exposure

GOAL

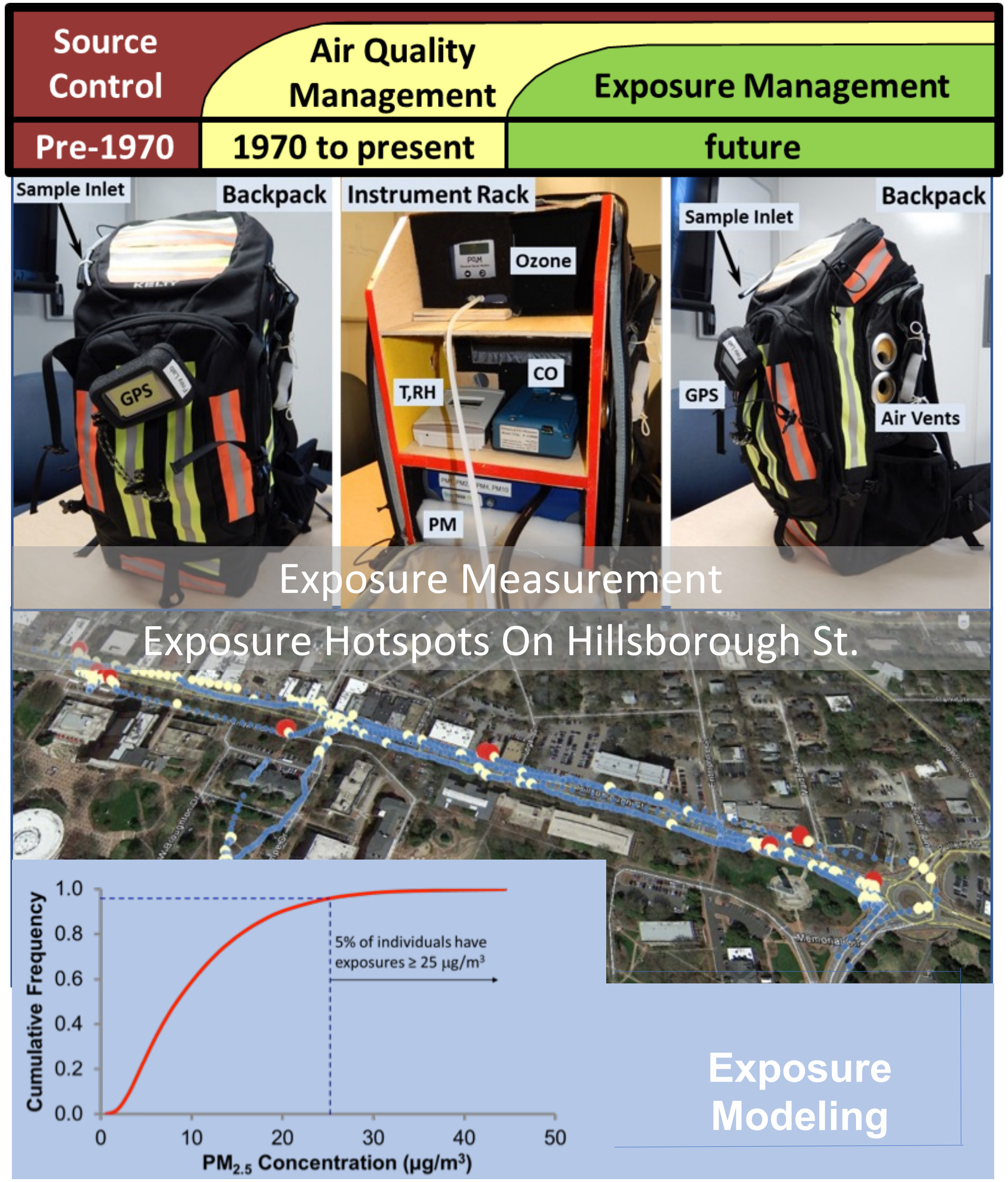
Quantify human exposure to air pollution and identify ways to reduce exposures

APPROACH

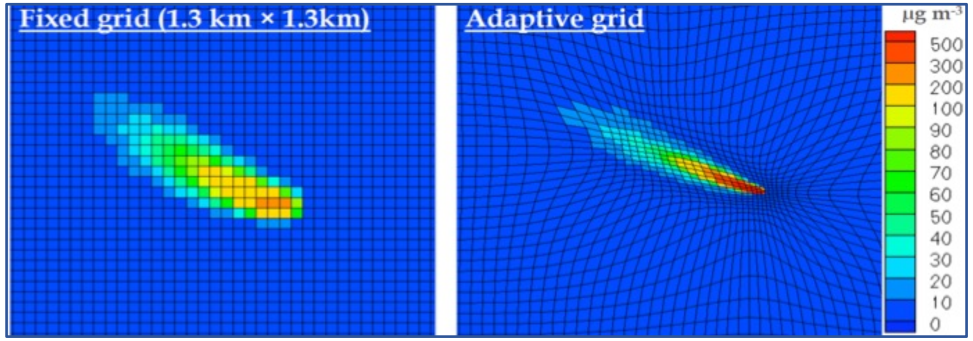
Measure air pollution exposure concentrations using portable instruments; model individual and population exposures

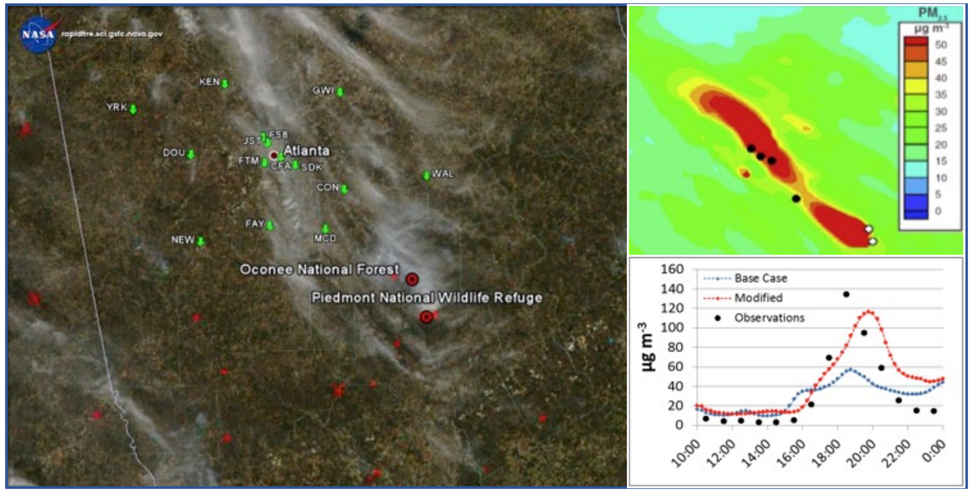
IMPACT

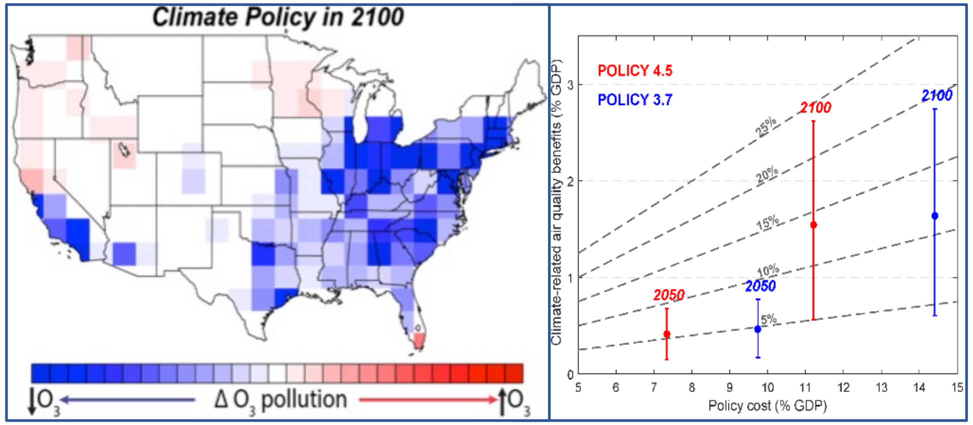
Prevent high exposures by modifying human activity, emission sources or enclosed environments (e.g., home, car)



Modeling Air Quality Under Global Change







GOAL

Identify and evaluate strategies to reduce air pollution and its impacts though computational modeling

APPROACH

Develop multiscale frameworks to simulate air quality and its interactions with climate, health, energy resources and other environmental systems

IMPACT

Improve air quality and earth systems models, guide environmental regulatory decision-making and policy

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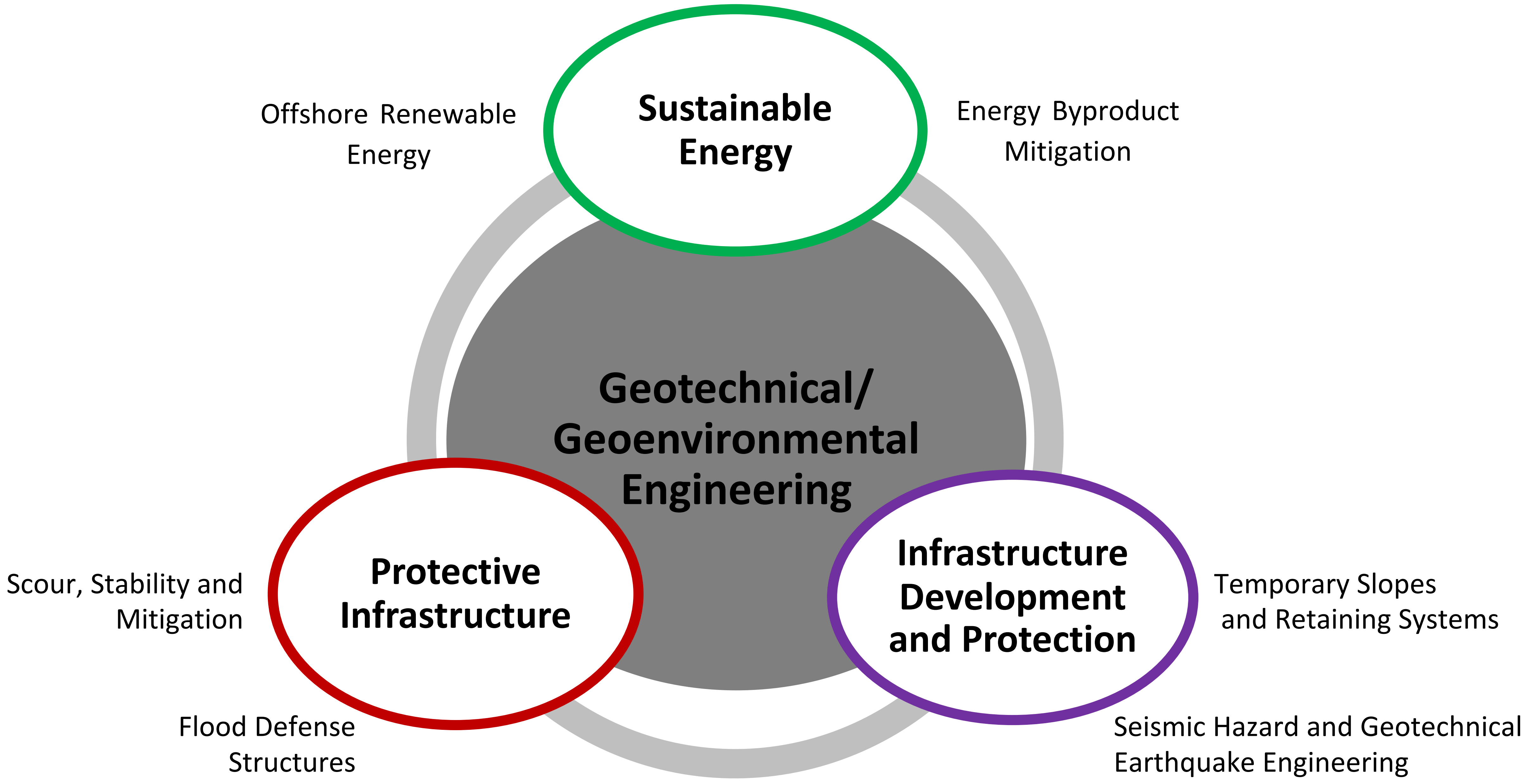
Geotechnical / Geoenvironmental Engineering

Geotechnical/Geoenvironmental Engineering



Offshore Renewable Ocean Energy

GOAL

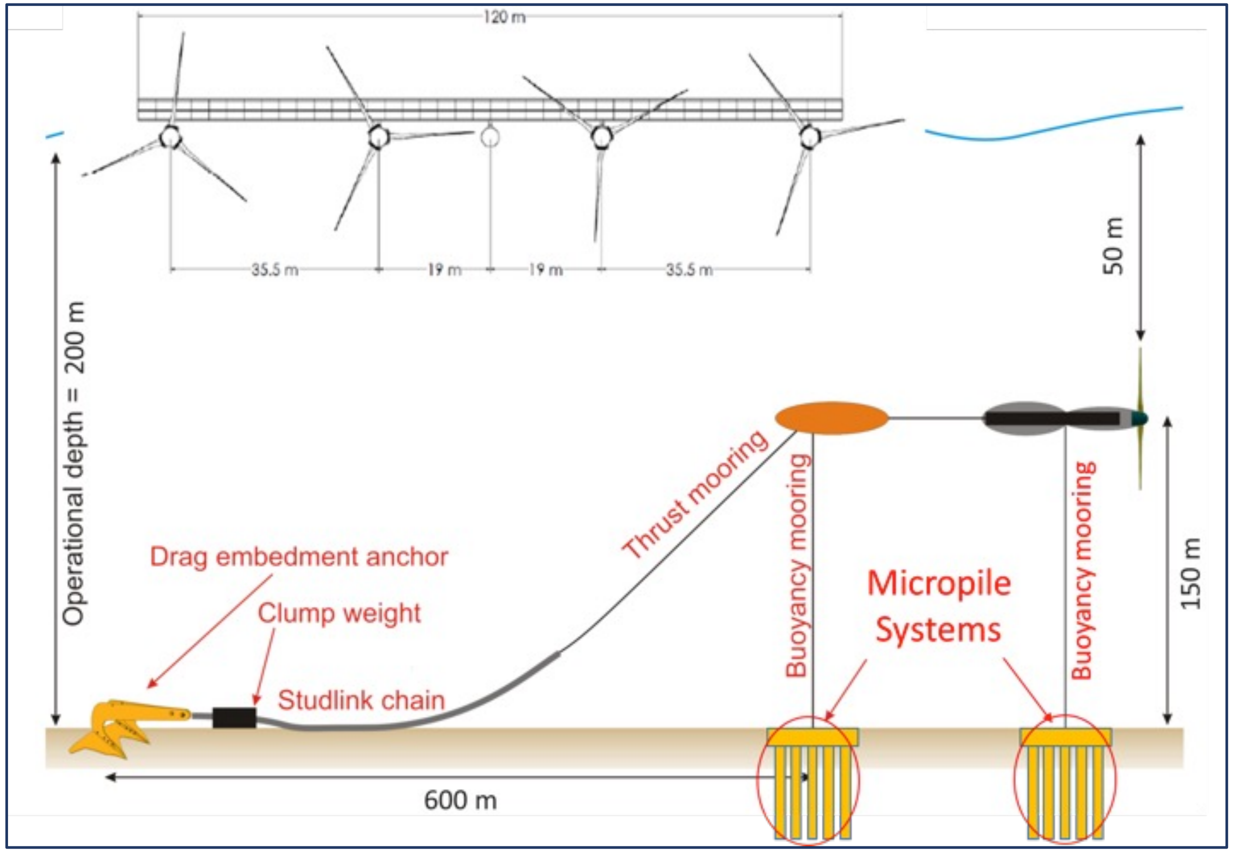
Develop innovative systems for anchoring and mooring of offshore marine hydrokinetic devices in waves, tidal and ocean currents

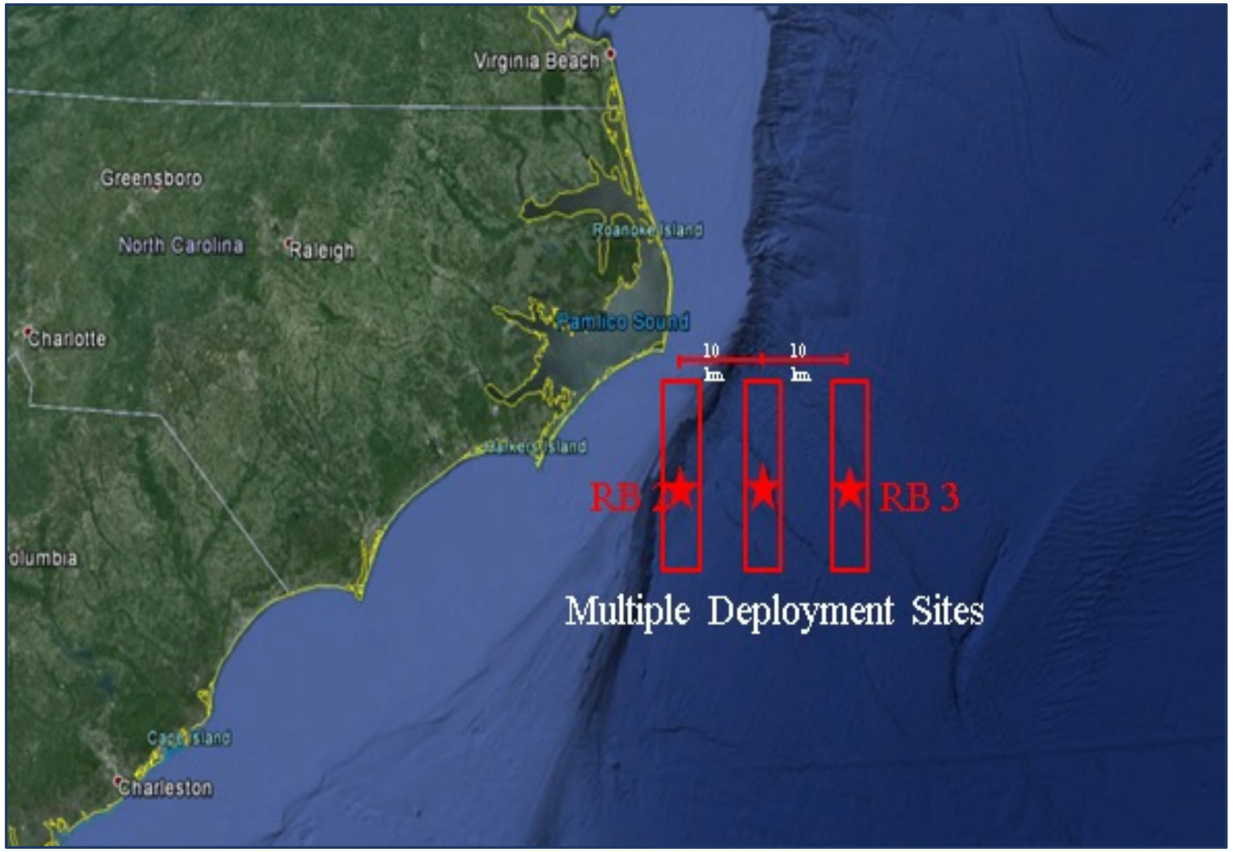
APPROACH

Develop the use of Plate Anchors and Micropiles in marine environment and investigate construction approaches for deploying formed Micropiles and Plate Anchors

IMPACT

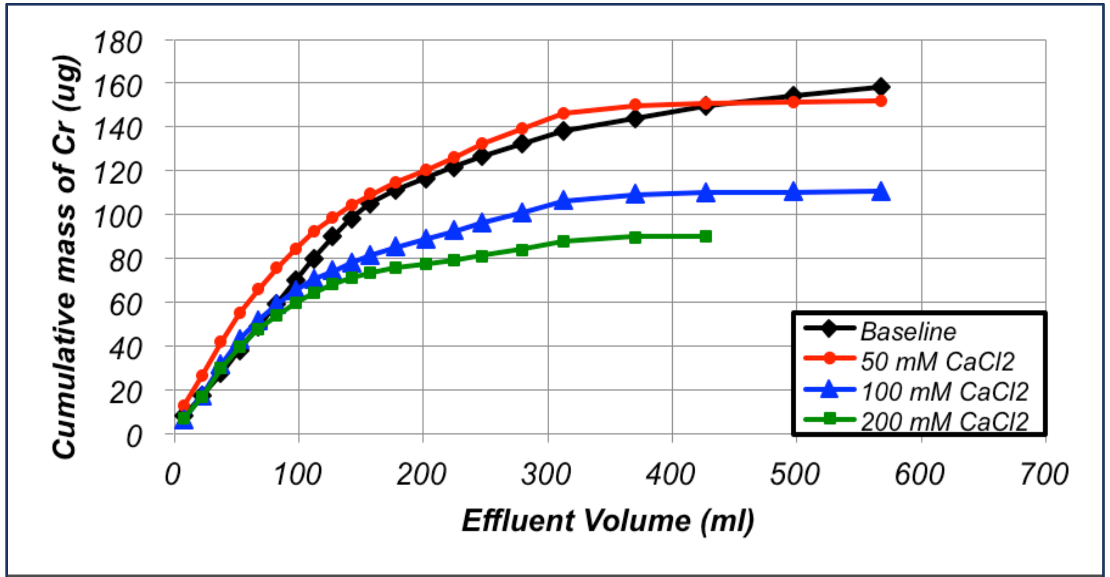
Specification guidelines and "road map" for deploying cost effective anchoring systems in offshore environments in support of an emerging renewables energy market





Energy Byproduct Hazard Stabilization

Column testing to assess improvement in mechanical properties



Immobilization of chromium from fly ash at varying cementation

GOAL

Improve the strength and stiffness of energy byproduct materials, like coal ash ponds, while also immobilizing heavy metals within the material

METHOD

Leachability, compressibility and geophysical tests are conducted on treated and untreated coal ash material to assess suitability of bio-cementation

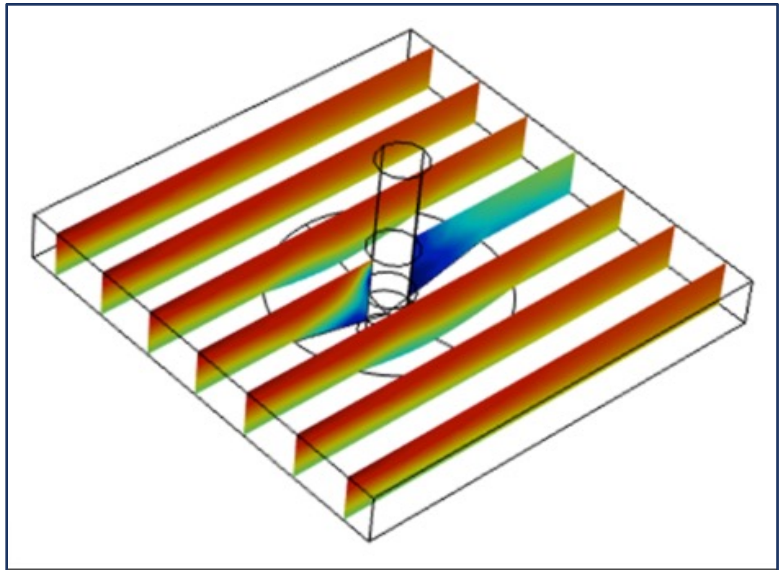
APPROACH

Utilize bio-cementation within the energy byproduct material to improve the mechanical properties and immobilize heavy metals

IMPACT

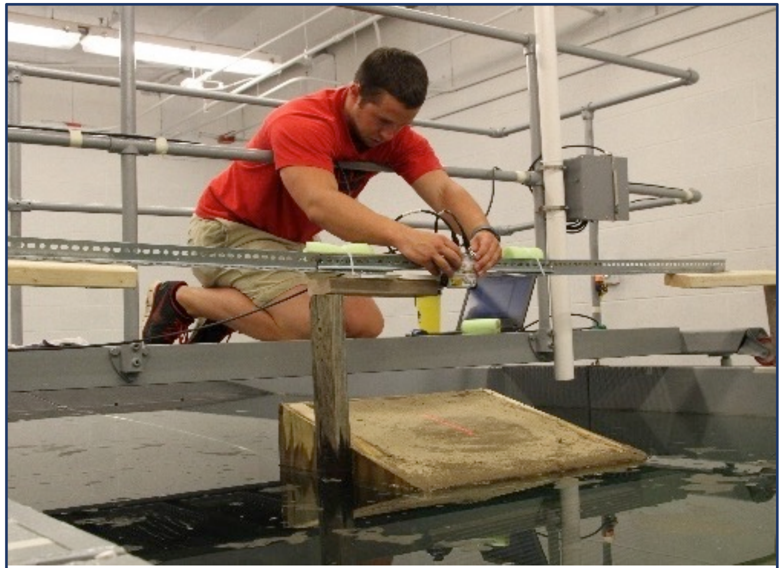
Provide a natural, innocuous method to improve the long-term performance of coal ash impoundments and other energy byproduct materials

Scour Assessment & Mitigation



Numerical modeling of velocity flow around pile experiencing scour

ISEEP Field Deployment



Bio-cemented Sand in Wave Tank

GOAL

Understand soil susceptibility to scour within onshore and offshore environments and reduce the susceptibility to scour using natural methods

APPROACH

Assess soil susceptibility to scour using In Situ Erosion Evaluation Probe (IEESP) and predictive modeling and prevent scour using bio-cementation

IMPACT

- ISEEP is the first tool developed to assess soil erosion parameters with depth
- Deployed to study breaching during NC hurricanes
- Bio-cementation can be used to reduce erosion from wave action and reduce scour adjacent to offshore foundations without harmful ecological consequences

Flood Defense Structures

GOAL

Develop a framework to assess the stability of flood defense earth structures and integrate a comprehensive multiscale levee monitoring program to assess the probability of exceeding predefined performance limit states

APPROACH

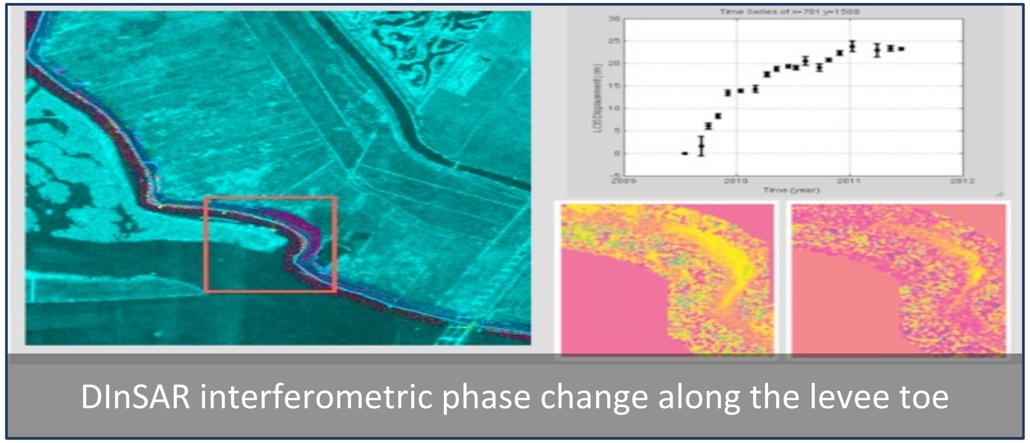
The concept of deformation-based limit states is introduced, using coupled deformation-seepage analyses and including various scenarios for rehabilitation measures; monitoring is achieved through coupled satellite-based JSInSAR and in-ground monitoring at high-risk sections

IMPACT

Method to diagnose current levee conditions, prognosis under varying future conditions, and assess potential property damage and loss of life, as well as impact of repair and rehabilitation of damaged levee

LIMIT STATE I: No visible signs of flooding, landside boils, through or under seepage, or significant deformation.

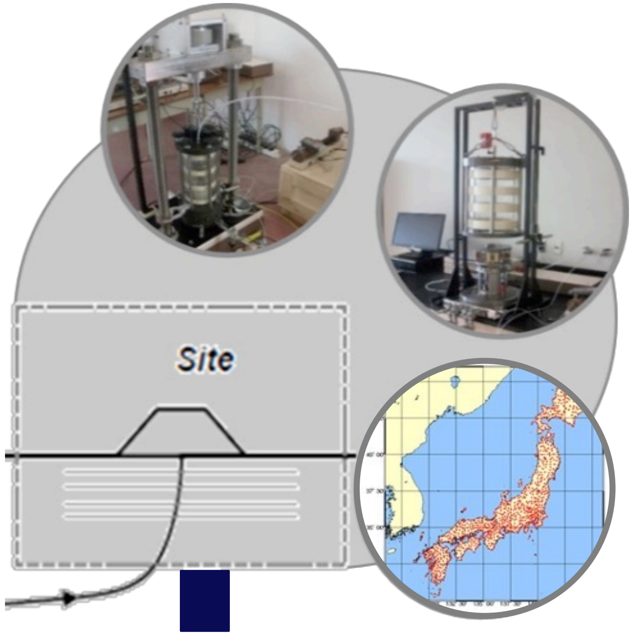
LIMIT STATE III: Levee is breached with major flooding of the protected property. Rebuild is needed.

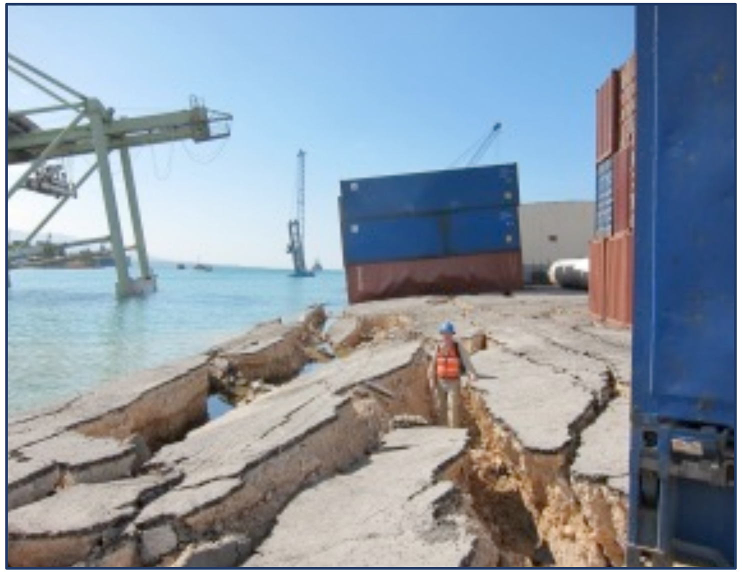


DInSAR interferometric phase change along the levee toe

Images by Getty and Associated Press 2011

Geotechnical Earthquake Engineering





GOAL

Improve the characterization of site-specific effects on ground motions and characterize spatial variability of hazard- and performance-relevant ground motion intensity measures

APPROACH

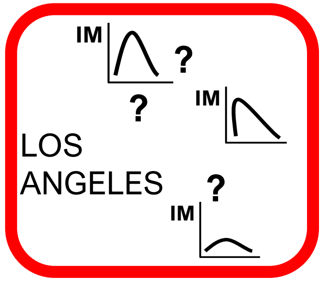
Numerical analysis of the propagation of seismic waves through porous media, uncertainty analyses and dynamic soil testing

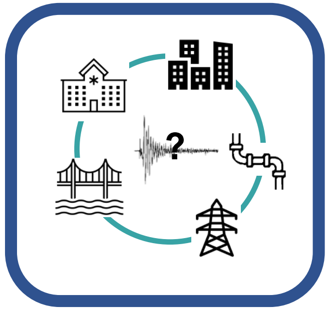
IMPACT

To improve our understanding of the impact that local soil conditions have on ground shaking intensity and distribution, while elucidating correlations with the response of critical infrastructure (e.g., lifelines, nuclear power plants)

Seismic Hazard and Risk Evaluations of Civil Infrastructure Systems

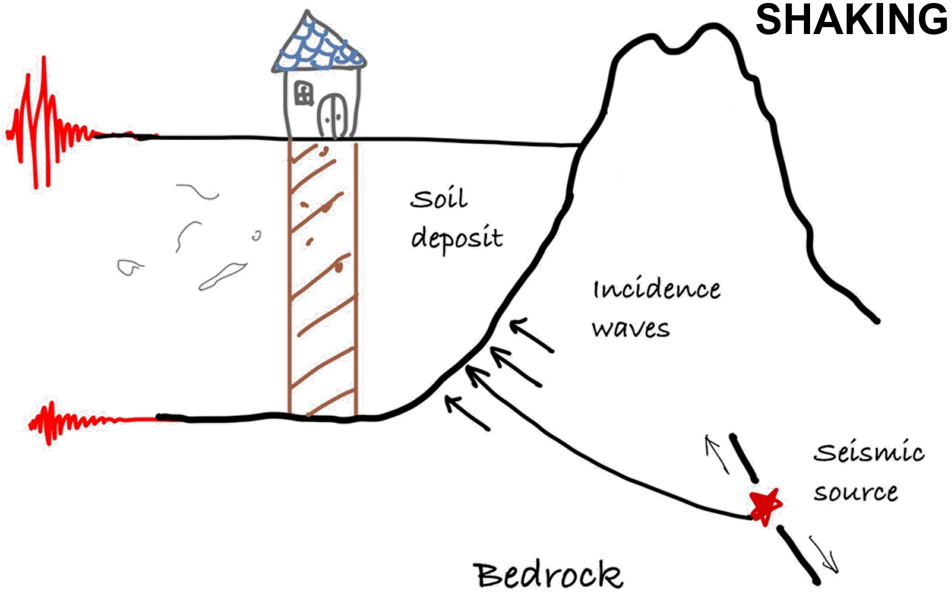
SPATIALLY VARIABLE SEISMIC DEMAND





INTERCONNECTED SYSTEMS

LOCAL SOIL CONDITIONS AFFECT GROUND SHAKING



GOALS

(1) New conditional site response models.
(2) Spatial correlations among ground motion parameters as functions of variable subsurface conditions.
(3) Incorporation of (1) and (2) into system-level probabilistic seismic hazard analysis for water distribution systems.

METHODS

Numerical modeling and geospatial analytics using existing (and creating new) large, global ground motion and site

IMPACT

To advance scientific knowledge on the **response of soils to earthquake ground shaking at multiple scales** and enable its incorporation into system-level probabilistic **seismic hazard assessments for civil infrastructure systems.**

Multiscale Evaluations of Seismic Hazards

GOALS

Develop regional site amplification and hazard models for incorporation into the USGS National Seismic Hazard Maps (NSHM).

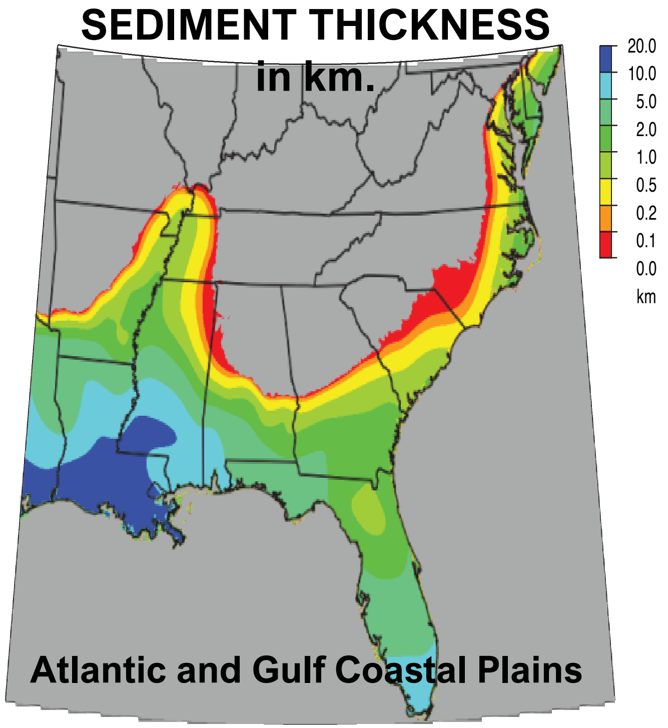
METHOD

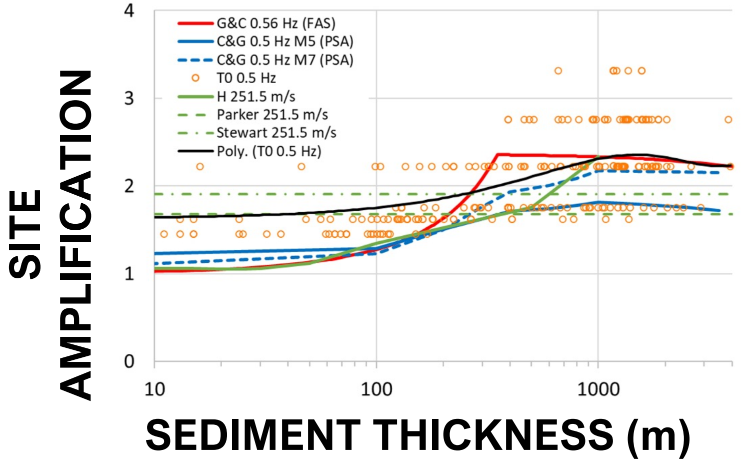
Development of a 3D data-driven and geology-informed shear-wave velocity models.

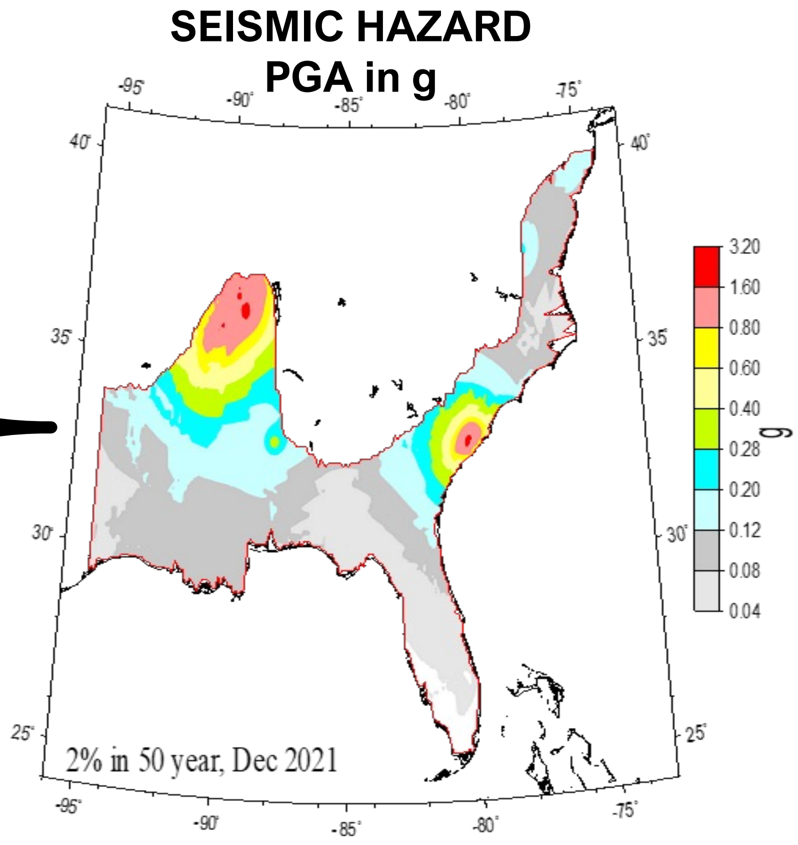
Incorporate effects of sediment thickness into regional site amplification models and inits implementation into PSHA for use in the USGS NSHM.

IMPACT

improve the characterization of seismic hazards in the CEUS region.







Human-centered Approaches to Disaster Resilience

GOALS

Advance the disaster resilience practices through intersectional lenses that include seismological, earthquake engineering and social sciences perspectives.

METHOD

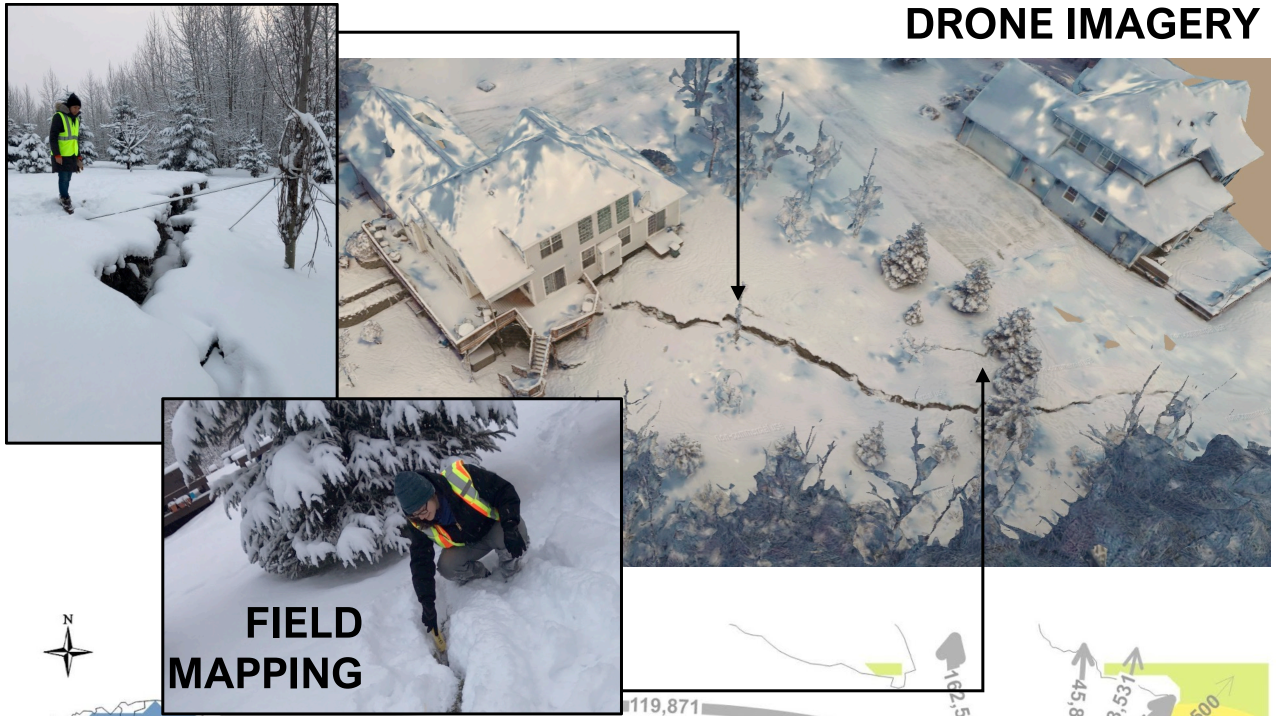
Collect perishable data in the field after major earthquakes and document relevant case histories.

Investigate the intersection of social, geosciences and engineering observations after major earthquakes through interdisciplinary collaborations.

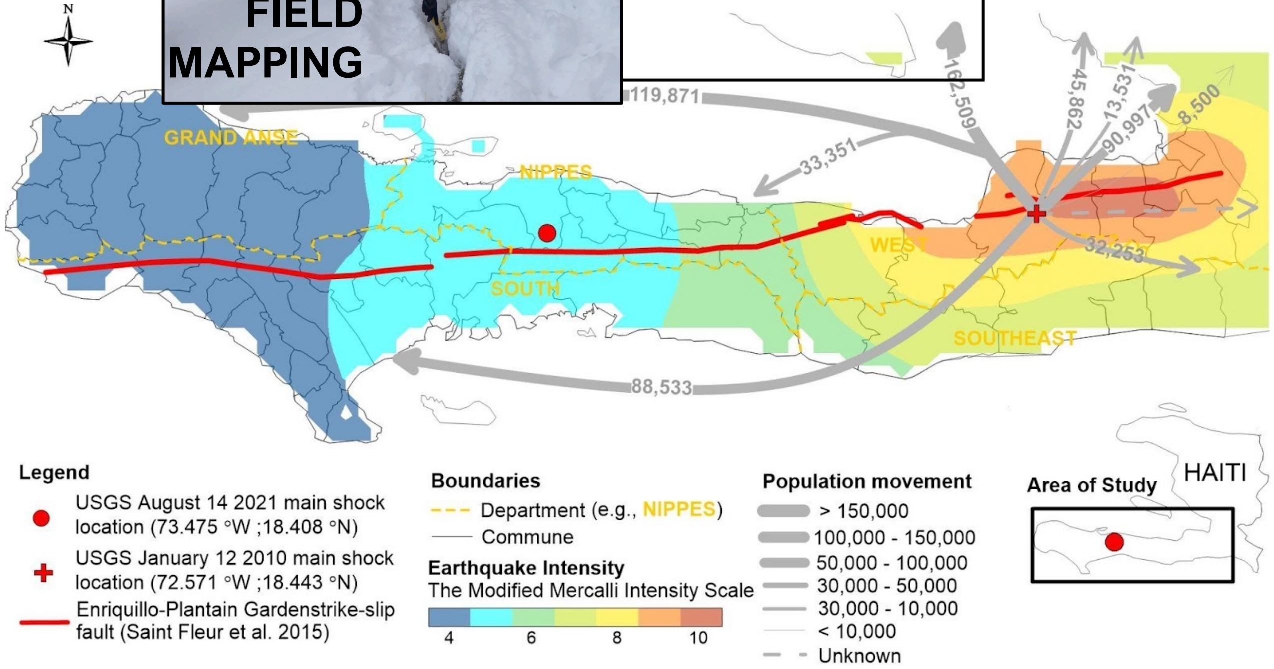
IMPACT

Propose short-term response and long-term recovery strategies to work within the greater social–political–cultural context of affected regions

POST-EARTHQUAKE RECONNAISSANCE MISSION AFTER THE **2018 ALASKA EARTHQUAKE**



POST-EARTHQUAKE RECONNAISSANCE MISSION AFTER THE **2021 HAITI EARTHQUAKE**



E²SCALA: Earthquake Engineering and Seismology Community Alliance in Latin America

15 partners/mentors in Latin America and counting

12 countries represented and counting

Key partnerships with Academic and Research Institutions around the globe

Content development in Spanish, English and Portuguese

GOALS

E²SCALA means to "climb" but also "scale" in Spanish and those are key drivers of this program; to help Latin American students and professionals reach their highest potential (climb), while building a network that grows with our community's goals (scale up).

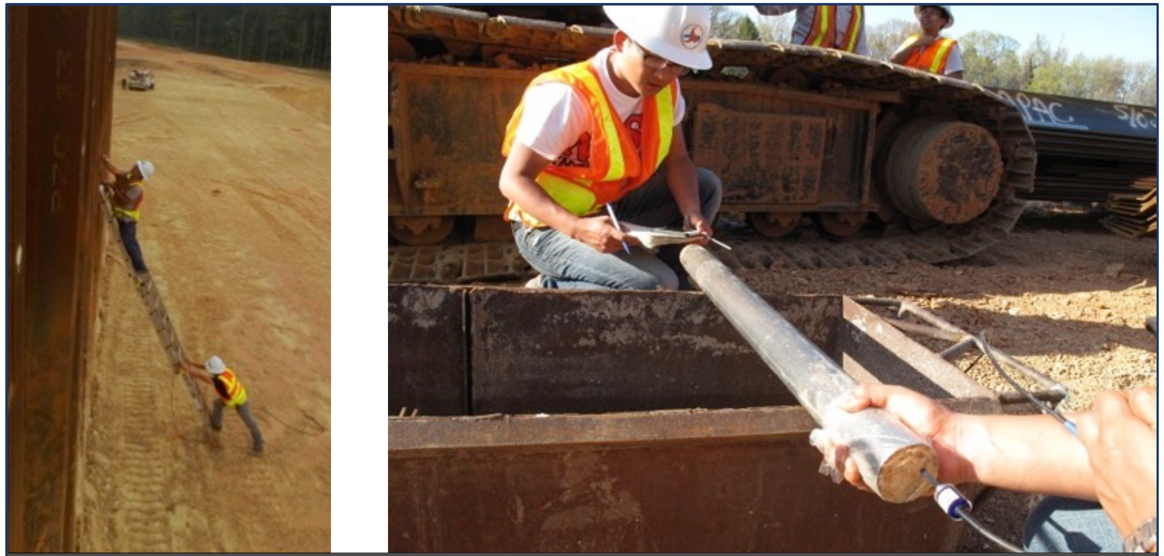
METHODS

Create a virtual learning and collaboration environment with global, open access to educational resources, virtual mentorship, and collaboration opportunities FOR COMMUNITY BUILDING AND ENGAGEMENT.

IMPACT

Enhancing representation of and collaboration with Latin American students and professionals will accelerate community and capacity building in Latin America.

Temporary Slopes and Retaining Systems



Graduate students assessing test sheet pile wall and soil properties

Experimental Steep Slopes (slope down to the left) Prepared for Water Ponding

GOAL

Design approach for temporary slopes and retaining structures in North Carolina residual soils, taking into account the unsaturated properties of the soil

APPROACH

Field testing on sheet pile wall and three steep slopes, coupled with numerical analyses incorporating suction effects

METHOD

Full-scale testing of field structures with supplemental laboratory testing and extensive numerical modeling

IMPACT

Reduced construction costs, as steeper slopes and lighter wall sections might be possible during temporary construction with the incorporation of soil suction

Post-Wildfire Slope Stability


A slope burned by 2022 Bolt Creek Fire, near Skykomish WA


Research team at the Bolt Creek Site


Macropores at a site burned by the 2019 Williams Flats Wildfire that change the hydrologic behavior of the soil

GOALS

- Quantify the temporal changes in soil properties, forest system dynamics (tree loss, regrowth, ash redistribution), and soil water retention after a wildfire and develop a wildfire-specific slope stability model.
- Use environmentally-friendly additives for post-wildfire slope stabilization and evaluate the impacts of mobilized soil, ash, and additive on downstream water quality

METHODS

- Micro-scale surface characterization through water vapor sorption
- Laboratory-scale testing of physicochemical, mechanical, and hydraulic soil behavior
- Model experiments to evaluate soil loss and infiltration
- Field-scale testing of hydrologic behavior
- LiDAR, satellite, multispectral images to quantify forest system dynamics

IMPACT

First wildfire-specific, comprehensive slope stability model toward generating fire-resilient communities.

Translating from Kangaroo Rat Burrows to Geotechnical Engineering

Kangaroo rat habitat in the Sonoran Desert near Yuma, AZ

Research team

A kangaroo rat leaving its burrow

GOALS

- To understand how kangaroo rats construct stable burrows in loose desert sand and maintain the stability of their burrows in extreme environmental conditions.
- Develop a suction stress model for cemented soils, including the contribution of interparticle stresses from water retention by the cementing agent

METHODS

- Tunnel stability analysis
- Sampling from desert sand and kangaroo rats
- Microbial community testing
- Laboratory growth of fungal and microbial biofilms
- Strength and hydraulic conductivity testing

IMPACTS

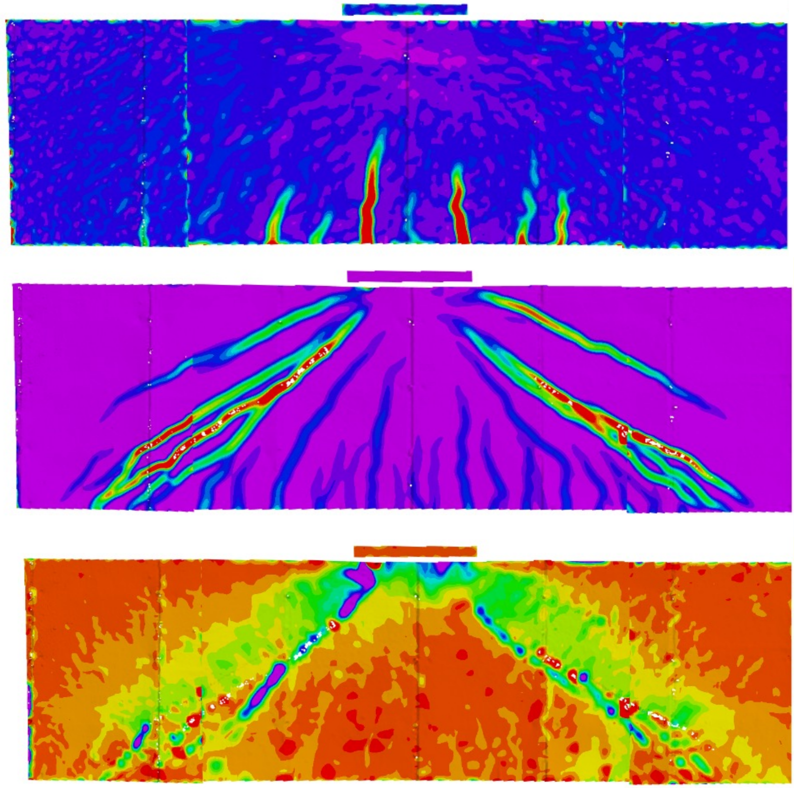
- A new cementing agent for human geotechnical systems that is resistant to extreme temperature and relative humidity fluctuations and flash flood events
- A new effective stress framework for cemented soils

NC STATE UNIVERSITY

Structural Engineering

- Advanced/innovative infrastructure systems
- Development of fundamental models for performance of concrete and steel structures
- Development of novel assessment techniques
- Probabilistic analysis and design
- Repair of concrete, masonry and steel structures with advanced fiber-composites
- Earthquake engineering
- Nuclear power plant structures and components
- Structural health monitoring and prognostics

Assessment of Shear Critical Concrete Structures



GOAL

Assess performance of shear critical reinforced concrete infrastructure and use crack information to directly quantify level of safety

APPROACH

Conduct heavily instrumented, large-scale experiments to assist in the development of fundamental mechanical models

IMPACT

Improve understanding of how structures carry load and modernize safety assessments of critical infrastructure

Rapid Repair of Damaged Columns by Plastic Hinge Relocation

GOAL

Repair rather than replace columns heavily damaged in an earthquake

APPROACH

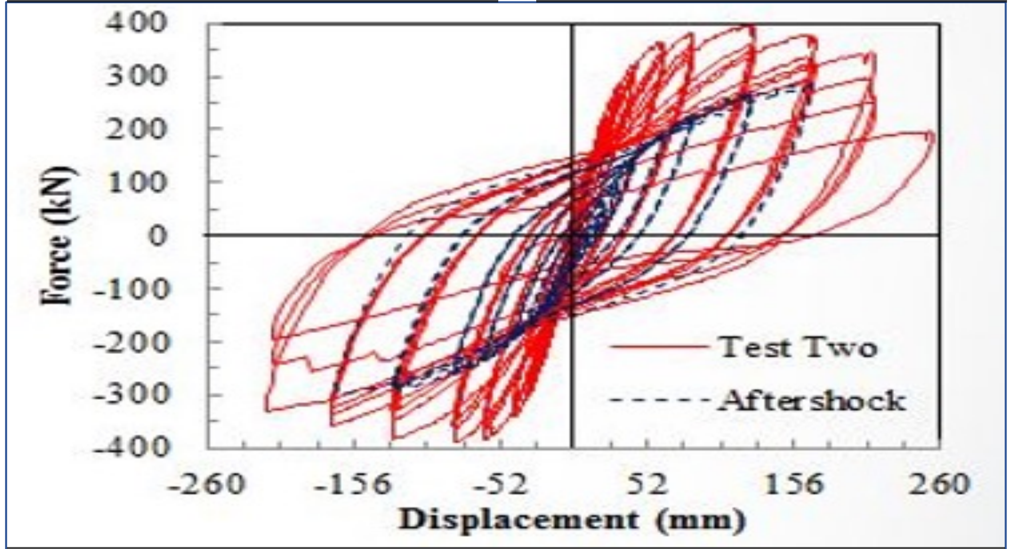
New repair techniques using portions of the column previously undamaged; verify with full-scale seismic testing and analysis

IMPACT

Suite of rapid repair techniques for bridge engineers

Damaged Column

Repaired, Retested Column



Column Improved Behavior

Advanced Composites for Rehabilitation: FRP Strengthening of Masonry Structures

GOAL

Brittle behavior of unreinforced masonry walls in out-of-plane bending subject to wind, earthquake or blast loading

APPROACH

Develop advanced fiber composite strengthening alternatives to enhance the deformation capacity of existing walls

IMPACT

Enhanced resilience and public safety from premature failure, and extended service life of existing infrastructure

Column Improved Behavior

Seismic Performance Enhancement of Steel Building Connections

GOAL

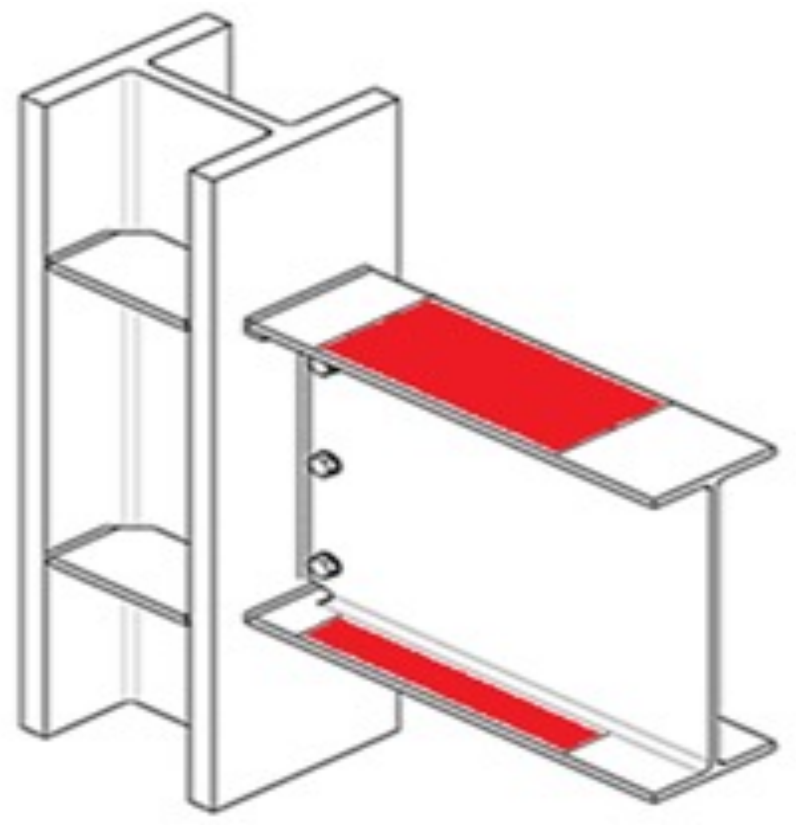
Develop innovative seismic performance enhancement techniques for welded steel building connections

APPROACH

Heat treatment of beam to induce seismic damage at desired beam location and thereby reduce stress or strain concentrations at weld; develop robust numerical models to simulate failure mechanisms

IMPACT

Enhanced seismic performance of steel building



Heat-treated beam section highlighted red

Large-Area Sensing Skin

GOAL

Monitoring critical infrastructure for damage and corrosion requires advanced sensing technologies

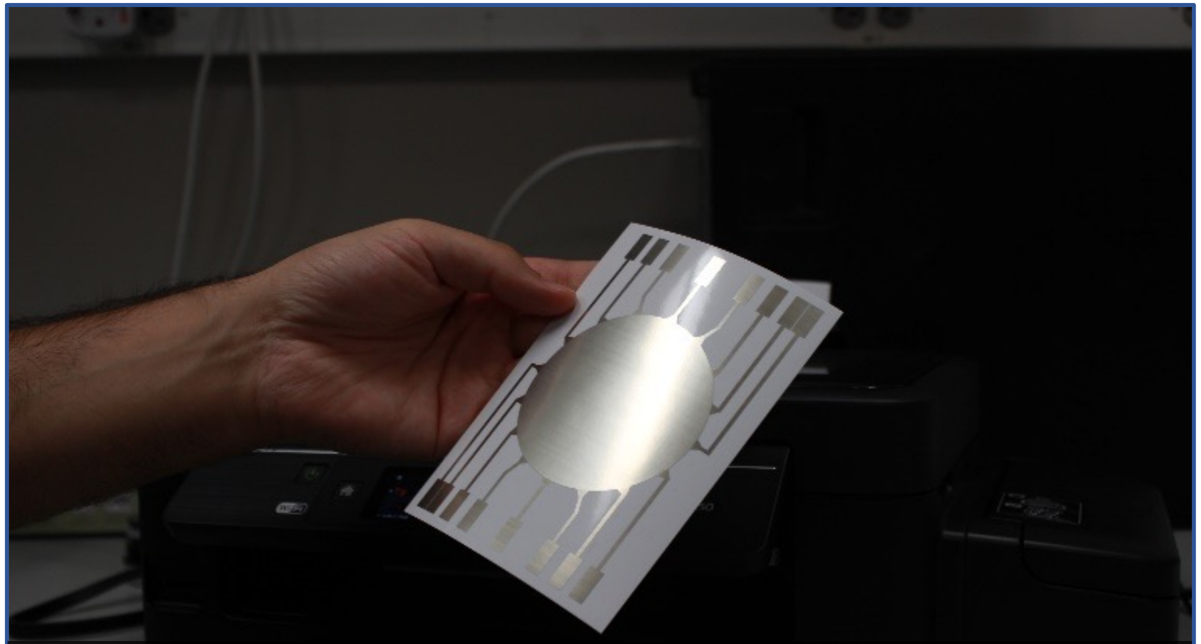
APPROACH

We have developed a large-area sensing skin that enables detection of cracks and aggressive elements such as chlorides

IMPACT

Rapid and reliable monitoring solution for critical infrastructure that can be combined with prognostic methods to get more out of our new and aging infrastructure

NCSU team has developed full-scale sensing skin


NCSU's team has developed technology to print the sensing skin to be installed like wallpaper.

Welding Residual Stresses on Structural Failure

GOAL

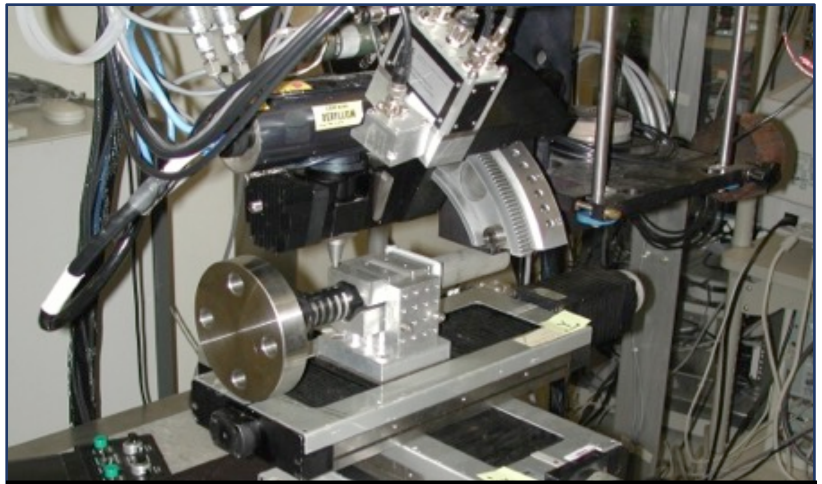
Determine the effect of residual stresses on local fatigue crack initiation

APPROACH

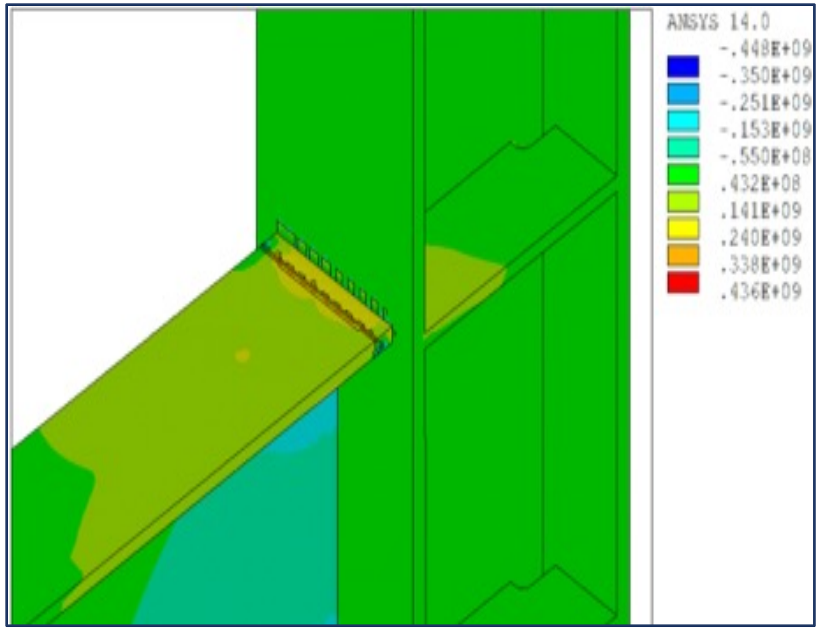
Develop an experimentally validated thermo-mechanical simulation model to estimate residual stresses and their effect on crack initiation life

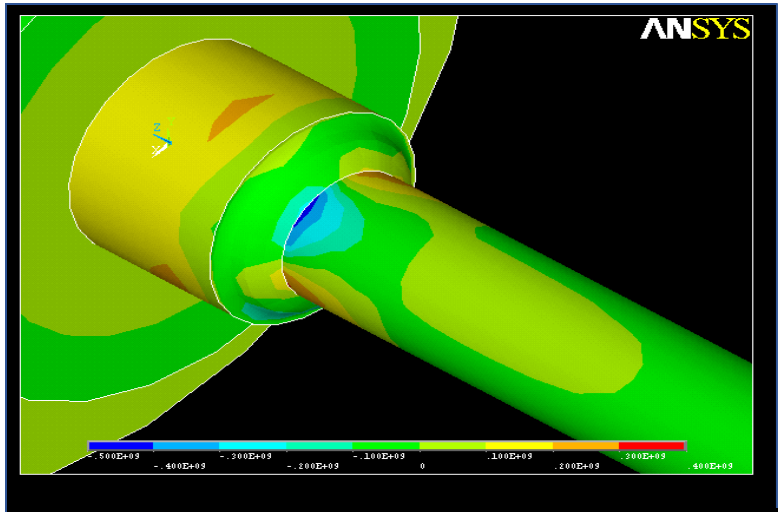
IMPACT

Improved estimation of structures and component lives and thereby improve design methodologies



Residual stress measurement at Oak Ridge National Lab





Simulation of residual stresses at welded joints

Evaluation of Fire Damaged Steel Structures

ISSUE

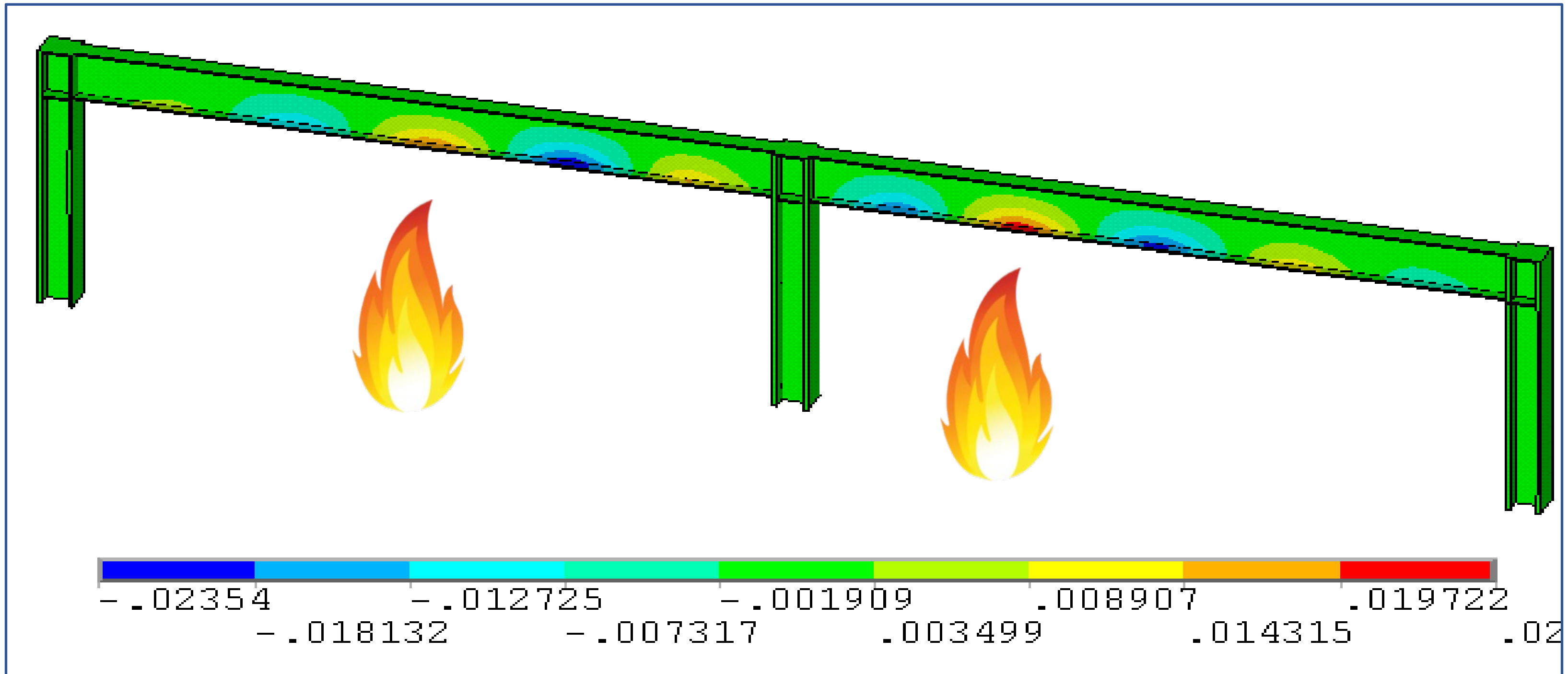
Currently there is no method to determine structural performance of fire-damaged steel structures

APPROACH

Develop a simulation model to determine fire damage in steel structures and its influence on structural performance under seismic loading

IMPACT

Structural rehabilitation to extend life of fire-damaged structures



Simulation of fire damage in steel frame

Earthquake Characteristics and Bridge Column Response

ISSUE

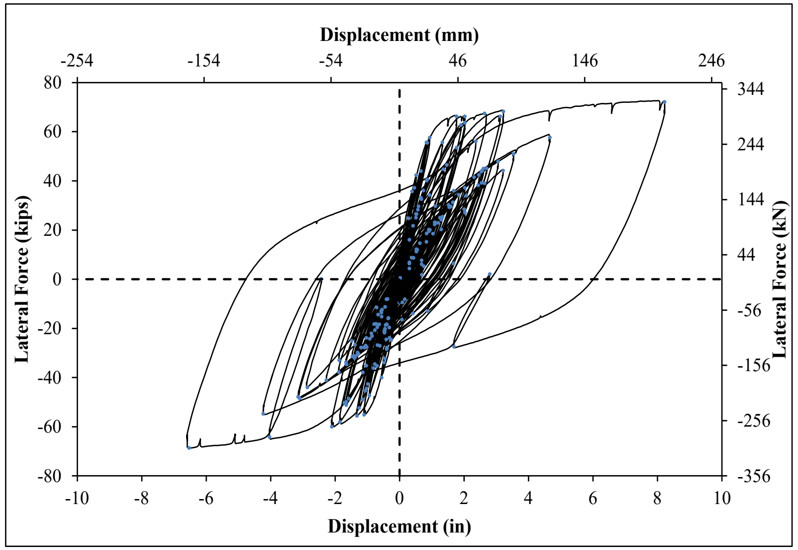
Bridge performance is related to material strains, which can be affected by earthquake characteristics

APPROACH

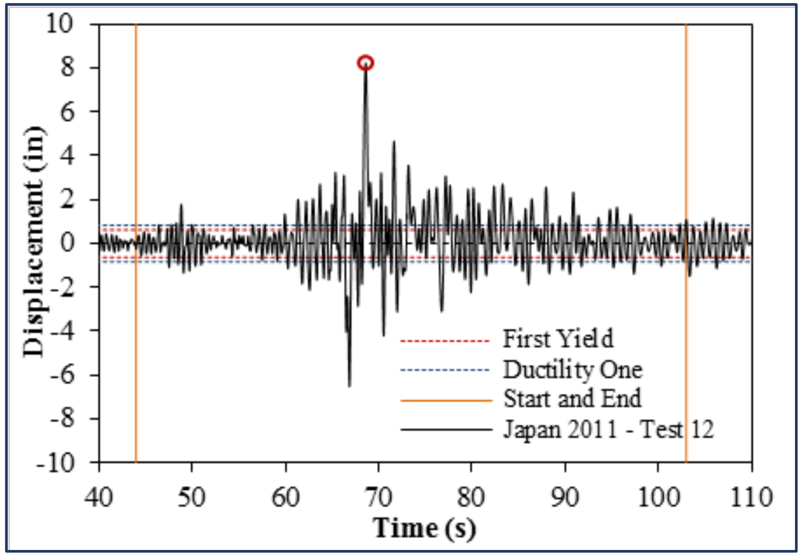
Full-scale seismic testing of columns; fiber and finite element analysis for parameter studies

IMPACT

New bridge performance measures and design methods



Simulation of fire damage in steel frame



Ductility Capacity of Steel Bridge Bents

ISSUE

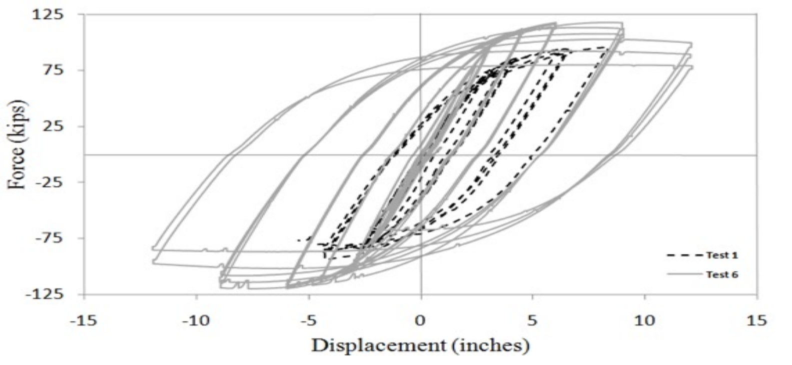
Limited ductility capacity due to connection geometry, weld size and weld quality

APPROACH

Full-scale seismic testing of existing design; finite element modeling of existing and new designs to develop alternatives; dynamic shake table testing for proof-of-concept; full-scale seismic testing of new designs to resist high seismic demands

IMPACT

New bridge performance measures and design methods



Improvement in Performance

Full-scale lab test

Bird Creek Pedestrian Bridge (Compliments of AKDOT)

Digital Twin for Nuclear Structures

GOAL

Improve the resiliency of nuclear power plant structures, systems, and components during normal operations as well as extreme external hazards

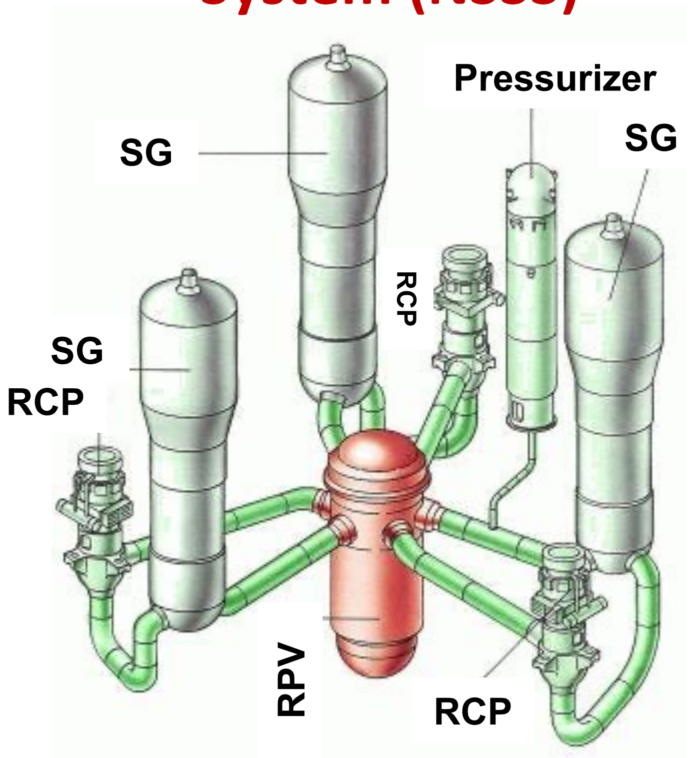
APPROACH

Create "Digital Twin" of systems and components using high fidelity simulations and plant sensor data; use Digital Twin for Diagnosis and Prognosis to optimize plant maintenance; support operators during accident condition by providing ranked list of actions

IMPACT

Reduction in uncertainty, enhanced safety, reduction in cost of operating existing plants and building new ones

Nuclear Steam Supply System (NSSS)



RCP: Reactor Coolant Pump
SG: Steam Generator
RPV: Reactor Pressure Vessel

Multi Hazard Risk Assessment of Nuclear Plants

GOAL

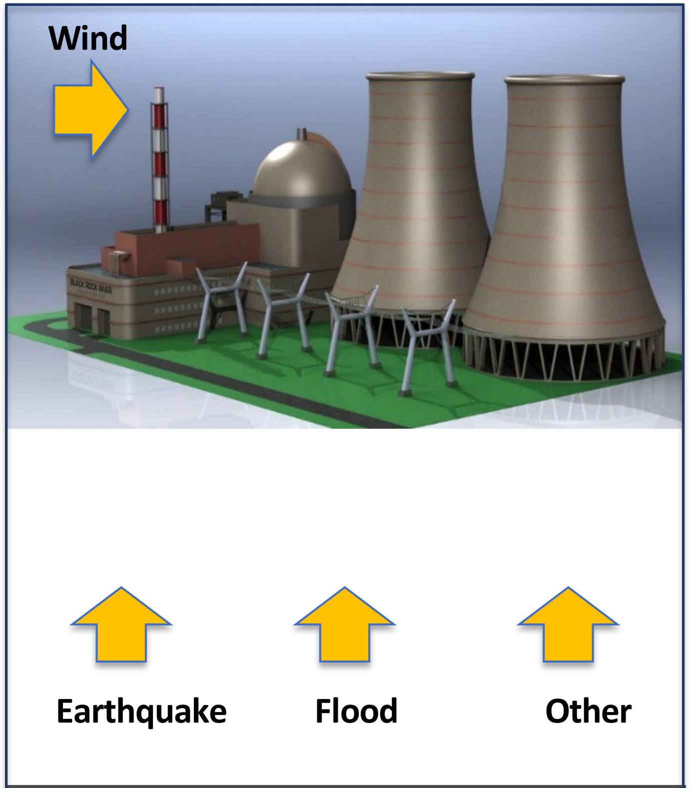
Evaluate interdependencies among different external hazards and determine potential vulnerabilities of nuclear power plants due to such correlations

APPROACH

Mapping of Logic Tree models into Bayesian networks; account for potential correlations between failure modes and events; use Bayesian Inference to determine vulnerabilities

IMPACT

Significant advancement in risk-assessment for beyond design basis events



System under Multiple Hazards

Multi Hazard Risk Assessment of Nuclear Plants

GOAL

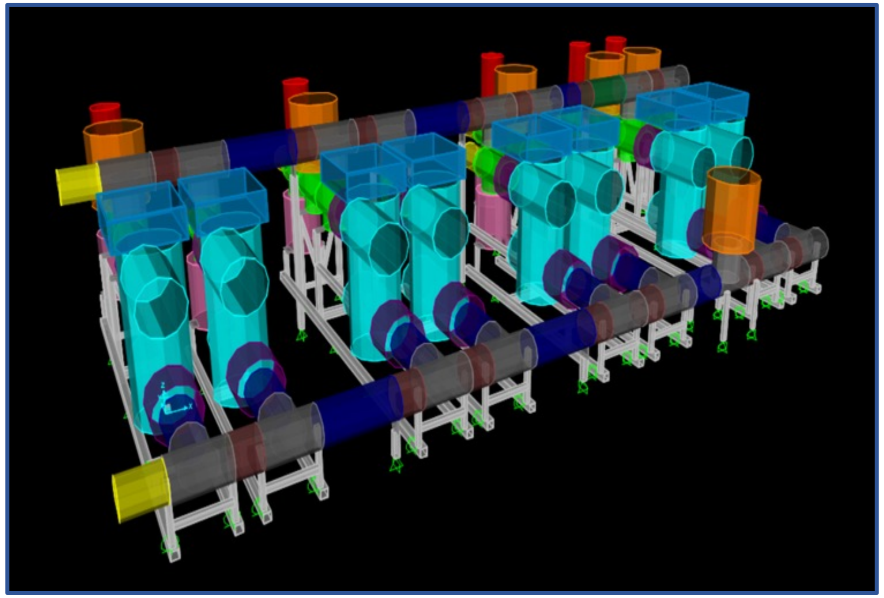
Simulating the seismic behavior of electrical substations and switchgears for robust design

APPROACH

Use of advanced simulations; reconciliation of simulation models with experimental data; account for interactions between multiple units and supporting structures

IMPACT

San Francisco International Airport; Disneyland in Anaheim, C.A.



Protection of Structures Against Tornado Missiles

GOAL

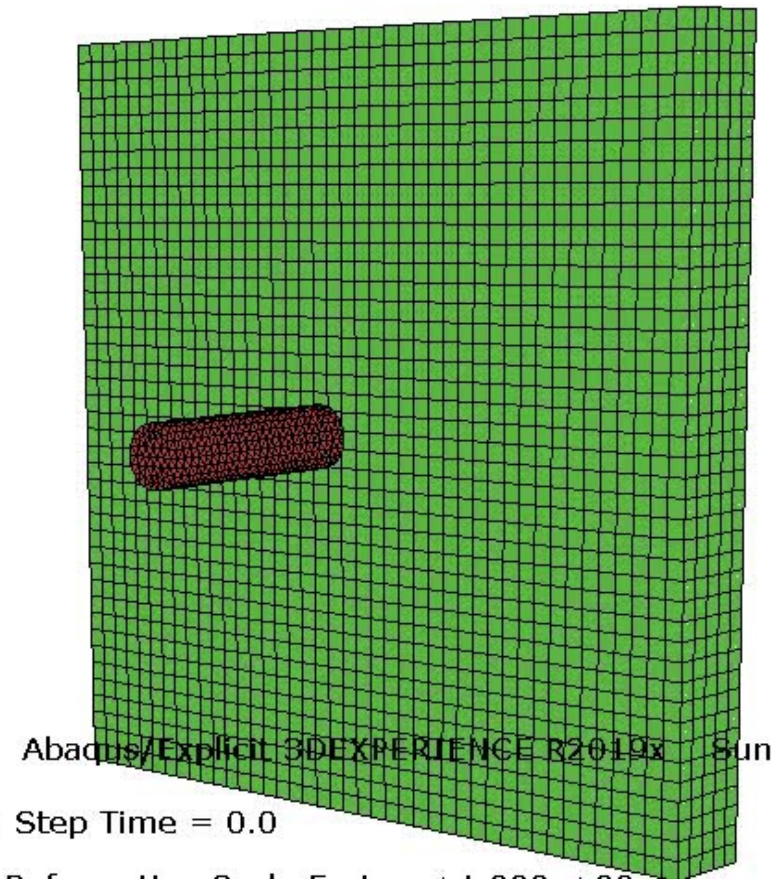
Simulating the behavior of reinforced concrete slabs subjected to impact with a tornado missile

APPROACH

Use of advanced simulations; reconciliation of concrete material models with experimental data; blind prediction analysis

IMPACT

Accurate prediction of missile residual velocity and penetration depth



Nondestructive Testing of Pile Foundations

GOAL

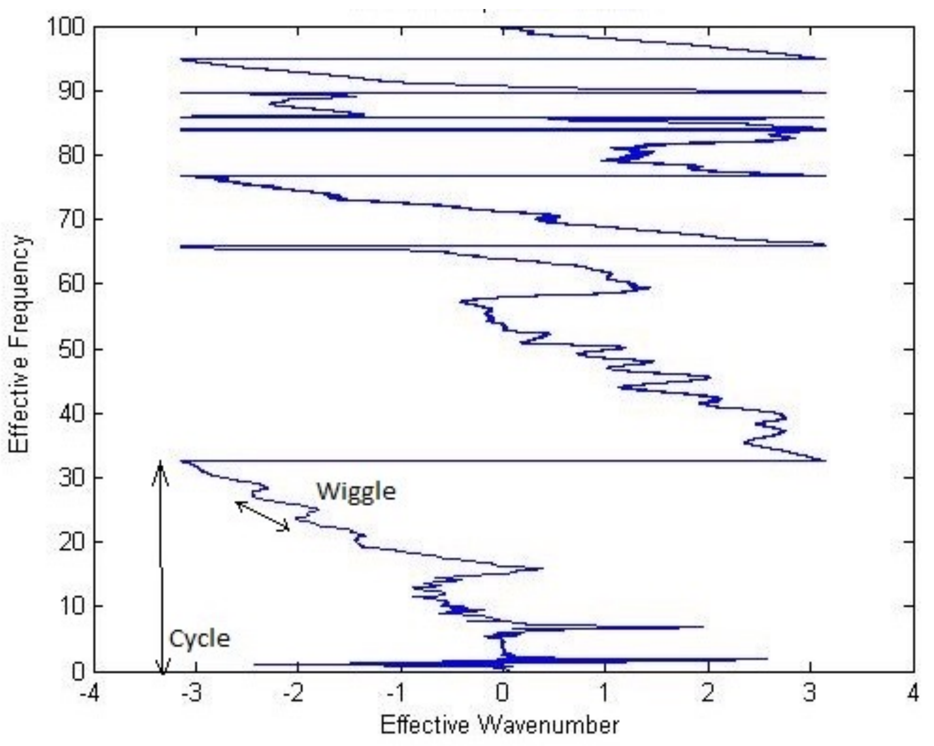
Estimate unknown depth of pile foundations

APPROACH

Novel physics-based data processing of dispersive wave propagation — effective dispersion analysis of reflections (EDAR)

IMPACT

Reliable estimates of strength for continued use for old bridges and reuse of foundations for new bridges



EDAR Plot used for estimating embedded depth

In laboratory settings,
EDAR resulted in <5% error compared to as much as 45% from the current state-of-the-art

Surface Wave Testing of Soils and Pavements

GOAL

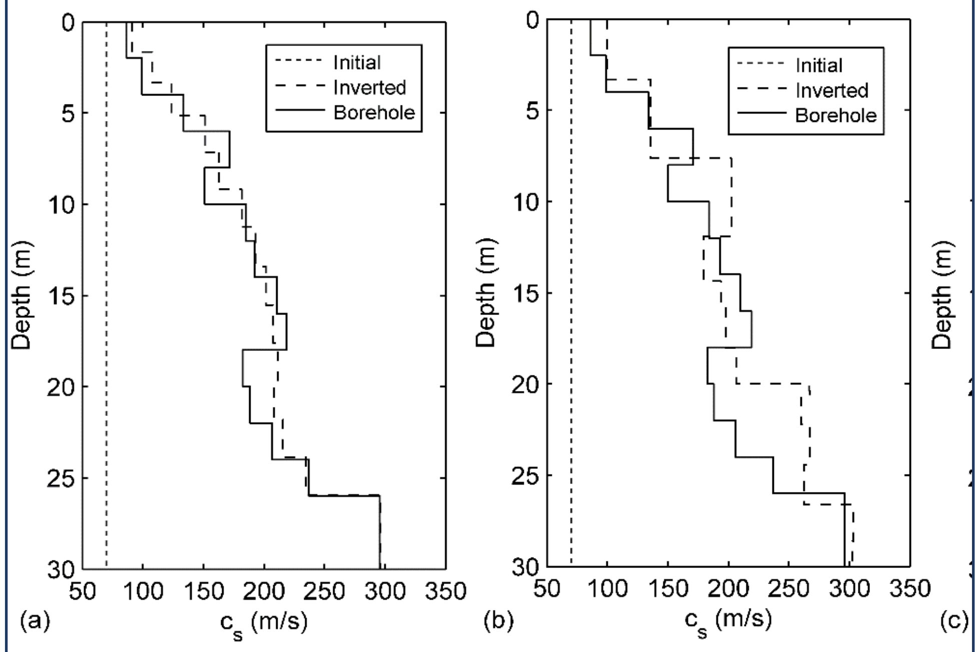
Estimate layered properties of soil and pavements

APPROACH

Invert for material properties from observed dispersion of waves propagating along the surface

IMPACT

(a) Site characterization for geotechnical earthquake engineering; (b) Nondestructive testing for damage, delamination and oxidation of pavements

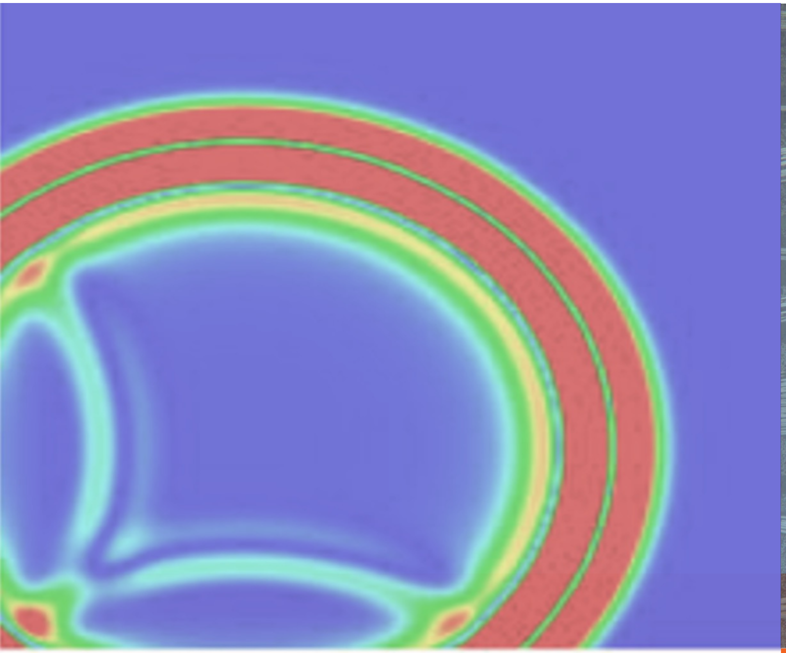
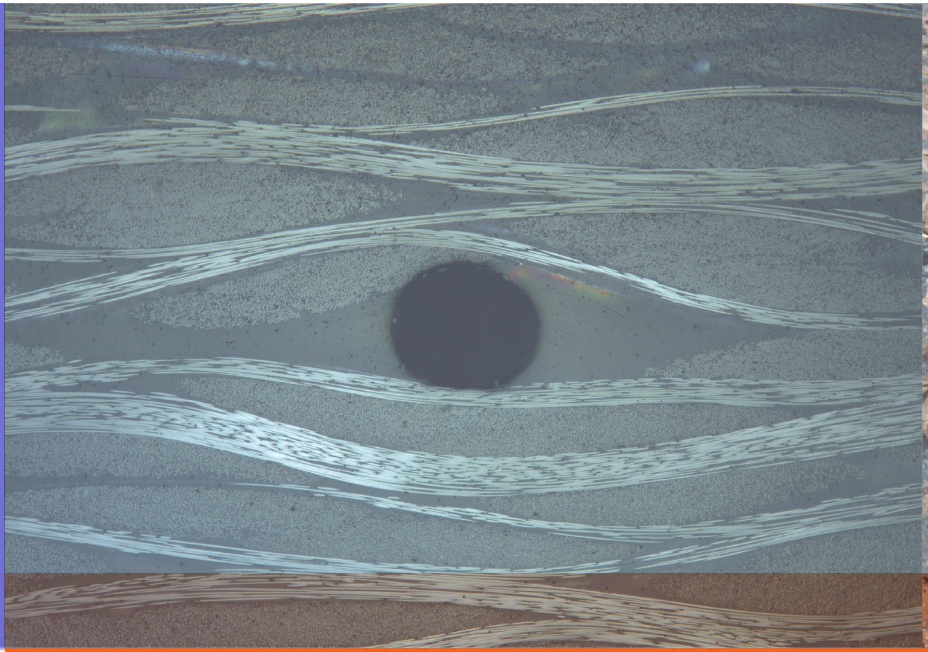
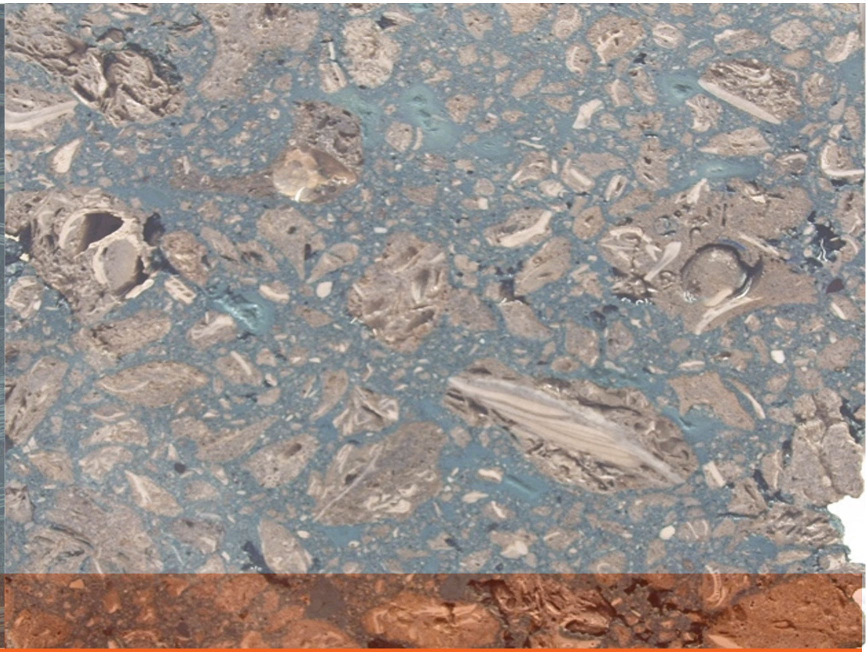


Geotechnical site characterization: comparison with borehole data

Our method (left) results in more accurate results in less than 1/300th time compared to the state-of-the-art (right)

NC STATE UNIVERSITY

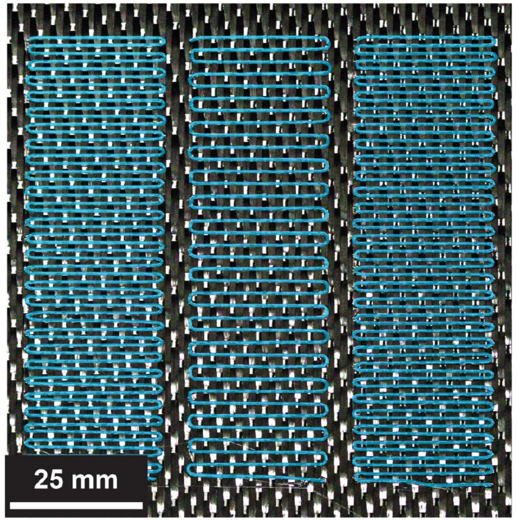
Mechanics and Materials

Interdisciplinary group working towards the common goal of:
Understanding, modeling and improving a wide spectrum of traditional and emerging materials — using theoretical, experimental and computational mechanics that span the nano- to macro-scale

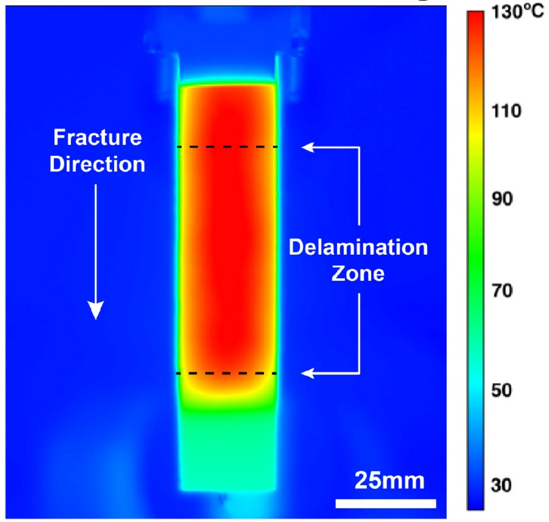
Self-healing Structural Composites

Printed Polymer on Carbon-fiber

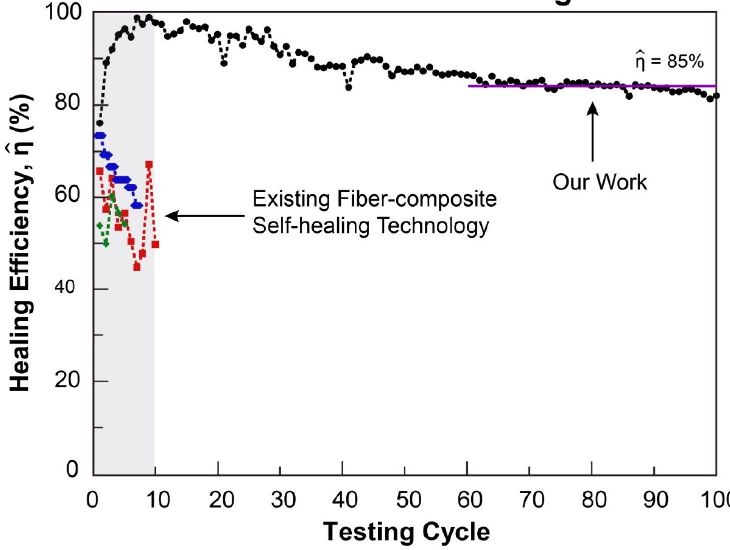


Nature Comm. **13**:6511 (2022)

In Situ Thermal Remending



Sustained Self-healing



Multifunctional Composites Group

IMPACT

Enhanced lifetime, safety, resilience, and reliability of FRC for civil, aerospace, automotive, naval, and renewable energy sectors

GOAL

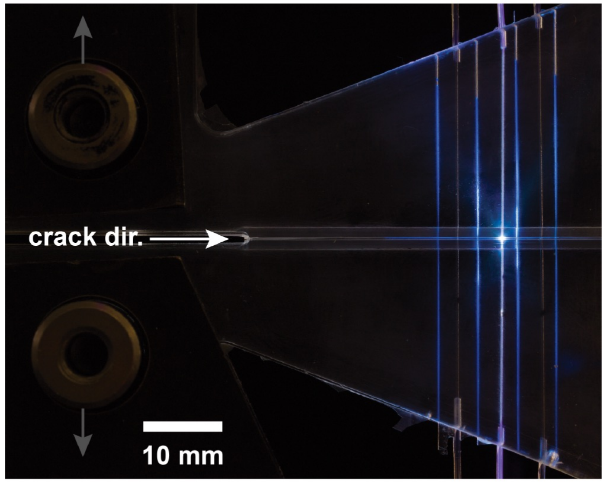
Develop structural fiber-reinforced composites (FRC) with capabilities for *in-situ* self-repair and real-time health monitoring

APPROACH

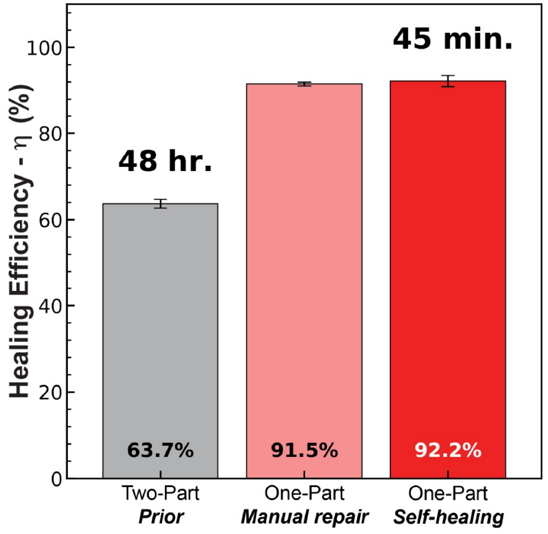
(top) 3D printed polymer & electrical nanomaterials

(bot.) Microvasculature & optical fibers

Optical Fibers + Micro Fluidics



Rapid *In situ* Repair



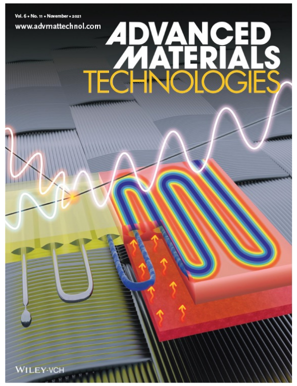
Multifunctional Metamaterials

GOAL

Develop structural composites with *multifunctional* capabilities: thermal regulation & electromagnetic modulation

APPROACH

Fluid circulation within bioinspired microvascular networks and fully integrated microelectronics

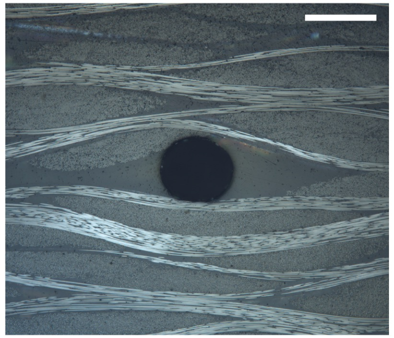


IMPACT

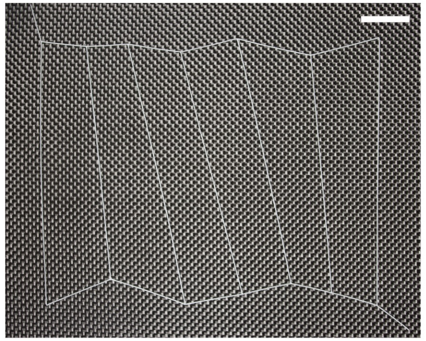
Enhanced versatility, operating environments, and new applications for polymer-matrix composites

Lightweight Structures

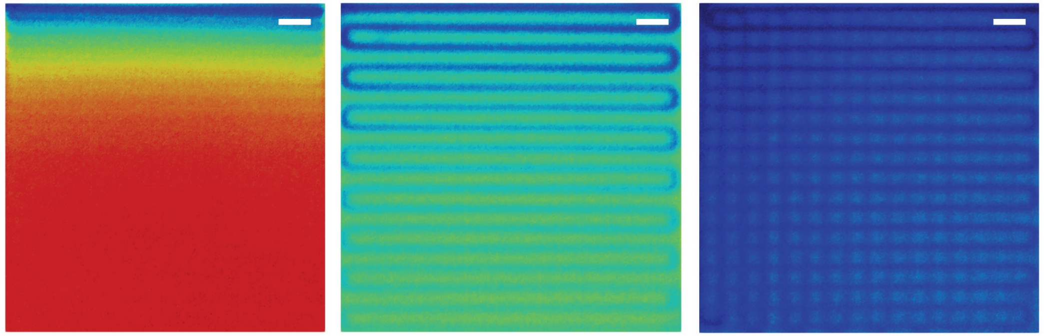
Vascular Composite



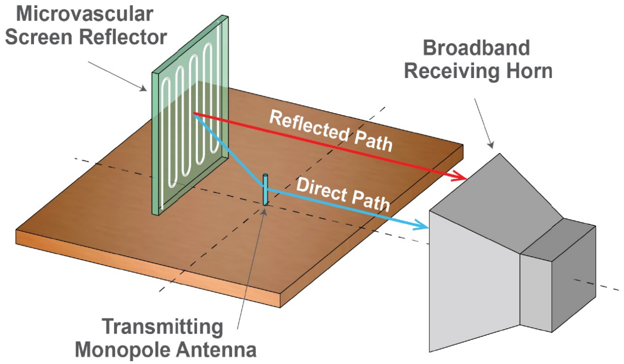
Design Optimization



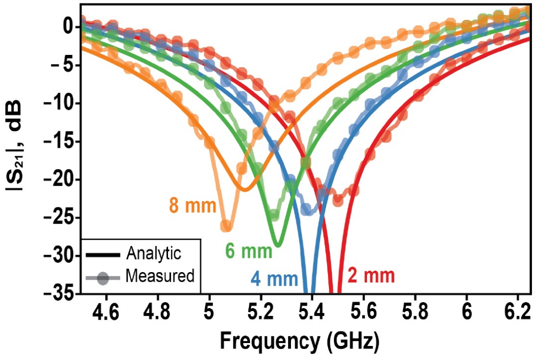
Thermal Regulation Experiments and Simulations



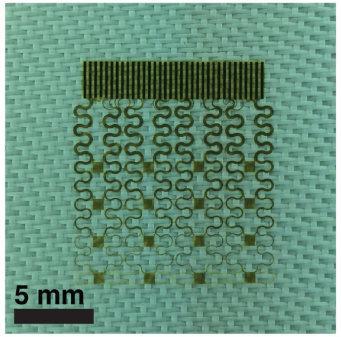
Liquid-metal Microfluidics



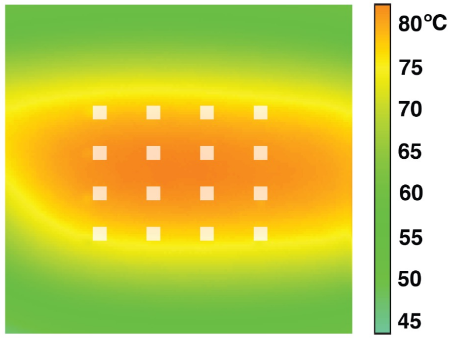
Radio Frequency Filtering



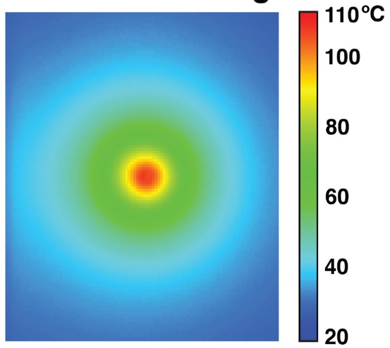
Multiplexed Device



Spatial Thermal Sensing



Localized Heating



Computational Mechanics: Wave Propagation Algorithms

GOAL

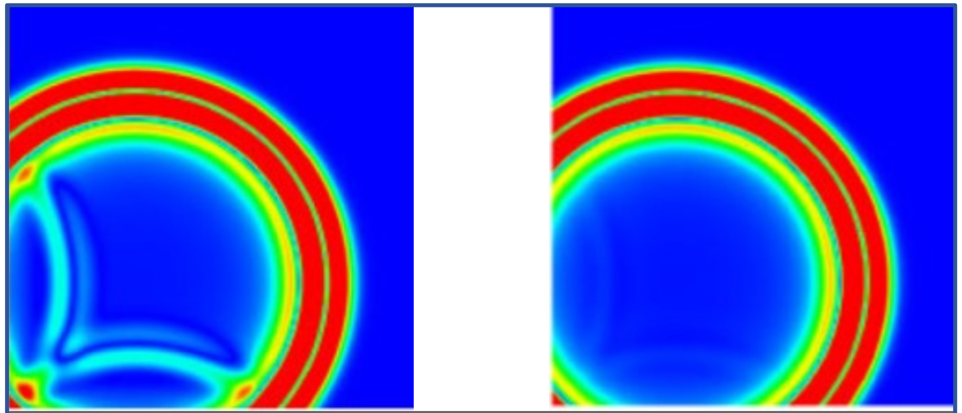
Model large-scale structures under earthquakes

APPROACH

Efficient methods to capture dynamic interaction between soil and structure; use elastic wave equation, finite element methods, computational science

IMPACT

Better design of earthquake-resistant structures



Reduction of spurious reflections through new absorbing boundary conditions

GOAL

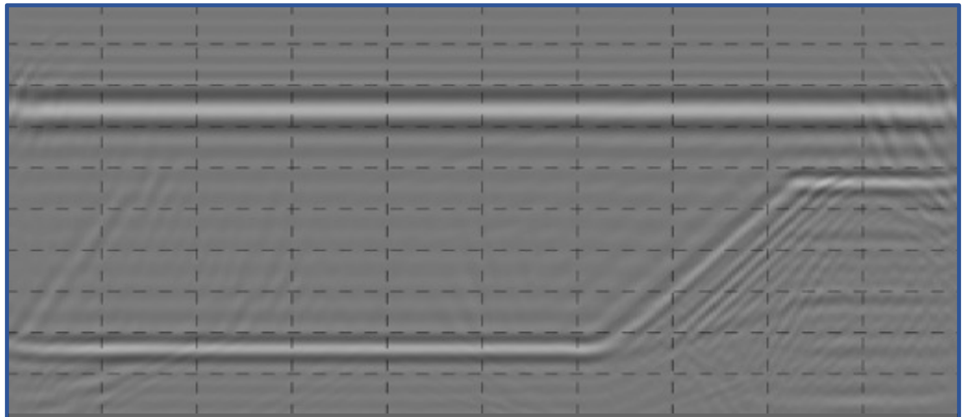
Detecting hidden objects by exciting the surface using high-frequency waves

APPROACH

Special imaging algorithms; newly developed equations (one-way wave equations)

IMPACT

Crack detection, mapping oil reservoirs, medical imaging



Predicted substructure of a valley using the new imaging algorithm

Sequestering Carbon in Concrete

GOAL

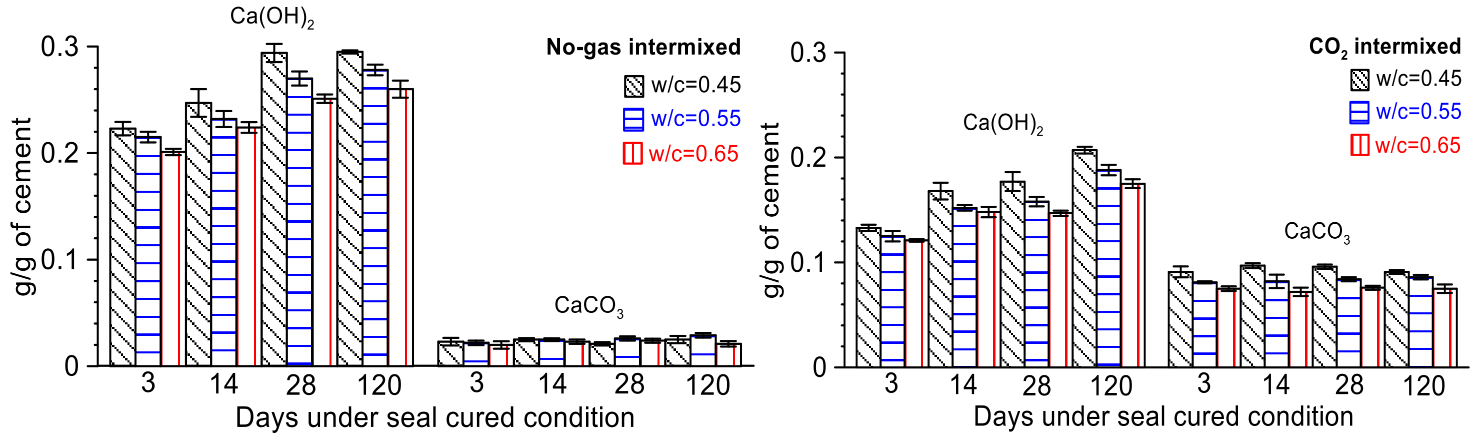
Ca(OH)2 is a secondary hydration product of cement that is unstable and is contributor to many durability problems

APPROACH

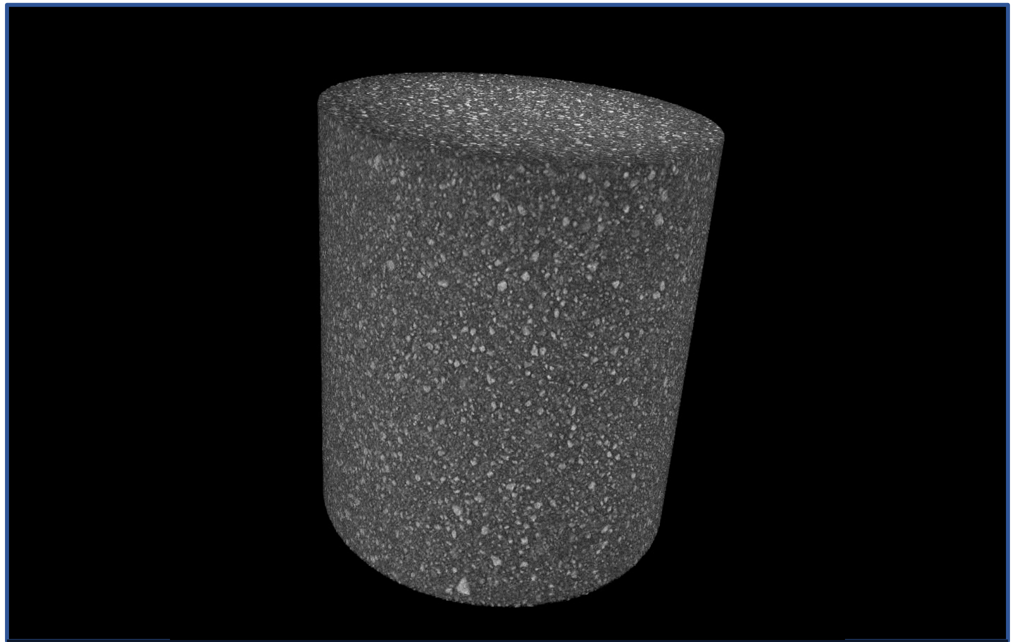
$Ca(OH)_2$ reacts with CO_2 forming $CaCO_3$ which is stable, sequestering carbon and improving concrete performance

IMPACT

The production of Portland cement is energy intensive and results in CO_2 liberation; we put some of the CO_2 back in concrete and make it more durable



Reduction in $Ca(OH)_2$ and increase of $CaCO_3$ in CO_2 intermixing concrete



X-ray CT showing distribution of $CaCO_3$ (bright particles)

Quantifying the Rate of Transport of Volatile Organic Compunds (VOCs) through Concrete

ISSUE

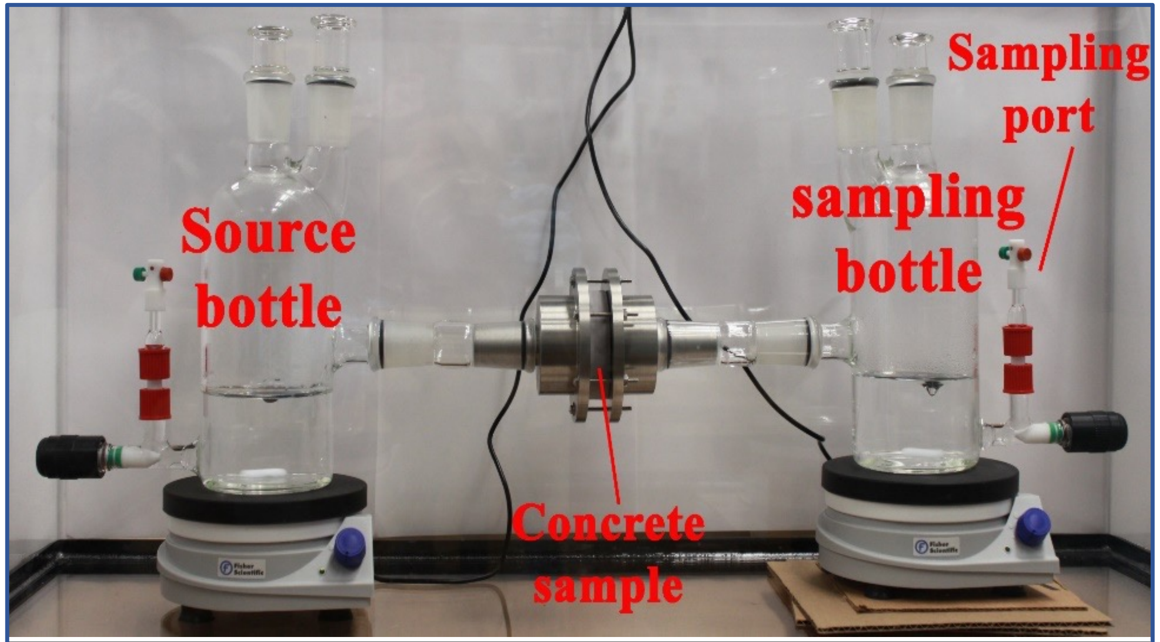
At times, subsurface utilities including water and/or drainage pipes need to be installed, in soil and groundwater that are contaminated with VOCs

APPROACH

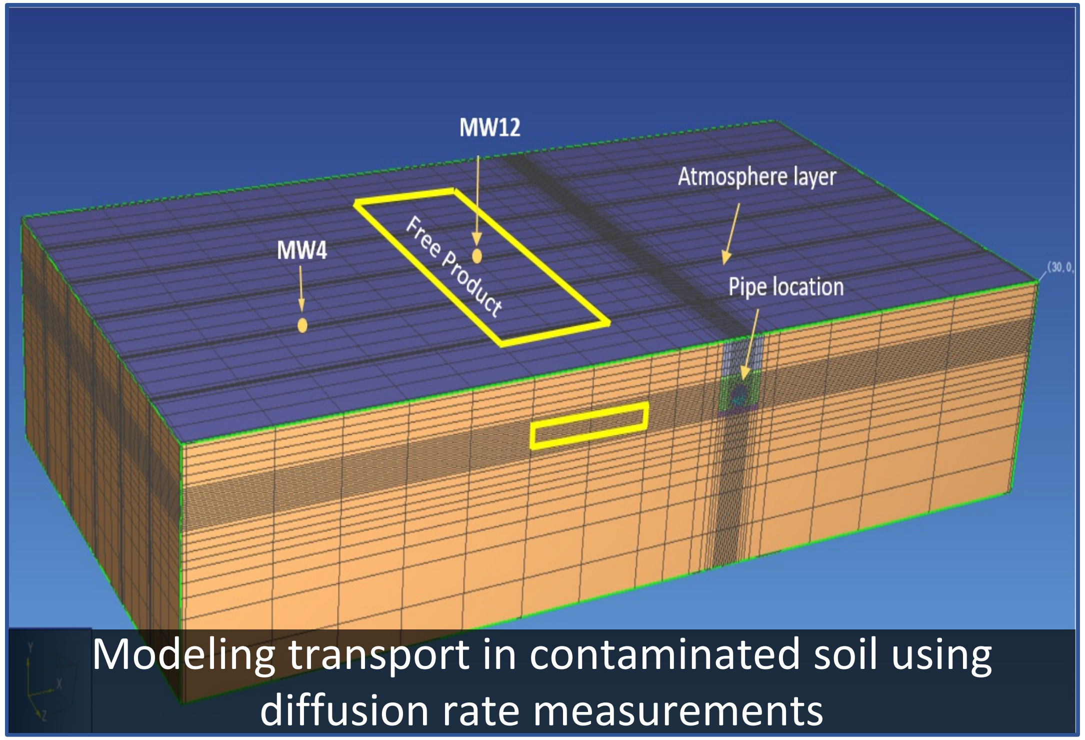
Quantifying the rate of transport of benzene and PCE through concrete and modeling transport; developing novel measurement techniques

IMPACT

Understand (1) how fast VOCs transport through concrete (2) whether their concentration poses any



New measurement techniques were developed to measure VOC diffusion rates



Modeling transport in contaminated soil using diffusion rate measurements

Non-Nuclear Imaging of Concrete

ISSUE

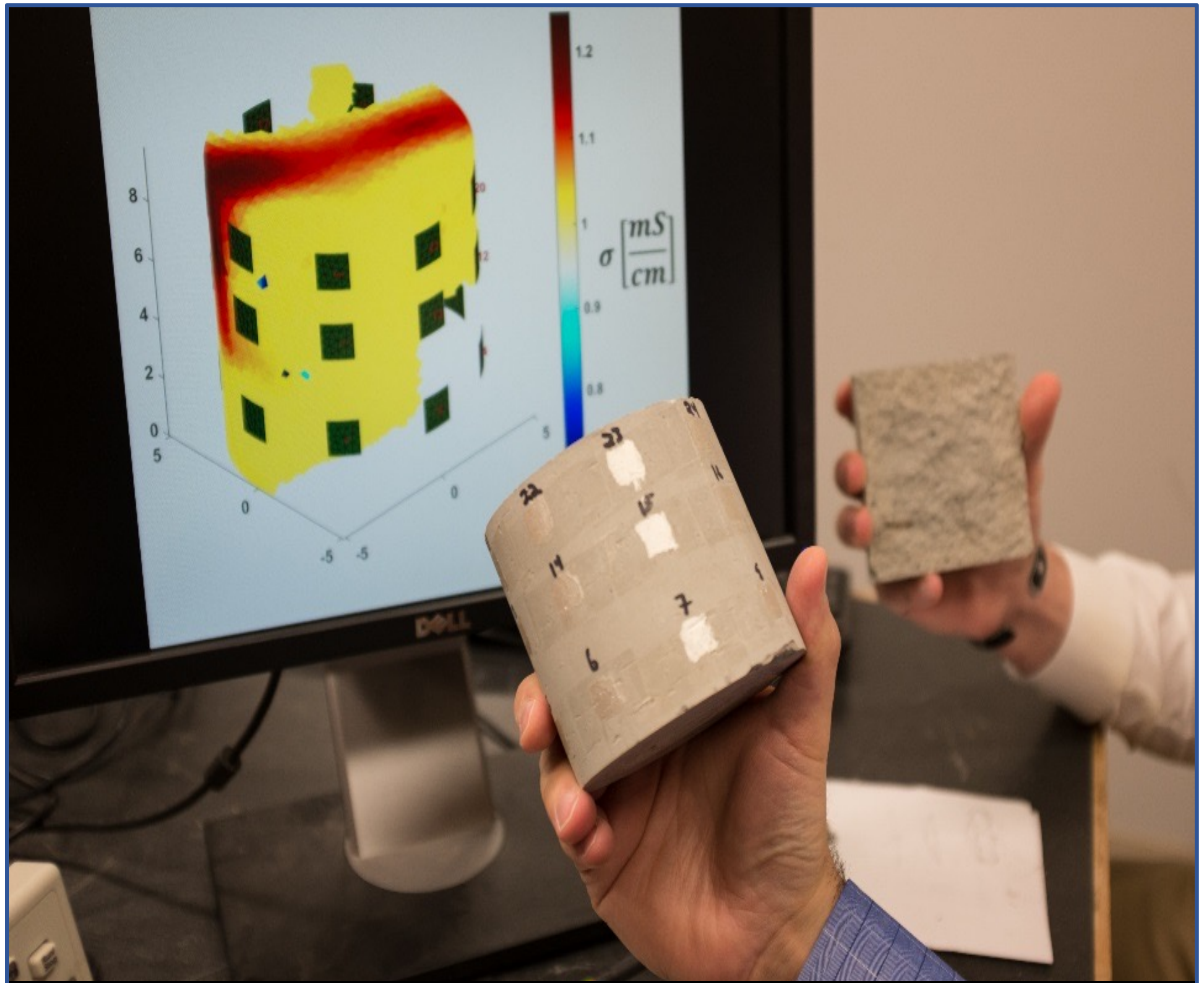
The resistance of concrete structures to the ingress of moisture and aggressive ions is considered a measure of their durability; methods for monitoring moisture ingress in concrete materials are needed

APPROACH

We use electrical conductivity imaging of concrete to quantitatively monitor moisture ingress in concrete materials with and without cracks

IMPACT

This method enables imaging concrete materials and potentially other porous media without the use of nuclear methods such a neutron tomography



Electrical conductivity image of cracked concrete showing preferential flow of water in the crack; also shown is the actual specimen tested

Organic Acid Attack on Concrete

ISSUE

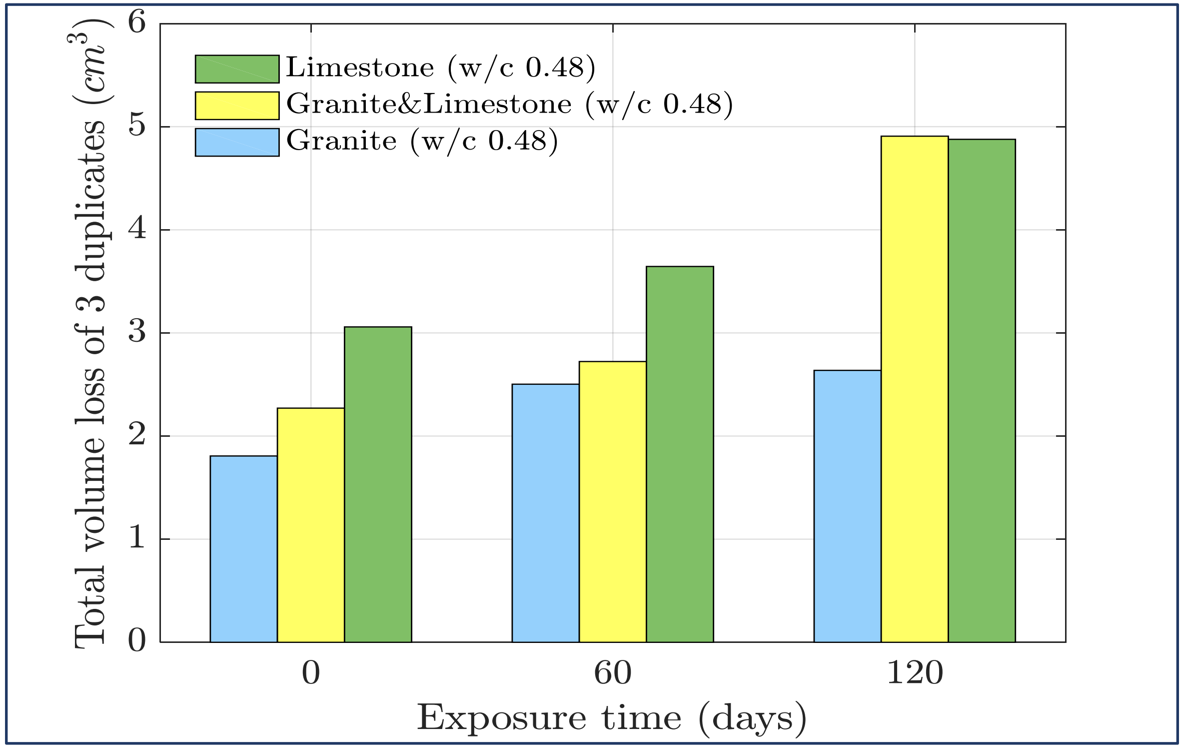
Premature deterioration of concrete overlays in waste transfer stations as a result of simultaneous exposure to leachate and mechanical abrasion

APPROACH

Understand factors contributing to the deterioration and resistance of concrete against organic acids and mechanical abrasion; develop design-for-durability specification

IMPACT

Provide owners and operators with data and tools that can be used to develop specifications and performance requirements to reduce the premature deterioration of concrete overlays



Porosity of the matrix and harness of aggregates are important in resisting acid and abrasion

Sequestering Carbon Underground

ISSUE

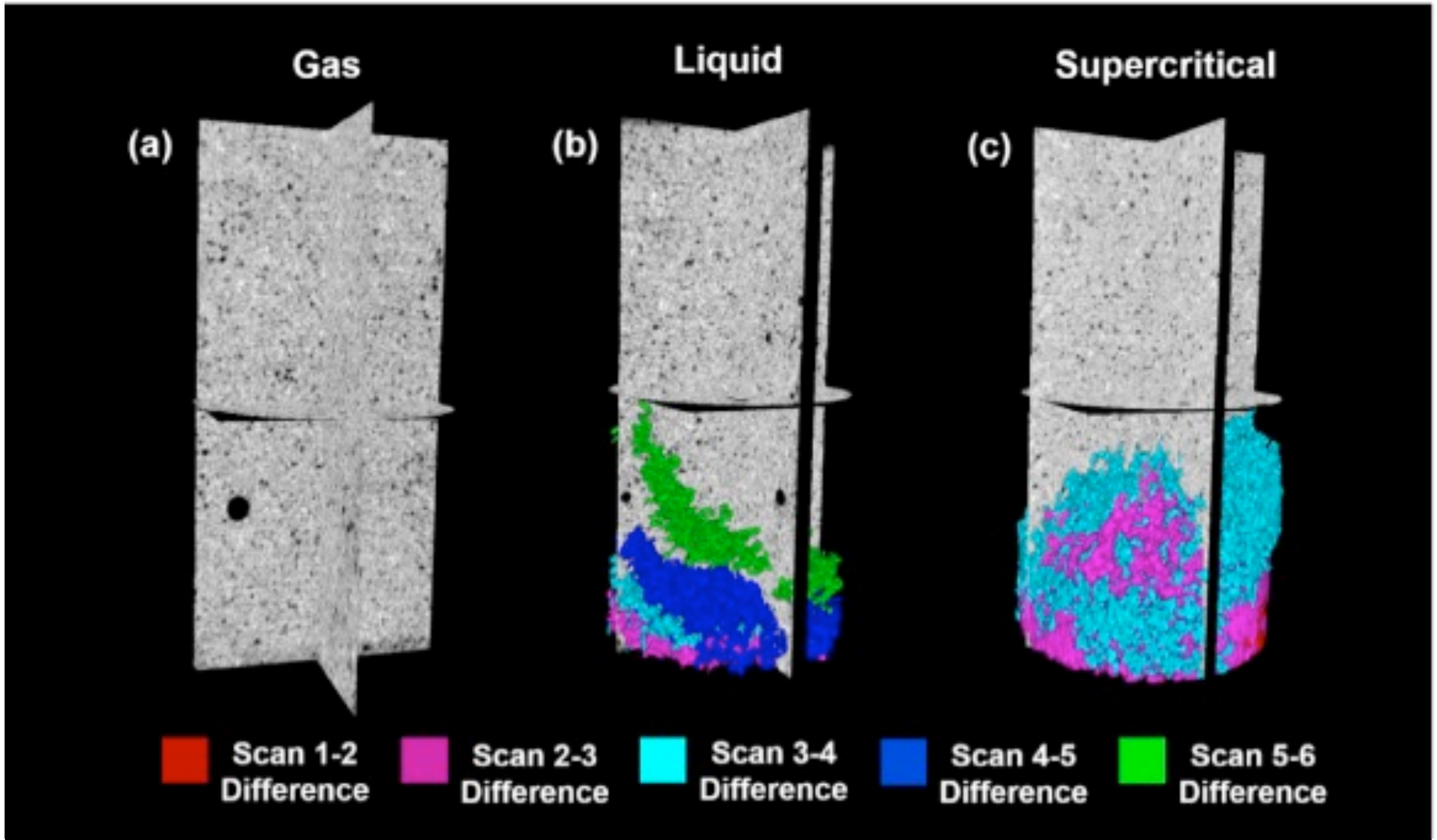
In below-ground structures (e.g., carbon sequestration wells), cement-based materials have the potential to be exposed to gas, liquid and supercritical CO2. How does this affect their microstructure and therefore their mechanical and durability performance?

APPROACH

Measure the effect of gas, liquid and supercritical CO_2 transport on cement-based materials by quantifying carbonate formation and phase dissolution

IMPACT

Provide an understanding of the rate of degradation of below-ground structures and the rate of release of sequestered carbon back into the atmosphere

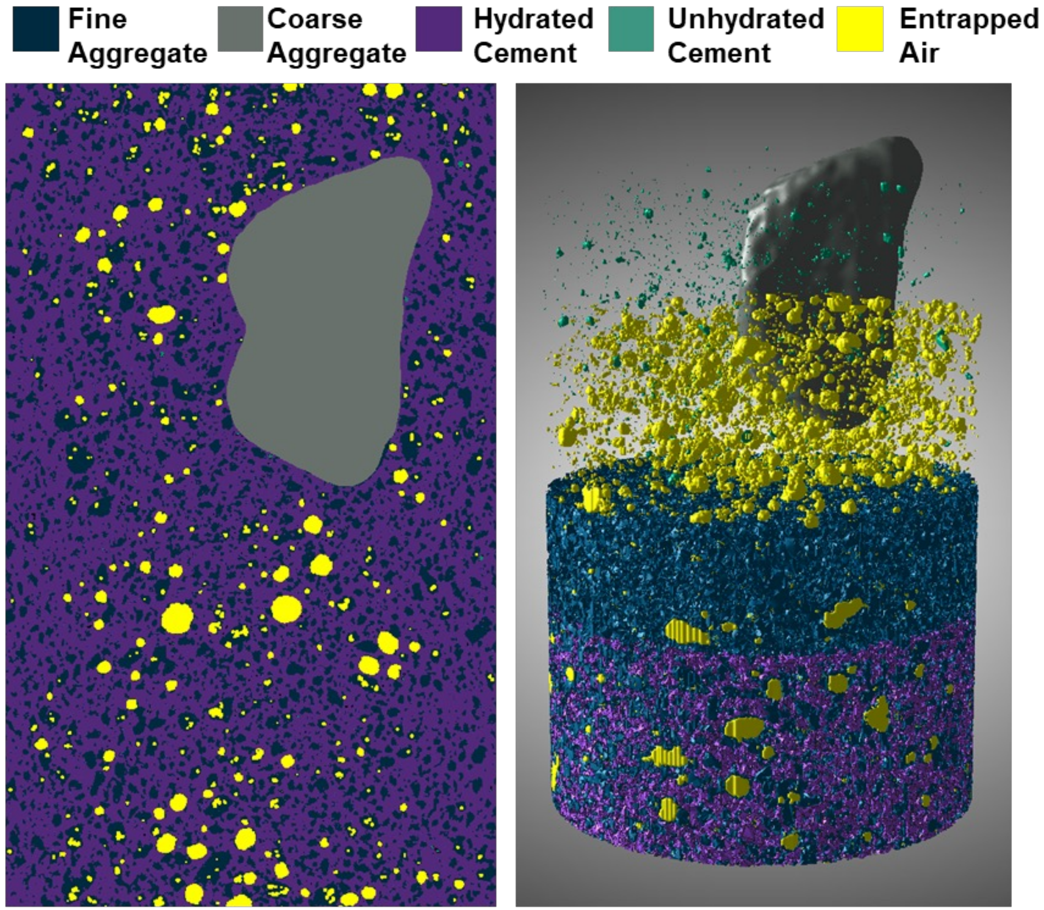


X-ray CT shows carbonates form in concrete when exposed to gas, liquid and supercritical CO2

Understanding the Role of Interfaces in Mass Transport

ISSUE

Interfaces in cement based materials influence the extent and rate of gases and liquids transport through these materials when used in carbon sequestration infrastructure. How do these interfaces contribute to the rate of transport?



APPROACH

Quantify the rate of gas and liquid transport in cement based materials using quantitative simultaneous X-ray and neutron tomography

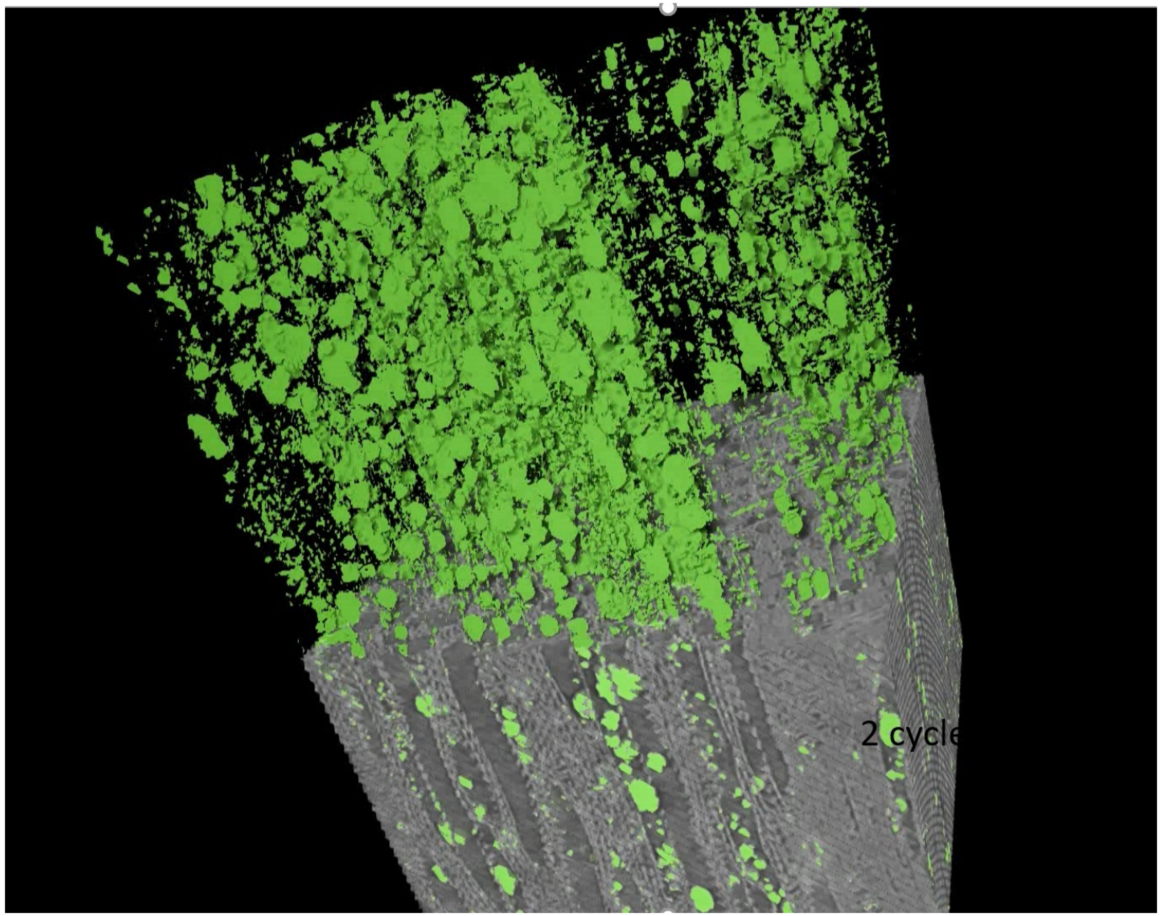
IMPACT

Understand the implication of interfaces and develop methods to manipulate their properties to control mass transport

Depositing Limestone in Wood

ISSUE

Approximately 92% of American homes built in 2021 were wood-frame structures and the estimated property loss to fires in was $8.4 billion; the number of reported civilian deaths was 2,580. Can we deposit stone in wood to make it more fire resistant?



APPROACH

Develop methods to despite calcium carbonate (limestone) in wood and measure its mechanical properties and fire retardancy.

IMPACT

Developing high performance wood materials with superior fire retardancy, termite resistance, and mechanical properties.

Asphalt Materials and Pavement Modeling

GOAL

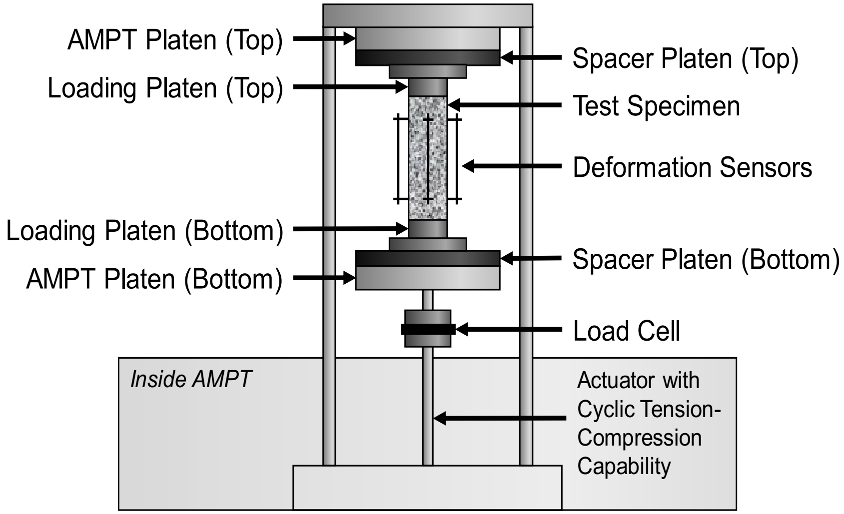
Develop test methods, mechanistic models, and software tools to predict the long-term performance of asphalt pavements under realistic loading and environmental conditions

APPROACH

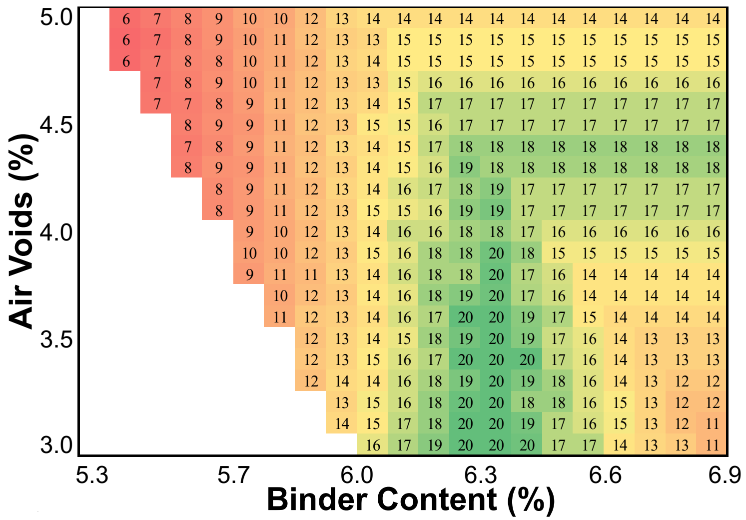
Laboratory testing, field observations, mechanistic and computational principles, and numerical simulation

IMPACT

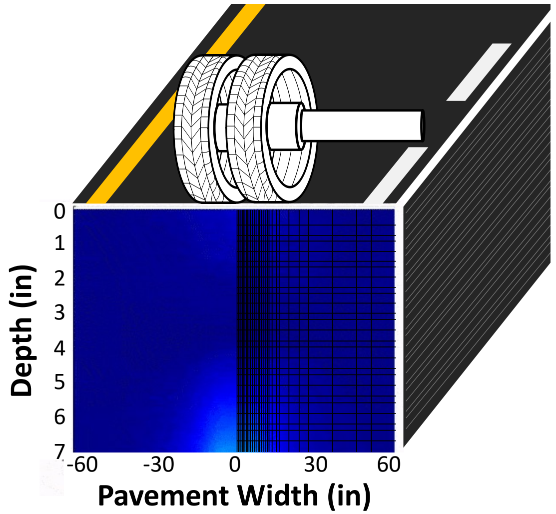
Seamless integration of asphalt mixture design, pavement design, and highway construction specifications



Laboratory test setup to characterize the fatigue cracking behavior of asphalt concrete



Pavement life as a function of asphalt mixture volumetrics (binder content, air void content, and gradation)

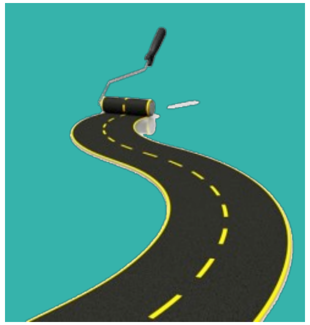


Damage evolution with time of a pavement cross-section due to repeated traffic and climatic loading

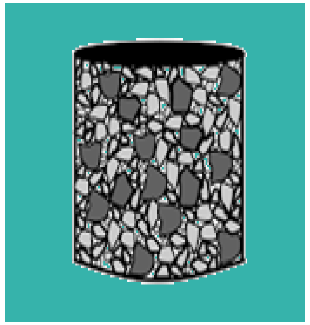
Sustainable Pavements

Selection Criteria for the type and dosage of RAs

Standard test methods to characterize RAs



Long-term benefits of using RAs (considering aging)



Performance evaluation criteria of RAs in asphalt mix

Standard blending protocols for RAs in asphalt mix

Long-term economic benefits on the use of RAs

GOAL

Increase the use of recycled asphalt materials in new pavements by employing recycling agents (RAs)

APPROACH

Dosage selection, material characterization, mechanistic and statistical modeling

IMPACT

Sustainable roads made from recycled asphalt materials that are long lasting with acceptable performance

Carbonate Formation in Concrete during CO_2 Ingress

ISSUE

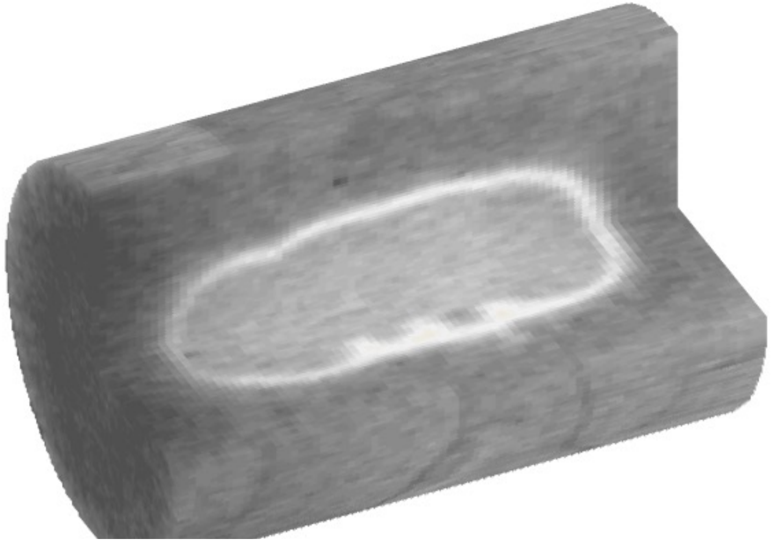
Carbonate formation in cement-based materials during CO_2 transport results in the formation of $CaCO_3$, altering transport properties of cement-based materials. Advanced characterization methods are needed to understand the kinetics of reaction

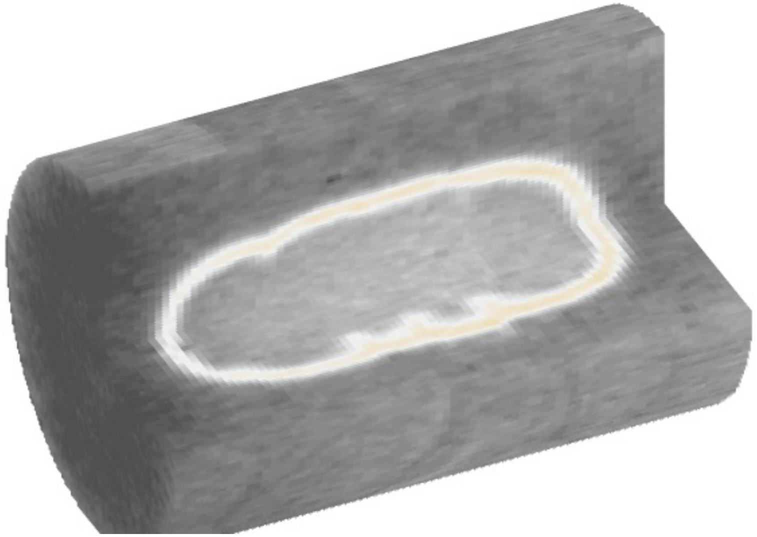
APPROACH

Quantitative X-ray tomography methods are developed to monitor the formation of a carbonate shell and its impact on multiphase flow

IMPACT

Understand the conditions that promote formation of carbonates and how carbonates alter the rate of ingress of fluids in concrete; this has implications on design of underground carbon sequestration technologies





Formation of carbonate shell in cement-based materials during transport of CO_2

Material Modeling and Simulation for Energy, Aerospace and Automobile Industries

GOAL

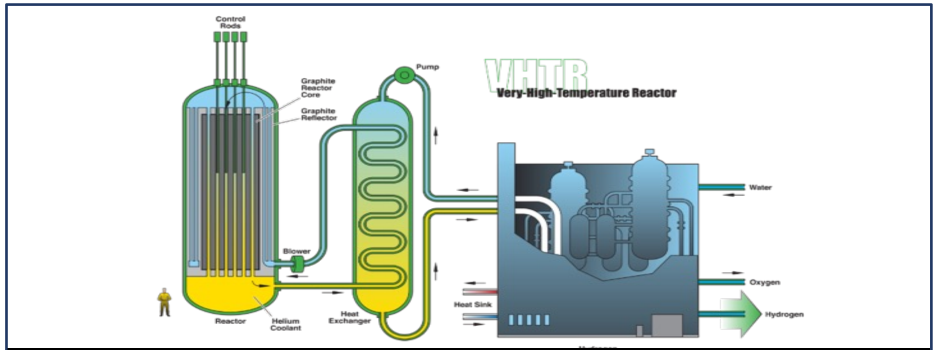
Increased operating temperature increases energy efficiency of machines and plants

APPROACH

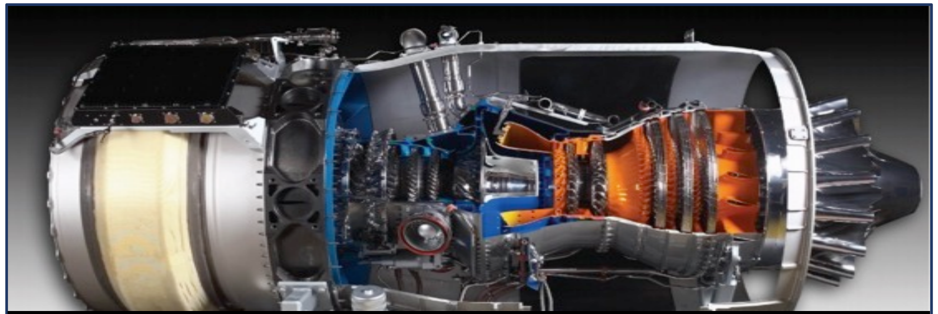
Develop advanced material model for simulation based structural design and analysis

IMPACT

Economy and sustainability of high-temperature industries and systems



Next generation nuclear power reactor



Gas turbine jet engine

Superheater boiler header

Multiaxial Miniature Testing System for Advanced Material and Engineering Research

GOAL

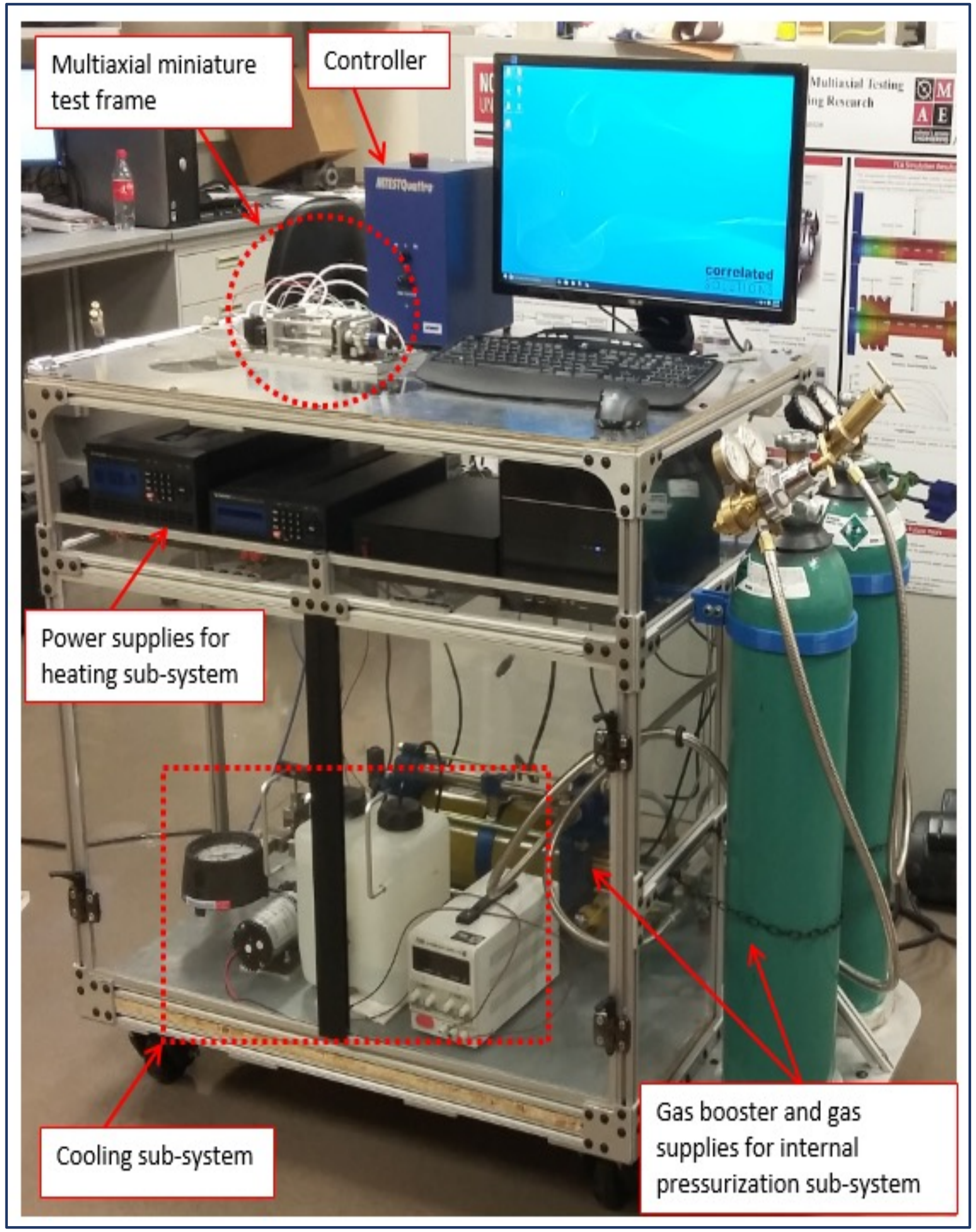
Develop a testing system capable of performing elevated temperature multiaxial tests inside a scanning electron microscope

APPROACH

A team of investigators from various disciplines and industry experts designed and developed the system

IMPACT

Efficient and economic design of new materials and high-performance components



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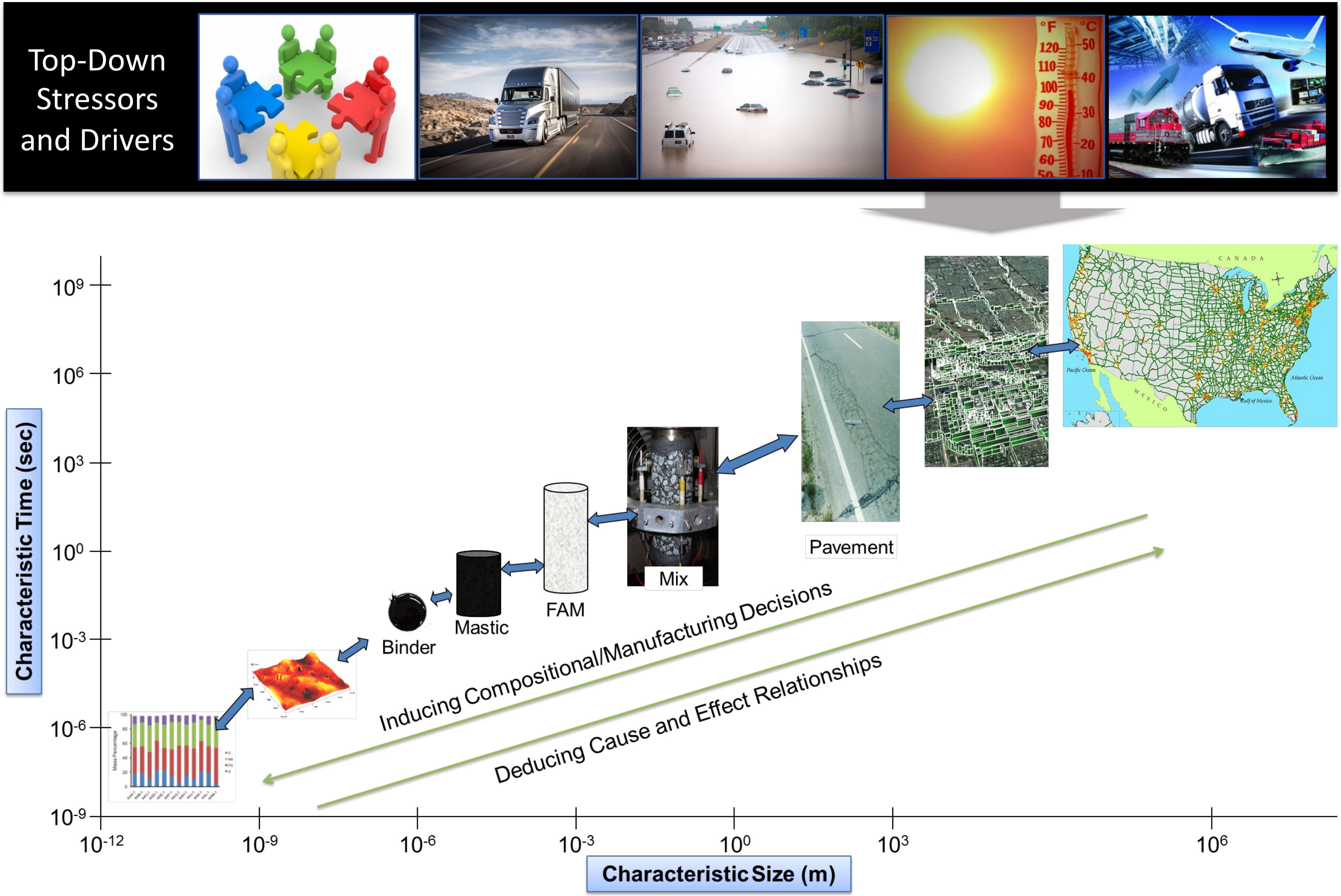
Transportation Materials

NCSU Perspective on Pavement Research



Asphalt Binder and Mixture Testing

GOAL

Develop efficient test methods to characterize the behavior of asphalt binder and mixture

APPROACH

Apply mechanistic principles and advanced techniques

IMPACT

Improved efficiency and accuracy of test methods in predicting material behavior under various conditions; allow the seamless integration into pavement structure models

Asphalt Mixture Performance Tester

Bitumen Bond Test

Direct tension fatigue test

Asphalt Mixture Performance-Related Specification (AM-PRS)

GOAL

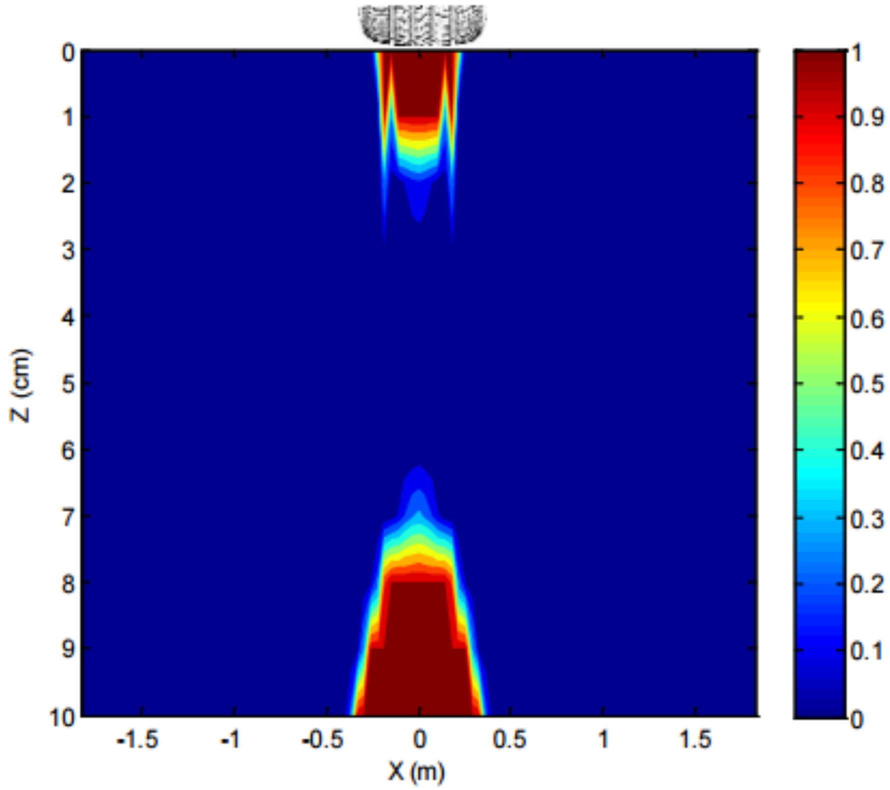
Develop PRS for asphalt mixtures for design-build projects, warranty projects, and estimating penalty-bonus factors

APPROACH

Integrate asphalt mixture performance test results into pavement structural model to assess how deviations in materials and construction properties affect pavement performance

IMPACT

Improved condition of the largest investment in civil infrastructures in the U.S.; asphalt pavements



Pavement Performance Prediction

Performance Testing

Specifications for Asphalt Emulsions Used in Preservation Surface Treatments (PSTs)

GOAL

Develop PRS for asphalt emulsions used in preservation surface treatments

APPROACH

Identify binder properties that correlate to critical preservation surface treatments performance thresholds

IMPACT

Improved selection of asphalt emulsions in preservation surface treatments, preventing premature failure

Biorenewable Alternative to Asphalt

GOAL

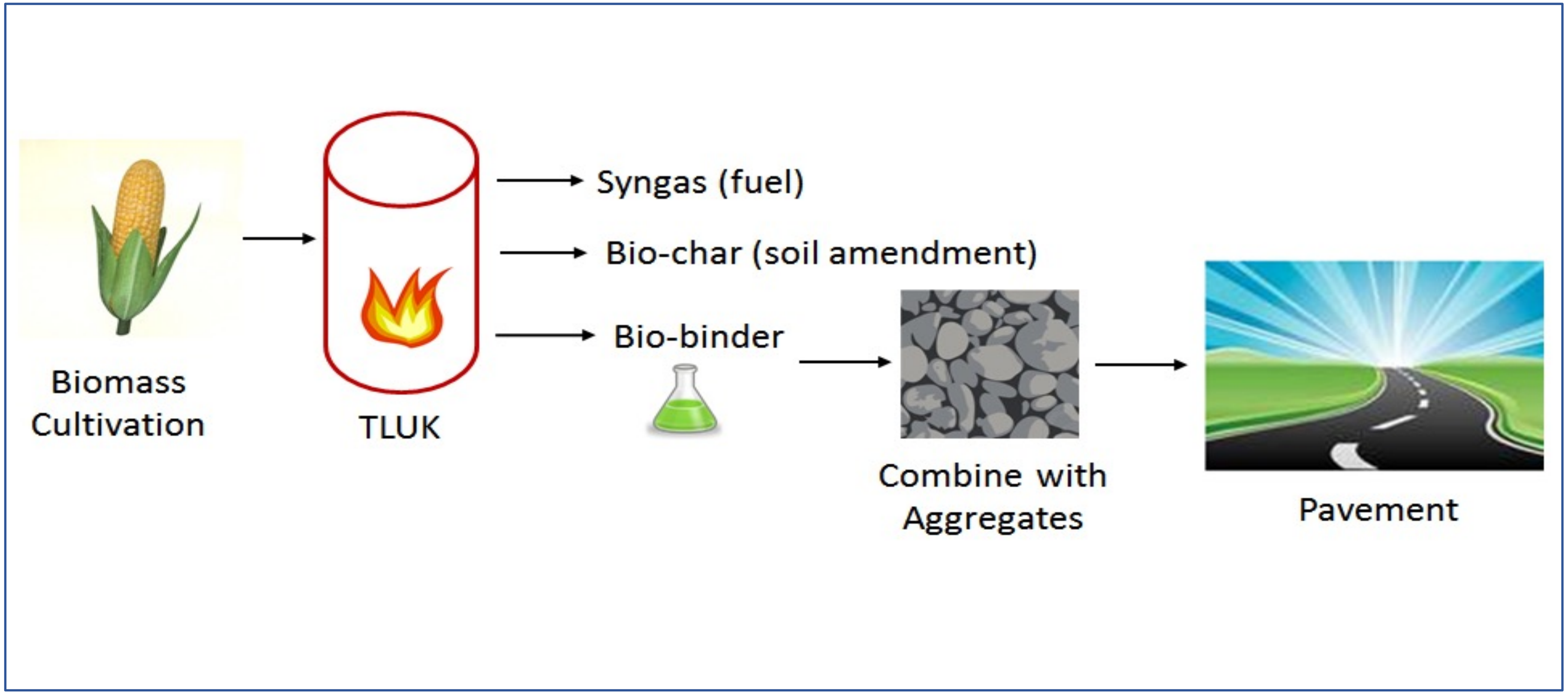
Produce sustainable alternative to petroleum-based asphalt binder

APPROACH

Produce biorenewable bio-binders through Top-Lit Updraft Kilning (TLUK) of biomass

IMPACT

Biorenewable alternative to asphalt; 30 millions tons of asphalt consumed annually in the U.S. to support transportation infrastructure



Asphalt Mixture Performance-Related Specification (AM-PRS)

GOAL

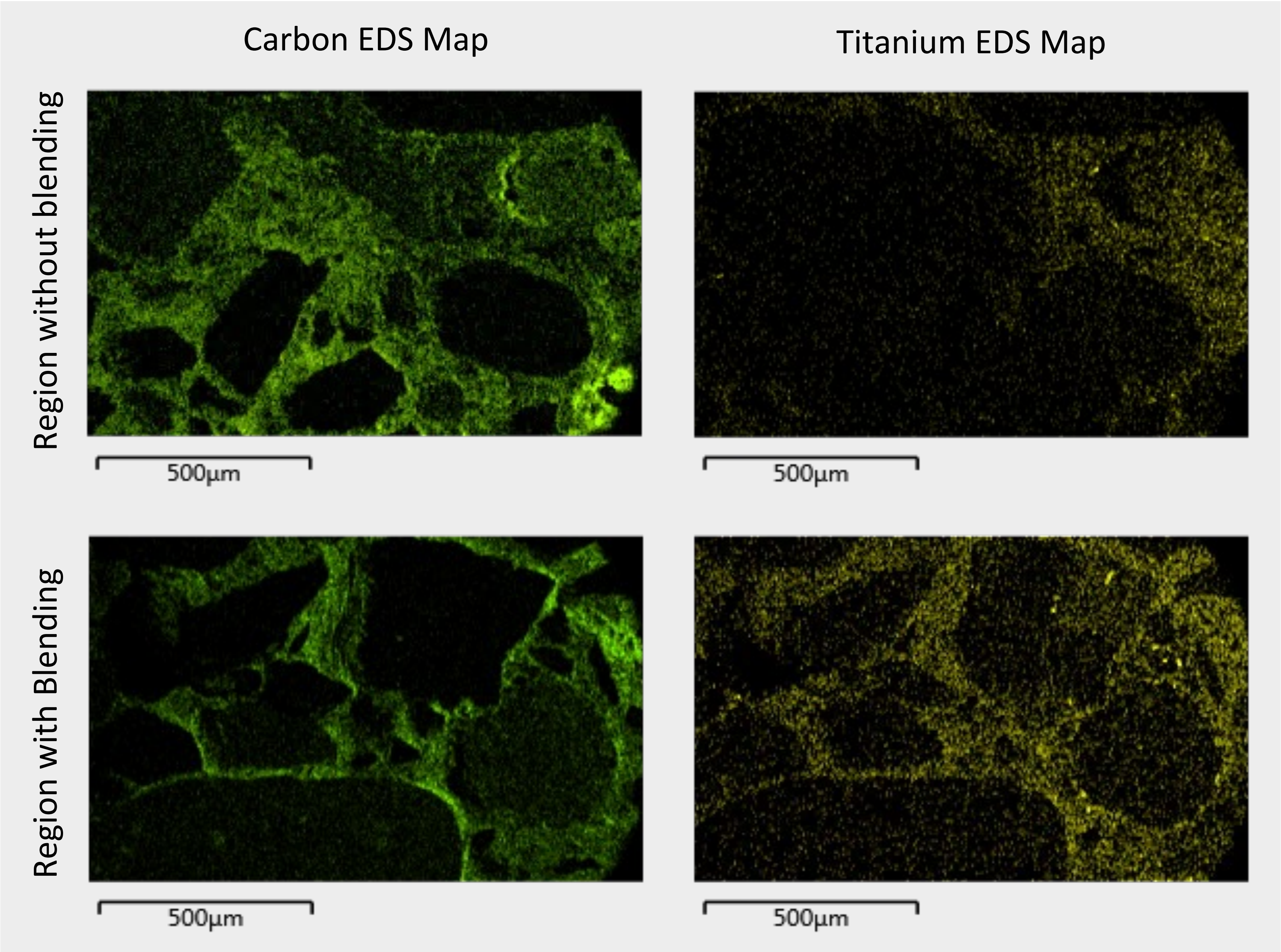
Develop high reclaimed asphalt pavement (RAP) mixture designs based on better understanding of RAP binder blending

APPROACH

Carbon and Titanium Energy Dispersive Spectroscopy (EDS) map of RAP mixtures using Scanning Electron Microscopy (SEM)

IMPACT

Improved understanding of RAP binder blending and high RAP mixture design



Safety of Earthen Storm Water Infiltration Best Management Practices (BMP)

Example Simulation

GOAL

Develop design guidelines for soil amendments that increase stormwater infiltration without negatively affecting roadside safety

APPROACH

Identify the effect of soil amendments on soil strength and use these findings to simulate rollover potential with computer simulation

IMPACT

Improved stormwater management without negatively affecting traveler safety

Calibration of Structural Layer Coefficients for North Carolina Pavements

GOAL

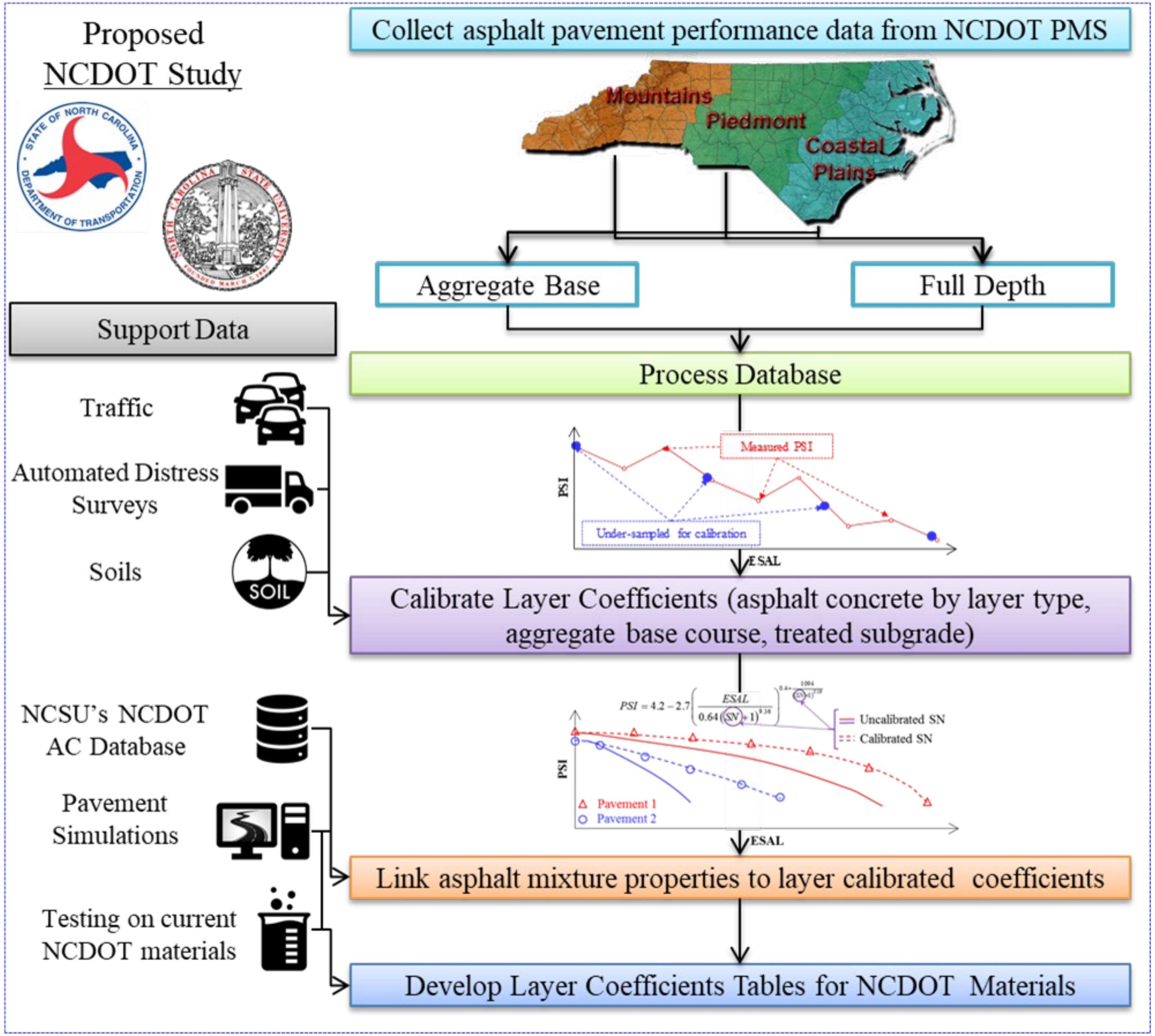
Develop updated design standards for NCDOT pavement design that more accurately reflect modern materials

APPROACH

Identify performance of existing asphalt pavements; characterize current NCDOT materials; conduct advanced pavement performance simulations to update standards

IMPACT

Improved material consideration will reduce costs and increase longevity of pavements in the state



Improvement of Quality Control of Asphalt Emulsion Application

GOAL

Develop improved field-testing framework for quality control of asphalt emulsion placement in tack coats and chip seals

APPROACH

Evaluate construction variability in emulsion application and quantify pavement emulsion absorption rates in field projects throughout North Carolina using the Tack Lifter

IMPACT

Improved quality control of emulsion application will extend pavement life and decrease life-cycle costs

Performance Evaluation of Geosynthetic Paving Interlayers

GOAL

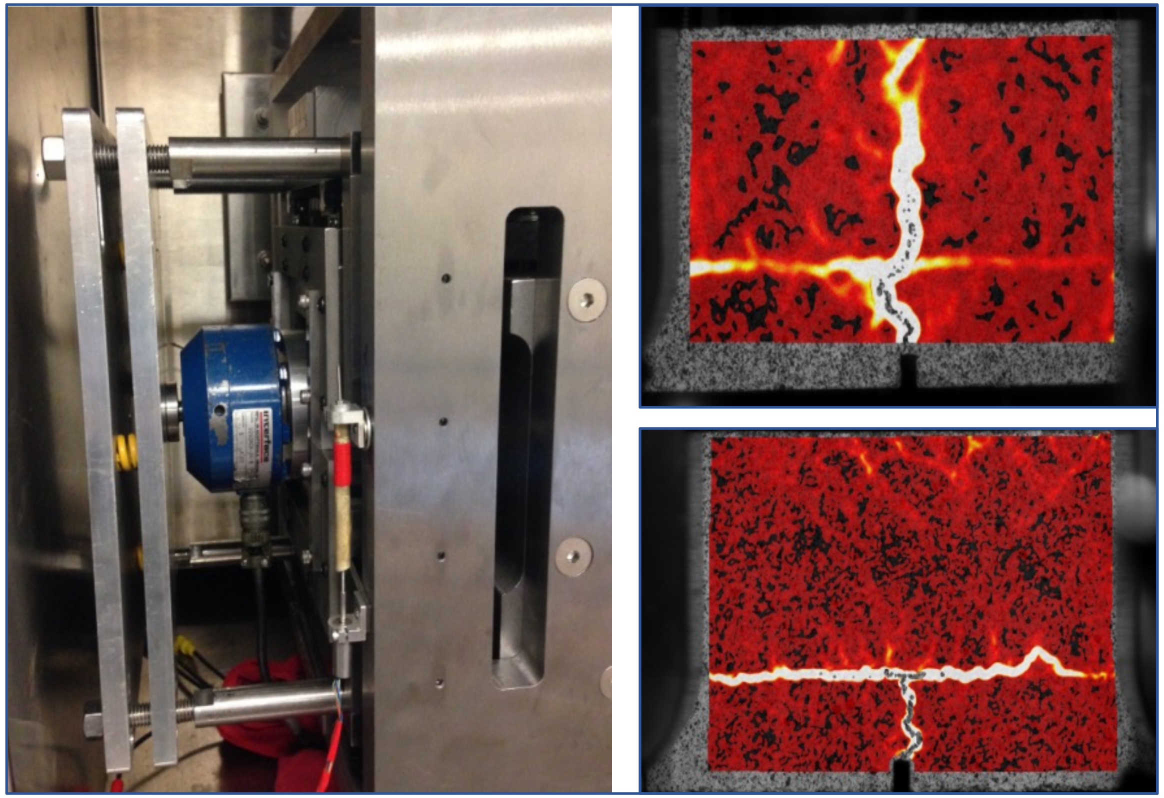
Develop performance testing methodologies and performance criteria for geosynthetic interlayers

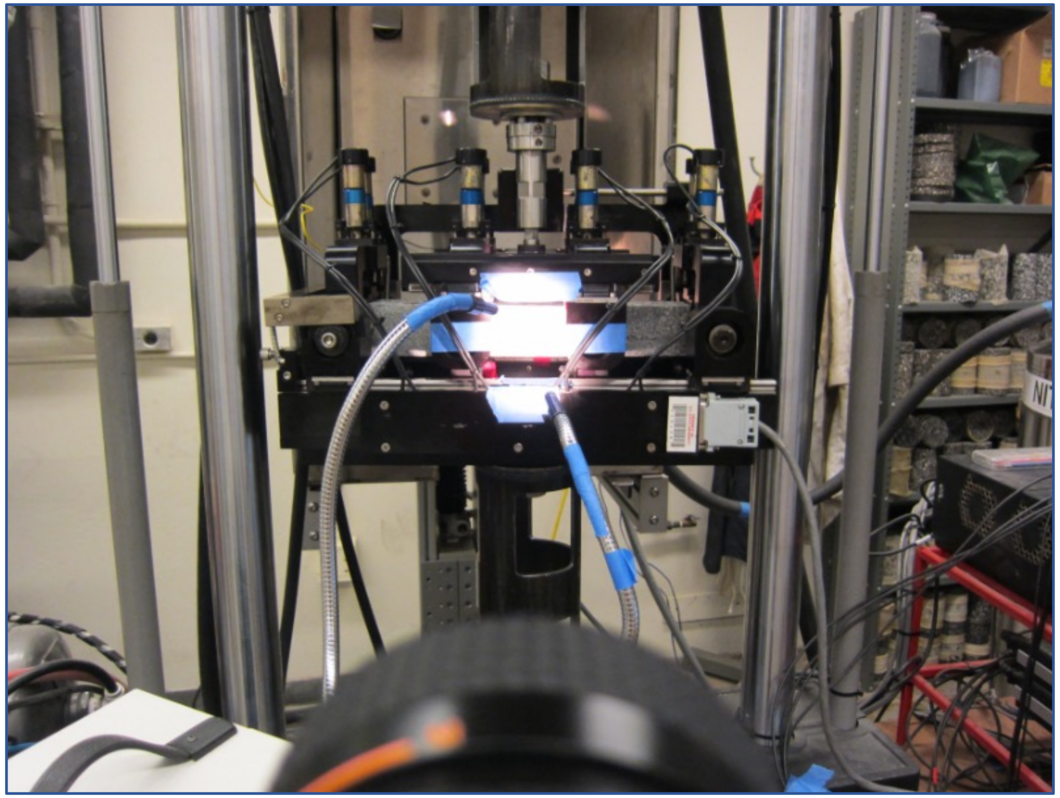
APPROACH

Evaluate reflective cracking and delamination potentials of AC specimens reinforced by geosynthetic interlayers using four-point bending notched beam fatigue test with DIC and MAST

IMPACT

Geosynthetic interlayer specifications and product selection guidelines for NCDOT based on performance tests





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Transportation Systems: Sustainability

Transportation Systems: Sustainability

GOAL

Achieve sustainable operation and funding and minimize the negative environmental impacts of transportation activities

APPROACH

Improvements in transportation technology, policy, and operational control in tandem with capacity investments to improve productivity, efficiency and sustainability

IMPACT

Industry practice, economic development, land use planning, environmental quality, travel time reliability, safety, and fiscal viability

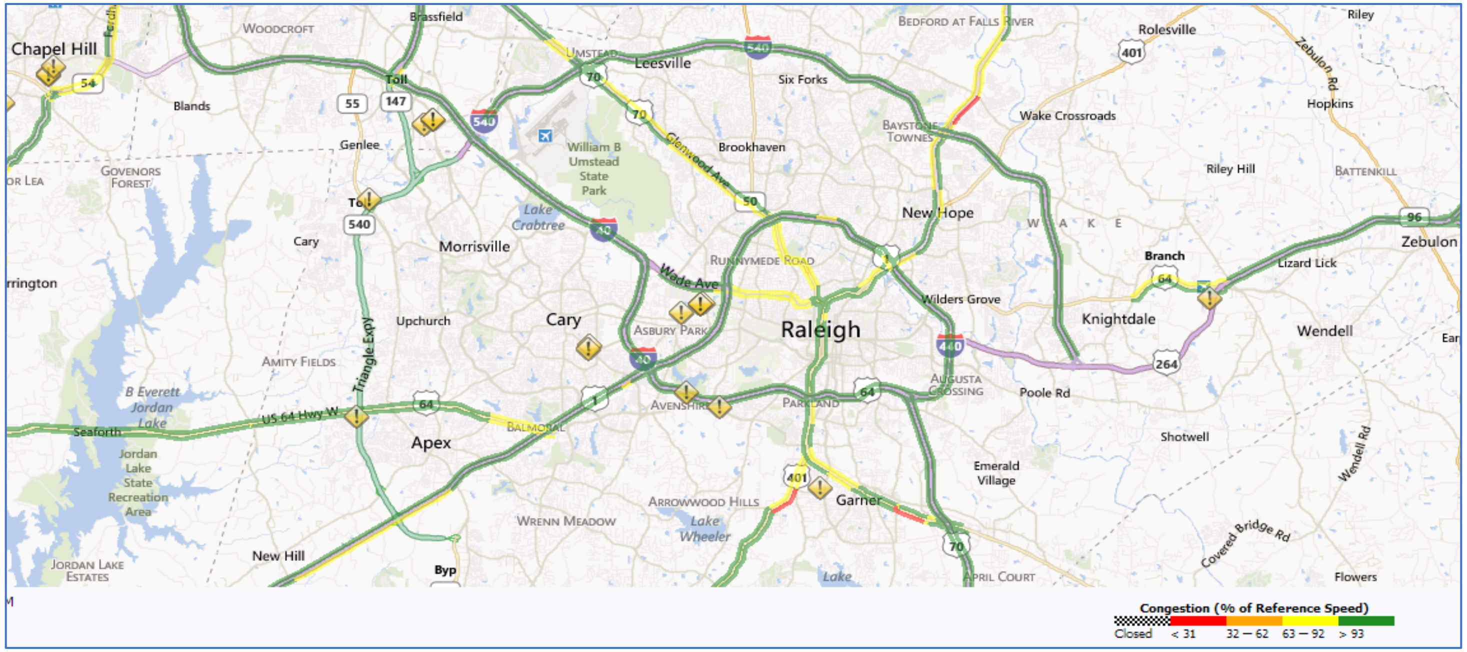
METHODS

- System Operations
- Environmental Impacts
- Design Innovations
- Impact Assessments: Economic and Socioeconomic
- Large-scale System Optimization

Close relationship with the Institute for Transportation Research and Education

itre.ncsu.edu/

System Operations



GOAL

Maximize system productivity and efficiency

APPROACH

Improvements for system monitoring, management and planning

IMPACT

- Connected vehicle research
- Highway Capacity Manual procedures
- National guidebook for transportation system simulation
- National guidebook for travel time reliability monitoring
- Operational efficiency and pedestrian safety for roundabouts
- Work zone practice

METHODS

- Data from connected, autonomous and other probe vehicles
- Simulation and optimization
- Model and tool building
- Guidebook development

Traffic Control with Automated Vehicles

GOAL

Advance real-time traffic control in large-scale transportation networks with enhanced system information connectivity and automated vehicles

APPROACH

Develop distributed techniques for traffic system monitoring, management and planning

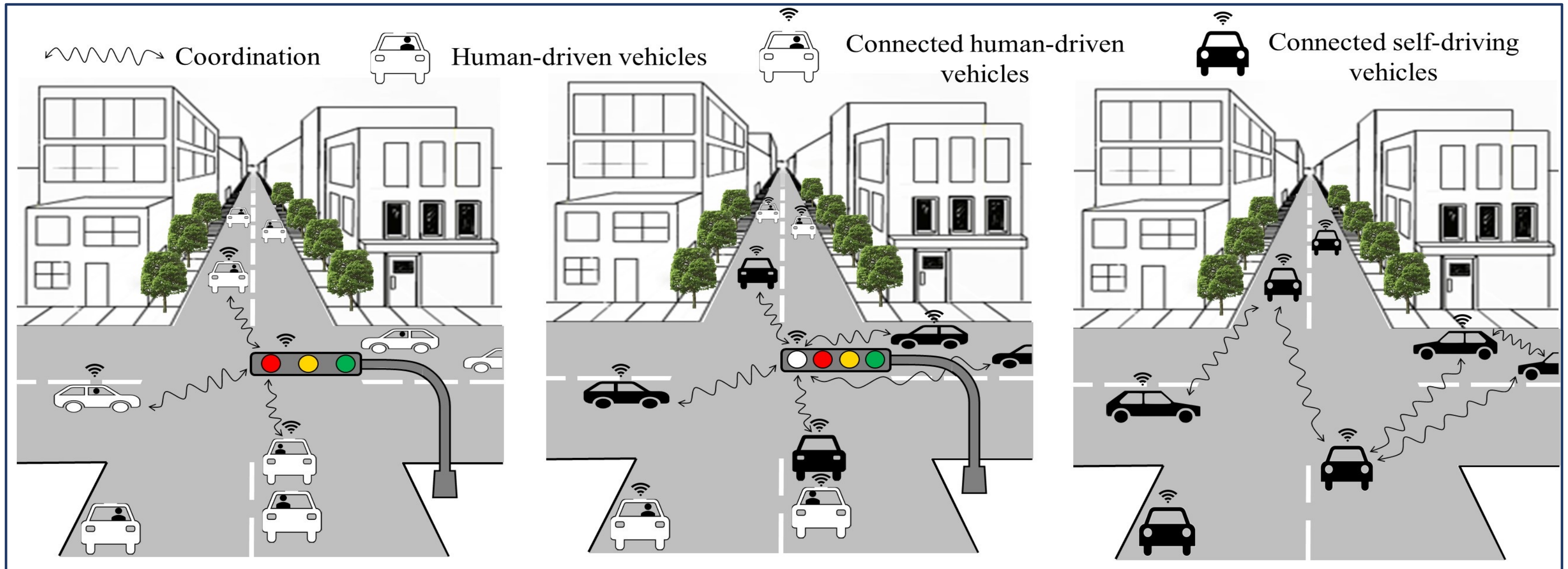
IMPACT

Improvement in:

Traffic operations
- Safety
- Environment

METHODS

- Modeling
- Optimization
- Data analysis
- Simulation



Intersection control with a mix of connected and unconnected human-driven vehicles

Intersection control with “**White Phase**” for a mix of connected human-driven & connected self-driving vehicles

Signal-free intersection control with connected self-driving vehicles

Environmental Quality

GOAL

Maximize the energy efficiency of transportation activities, minimize the negative impacts (e.g. fuel consumption, emissions of greenhouse gases and other pollutants), both passenger and freight

APPROACH

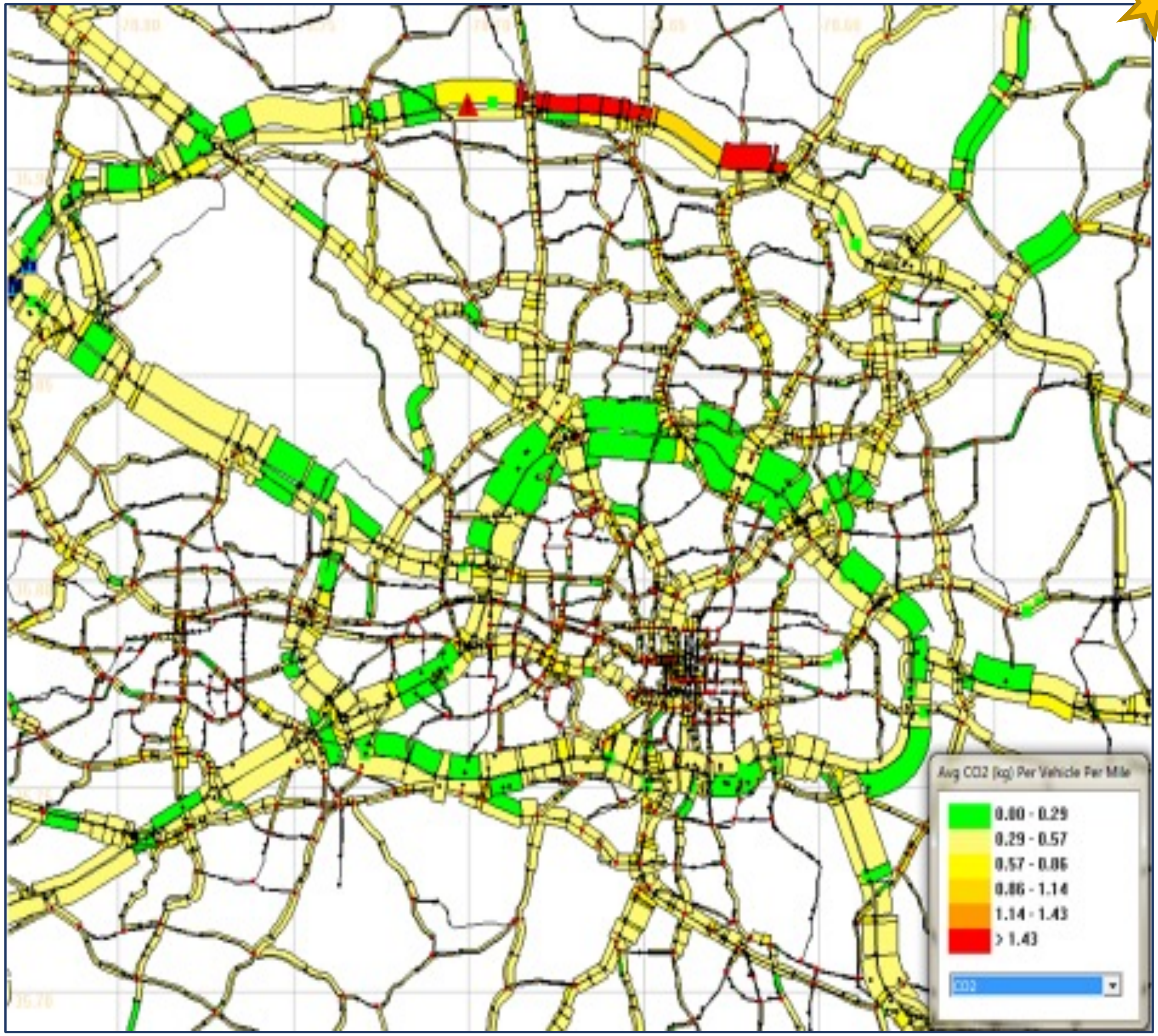
Monitor and model transportation networks to identify hotspots in both temporal and spatial dimensions

IMPACT

- Regional emissions modeling (EPA)
- Environmental impacts of intelligent transport systems
- Environmental-focused model calibration
- Trade-offs of safety and environmental objectives

IMPACT

- Multiscale simulation modeling
- Empirical data collection
- High resolution in-vehicle sensing



Coordination with Economic Growth

GOAL

Foster economic prosperity through coordinated transportation investments (MAP-21)

APPROACH

Focus on freight productivity and efficiency as well as personal mobility

IMPACT

Recommended investment actions and policies that foster economic growth

IMPACT

- Economic impact analysis
- Input-output models
- Benefit-cost analysis
- Land use and transportation planning
- Modal and intermodal innovation

Design Innovation

GOAL

Consume less space per unit of capacity, provide better operational performance, reduce delays, enhance safety

APPROACH

Innovative design ideas

IMPACT

Documentation of facility performance, experimentation with innovative designs

METHODS

- Performance assessment tools and techniques
- Design concepts
- Analysis tools

Social Prosperity

GOAL

Enhance prosperity via policies and actions that provide mobility for all socioeconomic groups and foster efficiency and equity in transportation systems and land use

APPROACH

Study interdependencies between patterns of urban development and transportation systems and policies

OUR CONTRIBUTIONS

Policies and operational strategies that ensure equitable access to public transportation, social inclusion, improved quality of life, urban sustainability

METHODS

- Equitable transit-oriented development
- Quasi-experimental studies
- Spatial analysis and econometrics; policy analysis

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Water Resources Engineering

- Sustainable water resources development
- Urban water system planning and optimization
- Hydroclimatology, drought and flood management
- Water-quality modeling and forecasting
- Uncertainty quantification and reduction
- Integrated system analysis and risk assessment

Hydroclimatology and Water Management

GOAL

Improve water management practices by incorporating climate information

APPROACH

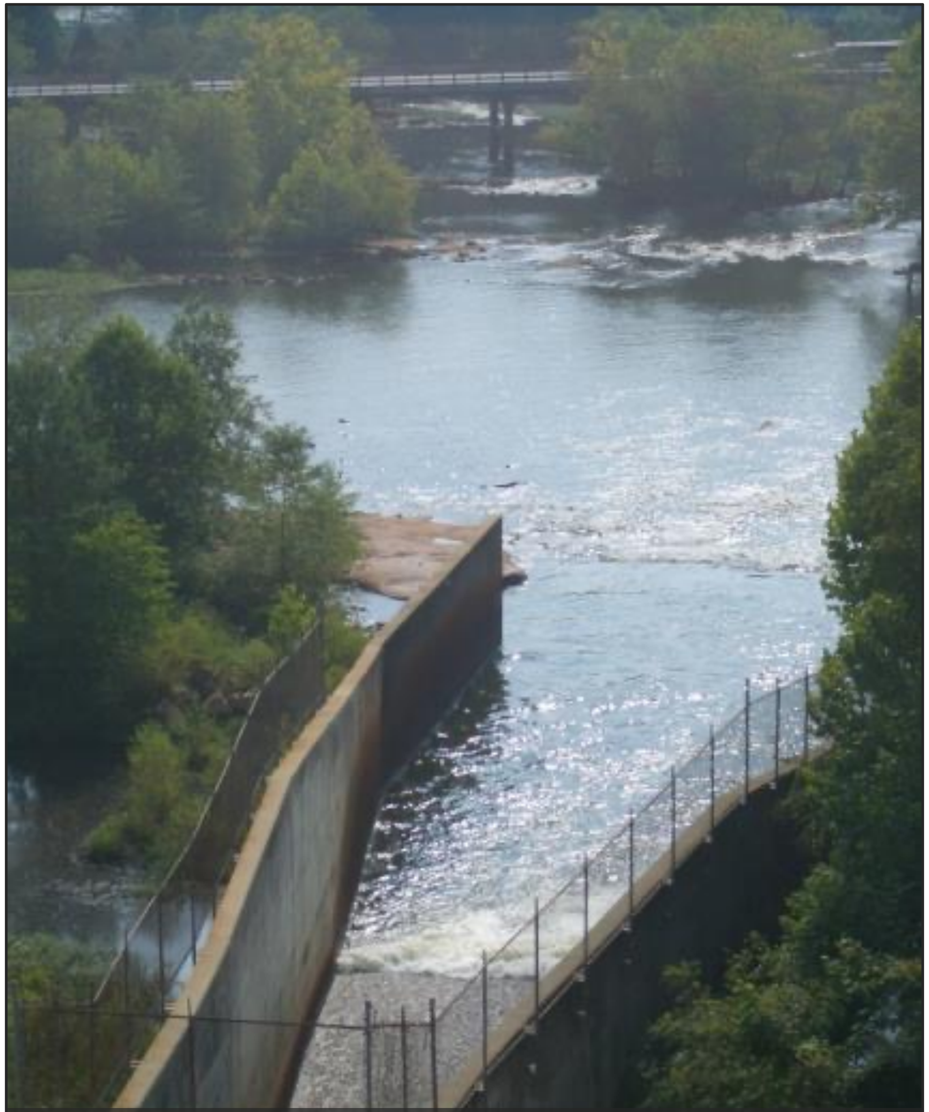
Innovative data fusion methods with statistical modeling and inference, and optimization

METHOD

Stochastic modeling, simulation, optimization

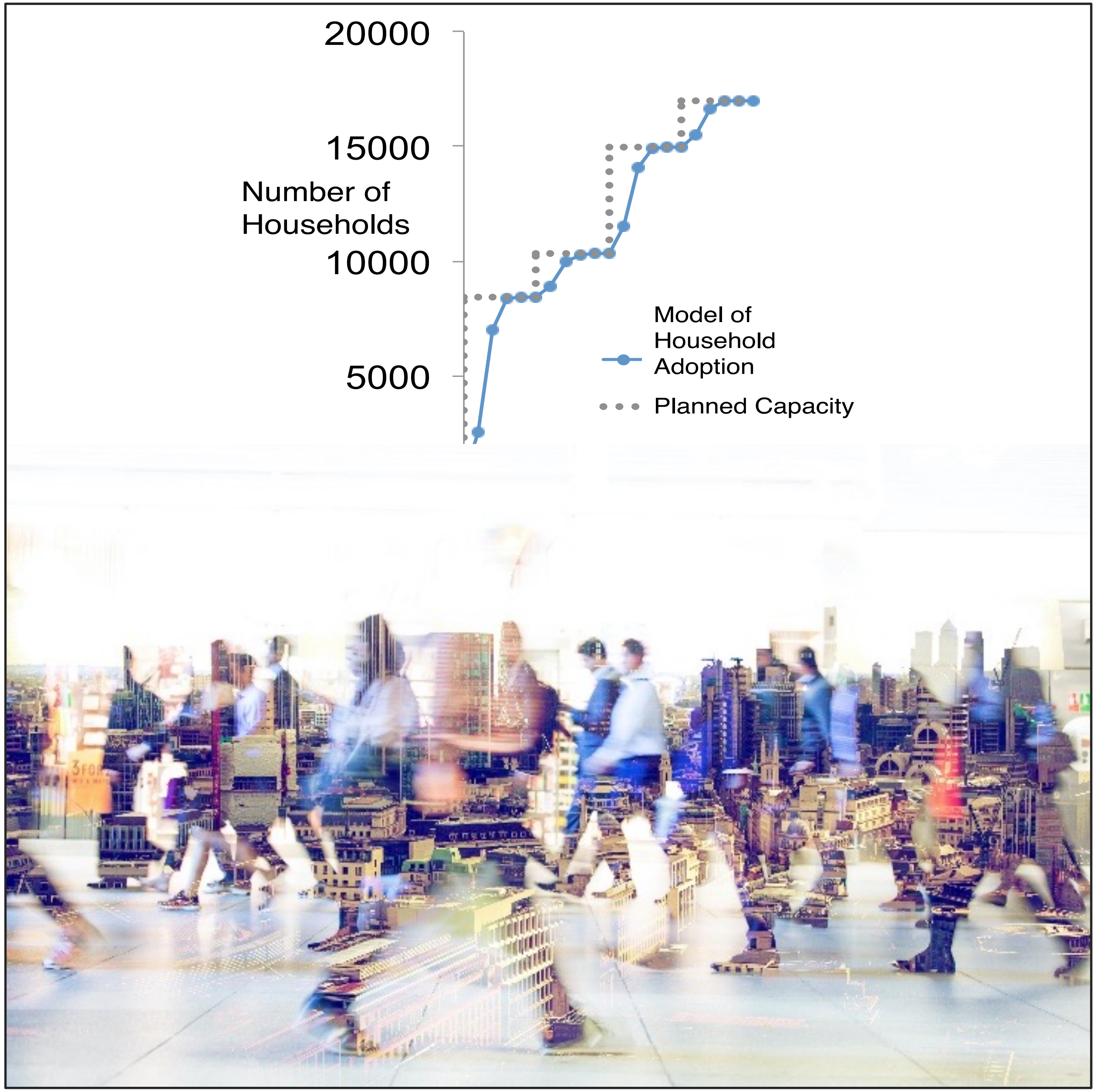
IMPACT

Improved water sustainability, flood and drought management, reservoir operation, hydropower management, water quality, and risk management



Climate Informed Drought Management at Falls Lake

Socio-Technical Systems Analysis for Planning Water Reuse Programs



GOAL

Novel modeling approach for how humans interact with infrastructure to improve engineering design and management policies

APPROACH

An adaptive model of diffusion of innovation coupled with infrastructure expansion plans; illustrative case application for Cary, N.C.

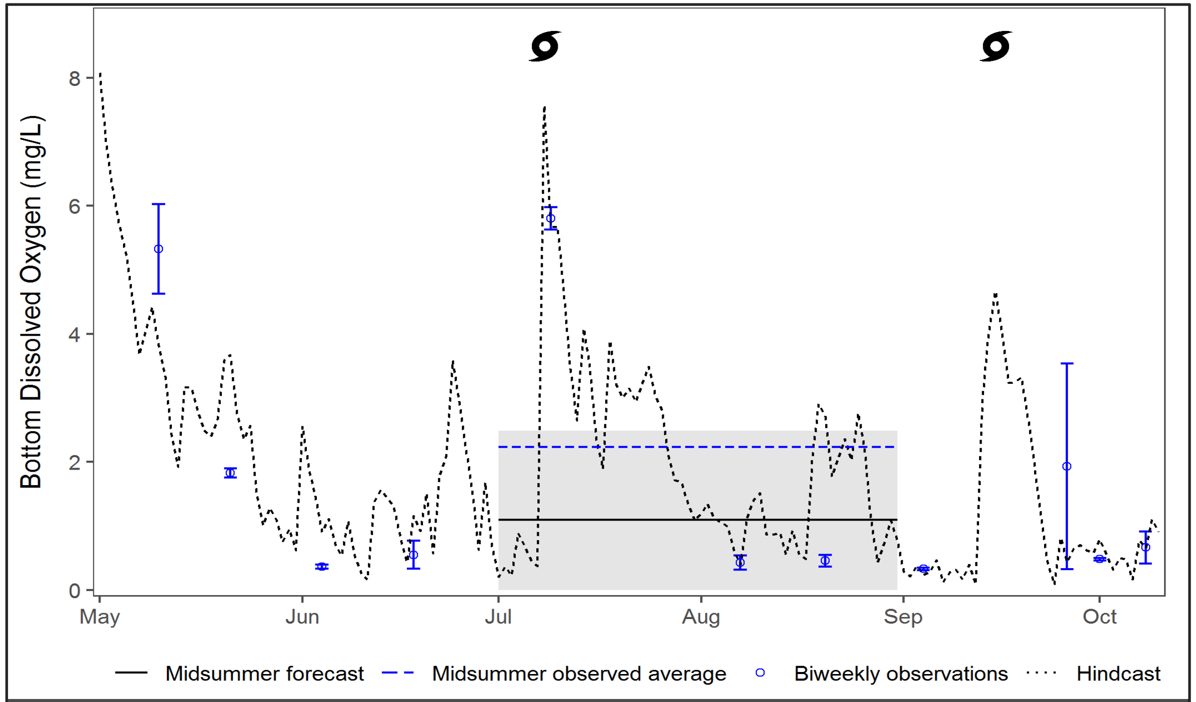
METHOD

Agent-based modeling, optimization

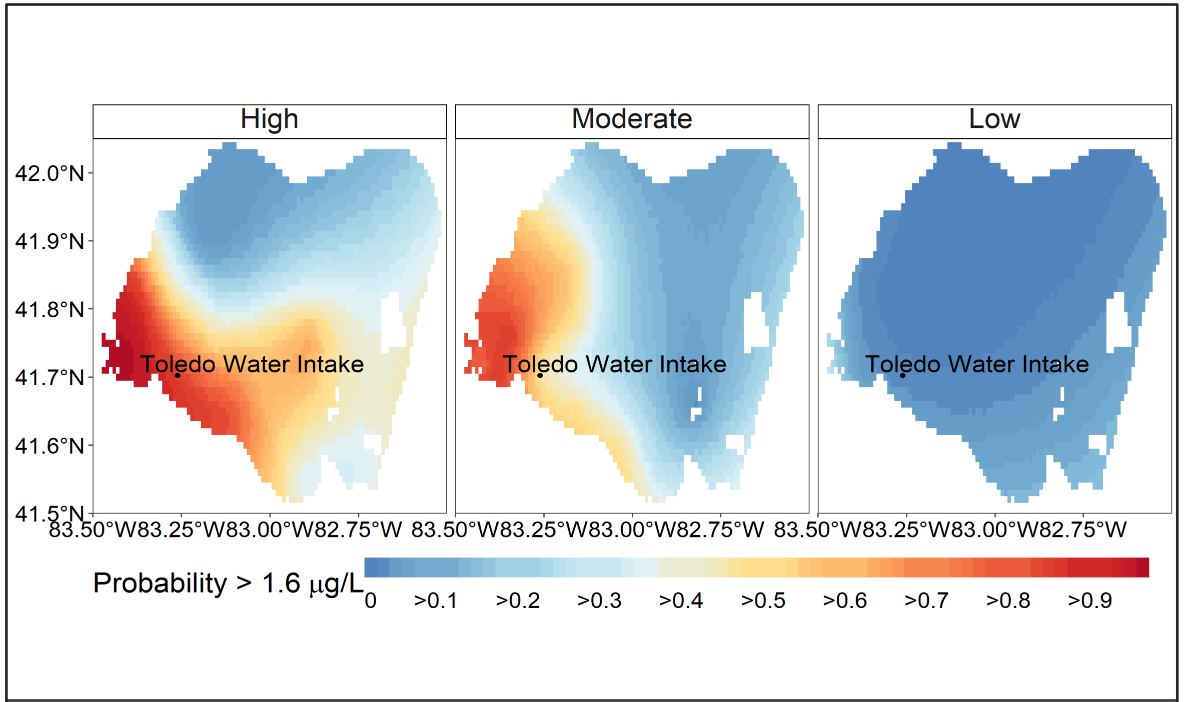
IMPACT

Evaluate plans for new infrastructure based on simulation of willingness of consumers to adopt water reuse technologies

Water-Quality Forecasting



Neuse Estuary Hypoxia Forecasting and Hindcasting



Probability of Exceeding Cyanotoxin Thresholds (Lake Erie)

GOAL

Predict how human actions impact water quality

APPROACH

- Assess water quality impairments, such as hypoxia and harmful algal blooms, through geospatial modeling and data fusion
- Develop biophysical models to forecast impairments based on pollutant loading, weather and climate

IMPACT

Inform watershed, fisheries, and water supply management; raise public awareness through timely water quality forecasts

Protection of Freshwater Resources

GOAL

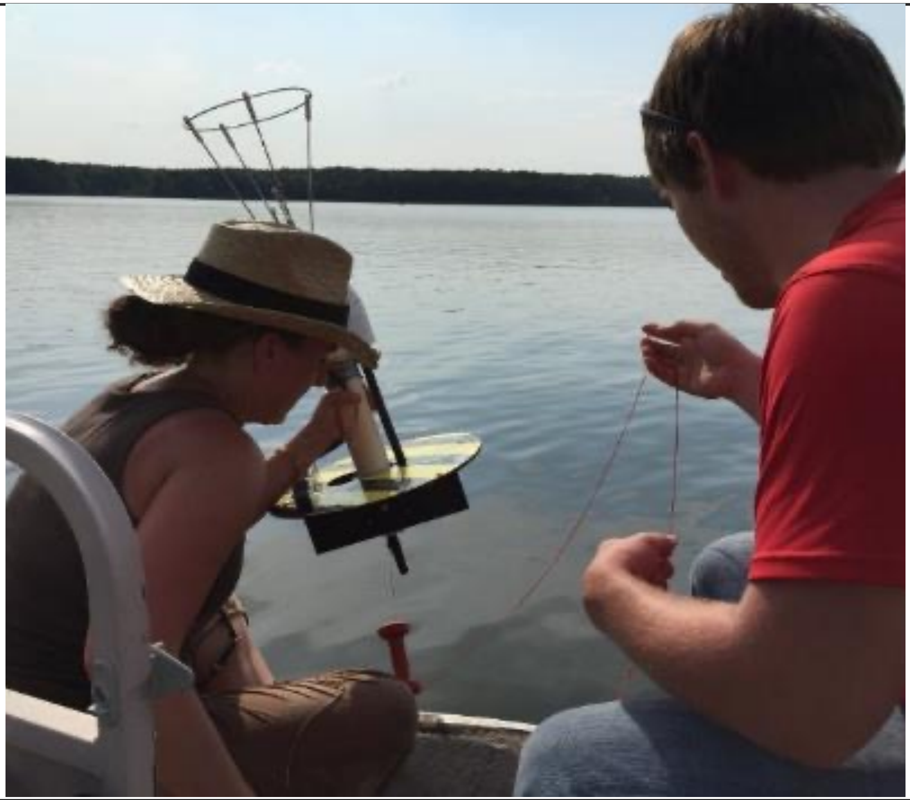
Develop strategies to protect and restore water quality

APPROACH

- Field and experimental studies to measure water quality, algae proliferation, and controlling factors
- Develop numerical models that generalize field and experimental results

IMPACT

Improve water quality in lakes and reservoirs through science-based engineering and management solutions



Thank you for your interest

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