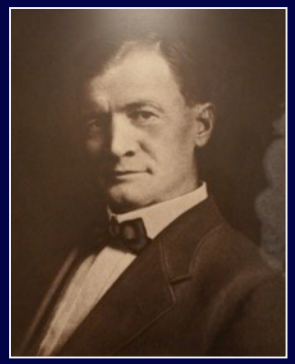
NC STATE UNIVERSITY

Department of Civil, Construction, and Environmental Engineering

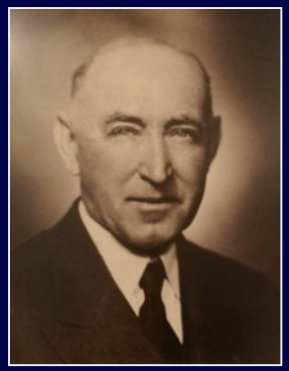
Morton A. Barlaz, Ph.D., P.E.
Professor and Head

Fall, 2019

Department of Civil, Construction, and Environmental Engineering
est. 1895, 10700 B.S degrees



Wallace C. Riddick
1895-1908



Carroll L. Mann
1916-1948

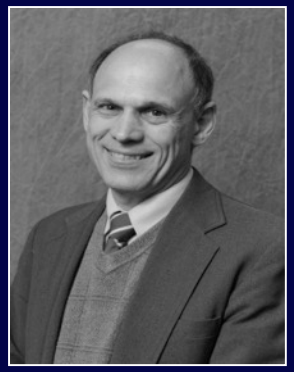
Charles R. Bramer
1948-49; 1962-65

Ralph E. Fadum
1949-1962

Donald L. Dean
1965-1978

Paul Zia
1979-1988

E. Downey Brill
1988-2005



George List
2005-2010

NC STATE UNIVERSITY

Outline

- Who are we?
  - Students, faculty, staff
- Academic Programs
  - Undergraduate & Graduate
- Research Programs
  - Research Funding and Highlights
    - Construction Engineering
    - Geotechnical Engineering
    - Structural Engineering
    - Mechanics and Materials
    - Transportation Systems
    - Transportation Materials
    - Computing and Systems
    - Coastal Engineering
    - Water Resources and Environmental Engineering
- Our New Building in Fitts-Woolard Hall

Who Are We?

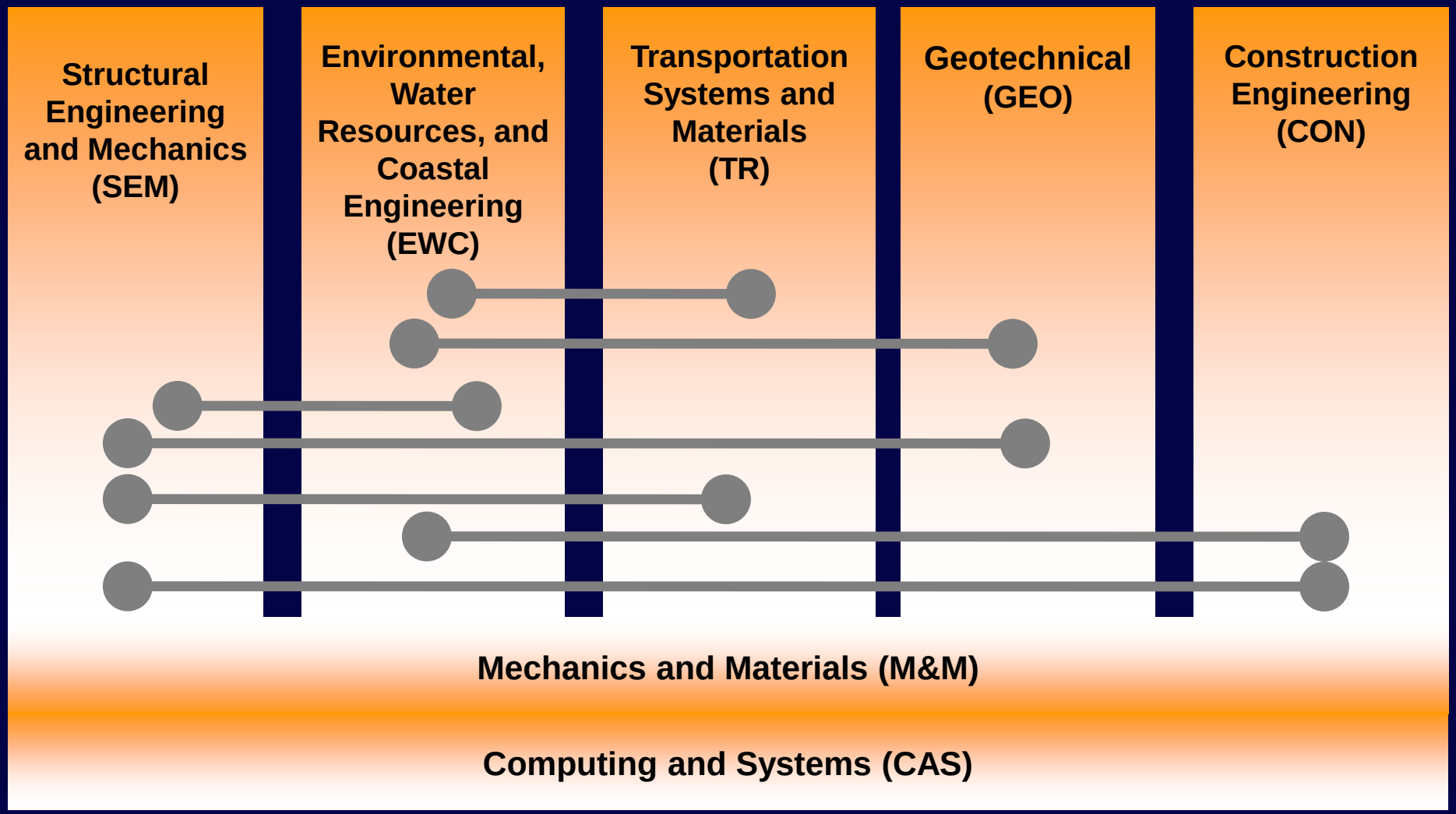
- An excellent group of scholars
  - 50 faculty members
  - 2 extension specialists
  - 1 teaching faculty
  - post-docs and visiting scholars

- Supported by 16 staff members
  - undergraduate and graduate programs
  - grant management personnel
  - IT, machine shop, lab managers
  - administrative assistants
  - Foundation/external relations

Who Are We?

Energy Cluster

WaSH Cluster



Who are We?

- A top department
  - CE: ranked 20th best undergraduate program and 24th best graduate program
  - ENE: ranked 21st best undergraduate program and 26th best graduate program
  - Best Value Public University (Princeton Review)
  - Engineering Online: 1st in Civil and 2nd in Environmental

We are Large?

Civil Engineering Degrees Awarded by School

1.	Texas A&M University	221
2.	Univ. of Illinois, Urbana-Champaign	210
3.	Virginia Tech	199
4.	Georgia Institute of Technology	198
5.	University of California, San Diego	185
6.	The Ohio State University	183
7.	California State Poly. U., Pomona	181
8.	The Pennsylvania State University	156
9.	University at Buffalo, SUNY	150
9.	University of California, Davis	150
11.	Iowa State University	148
12.	The University of Alabama	139
13.	North Carolina State University	138

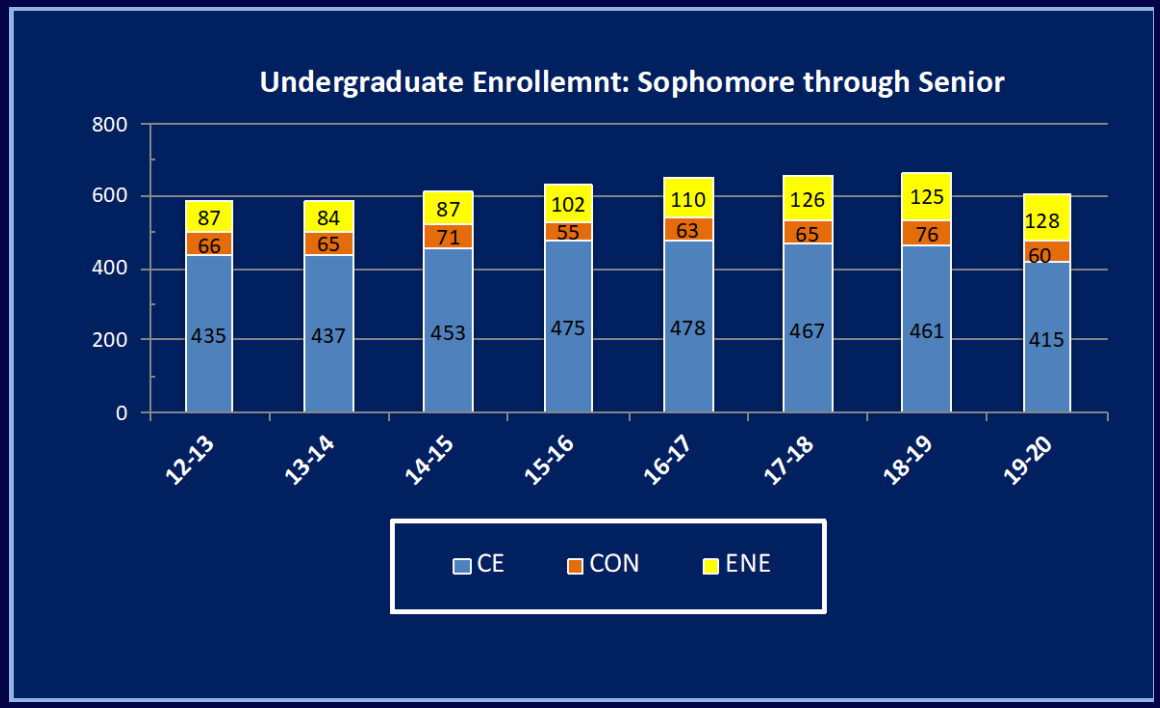
College-wide undergraduate enrollment

1.	Arizona State University	12,995
2.	Texas A&M University	12,982
3.	University of Central Florida	9,467
4.	Georgia Institute of Technology	9,377
5.	Univ. of Illinois, Urbana-Champaign	9,337
6.	Purdue University	8,918
7.	The Pennsylvania State University	8,461
8.	Iowa State University	8,211
9.	Virginia Tech	8,151
10.	The Ohio State University	8,022
11.	Oregon State University	7,748
12.	University of Florida	7,047
13.	North Carolina State University	6,986

NCSU is 195 actually including construction and environmental

Academic Programs: Undergraduate

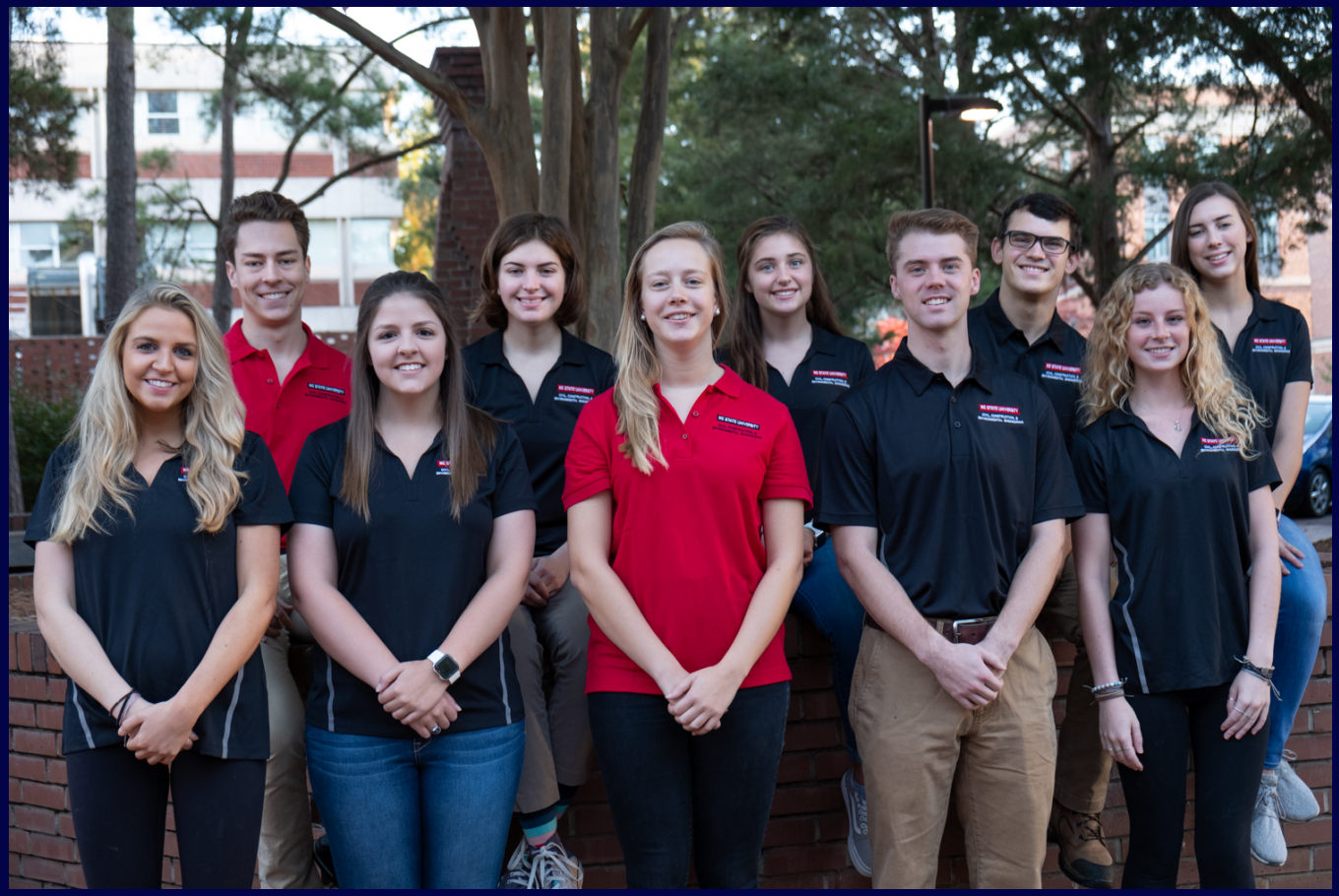
- Undergraduate Degrees
  - Civil Engineering
  - Construction Engineering
  - Environmental Engineering



604 matriculated
756 with freshman

Undergraduate Programs

- Student ambassadors program
  - Outreach events scheduled in the freshman dorms and in Mann Hall



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
- AGC Green Building Competition
- Alliance Building One
- Cary Wastewater Treatment Plant
- Design Competitions
- Kenan Memorial Stadium
- Sharon Harris nuclear plant
- South Wake Landfill
- Transportation Research Board Annual Meeting

Academic Programs: Student Groups

- 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
- Construction Managers Association of Amer
- 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

NC State hosting ASCE Carolinas Conference

- Competitions: for 316 students from 10 schools
  - NC State
  - NC A&T
  - Duke
  - UNC-C
  - Clemson
  - Ga. Tech
  - Citadel
  - Horry Georgetown (Civil Engineering Technology)
  - Univ. of Georgia
  - Univ. of South Carolina (hosting in 2020)

April 4th, 5th, and 6th, 2019

NC State hosting ASCE Carolinas Conference

- Competitions
  - Concrete Canoe Competition
  - Innovation Competition
    - Pilot program for ASCE hosted in two region
    - Similar to Shark Tank where the students developed, polished, and pitched ideas to help meet future challenges of society
    - Internet of things
    - Sustainable Engineering
    - Next Generation Transportation
    - Improvements in Clean Water
    - New construction Materials & Methodology
  - Mead Paper – The value of Canon 8:

Engineers shall, in all matters related to their profession, treat all persons fairly and encourage equitable participation without regard to gender or gender identity, race, national origin, ethnicity, religion, age, sexual orientation, disability, political affiliation, or family, marital, or economic **status** .

NC State hosting ASCE Carolinas Conference

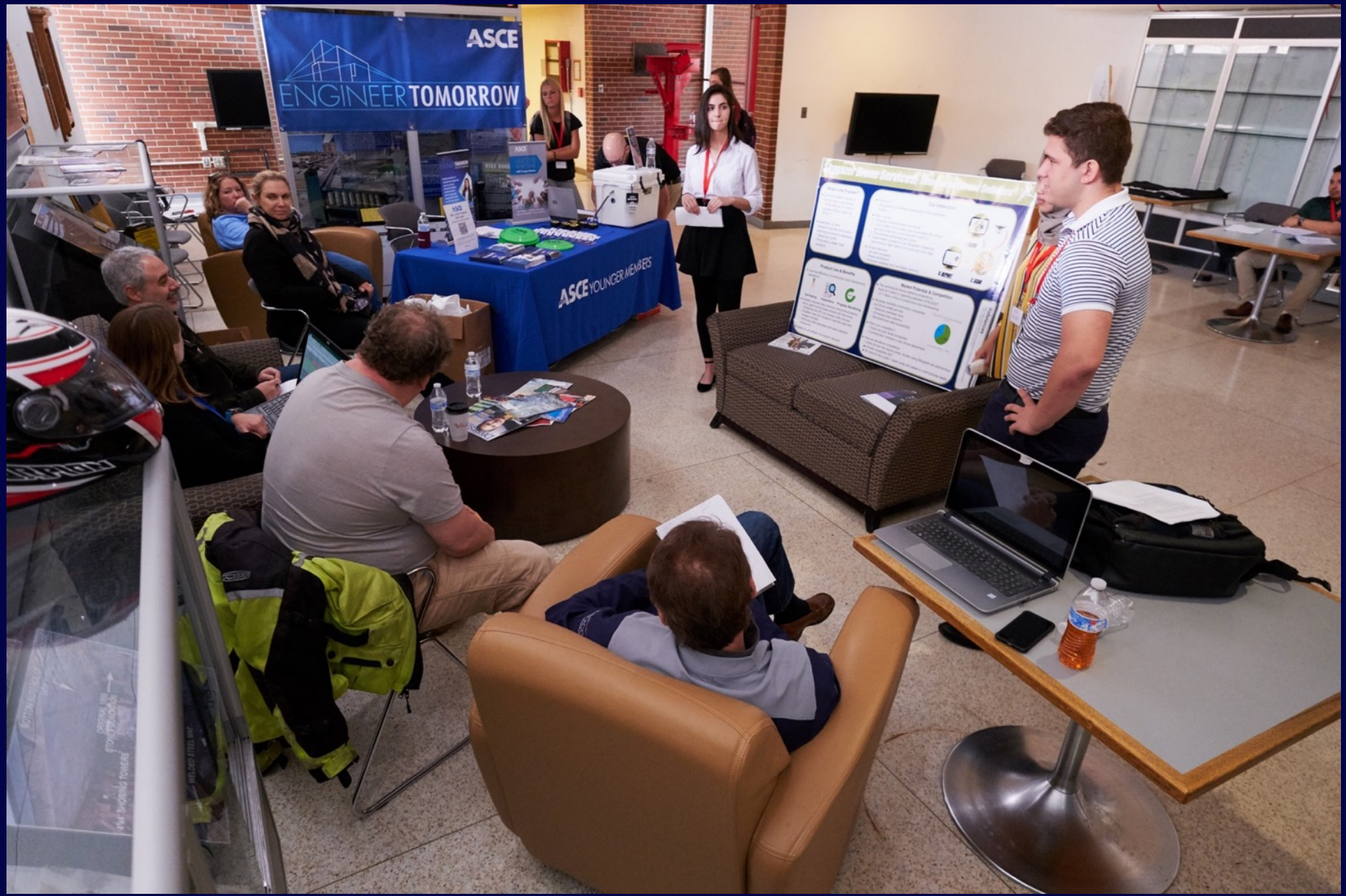
- Competitions
  - Freshman Competition – Paper column load test competition
  - Concrete Cornhole – Design, fabrication and testing of concrete cornhole boards for display, lightness, and functionality
  - Transportation competition – student layout challenge
  - Quiz Bowl – student challenge for engineering knowledge

NC State hosting ASCE Carolinas Conference

- Competitions
  - 3D printed tower for lateral loads – to replace the structural competition of bridge, NC State initiated a new competition to test towers that were 3D printed and then subjected to lateral loads to determine efficiency.

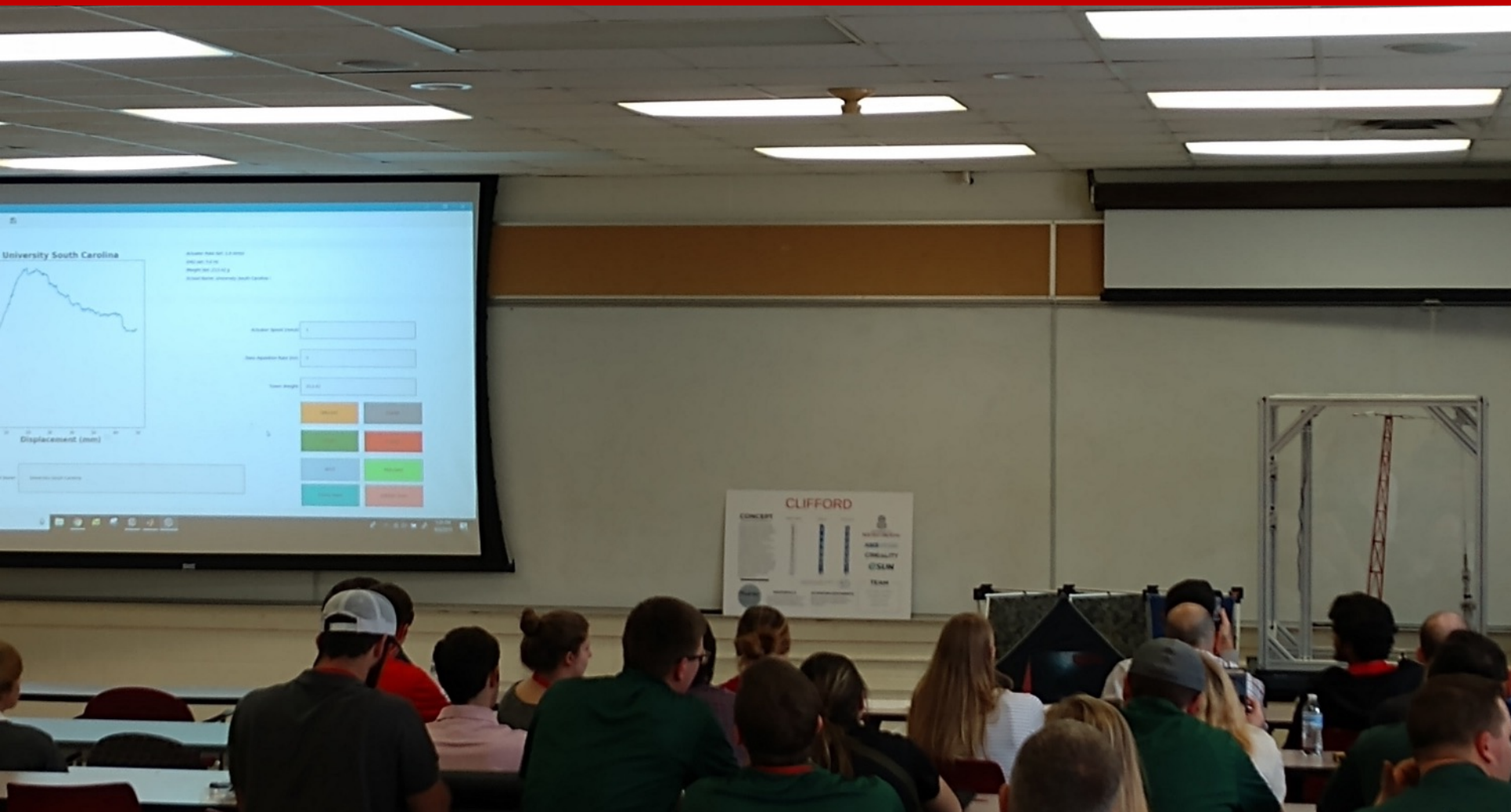
    (Note: This engaged new corporate sponsors and new opportunities.)

ASCE Pilot – Innovation Competition



NC State Pilot – 3D Printed Tower Competition

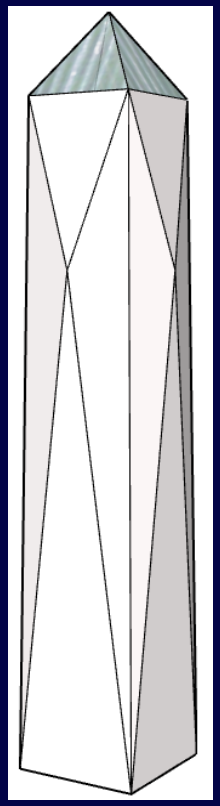
3D Printed Tower Laterally Loaded – Real time load and displacement displayed to audience



Earthquake Engineering Research Institute

<u>Seminars to Prepare:</u>

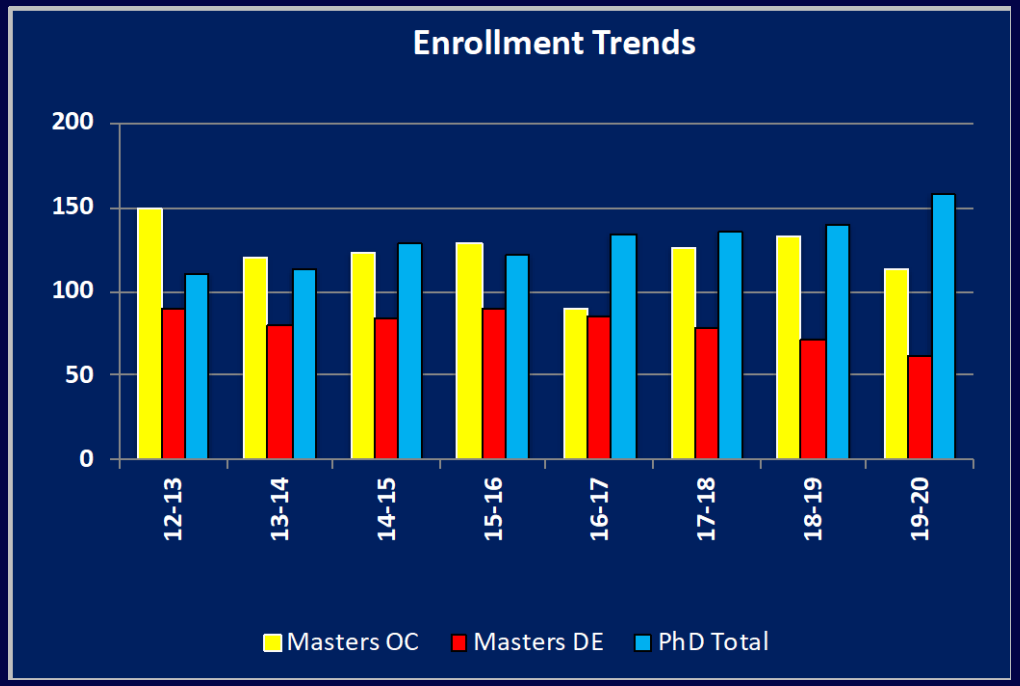
- Introduction
- Structural Dynamics
- Seismic Design
- Seismic Analysis of Frame Buildings
- Seismic Analysis of Dual Systems
- Materials -- Balsa Wood
- SAP2000 -- Time History Analysis
- SAP2000 Part II

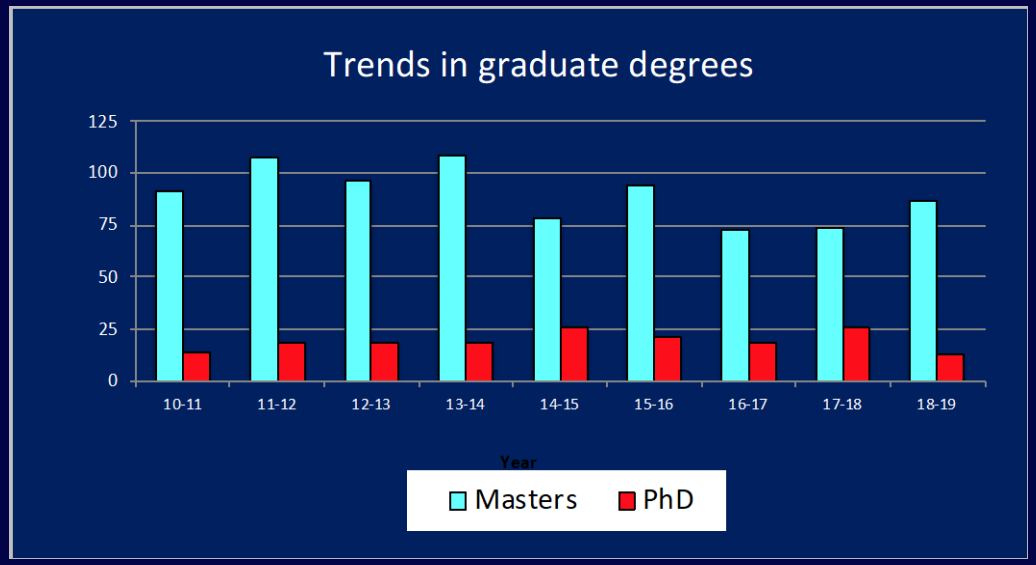


Academic Programs: Graduate

- Masters of Civil Engineering
- Masters of Environmental Engineering
- Masters of Science - Civil Engineering
- Masters of Science – Environ. Engineering
- Distance Education Masters
- PhD
- Total of 334

169 students on assistantships





Graduate Programs

- Dr. Meagan Kittle Autry, Director of Graduate Professional Development
- PhD Communication, Rhetoric and Digital Media with a focus on scientific and technical communication
  - Research Skills
  - Professional Skills
  - Career Support
- Summer Distance Education Course

https://sites.google.com/ncsu.edu/ccee-professional-development/home?authuser=1

Research Internship Summer Experience

- 2019 RISE program (go.ncsu.edu/rise)
  - 11 non-NCSU participants (from, for example, UIUC, UMBC, JHU, UPRM, MSU, FL)
  - 14 NCSU participants
  - 18 mentors
  - females: 10 non-NCSU; 6 NCSU
  - ethnic diversity: 45% among the non-NCSU participants
  - ISE and MSE participants
  - Overwhelmingly positive responses to questions like:
    - Recommend RISE to a friend
    - RISE was effective and useful in preparing for graduate studies
    - RISE program met my expectations
  - Investment in graduate student recruiting
  - Seminars on research skills, fellowship application preparation, poster preparation

Louis Stokes Alliance for Minority Participation (LSAMP) Bridge to the Doctorate Fellowship NSF HRD Program

Joel Ducoste, PhD, BCEEM
Professor
Civil, Construction, Environmental Engineering Dept.
jducoste@ncsu.edu

CCEE Engineering Online

https://go.ncsu.edu/CCEE-EOL

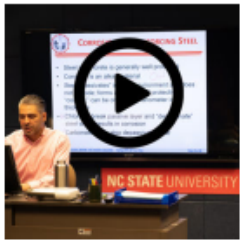
- Engineering Online Degree Programs
  - Masters in Civil Engineering (MCE)
    - 8 areas of specialization
  - Masters in Environmental Engineering (MENE)
    - 6 areas of specialization
- Average age of online student – 34 years
- EOL students in 45 states and 21 countries
- We offer ~15 courses a semester
- Developing four-course certificate programs in multiple specializations

Spring 2020 CCEE-EOL Course Offerings

Construction	CE 538	Information Technology and Modeling
	CE 564	Legal Aspects of Contracting
	CE 567	Risk and Financial Management in Construction
	CE 762	Construction Productivity
Environmental	CE 571	Physical Principles of Environmental Engineering
	CE 577	Engineering Principles of Solid Waste Management
	CE 585	Surface Water Quality Modeling
Structural	CE 526	Finite Element Methods in Structural Engineering
	CE 527	Structural Dynamics
	CE 528	Structural Design in Wood
	CE 530	Properties of Concrete and Advanced Cement-Based Composites
	CE 794	Seismic Design of Bridges
Transportation	CE 503	Highway Design
	CE 505	Railroad System Planning, Design, and Operation
	CE 509	Highway Safety
	CE 595	Asphalt and Bituminous Materials
	CE 759	Inelastic Behavior of Construction Materials
Geotechnical	CE 741	Geomechanics of Stress Deformation
	CE 793	Physico-chemical and Biological Aspects of Soil Behavior

CCEE-EOL Intro Videos

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



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

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

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

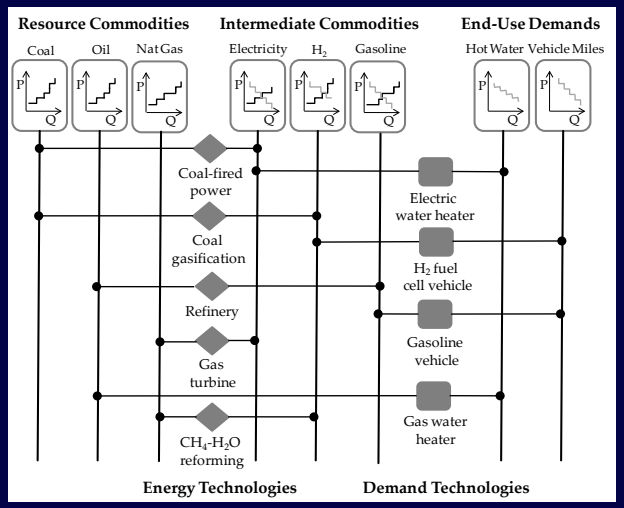
CCEE-EOL Lunch and Learn Sessions

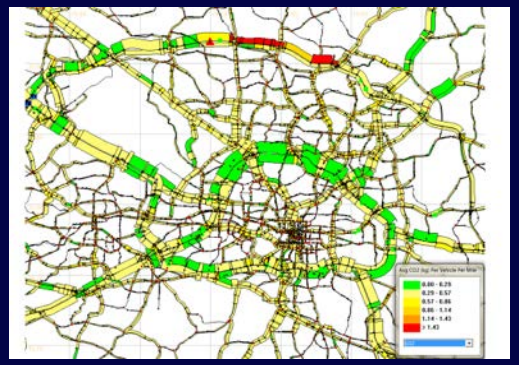
- We are looking for opportunities to discuss our online graduate programs through on-site and remote corporate lunch and learn sessions.
- Dr. James Levis is available to provide a short presentation on our programs, available specializations, logistics, and requirements and to answer any questions.
- If you are interested in learning more, you can email him at jwlevis@ncsu.edu and/or speak with him today.

Research: Diverse in Expertise and Strengths

- We model, we test, we analyze and we solve
- Our research capabilities and methodologies span from the fundamental to the applied
- 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

US Energy and Environmental Policy

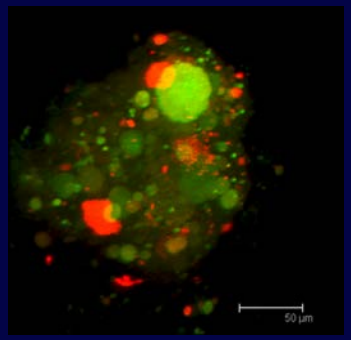




Energy efficiency and transportation

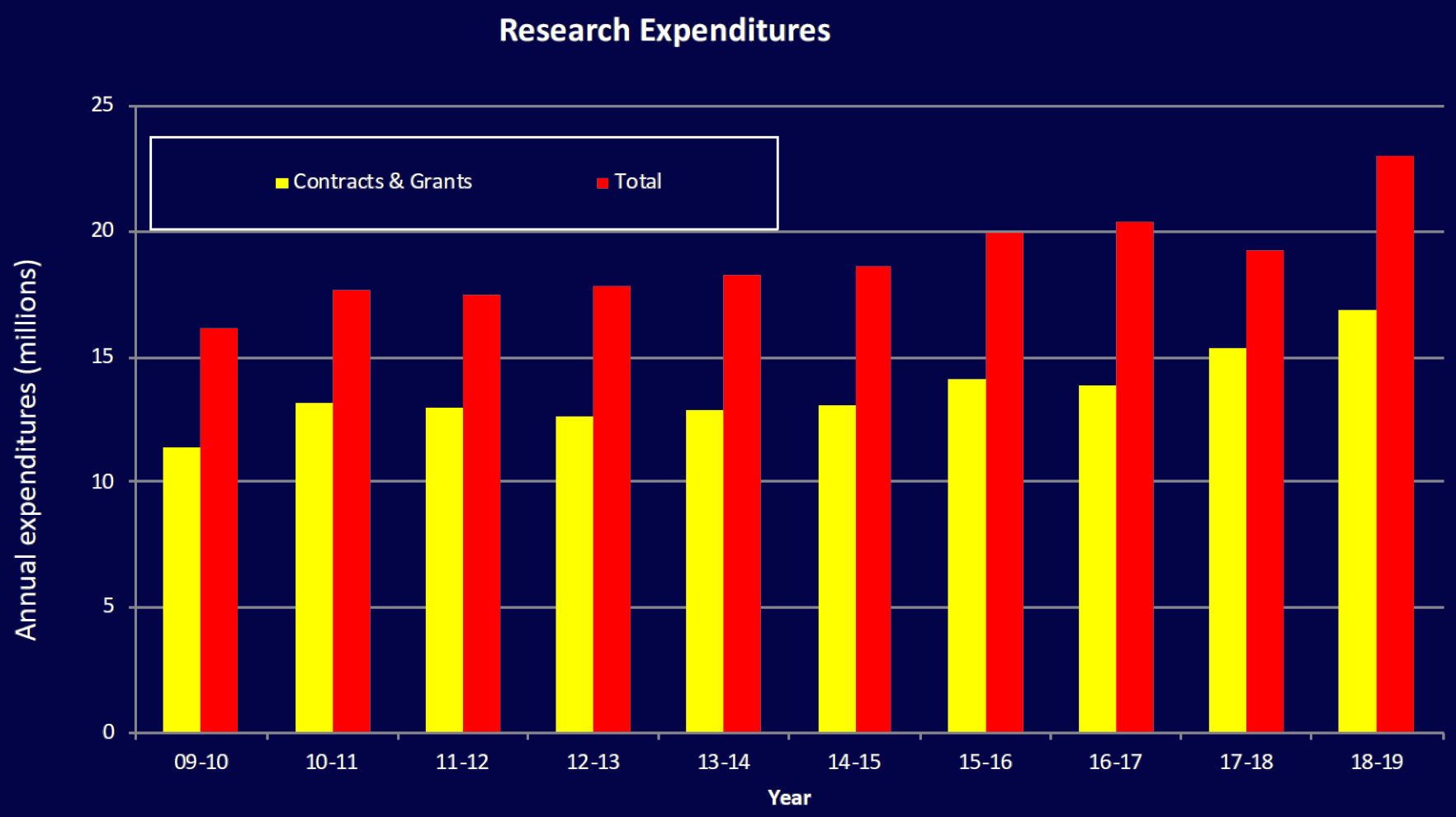
Soil flushing

Accelerated pavement testing

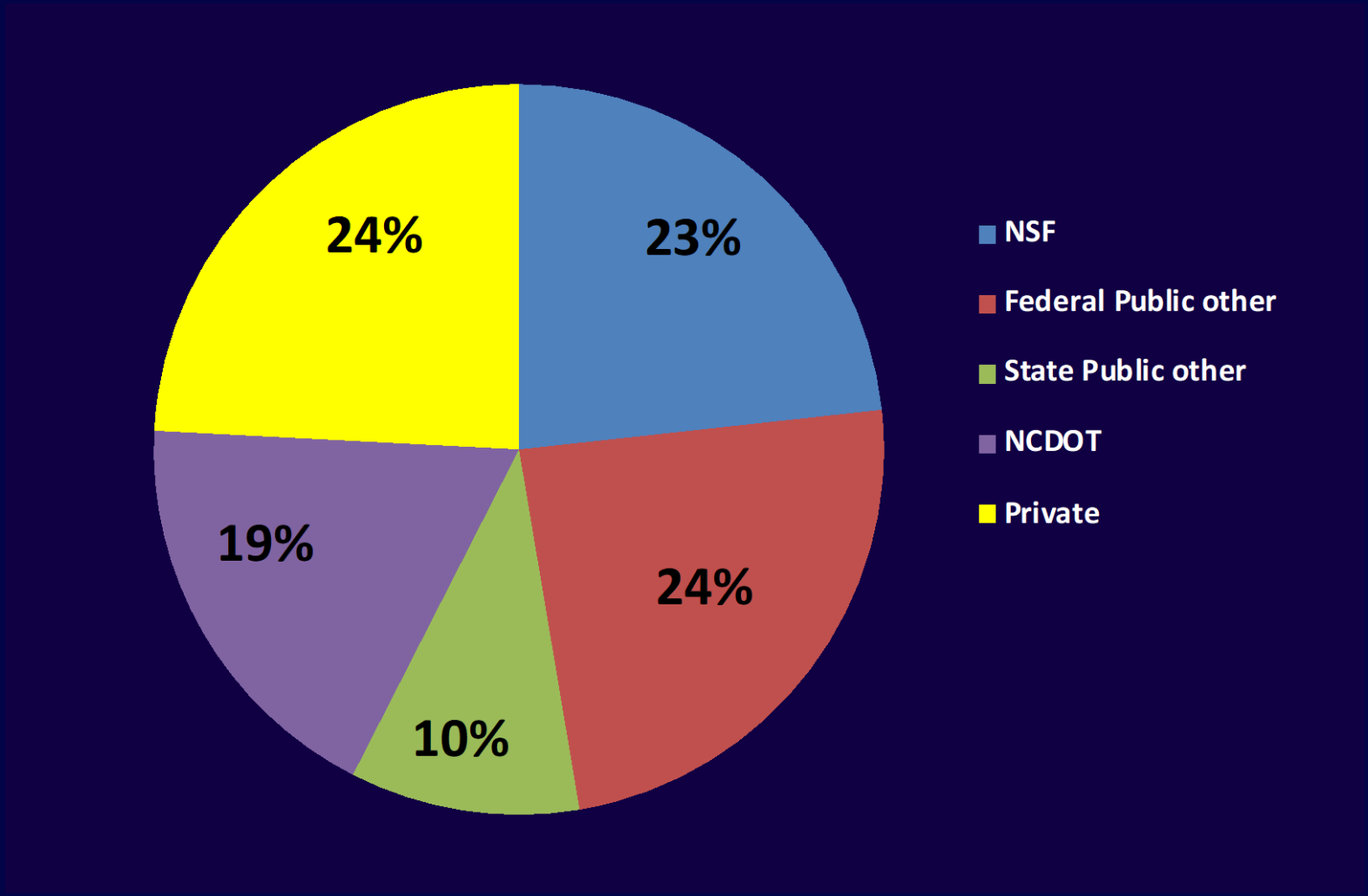


Colonies containing the nirS gene

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 Admin. (NASA)
- National Science Foundation (NSF)
- National Oceanic and Atmospheric Admin. (NOAA)
- NC, CA, AL and US Departments of Transportation
- Sloan Foundation
- US Environmental Protection Agency (US EPA)
- US Geological Survey
- UNC Costal Studies Institute (UNC-CSI)

Working Across Disciplines

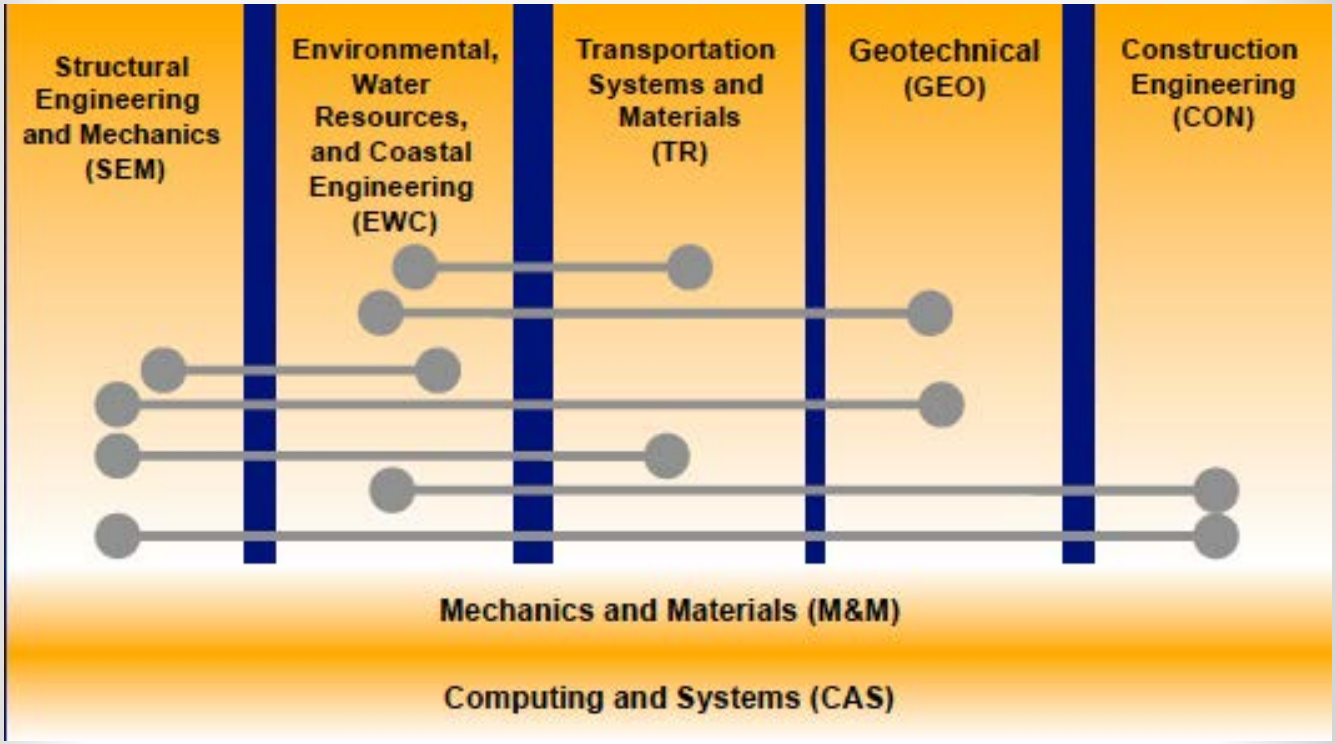
Architecture

Microbiology

Statistics

Mechanical & Aerospace Engineering

Biological & Agricultural Engineering



Marine, Earth & Atmospheric Sciences

Computer Science

Operations Research

Materials Science

Industrial Systems Engineering

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) (De los Reyes)
  - Sustainable Energy Systems and Policy (DeCarolis)

Sustainable Energy Systems

The pursuit of energy sustainability represents a multi-generational 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.

Cluster hires:

- Harrison Fell, Agricultural and Resource Economics
- Christopher Galik, Public Administration
- Jeremiah Johnson, Civil, Construction, and Environmental Engineering
- Wenyuan Tang, Electrical and Computer Engineering

Global Water, Sanitation and Hygiene

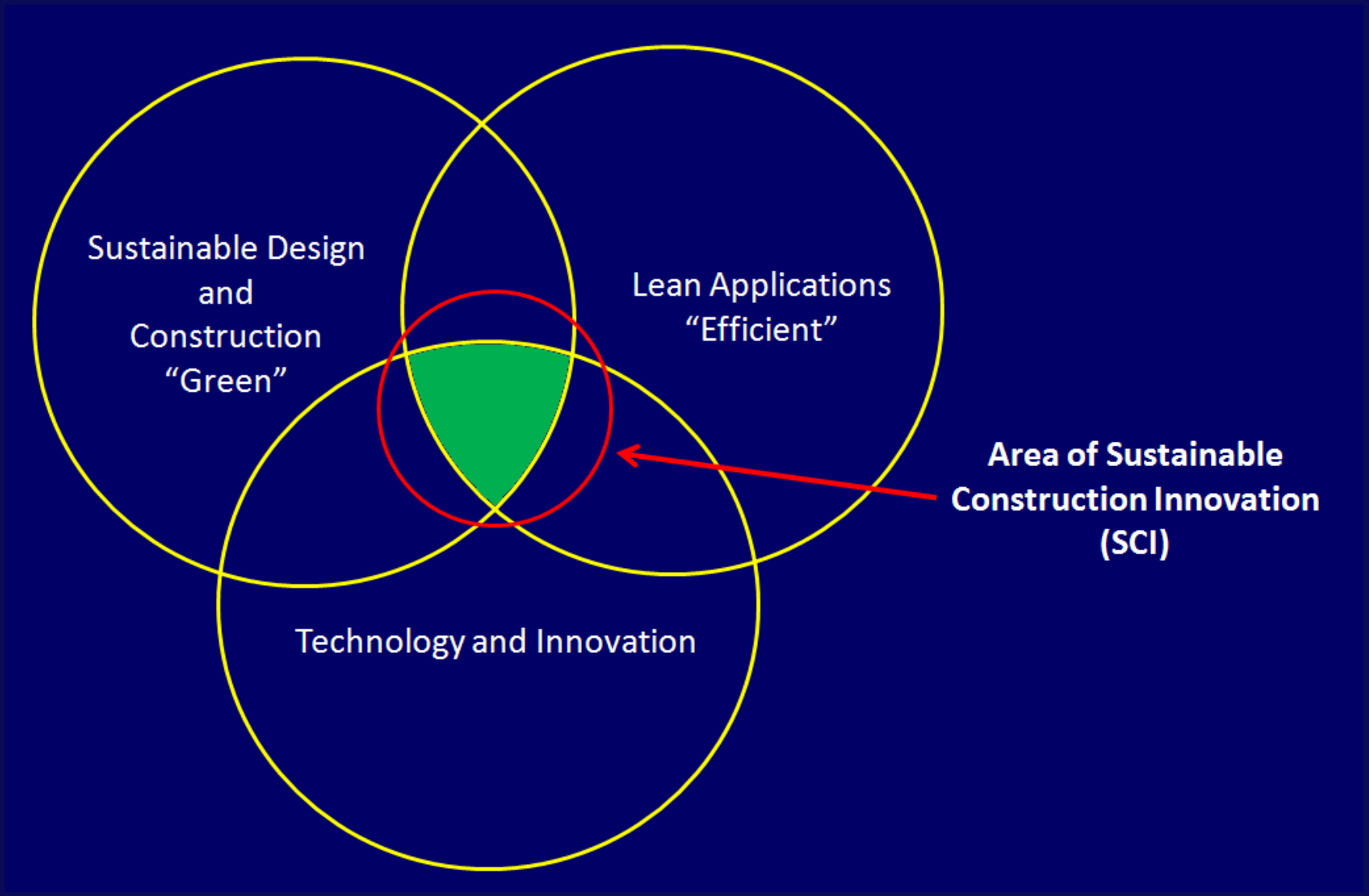
Mission: The NC State WaSH Cluster catalyzes & conducts transformational research and education to serve the water, sanitation, and hygiene needs of marginalized people.

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

Faculty Hires

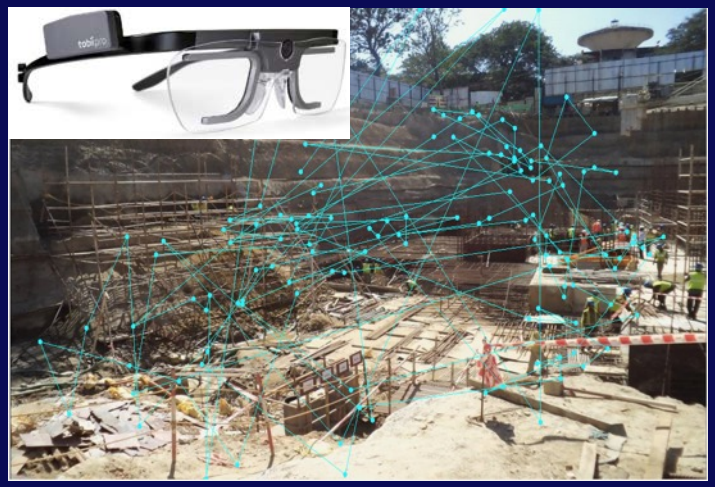
Ayse Ercumen- Forest & Env. Resources
Raymond Guiteras- Ag. Resource Econ.
Angela Harris – CCEE
Josh Kearns – CCEE

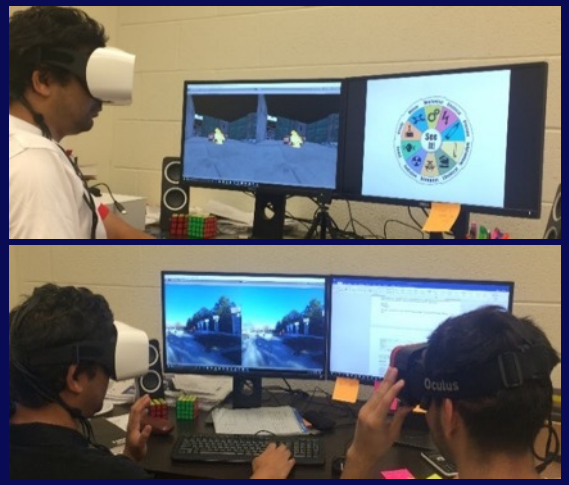
Construction Engineering: Research Framework



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

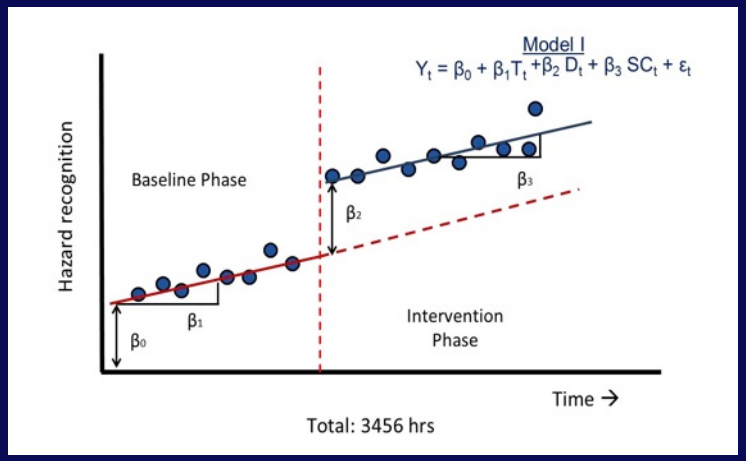
Training Strategy

Planning Strategy

Execution Strategy

- Approach: Integrate Visual Cues

- Method: Multiple baseline testing

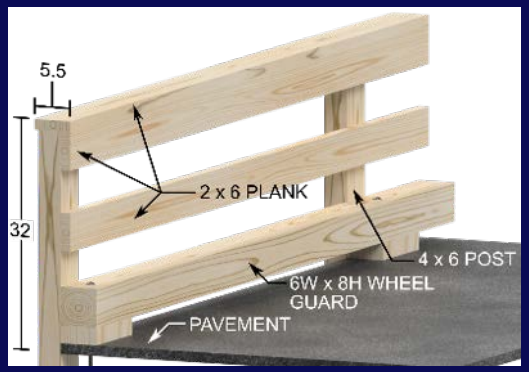


- Impact: > 20% hazard recognition improvement after intervention

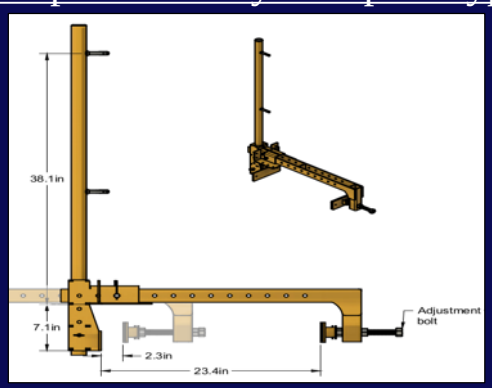
Preventing Falls among Bridge Workers

- 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.

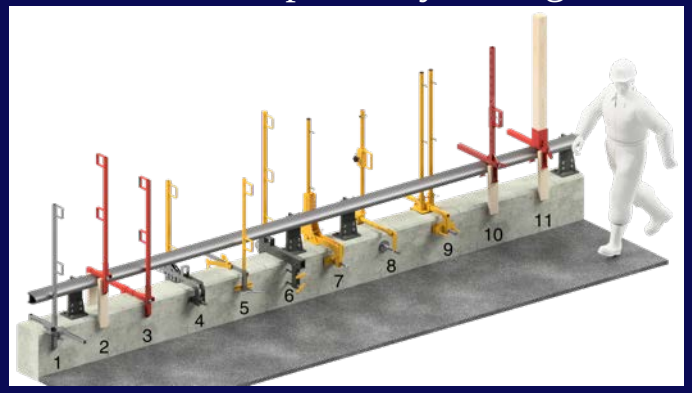
Bridge Guardrail Prototype



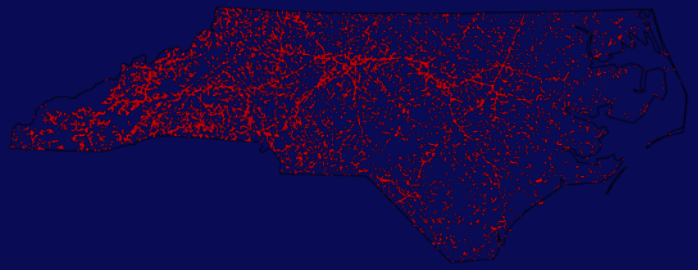
Fall protection system prototype



Virtual compatibility testing

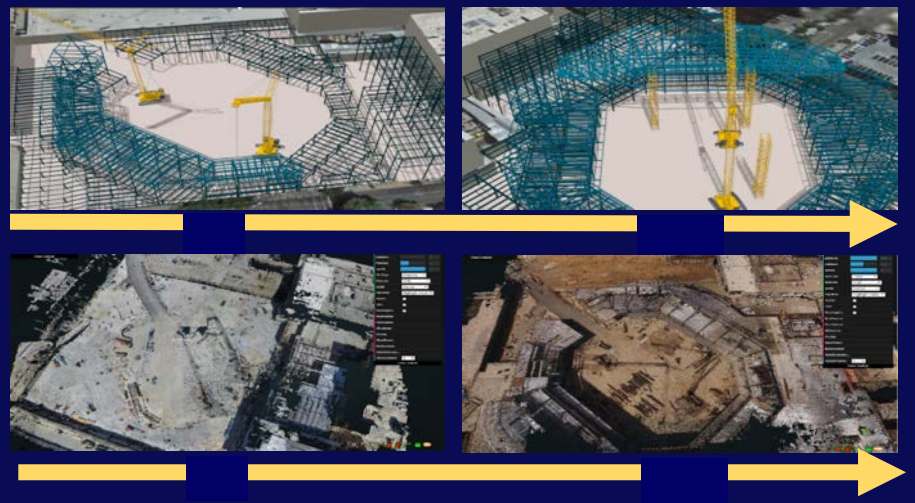


- Impact: Identify fall protection measures for over 22,000 guardrails across the state of North Carolina.



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.



Construction Automation and Robotics

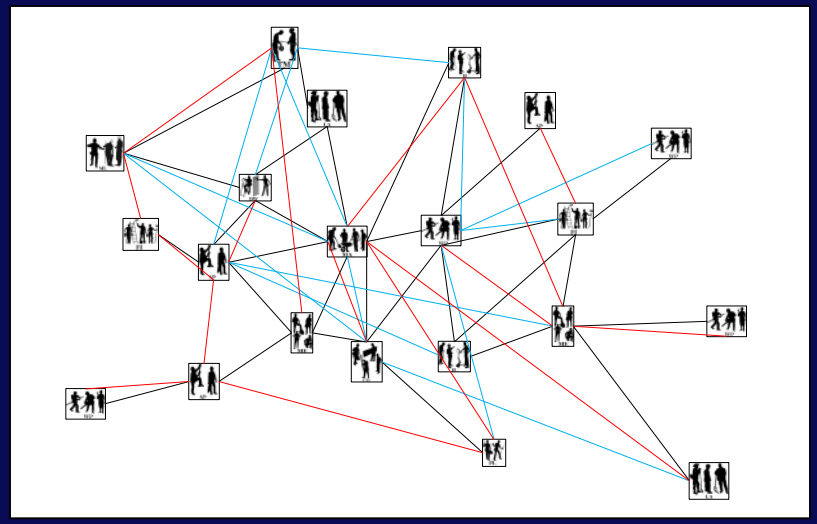
- Goal: Automate construction management practices through advances in robotics
- Approach: Autonomous navigation for construction performance monitoring; multiple robots interacting with humans; automated construction tasks using a robotic arm.
- Method: Custom built unmanned aerial and ground vehicles 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.

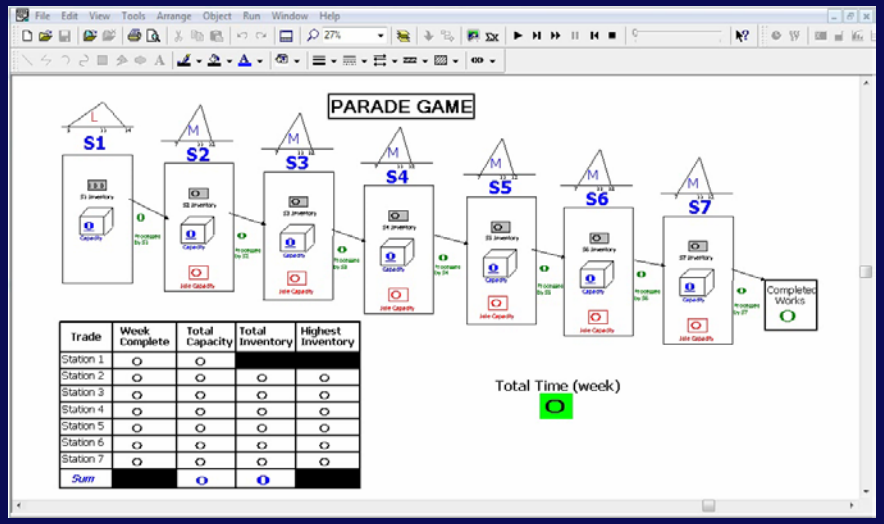
Achieving Success on Complex Projects

- 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.

The Social and Engineering Aspects of Construction Planning

Goal: Improve plan reliability and productivity by studying the social and engineering aspects of construction site management.



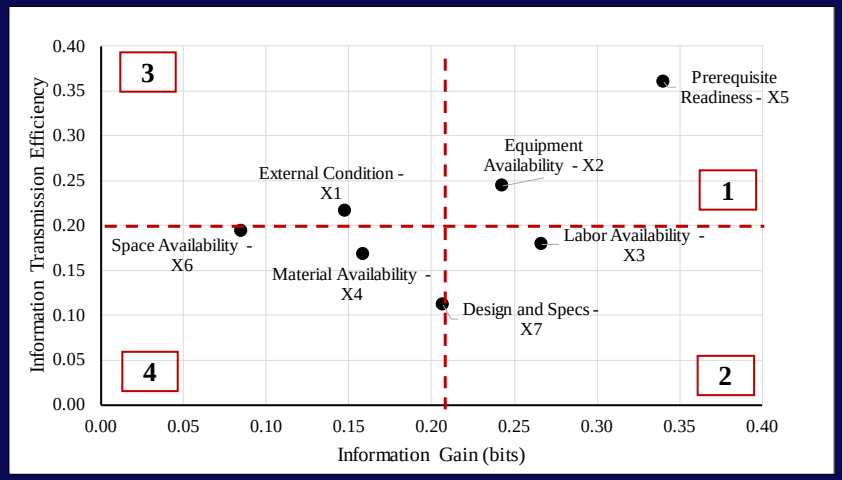


Approach: collect planning and production data, interview site managers, guide and participate planning

Impact: Help contractors increase *value* and *reduce waste* in project delivery process

Effective Planning Meetings and Productivity

Goal: Study construction planning meeting process to improve plan reliability and productivity



Approach: collect meeting minutes, interview site managers, and collect production data

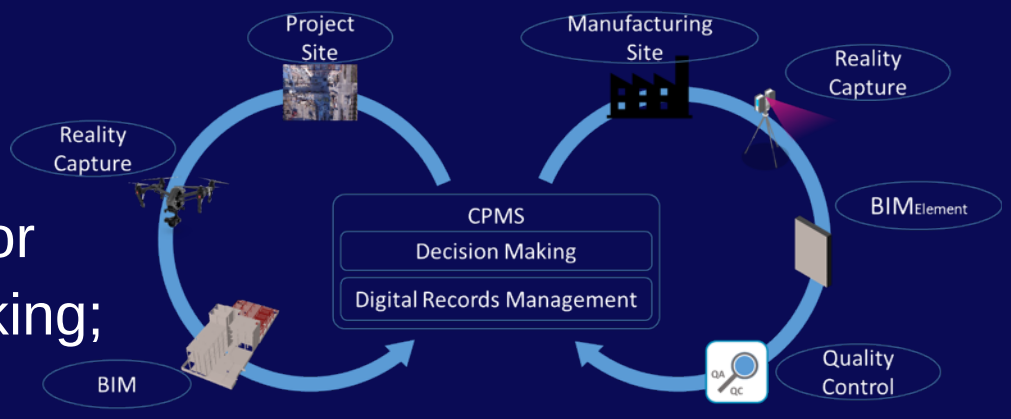
Impact: Help construction site managers to improve planning process efficiency and productivity

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.

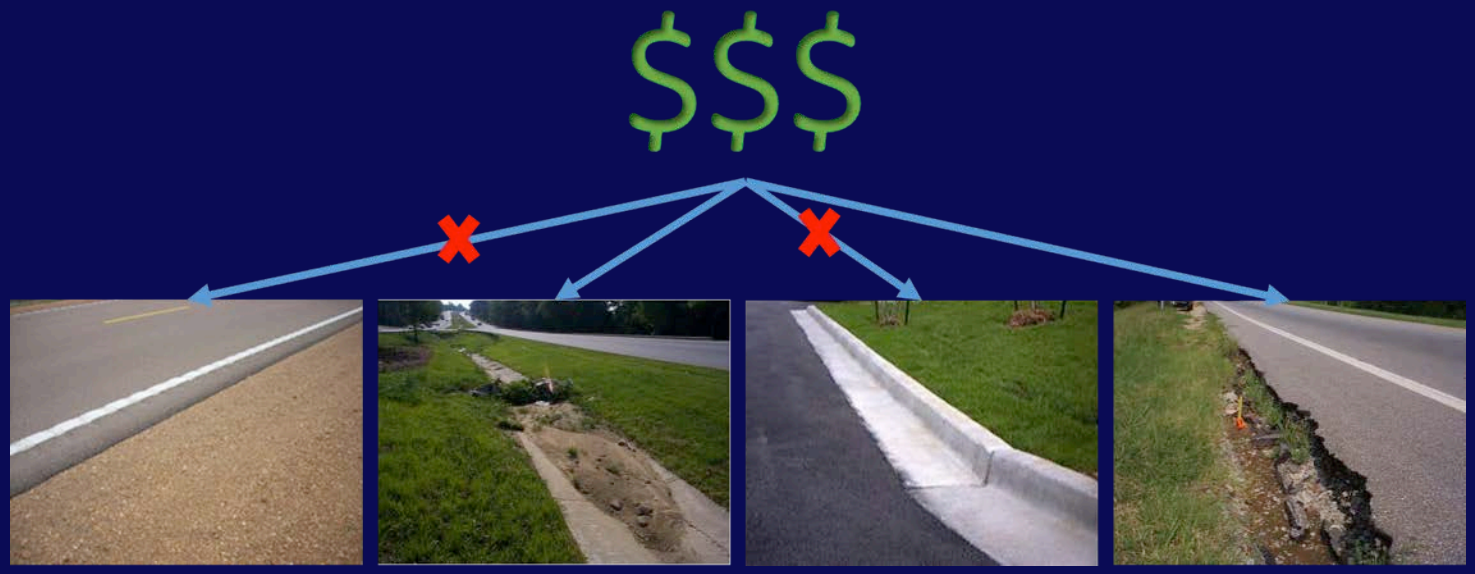
Advances in Construction of Nuclear Power Plants

- Goal: Improve cost and schedule performance of nuclear construction
- Approach: Advances in modular construction, visual data analytics, and BIM
- Method: Automate and improve QA/QC process at off-site facilities. Virtually connect performances at off-site facilities to the project site.
- 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.

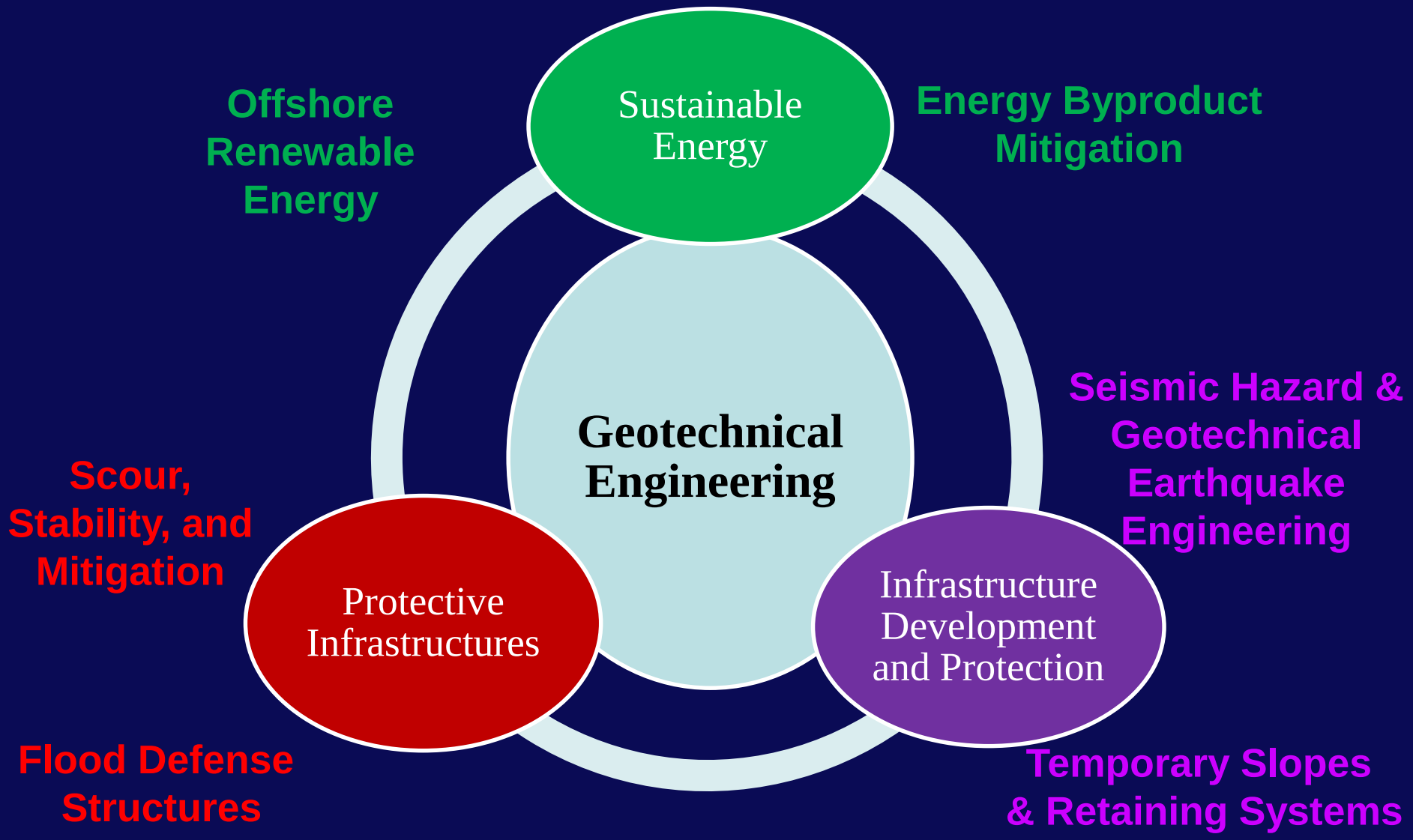


Balancing Highway Asset Condition Improvement with Budget Allocation

- 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.



Geotechnical Engineering

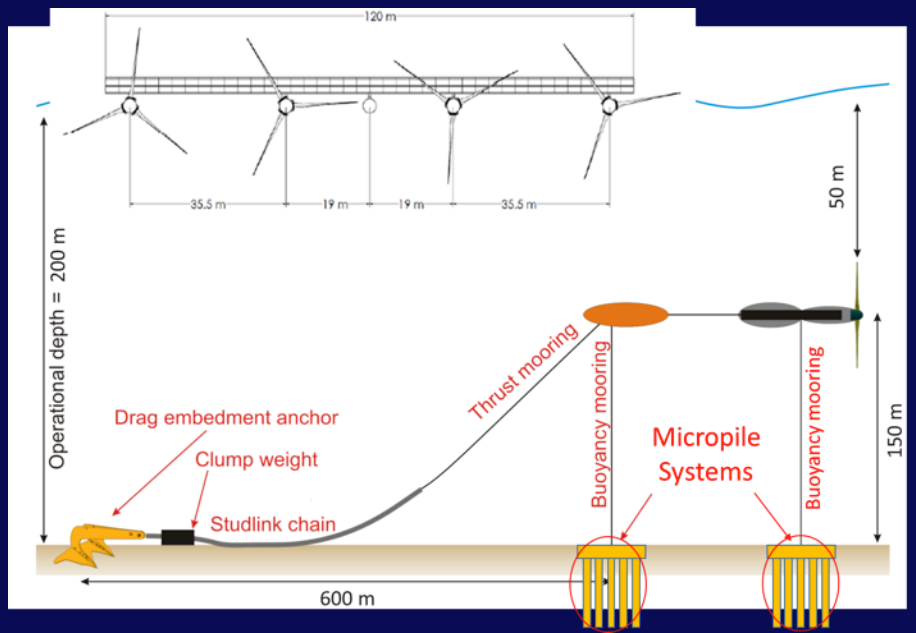


Offshore Renewable Ocean Energy

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

Approach: Develop the use of micropiles in marine environment and investigate possible construction approaches for deployment formed Micropiles in a large scale sand pit

Impact: A “road map” for deploying micropiles in marine environments in an emerging market



Energy Byproduct Hazard Stabilization

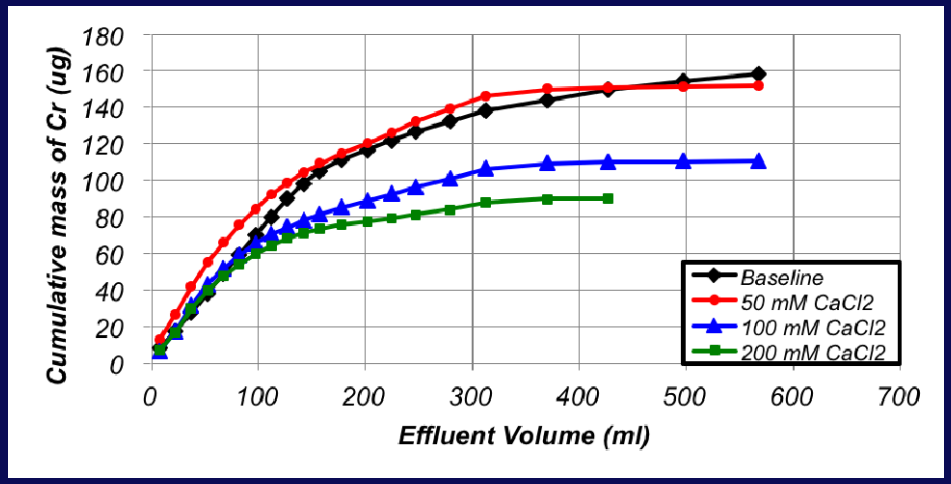
Goal: Improve the strength and stiffness of energy byproduct materials, like coal ash ponds, while also immobilizing heavy metals within the material

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

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

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

Column testing to assess improvement in mechanical properties



Immobilization of chromium from fly ash at varying levels of cementation

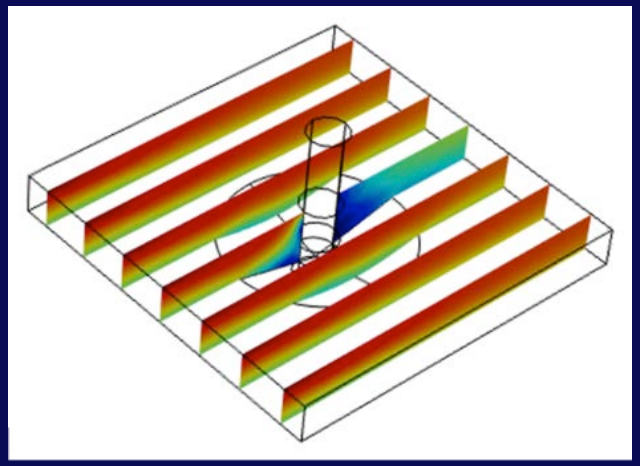
Scour Assessment & Mitigation

Goal: Understand soil susceptibility to scour within on-shore and off-shore environments, and reduce the susceptibility to scour using natural methods

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

Impact: ISEEP is the first tool developed to assess soil erosion parameters with depth. It has been deployed to study breaching during hurricanes along the NC coast. Bio-cementation can be used to reduce erosion from wave action and reduce scour adjacent to offshore foundations without harmful ecological consequences.

ISEEP Field Deployment



Numerical modeling of velocity flow around pile experiencing scour

Bio-cemented Sand in Wave Tank

Flood Defense Structures

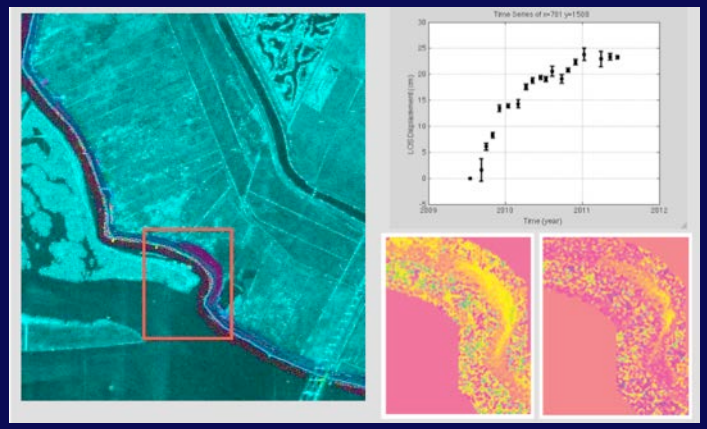
Goal: Develop a framework to assess the stability of flood defense earth structures and integrate a comprehensive multi-scale levee monitoring program to assess the probability of exceeding predefined performance limit states

Approach: The concept of deformation-based limit states is introduced, using coupled deformation-seepage analyses and including various scenarios of 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. Rebuilding is needed



DInSAR interferometric phase change along the levee toe

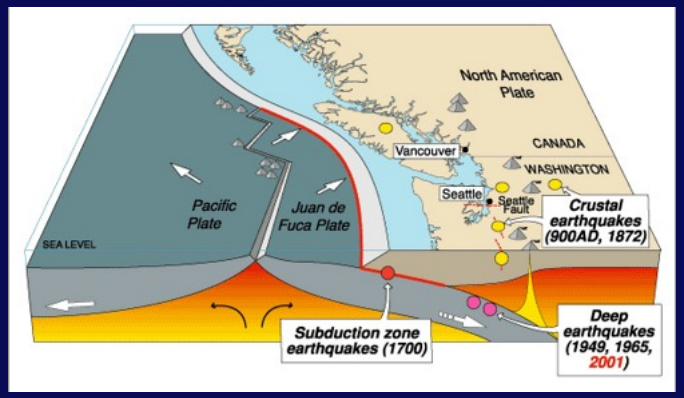
Images by Getty and Associated Press 2011

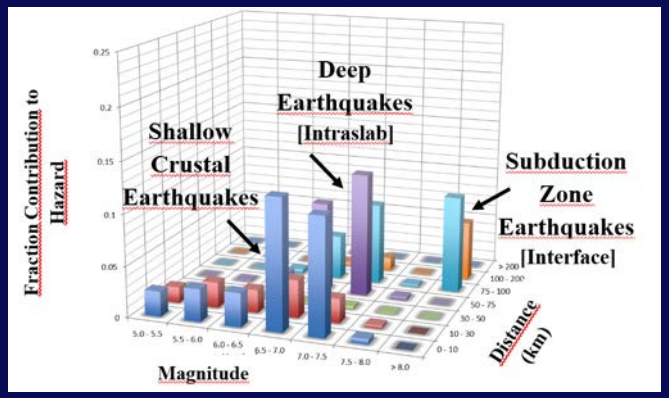
Seismic Hazard Assessment

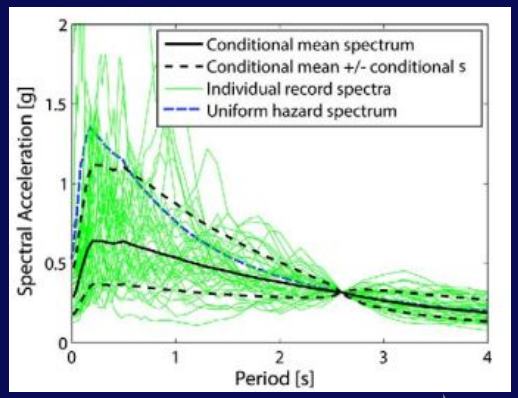
Goal: investigate the characteristics and variability of strong ground motions, near-surface wave propagation effects, and the correlation between ground motion parameters and structural response.

Approach: numerical and statistical analyses of very large global ground motion databases, development of analytical and physics-based models of the near-surface propagation of seismic waves.

Impact: advance the assessment of multi-hazard resilient soil-foundation-structural systems.







Understand tectonic environment → Compute contributions of each source to the hazard → Define representative seismic demands

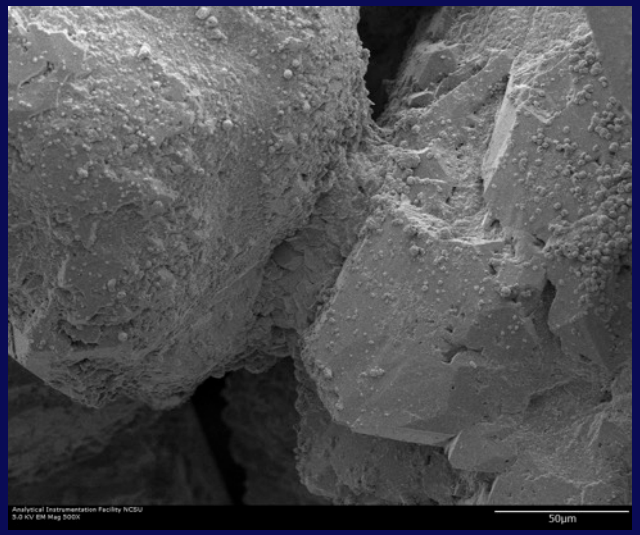
Seismic Hazard Mitigation

Goal: Improve soil behavior subjected to dynamic loading conditions through the introduction of natural microbial processes in the form of bio-cementation

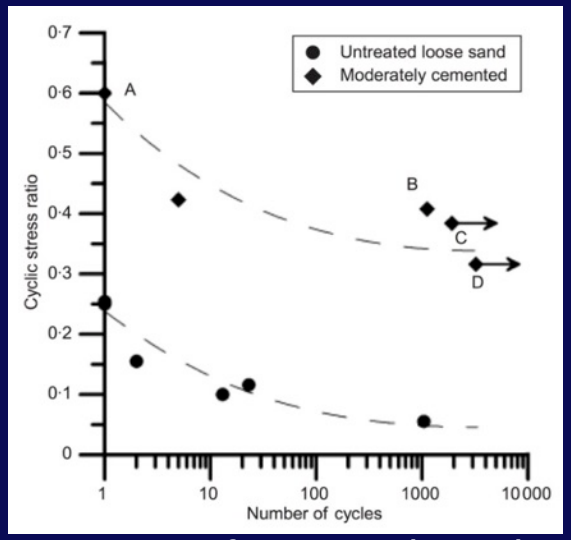
Approach: Soil bacteria can be harnessed to create cementation within the soil, reducing the susceptibility of both sandy and silty soil to liquefaction

Method: Liquefaction susceptibility is assessed through cyclic shear strength tests. Stud changes in the flow properties of the soil to assess potential in situ implementation.

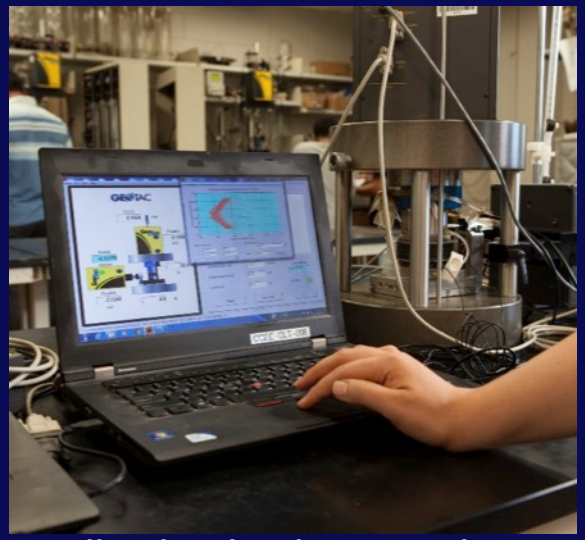
Impact: Provide a natural ground improvement alternative to improve the performance of infrastructure during earthquakes



SEM of bio-cemented sand



CSR curve for treated sand



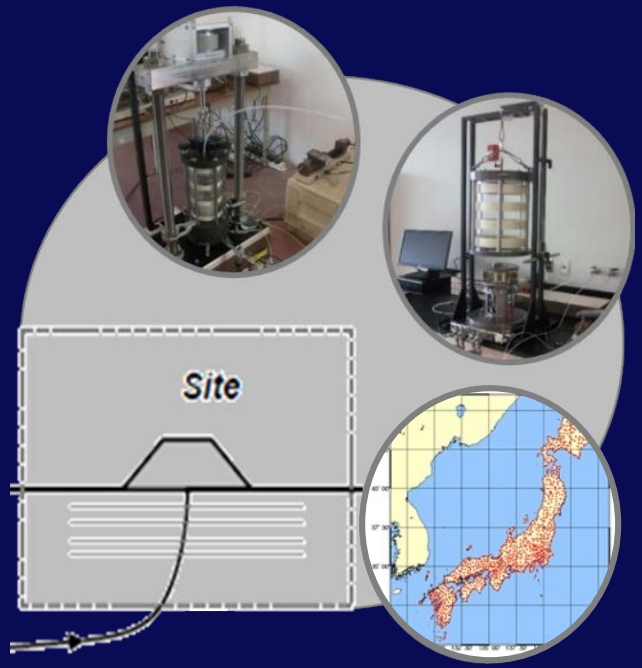
Cyclic simple shear testing

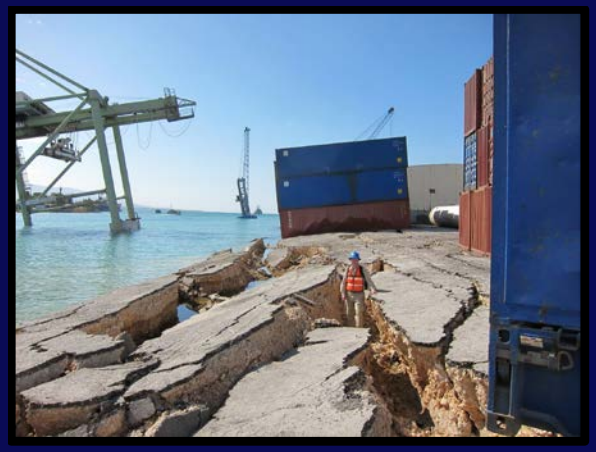
Geotechnical Earthquake Engineering

Goals: 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).





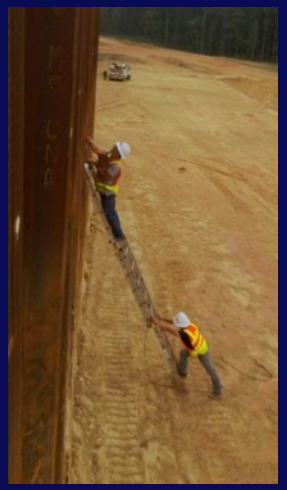
Temporary Slopes and Retaining Systems

Goal: Design approach for temporary slopes and retaining structures in North Carolina (NC) 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



Graduate students assessing test sheet pile wall and soil properties

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

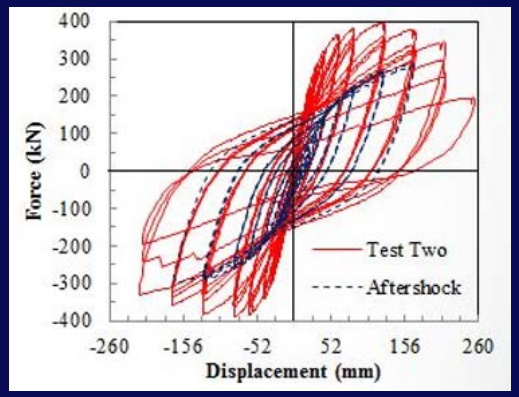
Structural Engineering Research Themes

- Repair of concrete, masonry and steel structures with advanced composite materials
- Earthquake structural engineering
- Nuclear power plant structures and components
- Structural health monitoring and prognostics
- Advanced/innovative systems

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, Above
Repaired and re-tested, Right
Improved behavior, Below



Advanced Composites for Structural Rehabilitation: FRP Strengthening of Masonry Structures

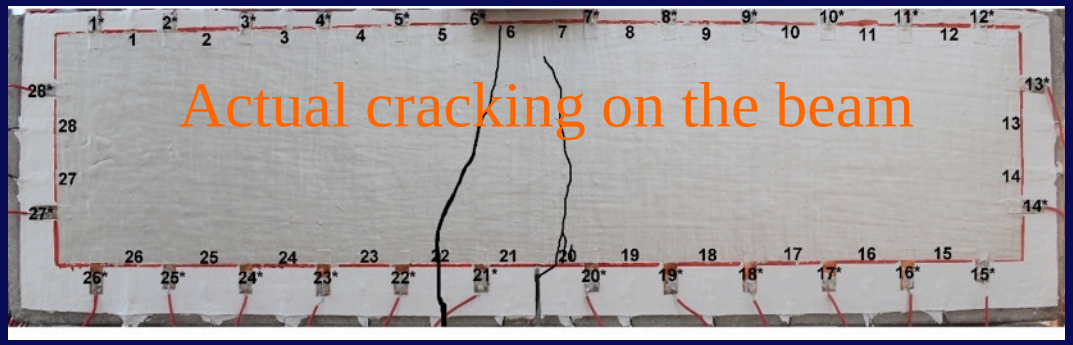
- **Goal**: Brittle behavior of unreinforced masonry walls in out-of-plane bending subject to wind, earthquake, or blast loading.
- **Approach**: Development of advanced fiber composite strengthening alternatives to significantly enhance the deformation capacity of existing walls.
- **Impact**: Enhanced resilience and public safety from premature failure, and extended service life of existing infrastructure.

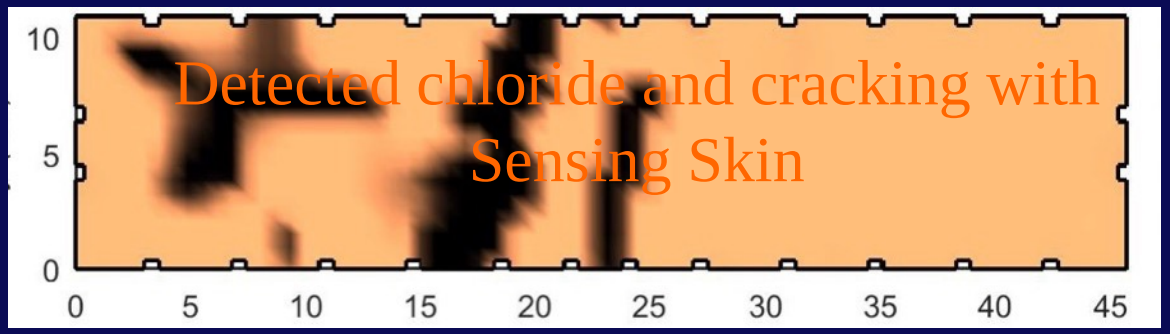
Large-Area Sensing Skin

- **Goal**: Monitor critical infrastructure for damage and corrosion using advanced sensing technologies

- **Approach:** Developed large-area *sensing skin* that enables detection of cracks and aggressive elements such as chlorides

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



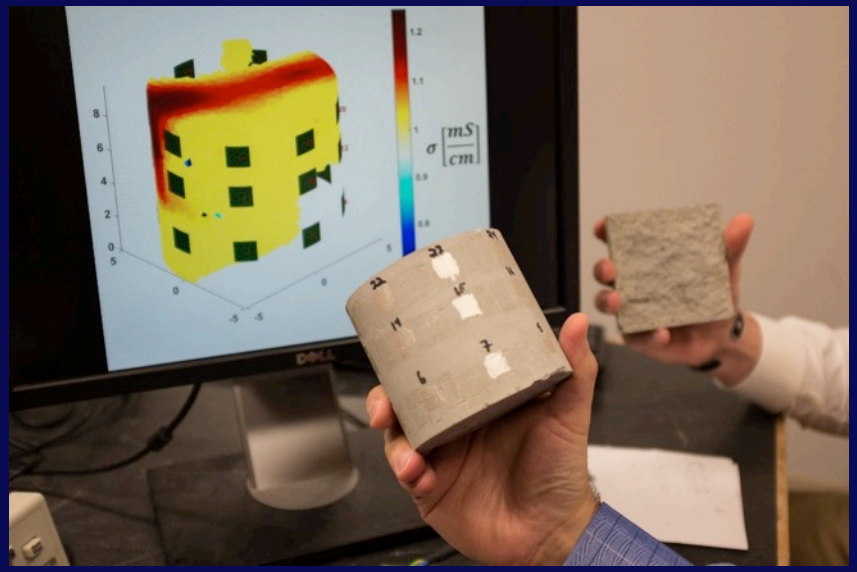


Non-Nuclear Imaging of Concrete

- **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:** Use electrical conductivity imaging of concrete to quantitatively monitor moisture ingress in concrete materials with and without cracks

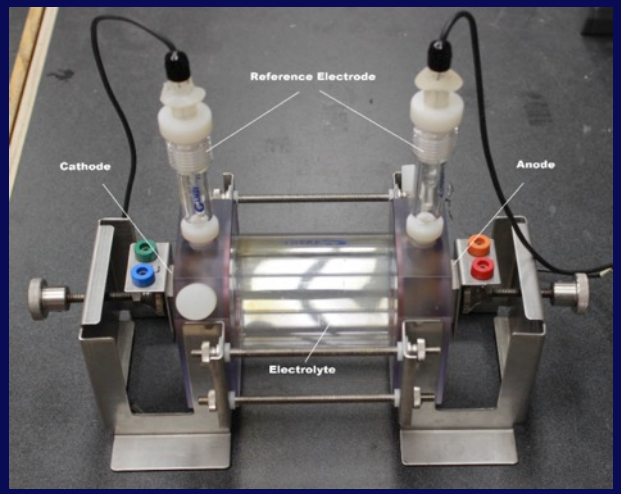
- **Impact**: Image concrete materials and potentially other porous media without the use of nuclear methods such a neutron tomography



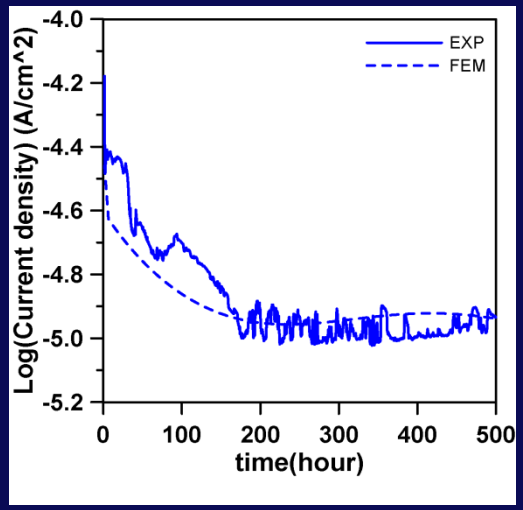
Electrical conductivity image of cracked concrete showing preferential flow of water in the crack. Also shown is the actual specimen tested.

Modeling Corrosion of Metals

- **Issue**: Corrosion of structural metals is a major concern for infrastructure owners and operators.
- **Approach:** Develop computational models to predict metals corrosion and experimentally verify models under controlled conditions. Quantify the effect of uncertainties using Monte Carlo simulations
- **Impact**: Models will enable predicting the future rate of corrosion and contribute to the safety of structures and maintenance planning



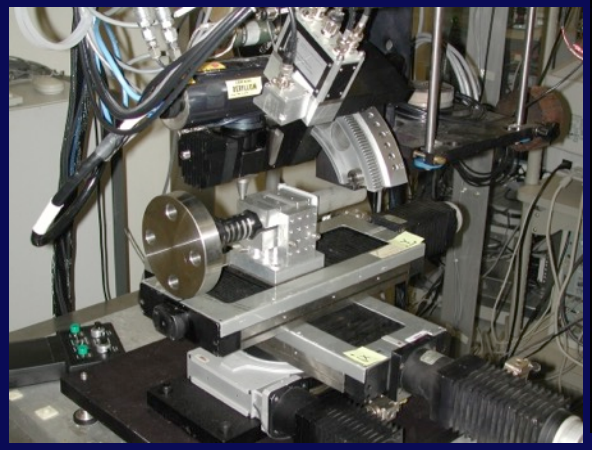
Controlled galvanic corrosion experiment



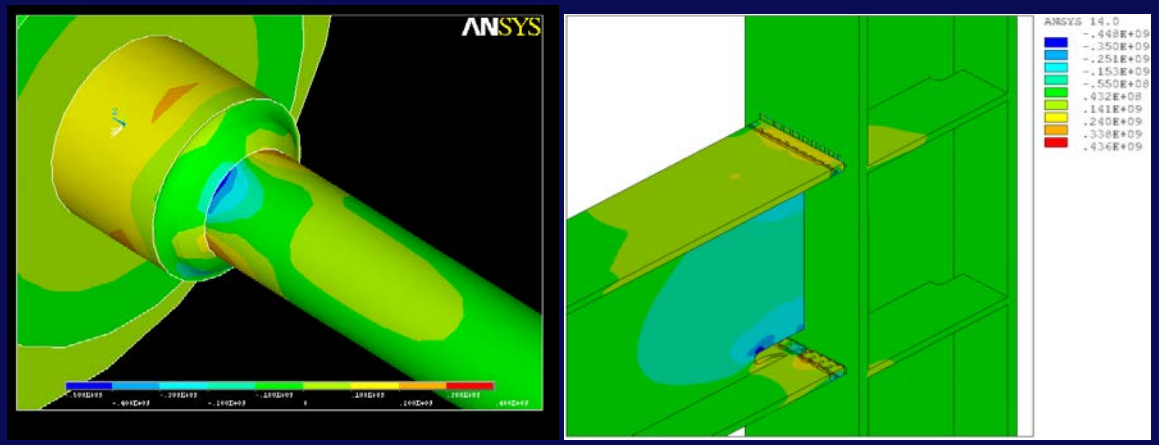
Comparison of experimental and computational results

Effect of Welding Residual Stresses on Structural Failure

Goal: Determine the effect of residual stresses on local fatigue crack initiation



Residual stress measurement at Oak Ridge National Lab



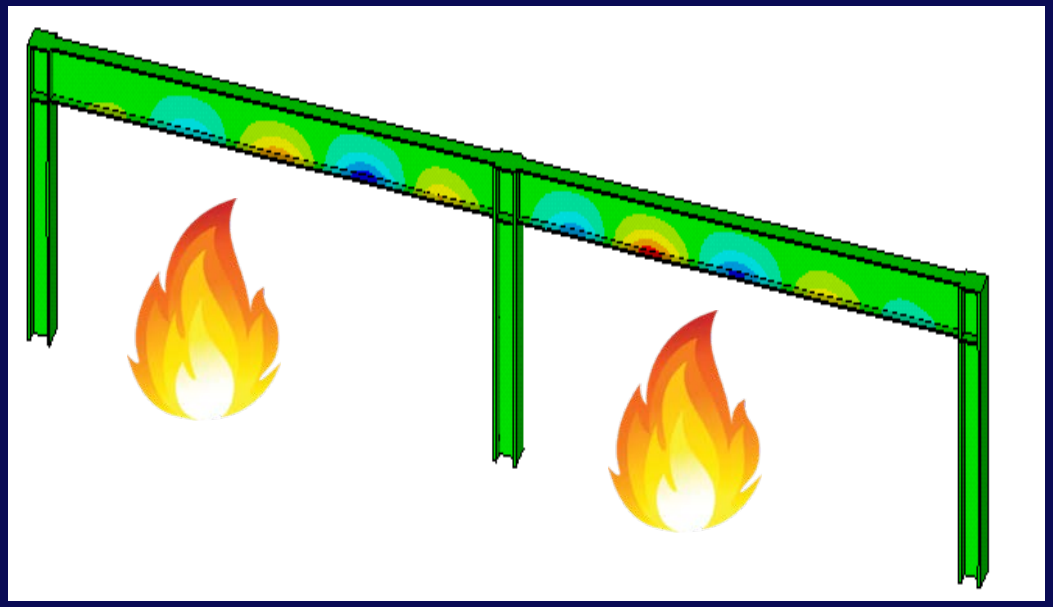
Simulation of residual stresses at welded joints

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 components lives and thereby improve design methodologies

Performance Evaluation of Fire Damaged Steel Structures

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



Simulation of fire damage in steel frame

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

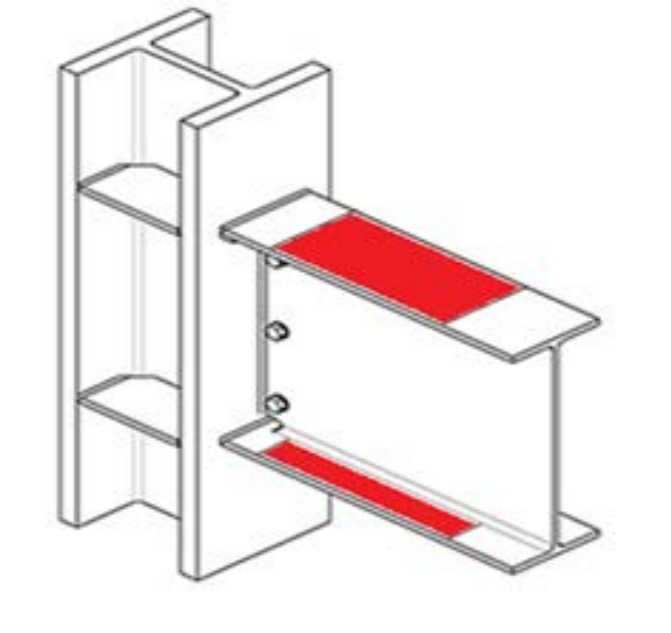
Impact: Structural rehabilitation to extend life of fire damaged structures

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

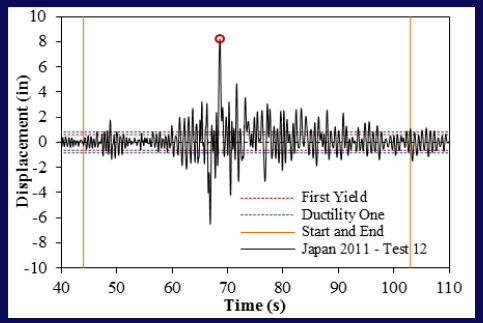
Impact: Enhanced seismic performance of steel building.

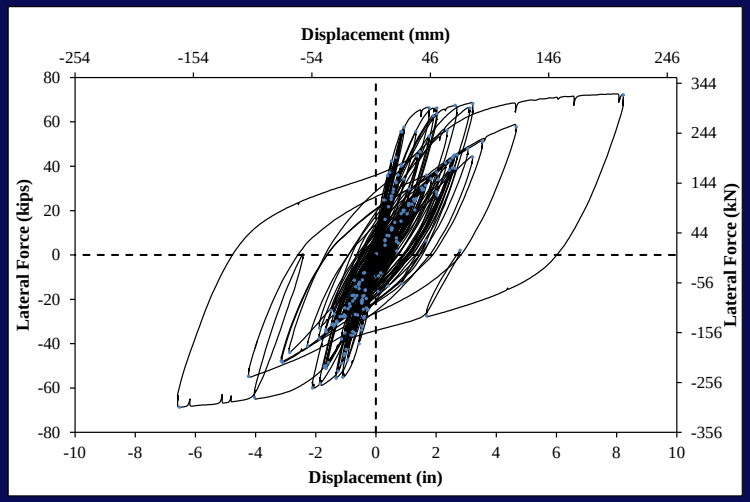


Heat treated beam section highlighted red

Earthquake Structural Engineering:
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.





Earthquake Structural Engineering: Ductility Capacity of Steel Bridge Bents

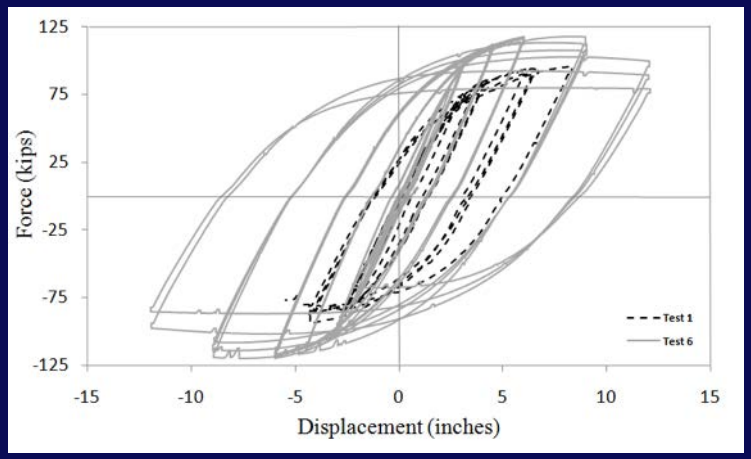
Issue: Limited ductility capacity due to connection geometry, weld size, and weld quality

Bird Creek Pedestrian Bridge
(Compliments of AKDOT)

Full-scale lab test

Approach:

- Full-scale seismic testing of existing design
- Finite element modeling of existing and new designs to develop alternatives.
- Full-scale seismic testing of new designs capable of resisting high seismic demands.
- Dynamic shake table testing for proof-of-concept.



Improvement in Performance

Impact: New bridge design detail Employed by AKDOT engineers

Soil-Structure Interaction for Concrete Bridge Foundations in Seismic Regions

Issue

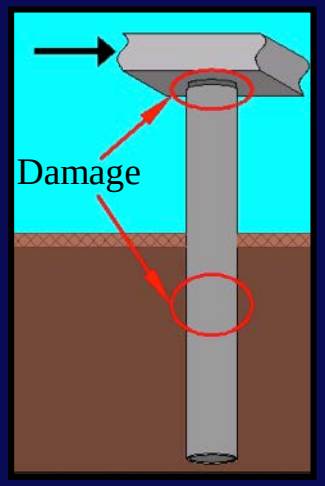
- Reinforced concrete filled steel tubes are beneficial for bridge foundations, but the impact of soil on their seismic behavior is unknown.

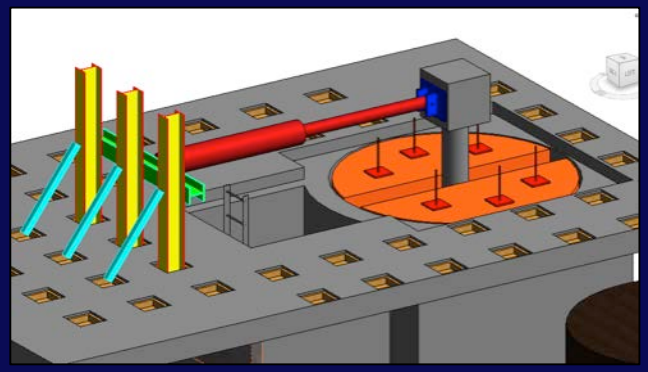
Approach

- Large-scale soil-structure interaction tests and modelling to develop design recommendations.

Impact

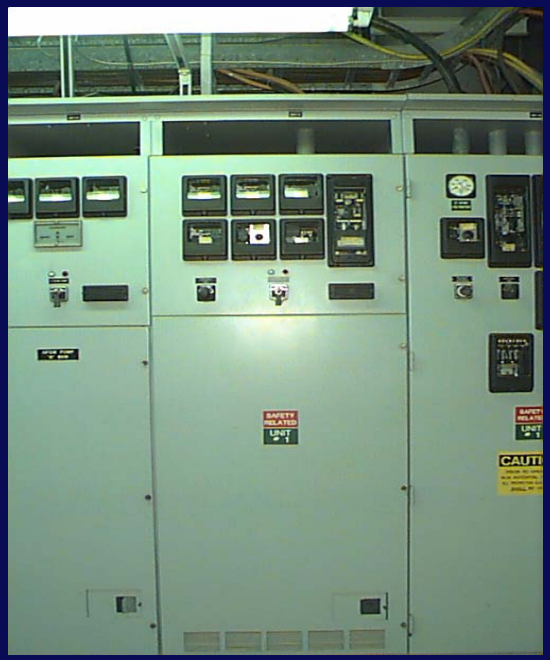
- More efficient bridge foundations in seismic regions.





Clockwise from top left: Bridge in Alaska using system, possible damage locations, test setup, pile inserted into soil at lab

Earthquake Performance of Equipment & Piping in Nuclear Facilities

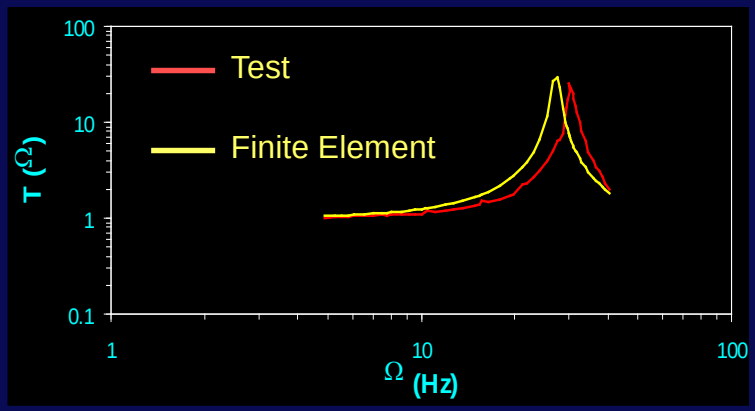


Goal: Improve the seismic performance of safety related piping and equipment in a power plant.

Approach: Account for mass interaction, multiple support motion, non-classical damping, nonlinearity in anchorage.

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

Methods: Experimental and finite element based qualification of electrical control panels.



Seismic Probabilistic Risk Assessment and Fragility of Nuclear Structures

Goal: Account for uncertainty and randomness in material properties, dynamic characteristics, earthquake input, modeling, and structural behavior.

Approach: System-level fragility evaluation by combining test data for components with system-level simulation models.

Impact: Improved estimates of seismic fragilities and new methodologies for updating the fragility curves.

Method: Framework for considering uncertainty in constitutive model of concrete and Bayesian updating of fragility estimates.

STEP 1: Seismic-Hazard Analysis at the Site

↓

STEP 2: Response of Plants and Systems

↓

STEP 3: Component Fragilities

↓

STEP 4: System Fragilities

↓

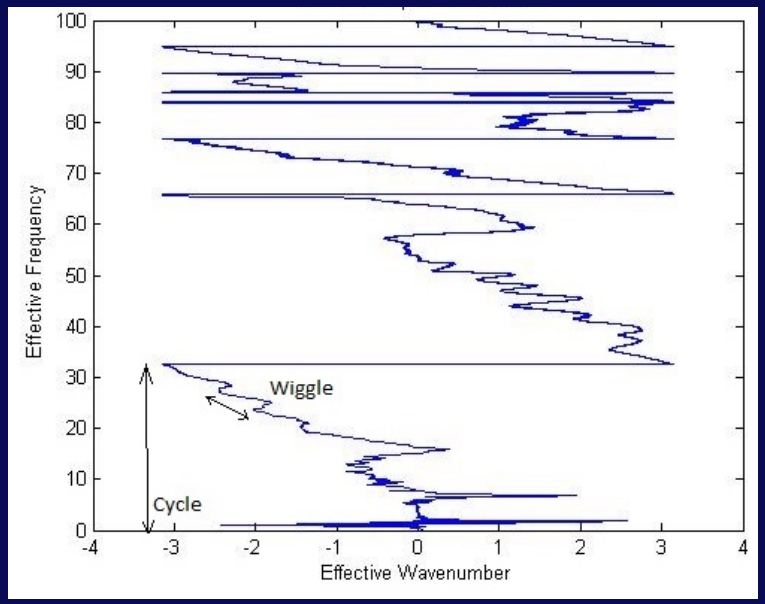
STEP 5: Consequence Analysis

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

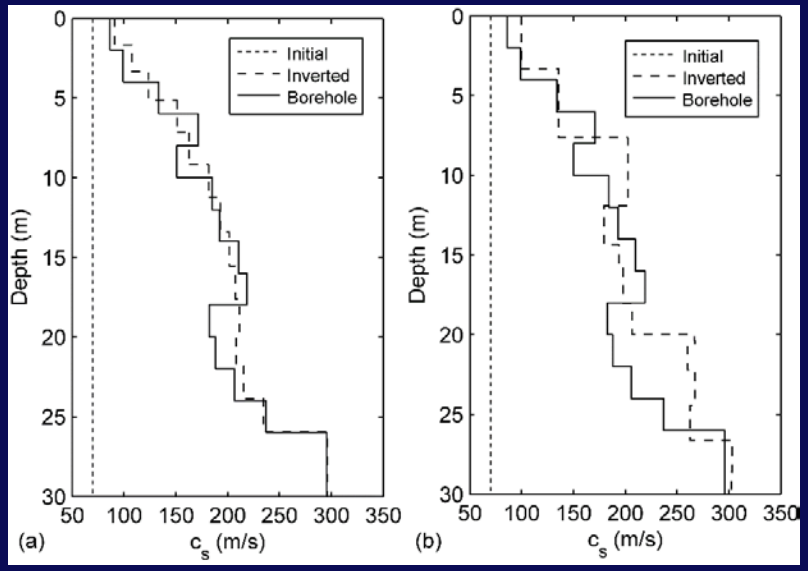
In laboratory settings, EDAR resulted in <5% error compared to as much as 45% from the state-of-the-art

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

Impacts:
(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)

Mechanics and Materials

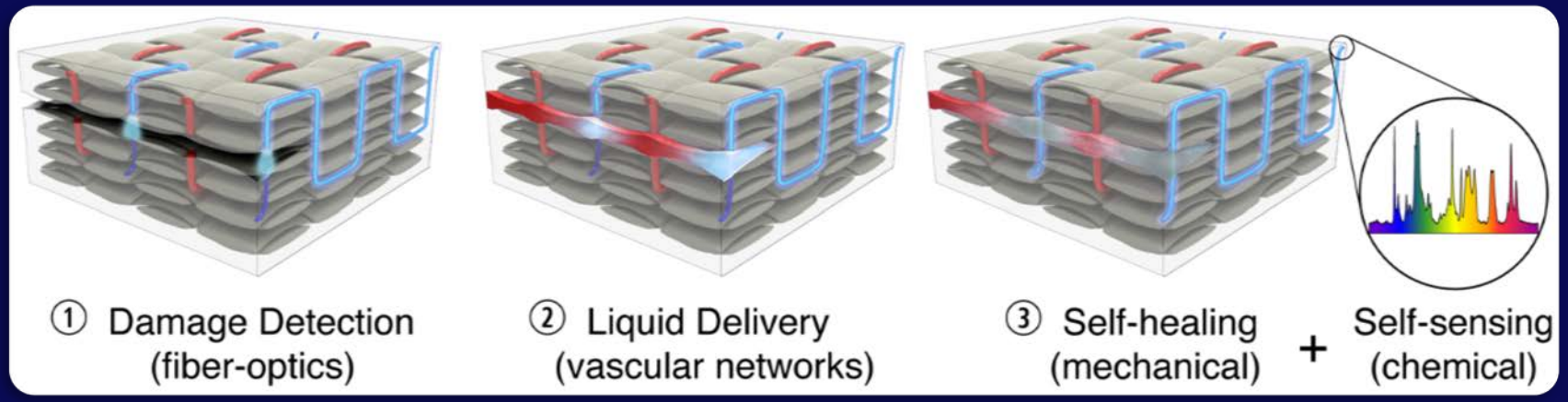
Interdisciplinary group working towards the common goal of understanding, modeling and improving a wide spectrum of traditional and emerging materials, using theoretical, experimental and computational mechanics from nano- to macro-scale.

Multifunctional Self-healing/Sensing Composites

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

Approach: Integration of bioinspired microvascular networks with interwoven optical fibers.

Impact: Enhanced safety, resilience, and reliability of FRC for aerospace, automotive, civil, energy, and naval infrastructure.



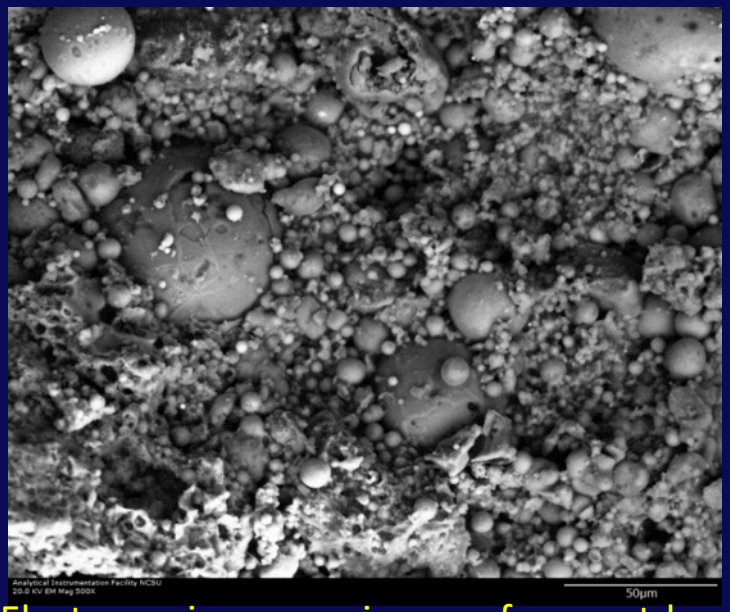
AFOSR YIP # FA9550-18-1-0048

Cement-Less Concrete?

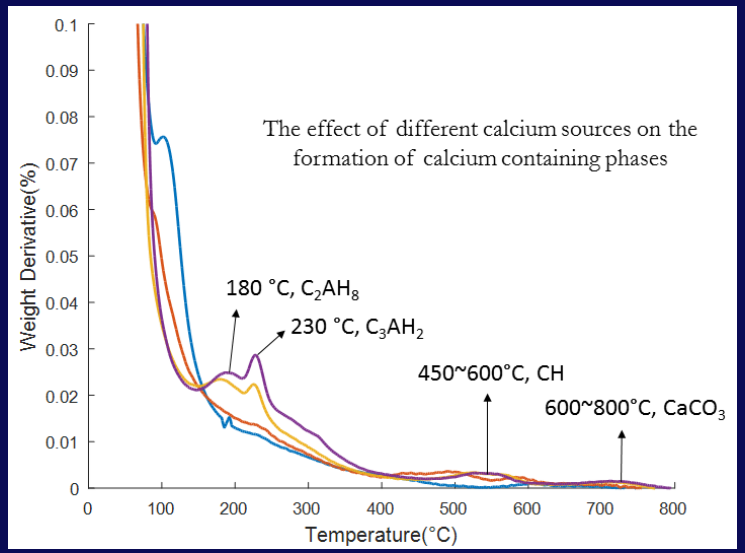
Issue: The production of portland cement is energy intensive and results in high environmental emissions

Approach: Understand the role of calcium, calcium source, and water in microstructure formation of geopolymers and multi-scale modeling of microstructure

Impact: Reduce the environmental implications from cement production; reduce the amount of fly ash in landfills



Electron microscope image of cement-less concrete made with fly ash geopolymer

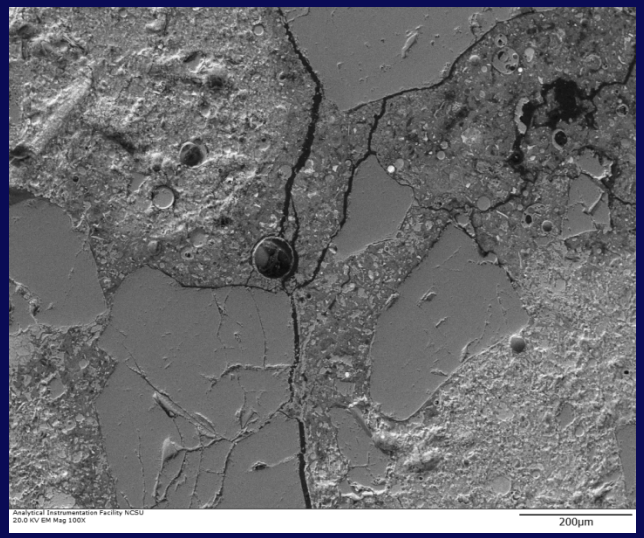


The Role of Micro-Cracks in Mass Transport

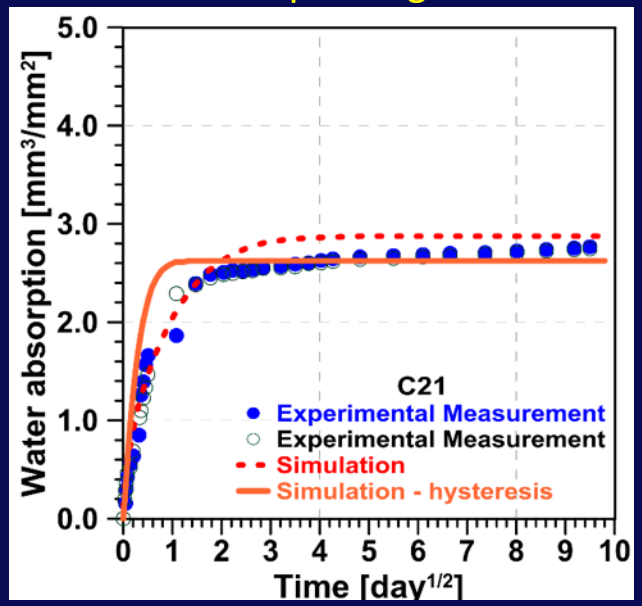
Issue: Premature deterioration of concrete infrastructure resulting from accelerated ingress of water and aggressive elements in micro-cracks

Approach: Understand the effect of micro-cracks on water and ion transport in concrete; numerical simulation of moisture ingress in damaged concrete

Impact: Resilient concrete, accurate service life predictions for scheduling maintenance and repair activities, potentially reducing the downtime of infrastructure



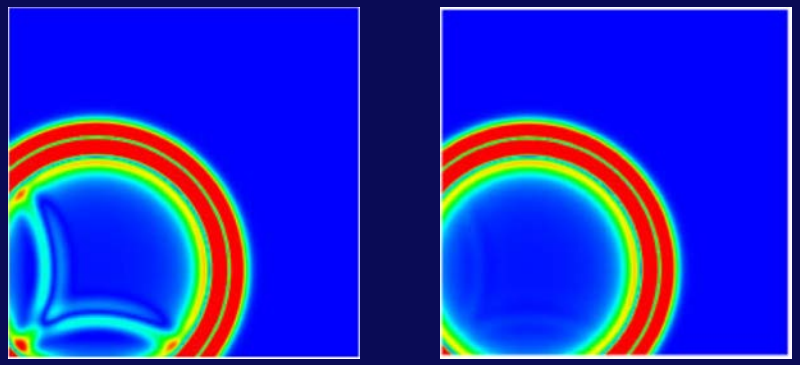
Electron microscope image of concrete



Comparison of simulations with experiments

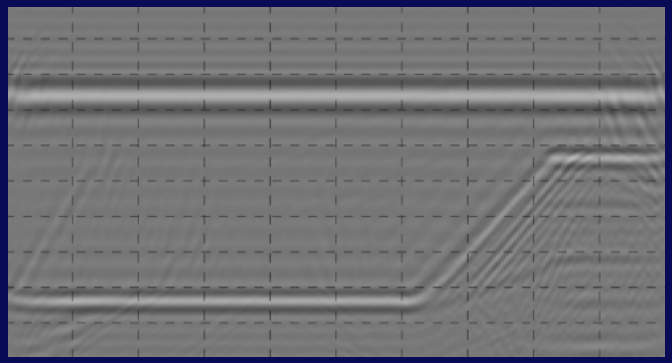
Computational Mechanics: Wave Propagation Algorithms

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)
Impacts: crack detection, mapping oil reservoirs, medical imaging



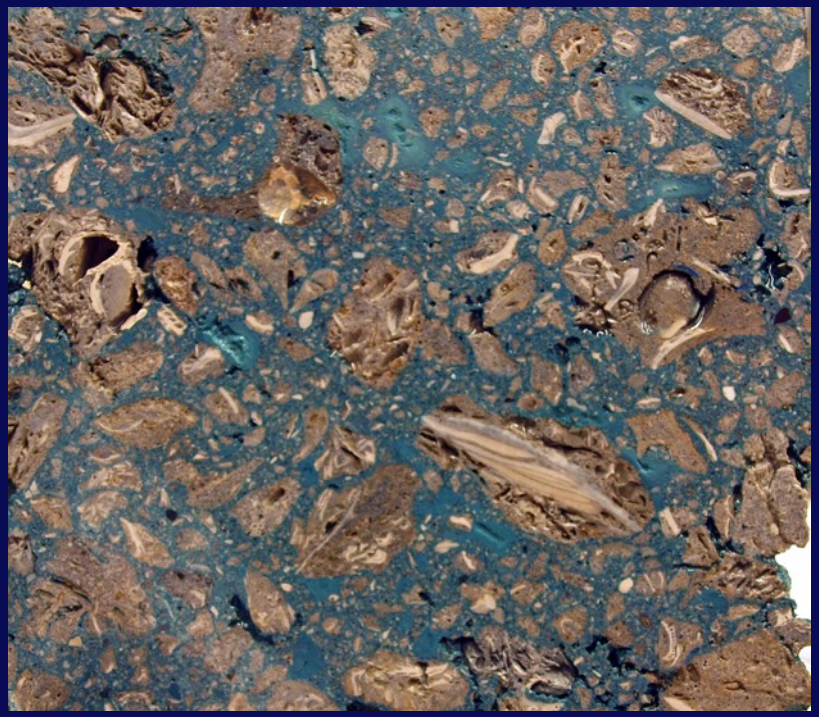
Predicted substructure of a valley using the new imaging algorithm

Re-Appraisal of the Specification of Aggregate Base Course

Goal: Link mechanical performance to the aggregate base course (ABC) material specification (e.g., gradation, geometric properties, mineralogy).

Approach: Use material testing, mechanical performance, and numerical techniques to enhance ABC specification.

Impact: Improve ABC performance and directly relate to ABC design.

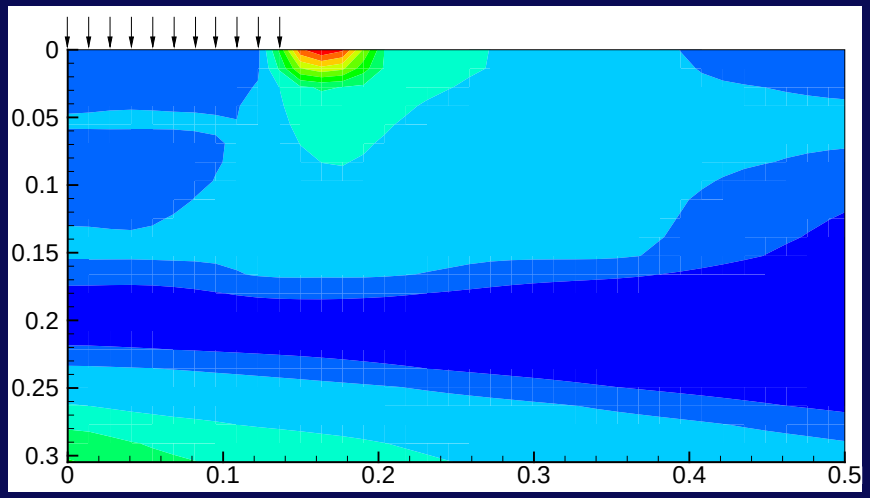


Asphalt Material and Pavement Modeling

Goal: Develop material and structure level models to predict long-term performance of asphalt pavement under realistic loading and environmental conditions.

Approach: Apply mechanistic and computational principles.

Impact: Accurate prediction of long-term pavement performance. Provide a foundation to mechanistic pavement design and performance-related specifications.



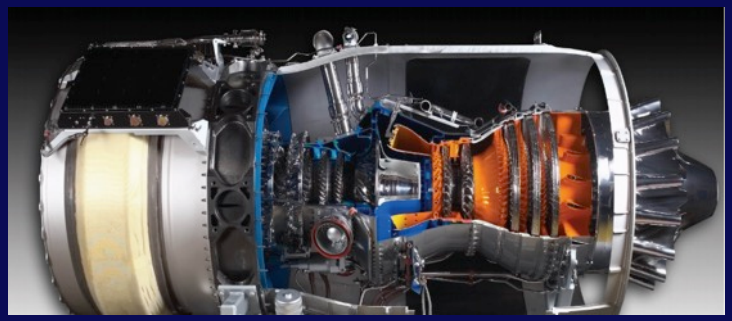
$$\varepsilon = E_R \int_0^{\xi} D(\xi - \xi') \frac{d\left(\frac{\sigma}{C(S)}\right)}{d\xi'} d\xi' + \left(\frac{p+1}{Y}\right)^{1/p+1} \times \left(\int_0^{\xi} \sigma^q d\xi\right)^{1/p+1}$$

High Temperature Material Modeling and Simulation for Energy, Aerospace and Automobile Industries

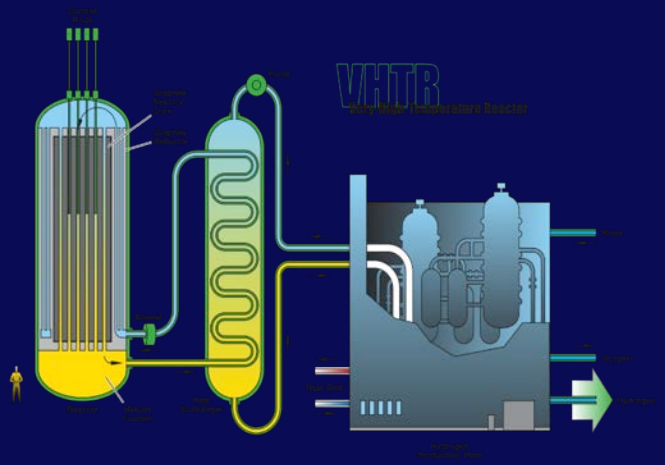
Goal: Increased operating temperature increases energy efficiency of machines and plants

Approach: Develop advanced material model for simulation based structural design and analysis

Impact: Economy and sustainability of high temperature industries and systems



Gas turbine jet engine



Next generation nuclear power reactor

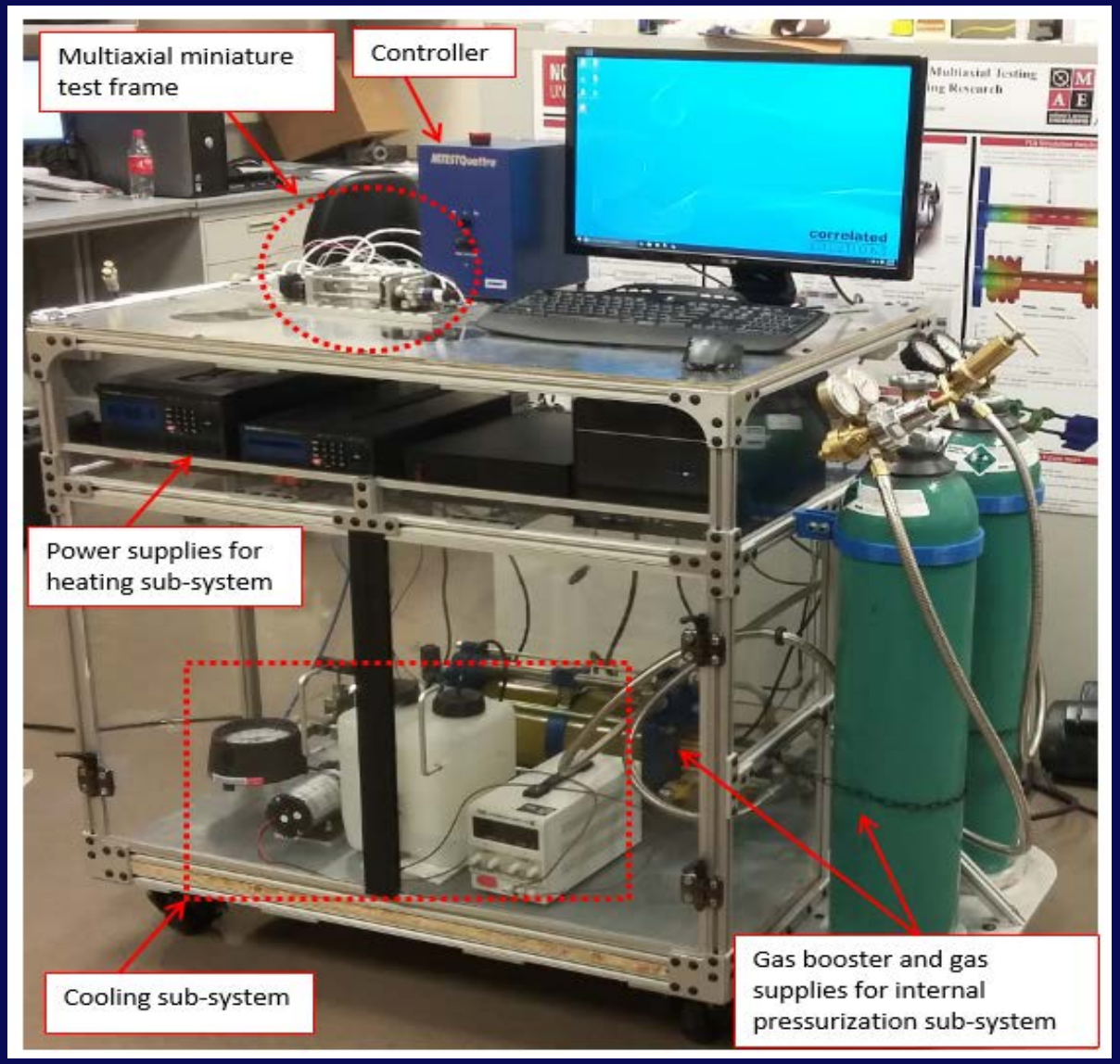
Superheater boiler header

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 discipline and industry experts designed and developed the system

Impact: Efficient and economic design of new materials and high performance components



Transportation Systems: Sustainability

- **Goal:** Achieve sustainable funding and minimize the negative environmental impacts of transportation activities
- **Approach:** Improvements in transportation system operations in tandem with capacity investments to improve productivity, efficiency and sustainability.
- **Impacts:** Industry practice, economic development, land use planning, environmental quality, travel time reliability, safety, and fiscal viability
- **Methods:**
  - System Operations
  - Environmental Impacts
  - Design Innovations
  - Wider Economic Impacts
  - Socioeconomic Impacts
  - Maintenance

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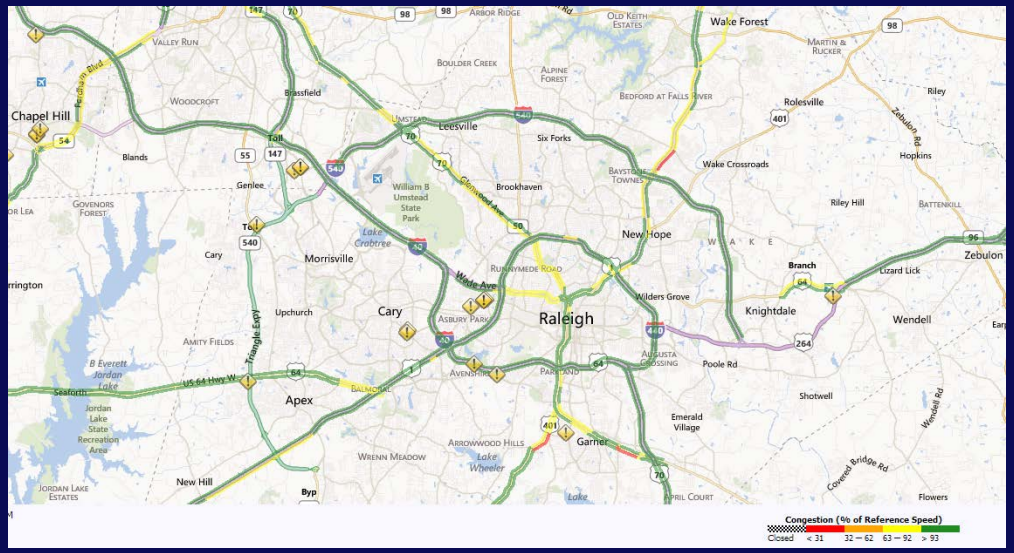
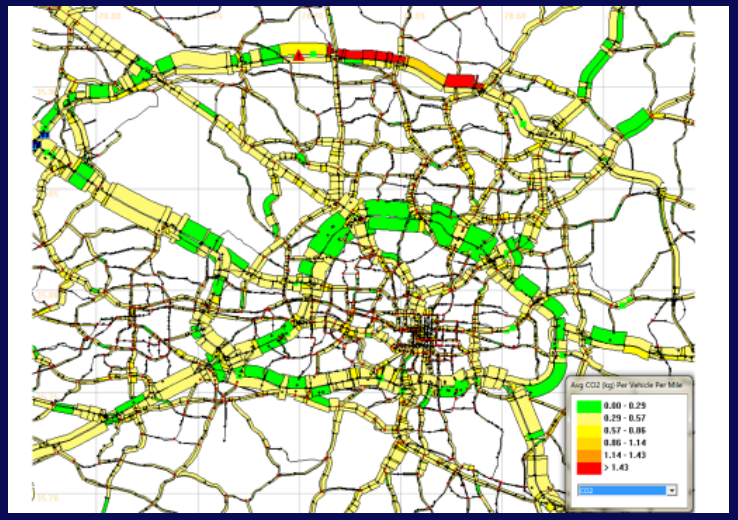
System Operations

- **Goal:** Maximize system productivity and efficiency
- **Approach:** Improved techniques for system monitoring, management, and planning
- **Impact**
  - National guidebook for travel time reliability monitoring
  - Highway Capacity Manual procedures
  - Connected vehicle research for Federal Highway Administration
  - Operational efficiency and pedestrian safety for roundabouts
  - Work zone practice
  - Practitioner handbooks
- **Methods:**
  - Data analysis from connected, autonomous, and other probe vehicles
  - Simulation
  - Model and tool building
  - Guidebook development



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)
- **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
  - Environmentally—focused transportation model calibration
  - Trade-offs between safety and environmental objectives
- **Methods:**
  - Multi-scale simulation modeling
  - Empirical data collection
  - High resolution in-vehicle sensing



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

Economic Prosperity

- **Goals**: Foster economic prosperity through coordinated transportation investments (MAP-21)
- **Approach**: Focus on freight productivity and efficiency as well as personal mobility
- **Impact**: Recommended investment action plans and policies
- **Methods**:
  - Economic impact analysis
  - Input-output models
  - Benefit-cost analysis
  - Land use and transportation planning
  - Modal and intermodal innovation

Social Prosperity

- **Goal**: Enhance social prosperity through policies and actions that provide mobility for all socioeconomic groups and foster efficiency and equity in transportation systems and land use
- **Approach**: Study the interdependencies between the spatial 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

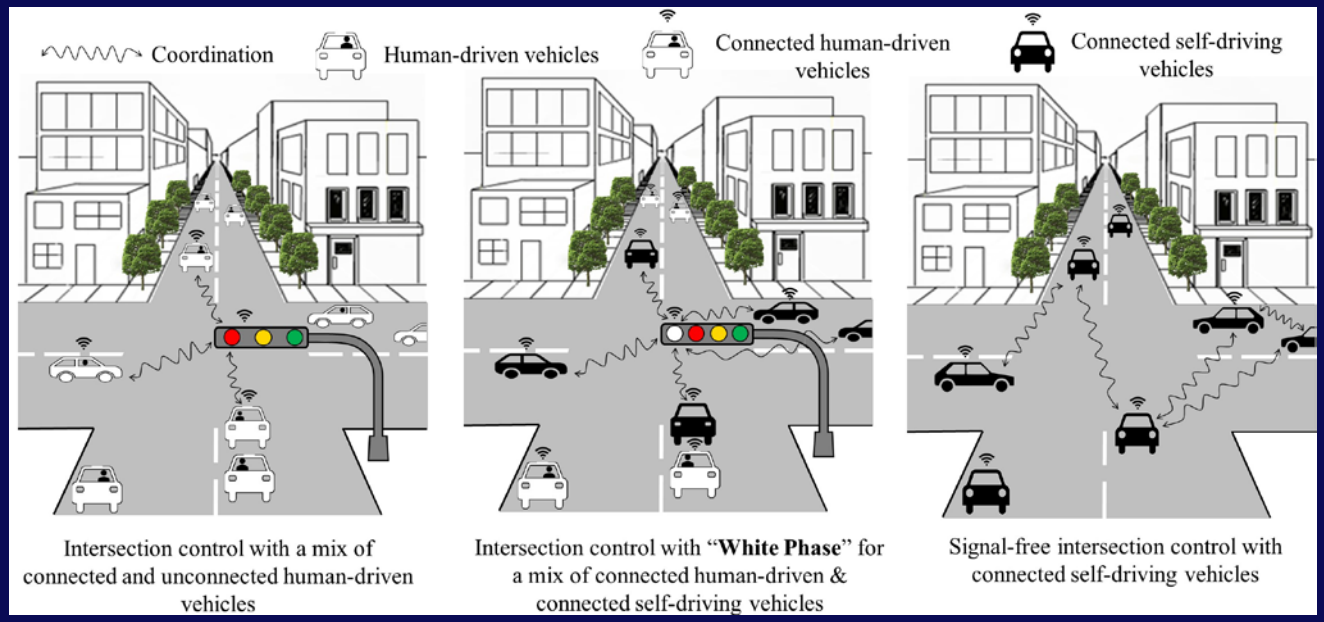
Traffic Control with Automated Vehicles

- **Goal:** Advancement of real-time optimal traffic control in large-scale transportation networks with connected and automated vehicles

- **Approach:** Develop distributed techniques for traffic system monitoring, management, and planning

- **Impact:** Improvement in
  - Traffic operations
  - Safety
  - Environment

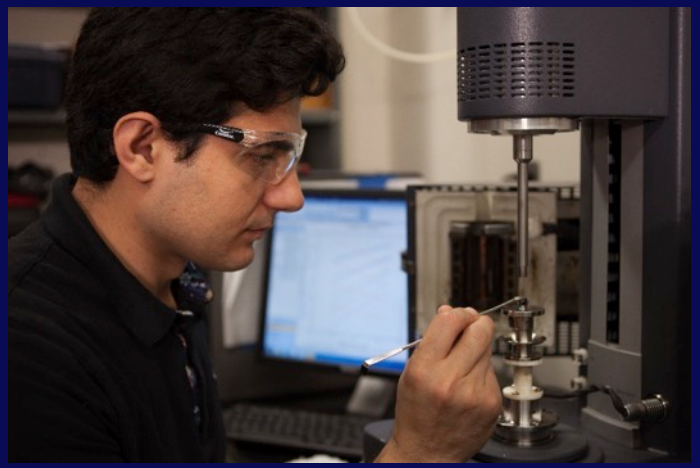
- **Methods:**
  - Modeling
  - Optimization
  - Data analysis
  - Simulation



Road Maintenance

- **Goal**: Create investment and maintenance strategies that maximize infrastructure condition and long-term sustainability
- **Approach**: Analyze truck traffic counts, weights, and locations
- **Impact**: Cluster analyses that map treatment options to facility use, consistent with the Mechanistic-Empirical Pavement Design Guide method
- **Method**: Mechanistic-Empirical Pavement Design Guide and truck datasets including super-heavy trucks

Transportation Materials

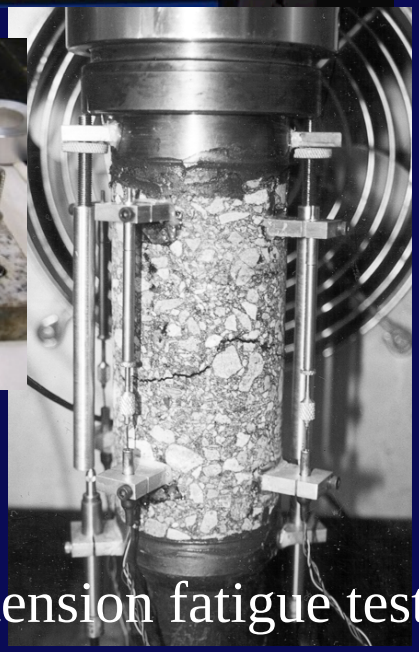


Asphalt Binder and Mixture Testing

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.



Direct tension fatigue test

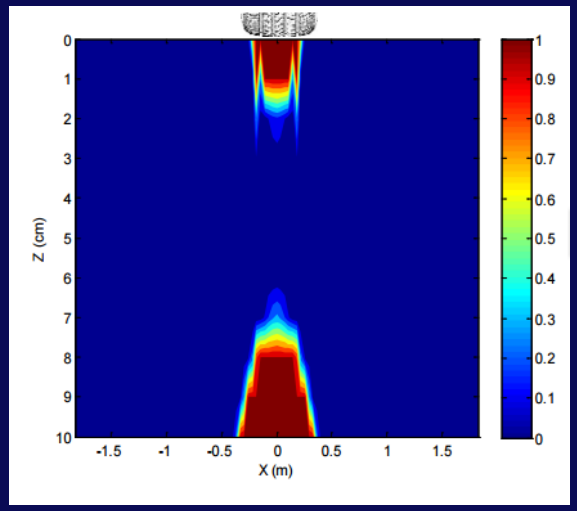
Hot-Mix Asphalt Performance-Related Specification (HMA-PRS)

Goal: Develop PRS for HMA to provide the foundation 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 United States; asphalt pavements

Performance Testing



Pavement Performance Prediction

Performance-Related Specifications (PRS) 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

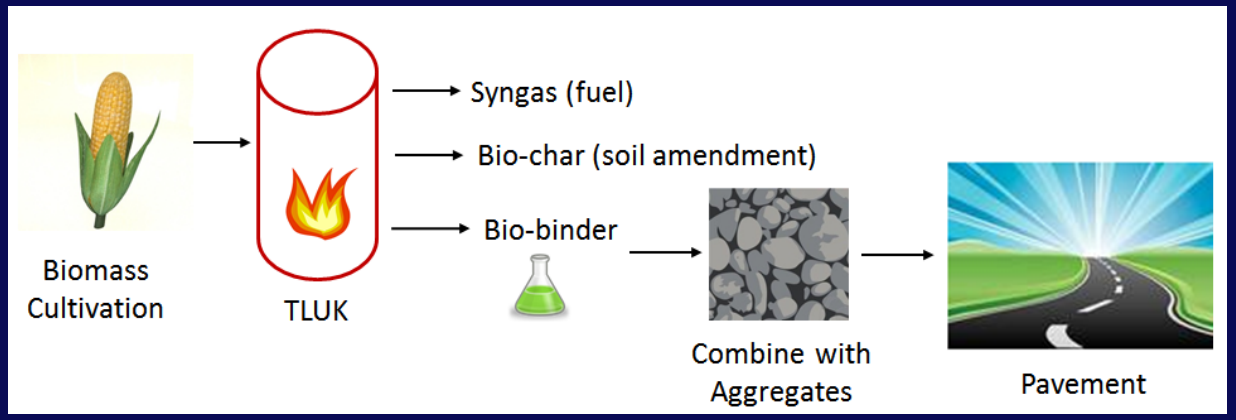
Impact: Improved selection of asphalt emulsions in preservation surface treatments, preventing premature failure

Bio-renewable Alternative to Asphalt

Goal: Produce sustainable alternative to petroleum-based asphalt binder

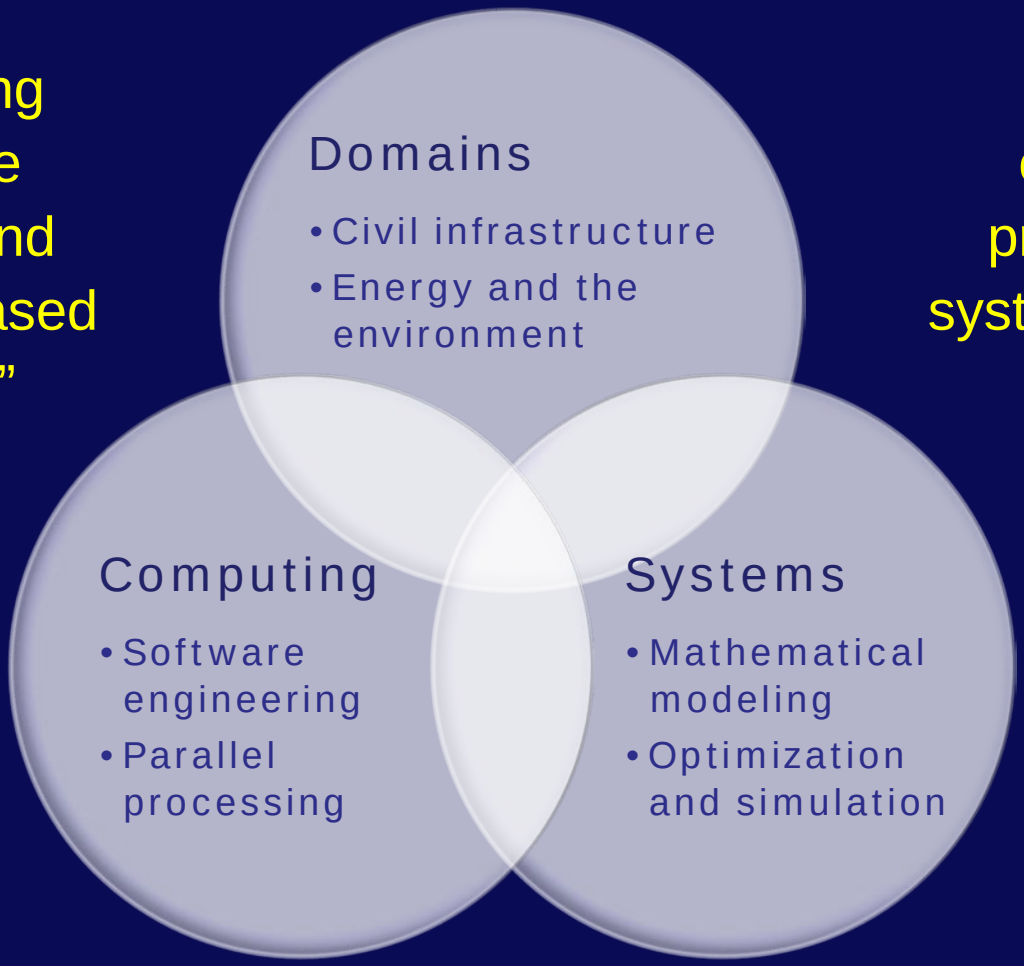
Approach: Produce bio-renewable bio-binders through Top-Lit Updraft Kilning (TLUK) of biomass

Impact: Bio-renewable alternative to asphalt. 30 millions tons of asphalt consumed annually in the U.S. to support transportation infrastructure.



Computing and Systems

"Developing innovative software and computer-based solutions"



"Tackling challenging problems with systems concepts"

Computing and Systems

- An interdisciplinary program in civil engineering
- Faculty expertise in core computing and systems areas as well as traditional areas: structures, coastal engineering, environmental engineering
- 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
- Our graduates pursue careers at traditional firms, government agencies, national laboratories, and universities, as well as at others such as SAS, Cisco, IBM, Microsoft, GE, and Intel

Four Core Areas of Strength

- High Performance Computing
  - Parallel and distributed computing, concurrent systems, and performance analysis.
- Software Engineering
  - Programming methodology, formal approaches for reasoning about computer systems, and verification and validation.
- Systems & Optimization
  - Mathematical modeling, search algorithms, decision support systems, stochastic modeling, inverse problems, forecasting and data assimilation, and uncertainty quantification.
- Numerical Methods
  - Algorithm development and analysis, finite element and other discretization methods, and particle methods.

Optimization of Transportation Systems

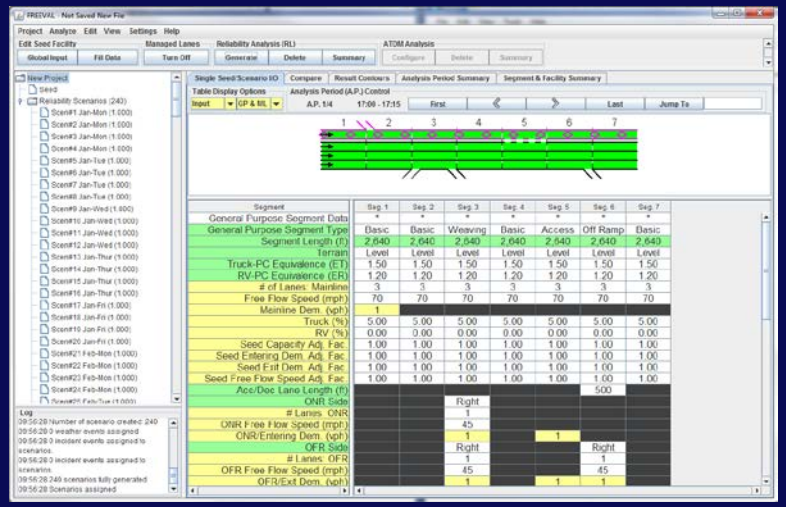
Goal: Better decision-making tools for network design and traffic management

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

Methods: Software design, mathematical optimization, integer programming, metaheuristics



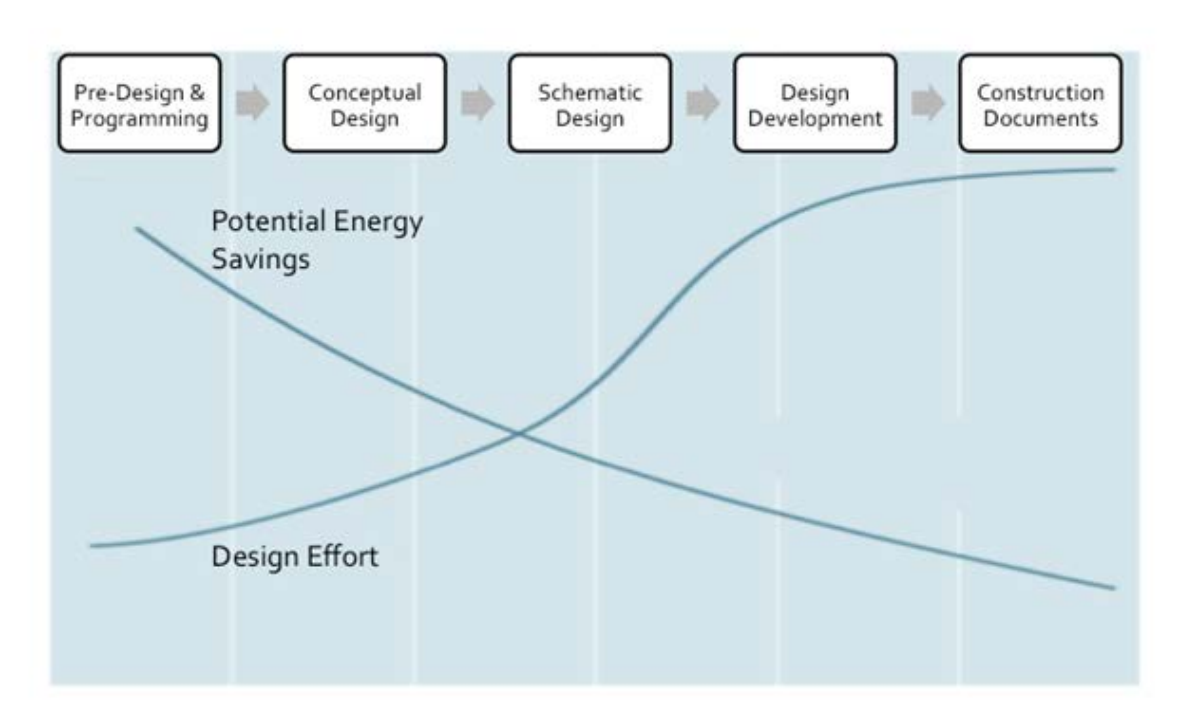
Energy Efficient Buildings

Goal: Increase energy efficiency of buildings

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

Impact: green buildings, energy sustainability

Methods: Optimization, simulation and modeling



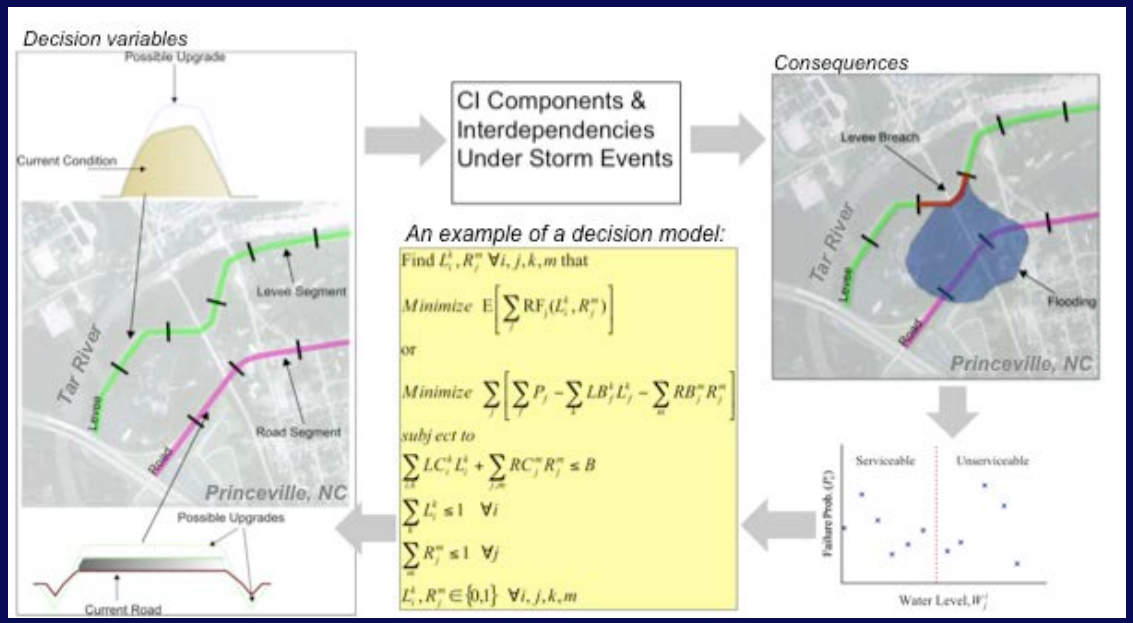
Infrastructure Resilience

Goal: Prioritize infrastructure investments to improve lifeline service resilience

Approach: Storm hazard impact simulation, mathematical modeling and computational procedures

Impact: Civil infra-structure investment prioritization to improve lifeline service resilience to storm hazards

Methods: Optimization, simulation and modeling, high performance computing



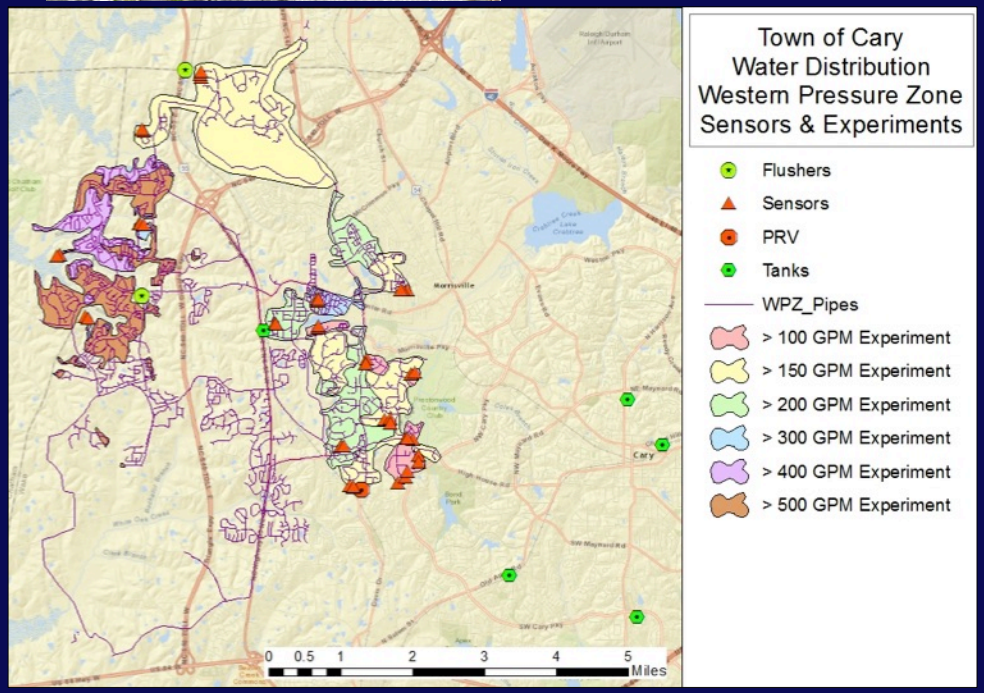
Water Distribution System Management

Goals: 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, Bayesian inference



Pressure Sensor Placement for Leak Detection

Socio-Technical Systems Analysis for Adaptive Water Resources Sustainability

Goals: 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, optimization

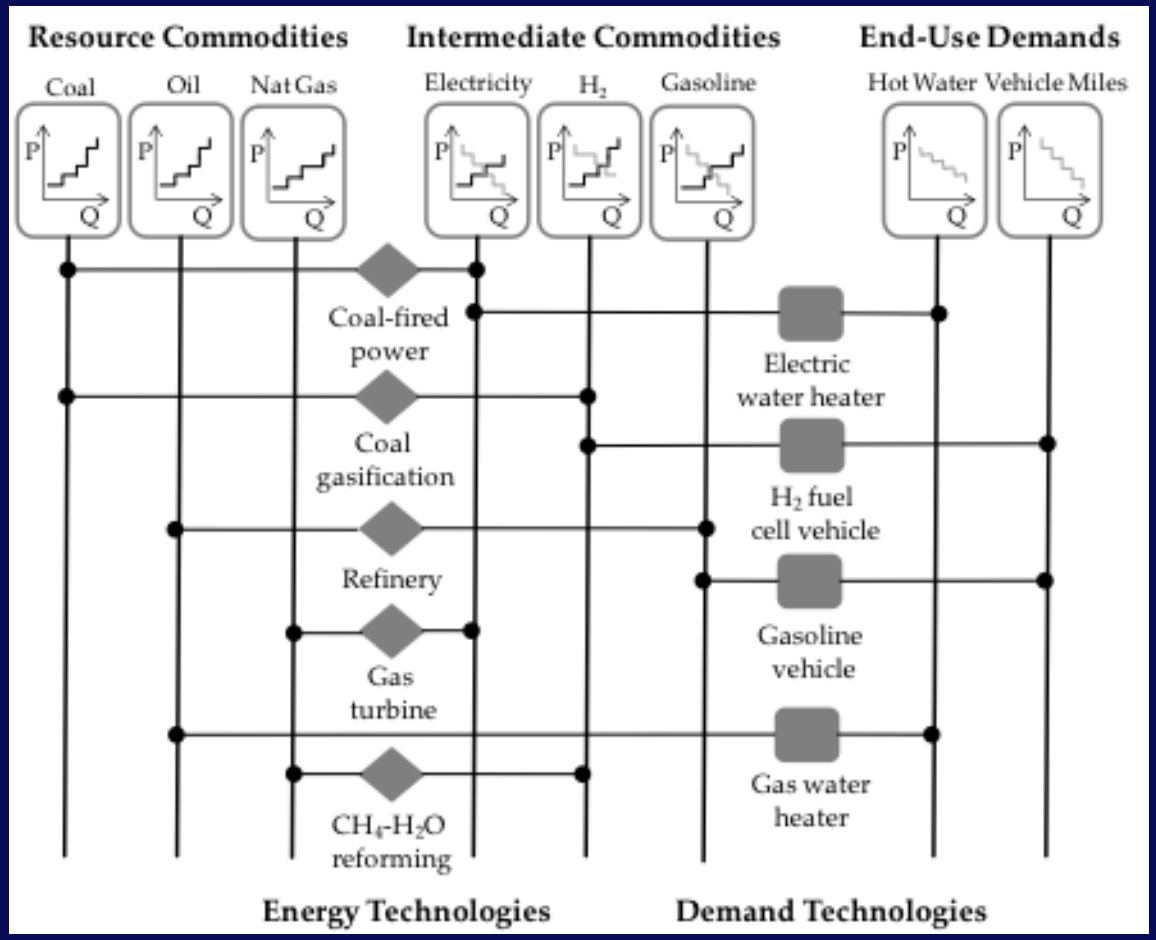
Energy Systems Modeling

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, high performance computing



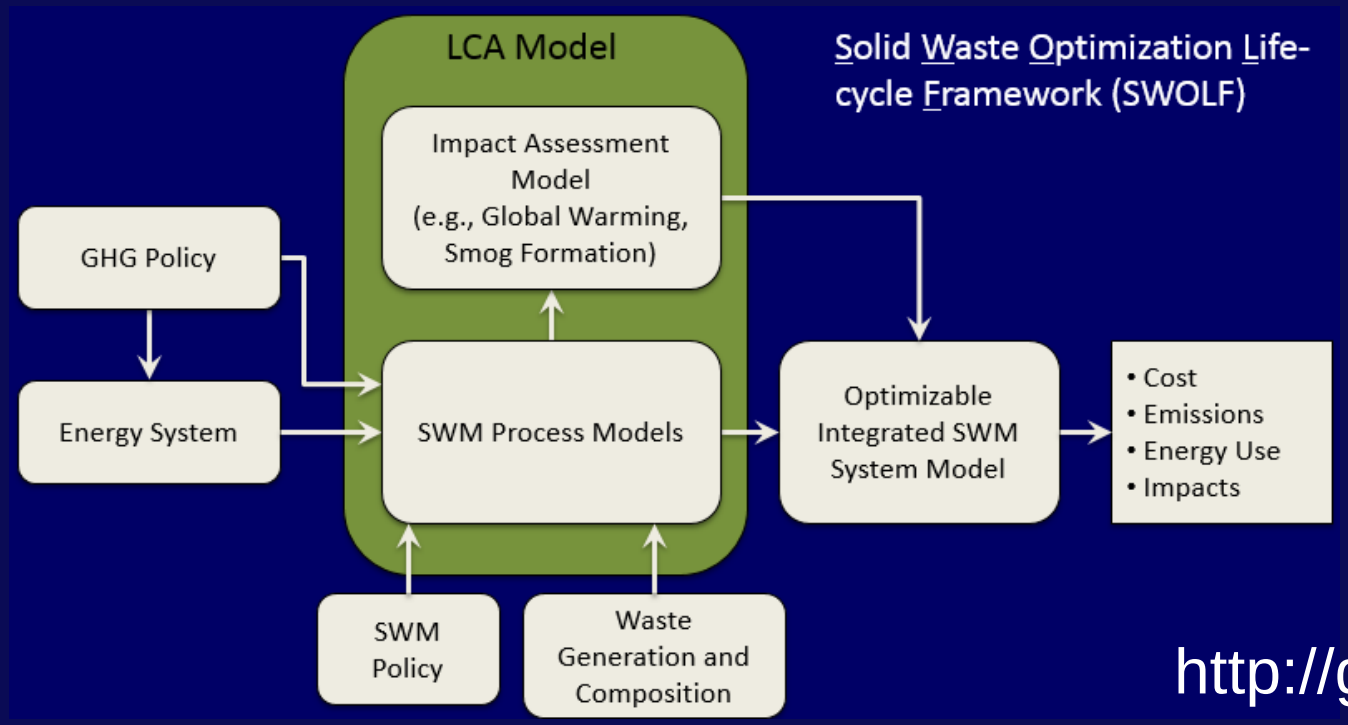
Integrated Solid Waste Management

Goals: 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, software engineering



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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

Impact: Improved water sustain-ability, flood and drought management, reservoir operation, hydropower management, water quality, and risk management

Methods: Stochastic modeling, simulation, optimization

Climate Informed Drought Management at Falls Lake

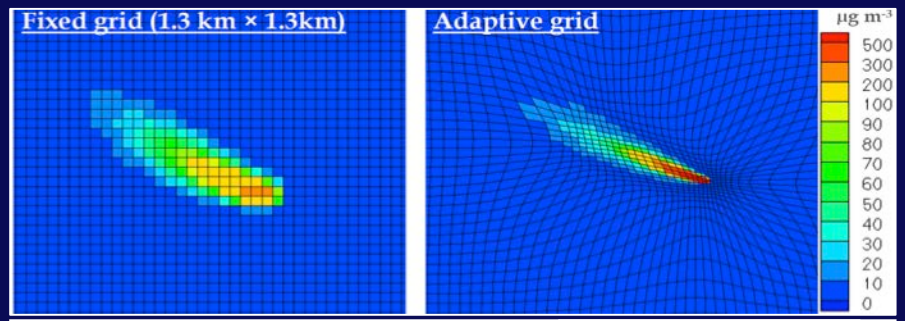
Air Quality Modeling

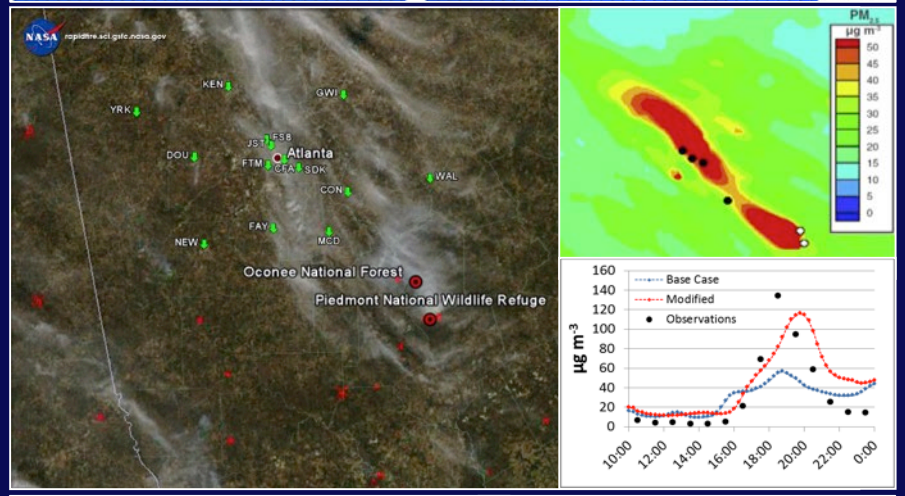
Goal: Identify and evaluate strategies to mitigate air pollution and its impacts using computational models

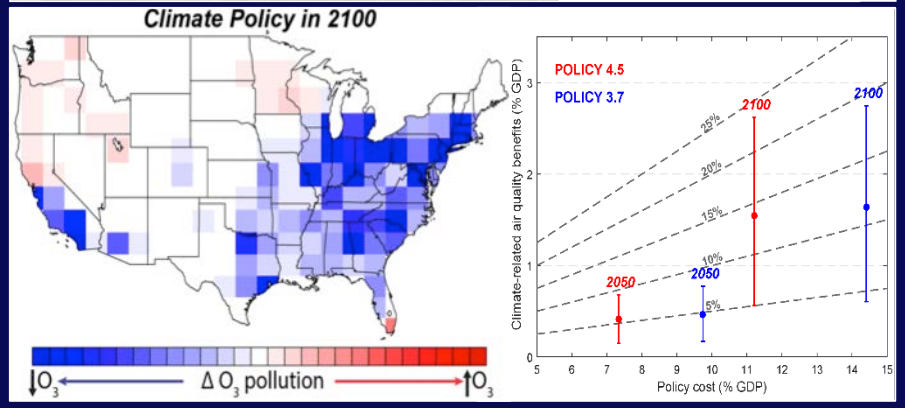
Approach: Multiscale modeling frameworks to simulate air quality and its interactions with other environmental and human systems

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

Methods: Numerical methods, uncertainty analysis, integrated assessment modeling, high performance computing







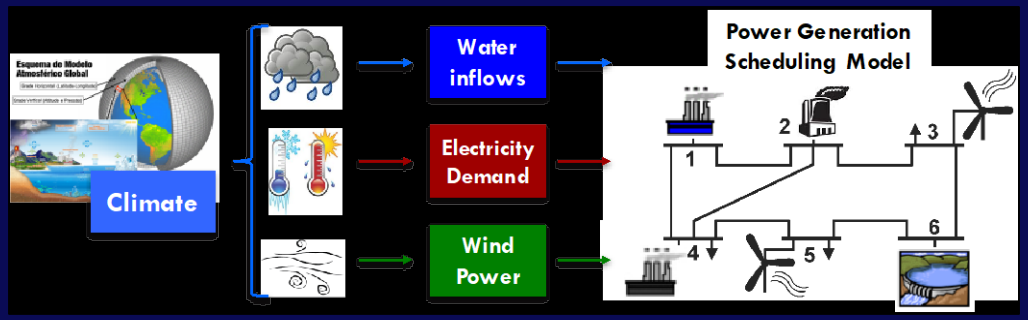
Decision-Making Under Uncertainty

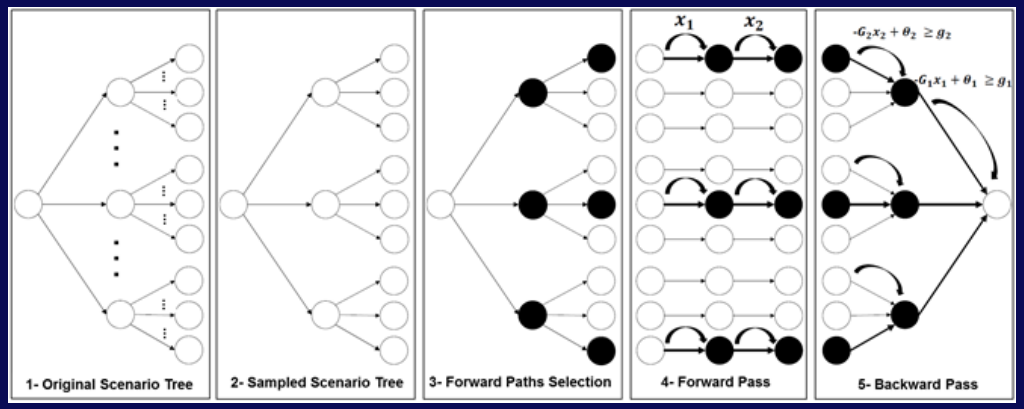
Goal: To create modeling and problem solving frameworks that enable users to make consistent and robust decisions when facing uncertainty

Applications: Water-Energy Nexus, Electricity Power Systems, Systems Engineering

Impact: Insight relevant to investors, system users and policy makers

Methods: Math programming, Stochastic optimization, decision analysis, high performance computing





Water Resources and Environmental Engineering: Engineering for Sustainable Civilization

- **Air**
  - Onroad & nonroad vehicle emissions
  - Human exposure & risk management
  - Atmospheric aerosols
  - Energy & 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

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

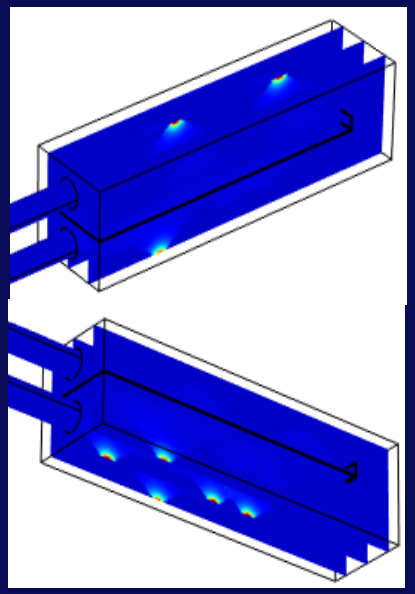
Environmental Engineering and Science

- **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

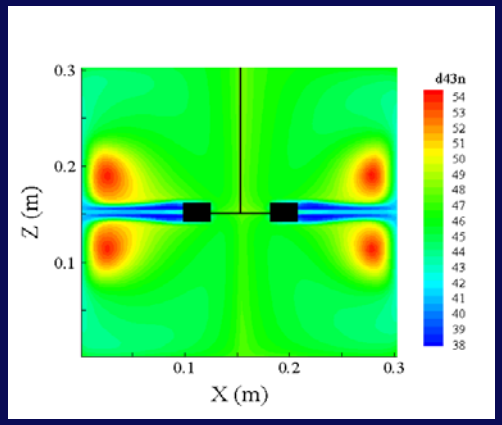
Water and Wastewater Treatment

- Goal: Optimize the efficiency of water and wastewater treatment processes
- Approach: Use validated numerical transport models coupled with global search optimization algorithms
- Impact: Efficient treatment systems that enhance pollutant removal and uses less resources
- Methods: CFD, Optimization, laboratory analytical measurements

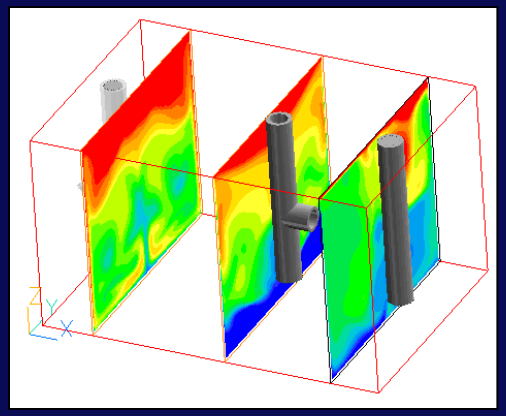
Microalgae Photobioreactor



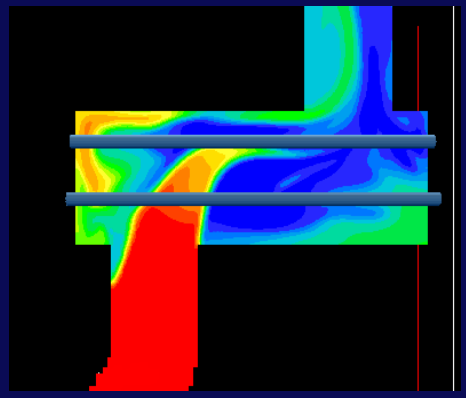
Impeller mixing



Oil removal



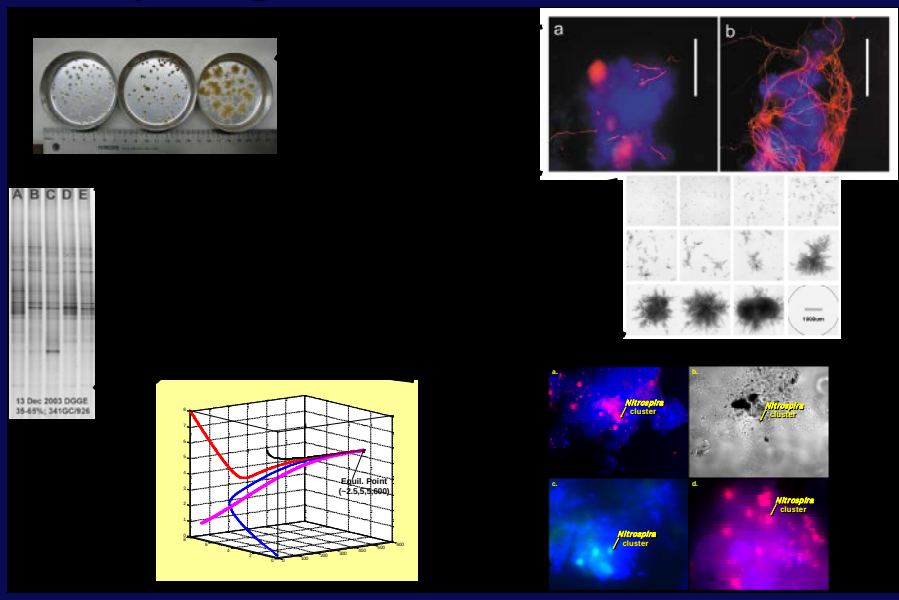
UV disinfection



Environmental Biotechnology

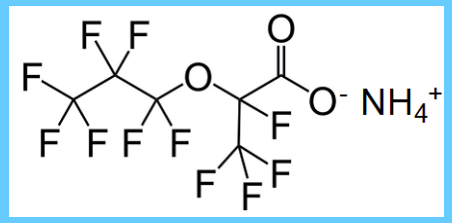
- Goals: Understand fundamental microbiological processes in waste treatment, develop waste-to-energy technologies, design appropriate sanitation for developing countries, quantify risk of water reuse
- Approach: Analysis of microbial function in lab- and full-scale systems, application of ecological theory to bioreactors, detection and quantification of pathogens in water reuse systems, field testing of sanitation technologies
- Impact: Improved bioreactor designs for nutrient removal, methane production, and low-cost systems; acceptable water reuse; solving the sanitation challenge for underserved areas
- Methods: Molecular (DNA/RNA) techniques, modeling, reactor studies, field testing

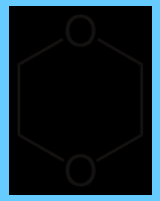
Opening the bioreactor "black box"

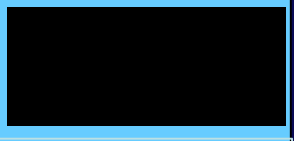


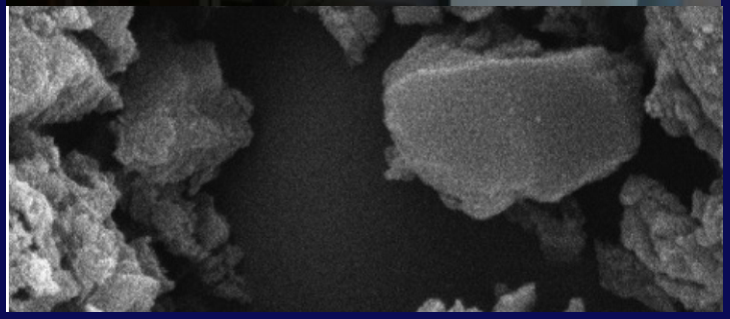
Drinking Water Treatment

- 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









Superfine Powdered Activated Carbon

Renewable Electricity Generation

Goal: Recover energy from wastewater and salinity gradients

Approach: Develop effective (bio)electrochemical technologies to:

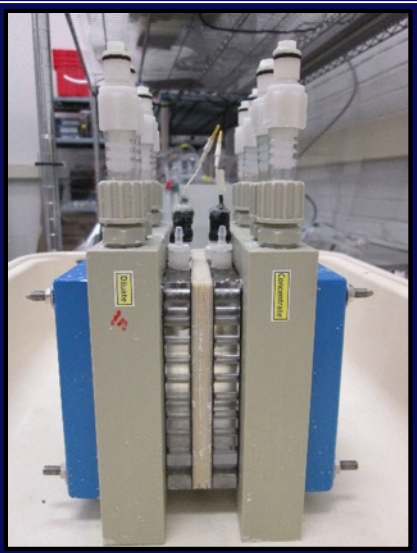
- simultaneously recover energy and treat wastewater, and
- generate electricity from the controlled mixing of low- and high-salt waters.

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

Methods: Electrochemical techniques, micro/molecular biology, reactor studies

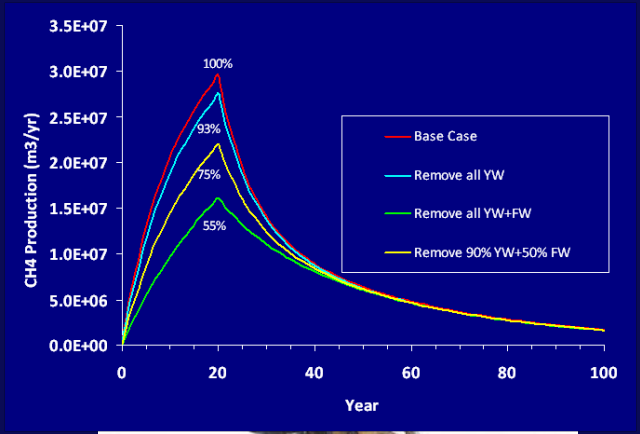
Pilot-Scale Microbial Electrolysis Cell

Reverse Electrodialysis Cell



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, manage elevated temperature landfills



Pathogen Detection and Transmission Pathways & Creating Effective WaSH Indicators

Goals: Identifying fecal contamination transmission pathways

Approach:

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

Impact: Recommendations for water quality sampling, reductions to human exposure to fecal pathogens

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

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

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

Impact: Increased access to safe and healthy drinking water

Methods: mass spectrometry, pyrolysis

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
- **Impact:** Reductions in fecal contamination. Providing dignity to sanitation workers. Scaling up solutions.
- **Methods:** CAD, CFD Modeling, rapid prototyping, time-motion studies, field testing

Manual (top) vs mechanized emptying (bottom)

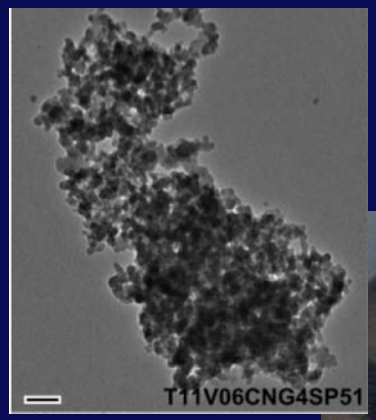
www.ted.com/talks/francis_de_los_reyes_sanitation_is_a_basic_human_right?language=en

Understanding Atmospheric Aerosols

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

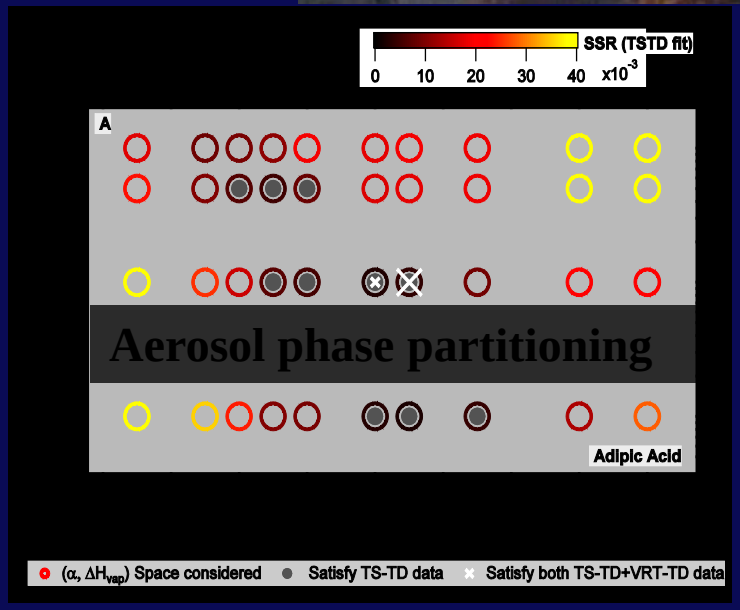
Approach: Develop data, tools and insights to improve our understanding of sources and atmospheric transformations of emissions.

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



Black Carbon Particle

Solid fuel cooking in India

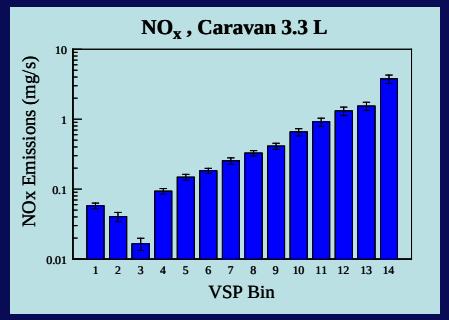


Transportation and Air Emissions

Goal: Identify effective ways to reduce real-world energy use and emissions of onroad 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

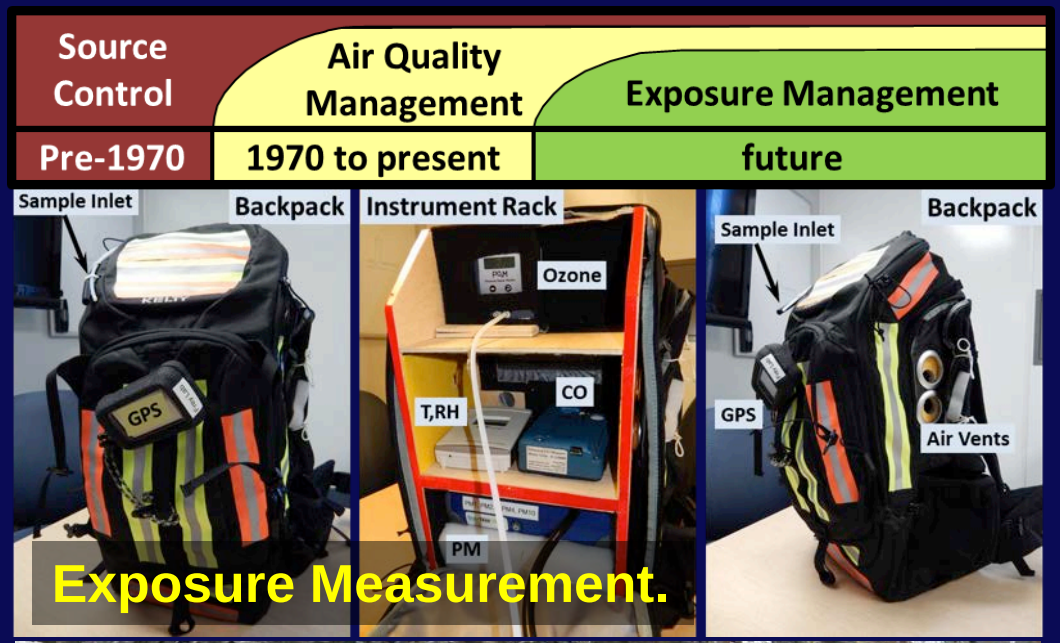


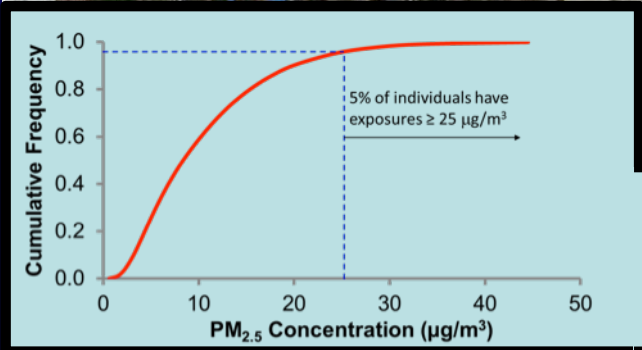
Measurement and Modeling of Human Exposure

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)





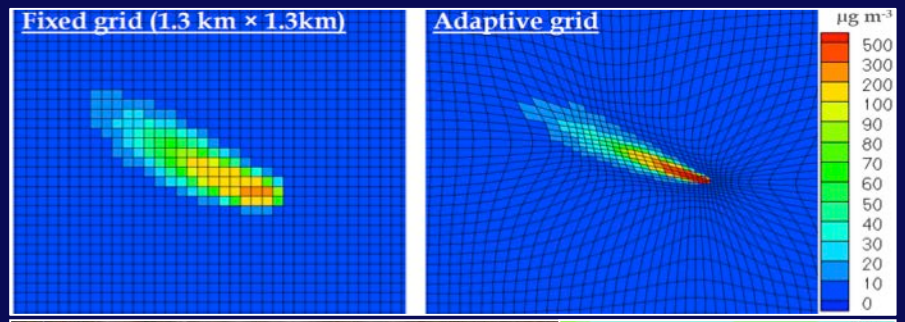
Exposure Modeling

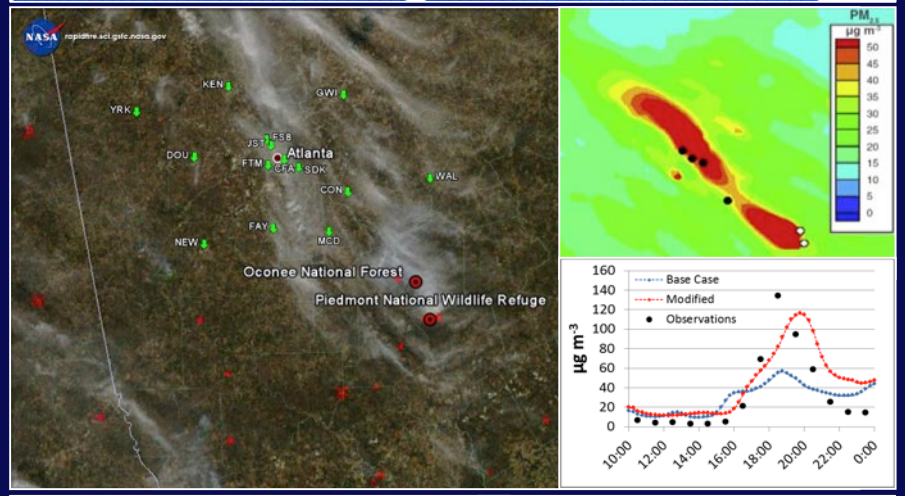
Modeling Air Quality Under Global Change

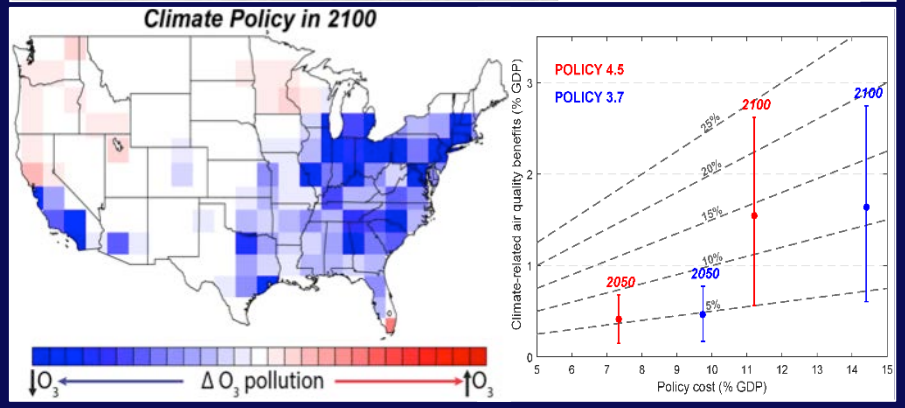
Goal: Identify and evaluate strategies to reduce air pollution and its impacts though computational modeling.

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

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







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.

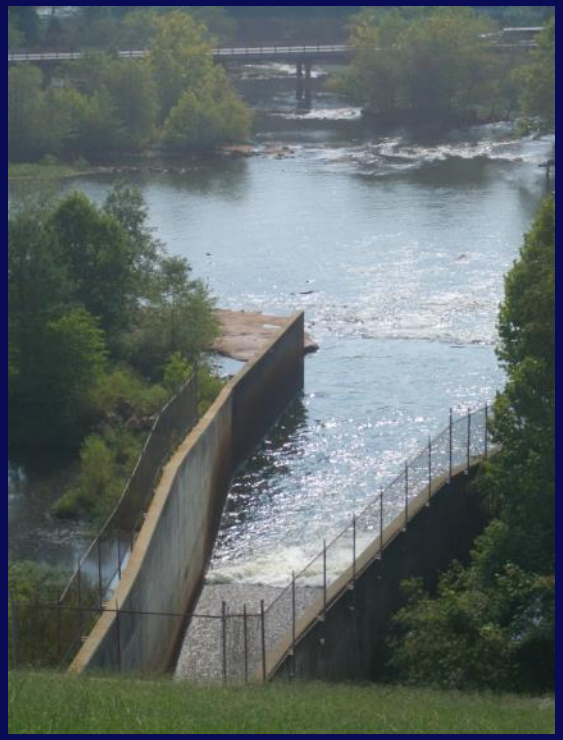
Hydroclimatology and Water Management

Goal: Improve water management practices by incorporating climate information.

Approach: Innovative data fusion methods with statistical modeling and inference, and optimization.

Impact: Improved water sustain-ability, flood and drought management, reservoir operation, hydropower management, water quality, and risk management.

Methods: Stochastic modeling, simulation, optimization.



Climate Informed Drought Management at Falls Lake

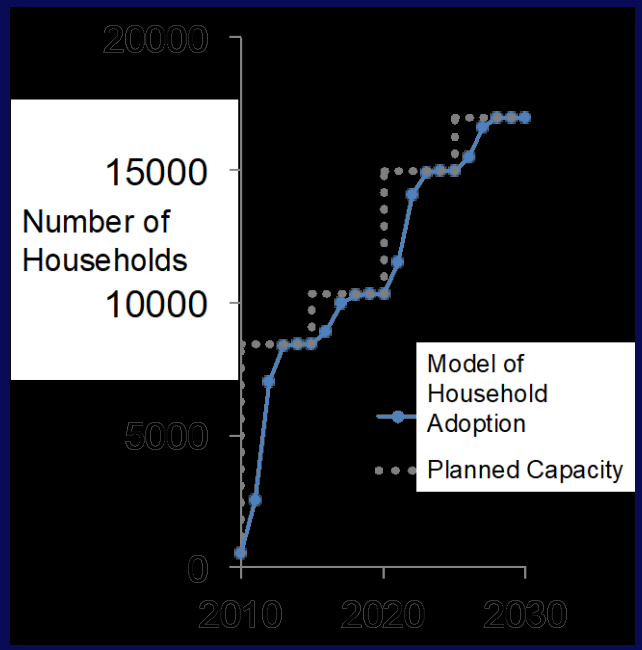
Socio-Technical Systems Analysis for Planning Water Reuse Programs

Goals: An adaptive modeling method to capture the diffusion of innovation and how it affects infrastructure design and management policies.

Approach: A novel adaptive simulation modeling procedure coupled with infrastructure expansion plans. Illustrative case application for Cary, NC.

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

Methods: Complex adaptive systems modeling, optimization.



Protection of Freshwater Resources

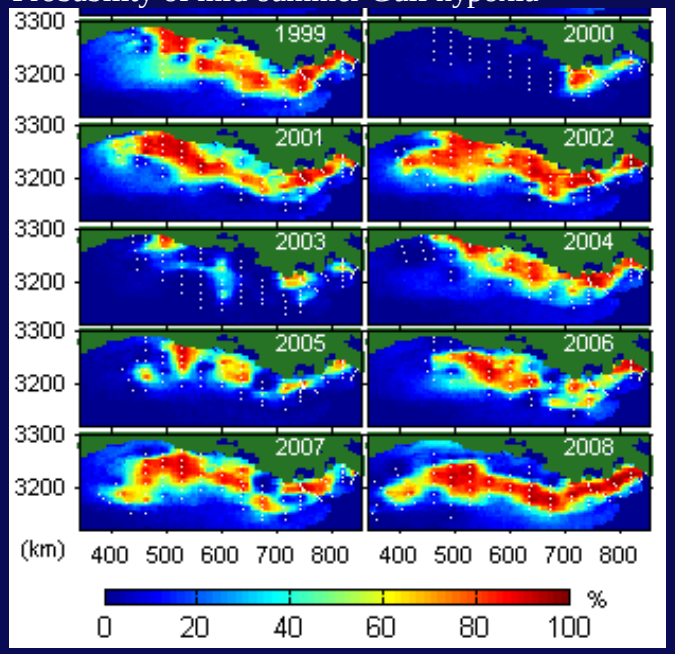
- Goal: Develop strategies to protect and restore water quality.
- Approach:
  - Field and experimental studies to measure water quality, algae proliferation, and controlling factors.
  - Develop biophysical models to predict how watershed management and geo-engineering can improve water quality.
- Impact: Improve water quality in lakes and reservoirs through science-based engineering and management solutions.2

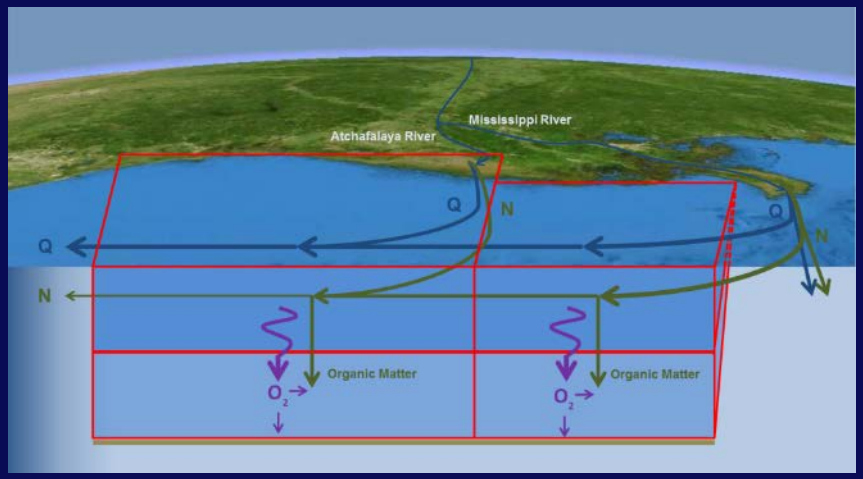
Measuring diffusion rates in Jordan Lake

Water Quality Forecasting

- Goal: Understand how human actions impact natural systems.
- Approach:
  - Assess extent of water quality impairments, such as hypoxia and harmful algal blooms, through geospatial modeling and data fusion.
  - Develop biophysical models to predict impairments based on pollutant loading, weather, and climate.
- Impact: Inform watershed and fisheries management, and raise public awareness through timely water quality forecasts.

Probability of mid-summer Gulf hypoxia

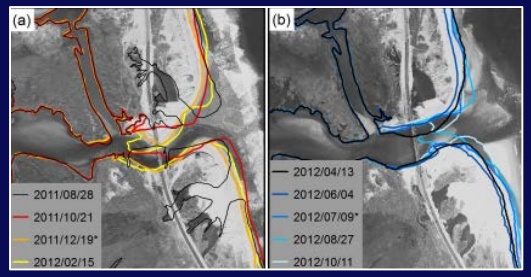




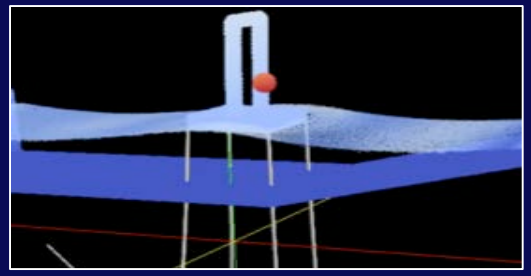
Coastal Engineering

Landform Change

How do beaches, dunes, barrier islands, atolls and inlets respond to coastal processes like waves and overwash, sea level rise?



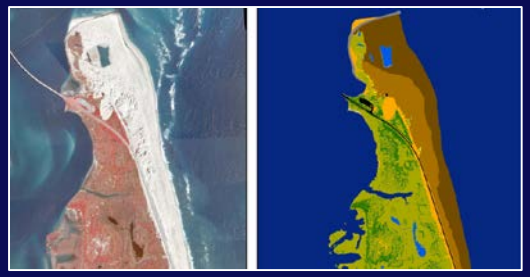
Inlet Formation & Evolution



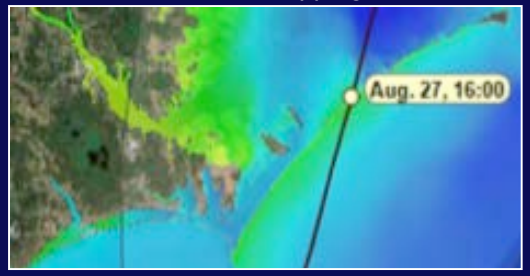
Wave Energy Devices

Applied Remote Sensing and Geospatial Modeling

How can we map and communicate impacts of coastal hazards on vulnerable highways, communities and ecosystems?



Habitat Mapping



Flood Forecasting

Ocean Energy

How can we model and quantify available tide and wave energy resources along our coast and offshore?

Coastal Hazards

What are the effects of tidal and rip currents, wave fields, storm surge and flooding in complex coastal regions?

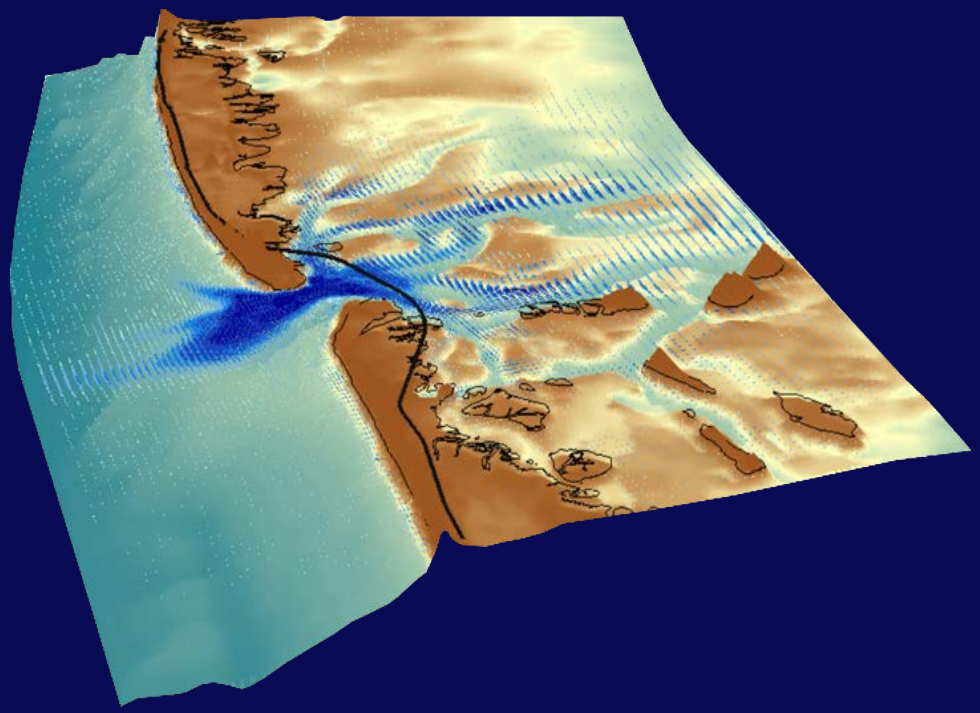
How do coastal processes change our beaches, inlets, and barrier islands?

- **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.

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

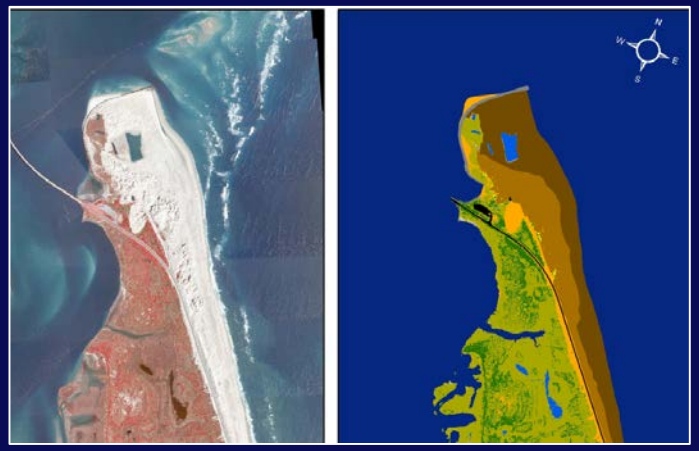
- **Methods:** Analysis of field and remotely sensed data, model simulations of flow, sediment transport and morphology.

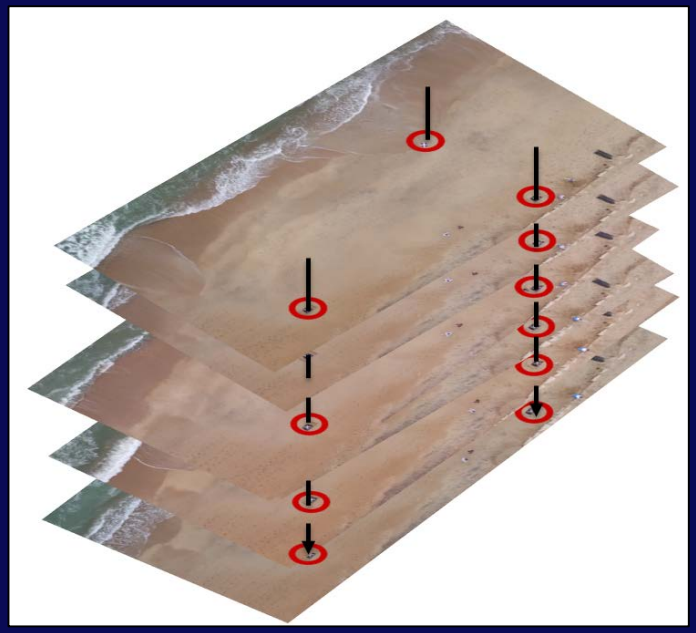
- **Impact:** Engineering solutions to enhance resilience of coastal environments and communities.



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

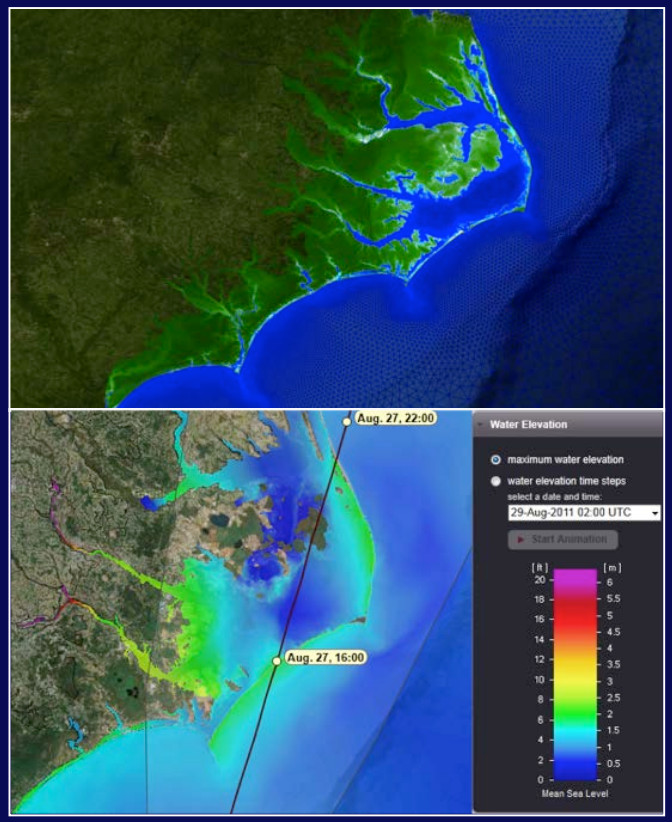
- Goal**:** Better methods to assess and communicate impacts of short- and long-term coastal hazards on vulnerable highways, communities and ecosystems
- Approach**:** Develop remote sensing algorithms for assessing and predicting changes in coastal ecosystems
- Methods**:** Software design, spatial algorithm development, 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

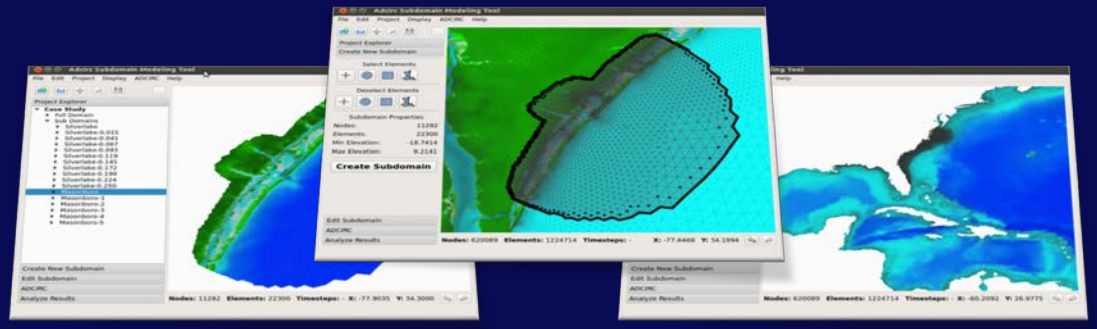




Can we predict coastal hazards due to storms by using flexible resolution along our coastline?

- **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 river flow
- **Methods:**
  1. Develop models on unstructured meshes and apply on supercomputers
  2. Capture localized behavior from large-scale simulations by working with subdomains
- **Impact:** Connect waves and flooding to built infrastructure in real-time and long-term design

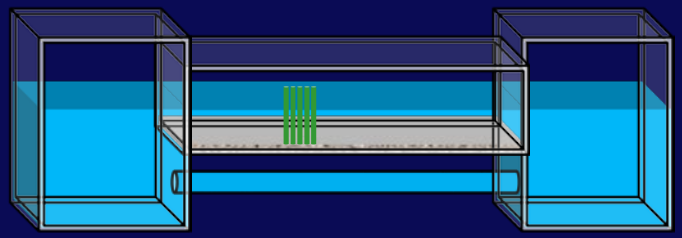




Sharing results with FEMA, the US Army Corps of Engineers, NC Emergency Management, and others

Field Work and Lab Facilities

- Goal: Test hypotheses about coastal processes and response
- Approach: Utilize state-of-the-art technology to conduct field and lab measurements
- Methods: Real-Time Kinematic GPS, UAV imaging and video in collaboration with ITRE, sediment grain sizer, sediment flume
- Impact: Improved understanding of physical processes to assess and predict:
  - Wave runup on nourished beaches
  - Evaluation of marsh erosion
  - Interaction between flow and vegetation
  - Response of living shorelines
  - Scour around structures



Research Centers

- Department of Homeland Security Center of Excellence on Natural Disasters, Critical Information on Engineering Management (UNC-lead)
- NSF Industry University Cooperative Research Center: Center for the Integration of Composites in Infrastructure
- Institute for Transportation Research and Education
- Center for Nuclear Energy Facilities and Structures

Our New Home in Fitts-Woolard Hall

- We are looking forward to our new home on Centennial Campus
  - We are scheduled to move in time for the Fall 2020 semester

Under Construction

- 225,000 gross ft^2
- Dept. of Civil, Construction, Environmental Eng
- Edward P. Fitts Department of Industrial and Systems Engineering
- College of Engineering

How Can You Help?

- CCEE Enhancement Fund
  - Student and faculty recruiting
  - Student and faculty conference travel
  - Student academic competitions
  - Student group support
  - Research and teaching equipment
- Firm of the Month Program
- Sponsorships
  - Newsletter
  - WE Symposium; EWC and SEM Symposia
  - Welcome Back Ice Cream
  - Adopt a faculty or research area
- Professorships
- EB-Oval - name a lab, classroom, office suite

Thank you for your interest

Additional Information

http://www.ccee.ncsu.edu/

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