Department of Civil, Environmental and Geodetic Engineering
The Ohio State University

Strategic Plan: 2014-17
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Revised October 28, 2014
Revised December 5, 2014
Revised November 3, 2015
Revised January 25, 2016

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With contributions from the entire faculty of CEGE
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CIVIL, ENVIRONMENTAL & GEODETIC ENGINEERING

The department prepares professionals to address the most demanding problem that faces human kind, the requirement to balance environmental health with growing societal needs for natural resources, sustainable infrastructure and services. This requires the skillful conception, planning, design, construction and operation of facilities that unfold modern life, ranging from transit systems, to waste treatment facilities, to earth observing systems. The demand for civil, environmental and geodetic engineers is increasing significantly, due in part by efforts to rebuild, improve and make secure our country’s infrastructure, which includes highways, bridges, tunnels, dams, harbors, airports, waterways, railways, power plants, air/water treatment plants, drainage systems, and waste disposal facilities.

ACADEMICS

BS Civil Engineering
BS Environmental Engineering
MS and PhD Civil Engineering with specialization areas:
  • construction engineering and management
  • geoinformation and geodetic engineering
  • structural engineering
  • transportation engineering
  • water resources
  • environmental engineering

Minor in Environmental Engineering Minor in Surveying and Mapping

The Civil Engineering and Environmental Engineering programs at Ohio State are accredited by the Engineering Accreditation Commission of ABET, abet.org

AUTUMN 2013 ENROLLMENT

| Civil undergraduate students | 562 |
| Environmental undergraduate students | 124 |
| Graduate students | 96 |
| **TOTAL** | **802** |

DEGREES CONFERRED 2012-2013

| Bachelor’s (137 CIV - 20 ENV) | 187 |
| Master’s (83 CIV - 5 ENV) | 38 |
| Doctorate (5 CIV - 0 ENV) | 5 |

The Ohio State University
COLLEGE OF ENGINEERING

LEARN MORE ONLINE
ceg.osu.edu

RESEARCH

World population growth and increased environmental concerns has spurred the need for civil, environmental and geodetic engineers. The civil engineering department addresses these societal needs by preparing graduates to contribute to the improvement of infrastructure and the protection of the environment.

The department is uniquely positioned to provide students with a cutting-edge learning experience through not only traditional training but also through our campus Living Labs.

- Campus Transit Lab (CTL) gathers and analyzes data received from the Ohio State Campus Bus Service (CABS)
- The William H. Schlee-DeWitt River Research Park (DWRP) takes research into the field
- Construction and demolition sites on campus provides field-scale testing and field application

Premier centers and labs include:

- Water Resources Center (WRC) promotes water-related research in Ohio and education outreach
- Satellite Positioning and Inertial Navigation Lab (SPIN) performs research in positioning and sensor integration
- Environmental Engineering Analytical Lab atmosphere-biosphere interactions and regional atmospheric modeling

The Ohio State University has committed to finding solutions for grand challenges on a global scale through the Discovery Themes Initiative. This initiative will provide the foundation for CEGE students to contribute in fields related to sensing and data acquisition, dynamic natural systems, smart urban services and infrastructure systems, and big data and high performance computing and analysis.

The department enjoys a diversified and balanced research portfolio currently consisting of:

- 52% State of Ohio
- 36% Federal Government Organizations
- 6% Non-Government Organizations
- 5% National Science Foundation
- 1% Other
our department by the NUMBERS

706 Civil, Environmental and Geodetic faculty members

582 Civil engineering undergraduate students which is 82.4% of total enrollment with 19% growth projection over the next six years

124 Environmental engineering undergraduate students which is 17.6% of total department enrollment and growing Environmental program is the first ABET-accredited program in Ohio with 29% growth projection over the next 6 years

96 Total graduate enrollment for Autumn 2013

26 female and 70 male

28 New graduate students for Autumn 2013

9 female and 19 male

16 New international graduate students from China, India, Iran, Jordan, Pakistan, and Russian Federation

26 Research facilities

11 dedicated department facilities and 22 interdisciplinary collaborative centers at Ohio State

FY 2013 CEGE Research Awards

State of Ohio 52%
Other Federal 36%
NSF 5%
Industry 8%
Other 1%

Progressive Growth in Department Research Expenditures

$4,596,744 FY 2013
$4,131,067 FY 2012
$3,964,247 FY 2011

Pie Chart shows research awards by source

12 Faculty members who are Professional Engineers and ONE Board Certified Environmental Engineer
Section 1
Mission, Vision, Goals and Challenges of CEGE

Our Mission: To address important problems that human kind faces: the requirement to balance the environmental health with the growing societal needs for natural resources, sustainable infrastructure and services. We recognize that interdisciplinary, broad perspective is needed to fulfill this mission, and we strongly believe that our expertise combined with that of our internal and external collaborators will create and disseminate world-class scientific knowledge about urban and natural environments and their interactions.

Our Vision: To become a preeminent department of civil, environmental and geodetic engineering, and be recognized as an academic leader in cutting-edge research, education, and scholarship by creating a vibrant and innovative place of learning, where the next generation of students will develop skills and acquire knowledge leading to transforming the disciplines of civil, environmental and geodetic engineering.

Our Goals: The University and COE Strategic Plans defined three discovery goals: (1) food security and production, (2) energy and the environment, and (3) health and wellness, in order to address the challenges of the contemporary world. All three goals are at the core of the research and educational activities of CEGE, as described in this strategic plan, and present unique opportunities for advancement through educational innovation, faculty investment, and world-class scholarly output.

We support ABET- accredited undergraduate programs in Civil Engineering (CE), and Environmental Engineering (EnvE) that prepare graduates for outstanding practice in their profession, and MS and PhD programs in CE that offer most rigorous engineering practice and broad, interdisciplinary research experience in the following specialty domains: Construction Engineering, Environmental and Water Resources Engineering, Geodetic and Geoinformation Engineering, Geotechnical Engineering (MS only), Structural Engineering, and Transportation Engineering, Surveying minor.

Organizational Goals:
Create a stimulating, self-reflecting and rewarding environment that fosters collaboration and promotes synergy by creating mechanisms to reward synergies among groups, develop opportunities, and remove administrative barriers.

OGS1 Allocate faculty and staff roles that are most balanced and reflective of their abilities, talents, creativity, and serve best the CEGE goals and objectives.

Suggested version:
Allocate faculty and staff roles such that there is equity and are reflective of individual abilities, talents, and creativity, and best serve the CEGE vision.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison of CEGE student to faculty ratio compared to ratio at Big Ten peer institutions.</td>
<td>CEGE student to faculty ratio at or above the average ratio at Big Ten peer institutions.</td>
</tr>
<tr>
<td>Retention rate of faculty.</td>
<td>95% retention rate of faculty.</td>
</tr>
<tr>
<td>OGS2</td>
<td>Promote equality and diversity among faculty, staff and students, to attract and retain the most talented people to deliver the best educational, research and outreach goals.</td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>Numbers of diversity students, faculty, and staff.</td>
<td>Diversity percentages amongst students, faculty and staff to be greater than or equal to the state percentages.</td>
</tr>
<tr>
<td>Increase success retention rate of faculty.</td>
<td>95% retention rate of faculty.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OGS3</th>
<th>Engage the External Advisory Board to assist CEGE in providing strategic directions, including counseling on identification of high-impact and vital research areas, and curriculum changes to further improve the quality of our graduates.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>CEGE fundraising revenue.</td>
<td>Increase in annual fundraising by greater than or equal to 5% per year. 3-year goal of greater than or equal to $2 million.</td>
</tr>
<tr>
<td>Improvements to undergraduate and graduate curriculum.</td>
<td>Address 100% of curriculum related issues identified by board and agreed to by faculty within one year of identification.</td>
</tr>
<tr>
<td>Implementation of strategic initiatives identified by advisory board.</td>
<td>Implement strategic initiatives identified by advisor board and approved by faculty within one year of identification.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OGS4</th>
<th>Engage the broad community of alumni across the region, country, and world to improve CEGE’s visibility, to acquire information on jobs for our graduates, and to strengthen research connections.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>Number of departmental newsletters.</td>
<td>Increase the number of departmental newsletters to greater than 2 per year by 2016.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OGS5</th>
<th>Develop non-credit certificate and/or on-line programs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>Number of certificate and/or non-credit programs.</td>
<td>At least one certificate or non-credit programs offered by academic year 2016.</td>
</tr>
<tr>
<td>OGS6</td>
<td>Create a Distinguished Lecture Series that will feature national and international eminent speakers, to increase visibility and prominence of the Department.</td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Metric</td>
<td>Number of distinguished lectures per year.</td>
</tr>
<tr>
<td>OGS7</td>
<td>Increase the quality and expand our physical facilities, including research labs, to support our pursuit for excellence.</td>
</tr>
<tr>
<td>Metric</td>
<td>Improvements and/or additions to laboratory facilities.</td>
</tr>
</tbody>
</table>

**Research and Innovation Goals:**

Become a premier center of excellence for pioneering research and scholarship in civil, environmental and geodetic engineering, recognized nationally and internationally for its quality and impact.

<table>
<thead>
<tr>
<th>RGS1</th>
<th>Increase the output of high quality research that impacts the field, enhances the department's reputation, and attracts high-caliber students, faculty and external funding.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Number of faculty lines directly related to the Discovery Themes.</td>
</tr>
<tr>
<td></td>
<td>Number of PhD students.</td>
</tr>
<tr>
<td></td>
<td>Number of students per semester with graduate research assistantships.</td>
</tr>
<tr>
<td></td>
<td>Number of PhD graduates.</td>
</tr>
<tr>
<td></td>
<td>Number of peer reviewed journal publications.</td>
</tr>
<tr>
<td></td>
<td>Research expenditures.</td>
</tr>
<tr>
<td>Number of centers of excellence.</td>
<td>Number of centers of excellence ≥1 by academic year 2019.</td>
</tr>
</tbody>
</table>

RGS2  
Increase the number of funded post-doctoral researchers and graduate students.  
**Metric**  
Number of postdoctoral and/or visiting researchers per year, per faculty tenure-track/research faculty member.  
**Target**  
Number of postdoctoral/visiting researchers per faculty member to increase 10% per year to 1 postdoctoral/visiting researchers per faculty per year by 2018.  
Number of PhD graduates.  
**Target**  
Number of PhD graduates per tenure track faculty member per year to increase 10% per year until ≥ 0.65 PhD graduates per TT faculty member.  
Number of students per semester with graduate research assistantships.  
**Target**  
Greater than or equal to 75% of graduate students to have research assistantship.

RGS3  
Establish a coordinated mentoring system for junior faculty.  
**Metric**  
Onboarding and mentoring team.  
**Target**  
Academic year 2016.

RGS4  
Become a catalyst for the development of Ohio’s technology-based sectors related to civil engineering, water and energy resources and geospatial information technologies.  
**Metric**  
Lead the development of Ohio center of excellence.  
**Target**  
Initiative seeded by 2016, 5-year target plan for a fully developed center.

Educational Goals:  
Increase the impacts on the profession by producing successful, influential graduates and improve the practice – near and long term – of civil, environmental and geodetic engineering.

EGS1  
Sustain and expand distinctive, targeted education programs at undergraduate and graduate levels.  
**Metric**  
The number of graduate students supported by fellowships.  
**Target**  
Increase in number of fellowships by 20% within 5 years.  
The number of undergraduate scholarships.  
**Target**  
Increase the number of graduate scholarships by 20% within 5 years.
Number of undergraduates who participate in one or more of the following: study abroad, research, student organizations, competitive project teams, and outreach.  
Increase to 100% participation within 5 years.

Percentage of graduate students who participate in professional development activities.  
Increase participation to 80% within 5 years.

<table>
<thead>
<tr>
<th>EGS2</th>
<th>Increase cross-disciplinary opportunities for our students through increased internal partnerships and partnerships with other departments and industry.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>Participate in MGEL.</td>
<td>2016</td>
</tr>
<tr>
<td>Host ASCE Ohio Valley Student Conference.</td>
<td>2017</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EGS3</th>
<th>Increase the quality of our incoming students.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>The number of graduate students supported by fellowships.</td>
<td>Increase in number of fellowships by 20% within 5 years.</td>
</tr>
<tr>
<td>The number of undergraduate scholarships.</td>
<td>Increase the number of graduate scholarships by 20% within 5 years.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EGS4</th>
<th>Recruit a high quality diverse student body.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>Numbers of diversity students.</td>
<td>Diversity percentages amongst students to be greater than or equal to state percentages.</td>
</tr>
<tr>
<td></td>
<td>Diversity percentages amongst students to be greater than or equal to our Big Ten peer institutions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EGS5</th>
<th>Grow graduate program size and visibility by active recruitment at top institutions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>The number of graduate students from top institutions.</td>
<td>Increase in number of graduate students from institutions nationally ranked in the top 10 within their peer group. (Two groups: Those that offer PhD and those that do not).</td>
</tr>
<tr>
<td></td>
<td>Increase number of graduate students from internationally recognized institutions.</td>
</tr>
<tr>
<td>Number of students per semester with graduate research assistantships.</td>
<td>Greater than or equal to 75% of graduate students to have research assistantship.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>EGS6</strong></td>
<td>Implement e-learning methodology where applicable to enhance the quality of instruction.</td>
</tr>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>Number of on-line courses offered by CEGE</td>
<td>At least 4 by 2017</td>
</tr>
<tr>
<td><strong>EGS7</strong></td>
<td>Offer Departmental funding for expanding our departments’ reach/visibility through guest lectures at other universities.</td>
</tr>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>The number of faculty presenting at other universities.</td>
<td>Increase the number of faculty presenting at other universities to 0.5 presentations per faculty member within 5 years.</td>
</tr>
</tbody>
</table>

**Service and Outreach Goals:**

Integrate civil, environmental and geodetic engineering discoveries with the public, and translate knowledge in and of our field to the broader public.

<table>
<thead>
<tr>
<th><strong>SOGS1</strong></th>
<th>Support distinctive, targeted education programs at the K-12 level to ensure the robust continued development of this interdisciplinary field, and to arm the field with the brightest and most creative young minds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>Faculty participation in outreach activities.</td>
<td>Increase the number of lectures per faculty member per year to the broader public and K-12 to greater than 1 per year per faculty member.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>SOGS2</strong></th>
<th>Promote broader awareness about the need for effective, resilient, and sustainable civil services and infrastructure systems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Target</td>
</tr>
<tr>
<td>Number of departmental newsletters.</td>
<td>Increase the number of departmental newsletters to greater than 2 per year by 2015.</td>
</tr>
<tr>
<td>Faculty participation in outreach activities.</td>
<td>Increase the number of lectures per faculty member per year to the broader public and K-12 to greater than 1 per year per faculty member.</td>
</tr>
</tbody>
</table>
Social media presence. Increase the number of website visits by 25% by 2017.
Increase the number of Facebook members by 20% by 2017.
Increase the number of Twitter followers by 20% by 2017.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of departmental newsletters.</td>
<td>Increase the number of departmental newsletters to greater than 2 per year by 2016.</td>
</tr>
</tbody>
</table>

Our Challenges:
- Increasing the number of highly qualified, interdisciplinary tenure track and research faculty, and high-caliber clinical faculty to address our research and education mission goals
- Improving our scholarly reputation: while our educational and scholarly accomplishments are substantial, in several areas of specialization, we must achieve commensurate national and international recognition as a department with substantial interdisciplinary expertise
- Increasing and strengthening our graduate program
- Strengthening the culture for innovation and interdisciplinarity
- Increasing external funding from government and non-government sources
- Establishing effective partnerships and cooperation with internal and external stakeholders
- Creating an engaged department
- Allocating resources to invest in aging and outdated infrastructure

Section 2
Civil, Environmental and Geodetic Engineering: Proven Leadership

The Department of Civil, Environmental and Geodetic Engineering (CEGE) offers broad areas of engineering and science expertise, with a proven record of excellence in many areas, and is uniquely positioned to address a number of contemporary and emerging engineering challenges. This section provides a summary of the existing Departmental expertise to illustrate our transition to “Collaborative Themes” that define our future growth and describe our strategic connections to other fields of engineering and science and their applications. These interdisciplinary themes will stimulate and expand our collaborations with scientists, engineers, policy makers and researchers in social sciences, humanities, business and law, enabling us to successfully address a manifold of complex technological and societal issues.

Current expertise areas in Environmental Engineering include:
- Physical and chemical mechanisms that determine the fate and transport of chemical compounds in natural and engineered systems
- Water quality treatment through engineered and natural photochemical transformation of pollutants and advanced membranes
- Computational and geospatial modeling of environmental systems – coastal, oceans, wetlands, landslides,
• Vegetation canopies and surface and subsurface hydrology
• Ecological engineering mechanism that control biogeochemical and hydrologic processes within built and natural systems
• Climate mitigation engineering as an adaptation to climate change impacts
• Geospatial-optimization for energy development and technology deployment

Faculty: Jeff Bielicki, Gil Bohrer, Zuzana Bohrerova, Tarunjit Butalia, Ethan Kubatko, John Lenhart, Andy May, Paula Mouser, Gajan Sivandran, Linda Weavers, Alper Yilmaz.

Current expertise areas in Geodetic Engineering include:
• Positioning, Navigation and Timing (PNT) using Global Navigation Satellite Systems (GNSS) and modern augmentation systems
• Imaging, photogrammetry, videogrammetry and computer vision
• High dimensional analytics, mining of geospatial data
• Applications of imaging and PNT to: transportation safety and security, cooperative mobility, autonomous navigation, precision farming, emergency response, change detection, Location based services (LBS)
• Data-driven geospatial modeling of structural health and ecological disasters, and nuclear plant risk assessment
• Experimental navigation and imaging system engineering, such as unmanned aerial vehicle (UAV)-based systems, development, and performance benchmarking

Faculty: Dorota Grejner-Brzezinska, Jeff Bielicki, Gil Bohrer, Ethan Kubatko, Gajan Sivandran, Charles Toth, Alper Yilmaz.

Current expertise in broad areas of Infrastructure Engineering include:
• Analytical modeling and experimental evaluation of reinforced and prestressed concrete, and steel structures (e.g. buildings, bridges, wharves, and non-structural components), and structural composites under service loads and extreme hazards
• System analysis, reliability and resilience assessment of critical infrastructure systems, and infrastructure planning/management
• Performance evaluation and enhancement of structures through structural analysis, structural dynamics, reliability, and optimization, progressive collapse analysis, and repair and rehabilitation of structures
• Artificial intelligence and knowledge-based expert systems for smart bridges and structures, and control and health monitoring of geo-structural systems
• Construction engineering and management: construction safety and reliability, quality control and risk analysis, and construction simulation and automation
• Field performance of earth and rock structures
• Soil mechanics modeling, beneficial use of coal fly ash; geotechnical and foundation engineering, and dynamic soil-foundation-structure interactions analysis


Current expertise in Transportation Engineering and Systems includes:
• Transportation planning, service design, and life-cycle management.
• Modal and multimodal real-time and off-line operations research
• Travel behavior surveying technologies for transportation demand and supply data analytics
• Data-driven mathematical modeling methods for evaluation and decision-support tools considering uncertainty in data, travel behavior, network interactions, and operational outcomes.
Road surface monitoring and highway infrastructure mapping with modern geospatial technologies
Airport and aviation system planning, design, operations, and management

Faculty: Benjamin Coifman, Frank Croft, Dorota Grejner-Brzezinska, Andy May, Mark McCord, Rabi Mishalani, Charles Toth, Seth Young.

Section 3
Civil, Environmental and Geodetic Engineering: Collaborative Themes

As environmental concerns increase with the growing world population, the technological revolution expands, and the demand for civil, environmental and geodetic engineers will grow. They will design, build, monitor and maintain the facilities essential to our civilization. The ongoing effort to rebuild the nation’s infrastructure, including highways, bridges, water and wastewater treatment plants, and other public buildings is a matter of national importance, to sustain and foster long term security and economic competitiveness in the U.S. Issues such as climate change and food security, protecting and restoring land, water, air, habitat and biodiversity, and utilization and equitable distribution of energy resources are global, and civil, environmental and geodetic engineers will be fundamental in adapting solutions.

New technologies are changing the face of urbanization. Innovation in planning and governance of urban spaces is fostered through technological advancements, democratization of technologies, and availability of open data, leveraged by citizen participation. Consequently, we are seeing an unprecedented rate of innovation in design, planning, and management of our cities, as well as natural and transportation systems today. For example, ‘smart cities’ embrace just about every aspect of natural-built-human integration, where self-monitored infrastructure and environmental systems, and better managed transportation flows will make for a safer, more efficient world, where investments in human capital and utilization of networked infrastructure fuel sustainable growth, improve economic and political efficiency, and enhance the quality of life, through participatory governance. Social and environmental sustainability is a major strategic component of smart natural-built-human integration. In a world where natural resources are becoming scarce, and, at the same time, fundamental to the growth and wealth of urban environments, their exploitation must guarantee the safe and renewable use of natural heritage, which is a cornerstone for sustainable urban development.

Civil, environmental and geodetic engineering are natural components of the future “system of systems,” where built and natural environments are balanced and sustainable. This section describes the collaborative themes relevant to the existing departmental expertise and our strategic, interdisciplinary linkages. The collaborative themes are: (1) Smart urban services and infrastructure systems, (2) Public health and safety systems, and (3) Dynamic natural systems. In addition, this section also addresses interdisciplinary tools, relevant to collaborative themes. Figure 1 below illustrates the current involvement of the CEGE faculty and students in research on collaborative themes, and Figure 2 illustrates the current proportional usage of interdisciplinary tools.
Figure 1. Current involvement (as of 2013) of the CEGE faculty and students in research on collaborative themes; shown as percentage of total research activities, external funding, publications and students; past five years. Legend; grey – smart infrastructure systems, green – natural environment systems, brown – public health and safety.
The Department of Civil, Environmental and Geodetic Engineering, in collaboration with our internal and external partners, is uniquely positioned to face several of the grand challenges for engineering, identified collectively by engineers, scientists and policy-makers. In order to address these challenges, research efforts must be high impact, interdisciplinary, and socially relevant. Hence, a need for the fusion of civil and environmental research with other disciplines - in particular earth, social and geospatial sciences. The following sections describe the collaborative themes, interdisciplinary tools and relevant current and emerging engineering challenges that we plan to address in the next 5-10 years. Departmental expertise in collaborative themes and interdisciplinary tools is illustrated in Figure 3.

Collaborative Themes:

1. **Smart urban services and infrastructure systems**: Planning, designing, monitoring, navigating, operating, and managing urban built environments, facilities, activities, and services such as dwelling and commercial built systems, multi-modal transportation facilities and services, power generation and distribution, storm water management, waste collection and treatment, emergency response. The focus is on supporting social and economic activities by providing effective demand-responsive infrastructure and services that recognize the value of customization, information rich environments, networks and location-based services to achieve a sustainable management, protection, and renewal of such complex urban systems.

2. **Public health and safety systems**: Monitoring, predicting, mitigating, and managing natural and man-made hazards, such as floods, earthquakes, hurricanes, environmental contamination, structural and operations
failures, disease and epidemic spread, and accidents, etc. The focus is on the quantitative support of sustainable policies and strategies, implementation of advanced technologies, and incorporation of human factors designed to enhance public well-being, including improved air and water quality and reduced damage, injury, and loss of life.

3. **Dynamic natural systems**: Monitoring, predicting, mitigating, and managing the impacts of climate change, land management practices, and human activities through an understanding of the physical mechanisms that drive the hydrologic, ecologic, and biogeochemical processes within natural ecosystems. The focus is on enhanced and sustained natural and man-made settings through the use of an improved mechanistic understanding of ecosystem functioning to develop appropriate strategies, predictive modeling tools, and technologies to manage water, soil and atmospheric resources.

**Interdisciplinary Tools:**

1. **Sensing and data acquisition**: multi-modal sensing, geo-locating, remote and in-situ measurements and surveying of human environments, behavior and activities. Examples include multi-sensory networks, airborne and space-based geospatial sensing of natural and built environments, such as transportation, structures, materials, and hydrological and coastal settings, and impacts on human health and environment; planetary exploration and 3D mapping.

2. **Natural-built-human integration**: Descriptive and normative time-space modeling, risk and reliability assessment, geospatial optimization, decision making and knowledge engineering, probabilistic modeling, mechanistic modeling, data fusion, computational intelligence, and large-scale optimization. Examples include hydro-economic modeling of watersheds to examine the impact of increased urbanization; monitoring, modeling and forecasting of sea level and coastal ecosystem variation; combining construction, architectural, and structural design data for improved delivery; travel behavior modeling to support design and operations of transportation systems; quantitative evaluation of urban, safety, and environmental policies; and optimization of the location and timing of infrastructure and transportation systems. The ultimate goal is to develop an earth systems engineering and management capability based on sustainability principles, to achieve economic, social and environmental resilience.

3. **Big data and high-performance computing**: Many of the applications associated with the themes described above require dedicated systems that process large quantities of data that require high-performance computing to manage, analyze, and use for modeling and decision-making. Such data are typically produced from simulated models or in real-time from a single “high spatial and spectral resolution” sensor or a multiple set of sensors observing complex systems. These systems include large structures, hydrologic and climate processes, transportation infrastructure and services, and human and robotic missions to the Moon and planets. The collected data are analytically modeled for mining certain patterns and untypical changes. Examples include automated mining of nuclear plant failures, sudden increase in carbon emissions and human activities in surveillance videos.
Intersection of Collaborative Themes and Interdisciplinary Tools: Living Labs

Development, deployment and testing of new technologies and strategies in modern science, engineering and policy are making a move from traditional settings to a larger scale operation, in the actual living environment, where interdisciplinary experts are brought together, to address complex problems of our dynamic world. Living Labs represent a user-centric research methodology for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts, such as city, agglomeration, or region, integrating concurrent research and innovation processes within a public-private-people partnership. A living lab is not a testbed, as its philosophy is to turn users from being traditionally considered as observed subjects for testing solutions against requirements, into co-contributors, co-inventors and co-explorers of emerging ideas, innovative concepts and related artifacts. Hence, a living lab constitutes an environment, which could be compared to the concept of experiential learning, where users are submerged in a creative social space for designing, understanding, exploring and experiencing their own future, and refining new policies and regulations in real-life scenarios for evaluating their potential impacts before their implementations.
Living Lab concept represents a perfect scenario to demonstrate how our synergistic collaborative themes and interdisciplinary tools interact in complex environments that can be effectively transferred into real life settings. Multiple faculty and research staff from CEGE are actively involved in Living Labs, as illustrated next.

Campus Transit Lab: The Ohio State University (OSU) Campus Transit Laboratory (CTL) is a unique living laboratory that provides comprehensive support for integrated transit-related research investigations, educational activities, and applied studies. The CTL [https://transitlab.osu.edu/campus-transit-lab](https://transitlab.osu.edu/campus-transit-lab) takes advantage of OSU’s large and diverse physical campus, its large student, staff, faculty, and visitor population, and the excellent institutional relations between transit operators and the academic departments of the university. In addition, the CTL benefits from advanced automatic data collection and information technologies deployed on the OSU Campus Area Bus Service (CABS), easy access to the CABS system and to the OSU community for researchers, instructors, and students, and regular interaction between CTL investigators and CABS managers. CTL activities are devoted to:

- Collecting, processing, and archiving extensive transit data sets
- Exploiting the CTL infrastructure and data for research, education, and outreach activities
- Transferring results, data, and products to transit agencies and investigators

A variety of contributions regarding the above have already been achieved, documented, and recognized internationally.

OSU Construction and Demolition Sites: Construction and demolition sites on the OSU’s Columbus campus are used as living laboratories and real-scale testing facilities. Undergraduate and graduate students frequently visit construction sites on campus to observe field application of theoretical knowledge they gain in the classroom. Researchers work closely with the engineers and architects at the OSU Office of Facilities Operations and Development (FOD) to identify potential campus buildings suitable for experiments. With help from construction and demolition companies, the researchers instrument and test the identified buildings. For example, OSU Office of FOD included testing requirements in contract documents for Boyd Hall, Johnston Hall, Aviation Building and Haskett Hall before their testing and demolition in 2011 and 2012. Student researchers instrument the steel and concrete beams and columns with strain gauges and sensors prior to physical removal of one or more columns from the first story of the test buildings. Demolition companies help with instrumentation and remove the selected columns prior to demolition of each test building. The main objective is to simulate sudden column loss in buildings that may cause partial or total collapse. Another goal is to investigate the load redistribution within the building after each column removal. Student researchers develop computer models of the test buildings and use experimental data from the field tests to compare and verify the computational models and simulations. The field experiments have been carried out with current funding from the National Science Foundation and American Institute of Steel Construction.

Wetlands: The Wilma H. Schiermeier Olentangy River Wetland Research Park (ORWRP) is a long-term, large-scale aquatic research facility located along the northern edge of The Ohio State University’s Columbus campus. The Schiermeier Wetlands are a gateway to research, teaching and outreach related to water resources at the university. The Schiermeier Wetlands pursue basic and applied research at multiple levels of ecological organization, from microbes to ecosystems to landscapes. The Schiermeier Wetlands also provide training for undergraduate and graduate students and service to the community through environmental outreach and extension. Through these activities, the Schiermeier Wetlands play an essential role in developing science-based solutions to critical issues in water resource management, restoration and conservation.

The environmental engineers in our Department use the ORWRP as a “living lab” to take their research out of the bubble of controlled bench top or super computer experiments and into more complex systems in the field. We combine our unique expertise in analytical chemistry, microbiology, high performance computing, sensing and data acquisition while working to find solutions to pressing public health and safety issues and issues related to natural environment. An example of this is understanding the carbon budget in these constructed wetlands. Wetlands are considered sinks of CO₂, but also a source of methane, a very potent greenhouse gas. As recent concerns over GHG emissions are starting to conflict with
the need for wetland restoration, it has become pivotal to assess the GHG budgets from temperate urban wetlands. We set up a meteorological station for continuous micro-meteorological and eddy-covariance flux measurements of CO$_2$ and methane using an open-path gas analyzer at the ORWRP. The sustainability of these wetlands is dependent on their potential benefits provided through their ecosystem services and their GHG budget.

Section 4
Faculty Hiring Plan

Leveraging and building upon existing strengths in CEGE, COE and OSU, CEGE proposes a strategic cluster hire to further enhance our capabilities to develop effective, resilient, and sustainable civil services and infrastructure in harmony with the natural environment. This cluster hire will promote regional to global scale the integration of deliberate data collection, automated sensing, computational and analytical modeling, and system analysis in support of planning, designing, managing, and operating civil systems over their life-cycle. In doing so, we seek to elevate CEGE to international eminence. Several of the proposed positions are correlated to the OSU/COE discovery themes, and are planned as split appointments with 60-80% at CEGE.

Fiscal Year 2015

1. Non-tenure-track Assistant Professor of Practice, Associate Professor of Practice, or Professor of Practice position in civil engineering. The successful candidate will be responsible for teaching capstone design classes, and core civil engineering undergraduate classes in one or more of the following areas: construction, geotechnical engineering, geospatial engineering, hydraulics, structures, or transportation. The primary duties of the faculty position are teaching and professional practice and service. After teaching obligations are satisfied, the successful candidate may also become active in research. The candidate must have the ability to effectively teach civil engineering courses and effectively communicate with undergraduate students. Successful candidates must have an earned Ph.D. degree in civil engineering. Professional engineer registration or ability to obtain P.E. license is expected.

2. Tenure-track position at the rank of Assistant Professor in Energy and the Environment. Successful candidates must clearly demonstrate how their research addresses impacts of energy production, conversion, distribution, or consumption on the environment. Research examples include (but are not limited to) subsurface sequestration of energy-related contaminants and greenhouse gases and their transport through subsurface, surface, and atmospheric systems; impacts of energy-related contaminants and greenhouse gases on soil quality, water quality, air quality, and global warming; comparing the externalities associated with adopting alternative and unconventional energy sources (e.g., natural gas, solar, wind, geothermal, hydrogen, nuclear, or bioenergy) to those associated with conventional fossil fuel development; and development and provision of viable and reliable distribution systems for emerging energy technologies and approaches.

Fiscal Years 2016-2017

1. Tenure-track position at the rank of Assistant Professor focused at the intersection of the science and technology of collecting, manipulating, modeling, visualizing, and applying spatial and temporal data. Emphasis placed on sensing and sensor systems and integration of big data for applications, such as infrastructure monitoring, planning and operating civil services, ensuring public health and safety systems, assessing and mitigating environmental impacts and man-made and natural hazards. The technologies of interest include portable imaging and navigation sensors, sensor networks, sensor fusion, ubiquitous positioning and sensing, cooperative mobility, and platforms, such as Unmanned Aerial Systems (UAS). This position is at the intersection of the CEGE strategic focus areas of “smart urban services and infrastructure systems” “public health and safety systems”, and “natural dynamic environments.” It directly addresses the immediate need to expand our expertise in “sensing and data acquisition” and “big data and
high-performance computing,” which are recognized as interdisciplinary tools, cutting across the strategic focus areas listed above. This hire has a strong potential for significant return on COE investment.

2. Tenure-track position at the rank of Assistant Professor with research focus on monitoring and managing infrastructure facilities and networks to achieve more effective designs, more efficient energy consumption, safer systems, resilience to impacts of man-made and natural hazards and more effective interventions. Particular interest is centered on the use of real-time sensing and computational technologies for monitoring infrastructure and natural environment systems to improve public health and safety. The example research challenges expected to be addressed include: improving air and water quality, reducing the impacts of waste collection and disposal on the environment, and improving public health and safety in relation to civil services and infrastructure including commercial and residential built-systems, water supply and wastewater treatment, and transportation. Advanced sensing systems and new material and computational technologies can be used to monitor deterioration of aging infrastructures and significantly reduce the cost of inspection and maintenance programs. Continuous monitoring of infrastructures by new technologies and complex sensing networks produce big data and may require data mining. The ultimate goal is on supporting social and economic activities in complex urban systems by providing effective and responsive infrastructure and services that adapt and evolve with the ever-changing urban environments.

3. Non-tenure-track Assistant Professor of Practice, Associate Professor of Practice, or Professor of Practice position in civil engineering. The successful candidate will be responsible for teaching capstone design classes, and core civil engineering undergraduate classes in one or more of the following areas: construction, geotechnical engineering, geospatial engineering, hydraulics, structures, or transportation. The primary duties of the faculty position is teaching and professional practice and service. After teaching obligations are satisfied, the successful candidate may also become active in research. The candidate must have the ability to effectively teach civil engineering courses and effectively communicate with undergraduate students. Successful candidates must have an earned Ph.D. degree in civil engineering. Professional engineer registration or ability to obtain P.E. license is expected.

4. Opportunistic hires within the Discovery Themes initiatives.

Faculty Positions Proposed Beyond Fiscal Year 2017

1. Tenure-track position at the rank of Assistant Professor focused on applying novel analytical, numerical or experimental approaches to problems involving engineered or natural systems in the built environment that includes, but is not limited to, advanced materials and technologies for sustainable infrastructure, clean and responsible energy production and hazard mitigation. The degradation of the nation’s infrastructure coupled with the need to adapt to our changing climate has led to an unprecedented demand on engineers to develop creative advances in the approaches applied, materials used, ability to withstand extreme events, and compatibility with the environment into engineered infrastructure design. Coupled to these research skills must be a fundamental background in mechanics or geotechnical engineering. This position is consistent with all three strategic directions of CEGE to foster development of “smart urban services and infrastructure systems”, “public health and safety systems”, and “dynamic natural systems” while also aligning with college and university themes on “Climate and the Environment” and “Materials for a Sustainable World”.

2. Tenure-track position at the rank of Assistant Professor focused on understanding travel behavior in the context of big data from multiple sources and the use of such understanding in improved planning and service operations of multi-modal transportation systems. With the increasing use of personal geo-coded mobile devices, social media, and universal payment/farecard media, the resolution, extent, and scale of information on travelers’ modes, routes, departure and arrival times, and possibly travel purposes are ever increasing. In addition, the tracking of public and private transportation vehicles (whether off-line or in near-real-time) by a variety of agencies and companies is being adopted at a fast pace already covering large percentages of public fleets with the expectation that a non-trivial percentage of private vehicles will soon be tracked on an ongoing basis. Moreover, the use of geo-coded mobile
communication devices in broadband telecommunications environments is duties allowing for the development and application of advanced proactive surveying techniques that could amass travel diary-like information on a large number of participants spanning long periods of time. While each of the above sources of big data in its own right offers tremendous opportunities to understand travel, the value that could be brought about from integrating these various sources is likely to grow exponentially. The faculty member would particularly focus on such integration for improved travel behavior understandings and the effective use of such understandings in transportation planning and service operations.

3. Tenure-track position at the rank of Assistant Professor focused on the interactions, synergies, and conflicts between transportation and environment. The transportation services that are integral to economic competitiveness of cities and regions are hugely expensive, consume great quantities of various resources (e.g., land and energy), and negatively impact the environment in multiple ways (e.g., noise, pollution, global warming). This position/cluster of positions is/are aimed at using present and future quantities and types of data to improve the understanding of individual user behavior, the mapping of this individual behavior into aggregate travel patterns, and the determination of the impacts of these aggregate patterns on the natural environment and resource consumption. Research questions would include the following: How does access to new and timely information affect individual responses to land use policies and provision of alternative transportation modes? What could incentivize individuals to consider choices that yield important system-wide efficiencies and reductions in negative environmental impacts while possibly slightly increasing their own generalized travel costs? How can mobile applications and social networking best be used to collect massive, detailed travel behavior data that could help inform the understanding of emerging attitudes and behaviors? What are the critical transportation, land, and energy variables that determine the impact travel has on pollution and greenhouse gas emissions, public health, and global warming? What are the policy implications of such determinants and what are the appropriate institutions for devising effective policies that address emerging trends?

4. Non-tenure-track Assistant Professor of Practice, Associate Professor of Practice, or Professor of Practice position in civil engineering. The successful candidate will be responsible for teaching capstone design classes, and core civil engineering undergraduate classes in one or more of the following areas: construction, geotechnical engineering, geospatial engineering, hydraulics, structures, or transportation. The primary duties of the faculty position are teaching and professional practice and service. After teaching obligations are satisfied, the successful candidate may also become active in research. The candidate must have the ability to effectively teach civil engineering courses and effectively communicate with undergraduate students. Successful candidates must have an earned Ph.D. degree in civil engineering. Professional engineer registration or ability to obtain P.E. license is expected.

5. Research Assistant Professor with research expertise in general field of dynamic structural engineering with an emphasis on design and analysis of structural and nonstructural components; the development of numerical models for highly nonlinear motions; performance-based design using probabilistic models and statistical methods; and the vulnerability of critical nonstructural component systems subjected to various external events through traditional and innovative approaches.

6. Opportunistic hires within the Discovery Themes initiatives.
Section 5
Infrastructure

Facilities Enhancements: Funds will be acquired through the But For Ohio State Campaign and departmental funds impacting the student experience through modernized facilities and hands-on learning.

Wet Teaching Lab, 026B Hitchcock: updating this currently under-utilized facility will allow undergraduate students to learn by participating in simulations of groundwater monitoring, water treatment processes and hydrology.

$350,000

Structures and Materials Testing Lab, 050 Hitchcock: An MTS universal testing system will allow each undergraduate student to test and learn with rebar and reinforced concrete as well as aid current and new research opportunities for our structures faculty.

$150,000+$TBA

CAD lab: Needs for additions and enhancements to the currently offered student training/facilities will be determined.

$TBA

Graduate Student, 422 Hitchcock: Attracting highly qualified graduate students is a competitive process and their workspaces must be at acceptable standards. Power and networking updates along with new furniture.

$70,000

Improved research capabilities will allow for larger and more significant research projects which, in turn will expand the department’s overall capabilities.

Water/Environmental Engineering Research Labs, 008, 018, 022 & 026 Hitchcock
To accommodate the growing faculty, research labs will be updated with equipment repairs and upgrades and bench modernization.

Near-term: Replacement of 4 benches in 008, update sinks and hood space and capacity.

$170,000

3-5 year plan: Replacement of three benches in 018, 022, repair two benches in 026, update storage throughout, convert office space to a microscope/instrument lab.

$260,000

Micrometeorology Lab, 416 Bolz: This computational lab researches the environmental benefits of wetlands in Ohio and throughout the nation. Upgrades to the computing capabilities, student workspaces and the facility are needed.

$90,000

Photogrammetric Computer Vision Lab, 233 & 247 Bolz: This lab focuses on the wide range of capabilities in the field of remote sensing. Recent partnerships with ODOT, DOD, construction companies and cancer surgery departments have come from this lab. Network and power improvements, upgrades in student workspaces and physical improvements to the floors and walls will allow this lab to continue its strong performance.

$70,000

Soil Mechanics Lab, 130 Bolz: This geotechnical research space requires the replacement of a permeability panel as well as four new consolidation devices.

$36,000
Scholarships: long-term goal: establish 20 endowments @ $50k to impact 20 students on an annual basis. $1,000,000

**APPENDIX A**

**Collaborative Themes**

**Smart Urban Services and Infrastructure Systems**

**Departmental Expertise: Geospatial Modeling in Time-Space Domain**

Geospatial information infrastructure is a framework for digital, ubiquitous, layered sensing and modeling of the environment. Examples are: utility lines, transportation networks, public facilities, storm water systems, residential and commercial areas, human geography, environmental hazards, trend prediction, etc. Another relevant component is navigating in smart cities, which includes autonomous personal navigation, cooperative mobility, emergency response indoor, underground, under water and airborne, using digital models and geospatial information infrastructure.

**Departmental Expertise: Smart Structural Systems**

Smart structural systems take the advantage of advanced technologies for high-performance structural materials, and system response monitoring and control, to deliver more effective and reliable services. High-performance structural materials, such as composites and high strength reinforcing steel, are cost-effective solutions for creating lighter, stronger, blast-resistant, and more durable materials for structures, resulting in more efficient, effective, and sustainable designs. Sustainable building materials, including the use of industrial by-products that can reduce the carbon footprint of the built environment, while providing for longer service life of structural - subsurface and above surface - systems. Various structural health monitoring and control techniques will continuously sense the environment and feed the data back to control algorithms to determine the optimal actions for maintaining the serviceability of the systems.

**Departmental Expertise: Transportation Systems**

The advent and use of a variety of sensing technologies result in large quantities of real-time and off-line transportation data amassed on an ongoing basis. Such data, which relates to the quality of the provided transportation services and the nature of the demand for such services, allow for the modeling and forecasting of network conditions resulting to more effective off-line and real-time decision-making tools. Such tools lead to improved services that are responsive to travelers’ and shippers’ needs in a cost-efficient manner mitigating the negative consequences on the environment. Examples include real-time multi-modal traveler information systems and customized trip planning, comprehensive public transportation service provisions, real-time roadway traffic management, enhanced private automobile utilization through high-occupancy incentives and real-time ridesharing services, and seamless intermodal interfaces.

**Public Health and Safety Systems**

**Departmental Expertise: Networked Geospatial Technologies**

Networked geospatial technologies facilitate surveillance that generates information and models for infrastructure health monitoring, detection of hazardous events, population distribution and social patterns for safety and security, targeted energy consumption and waste management, etc.

**Departmental Expertise: Resilient Systems**

Maximizing the continued service of infrastructure systems and reducing their vulnerabilities in the face of perturbations from natural and manmade hazards are the goals of performance based engineering and resilience assessment and enhancement frameworks. These can be achieved via a number of key steps including, among others, enhancing predictive capabilities of hazard and structure performance models, increasing the reliability of system components against earthquakes, strong winds, and blast loadings, and devising informed strategies for recovery efforts. Design of resilient and sustainable materials and their enhanced characterization from macro to micro scales will facilitate rehabilitation of
aging and deteriorating structural systems.

**Departmental Expertise: Transportation Systems**

Transportation accidents and environmental pollution resulting from fossil fuel based transportation technologies reflect critical negative externalities on societies. Such public health hazards can be mitigated through a wide-range of technical, operational, and policy means. Examples include improved fleet utilization through enhanced public transportation services and incentives for high occupancy vehicle use, incident management, emergency response, and improved infrastructure supporting vehicle electrification.

**Departmental Expertise: Contaminants in the Environment**

We engineer new materials and chemical, the potential for these to have adverse impacts on human and ecosystem health grow. The need to understand the fate and transport of these materials in the natural environment is critical in addressing potential impacts and engineering remediation solutions. Examples of this include the computational modeling of the fate and transport of heavy metals, nano particles, pesticides and fertilizers through the soils and surface water bodies. Researchers in the department also apply various novel techniques, such as biological engineering and ultrasonic waves, in addressing the remediation of contaminated soils and water.

**Dynamic Natural Systems**

Remote sensing and monitoring of environmental changes is a key to understanding, managing and predicting environmental trends. Examples are monitoring of the atmosphere and cryosphere, global sea level variations, and detection, hind casting and forecasting of coastal ecosystem evolution due to human and natural impacts, using integrated geospatial systems. Reclamation of abandoned mined lands to improve their environmental and safety concerns and rehabilitation of failing pavement infrastructure.

**Departmental Expertise: Transportation Systems**

Transportation is a major contributor to the global warming process. Understanding the impacts various characteristics of the transportation system have on contributing to this process allows for the development of policies and measures specifically aimed at mitigating this critical negative externality. Possible example measures include increased transit utilization through improved services and information systems, introduction of real-time ridesharing services and incentives, and land-use policies aimed at increased densities and multi-uses.

**Departmental Expertise: Bioenvironmental Processes**

Understanding and quantifying the role of microbial community dynamics play in bioenvironmental processes such as legacy contamination, urbanization, energy development, and environmental stewardship, is an open science question. Researchers in the department use molecular-genome tools to monitor bacterial species and microbial community-level shifts in pristine and contaminated environmental systems, and determine the major nutrients (carbon, nitrogen, phosphorus) influencing their abundance and activities in the subsurface. Specific applications of this research include assessing nitrogen dynamics during the bioremediation of an aquifer impacted by uranium mining, the detection and attenuation of pollutants in aquifers impacted by leaking landfills, and the transformation of nitrogen and species and methane in wetland environments.

**Departmental Expertise: Ecological Research**

The mechanisms that control the interaction between the atmosphere and the land surface dictate the rate at which greenhouse gasses can be taken up by the land surface or released to the atmosphere. Researchers in the department develop hydrodynamic models of individual plants and atmospheric models of flux and dispersion that include the effects of canopy structures at the individual tree-crown scale in order to examine their coupled interactions. Eddy-flux and micrometeorological measurements are used to observe and characterize the same phenomena that he simulates in the models. Particular applications include modeling the wind-power generation potential on the OSU campus; studying the greenhouse gas budget of urban wetlands and how it is affected by vegetation around the wetland; the effects of canopy structure on smoke dispersal from prescribed fires and on the combustibility of forest-floor fuels; the coupling between forest structural heterogeneity and soil moisture variability in forests and the effects of successional changes to forest
structure on its greenhouse gas budget in Michigan; understanding evaporation from the coral-reef lagoon in the Red Sea, Israel; and the effects of wind and weather conditions on the flight strategy and movement-decisions relies parameters of migrating birds.

**Departmental Expertise: Ecohydrology and Urban Watersheds**
Understanding the complex and dynamic feedbacks between hydrology and ecology is required in order to access the resilience of natural systems against climate and land use change scenarios. Through the use of coupled models of land management decisions and hydrological processes and greenhouse based laboratory experiments the role of climate change and land management practices on the fate and transport of pollutants from a watershed to a receiving water body can be quantified and the resilience of these systems to climate change and land management decisions and contaminate fate and transport can be assessed. This research provides insights for long-term solutions as policymakers grapple with balancing a growing demand for agricultural output and sustainable management of aquatic ecosystems.

**Interdisciplinary Tools**
**Smart Urban Services and Infrastructure Systems Sensing and Data Acquisition**

**Departmental Expertise: Sensing**
Layered sensing, a modern tool for sensing natural and built environments, is defined as acquisition of multi-sensory data from sensor networks placed on the ground, airborne and space platforms with collaborative capabilities. Examples are wireless and wired monitoring of structures, structural components, fills, and landslide prone areas to evaluate performance and make observation-based decision in near-real time; micrometeorological and eddy flux stations to monitor gas exchange between the atmosphere and the land surface.

**Departmental Expertise: Transportation Systems**
The collection of a wide variety of data is essential for planning, designing, and delivering transportation services. Data collection technologies range from travel behavior surveys, automatic direct observation of vehicles and travelers using traditional (e.g., magnetic induction loop detectors) and emerging technologies (e.g., GPS-based vehicle location systems), indirect observation of travel through means intended for other purposes (e.g., transit fare or congestion pricing payments), to the integration of any of the above.

**Natural-Built-Human Integration:**

**Departmental Expertise: Sensing, Modeling, Quantitative-Evaluation, Decision Making**

Efficient and realistic representation of geo-structural components of infrastructure systems such as buildings, bridges, and seaports using deterministic and probabilistic/stochastic modeling techniques is essential for understanding the nonlinear static and dynamic behavior of these components against earthquake, hurricane, and blast loadings. These techniques need to be verified with experiment results to establish certain levels of confidence in their predictive capabilities.

Risk-informed decision making frameworks combining system-level performance measures, for instance hybrid life-cycle costs, with available information on the stochastic nature of hazards, reliability of components, and consequences of failures at both component and system levels are critical for efficient risk management of infrastructure systems against future threats.

Mechanistic characterization and multi-scale/multi-resolution modeling of structural materials and elements facilitates optimal design and effective implementation of innovative materials and elements in new and existing structures.

Novel computing techniques such as genetic algorithms, fuzzy logic, and parallel computing in conjunction with artificial intelligence play an important role in introducing some levels of intelligence in the built environment. Large-scale optimization methods and wavelets together with structural analysis techniques can be used to enhance the performance
of structures and reduce the construction cost.

Departmental Expertise: Transportation Systems
The planning, design, and operations of transportation services rely on descriptive and normative methods aimed at understanding travel behavior, forecasting demand, and subsequently prescribing measures that are sensitive or responsive to such behavior. Several methodologies are employed for these purposes including probabilistic modeling, statistical inference, and optimization. A key aspect of these approaches is the treatment of uncertainty ranging from measurement errors in the data used, incomplete knowledge of complex travel behaviors, forecasting errors, and unforeseen events occurring in the short and long terms.

Big Data and High Performance Computing:

Departmental Expertise: Modeling, Quantitative Analysis, Mining, Clustering
Big data is high-volume, high-velocity and high-variety datasets, which is difficult to process using traditional database management tools and data processing methods. They demand cost-effective and innovative processing methods for enhanced insight and decision-making. Our faculty research and develop techniques to analyze full waveform LIDAR point-clouds, high spatial and spectral resolution image sequences, green-house gas fluxes, and study the effects of resolution in the coupling of lake and hydrology models, trends and abrupt events in data generated from nuclear-plant simulations, simulation of solar flares and their effect on heliosphere. Data analytics and predictive decision-making regarding energy resources, production and usage, help us understand the drivers of global environmental and climate change.

High-performance computing (HPC) uses supercomputers and computer clusters to solve advanced science and engineering problems. Using the Stokes clusters in addition to the Ohio Supercomputing Center and BlueWaters Supercomputer, we study ecosystem and its relation to atmospheric forcing and develop ecological models of animal movement.

Departmental Expertise: Transportation Systems
Given the large extent of travel volumes and the increasing automation of data collection methods, large amounts of data are typically amassed on an ongoing basis and often in real-time. Given the numerous means of collecting transportation data, whether related to the services provided or the demand for travel, the data are highly varied. Therefore, essential aspects of taking advantage of transportation data include their storage, organization, processing, and management in a manner that renders them suitable for the various planning, design, and operations related applications.
APPENDIX B

Research challenges to be addressed by:

The following challenges are considered a matter of national security, crucial to maintaining US leadership in science and engineering, scientific discovery, research and innovation, as identified by the National Academy of Engineering [http://www.engineeringchallenges.org/cms/8996/9221.aspx](http://www.engineeringchallenges.org/cms/8996/9221.aspx), [http://www.nap.edu/catalog.php?record_id=13292](http://www.nap.edu/catalog.php?record_id=13292) and the National Research Council [http://www.nap.edu/catalog.php?record_id=12954](http://www.nap.edu/catalog.php?record_id=12954). Addressing these challenges will impact societal health and well-being and a vast array of commercial services and activities. The overall goal in overcoming these challenges is bridging the gap between climate change and environmental science and civil engineering practice, leading to sustainable engineering that will develop effective, resilient, and sustainable civil services and infrastructure in harmony with the natural environment.

Development of Carbon Sequestration Methods

Capturing the carbon dioxide (CO₂) produced by industrial processes and by burning fossil fuels and storing it safely away from the atmosphere is a principal challenge for the future vibrancy of societies. The growth in emissions of carbon dioxide—the most worrisome greenhouse gas due to its long residence time in the atmosphere and societal reliance on technologies that vent it as waste streams—is a prime contributor to climate change and a serious problem that must be addressed directly and indirectly. Numerous studies have concluded that deploying carbon capture utilization and storage (CCUS) technologies to mitigate CO₂ emissions from human activities is essential along with expanded deployment of technologies that generate useful energy from sources that do not emit CO₂. Major research challenges within CCUS include developing cost-effective CO₂ separation technologies, reducing the possibility of CO₂ or brine leakage from storage reservoirs, understanding the complexities of multi-phase and multi-fluid flow within porous and permeable media, investigating geochemical alterations of this media and the overlying confining units, addressing regulation and societal acceptance of the technology and approaches, and developing viable business cases for CCUS—for example, by developing means to use the large quantities of CO₂ to produce marketable products that reduce the net CO₂ emissions to the atmosphere as well as putting in place mechanisms that incentivize reductions in CO₂ emissions (e.g., cap-and-trade, CO₂ tax) that share the burden in economically efficient ways.

Managing the Nitrogen Cycle

Over the last 40 years, the population of the Earth doubled and our ability to feed this population can be directly attributed to the availability of nitrogen as a fertilizer. This process has removed nitrogen from the atmosphere and deposited on our soils, thus changing the natural nitrogen cycle. Leaching from the soil environment to waterways is the primary contributor of non point source pollution—identified by the EPA as the leading remaining cause for water quality problems in the US, impacting drinking water supplies, recreation, fisheries and wildlife. Maintaining a sustainable worldwide food supply in the future, without excessive environmental degradation, will require astute methods for remediating the human disruption of the nitrogen cycle. Environmental engineers, through the use application of innovative in-situ microbiological remediation techniques, modeling of the nitrogen transport pathways, development and assessment of conservation management practices and water treatment technological advancements, will play a critical role in management of the nitrogen cycle.

Providing Access to Clean Water

The availability of clean water and its sustainability is a global problem: about 1 out of every 6 people living today do not have adequate access to water, and more than double that number lack basic sanitation, for which water is needed. The global problem is not a lack of water, though, but it is a lack of clean water available in the quantities that are needed,
where it is needed, and when it is needed—a problem that will only be exacerbated by climate change and the concomitant increase in the frequency and extremity of droughts and precipitation events. With global water consumption doubling every 20 years, it is anticipated that 1 billion people will face absolute water scarcity by 2025, with many others facing water stress conditions. In terms of water and health, globally, 800 million people lack access to safe water; 2 billion people lack access to sanitation; 1 billion illnesses per year are due to water borne diseases; between 1.8 and 5 million deaths per year are attributed to water borne disease. Water is intricately related to food security worldwide as the major use of fresh water resources globally are for irrigation. Further, the energy needs for moving water for drinking water supplies and wastewater treatment are immense. In addition, each energy choice maintains a water footprint and the process of generating or using the energy may alter the water’s quality. Water is also critical for domestic and national security. Water resources do not respect international boundaries and many water scarce and stressed areas are in US Department of State critical areas. The world’s water supplies are facing new threats; new, affordable, advanced technologies could make a difference for millions of people around the world. Household water for drinking and personal use constitutes only a small part of society’s total water needs, and it normally accounts for less than 5 percent of total water use. Agriculture and industry use most of the water used on a global scale. Needless to say, water is also needed for ecological processes not directly related to human use. Engineering challenge of the first magnitude is developing methods of ensuring adequate water supplies for a healthy, sustainable future for our planet, for the people who live on it, and for the services that modern economies require.

Restoring and improving urban infrastructure

US infrastructure, along with those of many other countries, is aging and failing, as over that past decades funding has been insufficient to repair and replace it. The average grade that was given to various categories of U.S. infrastructure in the 2013 grading report, issued by the American Society of Civil Engineers, was an alarming D+. Our infrastructure will require $3.6 trillion investment by 2020. Engineers of the 21st century face the formidable challenge of modernizing the fundamental structures that support civilization. Infrastructure is the combination of fundamental systems that support a community, region, or country. It includes everything from water and sewer systems to transportation networks to the national power and natural gas grids. In urban areas, where population growth put a heavy weight on society’s support systems, the problem is particularly acute, and accidents, terrorist attacks and natural disasters threaten infrastructure safety and security, and consequently, impact the public health and safety. A new set of predictive models of infrastructures under normal operating conditions as well as extreme events such as earthquakes and hurricanes are required to capture the complex behavior of these systems. Such models should be multi-scale to capture the behavior of physical assets such as bridges, buildings, and wharves made of reinforced and prestressed concrete and steel at the component level, and the behavior of a network of interconnected components such as transportation networks and power grids at the system level. The integration of these predictive models with risk-informed decision-making frameworks will enable development of smart management policies of physical assets, operations, and services of critical systems, which will enhance the resilience of communities. In addition, novel construction materials may help address some of these challenges. But most substantial progress may be possible only by developing entirely new construction methods. The vast paved urban areas must be rethought, perhaps by designing new pavements that are permeable to allow rainwater to reach the ground table beneath, and that can reduce overhead temperatures. In general, multiple goals, such as better storm drainage and cleaner water may be achieved by proper engineering approaches, while also enhancing the appearance of the landscape, improving the habitat for wildlife, and offering recreational spaces for people. In addition, numerous policies and political barriers must be addressed and overcome, as redesigning, rebuilding and enhancing urban infrastructure faces problems beyond the search for new engineering solutions.

Modernizing the Current Earth Observing Systems
GNSS (Global Navigation Satellite Systems), deployment of multi-modal observing capability in constellation of agile satellites, improvements in positioning, navigation and timing, all are necessary driving factors of monitoring our environment, climate, urbanization, exploring and understanding of our world. The challenge is real-time multi-sensor and multi-platform sensing and integration of big data for applications, such as infrastructure monitoring, planning and operating civil services, transportation and transit application (see Figure B1 on cooperative mobility) ensuring public health and safety systems, assessing and mitigating environmental impacts and man-made and natural hazards, precision farming (see Figure B2), sea-level change, subsidence caused by pumping of groundwater, oil, and gas, and other environmental impacts.

Figure B1. Multi-sensor positioning and remote sensing combined with multi-infrastructure communication for cooperative mobility and collision avoidance. Vehicle-2-vehicle and vehicle-2-infrastructure cooperation, sensor networks and cooperative vehicle infrastructure, central system, communication with service center, roadside system (http://www.cvisproject.org/).
Figure B2. Concept of the “farm of the future” that enabled by ubiquitous positioning and other geospatial technologies and infrastructure technologies, combined with global communications (National Academies, 2010).

The technologies of interest include portable imaging and navigation sensors, sensor networks, sensor fusion, ubiquitous positioning and sensing, cooperative mobility, and platforms, such as Unmanned Aerial Systems (UAS). Evolution towards geodetic-grade imaging and real-time applications requires efficient data transfer from remote stations to data processing centers, and real-time astute methods of fusion of large heterogenic data sets for robust intelligence gathering and timely decision making support. This, in turn, necessitates development and use of big data and data analytics tools, developing human-machine and machine-machine interfaces and interaction models for collaborative completion of assigned tasks. Enhancements of current environmental sensor technologies to improve precision, resolution, stability, and the ability to generate new data in required. The focus is on fast detection of catastrophic events, e.g., tsunami, floods, earthquakes, environmental contamination early warning systems, etc. (see Figure B3), with the focus on global scale geospatial and temporal (4D) modeling, agent-based modeling, and implementation of advanced technologies that integrate multi-model data resources, including active (LiDAR) and passive (optical) sensory data to monitor ecosystem services, agricultural production, urban environments, watersheds and hydrological flows, urban to rural water use patterns, interaction of rainfall and aquifer recharge with rainfall patterns, and long term monitoring sites.

Figure B 3. The role of agile sensor systems in space, on the ground, and ocean floor, and the communications and advanced modeling systems in fast detection of catastrophic events: tsunami early warning system (Courtesy: GFZ Potsdam).