

TIER-1: UNIVERSITY TRANSPORTATION CENTER

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INSPECTING AND PRESERVING INFRASTRUCTURE THROUGH ROBOTIC EXPLORATION

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Awarded in December of 2016 by the U.S. Department of Transportation, the five-year **INSPIRE UTC** is a Tier 1 University Transportation Center with a research priority of preserving the existing transportation system as part of the UTC Program (<https://www.transportation.gov/utc/2016-utc-grantees>) that was authorized under the Fixing America's Surface Transportation Act.

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CONSORTIUM MEMBERS



From the Director

It's my pleasure to present to you the inaugural newsletter of the 10-member INSPIRE University Transportation Center (UTC) headquartered at Missouri University of Science and Technology (Missouri S&T) in Rolla, Missouri. The acronym for INSPIRE stands for Inspecting and Preserving Infrastructure through Robotic Exploration.



It is INSPIRE's vision that the future of inspection and preventative maintenance of highway bridges will be transformed into an automated and integrated process within a bridge asset management system. In the next 30 years, our highway and railway systems will face challenges ranging from aging infrastructure and increasing congestion to declining revenues due to reduced fuel tax and increasing service interruption. Cheaper, faster and safer inspection and preservation tools are urgently needed to keep our nation's ground transportation system in a state of good repair.

Currently, bridges are visually inspected and manually maintained under traffic control with the aid of boom and snooper trucks. In the future, with successful development and implementation of advanced sensing technologies and robotic platforms such as unmanned aerial vehicles (UAVs), these structures will be evaluated and sometimes maintained underneath bridge decks with no access equipment and no traffic control, reducing labor hours, avoiding rental, transportation and mobilization costs of equipment, alleviating traffic congestion, saving fuel and indirect costs associated with service interruption, and promoting work zone safety.

The above bold vision can be realized by developing, through interdisciplinary research, new technologies such as mobile manipulating UAVs, structural crawlers, lab-on-sensor calibrations and standardizations, hyperspectral and microwave imaging, risk-based inspections, data-driven preservation strategies and resilience analysis methods. The developed technologies can potentially amend inspection regulation for fracture critical members and re-invent an integrated inspection and preservation decision process from performance monitoring through emerging risk identification to support planning of preservation actions.

To the structural health monitoring community, the INSPIRE UTC will pave a clear path to implement sensing technologies within transportation infrastructure. The mobile inspection and maintenance platform enabled by the INSPIRE UTC can replace many inspection traveler cars underneath the deck of long-span bridges and thus save millions of dollars associated with their construction. It will provide a long-overdue vehicle for technology applications in elevated structures.

I invite you to browse the following pages and learn more about our team and facilities.

Genda Chen, Ph.D., P.E., F. ASCE

Robert W. Abnett Distinguished Professor of Civil Engineering, Missouri S&T

Center Overview

INSPIRE's Mission

The mission of INSPIRE is to make an impactful contribution to the overall University Transportation Center Program authorized under the Fixing America's Surface Transportation (FAST) Act by providing leadership in research, education, workforce development, and technology transfer aimed at infrastructure inspection and preservation solutions with advanced sensing and robotic technologies for a sustainable and resilient transportation system. This mission becomes increasingly important in addressing greater needs for condition assessment and maintenance of bridges as natural disaster risks increase and approximately 50 percent of bridges in the National Bridge Inventory approach their design life.

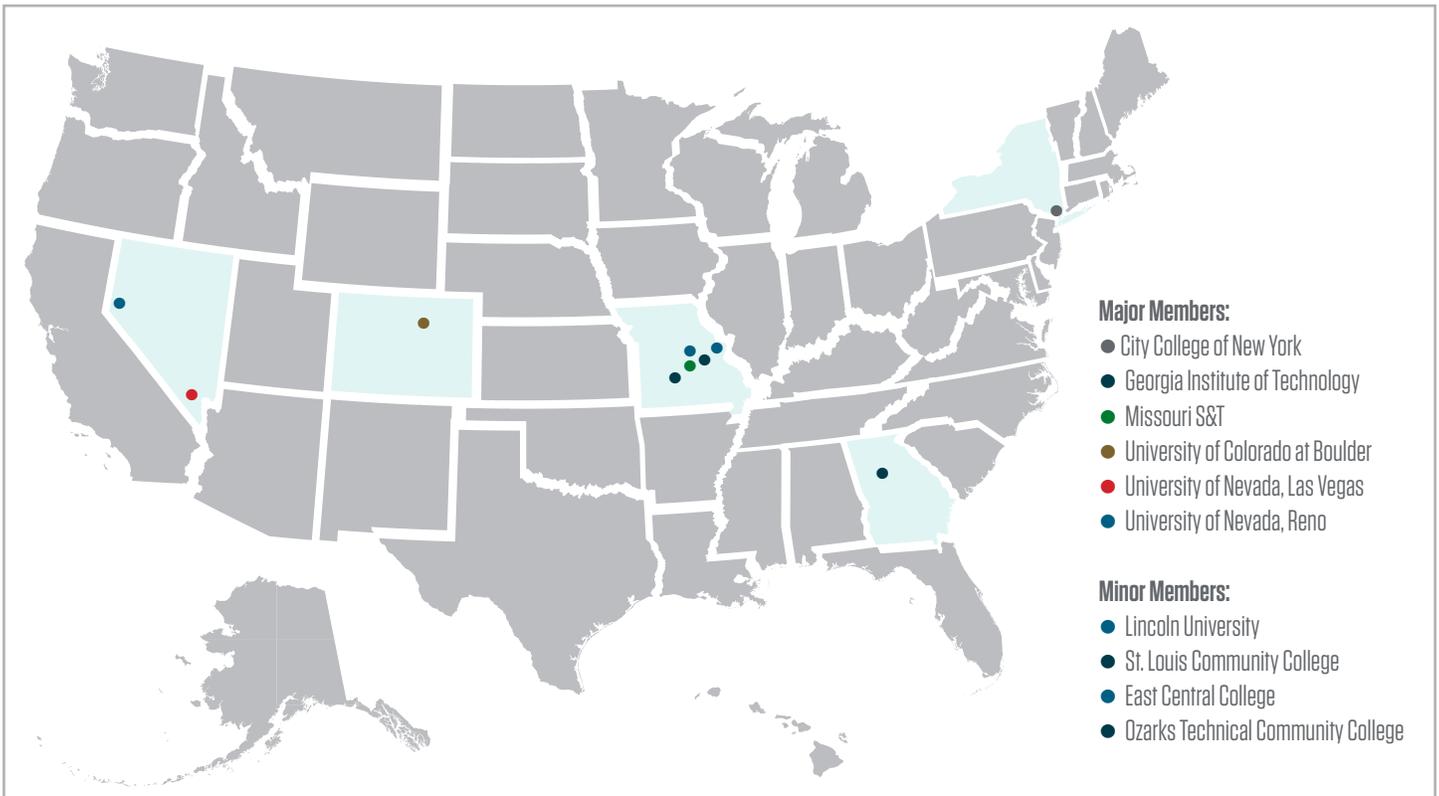
Consortium Members

The INSPIRE UTC is a diverse, experienced, and geographically distributed consortium of six major and four minor partners. The six major partner institutions from east to west are City College of New York (CCNY), Georgia Institute of Technology (GT), Missouri S&T, the University of Colorado at Boulder (CU), the University of Nevada, Las Vegas (UNLV), and the University of Nevada, Reno (UNR). Located in the state of Missouri, the four minor partners are Lincoln University (LU), St. Louis Community College (STLCC), East Central College (ECC), and Ozarks Technical Community College (OTCC). Major partners will support all research activities, whereas minor partners provide a conduit to develop the next-generation transportation workforce. (See map below.)



5-YEAR GOAL

The overarching goal of the center in five years is to transform in at least two demonstration cases from manual to automated inspection and preservation of bridges with sensors, nondestructive evaluation (NDE) devices, multi-modal unmanned vehicles, and data logistics, thus providing cost-effective, consistent, and reliable solutions in bridge condition assessment and maintenance, and to develop diverse transportation workforces mastering the advanced technologies.



MEET THE INSPIRE RESEARCH TEAM

● Dr. Anil Agrawal, P.E.



Dr. Anil Agrawal is a professor in the Department of Civil Engineering at the City College of New York and an associate director of the INSPIRE UTC. His research interests include the safety of bridges during extreme loads such as earthquakes, blast, fire and vehicular impacts, characterization of bridge foundations, bridge deterioration modeling and inspection, earthquake engineering, and smart materials and intelligent structures.

Website: <http://www-ce.engr.cuny.edu/People/Agrawal/index.htm>

● Dr. Genda Chen, P.E.



Dr. Genda Chen is a professor and the Robert W. Abbott Distinguished Chair in Civil Engineering at Missouri S&T. Chen is the director of the INSPIRE UTC, an associate director of the Mid-America Transportation Center (MATC), and director of the System and Process Assessment Research Laboratory at Missouri S&T. He has three years of practical experience in bridge design, inspection, and construction, and 20 years of research experience in structural health monitoring, structural control, in-situ tests of bridges, post-event field reconnaissance, interface mechanics and deterioration mechanism, and multi-hazard mitigation.

Website: <http://web.mst.edu/~gchen>

● Dr. Reginald DesRoches



Dr. Reginald DesRoches is the former chair of the School of Civil and Environmental Engineering at the Georgia Institute of Technology and the William and Stephanie Sick Dean of the School of Engineering at Rice University. His primary research interests are in design of resilient lifeline infrastructure systems under extreme loads and the application of smart and auto-adaptive materials. In particular, his research is focused on the vulnerability assessment of bridges and highways. His research is highly interdisciplinary and spans micro- to macro-scale.

Website: <http://desroches.ce.gatech.edu/>

● Dr. Mohamed ElGawady



Dr. Mohamed ElGawady is an associate professor and Benavides Faculty Scholar in the Department of Civil, Architectural and Environmental Engineering at Missouri S&T. ElGawady worked as a structural engineer for three years. His research interests include seismic behavior of bridges, rehabilitation of structures using shotcrete and fiber reinforced polymers (FRP), concrete-filled FRP tubes, segmental construction, geopolymer concrete, recycled aggregates, and sustainable concrete structures.

Website: <http://care.mst.edu/people/faculty/profiles/elgawady/>

● Dr. George Hearn, P.E.



Dr. George Hearn is an associate professor in the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado, Boulder and an associate director of the INSPIRE UTC. Hearn has more than 35 years of experience in bridge inspection, design, rehabilitation and management. He serves on committees on maintenance and preservation of highway bridges for the National Academies, the Federal Highway Administration, and AASHTO.

Website: <http://civil.colorado.edu/~hearn/>

● Dr. Hung La



Dr. Hung La is an assistant professor in the Department of Computer Science and Engineering and director of the Advanced Robotics and Automation Laboratory at the University of Nevada, Reno, and an associate director of the INSPIRE UTC. He works in the areas of robotics and control systems. His current interests are in bridge inspection robotic system developments, mobile sensor networks and multi-robot systems.

Website: <http://www.unr.edu/cse/people/la>

● Dr. Suzanna Long



Dr. Suzanna Long is a professor and chair of the Department of Engineering Management and Systems Engineering at Missouri S&T, and an associate director of the INSPIRE UTC. She has internationally recognized research expertise in critical infrastructure systems management focused on transportation/supply chain-logistics management, energy systems and organizational systems planning and effectiveness. Her transportation research interests include organizational decision making and data analytics related to transportation technologies and infrastructure life cycle planning.

Website: <http://emse.mst.edu/facultystafffacilities/emsefaculty/suzannalong/>

● Dr. Sushil Louis



Dr. Sushil Louis is a professor in the Department of Computer Science and Director of the Evolutionary Computing Systems Laboratory at the University of Nevada, Reno. He works in the areas of evolutionary computation and its applications in search, optimization and machine learning. His current interests are in evolutionary approaches to computer game AI and human behavior modeling. Major application areas include computer game AI and human computer interfaces.

Website: <http://www.cs.unr.edu/~sushil/>

● Dr. Hongyan MA



Dr. Hongyan MA is an assistant professor in the Department of Civil, Architectural and Environmental Engineering and Director of the Smart and Functional Construction Materials Laboratory at Missouri S&T. His research interests include nano- and biological technologies in construction, phase change materials, acoustics- and optics-based sensing techniques, novel cementitious materials, multi-scale modeling of cement-based materials, and deterioration mechanisms of concrete.

Website: <https://care.mst.edu/people/faculty/profiles/ma/>

MEET THE INSPIRE RESEARCH TEAM

● Dr. Paul Oh



Dr. Paul Oh is the Lincy Professor of Unmanned Aerial Systems in the Department of Mechanical Engineering and director of the Drones and Autonomous Systems Laboratory at the University of Nevada, Las Vegas, and an associate

director of the INSPIRE UTC. He has five years of industry experience in the design of target tracking systems, flight simulators, telecommunication network programming, and vehicle assembly. He has over 20 years of research experience in robotics including computer vision, unmanned aerial vehicles and humanoids.

Website: <https://www.unlv.edu/people/paul-oh>

● Dr. Ruwen Qin



Dr. Ruwen Qin is an associate professor in the Department of Engineering Management and Systems Engineering at Missouri S&T. Her research interests include data analytics and statistical modeling, dynamic optimization, systems of

systems, and their applications to the design, optimization and management of smart systems under highly uncertain conditions.

Website: <http://web.mst.edu/~qinr>

● Dr. Lesley Sneed, P.E.



Dr. Lesley Sneed is an associate professor and the Stirrat Faculty Scholar in the Department of Civil, Architectural and Environmental Engineering at Missouri S&T. Her research interests include the behavior and design of

concrete structures, repair and strengthening of structures subjected to seismic loading or other extreme hazards and evaluation of existing structures. Dr. Sneed has over seven years of professional consulting experience in structural design and rehabilitation.

Website: <http://people.mst.edu/faculty/sneedlh/>

● Dr. Iris Tien



Dr. Iris Tien is an assistant professor in the School of Civil and Environmental Engineering at the Georgia Institute of Technology. Her research experience encompasses traditional topics in civil and structural engineering, as well as

sensing and data analytics, infrastructure systems modeling, probabilistic risk and resilience assessment, and decision-making under uncertainty.

Website: <http://www.iritien.com>

● Dr. Yang Wang



Dr. Yang Wang is an associate professor in the School of Civil and Environmental Engineering and Director of the Laboratory for Smart Structural Systems at the Georgia Institute of Technology, and an associate director of the INSPIRE UTC.

Wang has an interdisciplinary background in civil engineering and electrical engineering. He has 15 years of research experience in structural health monitoring, vibration testing, system identification, finite element model updating, feedback structural control, and structural dynamics and earthquake engineering.

Website: <http://wang.ce.gatech.edu/>

● Dr. Jizhong Xiao



Dr. Jizhong Xiao is a professor in the Department of Electrical Engineering and Robotics Laboratory at the City College of New York. His research interests include robotics and control, cyber-physical systems, non-destructive evaluation

(NDE) of infrastructures, autonomous navigation and 3D simultaneous localization and mapping (SLAM), real-time and embedded computing, assistive technology, multi-agent systems and swarm robotics.

Website: <http://www-ee.ccny.cuny.edu/www/web/jxiao/jxiao.html>

● Dr. Zhaozheng Yin



Dr. Zhaozheng Yin is an assistant professor and Daniel St. Clair Fellow in the Department of Computer Science and Engineering and Director of the Computer Vision and Biomedical Imaging Laboratory at Missouri S&T. Yin specializes

in computer vision, image processing and machine learning, with broad applications in structure health monitoring.

Website: <http://cs.mst.edu/facultystaffandfacilities/zhaozhengyin/>

● Dr. Reza Zoughi



Dr. Reza Zoughi is the Schlumberger Distinguished Professor in the Department of Electrical and Computer Engineering and Director of the Applied Microwave Nondestructive Testing Laboratory at Missouri S&T. His research interests include

electromagnetics, antenna design, microwave and millimeter wave engineering and nondestructive testing (NDT), materials characterization, and microwave and millimeter wave high-resolution and real-time imaging. His current research activities are mostly related to composites, structures and materials evaluation and high-resolution 3D real-time imaging system development.

Website: <http://amntl.mst.edu/people/zoughi/zoughi2/>

INSPIRE STATS

- 10 Universities
- 6 Major Partners
- 4 Minor Partners
- 5 States across the U.S.

- Interdisciplinary expertise in civil engineering, electrical engineering, mechanical engineering, engineering management and computer science

Affiliated Research Facilities

Advanced Robotics and Automation Lab

Department of Computer Science and Engineering, the University of Nevada, Reno

The ARA Lab has approximately 1,000 square foot of floor space and is equipped with various state-of-the-art equipment, including a Motion Analysis motion capture system, drones, mobile robots, a Seekur Jr robot, bridge deck inspection robots, climbing robots, ground penetrating radar, electrical resistivity probes, eddy current sensors, laser scanners, LiDAR, cameras, GPSs, IMUs and PCs. The ARA Lab supports research in the areas of autonomous systems, multi-robot systems, control systems, human-robot collaboration, and wearable computing.

Website: <https://ara.cse.unr.edu>

Applied Microwave Nondestructive Testing Lab

Department of Electrical and Computer Engineering, Missouri S&T

Major activities in this laboratory include both basic R&D and applied research in the field of microwave and millimeter wave nondestructive testing and evaluation (NDT&E) of complex materials and structures, and testing and imaging system research and development. The AMNTL Lab is equipped with modular and integrated laboratory test equipment such as sweep oscillators and other solid state generators, vector network analyzers (HP8753E, HP8510C, and Anritsu MS64644A) up to 40 GHz and associated calibration equipment, waveguide components including precision slotted lines, attenuators, phase shifters, isolators, circulators, directional couplers, multi-port waveguide components, etc. The laboratory also includes several new generation personal computers equipped with numerical electromagnetic simulation and PCB design software.

Website: <http://amntl.mst.edu/>

Computer Vision and Machine Learning Lab

Department of Computer Science and Engineering, Missouri S&T

The CVML Lab has approximately 300 square foot of floor space and has supported interdisciplinary research collaborated among civil engineering, mechanical and aerospace engineering, biological sciences and computer science since 2011. It has eight workstations with GPUs and an indoor multicopter testing environment with motion capture camera systems. Different types of multicopters and a fixed-wing unmanned aerial vehicle (UAV) have been tested for various projects such as field monitoring of plants, bridge inspections with multicopters and ground suspect detection for security surveillance.

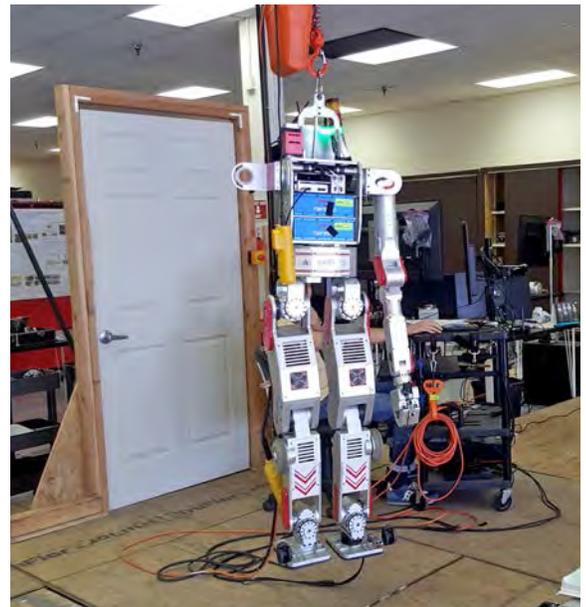
Website: <http://web.mst.edu/~yinz>

Drones and Autonomous Systems Lab

Department of Mechanical Engineering, the University of Nevada, Las Vegas

Under Dr. Paul Oh's direction, DASL was established at Drexel University in 2000 and moved into its new 10,000 square foot site at the University of Nevada, Las Vegas in 2014. It resulted from 17 years of extensive research collaborations among computer science, mechanical engineering and electrical engineering. DASL features several robotics including two full-sized and three mini-sized humanoids, over a dozen fixed- and rotary-wing unmanned aerial vehicles (UAVs), and modeling, mapping and localization equipment like motion capture units, high-resolution LIDARs, and differential GPS units. The lab also features dedicated workspaces for metal work (including CNC), fabrication (including laser cutter and 3D printers), and an electronics and instrumentation shop.

Website: <http://www.daslhub.org>



Affiliated Research Facilities (continued)



Evolutionary Computing Systems Lab

Department of Computer Science and Engineering, the University of Nevada, Reno

The ECSL Lab focuses on systems that use genetic algorithm (GA) search to evolve AI for Real-Time Strategy (RTS) games, to evolve interaction design and directed autonomy for large numbers of heterogeneous simulated and real-world agents, and to augment machine learning and deep learning approaches. The lab has developed new techniques for machine learning using Case-Injected Genetic Algorithms (CIGAR), for playing to learn to play computer games, and for evolving RTS game micro and macro.

Website: <http://cse.unr.edu/~ecsl/>

Highbay Structural Engineering Research Lab

Department of Civil, Architectural and Environmental Engineering, Missouri S&T

The Highbay Structures Lab has approximately 10,000 square foot of floor space and was built with easy access to I-44 and U.S. 63 Highways for the testing and evaluation of large-scale structural components and systems. The laboratory is also accessible to an adjacent materials laboratory and a machine shop. It has a bidirectional reaction wall 18 foot in height. It is equipped with a 20-ton overhead crane with a vertical clearance of 20 foot and five MTS actuators — three (one fatigue rated) with 110 kips force capacity and 20 in stroke capacity, and two with 330 kips force capacity and 30 in stroke capacity. To support the operation of the actuators, a 90 gallon/min hydraulic power pump, a MTS-493.05 FlexTest GT electronic control system, a 128-channel high-capacity data acquisition system, and hydraulic service manifolds are installed. The laboratory is also equipped with a unidirectional MTS shaking table (4x7 foot in size) and a unidirectional Shore Western shaking table (5x5 foot in size), which support a maximum payload of 20 tons and 10 tons, respectively.

Website: <https://care.mst.edu/research/facilities/high-baystructureslab/>

Lab for Smart Structural Systems

School of Civil and Environmental Engineering, Georgia Institute of Technology

The LSSS is dedicated to exploring state-of-the-art sensing, control, and information technologies for the development of future large-scale smart structural systems. The lab features a variety of wireless structural sensing devices, structural sensors for measuring static and dynamic structural performance, a Tektronix MSO4034 Oscilloscope and logic analyzer (4 Analog Channels + 16 Digital Channels), a Zephyrtronics ZT-1-CLS-MIL surface-mounting soldering and de-soldering machine, a National Instruments Compact DAQ portable data acquisition system, among others.

Website: <http://wang.ce.gatech.edu/>



TRANSPORTATION CAMP

In July, the INSPIRE University Transportation Center (UTC) hosted a one-day MoDOT Transportation Camp on the Missouri S&T campus as part of MoDOT's annual six-day Youth Transportation Conference.

Each summer MoDOT selects 30 students from across the state to participate in the camp exposing them to numerous career opportunities in the field of transportation.

Attendees spent a full day visiting Missouri S&T and explored a variety of topics related to transportation. The INSPIRE UTC showcased exciting research related to driver's behavior simulation, sensor applications in bridge condition assessment, the use of robotics in bridge maintenance and potential effects of tornados on transportation structures.

Following a welcome address by the center's associate director, **Dr. Suzanna Long**, students attended a series of activities coordinated by **Dr. Ruwen Qin** and organized by the faculty members: **Dr. Genda Chen, Dr. Dincer Konur, Dr. Grace Yan** and **Dr. Zhaozheng Yin**.

Students toured S&T's Virtual Reality (VR) Lab, Wind Hazard Mitigation (WHAM) Lab and the System and Process Assessment Research (SPAR) Lab. Students also had opportunities to participate in hands-on activities in the VR, WHAM, and SPAR Labs and attend a demonstration presentation in the CVBI Lab.



Robotics Lab

Department of Electrical Engineering, the City College of New York

The Robotics Lab has approximately 1,000 square foot of floor space and was established in 2002. The lab consists of a mobile robotics room, a project room, a design studio room, and a conference/presentation room. It is equipped with various robotic platforms, system development tools, a VICON motion capture system, a 3D fast prototyping machine, a networked computing environment, and a variety of sensors and actuators for robotics research and education. The ongoing research projects include: autonomous navigation and 3D SLAM of UAV, wall-climbing robots for NDE applications, DSP-based embedded system design, assistive navigation to help visually impaired people, and mobile sensor networks.

Website: <http://robotics.cuny.cuny.edu/>

Smart and Functional Construction Materials Lab

Department of Civil, Architectural and Environmental Engineering, Missouri S&T

The SmarF Lab is currently under construction. It will be equipped with a nano-materials processing facility, a non-contacting electrical resistivity analyzer, a thermogravimetry/differential thermal analyzer, a dynamic thermal property analyzing system, and self-modified Raman spectroscopy for in-situ analysis of concrete deteriorations.

System and Process Assessment Research Lab

Department of Civil, Architectural and Environmental Engineering, Missouri S&T

The SPAR Lab has approximately 600 square foot of space and features a complete process of fiber optic sensor fabrication, calibration, and application; a fully integrated loading/sensing or corrosion/sensing calibration system; and multiple measurement devices (acoustic, electromagnetic, magnetic, magneto-inductive, optical, and radar) for a complete assessment of structural behaviors in civil infrastructure. The lab is equipped with Micron Optics 16-channel si255-16-ST/160-NO and 4-channel SM125 interrogators, Yokogawa AQ6370C optical spectrum analyzer, Neubrex NBX-7020, 3D laser scanner, Polytec RSV-150 laser vibrometer, Samos Micro II acoustic emission system, SIR 3000 ground penetrating radar, Geometrics G-857 and 3-axis STL magnetometers, Gamry Reference 600 electrochemical multiplexer system, rapid chloride test (RCT), Quansar shake table II, Hi-Tech Synergy data acquisition system, and Dell Precision T7600 desktop workstation.

Website: <http://spar.mst.edu>



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