Partnering and Collaborating to Ensure Secure, Sustainable, Resilient and Reliable Operation and Maintenance of our Nation's Critical Infrastructure

ADVANCING INTELLIGENT INFRASTRUCTURE

THROUGH RESEARCH, OUTREACH AND APPLICATION

The Center for Intelligent Infrastructure (CII) Strategic Plan

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THE CENTER FOR INTELLIGENT INFRASTRUCTURE (CII) MISSION

CII creates, conveys, and applies engineering knowledge and operation intelligence that help solve the world's increasing challenges with aging infrastructure for a safe, sustainable and resilient community and environment.

THE CII VISION

CII will be the world's leading research center for intelligent infrastructures in order to achieve their sustainability, safety, and resilience under environmental, operational, and extreme conditions. We will be the center of choices for partners seeking a highly qualified and entrepreneurial workforce, innovative research, and novel ideas to integrate automation, informatics, and actuation into the lifecycle assessment, performance prediction, risk analysis, and post-disaster recovery of infrastructure systems through multi-scale modeling and sensing.

INTRODUCTION

The National Academy of Engineering Grand Challenges for Engineering include urban infrastructure as the combination of fundamental systems that support a community, region, or country. The urban infrastructure includes everything from water and sewer systems to road and rail networks to the national power and natural gas grids. The CII will deal with buildings, bridges, dams, pipelines, power plants, roads, tunnels, electrical grids and energy infrastructure.

Much U.S. physical infrastructure are approaching the end of their design life with significant deterioration. Their preservation under operational conditions, which is impacted by design and construction process, and their resilience under natural and man-made hazards contribute directly to the functionality, sustainability, and safety of affected communities. While materials are fundamental to the construction of durable and sustainable infrastructure, preservation of existing infrastructure is critical to the cost effectiveness of asset management. These infrastructure systems' operation is increasingly dependent on cyber infrastructure due to urgent needs for real time communication and information.

Thus, there is a critical need to transform currently disparate design, construction, and operation phases of cyber-physical infrastructures into an open-source, cloud-based application featuring modulated digital twins (computer simulations) of physical infrastructures overlaid with cyber infrastructure. Such a digital infrastructure initiative will enable grand-scale fundamental and convergent research on the integrated design-build-operation process of infrastructure, examining its environmental implications, life-cycle assessments, and socioeconomic impacts on community resilience in the case of catastrophic events.

OVERVIEW

Intelligent infrastructure is broadly defined as a seamless integration of technology from digital systems to advanced materials into the final deliverables to end users or owners. It involves nondestructive evaluation, remote sensing, sensors and sensing systems, smart materials, smart pavements, smart structures, intelligent transportation, intelligent building systems, intelligence in built environment construction, intelligent integration of components, adaptive operation and maintenance, artificial intelligence, data mining and analytics, augmented and virtual reality of infrastructure, adaptive management of infrastructure assets, infrastructure deterioration modeling, infrastructure performance evaluation and prediction, and smart cities. In a simple word, intelligent infrastructure represents an integration of informatics, automation, and actuation into the management of civil and power infrastructure assets.

The overarching goal of the CII is to become a global leader in research and application of various intelligent infrastructures within 5 years, and a pioneer in technology implementation in transportation infrastructure within 10 years. It will strategically reach 5 critical milestones over a period of 10 years from its establishment on September 1, 2019:

- Growing by securing center-level funding in 2021,
- Globalization by establishing sister centers worldwide in 2023,
- Implementation by applying advanced technologies into practice in 2025,
- Performance assessment by analyzing return of investment in 2027, and
- Societal impact by conducting end-users survey in 2029.

The overarching goal of the CII will be achieved by promoting, motivating, and recognizing collaborative research activities among center investigators, between the center investigators and other Missouri S&T faculty, and between the center investigators and off-campus domain experts in fields and disciplines closely related yet supplementary to the mission of the Center, by developing research infrastructure required for interdisciplinary center-level research, and by seeking and securing center-level funding opportunities.

The initial center investigators include faculty in civil engineering, computer science, economics, electrical engineering, and engineering management and systems engineering, thus making their team competitive for interdisciplinary project and program opportunities. This team will be expanded to strengthen the center research profile in artificial intelligence, augmented and virtual reality, building information modeling, internet of things and cloud application, and robotics research.

The CII will serve as a long-term, sustained umbrella center for externally-funded research projects and centers related to intelligent infrastructure, such as University Transportation Center (UTC), including:

- Tier 1 UTC (2016-2022, 10 institutions led by Missouri S&T) - Inspecting and Preserving Infrastructure through Robotic Exploration (INSPIRE)

- The S&T Portion of Region VII UTC (2016-2022, 8 institutions led by the University of Nebraska, Lincoln) - Mid-America Transportation Center (MATC)

OBJECTIVES, MEASURABLE GOALS, AND PERFORMANCE METRICS

The CII can help S&T achieve its strategic goals in all five Missouri Compacts:

- Excellence in Student Success
- Excellence in Research and Creative Works
- Excellence in Engagement and Outreach
- Inclusive Excellence
- Excellence in Planning, Operations, and Stewardship

To understand its direct impact on the Missouri S&T Strategic Plan as approved on September 20, 2018 by the University of Missouri Board of Curators, the CII Strategic Plan is developed following the structure of the S&T Strategic Plan. Tables 1-5 map the relation between the two strategic plans for five Missouri Compacts, respectively. For example, Objective 1/Strategy A in the CII and S&T Strategic Plan in Table 1 are the same: Increase quality of the student experience/Provide student services and experiences to maximize career success. The performance metrics in the CII Strategic Plan, which is to supervise 4 graduate students/year/faculty and graduate 1 Ph.D. student/year/faculty, directly contributes to the goal of increasing career outcomes rate from 81% in 2017 to 85% by 2023 in the S&T Strategic Plan.

Table 1 CII versus S&T Strategic Goals to Address Missouri Compact 1: Excellence in Student Success

CII Strategic Plan				**Missouri S&T Strategic Plan**		
Objective	**Strategy**	**Initial Tactics**	**Metrics**	**Objective**	**Strategy**	**Metrics**
1	A	• Expand student exposure to potential employers through the INSPIRE UTC's Industrial Advising Committee, annual meetings and Transportation Research Board annul meetings. • Engage students with interdisciplinary research to broaden their knowledge base. • Connect students with graduate programs and increase awareness of opportunities in graduate school in partner institutions of the INSPIRE UTC.	Supervise 4 graduate students/year/faculty and graduate 1 Ph.D. student/year/faculty	1	A	Increase career outcomes rate from 81% in 2017 to 85% by 2023
2	A	• Implement the INSPIRE UTC institution-pair program with Lincoln University. • Engage the S&T Chapters of the National Society of Black Engineers, the Society of Hispanic Professional Engineers, and the Society of Women Engineers for reaching out high school underrepresented students through the INSPIRE UTC Undergraduate Research Program.	Recruit 4 students every year from underrepresented groups	3	A	Increase the number of underrepresented students from 796 in 2017 to 1,000 by 2023
3	A	• Implement the INSPIRE UTC Freshman Undergraduate Research Program.	Provide 3 scholarships every year	4	A	Increase scholarships reported under other compacts

Table 2 CII versus S&T Strategic Goals to Address Missouri Compact 2: Excellence in Research and Creative Works

CII Strategic Plan				Missouri S&T Strategic Plan		
Objective	**Strategy**	**Initial Tactics**	**Metrics**	**Objective**	**Strategy**	**Metrics**
1	A	• Offer technical writing webinars to students and mentorship to junior faculty for proposal writing. • Connect junior faculty with program directors in funding agencies.	Publish at least 6 journal papers per faculty per year and submit at least 5 regular proposals every faculty per year	1	A	Increase research proposals and publications
	B	• Translate the advanced technologies developed for transportation infrastructure into other infrastructure. • Extract common topics from transportation infrastructure for fundamental/convergent research.	Submit at least 1 center proposal every year, such as NSF Industry-University Cooperative Research Center or Engineering Research Center		B	Increase the number of center proposals
	C	• Nominate investigators for national and international societies. • Nominate investigators for national and international society awards.	1 new fellow made every year and 1 major society award every two years		C	5 people per year made fellows, 5 people per year receive professional society awards by 2023
2	A	• Provide each investigator with over $400k annual expenditure with one-trip funds to attend meeting. • Provide 5 GRA supports/year with 1:1 match from discretional funds such as faculty indirect return funds.	Increase annual research expenditures to $200k per year per faculty, and train over 50 Ph.D. students every year	2	A	Increase annual research expenditures from $35M in 2017 to $70M by 2025, and increase on-campus Ph.D. enrollment from 654 in 2017 to 750 by 2023
	B	• Promote center activities to attract new faculty from new disciplines. • Promote center publications through the center professional network. • Develop research and training facilities in strategic direction, such as unmanned vehicle qualifications and navigation.	Involve faculty from at least 5 disciplines Publish at least 6 journal papers per faculty per year		B	Increase number of faculty and research scholars bridging departments and colleges through new centers, and increase the number of citations by 15% and overall number of publications by 10% by 2023
	C	• Recruit graduate students through professional meetings and university visits. • Provide group advising for Ph.D. students on across-discipline topics.	Train over 50 Ph.D. students per year Achieve 1 Ph.D. graduate per faculty per year		C	Enroll from 654 in 2017 to 750 students by 2023, and achieve 0.5 Ph.D. graduates per faculty per year by 2023

Table 3 CII versus S&T Strategic Goals to Address Missouri Compact 3: Excellence in Engagement and Outreach

CII Strategic Plan				**Missouri S&T Strategic Plan**		
Objective	**Strategy**	**Initial Tactics**	**Metrics**	**Objective**	**Strategy**	**Metrics**
1	A	• Organize summer camps as part of the INSPIRE UTC EOT activities.	Train at least 20 students per year through summer camps	1	B	Increase the number of students attending summer camps from 470 in 2017 to 600 by 2023
2	A	• Organize an annual visit by the Director of Technology Transfer and Economic Development to identify patentable technologies. • Market IP to potential licenses	Achieve 1 patent every two years	2	B	Increase the annual number of patents and intellectual property licenses issued by 25% by 2023
3	A	• Increase CII name recognition by increasing number of international partnerships.	Sign 1 memorandum of understanding with an international university per year	4	A	Increase the number of international contracts and collaborative relations pursued and secured by 15% by 2013

Table 4 CII versus S&T Strategic Goals to Address Missouri Compact 4: Inclusive Excellence

CII Strategic Plan				**Missouri S&T Strategic Plan**		
Objective	**Strategy**	**Initial Tactics**	**Metrics**	**Objective**	**Strategy**	**Metrics**
1	A	• Provide adequate personnel staffing to allow growth in campus-wide training and competency development operations.	Send each center staff to 1 professional training class per year	1	B	Double the number of participants in professional development opportunities by 2023
	B	• Encourage international scholars to visit campus. • Develop formal visiting scholar programs through center-to-center memorandum of understanding	Host 5 visiting faculty per year		C	Host 5-10 visiting faculty per year in the Visiting Scholar Program with international focus by 2023
2	A	• Expand international recruitment portfolio. • Organize summer camps to attract underrepresented undergraduate students.	Receive 2 underrepresented and minority undergraduates	2	B	Double underrepresented and minority undergraduate students by 15% by 2023

Table 5 CII versus S&T Strategic Goals to Address Missouri Compact 5: Excellence in Planning, Operations, and Stewardship

CII Strategic Plan				**Missouri S&T Strategic Plan**		
Objective	**Strategy**	**Initial Tactics**	**Metrics**	**Objective**	**Strategy**	**Metrics**
1	A	• Determine CII financial performance targets. • Evaluate current reserve use practices to ensure center optimization of financial reserves.	Achieve or exceed financial performance targets in the center	1	D	Achieve or exceed financial performance targets by unit and campus
	B	• Review staff operation process. • Review staff structure to improve service, satisfaction, and efficiency.	Review and modify as needed center staff operation process and structure		E	Number of processes or structures reviewed

CRITICAL ENABLERS

The success of the CII's Strategic Plan depends on 4 strategic enablers:

1. **Who we are:** World-class faculty are key to success. The CII is committed to recruiting the very best faculty, mentoring and inspiring them to achieve their full potential, and retaining their talents for a long and successful career.
2. **What we are made of:** High-quality staff and unique research infrastructure are the backbone of a successful research enterprise. We are committed to hiring the very best staff, training and empowering them to reach greater heights, and rewarding them according to their performance. We are also committed to developing unique research infrastructure and capabilities through external funding opportunities.
3. **How we sustain our operation:** Sustained campus resources are crucial to maintaining the center infrastructure and keeping staff operation in long term. We are committed to demonstrating the return of investment to justify continuing campus investments over years.
4. **Why we are funded externally:** Attracting external funds are the ultimate reason why the CII is in existence. We are committed to modifying and identifying research directions of grand societal impact over time, and taking interdisciplinary approaches to secure center-level programs from local, state and federal funding agencies.