UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING COLLABORATION WORKSHOP

NATIONAL ACADEMY OF ENGINEERING

NATIONAL ENERGY TECHNOLOGY LABORATORY

National Academies Activities on Infrastructure Sensing

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11/13/2024

Infrastructure Sensing

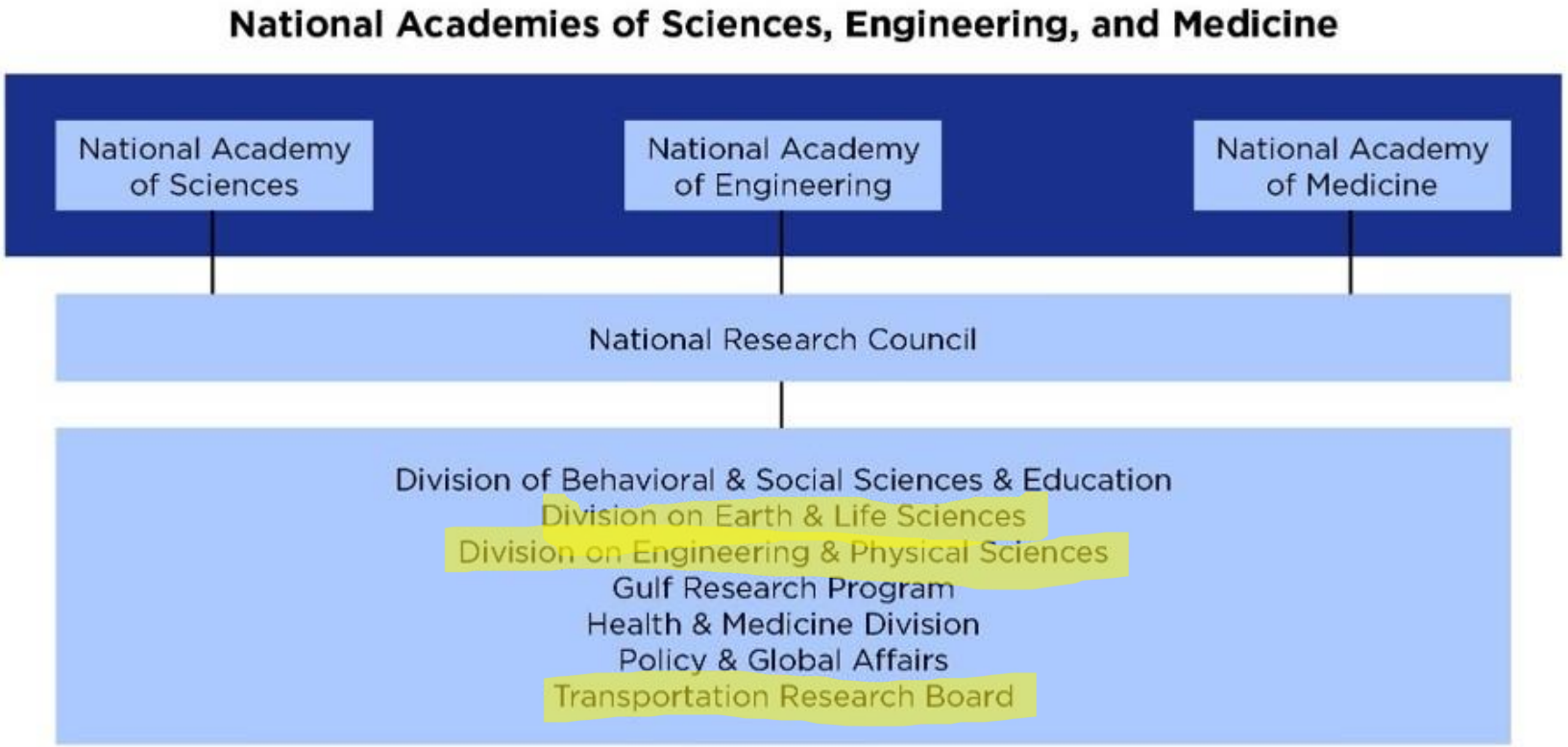
- Predictive monitoring to avoid catastrophic failures (structural, mechanical, electrical, etc.) in large-scale physical structures
- Determining when to replace or repair aging bridges, roads, rail lines, and other assets to assure the long-term viability of new assets.
- Optimizing safe, efficient, large-scale transmission of electricity, natural gas, hydrogen, data/voice, and other assets
- Detecting environmental contamination, including airborne/waterborne toxins and greenhouse gas emissions, caused by infrastructure flaws/failures

Importance of Infrastructure Sensing

- **"The condition and performance of the enormous interconnected systems of U.S.** transportation **infrastructure are critical for the safe and efficient movement of people and goods and achievement of transportation-related climate and economic goals, but**
- **Measures of their condition and performance are incomplete and imperfect.**
- **The lack of such information hampers decision making about the required scale of resource allocation and how most cost-effectively to ensure that transportation infrastructure serves a thriving society."**

National Academies of Sciences, Engineering, and Medicine. 2024. *Critical Issues in Transportation for 2024 and Beyond*. Washington, DC: The National Academies Press. https://doi.org/10.17226/27432.

The U. S. National Academies ("NASEM")



NASEM Division on Engineering and Physical Sciences (DEPS)

- Aeronautics and Space Engineering Board (ASEB)
- Air Force Studies Board (AFSB)
- Board on Army Research and Development (BOARD)
- **Board on Energy and Environmental Systems (BEES)**
- **Board on Infrastructure and the Constructed Environment (BICE)**
- Board on Mathematical Sciences and Analytics (BMSA)
- Board on Physics and Astronomy (BPA)
- **Computer Science and Telecommunications Board (CSTB)**
- Intelligence Community Studies Board (ICSB)
- Laboratory Assessments Board (LAB)
- National Materials and Manufacturing Board (NMMB)
- Naval Studies Board (NSB)
- Space Studies Board (SSB)

NASEM Division on Earth and Life Studies (DELS)

- Board on Atmospheric Sciences and Climate (BASC)
- Board on Chemical Sciences and Technology (BCST)
- **Board on Earth Sciences and Resources (BESR)**
- Board on Environmental Studies and Toxicology (BEST)
- Nuclear and Radiation Studies Board (NRSB)
- **Water Science and Technology Board (WSTB)**
- ….[others]

NASEM Transportation Research Board (TRB)

- **Consensus and Advisory Studies**
- Cooperative Research Programs
- Technical Activities
- Annual Meeting and Conference

Examples of NAE Work Related to Infrastructure Sensing

- "The Future of Electric Power in the United States" (Two Workshops and a Consensus Study)
- "Technologies and Practices for Plugging and Remediating Orphaned and Abandoned Oil and Gas Wells" (Roundtable)
- "Forum on Informed Investment, Technology, and Policy Pathways for the Electricity System and Interdependent Energy Infrastructure" (Roundtable)
- "Review of Approaches for Managing Pollutant Loads in Highway Stormwater" Runoff (Consensus Study in progress)
- "Electricity System Operability Under Increasing Complexity" (Workshop and webinar series)
- "The Role of Advanced Technologies in Structural Engineering for More Resilient Communities" (Workshop Proceedings)

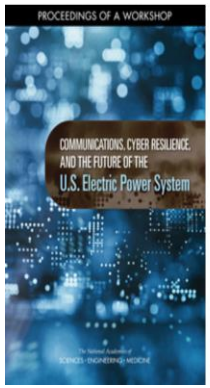
The Future of Electric Power in the U.S.

"Electric power is essential to the economic and social welfare of all Americans. That will be even more the case in the decades to come. In recognition of this fact, the congressional language that gave rise to this committee called for 'an evaluation of the expected medium- and long-term evolution of the grid … [focused] on developments that include the emergence of new technologies, planning and operating techniques, grid architecture, and business models.' In whatever ways the power system evolves in the future, the system must be simultaneously safe and secure, clean and sustainable, affordable and equitable, and reliable and resilient."

National Academies of Sciences, Engineering, and Medicine. 2021. The Future of Electric Power in the United States. Washington, DC: The National Academies Press. https://doi.org/10.17226/25968.

The Future of Electric Power in the United States

2019 Workshop Report

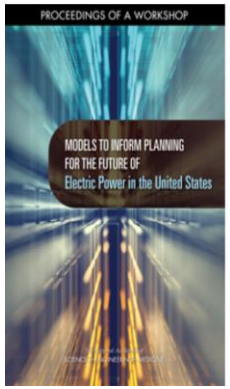


2020

Communications, Cyber Resilience, and the Future of the U.S. Electric Power System: Proceedings of a Workshop

Electric power is a critical infrastructure that is vital to the U.S. economy and national security. Today, the nation's electric power infrastructure is threatened by malicious attacks, accidents, and failures, as well as disruptive natural events. As the electric grid evolves and becomes increasingly interdependent with other critical infrastructures, the nation is challenged to defend against these threats and to advance grid capabilities with reliable defenses. On November 1, 2019, the National Academies of Sciences, Engineering, and Medicine convened a workshop to gather diverse perspectives on current and future threats to the electric power system, activities that the subsector is pursuing to defend itself, and how this work may evolve over the coming decades. This publications summarizes the presentations and discussions from the workshop.

2020 Workshop Report

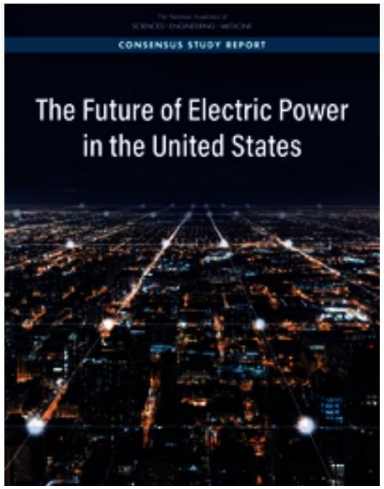


2020

Models to Inform Planning for the Future of Electric Power in the United States: Proceedings of a Workshop

Providing a reliable and resilient supply of electric power to communities across the United States has always posed a complex challenge. Utilities must support daily operations to serve a diverse array of customers across a heterogeneous landscape while simultaneously investing in infrastructure to meet future needs, all while juggling an enormous array of competing priorities influenced by costs, capabilities, environmental and social impacts, regulatory requirements, and consumer preferences. A rapid pace of change in technologies, policies and priorities, and consumer needs and behaviors has further compounded this challenge in recent years.

Read Full Description



2021

The Future of Electric Power in the United States

Electric power is essential for the lives and livelihoods of all Americans, and the need for electricity that is safe, clean, affordable, and reliable will only grow in the decades to come. At the request of Congress and the Department of Energy, the National Academies convened a committee of experts to undertake a comprehensive evaluation of the U.S. grid and how it might evolve in response to advances in new energy technologies, changes in demand, and future innovation.

Read Full Description

2021 Consensus Study Report

The Future of Electric Power in the United States

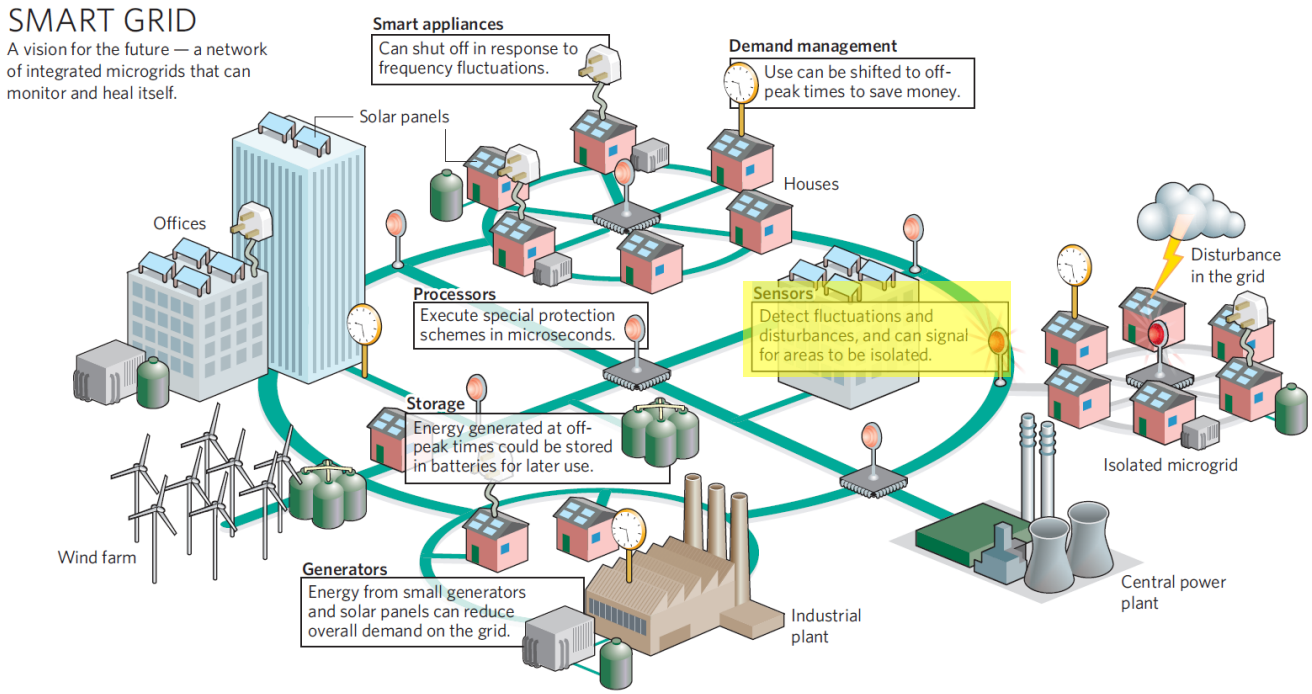


FIGURE 5.3 A depiction of a smart grid composed of integrated microgrids that could operate with smart appliances, storage, and additional advanced grid technologies. SOURCE: Reprinted by permission from Springer Nature Customer Service Centre GmbH, from E. Marris, 2008, "Energy: Upgrading the Grid," *Nature News*, copyright 2008.

"Examples of advances needed for distribution systems include… low-cost sensor networks that provide visibility and advanced analytics across the distribution network."

The Future of Electric Power in the United States

[From Chapter 6: Creating a More Secure and Resilient Power System]

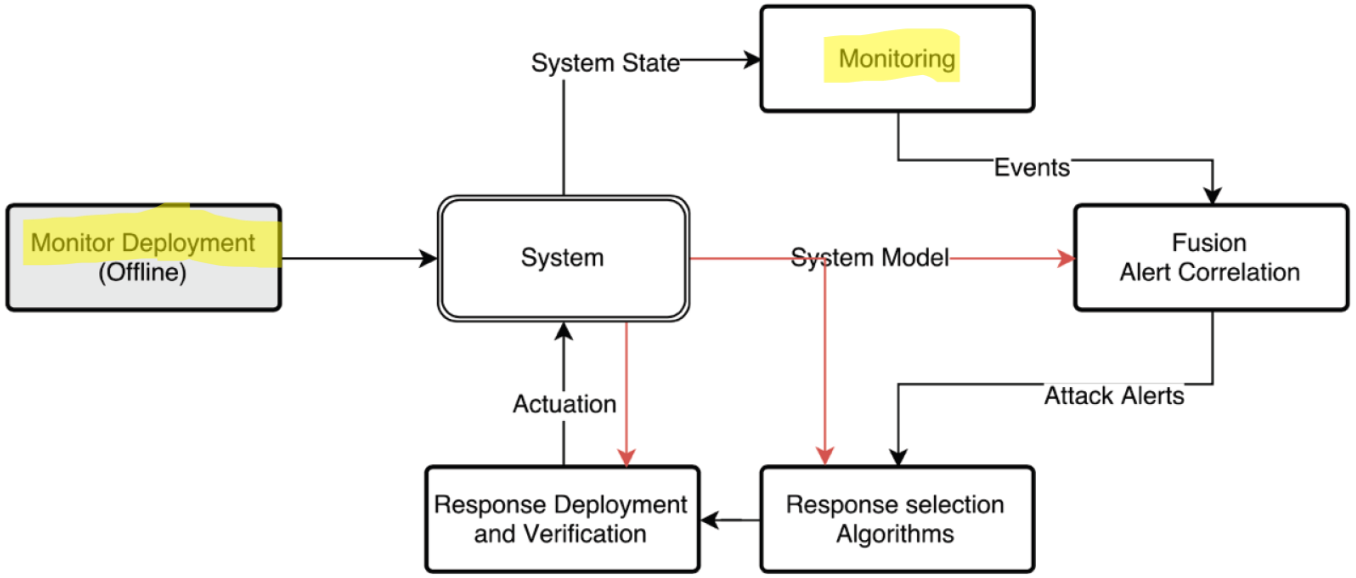


FIGURE 6.5 Prototypical monitoring, fusion and event correlation, and response framework.

"Key to effective detection and proper interpretation of attack indicators is the fusion of data from sensors into information that can lead to detection."

Technologies and Practices for Plugging and Remediating Orphaned and Abandoned Oil and Gas Wells

Orphaned wells can present a risk to the environment and public by emitting methane, contaminating groundwater, and/or impacting ecosystems. The National Academies will convene an ad hoc committee of experts to provide advice to U.S. Department of the Interior (DOI) Orphaned Wells Program Office (OWPO) on regulatory, technical, scientific, and economic considerations for plugging and remediating orphaned and abandoned oil and gas wells.

NEW Roundtable (starts December 2024)

- *Organizer: NASEM DEPS Board on Infrastructure and the Constructed Environment*
- *Sponsor: Department of the Interior*

Technologies and Practices for Plugging and Remediating Orphaned and Abandoned Oil and Gas Wells

"The National Academies of Sciences, Engineering, and Medicine will convene an ad hoc committee of experts to provide advice to U.S. Department of the Interior (DOI) Orphaned Wells Program Office (OWPO) on regulatory, technical, scientific, and economic considerations for plugging and remediating orphaned and abandoned oil and gas wells. The committee will:

- Examine current and emerging plugging and abandonment technologies, best practices, equipment, and materials for well characterization…
- Evaluate unexpected or unique circumstances that necessitate varying criteria and standards, including engineering design, cost, logistics, or technical management.
- Assess available data on potential causes, frequency, consequences, and remediation of plug failures.
- Examine post-plugging monitoring techniques, approaches, and technology that are or will be important for the long-term protection of the environment and public health and safety…"

Review of Approaches for Managing Pollutant Loads in Highway Stormwater Runoff

- About
- Upcoming Events
- Description

The committee will study methods to estimate and/or monitor highway stormwater pollutant transport (including sources and loads), total maximum daily load compliance strategies, and communication of stormwater management best practices by state and federal agencies.

Ongoing NASEM Consensus Study (Initiated December 2023)
Performed by: DELS Water Science and Technology Board and Transportation Research Board
Sponsor: Department of Transportation

Review of Approaches for Managing Pollutant Loads in Highway Stormwater Runoff

"A consensus study committee will:
.
1) Review the data sources and methods used … to: a) estimate and monitor pollutants in stormwater runoff from highways and pedestrian facilities that are eligible for federal aid, and b) determine the sources and loads of the pollutants…
2) ...
3) ...

On the basis of its assessment, the committee may make recommendations to state DOTs, FHWA, USDOT, EPA, and Congress regarding methods and practices for devising, selecting, and carrying out highway stormwater management compliance strategies and on FHWA's and USDOT's roles in promoting best practices. As appropriate, the committee may make recommendations"

Electricity System Operability and Reliability under Increasing Complexity: A Workshop

"A critical and emerging topic for the U.S. electricity system is how to maintain and improve the operational integrity of the grid while it integrates an increasing number of complex, distributed elements.

The National Academies will convene leaders from government, industry, academia, and nongovernmental organizations to consider how to maintain and improve the operational integrity of the United States' electricity grid while it integrates complex, distributed elements. Workshop participants will consider the research needs, operational standards, regulations, market incentives and other elements necessary to ensure the continuing operational integrity of the U.S. electricity system with increasing DER penetration"

Recently completed Workshop → ***Led to the creation of an ongoing webinar series***

- *Organizer: NASEM Division on Engineering and Physical Scienced Board on Energy and Environmental Systems*
- *Sponsors: DOE, EPRI, Edison Electric Institute*

Electricity System Operability Under Increasing Complexity

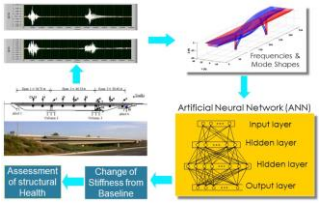
The workshop will include topics such as:

- How the continued rapid expansion of DERs, behind-the-meter technologies, and related distributed elements affect a grid operator's ability to maintain reliable and equitable electricity service
- What capabilities and technologies are required by the grid operators to improve system operations during normal operating conditions and during extreme conditions
- What technologies and capabilities for improved system visibility and operations can be provided by technologies and capabilities provided within the distribution system
- Which synergies and complications may arise from a more-complex and distributed grid which is simultaneously undergoing a process of switching to a greater share of renewable and net-zero energy sources

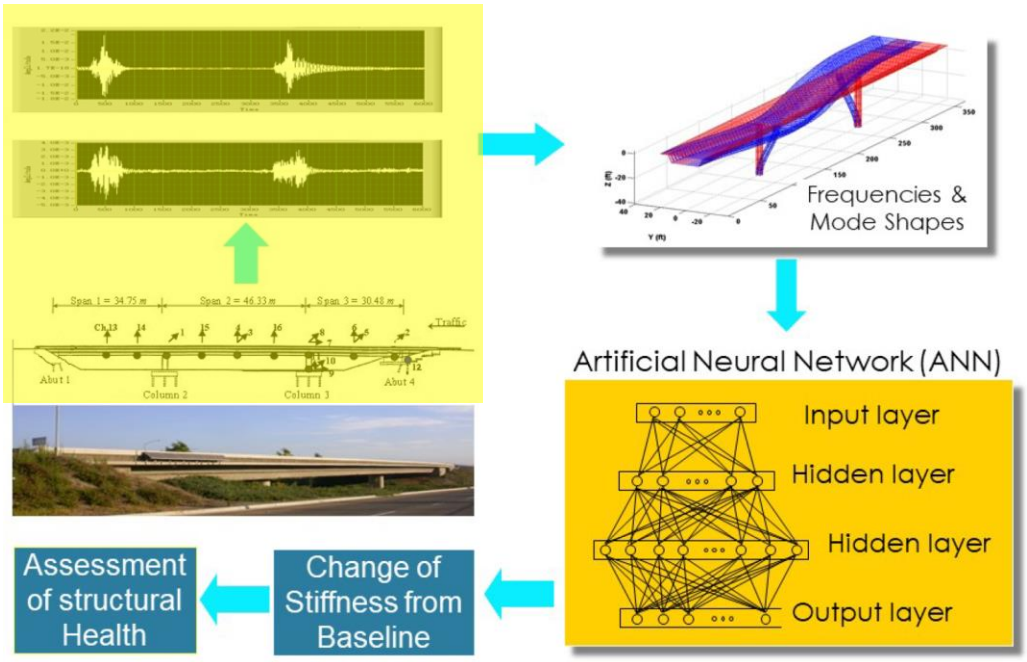
The Role of Advanced Technologies in Structural Engineering for More Resilient Communities

The Resilient America Roundtable (RAR) in partnership with the American Society of Civil Engineers (ASCE), Structural Engineering Institute (SEI), and the Advances in Information Technology Committee—co-hosted a one-day workshop on September 26, 2017. The event brought together experts, practitioners, and researchers from the public, private, and academic sectors …[that] featured moderated panel discussions that addressed questions such as:

- How can infrastructure investments today ensure resilience in communities in the future and across the design life of the infrastructure?
- How can new technologies be integrated into current infrastructure and planning to build resilience?
- How can decision makers build flexibility into their current decisions and initiatives to account for innovation and technological advancements to come?
- How can decision makers, planners, and other stakeholders effectively use emerging technologies and innovations with current and future infrastructure projects and initiatives?



The Role of Advanced Technologies in Structural Engineering for More Resilient Communities

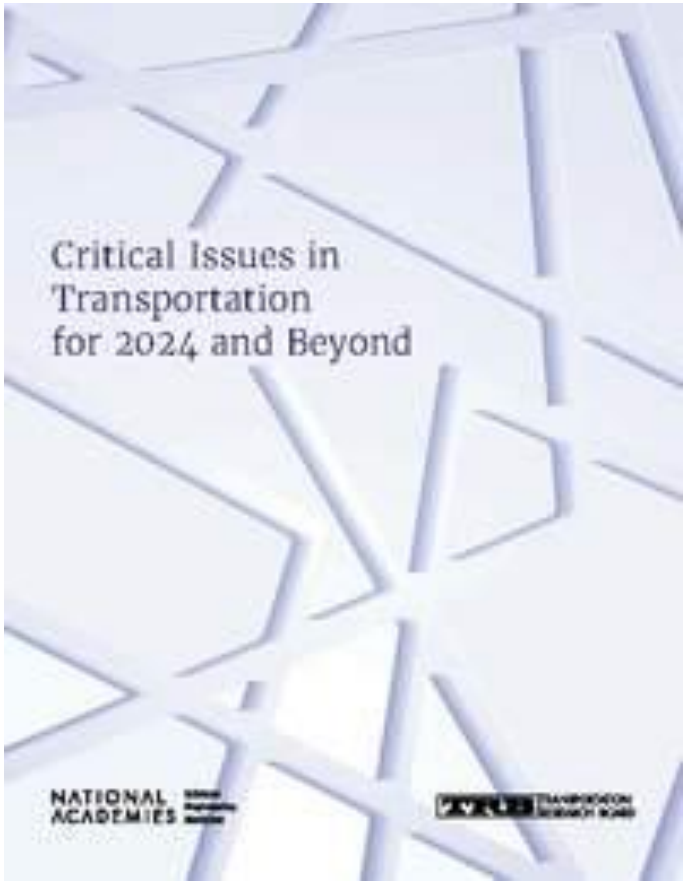


The workshop, The Role of Advanced Technologies in Structural Engineering for MoreResilient Communities… facilitated the exchange of information across the public, private, and academic sectors to explore how technological advancements in structural engineering and construction—including design, analysis, and performance evaluation—could be translated and used to advance resilience objectives, goals, and outcomes in communities as they prepare for future hazard events.

Workshop Proceedings

- *Organizer: NASEM Division on Global Affairs*
- *Sponsors: Federal and NGO entities*

Critical Issues in Transportation for 2024 and Beyond



Critical Issues in Transportation for 2024 and Beyond calls for reassessing the role of transportation in addressing major societal challenges and the research that informs the choices that society will need to make in 2024 and coming years.

Executive Report

- *Organizer: Transportation Research Board Executive Committee*
- *Sponsor: TRB internal funding*

Critical Issues [in Transportation] for 2024 and Beyond

"The condition and performance of the enormous interconnected systems of U.S. …. infrastructure are critical for the safe and efficient movement of people and goods and achievement of transportation-related climate and economic goals, but measures of their condition and performance are incomplete and imperfect. The lack of such information hampers decision making about the required scale of resource allocation and how most cost-effectively to ensure that transportation infrastructure serves a thriving society."

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Building Smart Water Systems

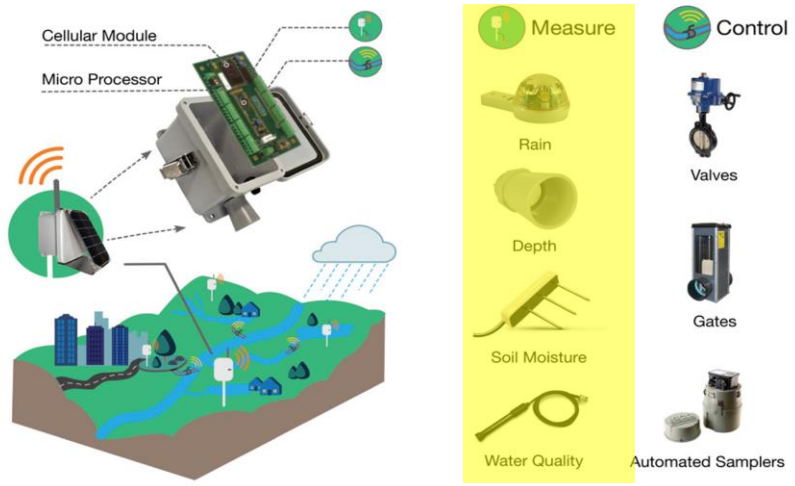
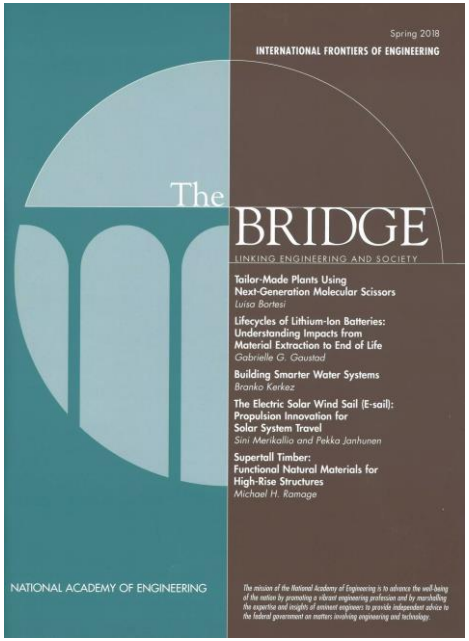


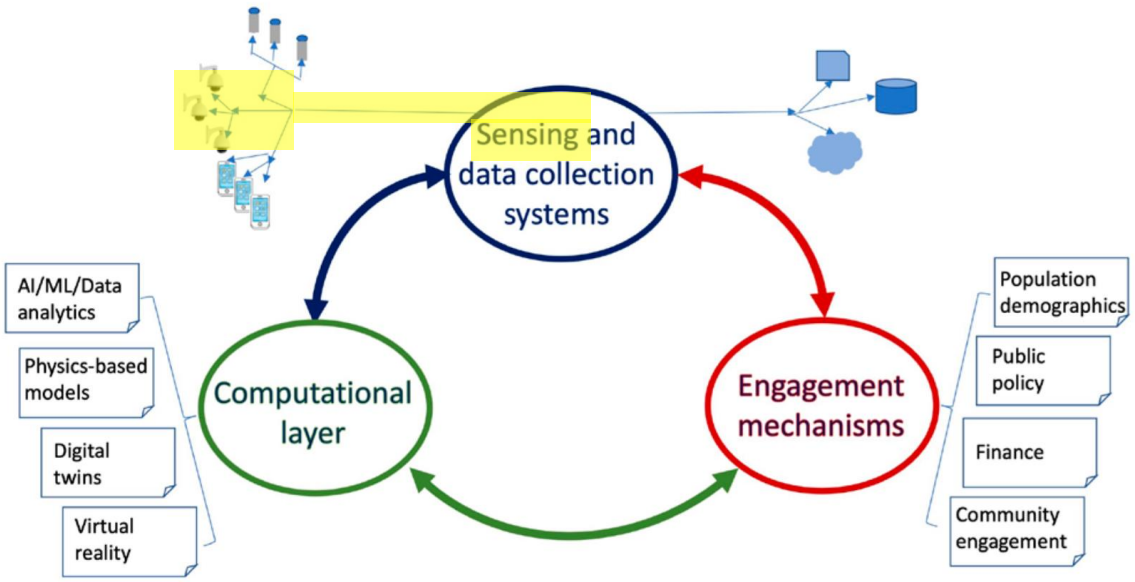
FIGURE 1 Technologies for the sensing and control of watersheds. A full wireless network is composed of many individual sensor nodes (left column) dispersed throughout a watershed, typically at least one per square mile. Each sensor node contains a low-power microprocessor, which collects measurements from a variety of connected sensors. The same unit can be used to control flows using gates, valves, or pumps (right column). A wireless radio, often a cellular module, allows sensor measurements or commands to be transmitted using cloud-hosted services in real time. Reprinted from Bartos et al. (2018) with permission from the Royal Society of Chemistry.



"A burgeoning smart water industry is beginning to fill the needs of modern water utilities and municipalities. The overall technology outlook for water supplies and drinking water systems is promising, notwithstanding much work that must still be done in the development of water quality sensors for important contaminants, such as lead, bacteria, and viruses… Efforts are under way to demonstrate the benefits of real-time sensing, computation, and wireless connectivity for the management of urban watersheds. The driving hypothesis behind this work is that smart stormwater systems will vastly shrink the size of infrastructure required to manage runoff pollution…"

"Building Smarter Water Systems"
-B. Kerkez, *The Bridge,* p. 20, NAE, Spring 2018 ("International Frontiers of Engineering")

Metastructure Approach to Smart and Sustainable Cities



"First proposed as a concept for urban transportation systems (Rogers 2016) the urban metastructure can be parsed into three critical elements of smart cities. The foundational element is a dense sensing and data collection network…"

- A. S. Kiremidjian, M. Lepech, "A Metastructure Approach to Smart and Sustainable Cities," *The Bridge,* p. 7, National Academy of Engineering, Spring 2023 issue ("Sustainable Smart Cities").

What the National Academies Can Do

- "Much of the national political discourse of late has revolved around the topic of infrastructure. As is typically the case for such matters, the political focus has been on the financial aspects of infrastructure investments—how much to spend and where to spend it…
- The question to be addressed is, How can our government identify appropriate priorities for infrastructure investment and ensure that such investments provide the greatest return…?
- This is where the National Academies and, particularly, the National Academy of Engineering can play a very important role. As a trusted advisor to government, we can provide unconflicted and nonpartisan advice on highly technical matters such as these."

D. Winter (NAE Chair), *The Bridge,* National Academies Press, Spring 2023 Issue ("Sustainable Smart Cities").

THANKS!

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