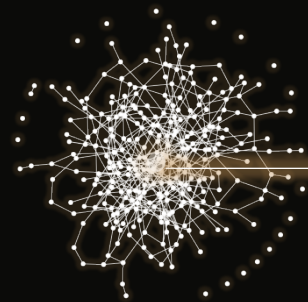


Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



John E. Taylor, PhD; *Frederick L. Olmsted Professor (CEE) & Director (Network Dynamics Lab)*
Debra Lam; *Managing Director (Smart Cities & Inclusive Innovation)*





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019

Georgia
Tech

COLUMBIA
UNIVERSITY

Stanford
University

UIC

8:00am

WELCOME + OPENING REMARKS

- **Tye Hayes**

Chief Technology Officer, City of Atlanta

- **Raheem Beyah**

Vice President for Interdisciplinary Research, & Motorola Foundation Professor of Electrical & Computer Engineering, Georgia Tech

- **Don Webster**

Karen & John Huff Chair, Civil & Environmental Engineering,
Georgia Tech





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



8:30am

INTRODUCTION TO WORKSHOP

- **Debra Lam**

Managing Director, Smart Cities & Inclusive Innovation, Georgia Tech

- **John E. Taylor**

Frederick Law Olmsted Professor, Civil & Environmental Engineering, Georgia Tech





Smart City Digital Twin

Convergence Workshop
September 16-17, 2019



Smart City Digital Twins

Neda Mohammadi & John E. Taylor
School of Civil & Environmental Engineering
Georgia Institute of Technology
Atlanta, GA, USA
{nedam, jet}@gatech.edu

Abstract—Driven by the challenges of rapid urbanization, cities are determined to implement advanced socio-technological changes and transform into *smarter cities*. The success of such transformation, however, greatly relies on a thorough understanding of the city's states of spatiotemporal flux. The ability to understand such fluctuations in context and in terms of interdependencies that exist among various entities across time and space is crucial, if cities are to maintain their smart growth. Here, we introduce a *Smart City Digital Twin* paradigm that can enable increased visibility into cities' human-infrastructure-technology interactions, in which spatiotemporal fluctuations of the city are integrated into an analytics platform at the real-time intersection of reality-virtuality. Through learning and exchange of spatiotemporal information with the city, enabled through virtualization and the connectivity offered by Internet of Things (IoT), this *Digital Twin* of the city becomes smarter over time, able to provide predictive insights into the city's smarter performance and growth.

Keywords—Digital Twins, Interdependence, IoT, Smart Cities, Spatiotemporal Flux.

I. INTRODUCTION

Cities, responsible for much of the world's total resource

expected increase in urban population to nearly 6.3 billion by 2050 [4], combined with the resulting complexities stemming from human activities, are managed to effect positive outcomes in allocating resources, providing security, maximizing services, facilitating human activities, and preventing disruption, while continuously adapting to the changing behaviors of the citizens. Leveraging effective instrumentation, interconnection, and collective intelligence of the city [5], smart cities are expected to improve operational efficiency and quality of life. However, cities, as complex adaptive systems, experience several changes of states in their operations with respect to individuals' activities that are increasing due to the dynamic pressure of population growth. Therefore, successful transformation of cities to smart cities demands advancing city performance through integration of human, infrastructure and technology (Fig. 1). Both spatial and temporal performance equilibria are subject to vulnerabilities that make human-infrastructure-technology systems susceptible to changes of state, or collapses. A better understanding of the underlying drivers of this process will facilitate the identification of the systems' reactive, recovery, and adaptive capacities across time and space.



'Transformative' urban digital twin and city modelling deployments to exceed 500 by 2025, says ABI

ABIresearch
for visionaries



Posted by ANASIA D'ELLO
SEPTEMBER 11, 2019

December 2017

September 2019

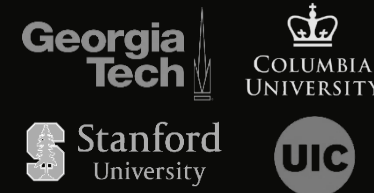




Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



DAY 1 — Monday, September 16

- 7:30am **Registration, Networking + Breakfast**
- 8:00am **Welcome + Opening Remarks**
Raheem Beyah, Vice President for Interdisciplinary Research, Georgia Tech
Tye Hayes, Chief Technology Officer, City of Atlanta
Don Webster, Karen and John Huff Chair, Civil & Environmental Engineering, Georgia Tech
- 8:30am **Introduction to Workshop Purpose and Goals**
Debra Lam, Managing Director, Smart Cities & Inclusive Innovation, Georgia Tech
John Taylor, Frederick Law Olmsted Professor, Civil & Environmental Engineering, Georgia Tech

PART 1: CURRENT SMART CITY DIGITAL TWIN EFFORTS

- 8:45am **First Panel – Mobility Infrastructure System Digital Twins**
Sybil Derrile, Associate Professor, University of Illinois, Chicago
David Emory, Director, Technology Strategy and Innovation, MARTA
Lillie Madali, Smart City Program Director, City of Atlanta
Jane McFarlane, Director of Smart Cities Research Center, University of California, Berkeley
- 9:45am **Second Panel – Water Infrastructure System Digital Twins**
Stephen Bourne, Director & Research and Development Chair, Atkins
Patricia Culligan, Robert A. W. and Christine S. Carleton Professor of Civil Engineering; Chair, Department of Civil Engineering and Engineering Mechanics, Columbia University
Mike Diaz, AVPI Area Manager, Arcadis
Jonathan Levy, Open Data Program Manager, City of Chicago
Grace Simrall, Chief of Civic Innovation, Louisville Metro Government
- 10:45am **Networking Break**
- 11:00am **Third Panel – Energy Infrastructure System Digital Twins**
Sam Edelstein, Chief Data Officer, City of Syracuse
Rishee Jain, Assistant Professor, Civil & Environmental Engineering, Stanford University
Laura Meixell, Enterprise Data Architect, Allegheny County Department of Human Services
Jack Montgomery, Digital Innovation & Thought Leadership, Siemens Management Consulting
Josh Sperling, Urban Futures & the Energy-X Nexus Fellow, National Renewable Energy Laboratory (NREL)

- 12:00pm **Working Lunch – Smart City Digital Twin Technology/System Showcase**
Burcin Becerik-Gerber, Professor of Civil and Environmental Engineering, University of Southern California
Michael Hunter, Professor, Civil & Environmental Engineering, Georgia Tech
Madhav Marathe, Division Director and Professor, Biocomplexity Institute, University of Virginia
Neda Mohammadi, City Infrastructure Analytics Director, Network Dynamics Lab, Georgia Tech
Kouros Mohammadian, Professor & Dept. Head, Civil & Materials Engineering, University of Illinois, Chicago
Mina Sartipi, UC Foundation Professor, Computer Science and Engineering, University of Tennessee-Chattanooga
Keith Swearingen, Office of Chief Information Officer, NASA

PART 2: TOWARD A SMART CITY DIGITAL TWIN FRAMEWORK

- 2:00pm **Kick Off Smart City Digital Twin Framework Discussion Breakouts**
- 2:30pm **Breakout Groups Discuss Elements of Framework**
- 4:00pm **Breakout Groups Report**
- 4:30pm **End of Day Summary, Discussion + Next Steps**
- 5:00pm **Reception & Group Photo (14th Floor Atrium)**
Merry Hunter Caudle, Program Manager – Economic Development, Georgia Tech

DAY 2 — Tuesday, September 17

- 7:30am **Registration, Networking + Breakfast**
- 8:00am **Discuss Smart City Digital Twin Framework Developed in Day 1 + Plan for Day 2**

PART 3: FUTURE OF SMART CITY DIGITAL TWINNING

- 8:30am **Kick Off Smart City Digital Twin Forward Looking Breakout Exercise**
- 9:00am **Breakout Groups Use Framework to Envision Future of Smart City Digital Twins**
- 11:00am **Breakout Groups Report**
- 11:30am **Closing Discussion + Next Steps**
- 12:30pm **Adjourn/Lunch**





Smart City Digital Twin

Convergence Workshop
September 16-17, 2019



What is a Smart City Digital Twin?

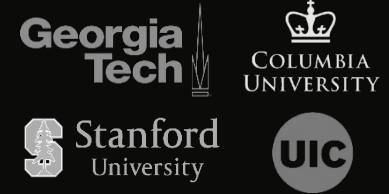


"A *Digital Twin* is a...pairing of virtual and physical worlds [that] allows analysis of data and monitoring of systems to head off problems before they occur, prevent downtime, develop new opportunities, and even plan for the future using simulations." [Forbes, 2017]

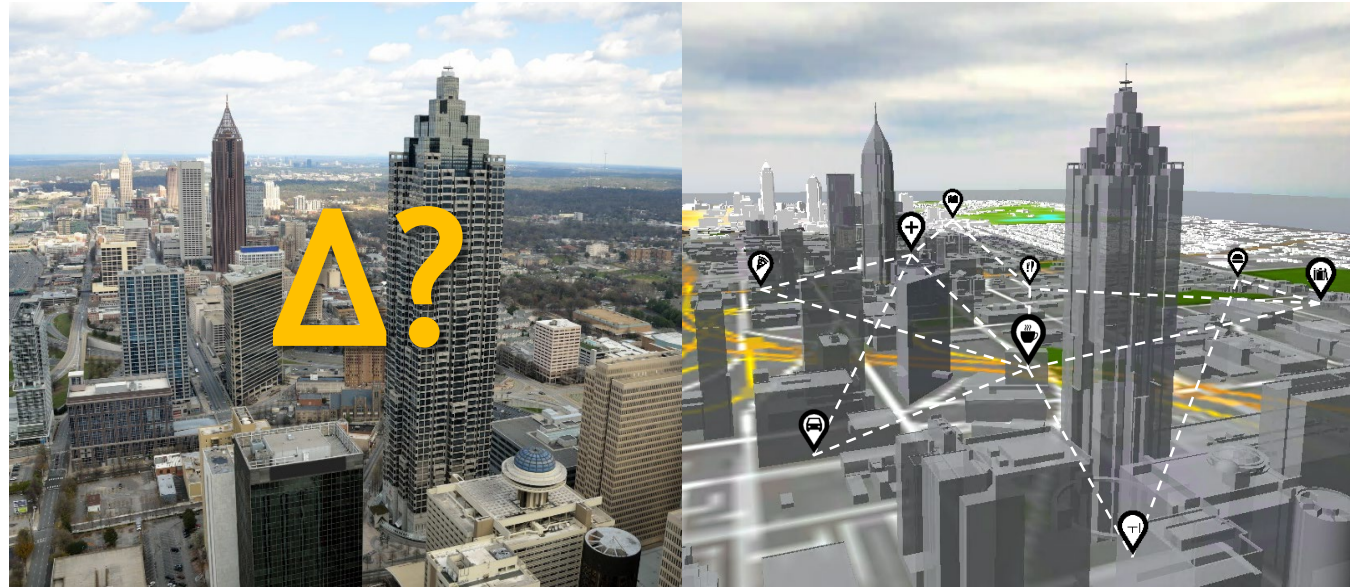
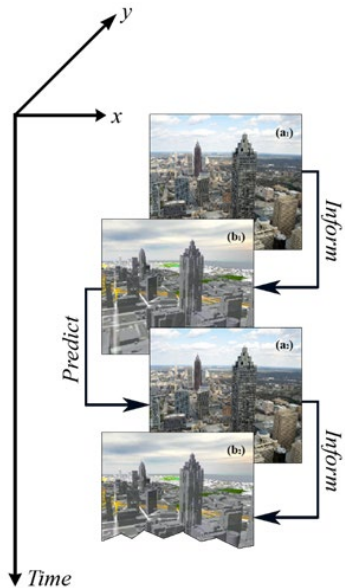


Smart City Digital Twin

Convergence Workshop
September 16-17, 2019



What is a Smart City Digital Twin?



A *Smart City Digital Twin* is a smart, IoT-enabled, data-rich virtual platform of a city that can be used to replicate and simulate changes happening in the real city to improve resilience, sustainability, and livability. [Mohammadi & Taylor, 2017]



Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



‘Identify areas of research where investment in **convergent** approaches...**united to solve problems** – have the potential to translate to high-benefit results and advance ideas from concept to deliverables’

‘To **enable capabilities far beyond what is currently possible** in either the private or public sectors’

‘Bringing together researchers with many different specialties, and partners from across the spectrum of scientific innovation and application -- will **create environments where innovation can thrive**’





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019

Georgia
Tech

COLUMBIA
UNIVERSITY

Stanford
University

UIC



8 Government

17
Universities

15+
disciplines

3 National Labs

6 Industry





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



Smart City Digital Twin Convergence Workshop Purpose/Goals

- Share *state-of-the-art knowledge* on on-going single infrastructure system digital twinning across community of scholars, practitioners and government officials.
- Discuss/develop *framework* for understanding and comparing Smart City Digital Twin evolution across cities.
- Discuss and develop a *road map* of an envisioned future for Smart City Digital Twinning efforts.





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



Smart City Digital Twin Convergence Workshop Format to Achieve Goals

- Share *state-of-the-art knowledge* on on-going single infrastructure system digital twinning across community of scholars, practitioners and government officials. → *3 Panel + 1 Technology/Systems Showcase*
- Discuss/develop *framework* for understanding and comparing Smart City Digital Twin evolution across cities. → *Breakouts Afternoon Day 1*
- Discuss and develop a *road map* of an envisioned future for Smart City Digital Twinning efforts. → *Breakouts Morning Day 2*





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



Smart City Digital Twin Convergence Workshop Communications

- *Social Media*
- *Filming Interviews for Short "Smart City Digital Twin" Video*
- *Note-takers*
- *Media*
- *Summary Article*





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



Smart City Digital Twin Convergence Workshop Code of Conduct

- *Did everyone receive it electronically? Please review it.*
 - *We are committed to having a safe/productive meeting that fosters open dialogue and exchange of ideas, promotes equal opportunity and treatment for all participants, and is free of harassment or discrimination.*
 - *This workshop is a forum to consider and debate science-relevant viewpoints in an orderly, respectful, and fair manner.*
 - *Any form of harassment, sexual or otherwise, is prohibited at this workshop. Harassment should be reported immediately to the Workshop Chairs:*

Chair: John E. Taylor; jet@gatech.edu; (540) 808-6063

Co-Chair: Debra Lam; debra.lam@gatech.edu; (530) 750-9881

Harassment can also be reported directly to NSF at programcomplaints@nsf.gov.





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



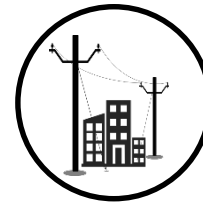
Smart City Digital Twin Convergence Workshop Panels



Sybil Derrible UIC
David Emory MARTA
Lillie Madali Atlanta
Jane Mcfarlane UCB+LBNL



Stephen Bourne Atkins
Patricia Culligan CU
Mike Diaz Arcadis
Jonathan Levy Chicago
Grace Simrall Louisville



Sam Edelstein Syracuse
Rishee Jain Stanford
Laura Meixell Alleghany
Jack Montgomery Siemens
Josh Sperling NREL

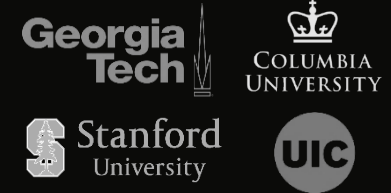




Smart City Digital Twin

Convergence Workshop

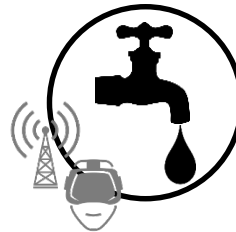
September 16-17, 2019



Smart City Digital Twin Convergence Workshop Panels + Technology Showcase



Sybil Derrible UIC
David Emory MARTA
Lillie Madali Atlanta
Jane Mcfarlane UCB+LBNL



Stephen Bourne Atkins
Patricia Culligan CU
Mike Diaz Arcadis
Jonathan Levy Chicago
Grace Simrall Louisville



Sam Edelstein Syracuse
Rishee Jain Stanford
Laura Meixell Alleghany
Jack Montgomery Siemens
Josh Sperling NREL

Burcin Becerik-Gerber USC
Michael Hunter GT
Madhav Marathe UVA
Neda Mohammadi GT

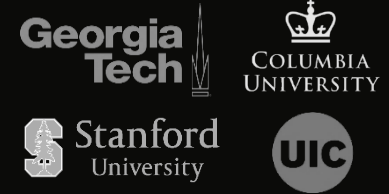
Kouros Mohammadian UIC
Mina Sartipi UT-C
Keith Swearingen NASA





Smart City Digital Twin

Convergence Workshop
September 16-17, 2019



MOBILITY INFRASTRUCTURE SYSTEMS PANEL



Sybil Derrible UIC
David Emory MARTA
Lillie Madali Atlanta
Jane Mcfarlane UCB+LBNL



Stephen Bourne UIC
Patricia Colligan UIC
Mike Shaw UIC
Jonathan Levy Chicago
Grace Stewart UIC



Sam Kishikida UIC
William Jahn UIC
Laura McLeod UIC
Jack Sperling UIC

Barbara Brown UIC
Michael Hunter UIC
Matthew Marshall UIC
Paula Mohammed UIC

Samuel Mohammed UIC
Mike Santiago UIC
Keith Sorenson UIC





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



WATER INFRASTRUCTURE SYSTEMS PANEL



Scott Burdick UIC
David Emery UIC
Little Martin UIC
John McFarlane UIC



Stephen Bourne Atkins
Patricia Culligan CU
Mike Diaz Arcadis
Jonathan Levy Chicago
Grace Simrall Louisville



Scott Burdick UIC
David Emery UIC
Little Martin UIC
John McFarlane UIC

Scott Burdick UIC
David Emery UIC
Little Martin UIC
John McFarlane UIC

Scott Burdick UIC
David Emery UIC
Little Martin UIC
John McFarlane UIC

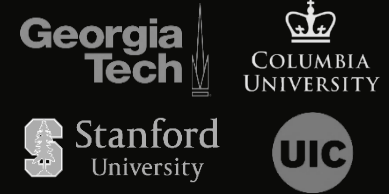




Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



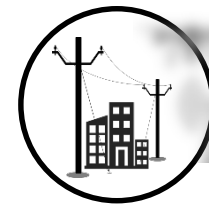
ENERGY INFRASTRUCTURE SYSTEMS PANEL



Spill Swartz MIT
David Emery MIT
Ulla Meixell Allegheny
Jack Montgomery Siemens



Stephen Brown MIT
Patrick Colligan UIC
Mike Shaw MIT
Jonathan Levy Chicago
Grace Stewart Columbia



Sam Edelstein Syracuse
Rishee Jain Stanford
Laura Meixell Allegheny
Jack Montgomery Siemens
Josh Sperling NREL

David Swartz MIT
Michael Swartz UIC
Matthew Swartz UIC
David Swartz UIC

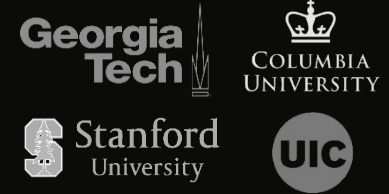
David Swartz MIT
Mike Swartz UIC
David Swartz UIC





Smart City Digital Twin

Convergence Workshop
September 16-17, 2019



Smart City Digital Twin Technology Showcase



Ngill Shrestha USC
David Emery USC
Ulla Madh USC
Joe McFarlane USC



Stephen Brown USC
Patrick Colligan USC
Mike Chen USC
Jonathan Levy USC
Chris Smith USC



Sam Kishore USC
William Jahn USC
Leona Minkoff USC
Jack Spurling USC

Burcin Becerik-Gerber USC
Michael Hunter GT
Madhav Marathe UVA
Neda Mohammadi GT

Kouros Mohammadian UIC
Mina Sartipi UT-C
Keith Swearingen NASA

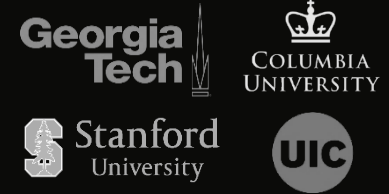




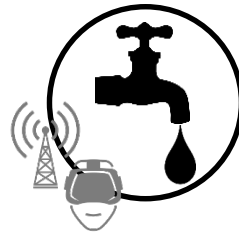
Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



Smart City Digital Twin Convergence Workshop Preparing for Breakouts





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019

Georgia
Tech

COLUMBIA
UNIVERSITY

Stanford
University

UIC

Smart City Digital Twin Convergence Workshop Preparing for Breakouts





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



Smart City Digital Twin Convergence Workshop Preparing for Breakouts



Distribution of Efficiencies
Interoperability of Technology/Systems

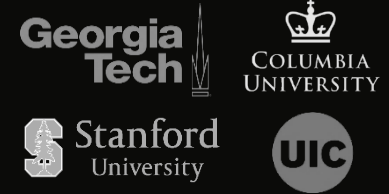




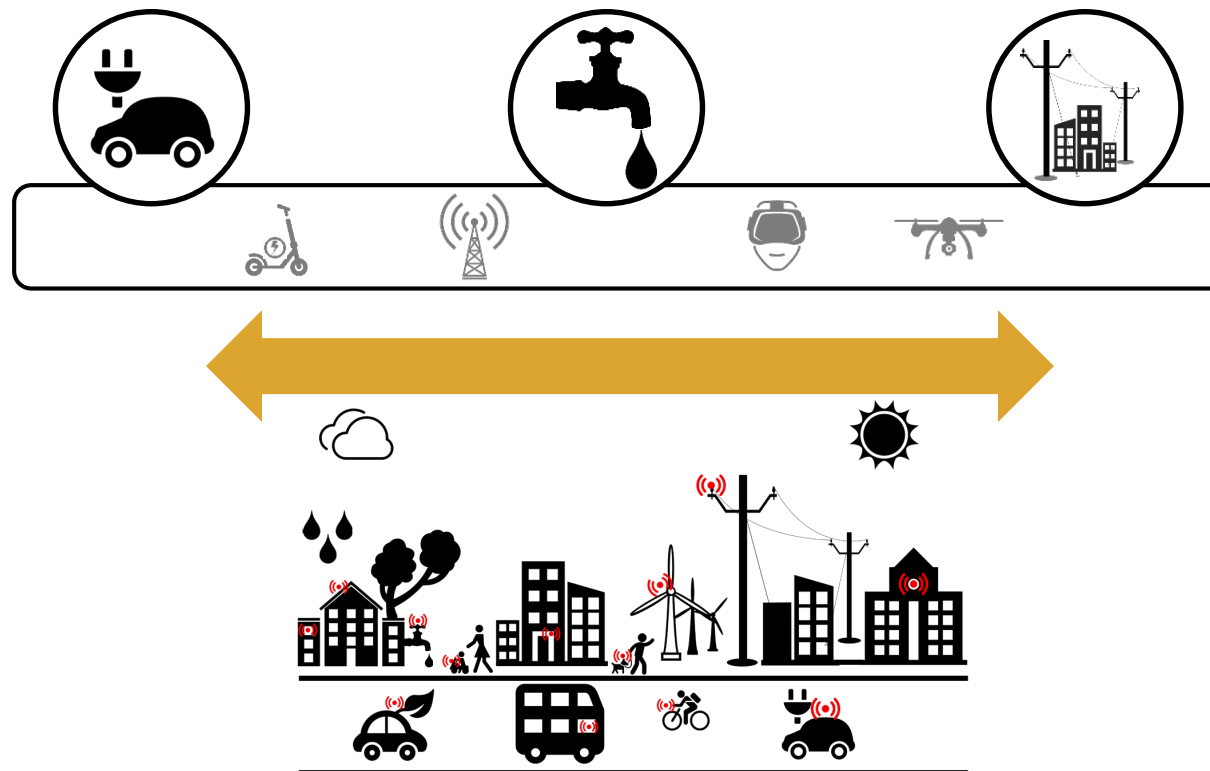
Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



Smart City Digital Twin Convergence Workshop Preparing for Breakouts





Smart City Digital Twin

Convergence Workshop

September 16-17, 2019



Smart City Digital Twin Convergence Workshop Preparing for Breakouts

Join the Mobility, Water, or Energy Panel for a breakout discussion...

- [DISTRIBUTION OF EFFICIENCIES]
 - *Based on the state-of-the-art knowledge discussed, and your own expertise, how could the infrastructure system digital twin focus in your breakout discussion benefit from or be extended by what you learned today or based on your expertise?*
 - *What new enabling technologies/features/functionalities or opportunities can you identify?*
 - *What are the barriers to or risks associated with each?*
- [INTEROPERABILITY OF TECHNOLOGY/SYSTEMS]
 - *How do Smart City Digital Twin technologies and systems need be adapted to integrate and/or function across multiple interdependent infrastructure systems?*
 - *What barriers, risks or other considerations are associated with each adaptation?*

