Current and Future Innovative Technologies for Community Resiliency: A Michigan Perspective

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COLLEGE OF ENGINEERING
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Massive Earthquakes

Devastating impact on communities resulting in slow recovery times

Source: Getty Images

Tropical Storms and Floods

Greatest number of human fatalities are attributed to floods

Source: Associated Press

Climate Change and Water Scarcity

Stressing communities in terms of drinking water and agriculture

Source: Huffington Post

Population Growth and Rapid Urbanization

Another stressor due to growing demand and societal complexity

Source: Huffington Post

Aging Infrastructure in United States

Aging infrastructure leaves communities vulnerable

Source: KQED

Communities Exposed to Economic Stressors

Economic well-being is another resiliency issue

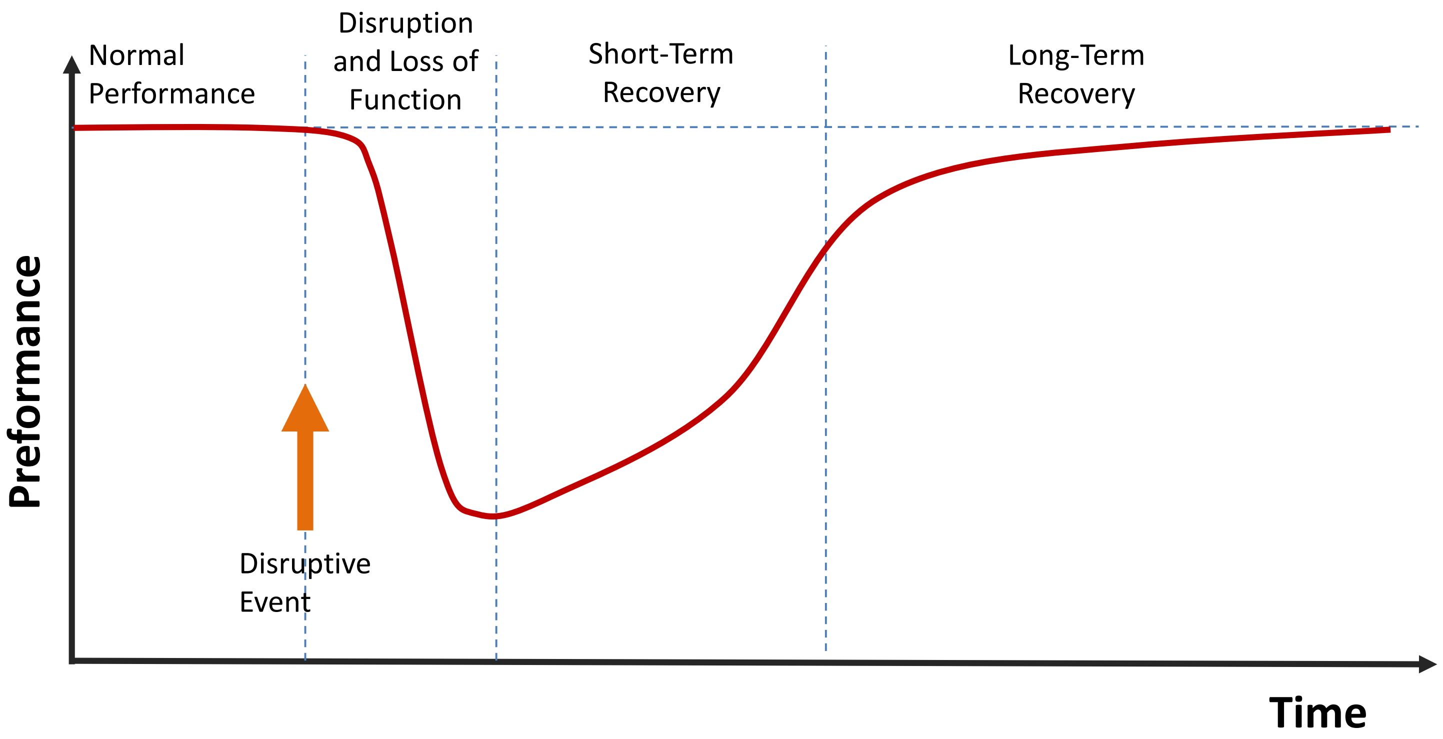
Source: You Tube

resiliency

noun | re·sil·ien·cy | \-yən(t)-sē\

1. the capacity to recover quickly from difficulties; toughness;
2. the ability of a substance or object to spring back into shape.

Source: Merriam Webster

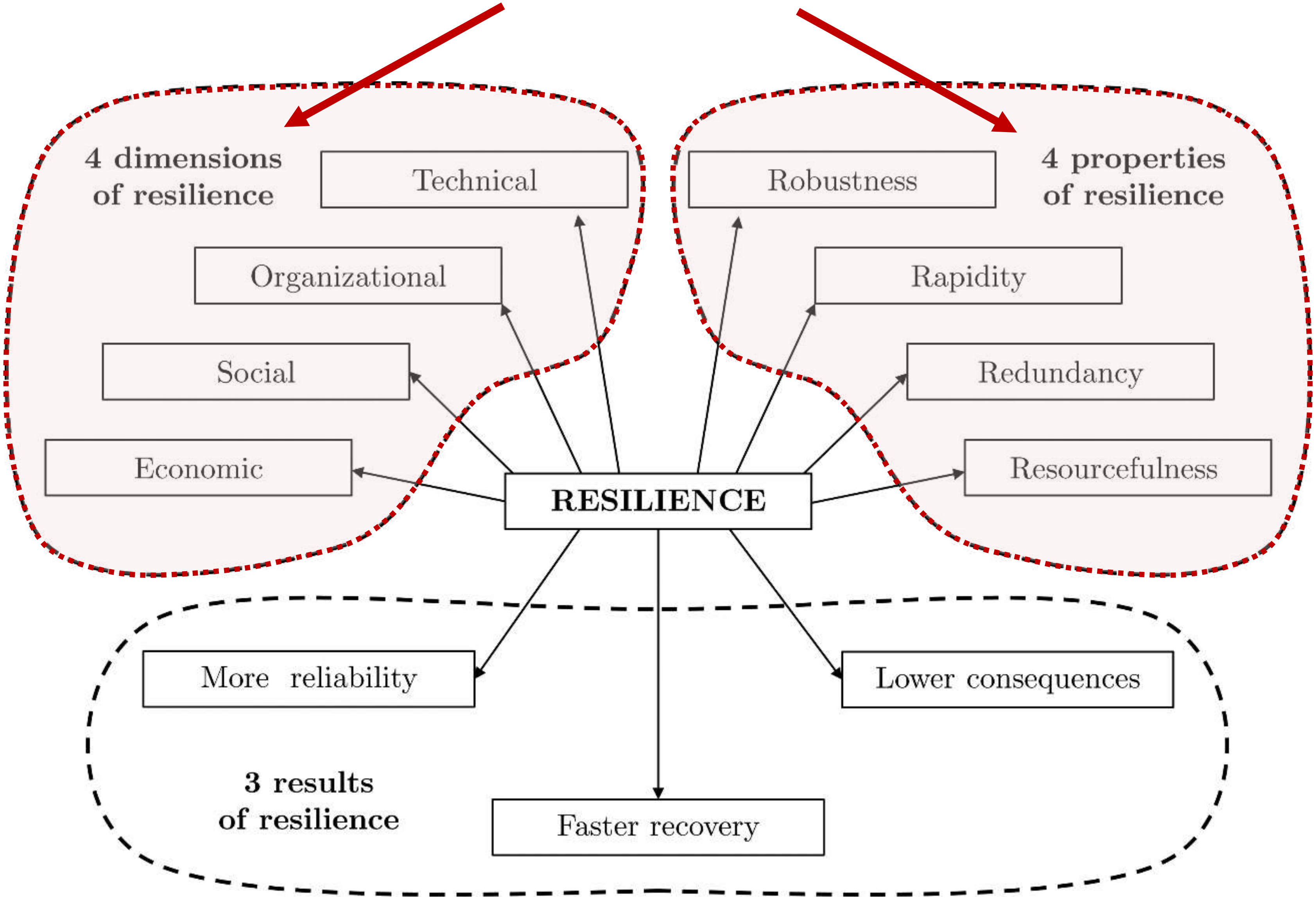


Normal
Performance
Disruption
and Loss of
Function
Short-Term
Recovery
Long-Term
Recovery
Preformance
Disruptive
Event
Time

RESILIENCE

Source: M. Ettouney

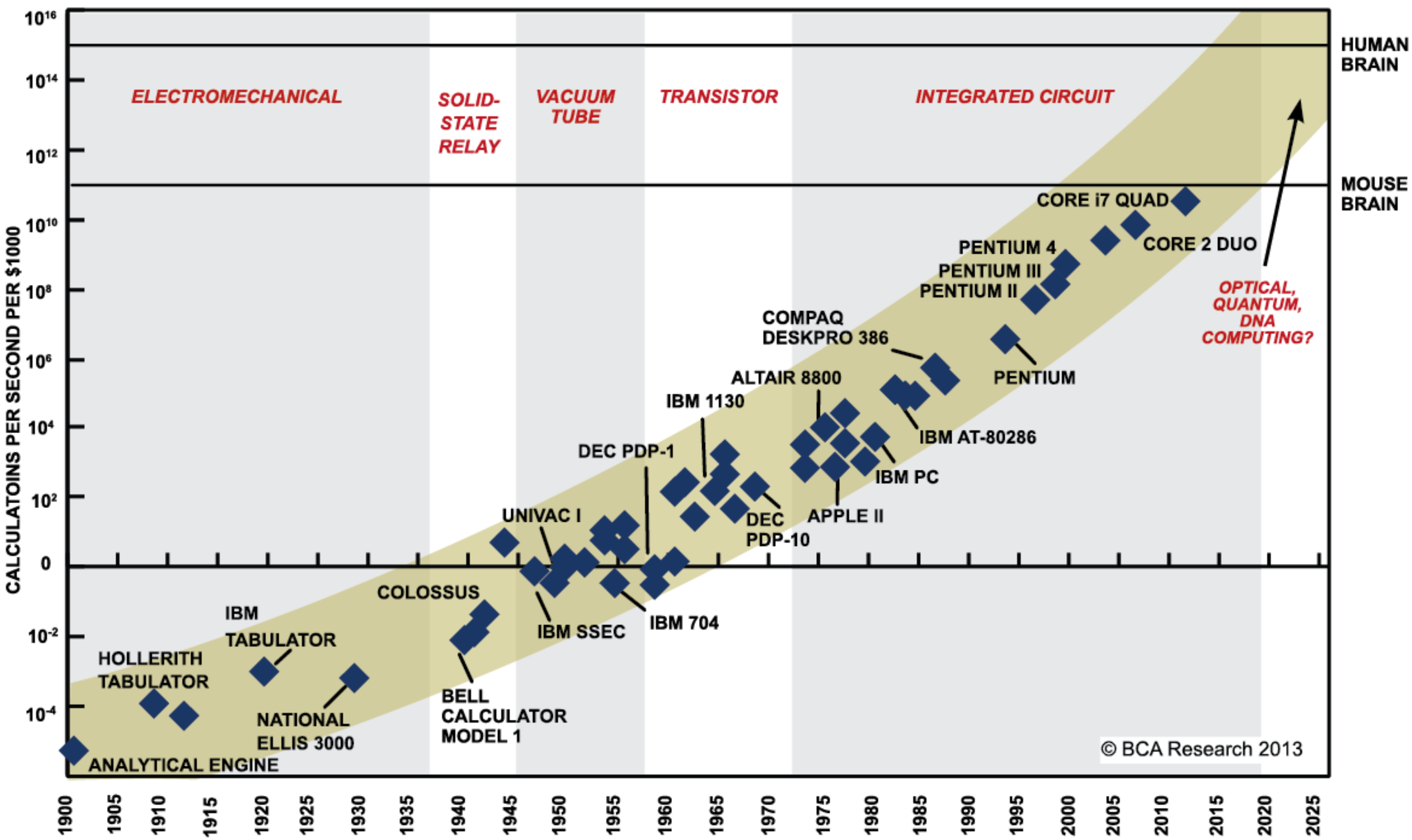
Opportunity Space for Innovative Technologies



Source: M. Ettouney

Explosion in Computing Power Since 1960's

Moore's Law Held True up to Recent Years

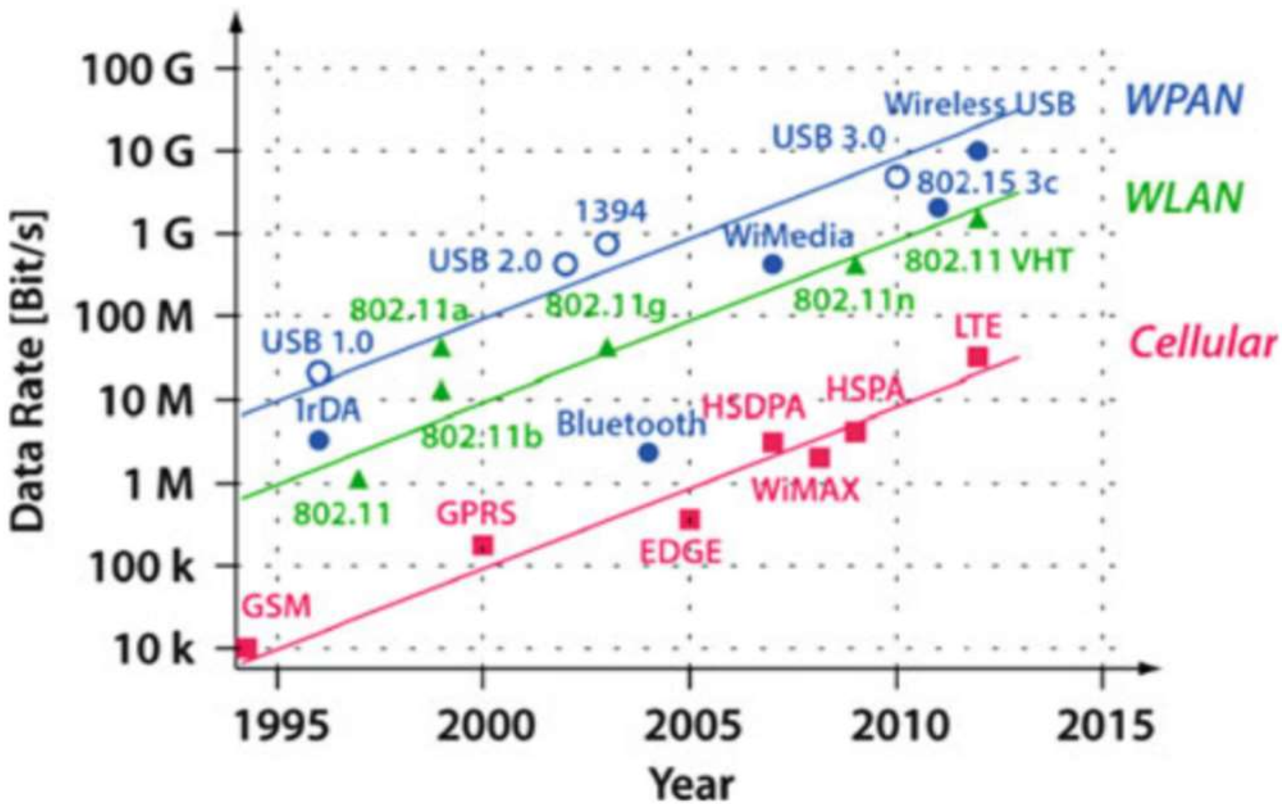


SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

Source: Kurzweil et al. 2013

Explosion in Wireless Communications

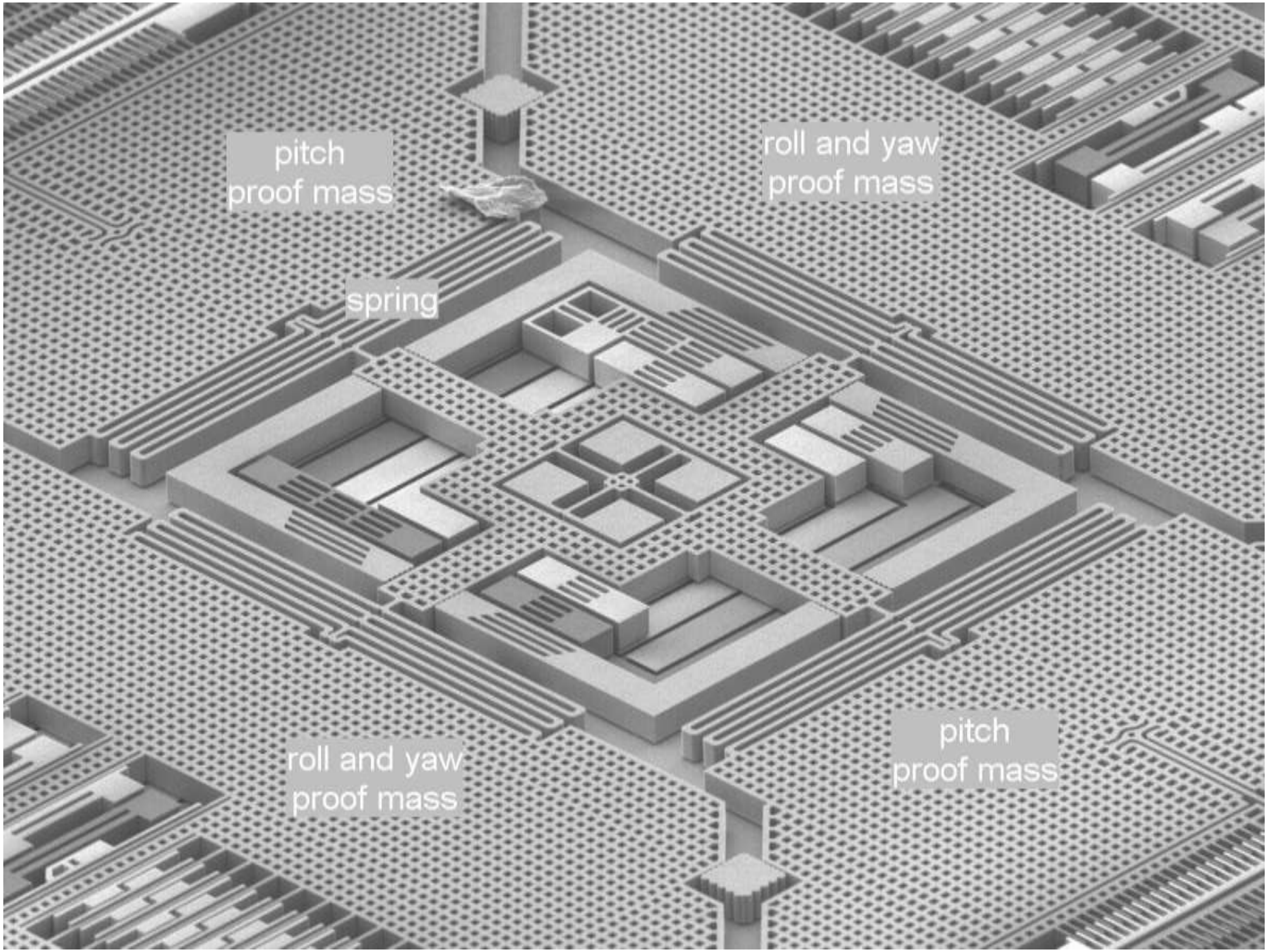
Edholm's Law is Still Going



Source: Chema et al. 2010

Microelectromechanical System (MEMS)

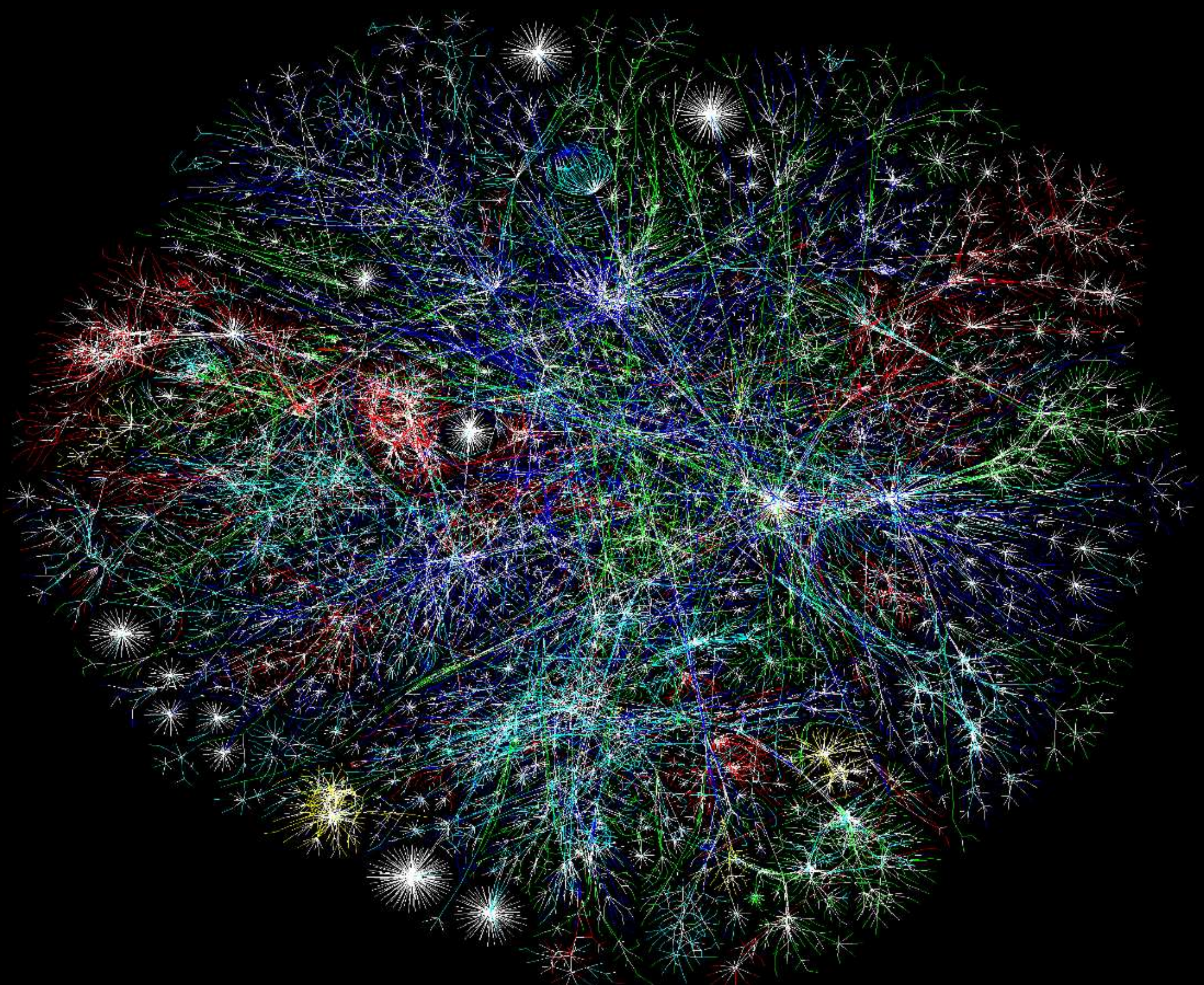
Explosion in Low-Cost Solid State Sensors Making Sensing Accessible



Source: ST Micro

The Internet

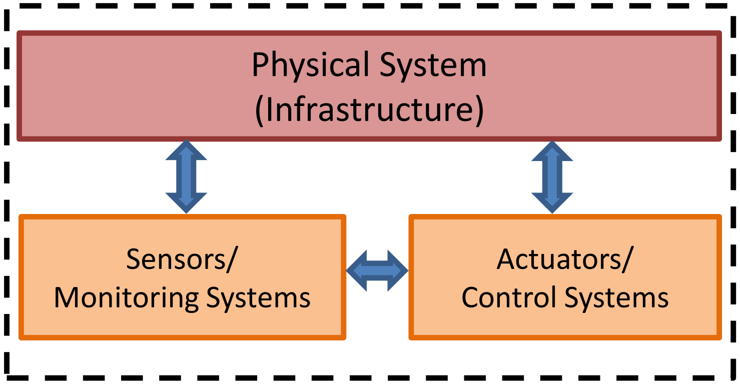
Greatest Technical Achievement of the 20th Century



Source: Neodystopia

Future Technologies: Cyber-Physical Systems

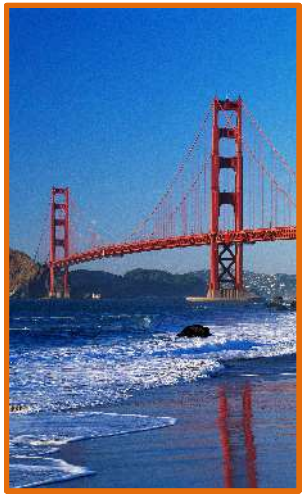
Confluence of Computing, Communication, Sensing and Internet



Physical principles define system dynamics

PDE-based

Monitoring data analysis and feedback control methods

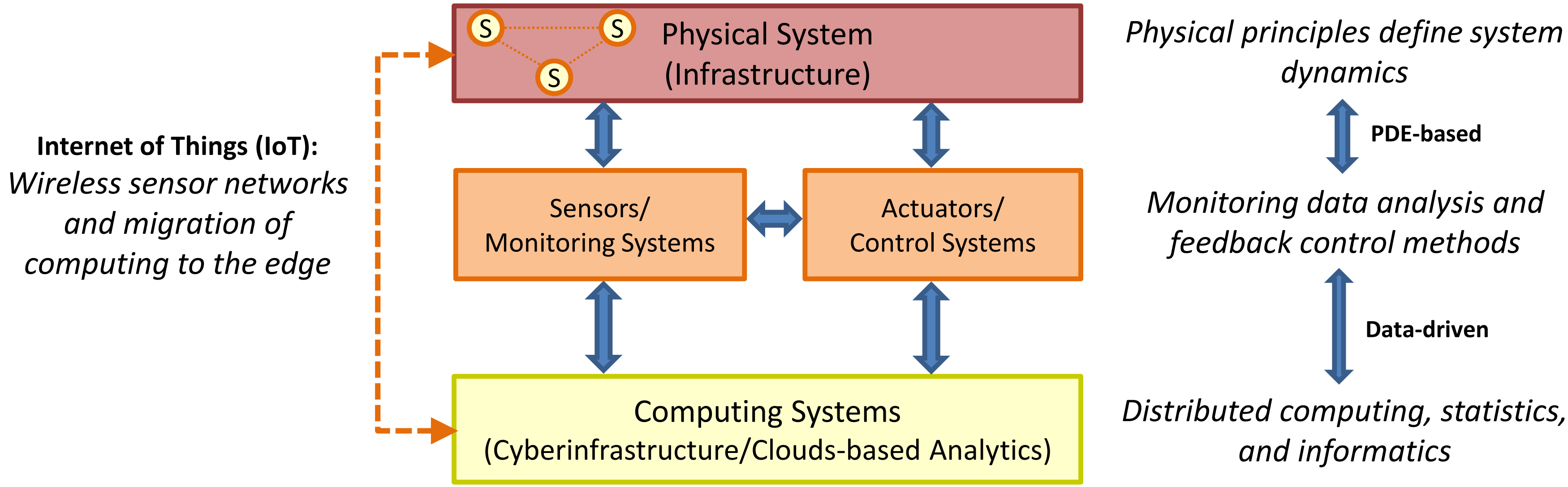


Golden Gate Bridge, CA
(100 Sensors)

Moori Tower, Tokyo
(350 Actuators)

Future Technologies: Cyber-Physical Systems

Confluence of Computing, Communication, Sensing and Internet



Early Earthquake Warning Systems
(Source: NIPPONIA)

Intelligent Transportation Systems
(Source: USDOT)

Offshore Wind Farms
(Source: The Telegraph)

I275 Corridor Cyber-Physical System

Objectives:

- Monitor trucks in a highway corridor to assess economic utilization
- Assess bridge and pavement health
- Control truck loads to minimize impact on infrastructure

Tools:

- Wireless Sensing for Affordable Sensing
- Cameras and Computer Vision for Truck Assessment
- Weigh-in-Motion System Weight Measurements

Cloud-based Data Analytics:

- Automated truck identification
- Automated triggering to capture movement of load
- Implement control algorithms to control trucks

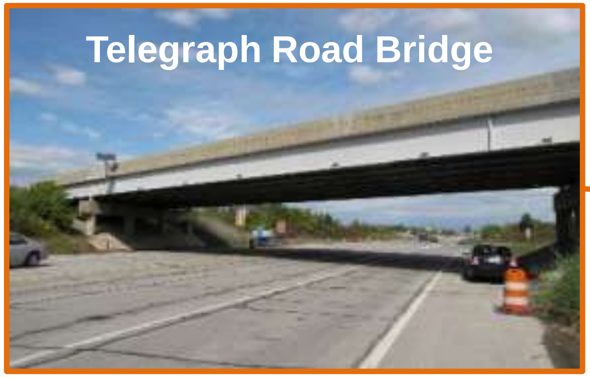

Lynch

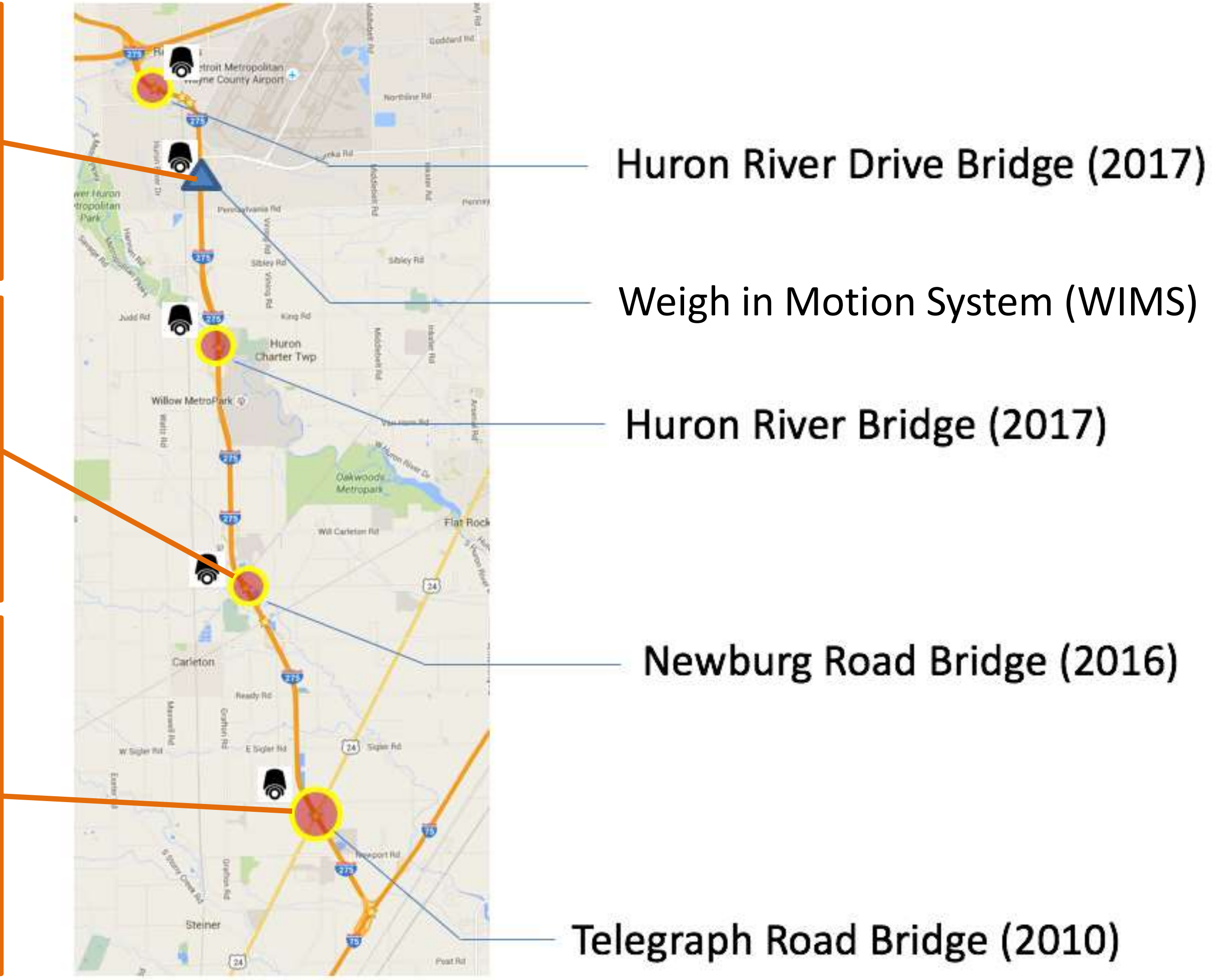

Law


Ettouney

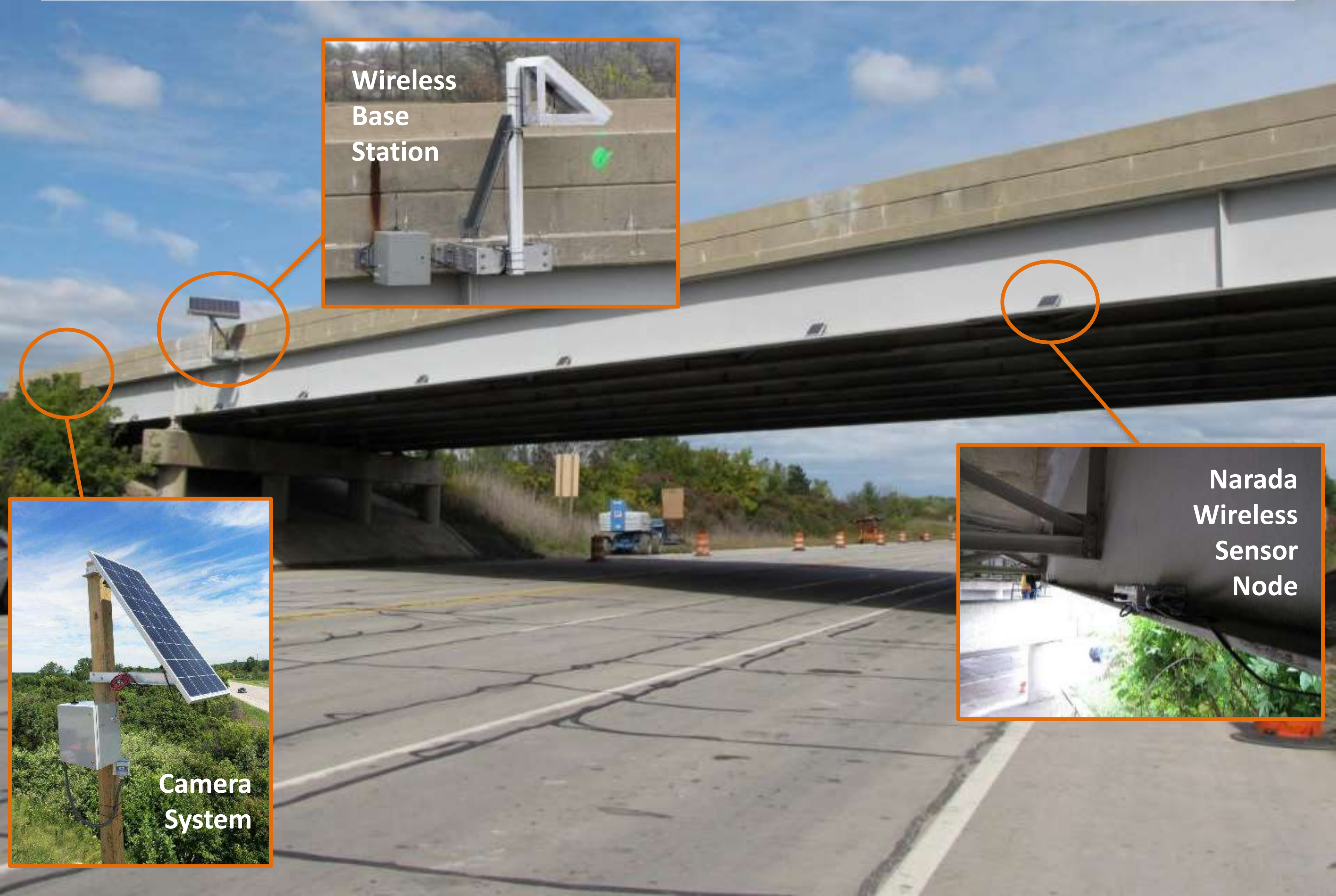

Orosz

I275 Corridor Cyber-Physical System

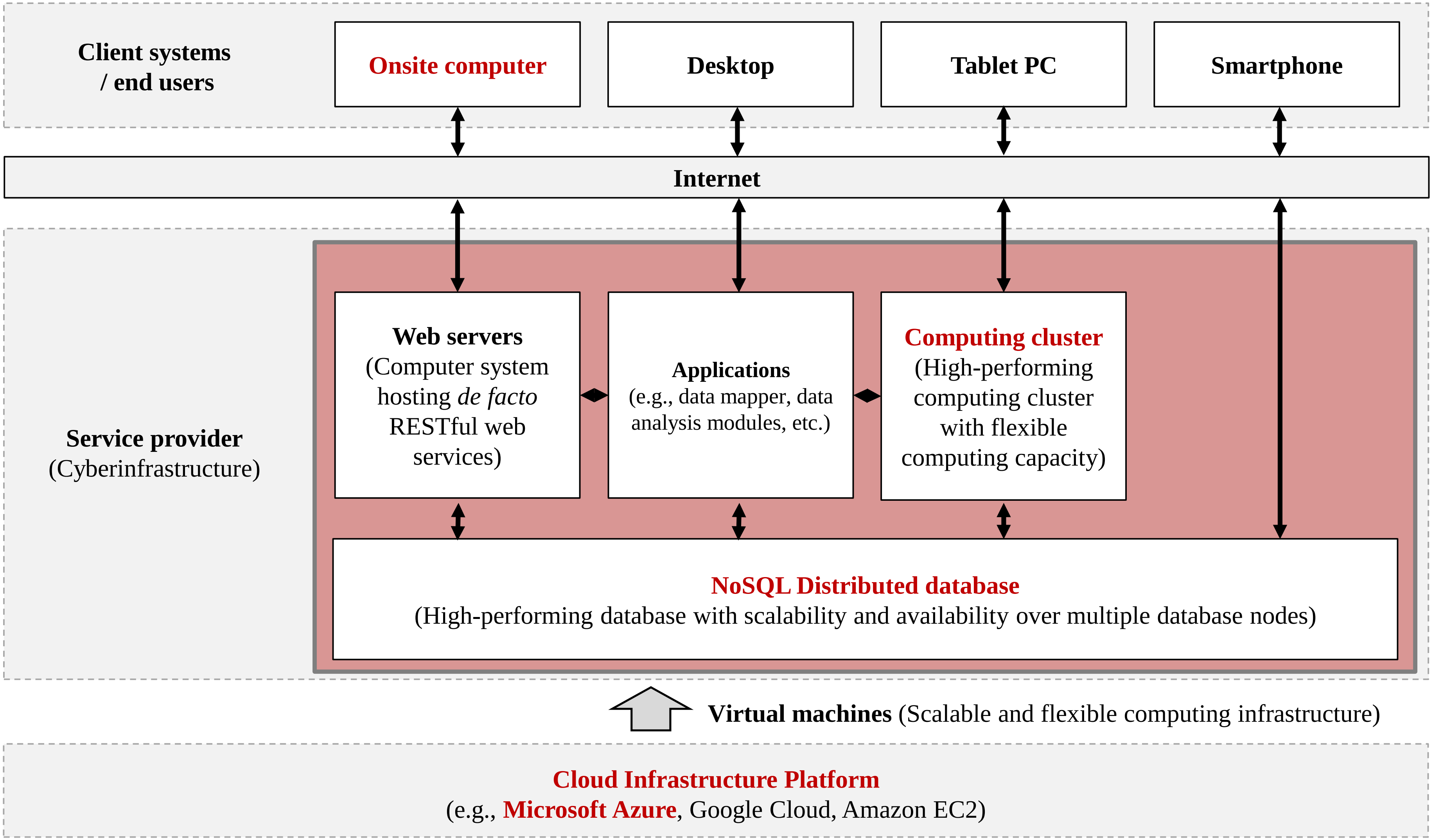




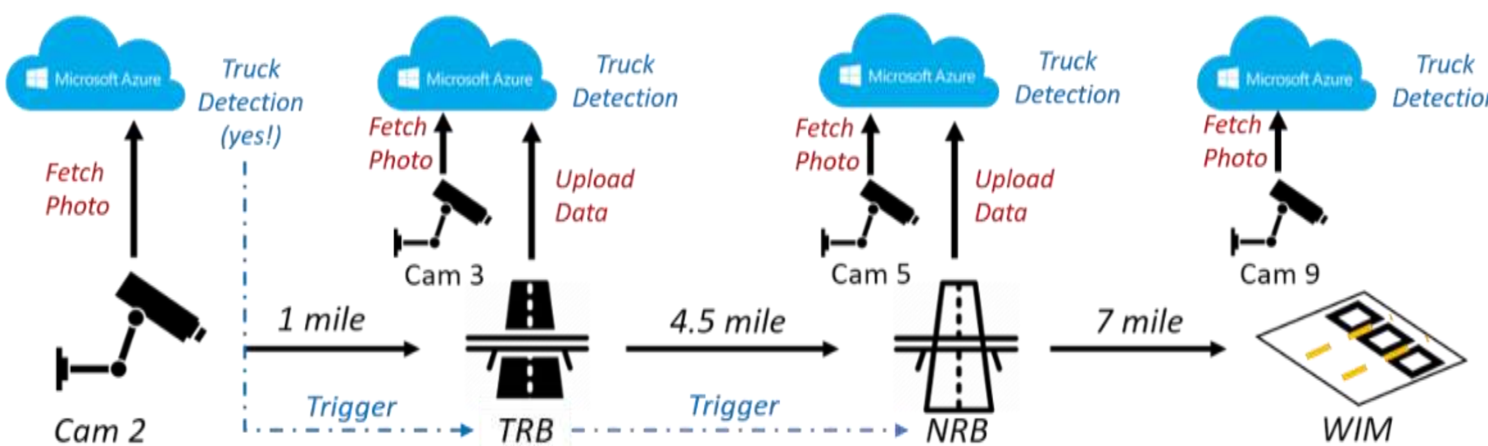
I275 Corridor Cyber-Physical System



I275 Corridor Cyber-Physical System



I275 Corridor Cyber-Physical System



I275 Corridor Cyber-Physical System

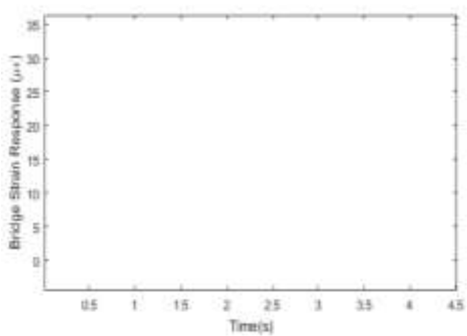
Truck Identified Entering I275N

Truck Captured on TRB

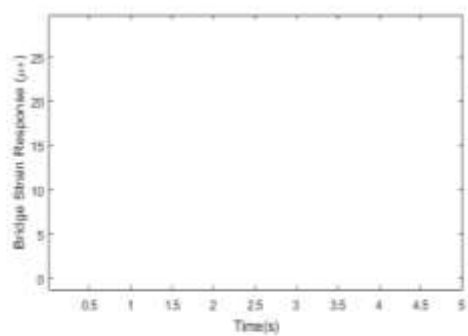
Truck Captured on NRB

Truck Captured at WIMS

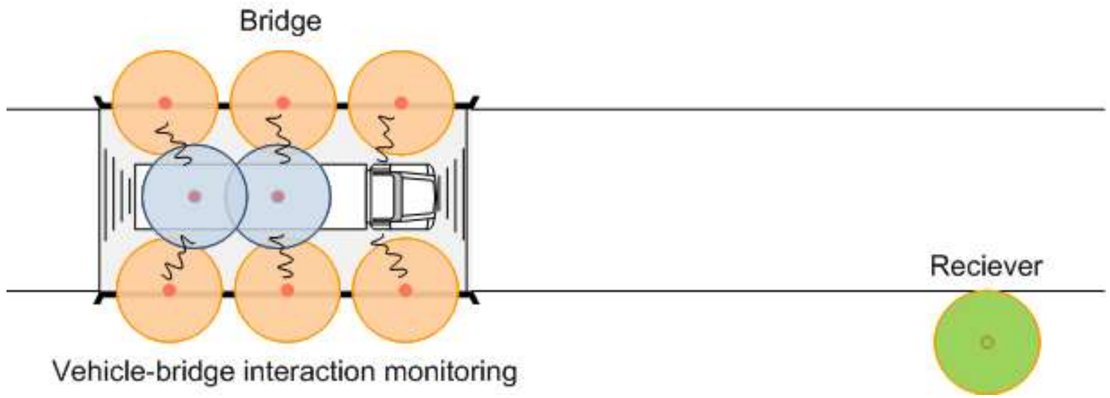
TRB Mid-span Strain



NRB Mid-span Strain



I275 Corridor Cyber-Physical System



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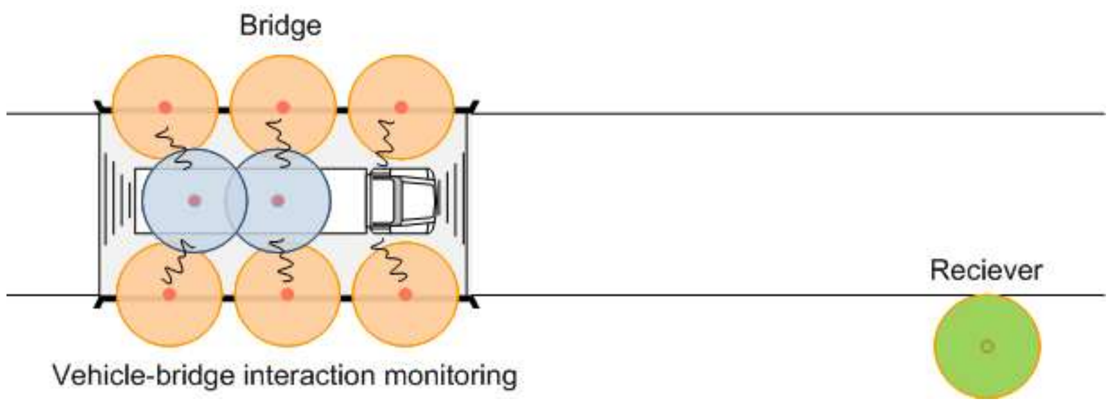

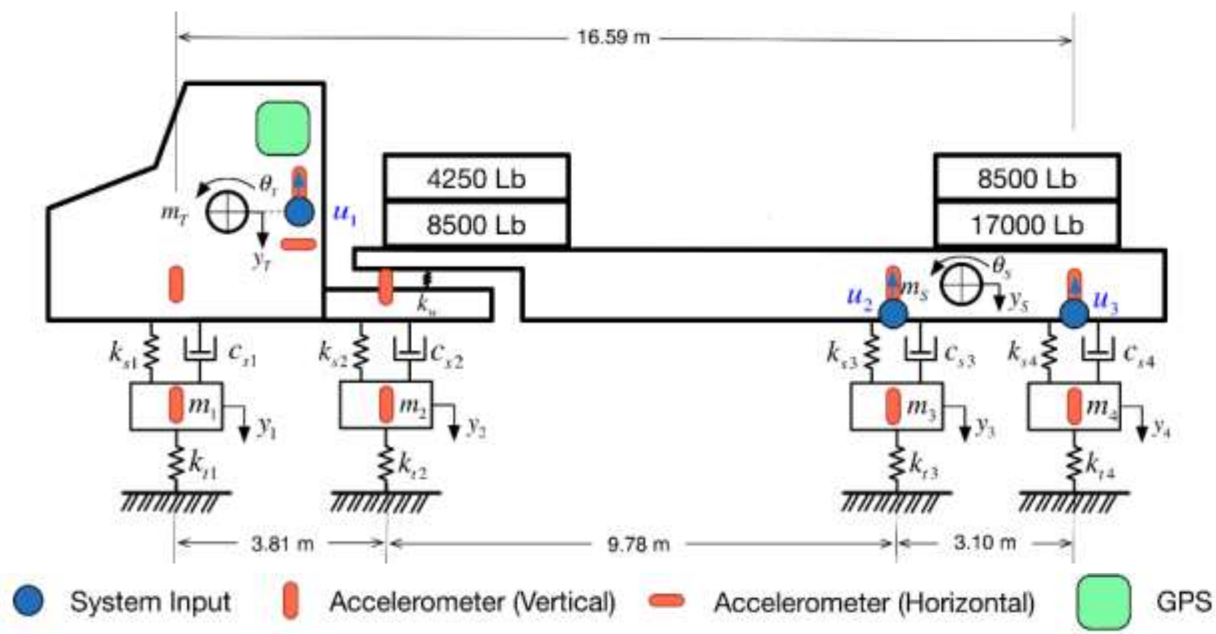

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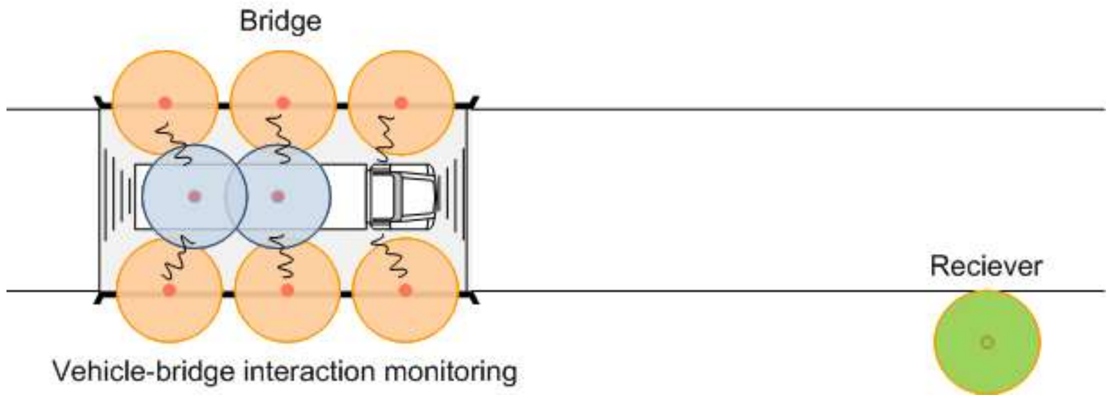
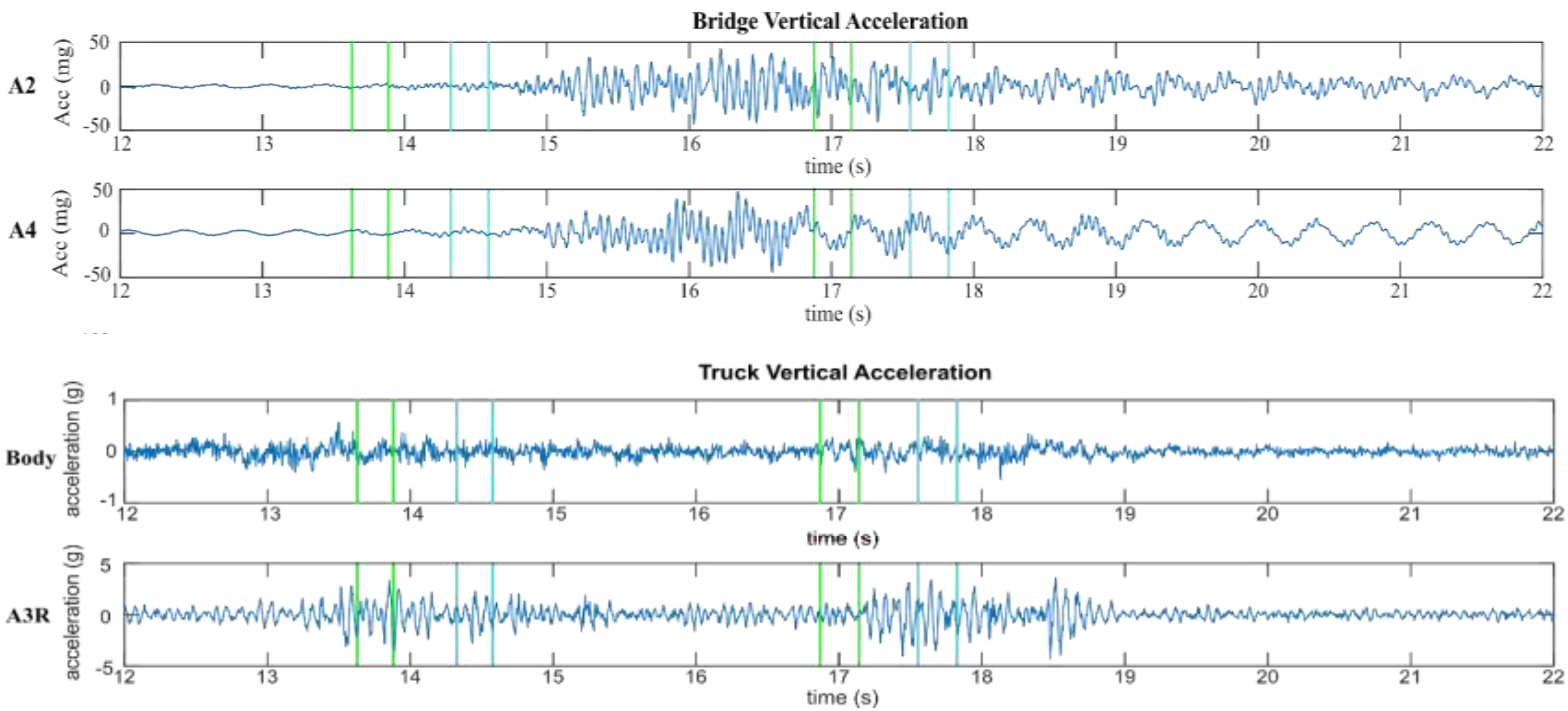
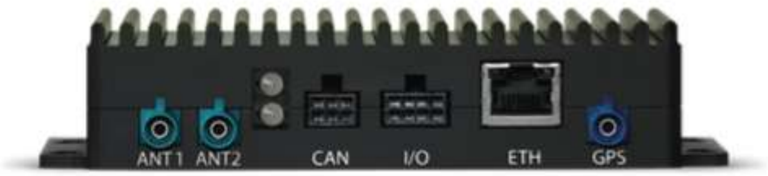




I275 Corridor Cyber-Physical System

KIA Soul:

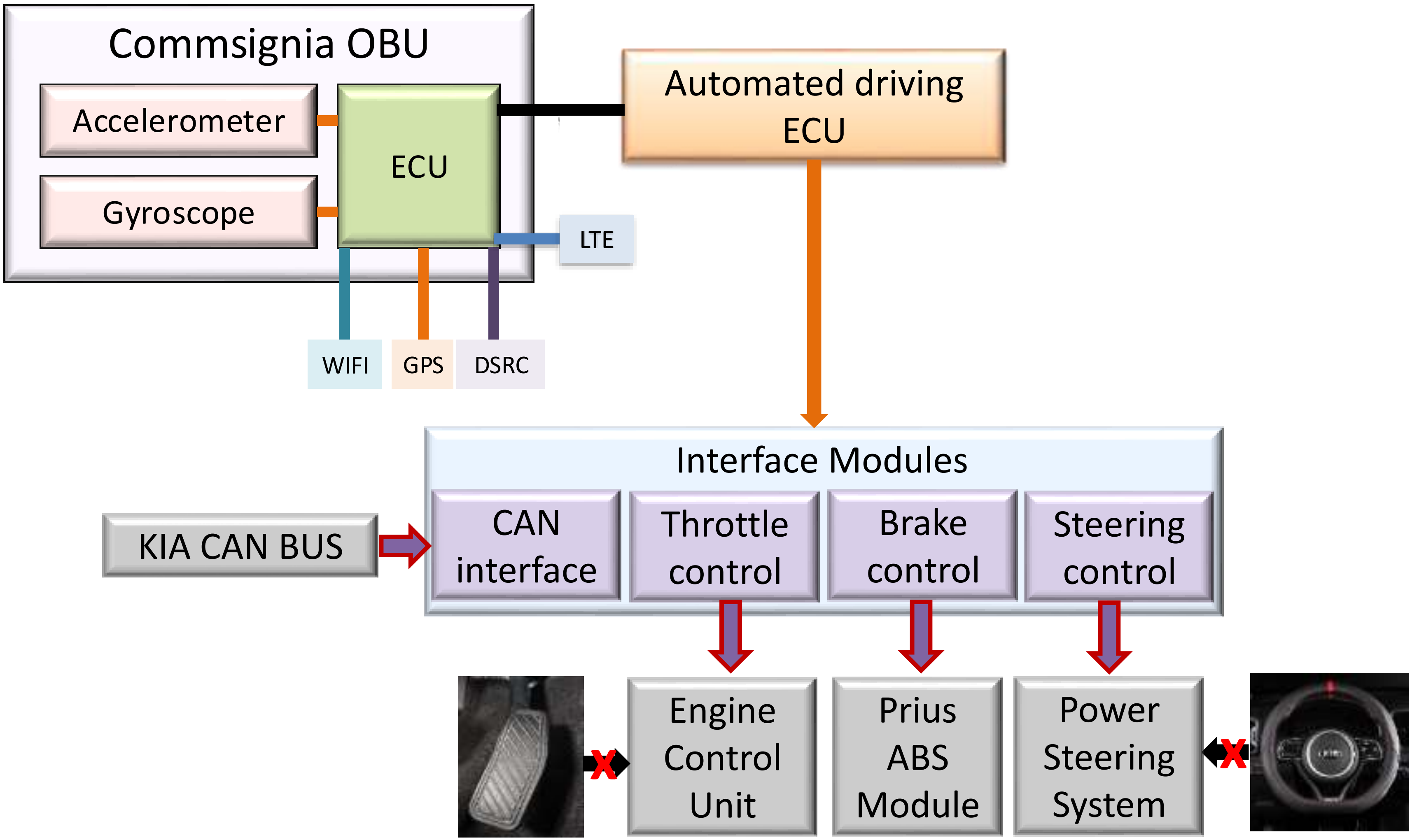
– 2017 model year
– Access to CAN bus
– Direct interface to controllable car elements:
  - Throttle
  - Steering
  - Braking



Commsignia OB3 Connected Vehicle Device:

– 2 channel DSRC
– 6-channel IMU and advanced GNSS
– Bluetooth and 802.11 a/b/g/n, 3G/LTE
– Security features:
  - Infineon Hardware Security Module (HSM)
  - Secure, tamper proof private key and certificate storage
  - Elliptic Curve Digital Signature Algorithm verification/encryption

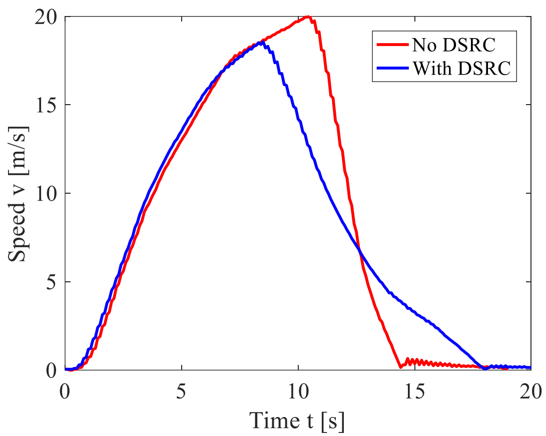
I275 Corridor Cyber-Physical System



I275 Corridor Cyber-Physical System

I275 Corridor Cyber-Physical System

Collision Avoided through Autonomy



Parked vehicle with DSRC in blind spot

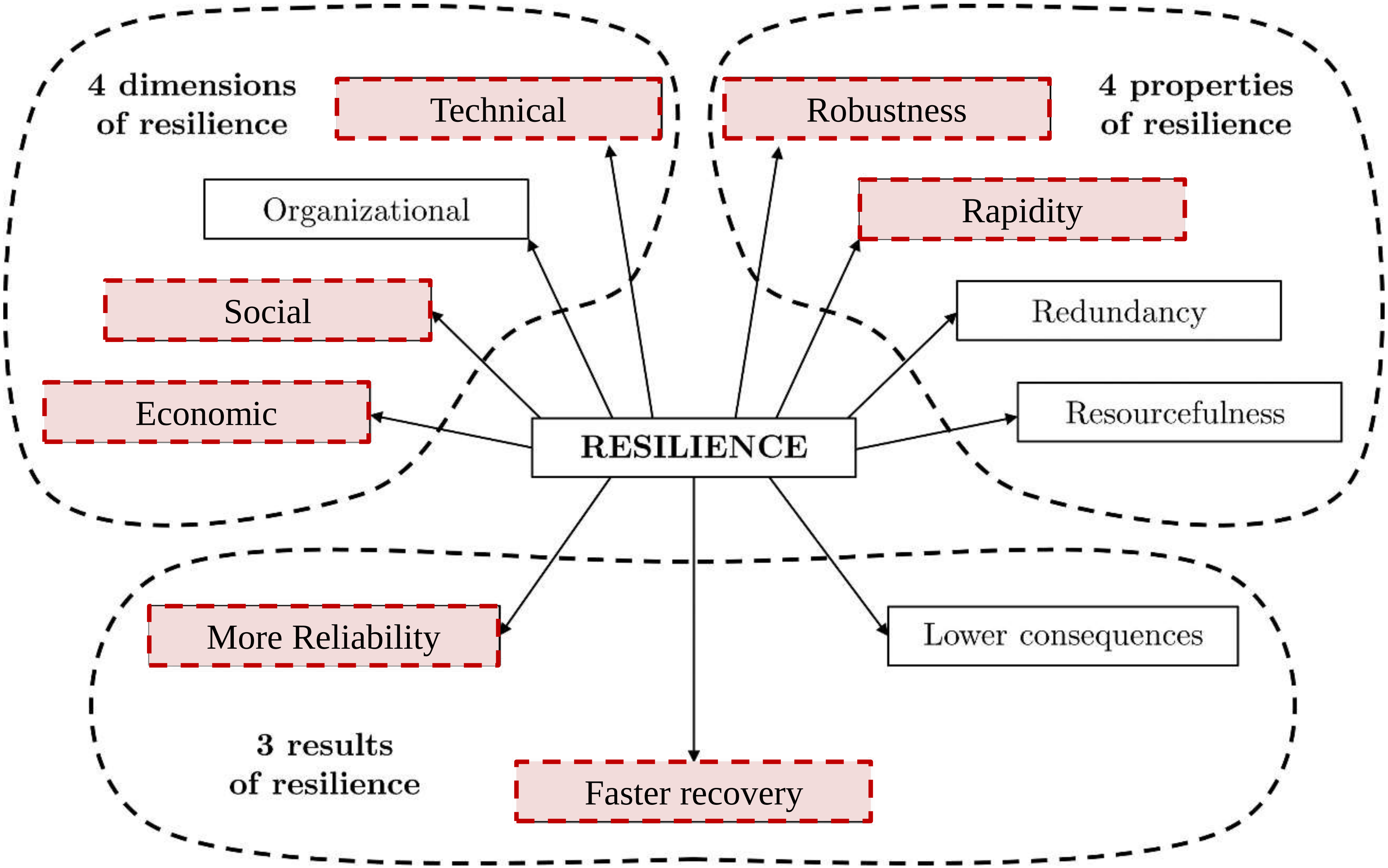
CV Detected and Collision Avoidance Control Applied

Collision Avoidance (CA) Initiated

Starting position of KIA

I275 Corridor Cyber-Physical System

I275 Corridor Cyber-Physical System



Source: M. Ettouney

Green Infrastructure Cyber-Physical Systems

Objectives:
- Monitor urban watersheds in high spatial density
- Model urban water systems to predict flows and demand
- Control green infrastructure to achieve high resiliency

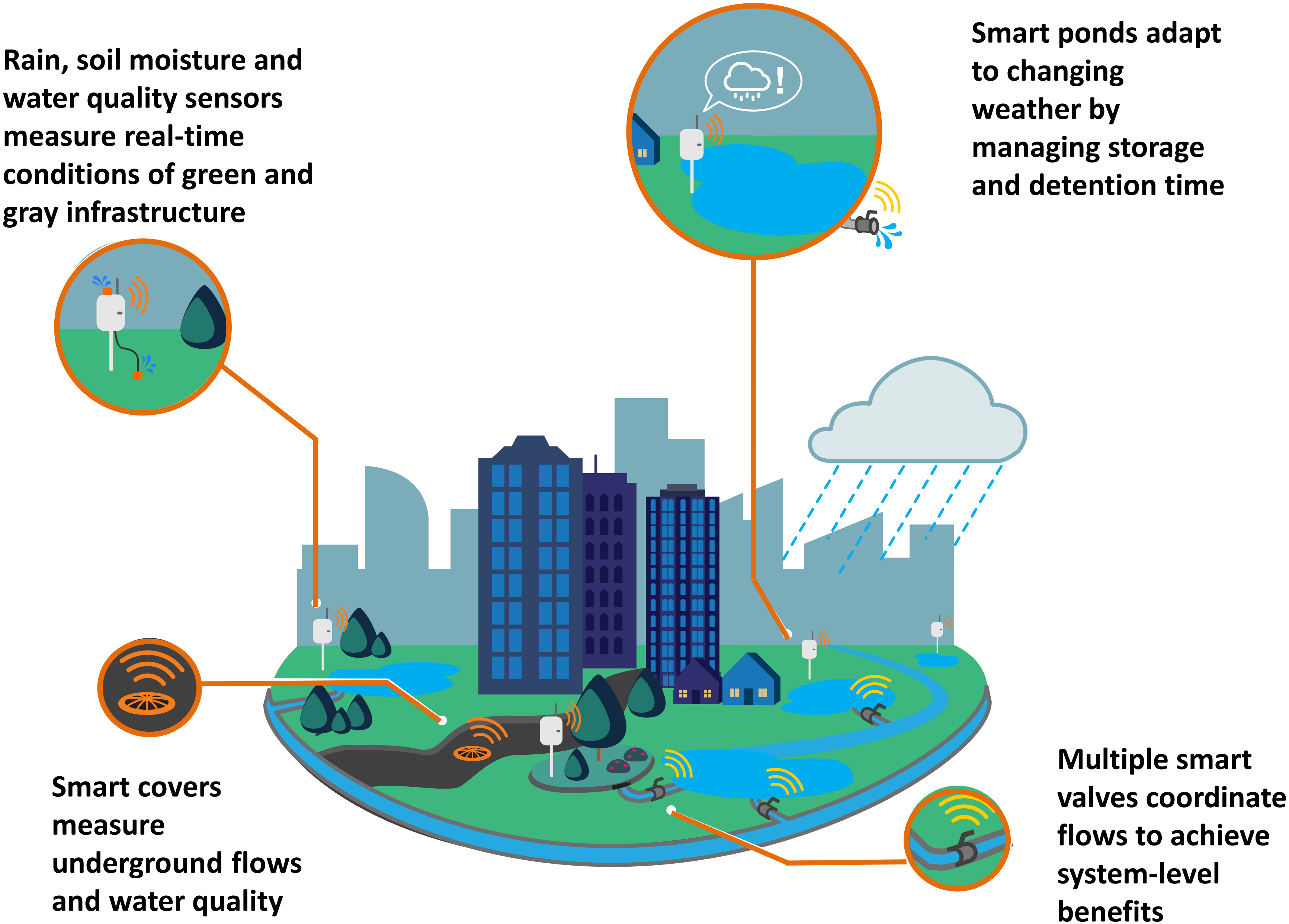
Tools:
- Wireless sensing for dense urban sensing
- Controllable Gates for control of flows

Cloud-based Data Analytics:
- Asynchronous sampling schemes for efficient data collection
- Model predictive control solutions run in the cloud
- Ingestion of meteorological data and models
- Addressing of actuation points

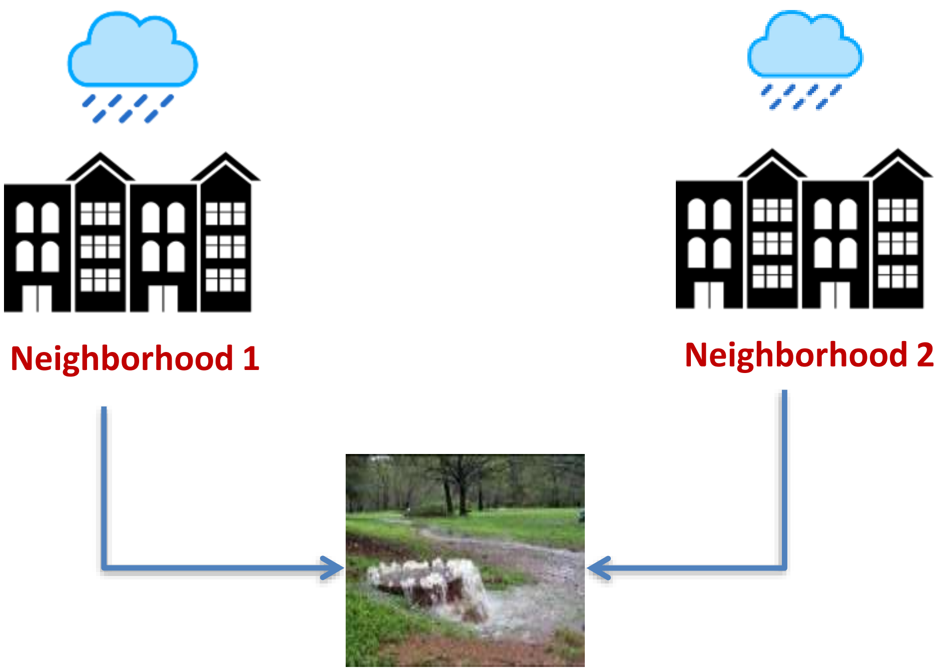
Kerkez

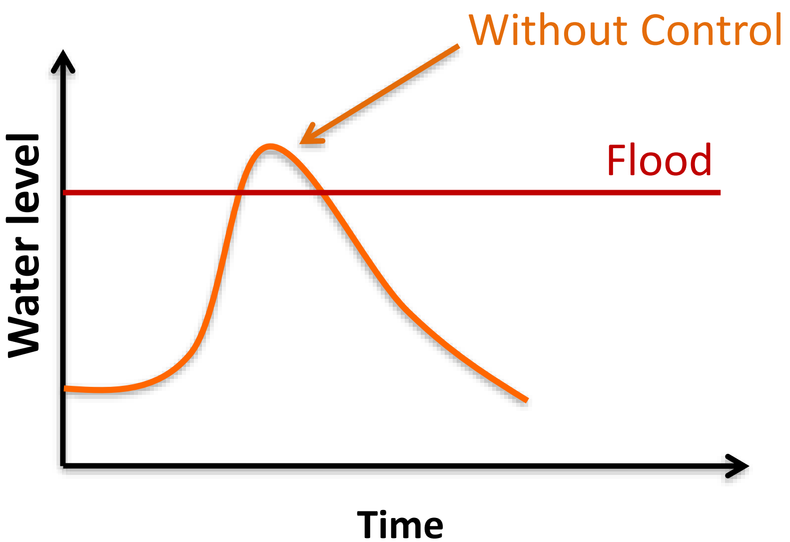
Green Infrastructure Cyber-Physical Systems

Green Infrastructure Cyber-Physical Systems

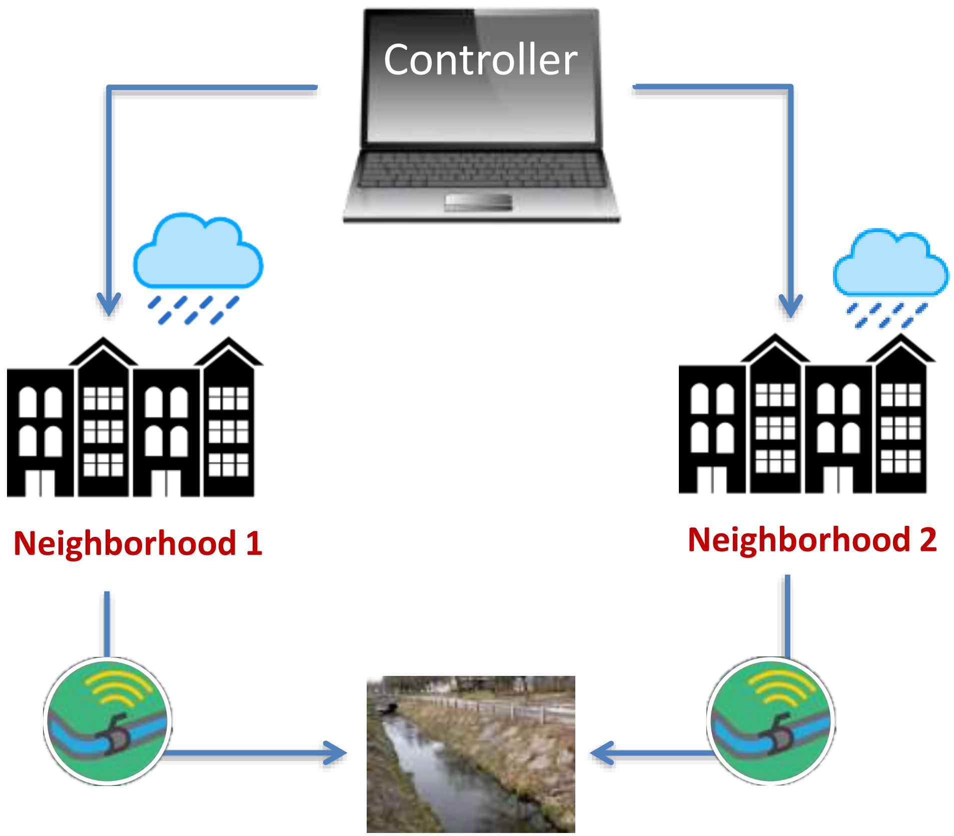


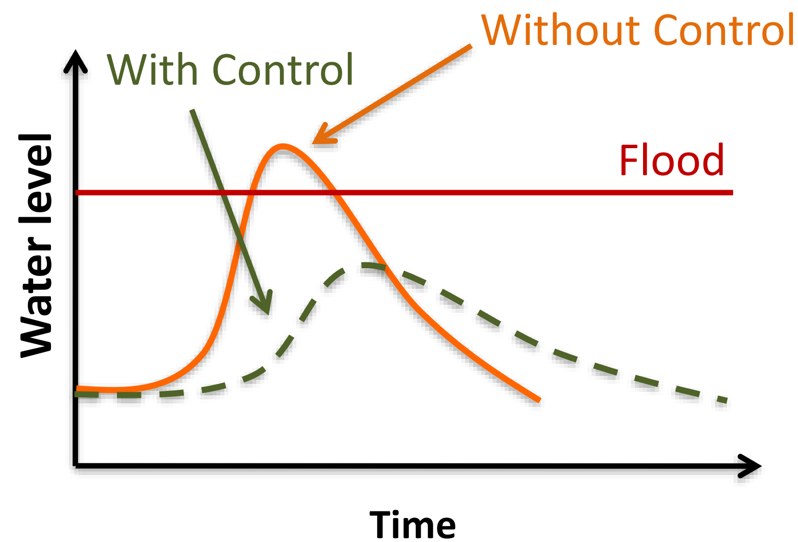
Green Infrastructure Cyber-Physical Systems



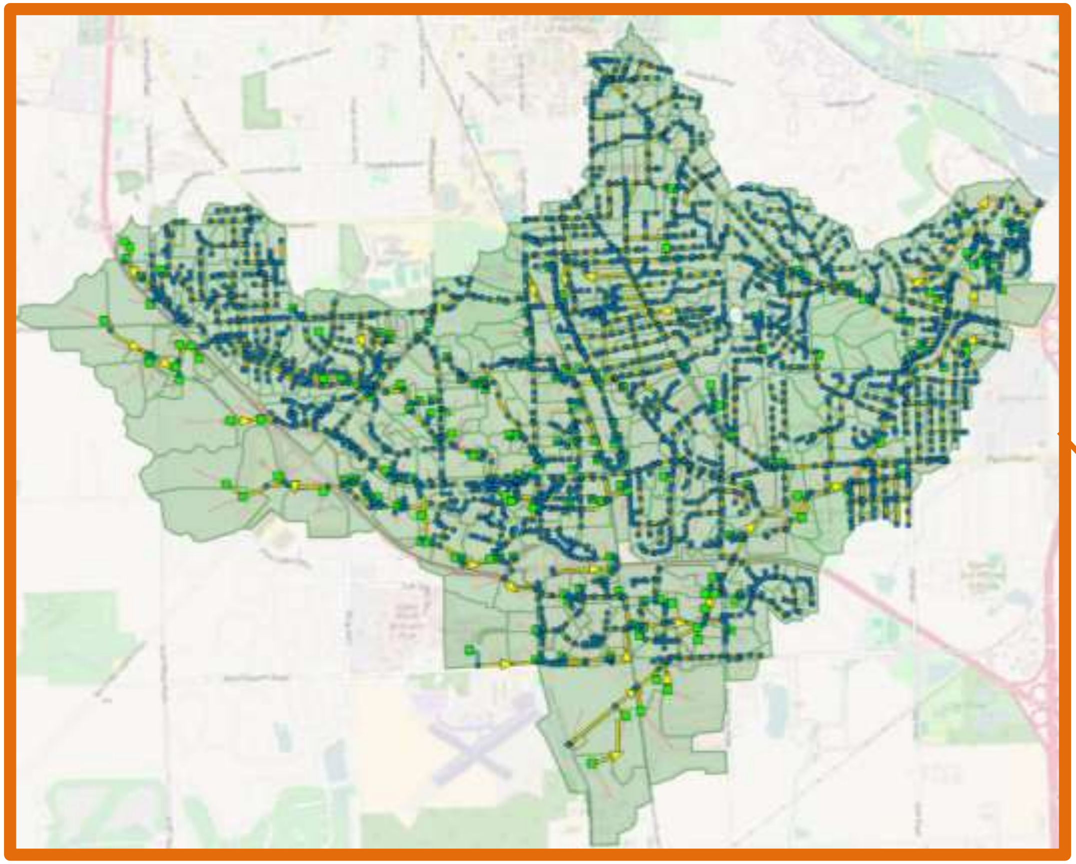


Green Infrastructure Cyber-Physical Systems



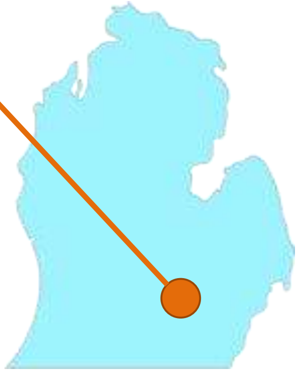


Green Infrastructure Cyber-Physical Systems



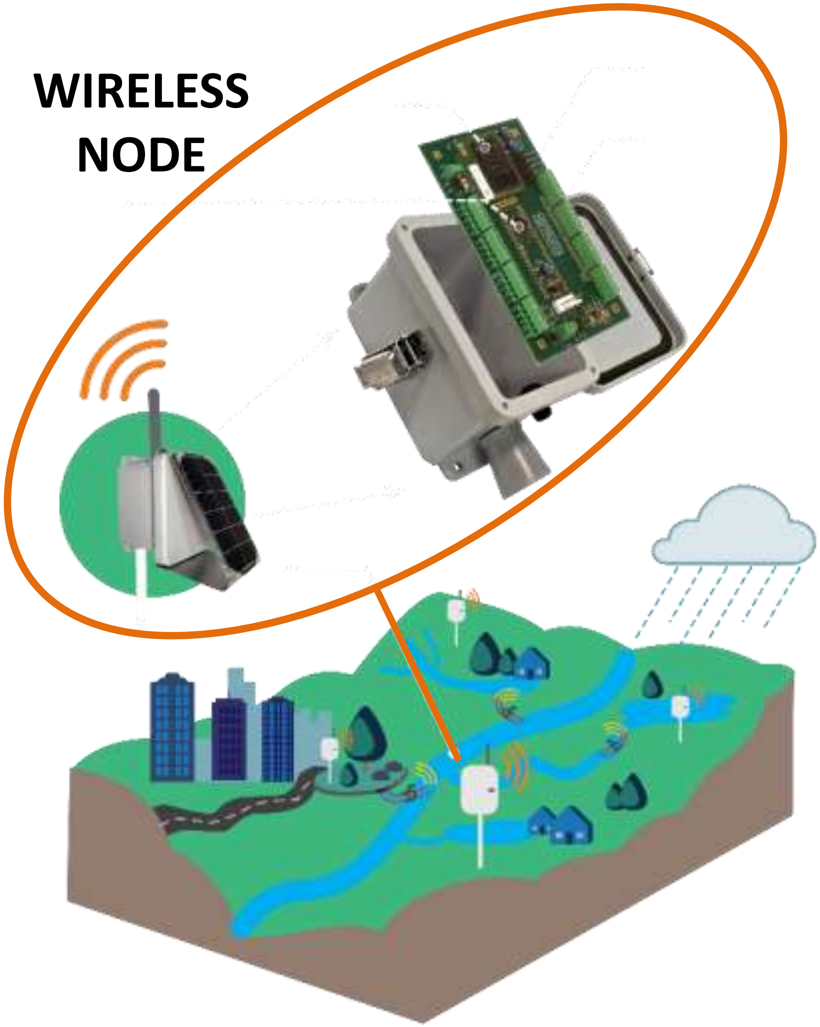
Ann Arbor Watershed

- 250 MG during 3" design storm
- 6620 acres
- 49% impervious
- 651 sub-catchments

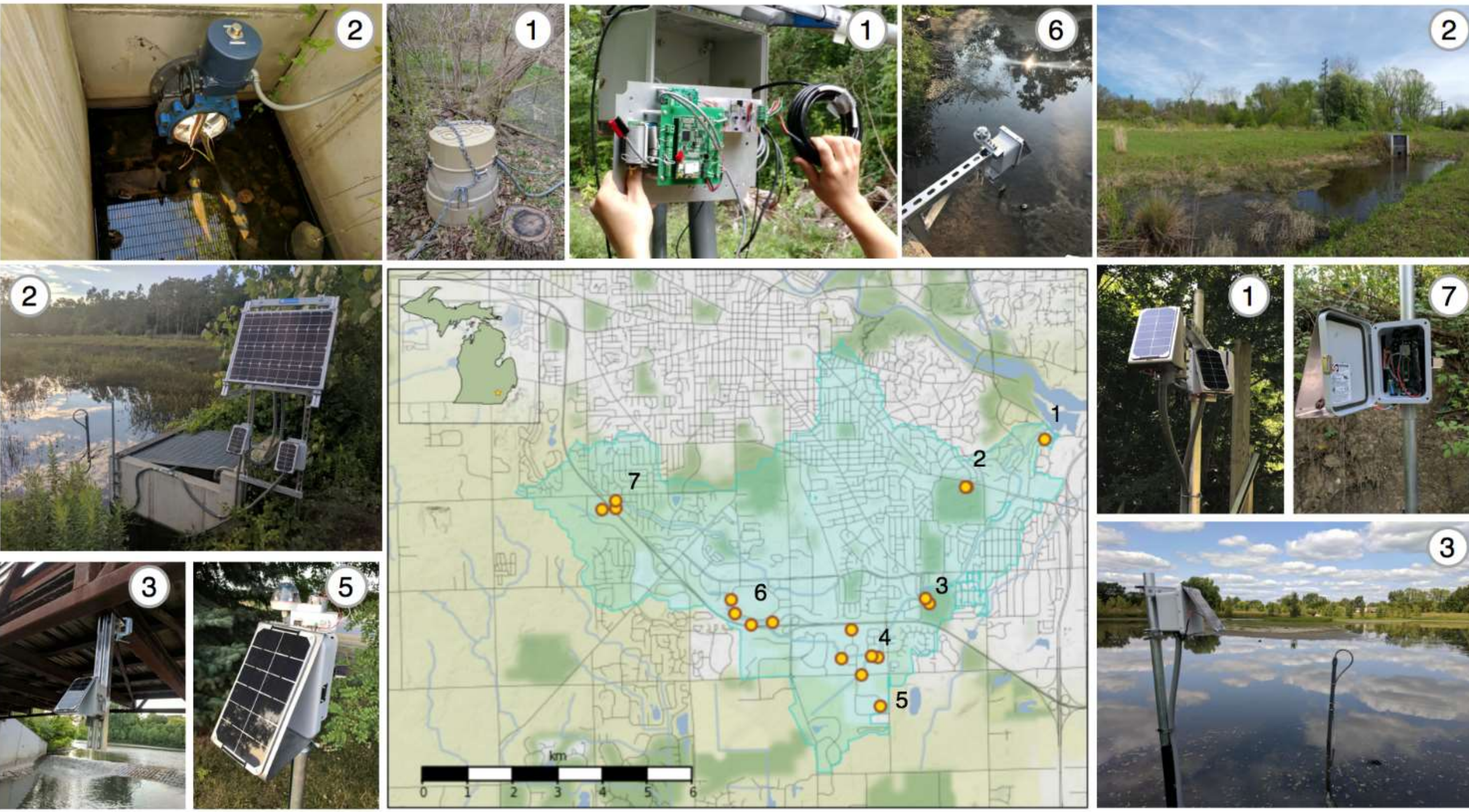


Green Infrastructure Cyber-Physical Systems

http://www.open-storm.org



Green Infrastructure Cyber-Physical Systems

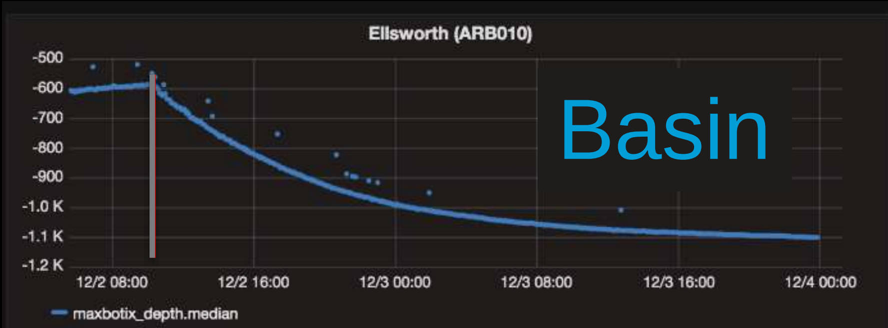


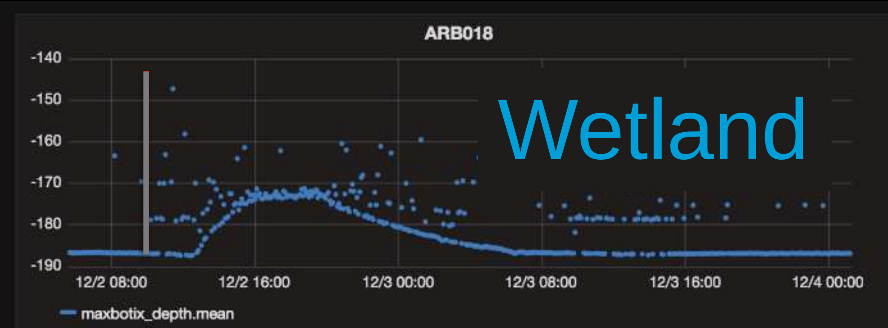
Green Infrastructure Cyber-Physical Systems

Mary Beth Doyle:

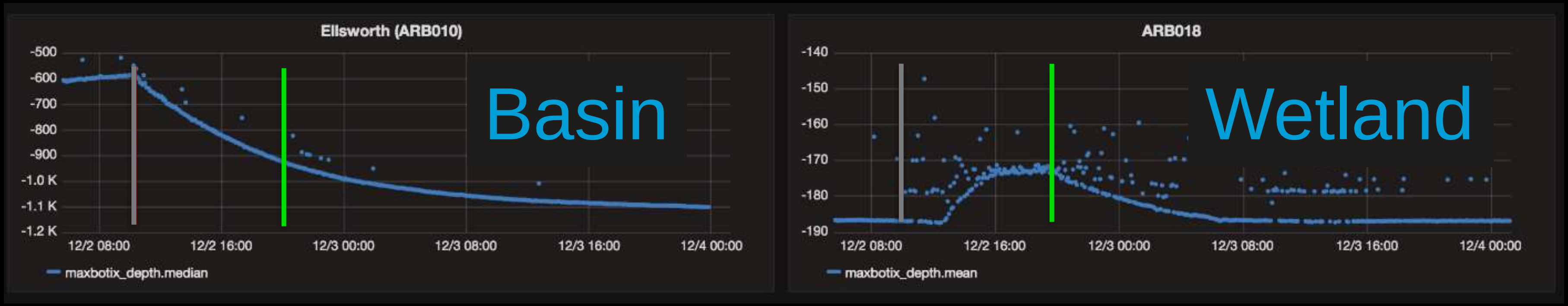
- 200 MG during 10-year storm
- 50 MG capacity

Green Infrastructure Cyber-Physical Systems





Green Infrastructure Cyber-Physical Systems



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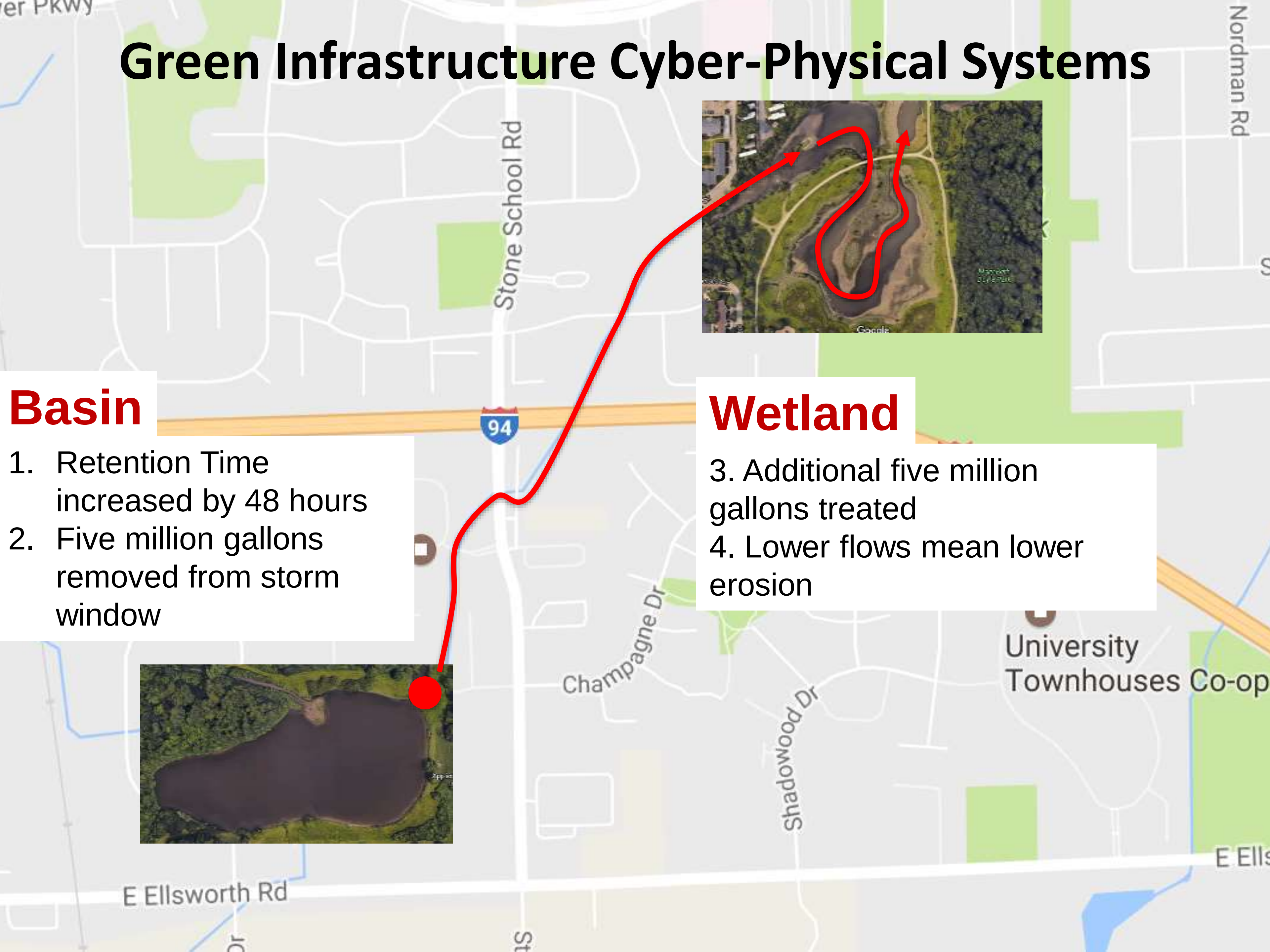


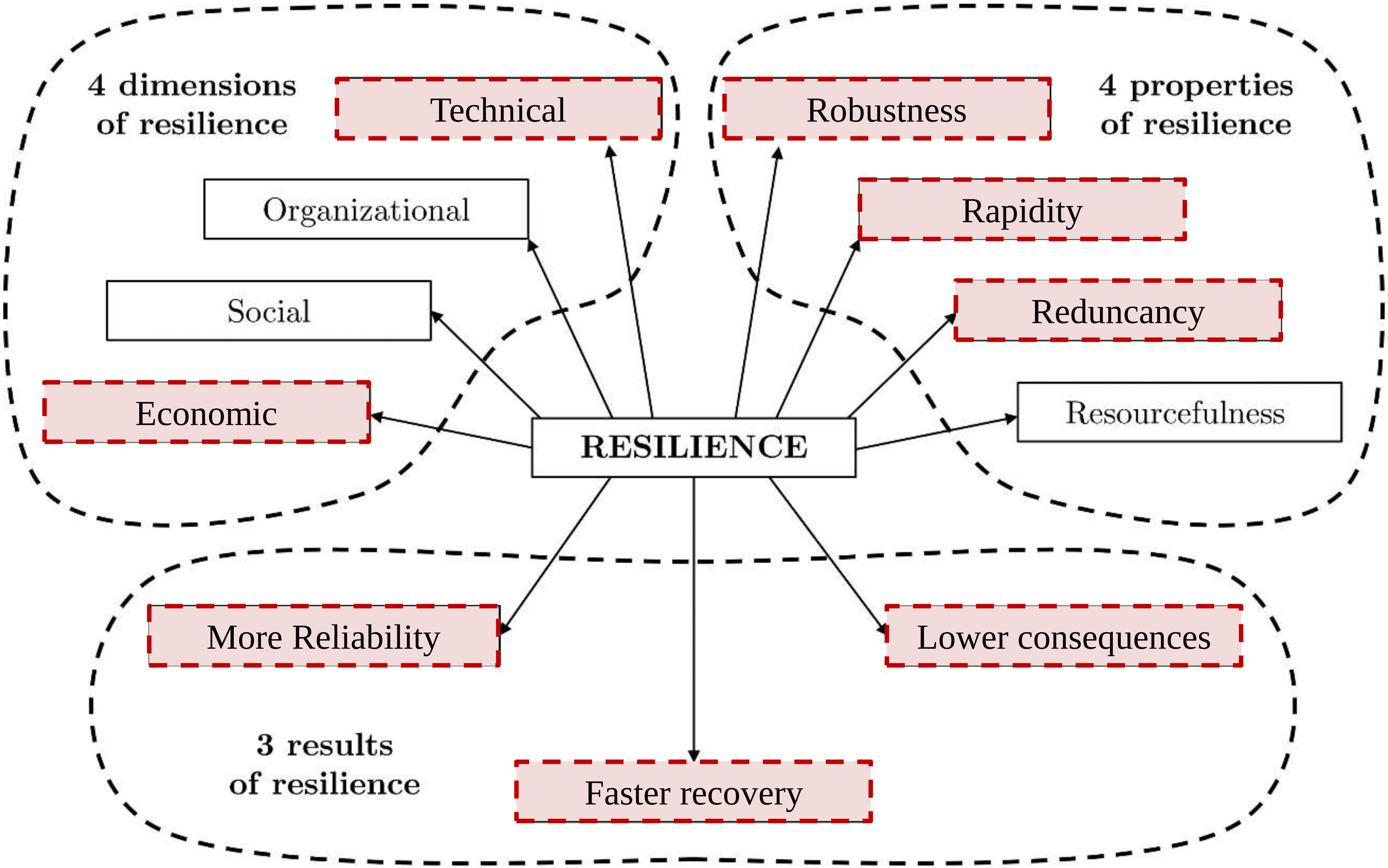
Basin

1. Retention Time increased by 48 hours
2. Five million gallons removed from storm window

Wetland

3. Additional five million gallons treated
4. Lower flows mean lower erosion

Green Infrastructure Cyber-Physical Systems



Source: M. Ettouney

Sensors in a Shoebox

Objectives:
- Empower citizens to collect data surrounding community issues
- Provide community with power to solve problems
- Focus on working with communities below the poverty line

Tools:
- Cellular wireless sensor nodes
- Social media for information dissemination

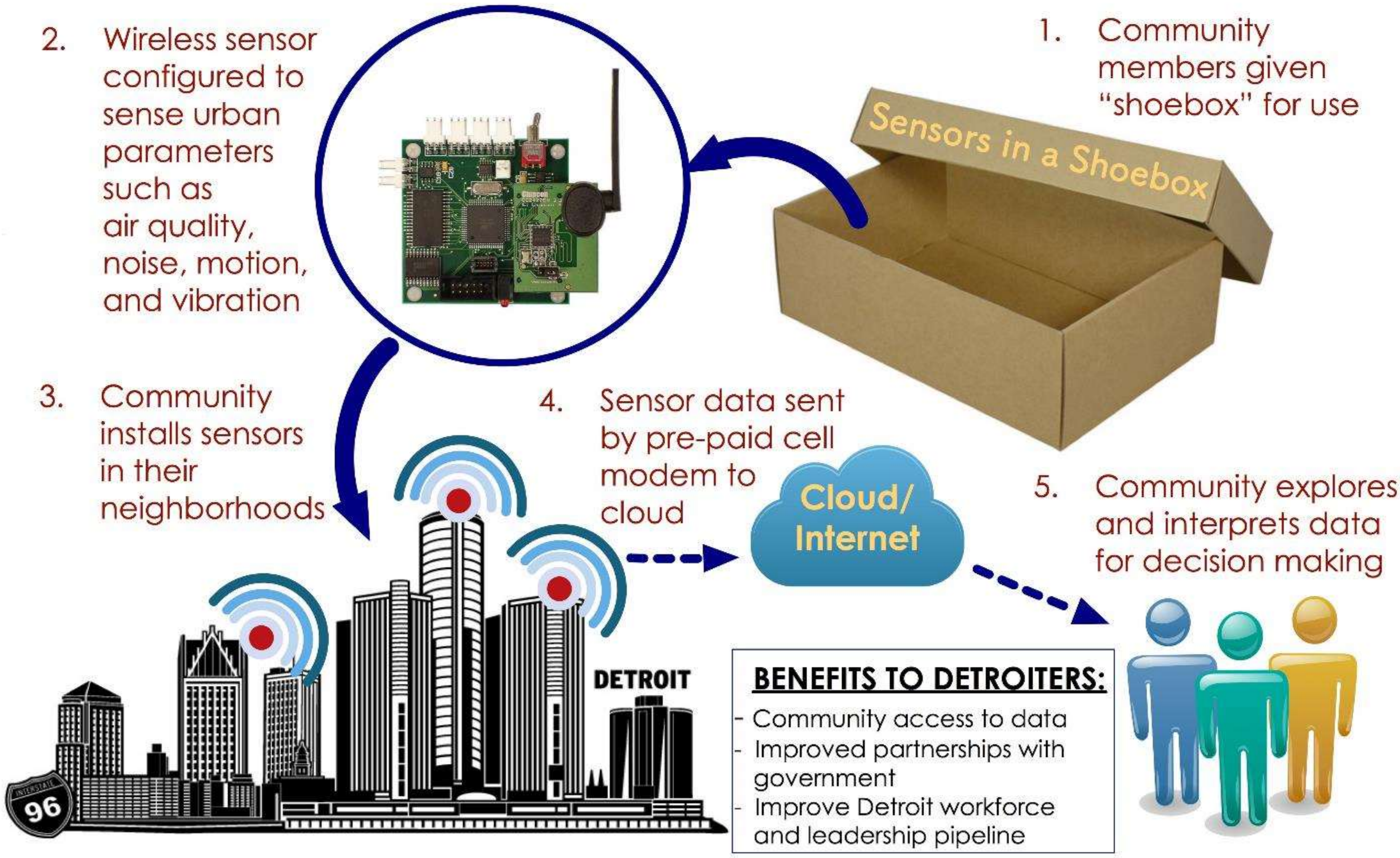
Cloud-based Data Analytics:
- Data visualization

URBAN COLLABORATORY
UNIVERSITY OF MICHIGAN

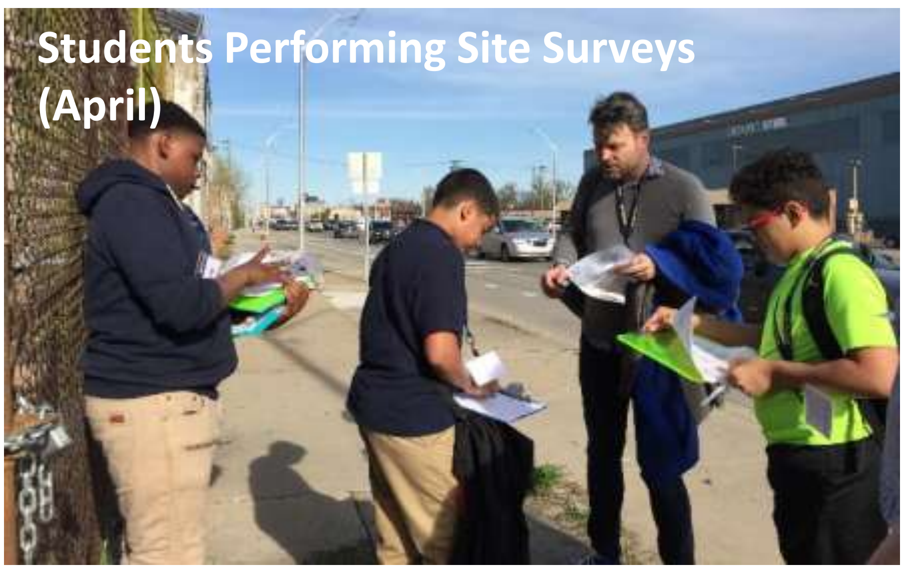

Lynch


Moje

Sensors in a Shoebox



Sensors in a Shoebox



Sensors in a Shoebox

Thank You!