CTwin – Chattanooga Digital Twin

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Computational Urban Sciences Group

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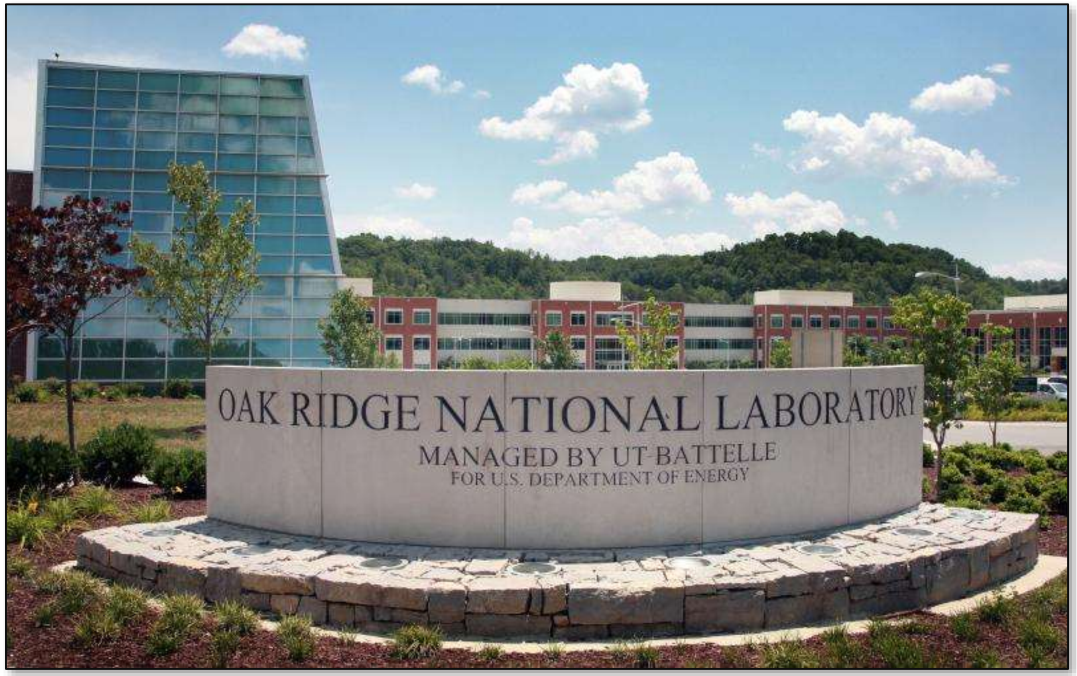
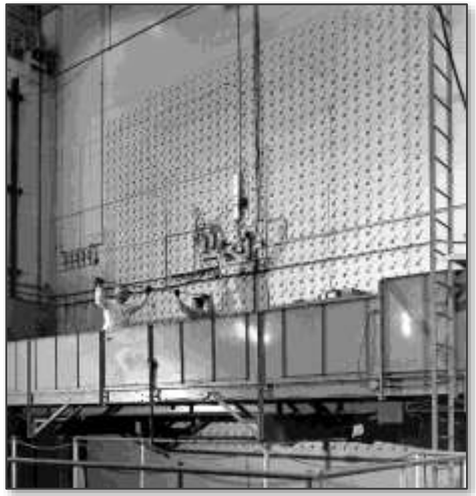
Washington, DC

DOE’s National Laboratories

About ORNL



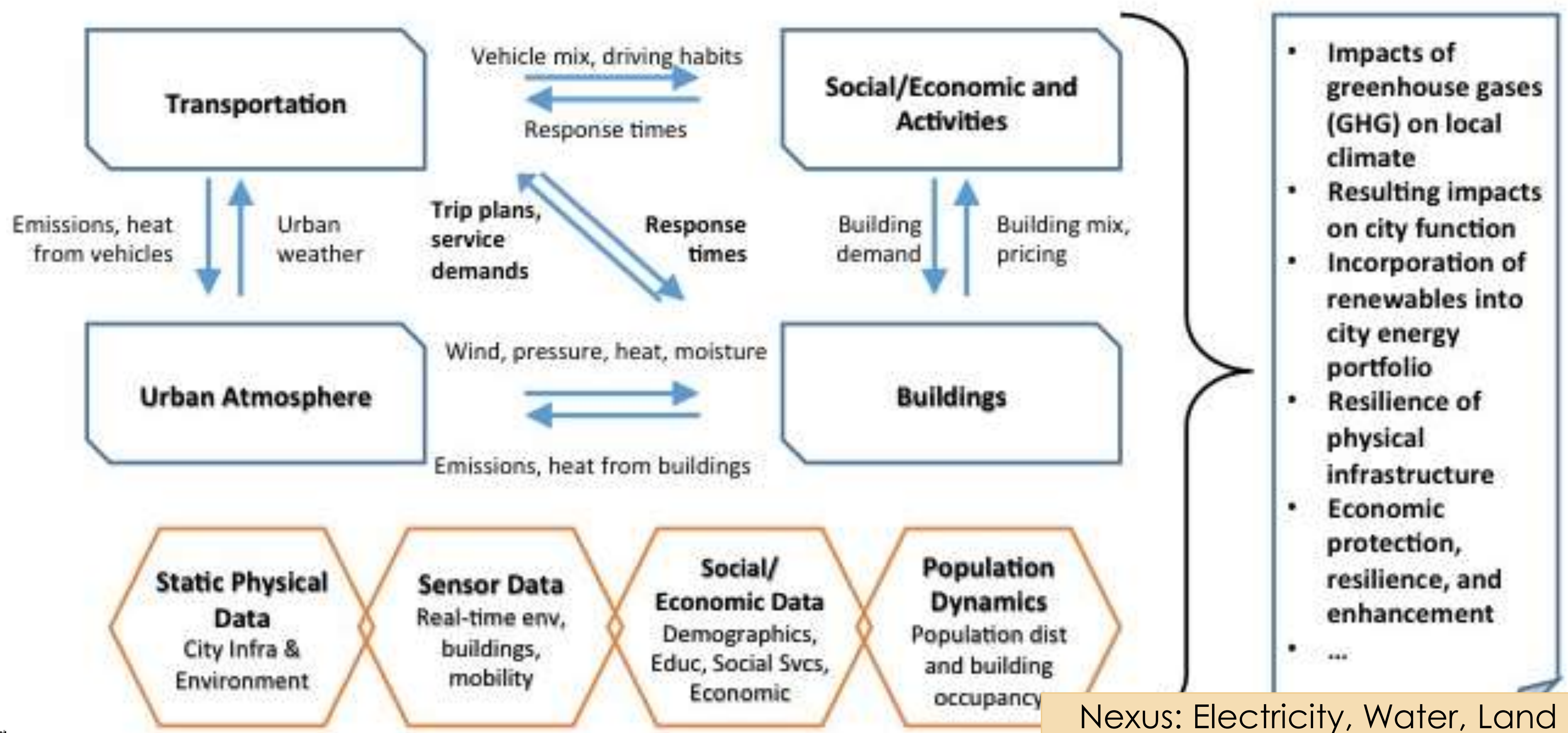
- Staff: 4,950, including scientists and engineers in more than 100 disciplines
- 3,200 users and visiting scientists
- Budget: $1.95 billion
- Established in 1943 as part of the Manhattan Project
- 665 patents since 2005
- 149 active licenses since 2015



Supporting national missions of **scientific discovery, clean energy, and security**

Leadership in computing, neutrons, materials, and nuclear

Computational Urban Sciences Group: Complex Interdependent Urban Systems



Nexus: Electricity, Water, Land Use, Telecommunications

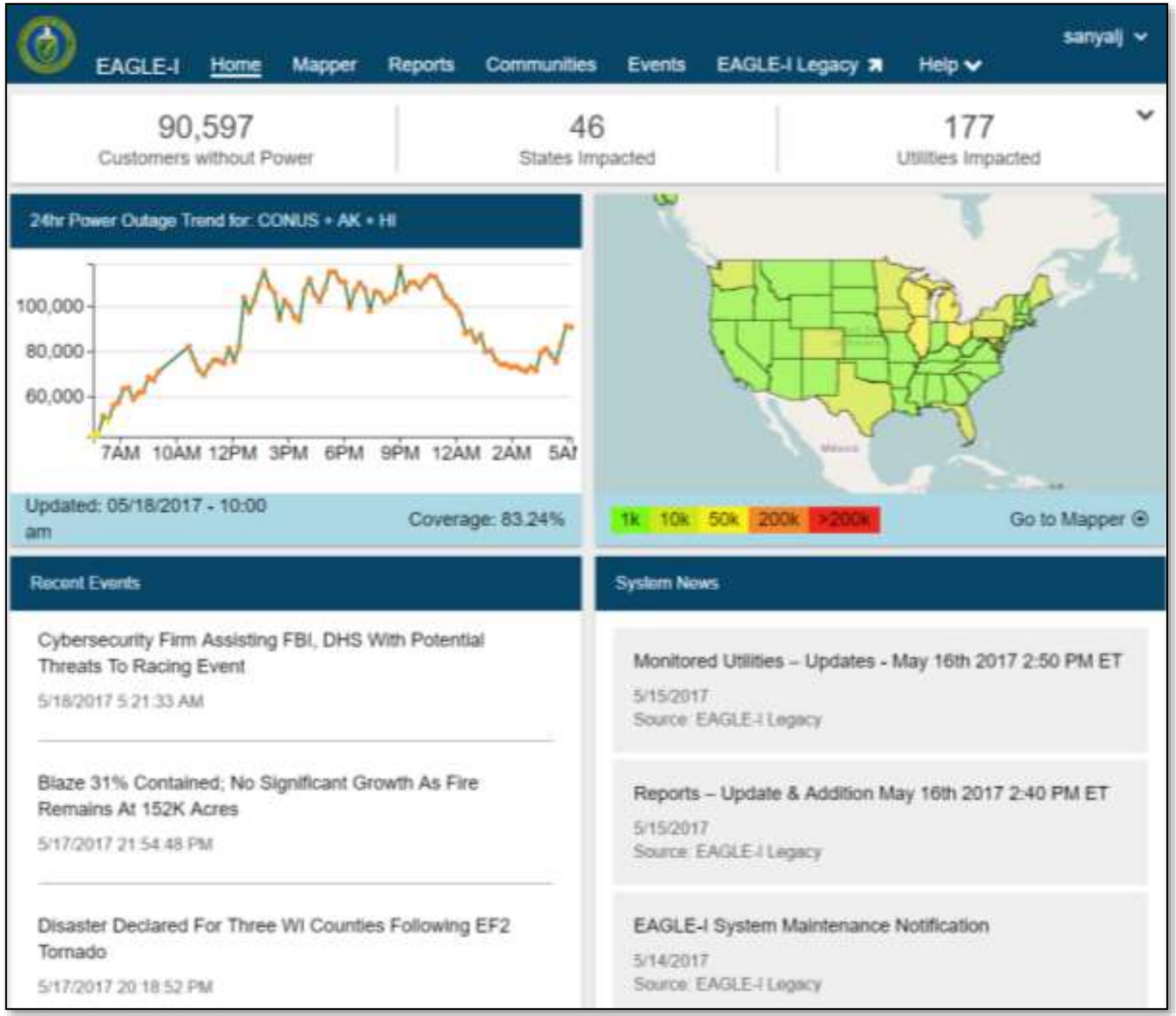
Oak Ridge National Laboratory

Supporting the nation's emergency response

Do people have power?

EAGLE-I: Environment for Analysis of Geo-Located Energy Information

- US DOE's operational energy-sector situational awareness tool
- Outage monitoring for over 128 million customers; 87%+ coverage of US
- Serves the ESF#12 function under the National Response Framework
- Users are from DOE, DHS, NGA, DOD, FEMA, USDA, White House, state emergency responders, among others
- Updates every 15 minutes



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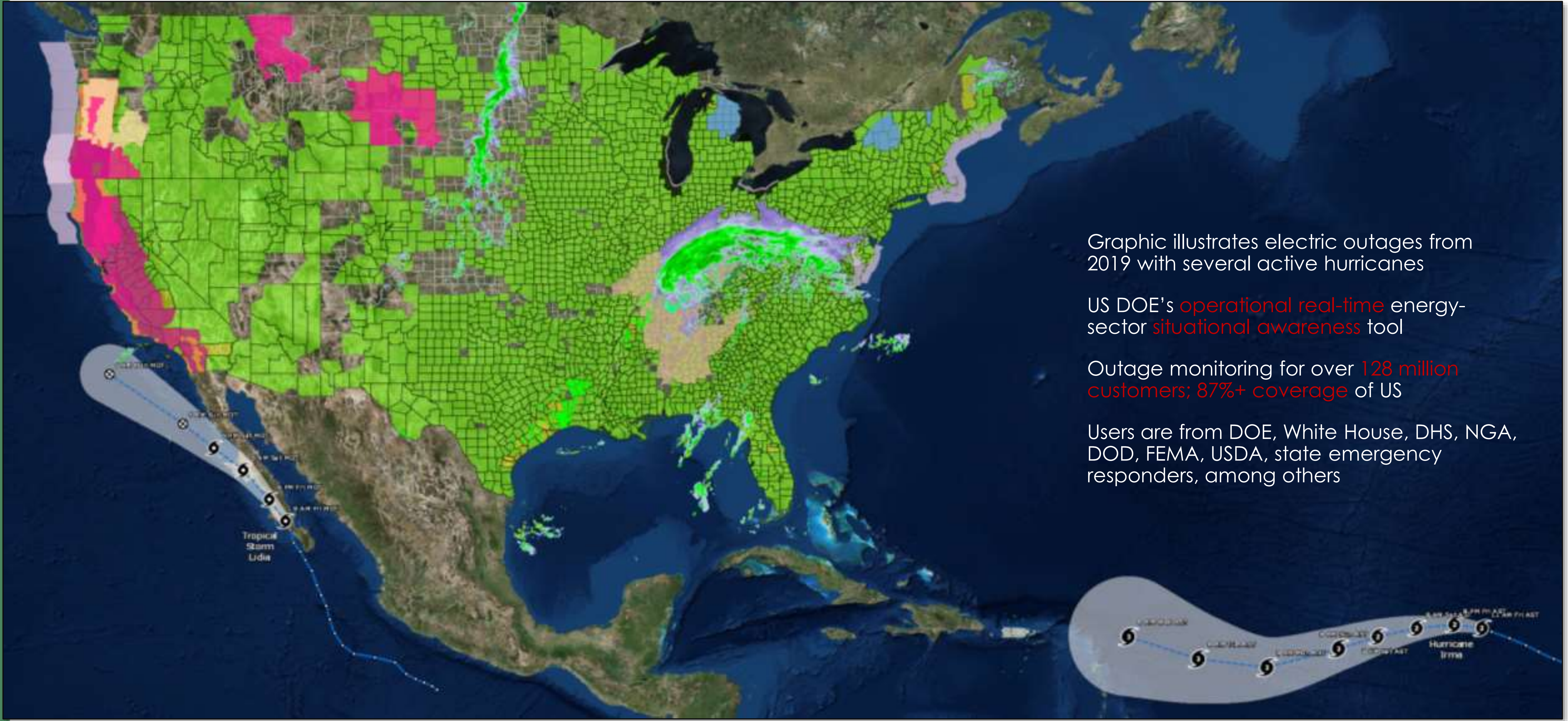

Graphic illustrates electric outages from 2019 with several active hurricanes

US DOE's operational real-time energy-sector situational awareness tool

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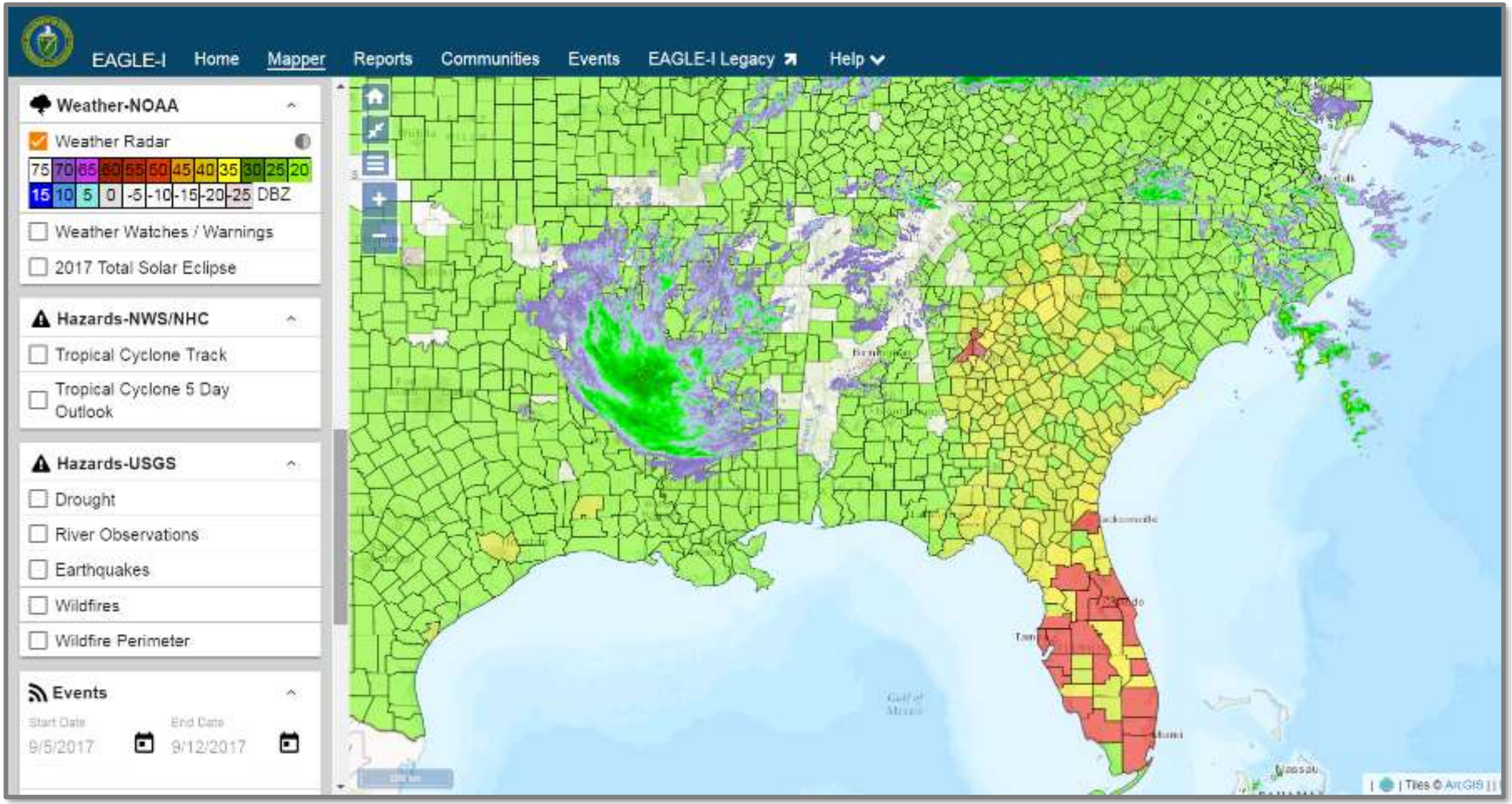
EAGLE-I during Hurricanes Harvey and Irma



Over 7 million impacted electric customers who were out of power in the morning of 9/11/17 during Hurricane Irma after landfall. Majority of the ~7 million impacted electric customers were from Florida, Georgia, and South Carolina.

OAK RIDGE National Laboratory

Real-time 'Digital Twin' for Regional Mobility

- ORNL: Lead lab
- NREL: Supporting lab

CTwin Project Objectives

- **Key target:** Achieve 20% energy savings at the regional level.
  - Highways, linked arterials and freight present an opportunity at the systems level.
  - Framework to be transferable and applicable to other regions.
- **Near real-time situational awareness:** Create a 'Digital Twin' of an entire metropolitan region providing real-time situational awareness for analysis of the entire region
  - Requires data processing at scale across a variety of data sources
  - Demands large scalable computing approaches
- **Near real-time control of traffic infrastructure and vehicles:** Digital Twin forms the basis of a cyber physical control system for control of the highway/road infrastructure and connected vehicles in the ecosystem
  - Fast simulation and algorithmic decisions
  - Orchestration of computational resources on High-Performance Computing resources
  - Data science and artificial intelligence/ machine learning approaches

‘Digital Twin’ for Regional Mobility, Chattanooga, TN

Situational Awareness from real-time data feeds
→ Allows observability at a regional scale

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Simulation and Modeling, and Machine Learning
→ Identifies and evaluates improvements
Demonstrates feasibility/ anticipated outcomes

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Cyber-Physical control actions
→ Algorithmically actuates hardware

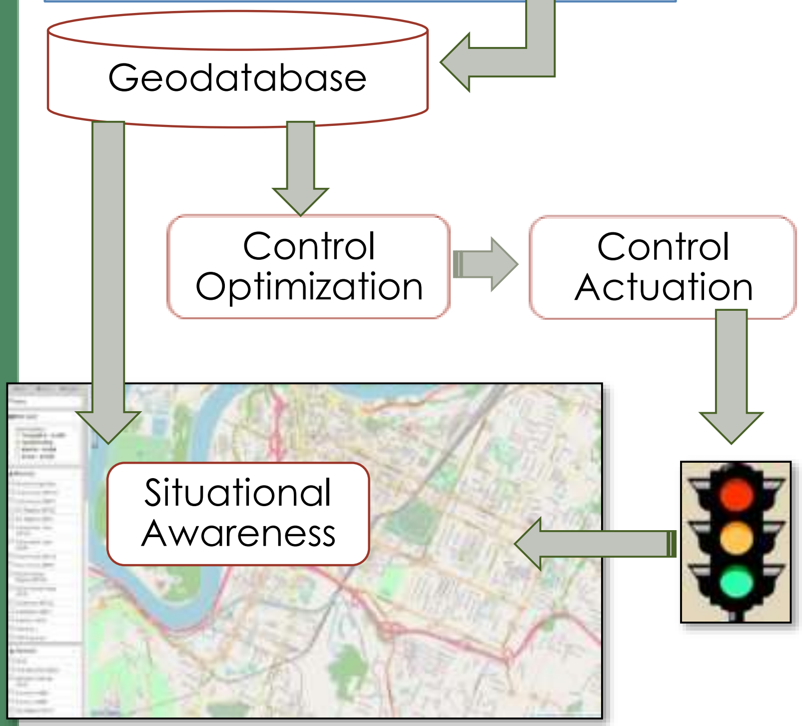
Significant opportunity as a live testbed for connected fleets, CAVs, V2I, and active control

Real-Time Data and Simulation for Optimizing Regional Mobility using HPC

Partnership with CDOT, TDOT, County

Data: 112 CCTV cameras
25 existing, 34 planned GridEye;
RDS data every ½ mile, On-street controllers, incident data, etc.

Provides Vehicle counts, types, lane occupancy, air quality, etc.



Phase 1

Situational Awareness

- Visualize real-time data
- Quantify baseline energy consumption
- Estimate energy savings for identified corridors

With TDOT and CDOT partners

|- Identify how to bridge to operations
|- Run the paperwork
|- Identify/address security risks

Phase 2

Simulation-based signal control

- Develop signal control optimization
- Simulation/AI driven control

Demonstrate feasibility

Demonstrate on city infrastructure

|- Understand infrastructure needs
|- Understand control logic
|- Be able to degrade gracefully

Out years

Phase 3
Scale-up to other areas
Operationalize
Connected freight

Phase 4
Light duty commercial;
Partnership;
Transport “App”

Phase 5
Autonomous Vehicles;
Advanced powertrain

Real-Time Data

- Data from partner stakeholders is key
- Data partners: City of Chattanooga, Tennessee Department of Transportation, Multiple other agencies: MPO, GA-DOT, Titan, INRIX, TomTom, HERE, ATRI, etc.
- Reference/dynamic data: characteristics of infrastructure/ data collected by sensors
- Significant complexity in variety and nuances of the data, and in the systems that serve the data

Map of Chattanooga illustrating the locations of the traffic signals.

RDS locations in the region

City of Chattanooga
- NDA executed
- Reference data, signal info received
- Real-time access to GridSmart cameras working (72 + 70 planned)
- Working on real-time access to SPaT

TDOT
- Radar Detector Sensors
  - Located every ½ mile on average
  - Receiving daily 2GB file once a day
  - 30s data from RDS sensors
  - Lane occupancy, speed, classification
- Weather sensors

CTwin

Home | Region | Corridors | Incidents | Metrics | Help

admin

Select a Date

1/14/2020

Regional Freeway Speed and Volume

Regional Overview

Road Incidents

Hazard
1/14/2020 11:57 PM

Law
1/14/2020 11:55 PM

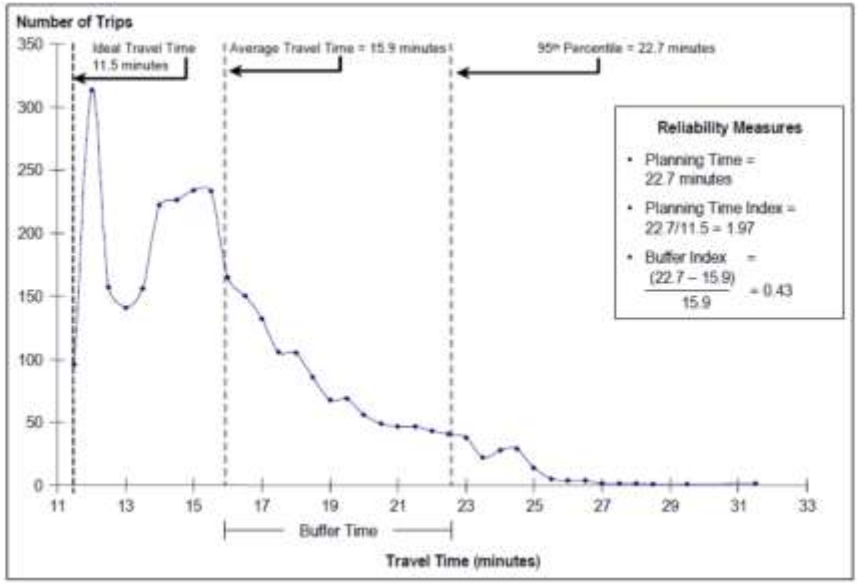
System News

Prototype stood up
7/8/2019 02:36 PM

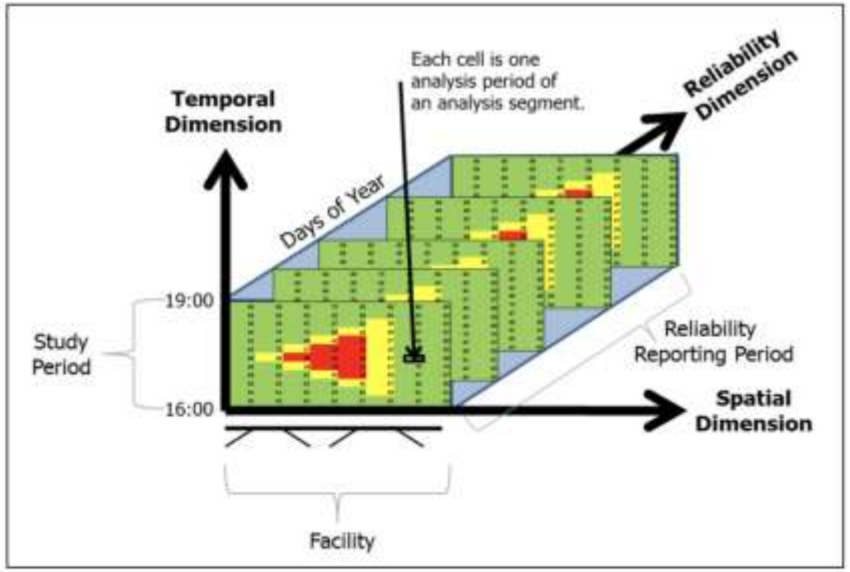
Go To System News

Metrics Implementable in C-Twin

- Primarily driven by USDOT MAP-21 measures
- Mobility Dynamics
  - Macroscopic – Freeway travel time reliability, level of service (average speed and volume to capacity ratio), vehicle miles of travel (VMT) by passenger and freight.
  - Microscopic – Level of service (vehicle delays, queue length and signal delays) from signalized intersections.
- Traffic Safety
  - Roadway segment level – fatalities per capita and serious injuries per capita (crashes per VMT)
  - Intersection level – crashes per 100,000 vehicles
- Energy Usage
  - Minute by minute on-road vehicle fuel consumption & cost
  - RouteE – Energy estimation over roadway segments
- Mobility – Energy – Productivity (MEP)
  - *f(mobility weighted by [energy, cost, trip purpose])*



Source: Travel Time Index Measures from Sample Travel Time Frequency Distribution (FHWA 2016)



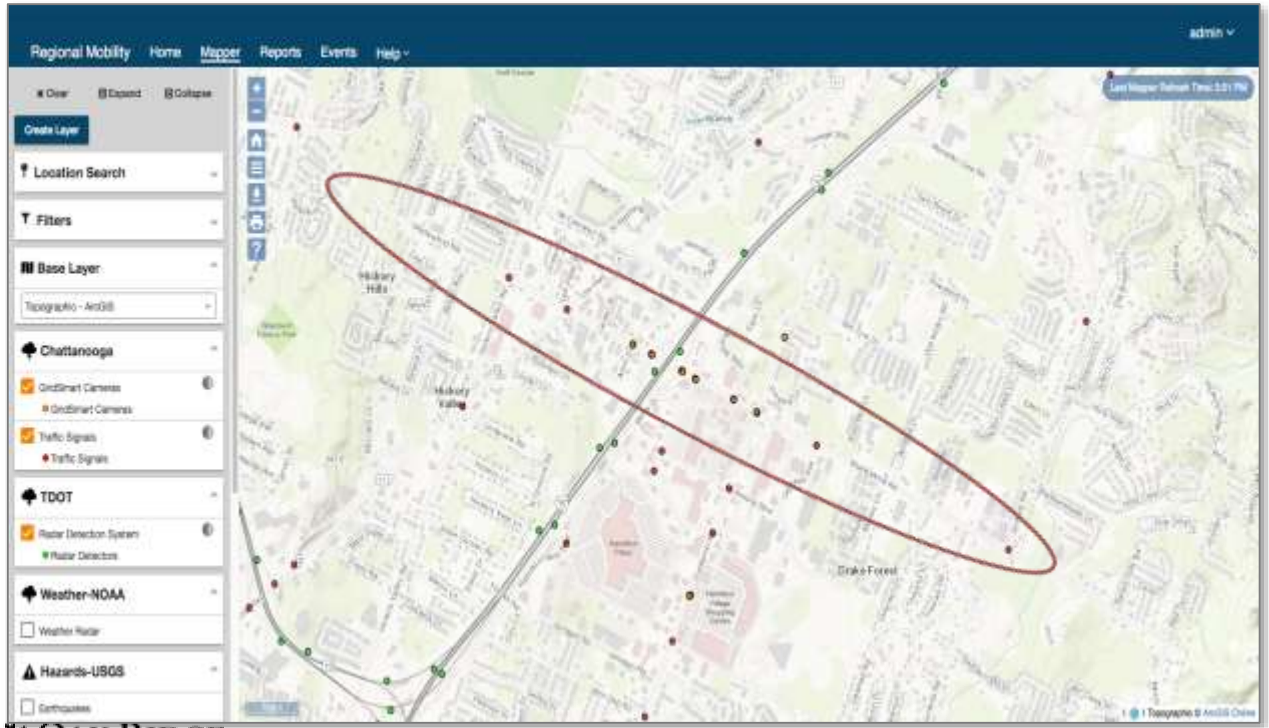
Source: Time-Space Reliability of Travel Time, Highway Capacity Manual 2017

Candidate Corridor for Simulation

Shallowford Road Arterial identified for analysis and optimization based on data availability and priority discussion with City of Chattanooga, TN

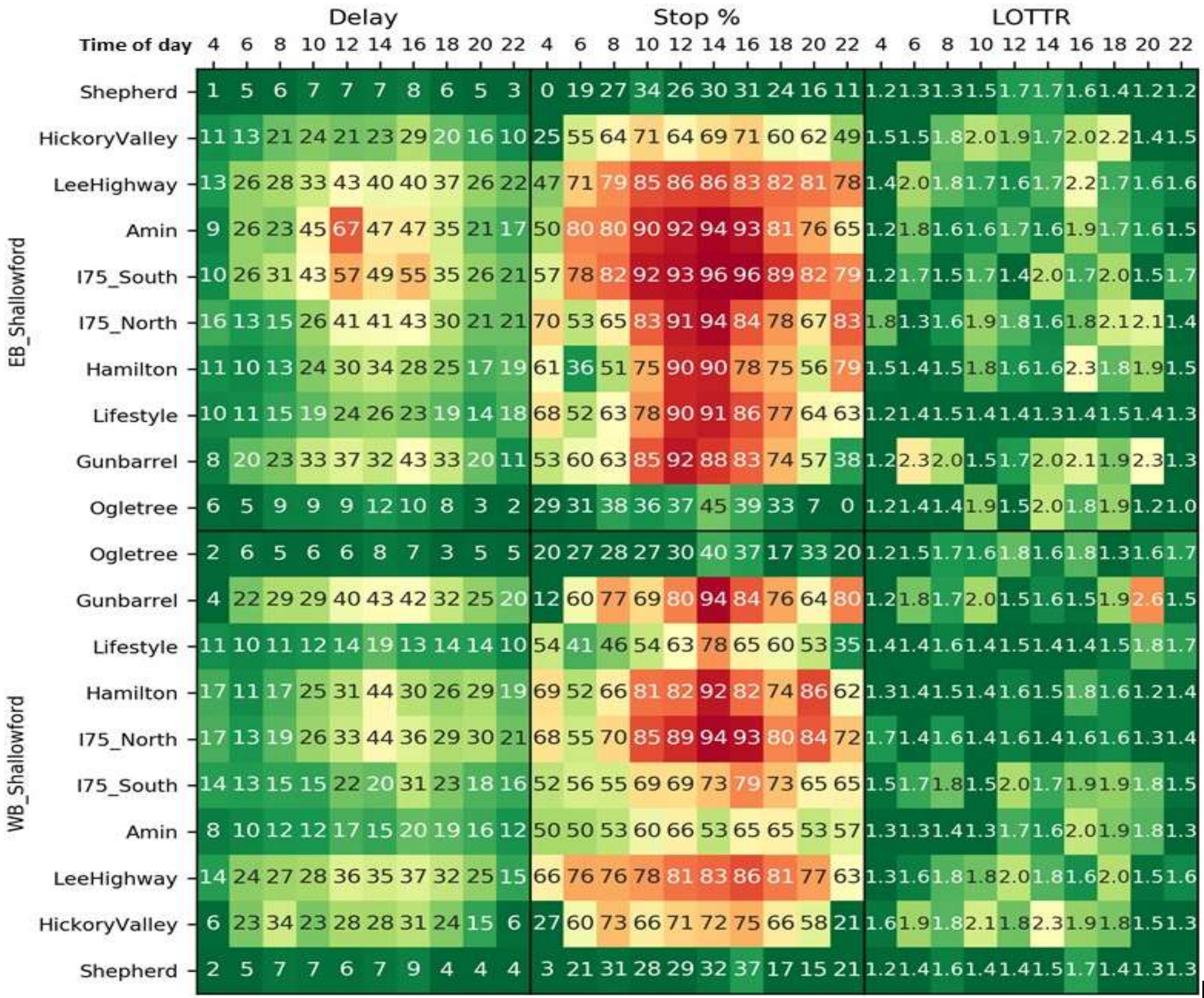
- GridSmart Cameras
- Signalized Intersections with timing information
- Radar Detection Systems
- Traffic Incidents for year 2018

Spatial scope: Signalized Arterial



Temporal scope: frequency of adjusting signal settings	Signal settings optimization-standard techniques	Performance-based optimization	Near real-time optimization
5-15 minutes	Yes	No	Yes
Hourly	Yes	No	Yes
Time-of-day	Yes	Flexible	No
Daily	Yes	Yes	No
Weekly	Yes	Yes	No

Signal Performance on Shallowford Road



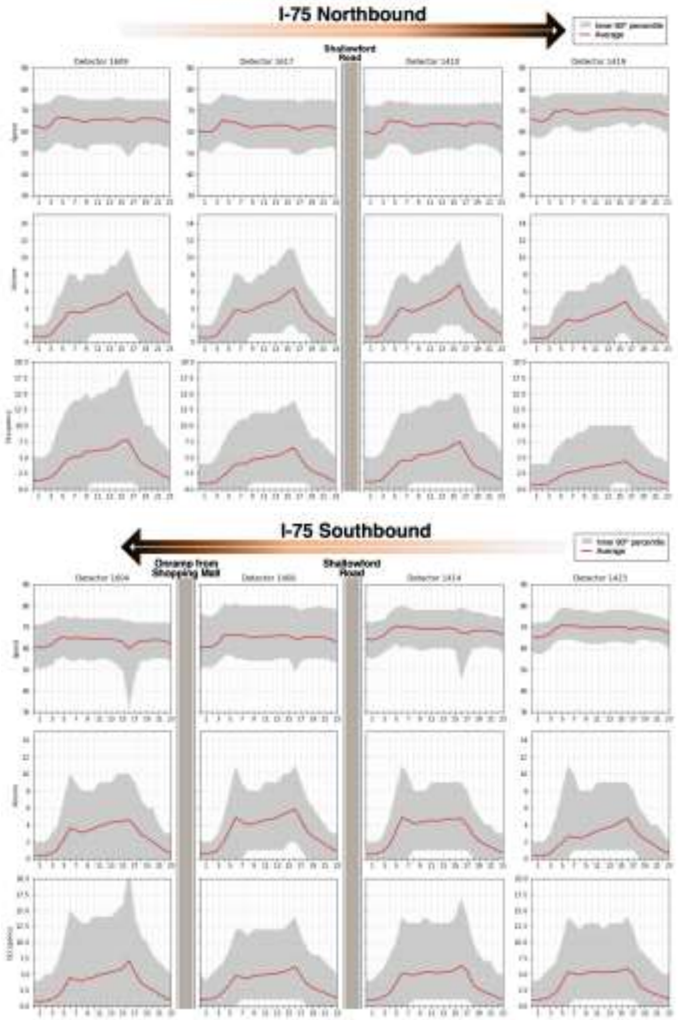
RDS Highway Data: Shallowford Road Corridor

- RDS sensors (November 2018 to March 2019)
- Gridsmart cameras
- Interstate on/off ramps
- TDOT SmartWay Traffic cameras

Analyze long-term RDS data to identify patterns in the traffic flow near Shallowford Road and the shopping center.

Northbound:
Noticeable speed-up and reduction of congestion north of Shallowford Road (detector 1419)

Southbound:
Significant influence of vehicles entering the interstate from shopping mall during evening peak
- Increases congestion and slows traffic



Using the You-Only-Look-Once (YOLO) deep image processing network to identify cars and trucks from low-resolution traffic cameras

Phase 2: Delivering intelligence at the edge

Can we control these in a swarm?

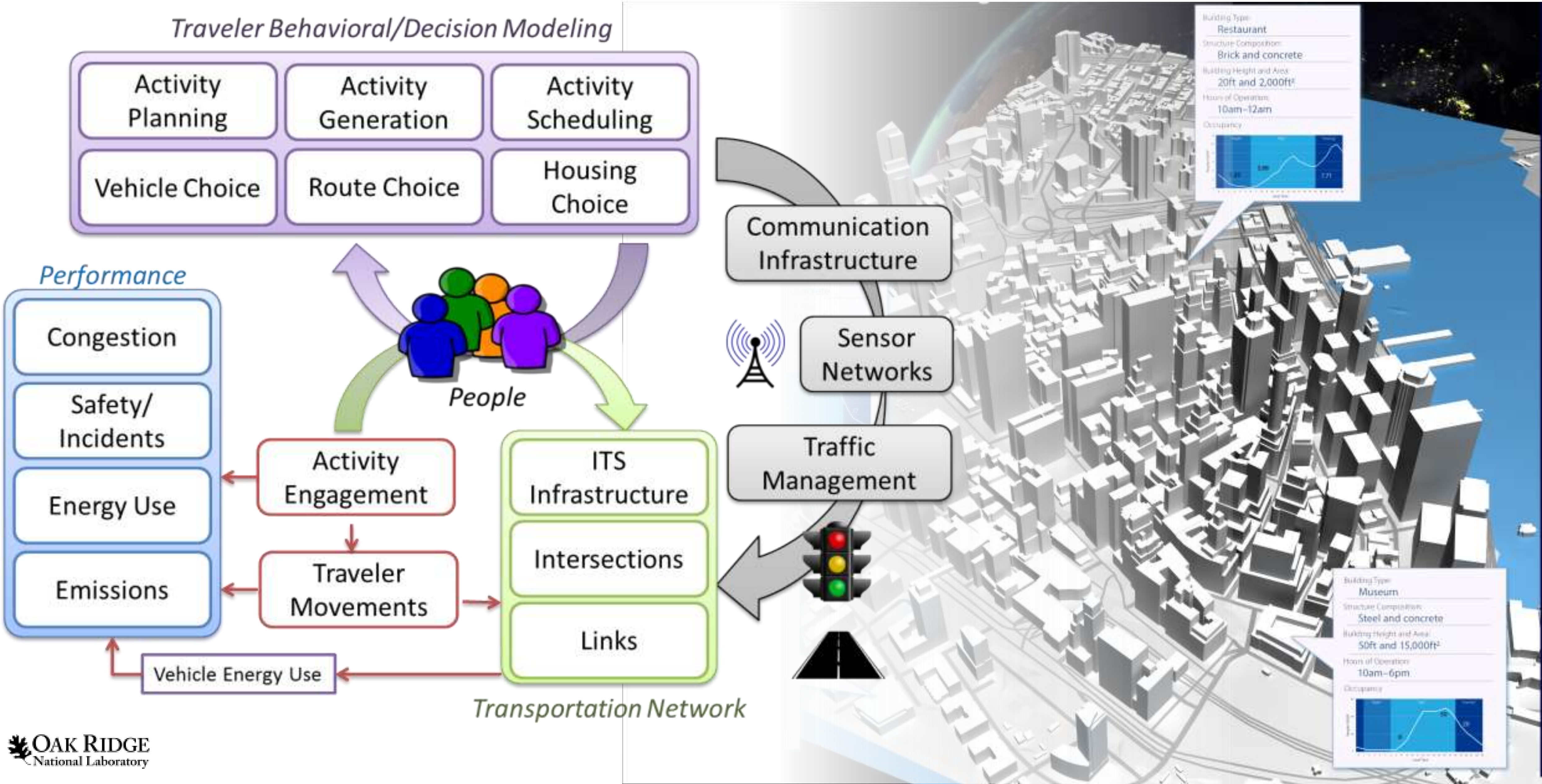
How much ‘control; do we really have?

Can we run AI on the device?
- How much compute resource are needed?
- How much power?
- How much bandwidth?

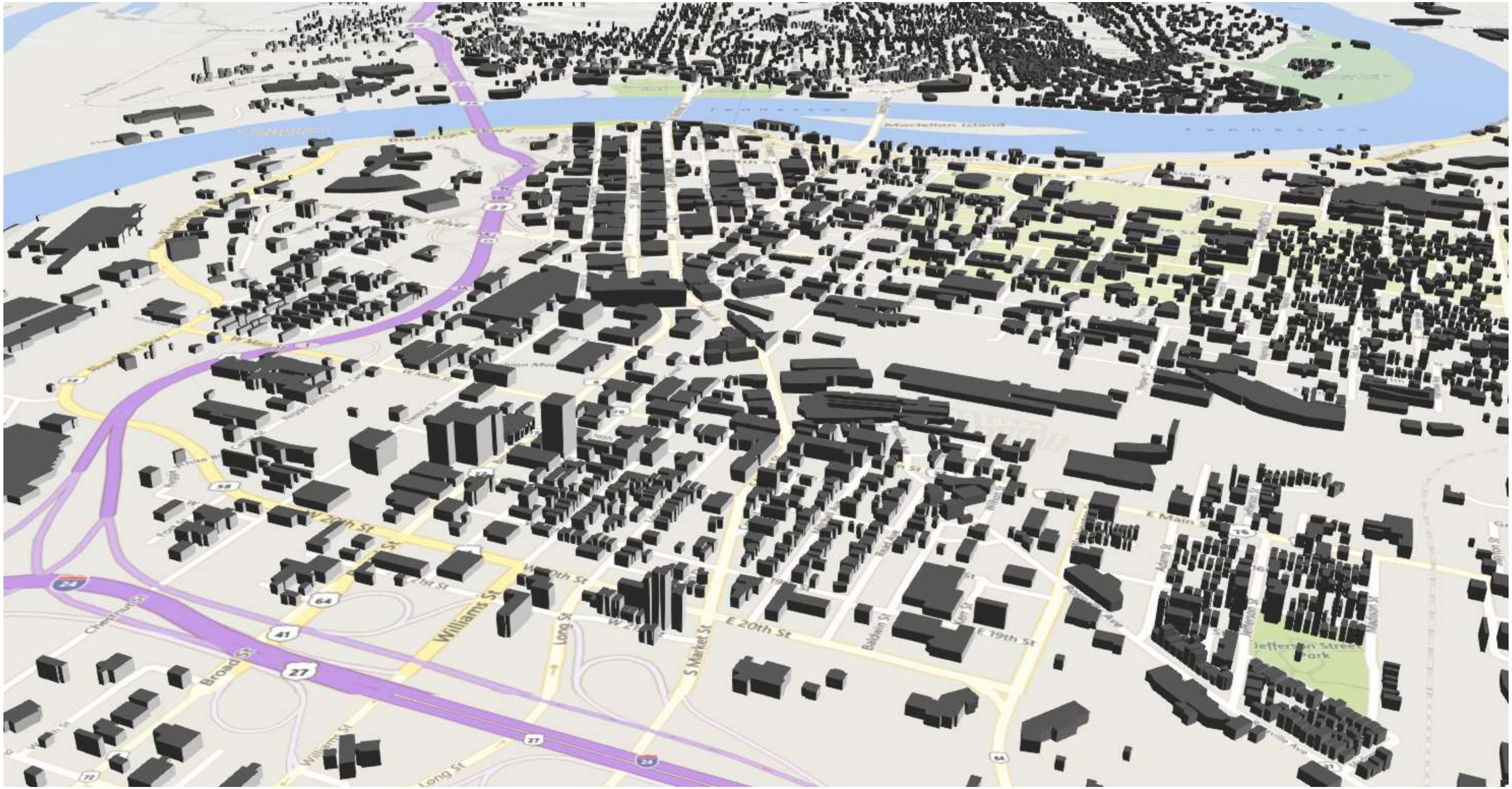
How do we degrade gracefully?

How do we assure sensor sanity?

Integrated Simulation of Travel Behavior

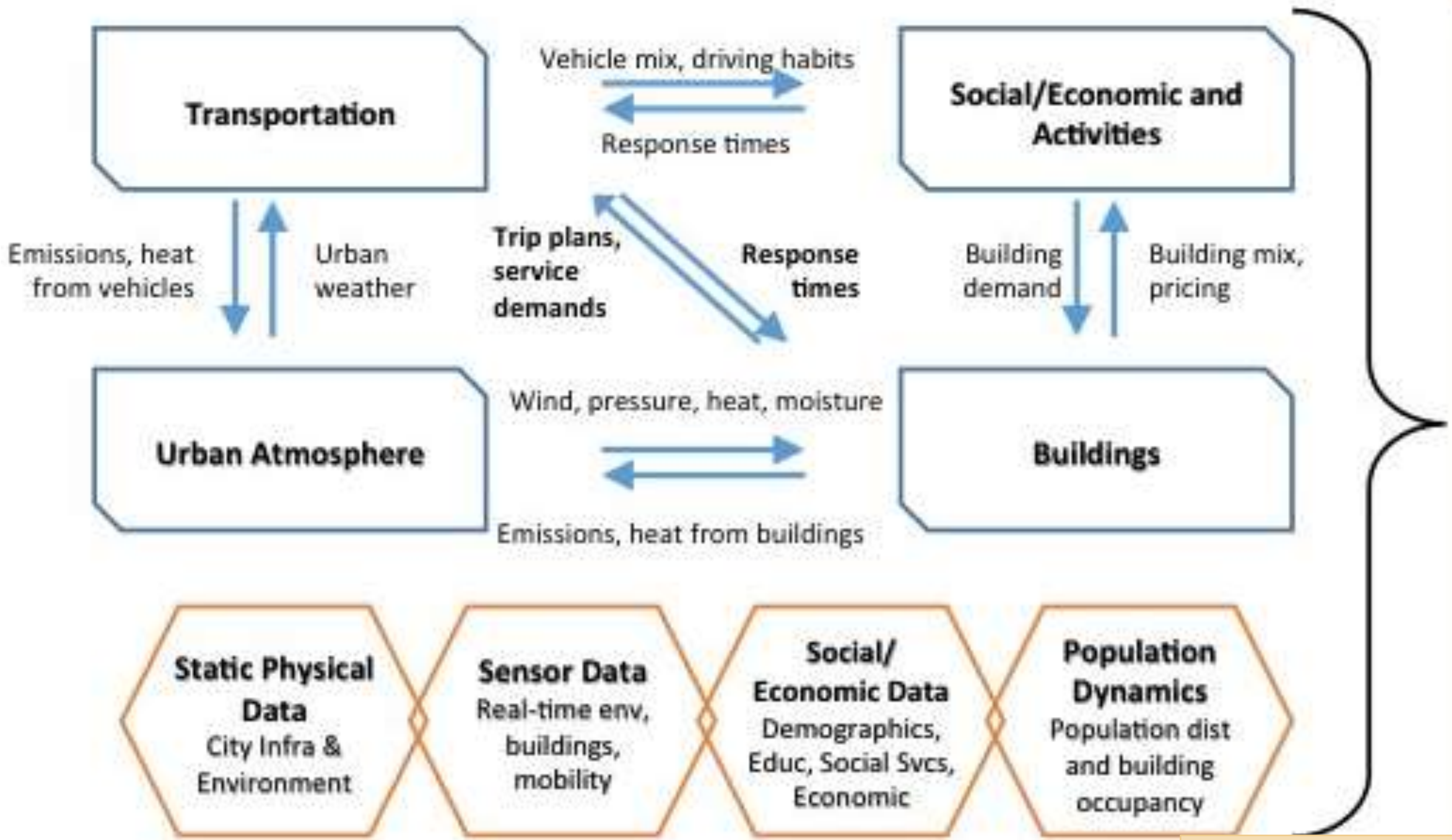


Digital Twin of an Electric Utility – Virtual EPB



Graphic Courtesy: Joshua New

Towards Integrated Co-Dependent Smarter Systems



Urban Science
Climate/Microclimate
Transportation
Buildings
HPC
Big-Data
Sensor Data
Simulation
Visualization
Situational Awareness
Machine Learning

Nexus: Electricity, Water, Land Use, Telecommunications

Smart Decisions in Practice

Graphic Courtesy: Airton Kohls

Thank you!

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