

# Geocomputational Capabilities for Multi-Scale Coupled Simulations and Real-Time Data

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Urban Computing Group

Chattanooga, TN  
October 4, 2018

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

# Urban Computing Group



Melissa Allen  
Climate, Resiliency



Jibo Sanyal  
HPC, Visualization



Hussain Aziz  
Transportation



Kuldeep Kurte  
Machine Learning



Ben Liebersohn  
GPUs, Cloud



Anne Berres  
Data, Visualization

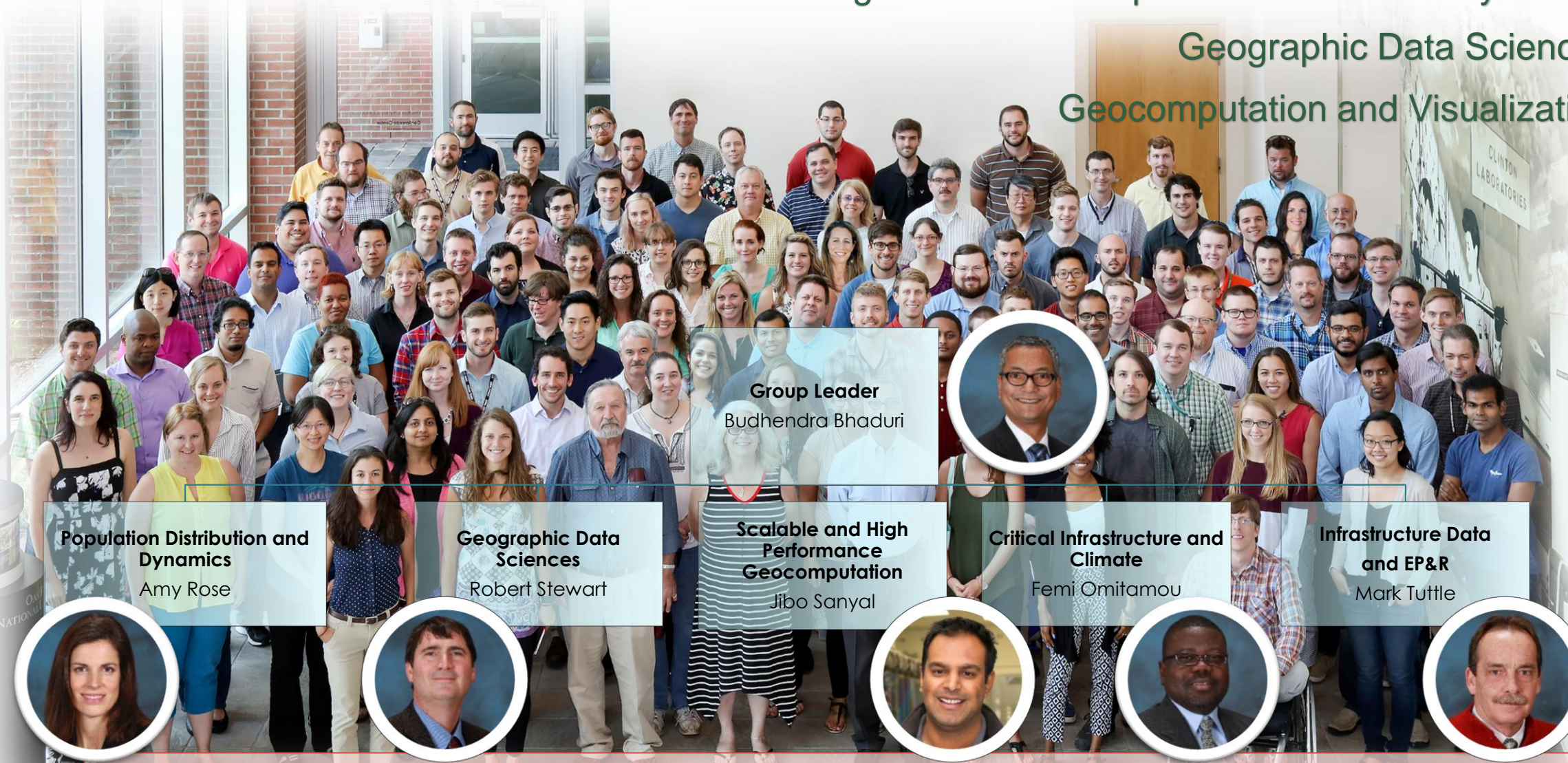
Urban Science  
Climate/Microclimate  
Transportation  
Buildings  
HPC  
Big-Data  
Sensor Data  
Visualization  
Machine Learning

# GIST Scientific focus areas

High Resolution Population and Social Dynamics

Geographic Data Sciences

Geocomputation and Visualization



**Group Leader**  
Budhendra Bhaduri



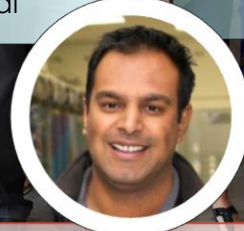
**Population Distribution and Dynamics**  
Amy Rose



**Geographic Data Sciences**  
Robert Stewart



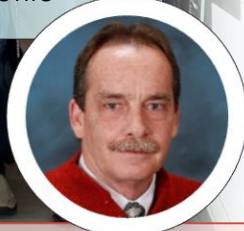
**Scalable and High Performance Geocomputation**  
Jibo Sanyal



**Critical Infrastructure and Climate**  
Femi Omitamou



**Infrastructure Data and EP&R**  
Mark Tuttle



- An interdisciplinary group of 100+ researchers
- Mission: Advance research, development, and applications of geographic information and analysis systems to support the nation's energy, environment, and security programs, from local to global scales.

# Population assessment at scale

## LandScan Global, USA, and HD databases

Geographic  
pattern  
recognition

★ Machine learning

★ HP  
Geocomputation

## Population dynamics

Demographic  
and open source  
data analysis

★ Machine vision

★ Transportation  
simulation

## Population characterization

Spatiotemporal  
data mining

★ Pattern  
recognition

★ HP  
Geocomputation

## Population Density Tables

Open source  
data analysis

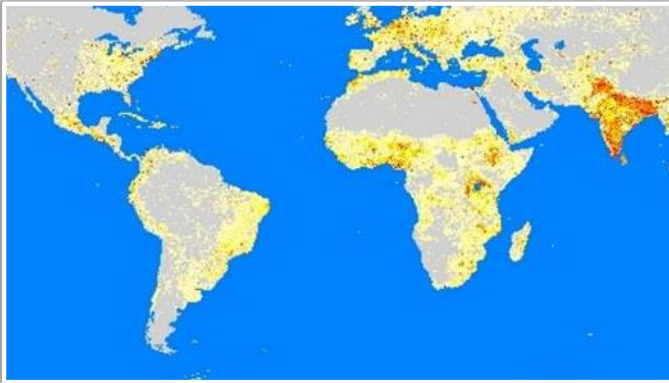
★ Uncertainty  
analysis

★ Visualization

# LandScan Population Project

## Improving Knowledge of Population Distribution and Dynamics

### LandScan Global

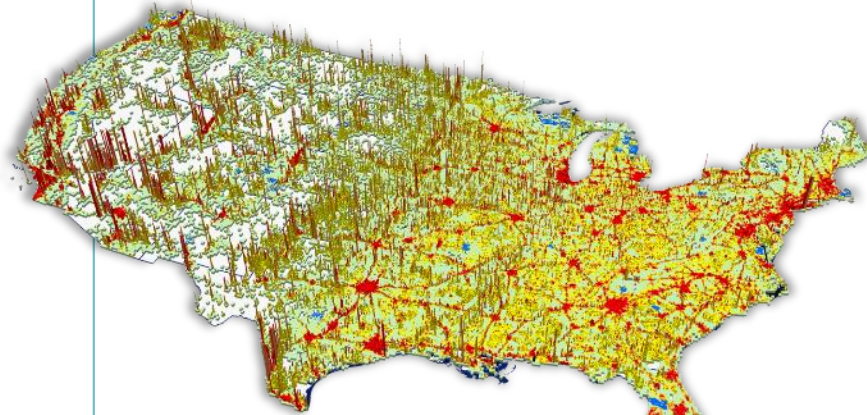


Resolution: 30 arc seconds  
(~1 km)

Ambient population  
(average of 24 hours)

Remote sensing-based global  
data modeling and mapping

### LandScan USA

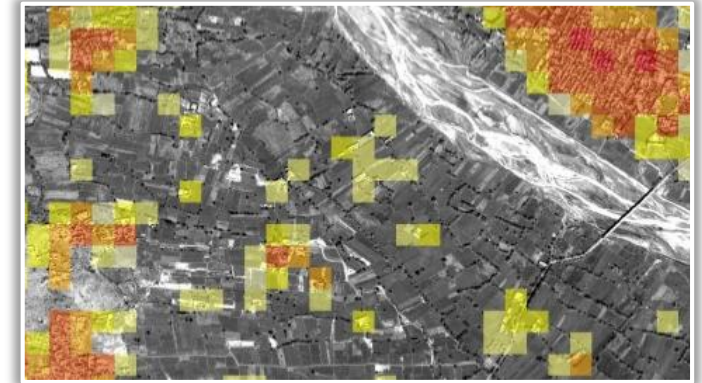


Resolution: 3 arc seconds  
(~90 m), US coverage

Nighttime and daytime  
population

Integration of infrastructure  
and activity databases

### LandScan HD (ongoing development)



Resolution: 3 arc seconds  
(~90 m), OCONUS coverage

Residential/ambient  
population

Settlement mapping from very  
high resolution imagery (<= 1m)

Integration of population  
density and activity databases

# Neighborhood, Settlement, and Building Mapping

## Settlement patterns as socioeconomic indicators

**Damascus, Syria**

**Unstructured Settlements**

- Lowest to lower middle income
- Rural migrants

**Very loosely structured**

- Historically ethnic neighborhoods
- Poor residents; displaced in some areas with urban development/tourism

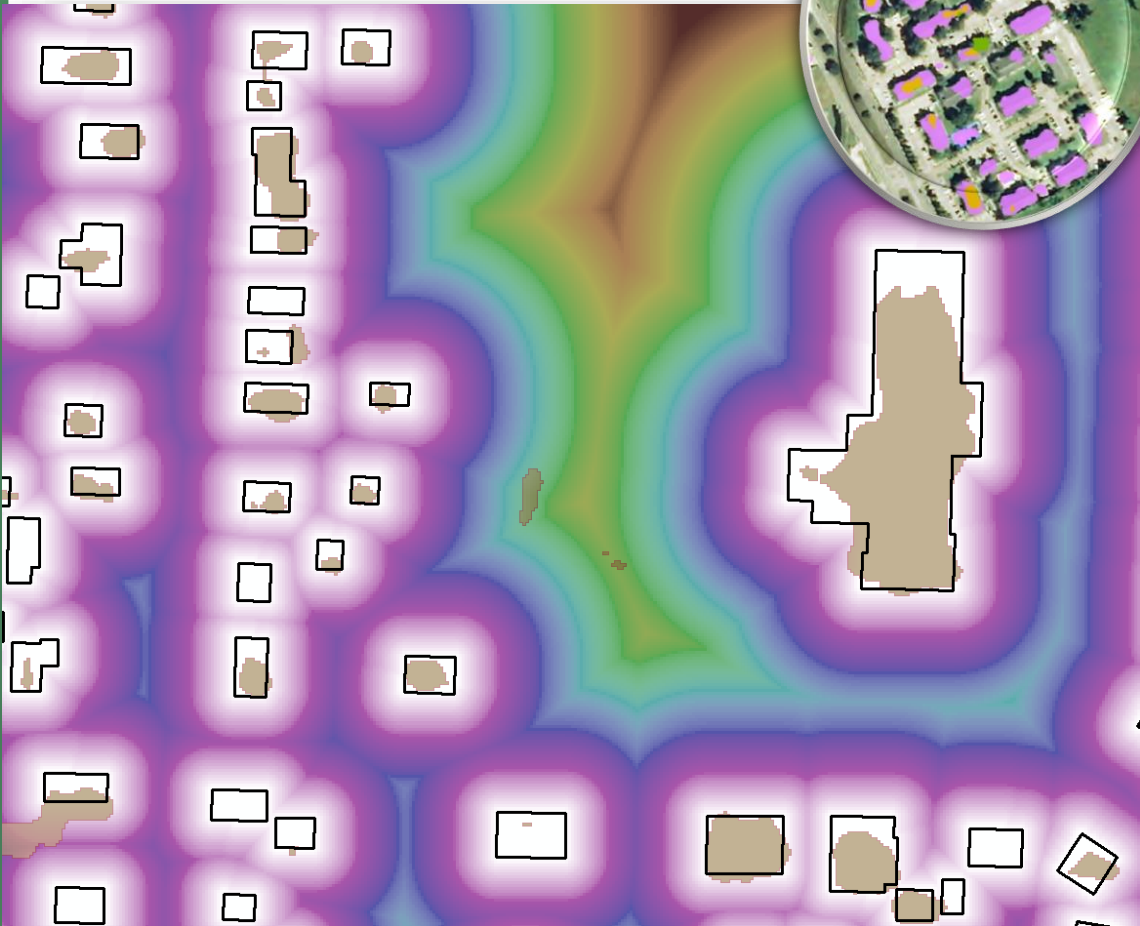
**Formal urban planning**

- Typical urban services
- Middle to upper income

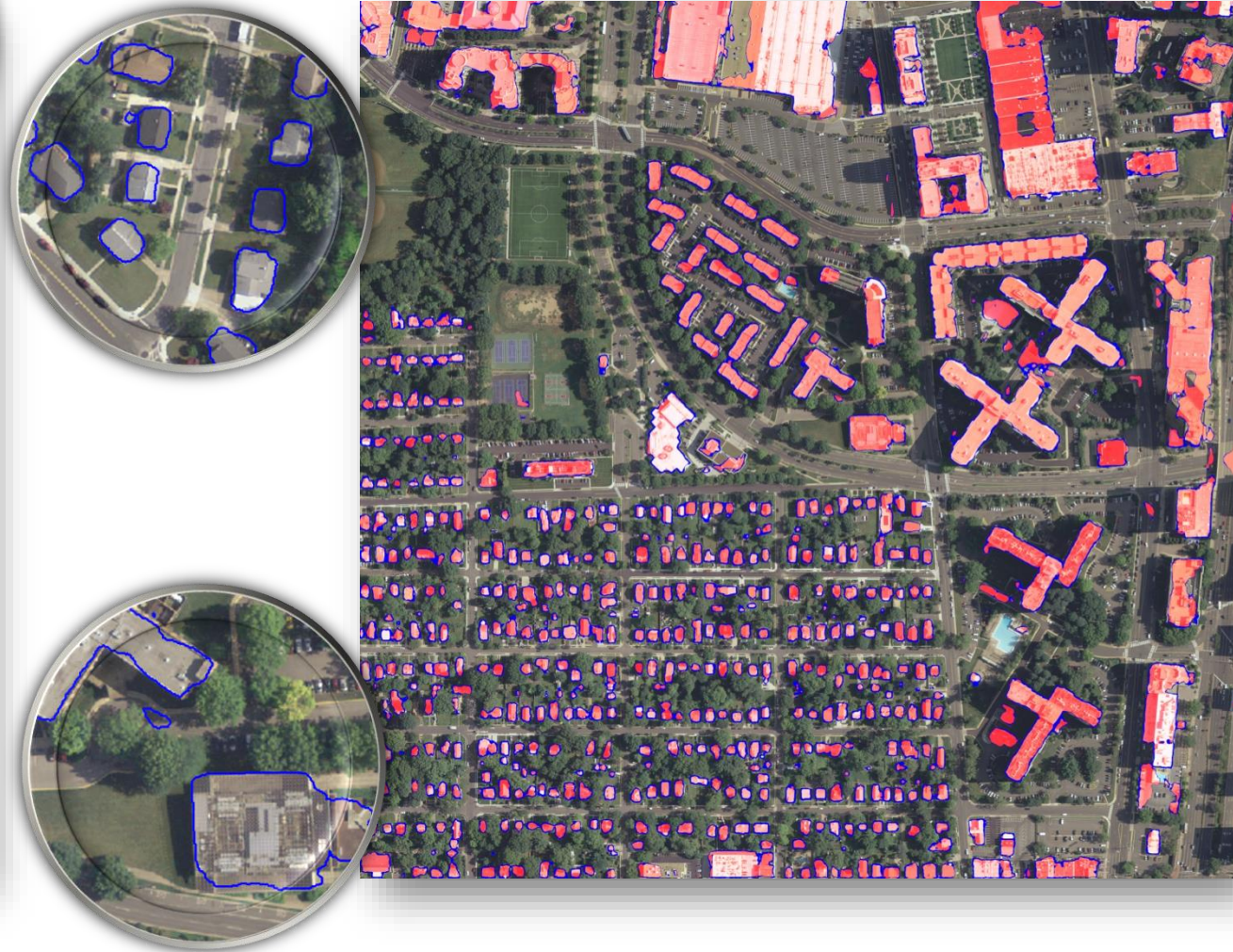
Open slide master to edit

# Detection of buildings with unprecedented accuracy (>95%)

From 1m NAIP imagery



From <1m WV and aerial imagery



# Accelerated Global Human Settlement Discovery

A scalable, **shallow and deep machine learning** training and execution framework for high-resolution geospatial imagery on HPC architectures

25 million core-hours ALCC allocation on Titan

Processed Yemen **in under two hours** using and 4,758 nodes and as many GPUs. There were 4,758 images totaling to 45.5 TBs

Processed Zambia in **3 hours 45 mins.**

Detected all swimming pools in TX in **~10 minutes**

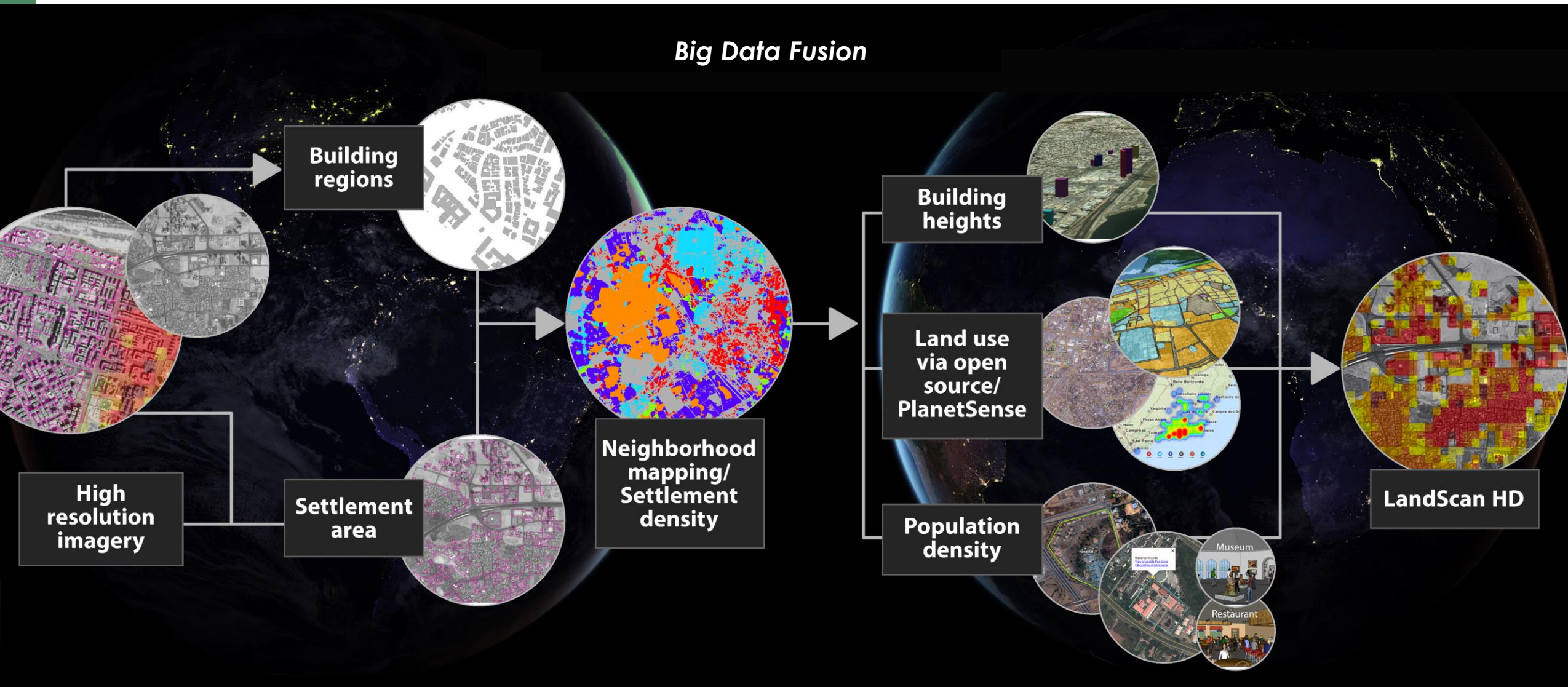
PYTORCH

Caffe





# High Resolution Population Distribution and Dynamics



# Critical Infrastructure Mapping and Analysis

## Mobile home park database

- ★ Pattern recognition
- ★ Machine learning
- ★ HP Geocomputation

## Open energy data layers

- Geographic pattern recognition
- Open source data analysis
- ★ Machine learning

## K-12 schools database

- Geographic and open source data analysis
- Demographic analysis
- Population infrastructure dependency

## Transportation routing analysis

- ★ Transportation simulations
- Population infrastructure dependency
- Demographic analysis

# Foundational Critical infrastructure Data

We develop and maintain spatially enabled, foundation level data for a number of critical infrastructures for research and operational communities.



**Educational  
Institutes**



**Prisons**



**Day-care  
Centers**



**Rail lines/Rail  
points**



**Hospitals**



**Solid Waste  
Landfills**

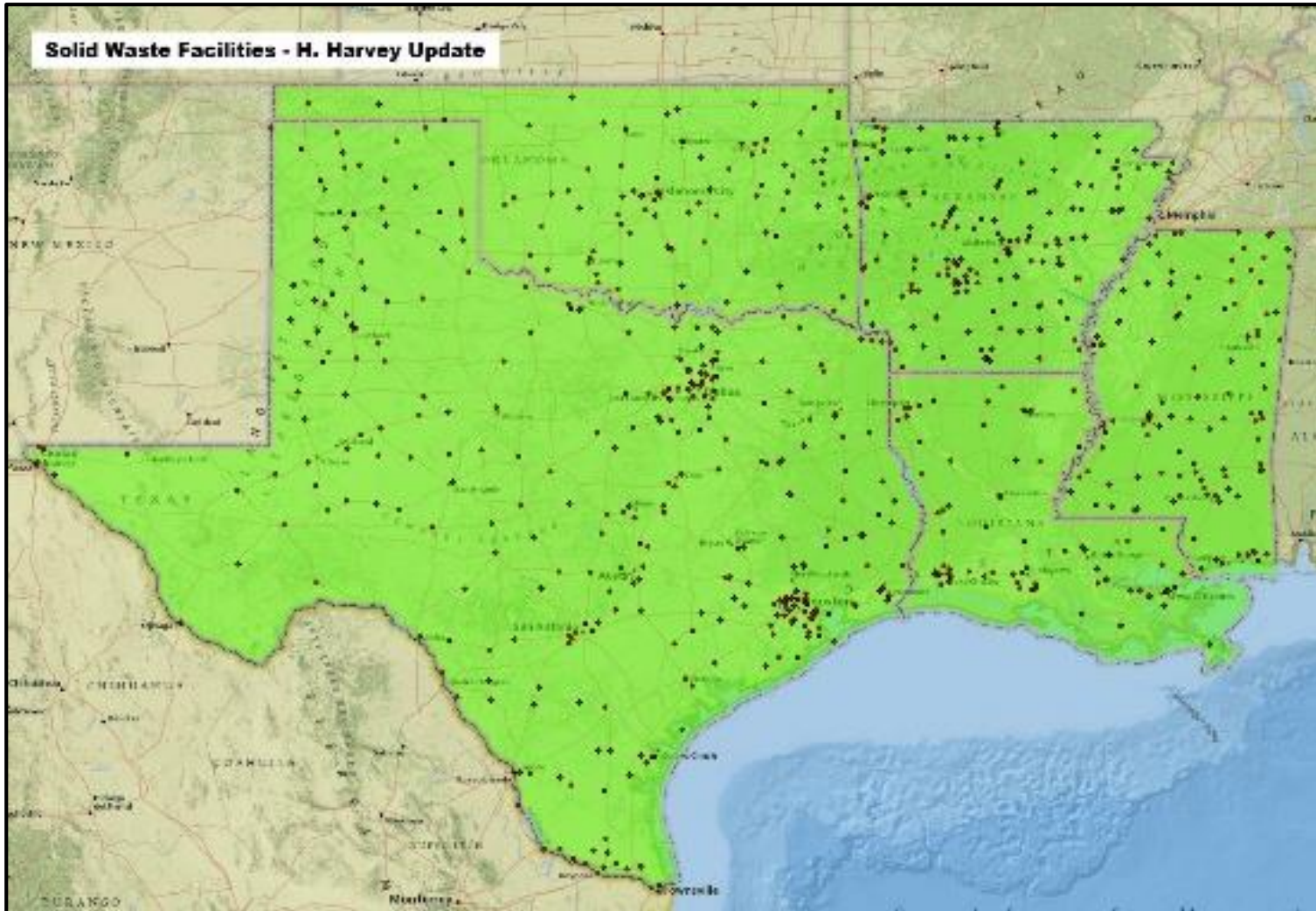


**Mobile Home  
Parks**



**Energy Data  
Layers**

# Solid Waste Facilities delivered on September 8, 2017



<https://respond-harveygeoplatform.opendata.arcgis.com/>  
<https://respond-irma-geoplatform.opendata.arcgis.com/>

# Energy assurance and extreme events

## Biomass monitoring

★ Spatiotemporal data mining

★ Pattern recognition

★ HP Geocomputation

## Energy technology (PHEV) adaptation

Demographic and open source data analysis

★ Geographic pattern analysis

★ Transportation simulation

## EAGLE-I

Open source data integration and analysis

★ Real-Time Situational Awareness

★ Visualization

## Emergency preparedness and response

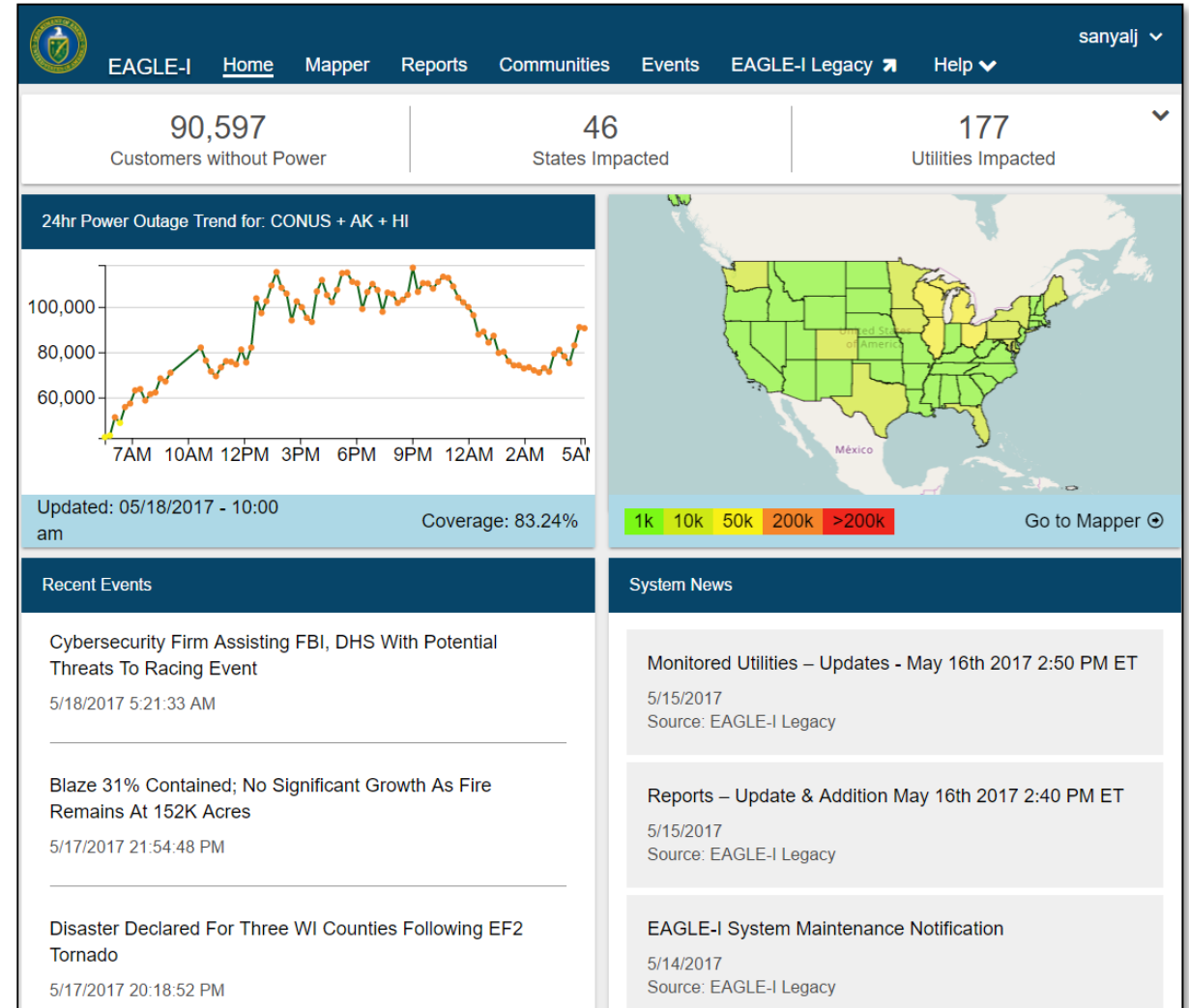
Demographic and open source data analysis

★ Spatiotemporal data mining

★ Visualization

# 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





45,547

Customers without Electricity

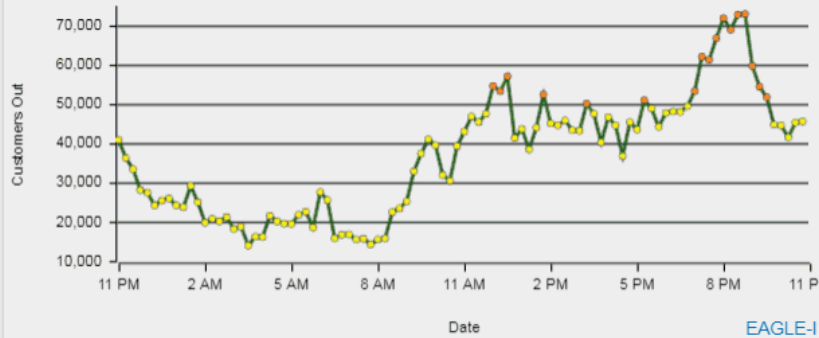
50

States Impacted

158

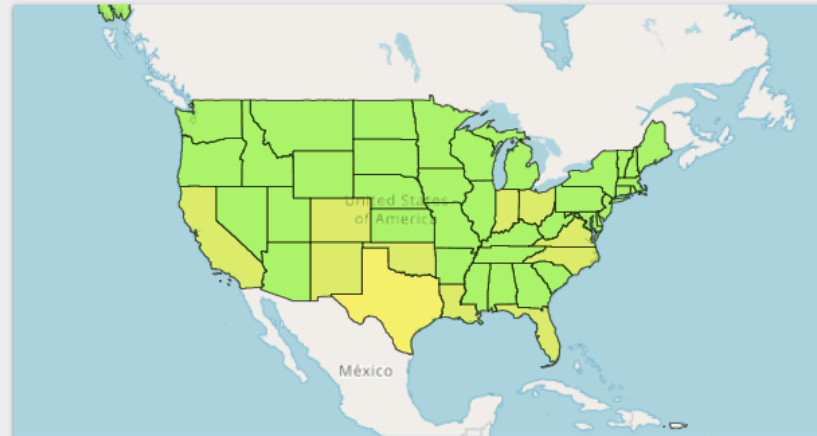
Electric Utilities Impacted

### 24hr Power Outage Trend for: CONUS + AK + HI



Updated: 6/7/2018 10:45 PM

Coverage: 86.85%



1k 10k 50k 200k >200k

[Go to Mapper](#) ↻

### Recent Events

AGT Pipeline Conditions for 5/25/2018

5/24/2018 03:58 PM

ETNG Pipeline Conditions for 5/25/2018

5/24/2018 03:55 PM

TE Pipeline Conditions for 5/25/2018

### System News

Monitored Utilities – Electric Utility Scripts Enabled

6/7/2018 05:47 PM

Monitored Utilities – Electric Utility Scripts Enabled

6/5/2018 07:29 PM

Monitored Utilities – Electric Utility Scripts Disabled

# 55 Data Layers Incorporated

**Boundaries and Places** ^

- FEMA Regions
- Congressional Districts
- DOE Facilities
- Hospitals

**Base Layer** v

- Electricity** v
- Petroleum** v
- Natural Gas** v
- Coal** v
- Weather-NOAA** v
- Hazards-NWS/NHC** v
- Hazards-USGS** v
- Events** v
- Transportation** v
- Boundaries and Places** v
- Population** v

**Electricity** ^

National Outage Map

Outage by **State** v

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FEMA Region Filter

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State Filter

- Control Areas (HIFLD)
- Control Areas (HSIP)
- ISO Regions (HIFLD)
- ISO Regions (HSIP)
- Transmission Lines (HIFLD)
- Transmission Lines (HSIP)
- Power Plants (HIFLD)
- Power Plants (HSIP)
- Electric Service Regions (HIFLD)
- Electric Service Areas (HSIP)
- Substations (HIFLD)
- Substations (HSIP)
- GridEYE Events
- FDR Status
- FDR Frequency

**Petroleum** ^

- PADD
- Production/Flow Status
- Petroleum Pipelines (HSIP)
- Refineries (HSIP)
- Terminals (HSIP)
- Gas Stations (HSIP)
- Alternative Fuel Stations
- Gas Prices

**Natural Gas** ^

- Natural Gas Pipelines (HIFLD)
- Natural Gas Pipelines (HSIP)
- Compressor Stations (HIFLD)
- Compressor Stations (HSIP)
- Processing Plants (HIFLD)
- Processing Plants (HSIP)

**Coal** ^

- Coal Mines
- Coal Regions

**Weather-NOAA** ^

- Weather Radar
- Weather Watches / Warnings
- 2017 Total Solar Eclipse

**Hazards-USGS** ^

- Drought
- River Observations
- Earthquakes
- Wildfires
- Wildfire Perimeter

**Events** ^

Start Date: 8/10/2017 End Date: 8/17/2017

- DHS NOC Media
  - Fire
  - Flood
  - Storm
  - Spill
  - Other

**Hazards-NWS/NHC** ^

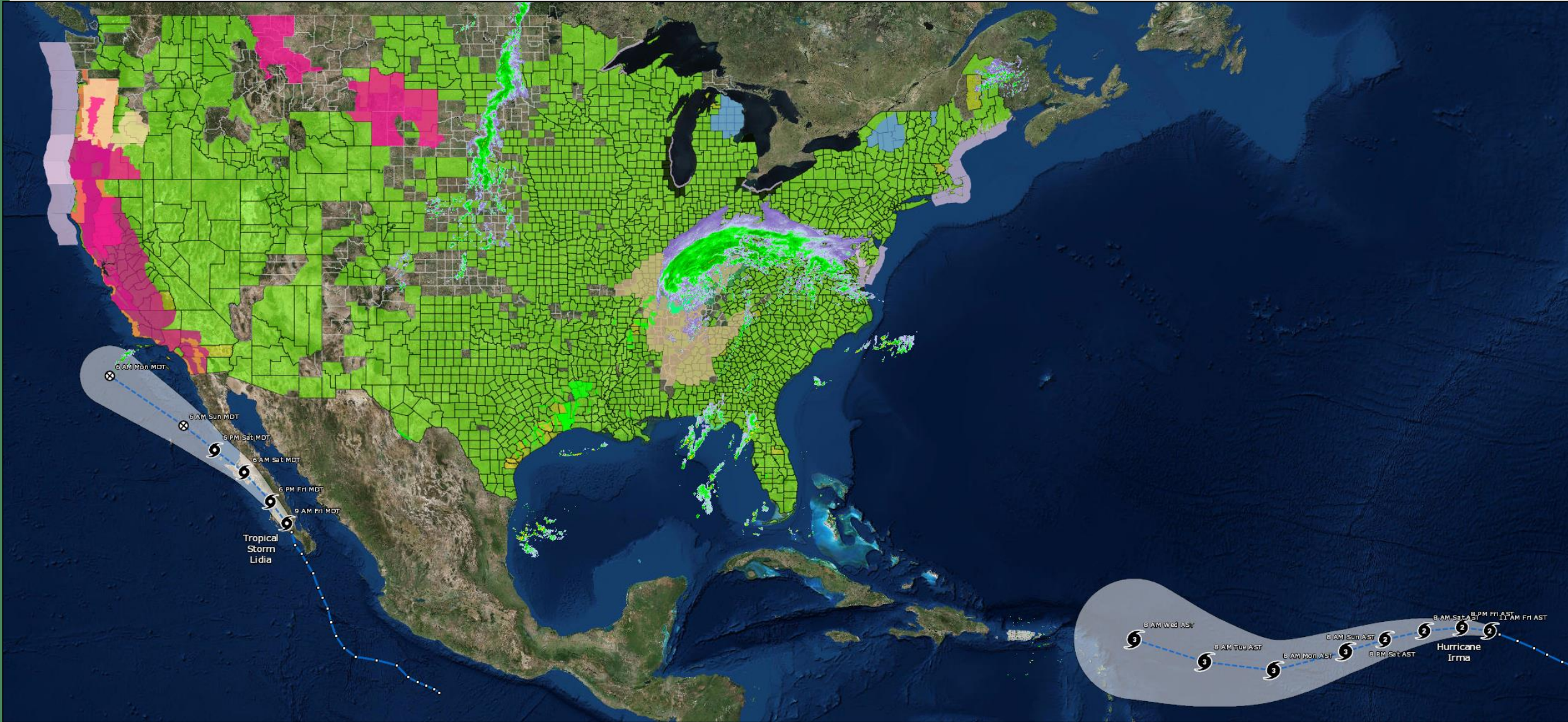
- Tropical Cyclone Track
- Tropical Cyclone 5 Day Outlook

**Transportation** ^

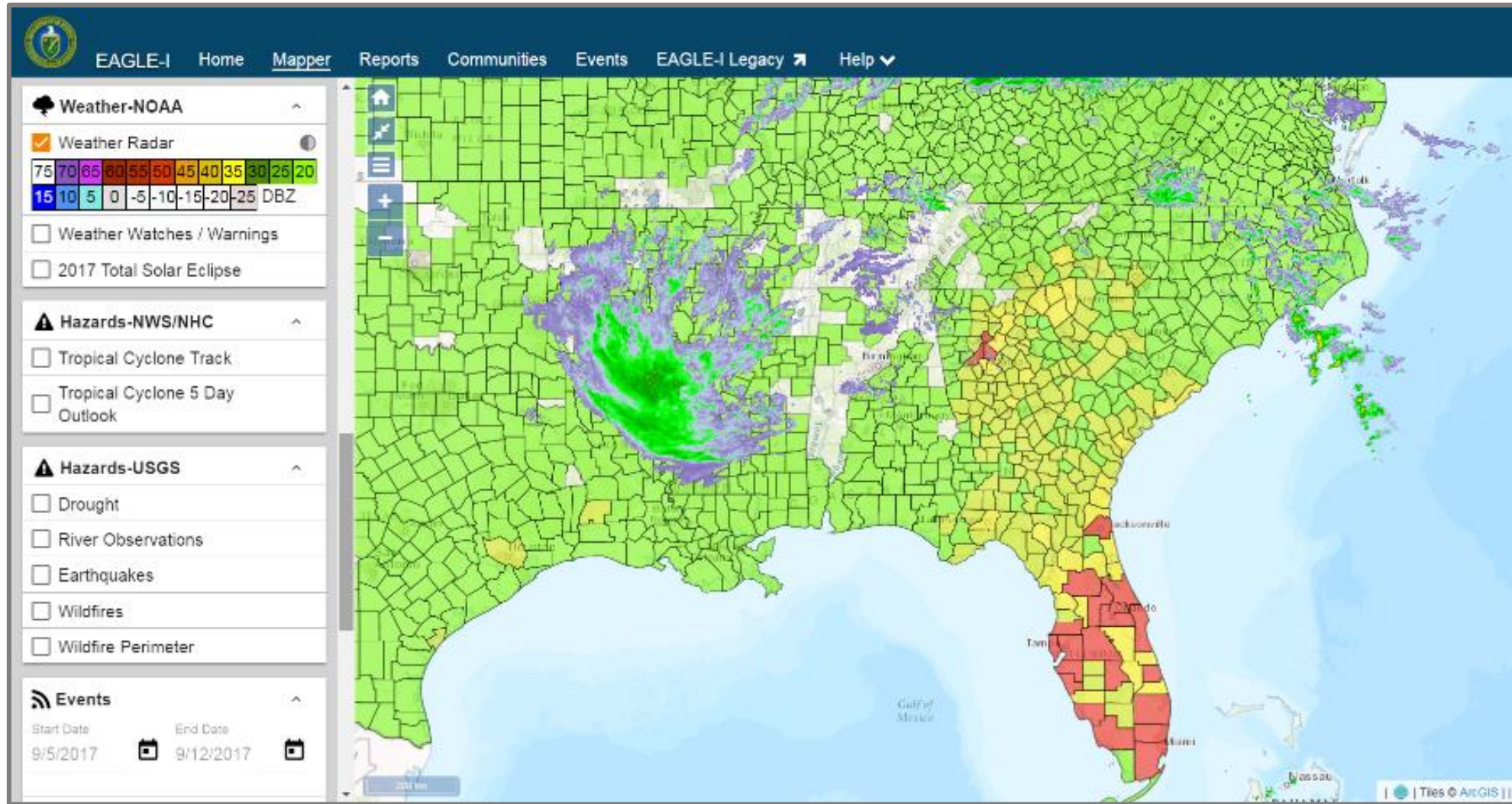
- Navigable Waterways

Layer	Count
<b>FILTERS</b>	
<b>BASE LAYER</b>	4
<b>ELECTRICITY</b>	16
<b>PETROLEUM</b>	8
<b>NATURAL GAS</b>	6
<b>COAL</b>	2
<b>WEATHER – NOAA</b>	2
<b>HAZARDS – NWS/HNC</b>	2
<b>HAZARDS – USGS</b>	5
<b>EVENTS</b>	1
<b>TRANSPORTATION</b>	1
<b>BOUNDARIES AND PLACES</b>	6
<b>POPULATION</b>	2





# 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.

## Data

Improved backend

Improve NOM coverage

Ingest alternate forms of outage data

QA/QC

Historical events and data archive, query-enabled, analysis enabled

Data ingestion improvements

## Models

### Event characterization and analysis

Consequence models

Decision support tools

Outage Impact and restoration estimate models

NOAA ice-storm estimation

Evacuation models

Energy resource transport and commodity flows

**Population impacted** estimation using night lights etc.

**Social media** such as PlanetSense etc.

Automated detection, alerts, and analytics for non-notice events

## Applications

New user interface (with OpenLayers/D3/etc using RESTful backend)

Downloadable and offline-usable layers

Mobile-friendly

Custom analytics query interface.

Portal Setup

Collaboration – User community framework

On the ground image capture and collaboration

## Infrastructure

Stand up dev-test-deploy environment

Improved access control

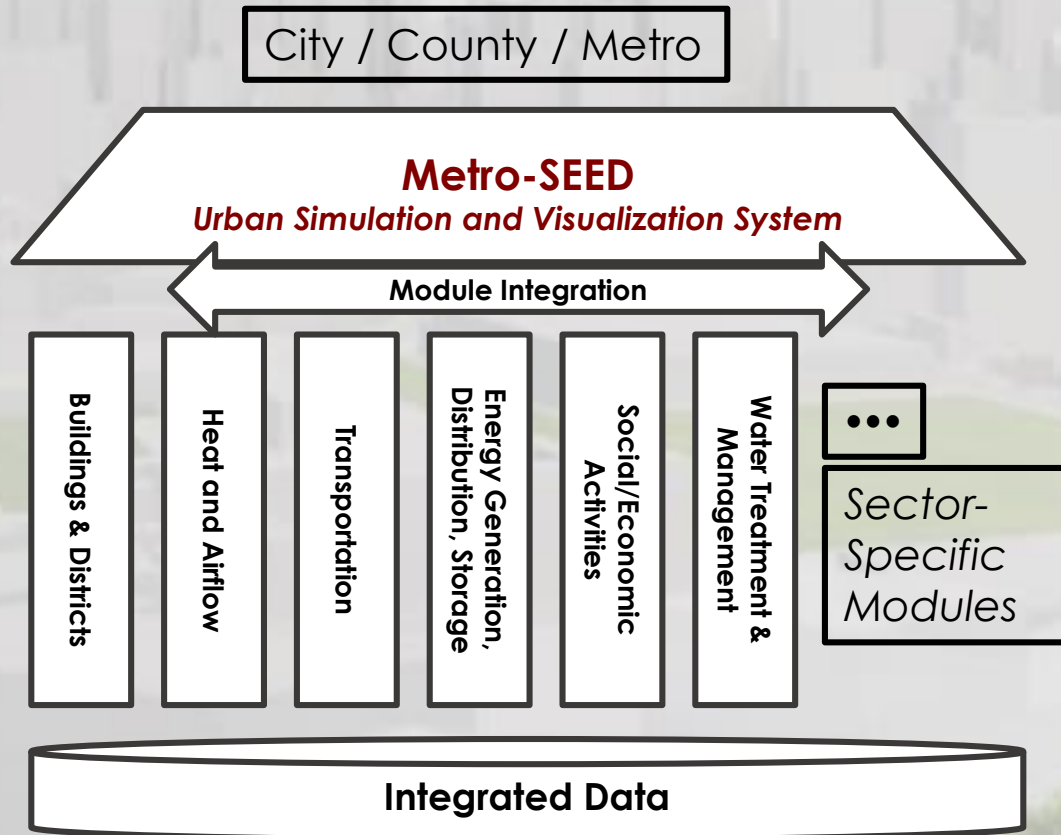
Automatic failover

Performance scale up

Cyber-threat/vulnerability assessment

Model integration framework

# Exascale Computing Project: Holistic Urban Modeling

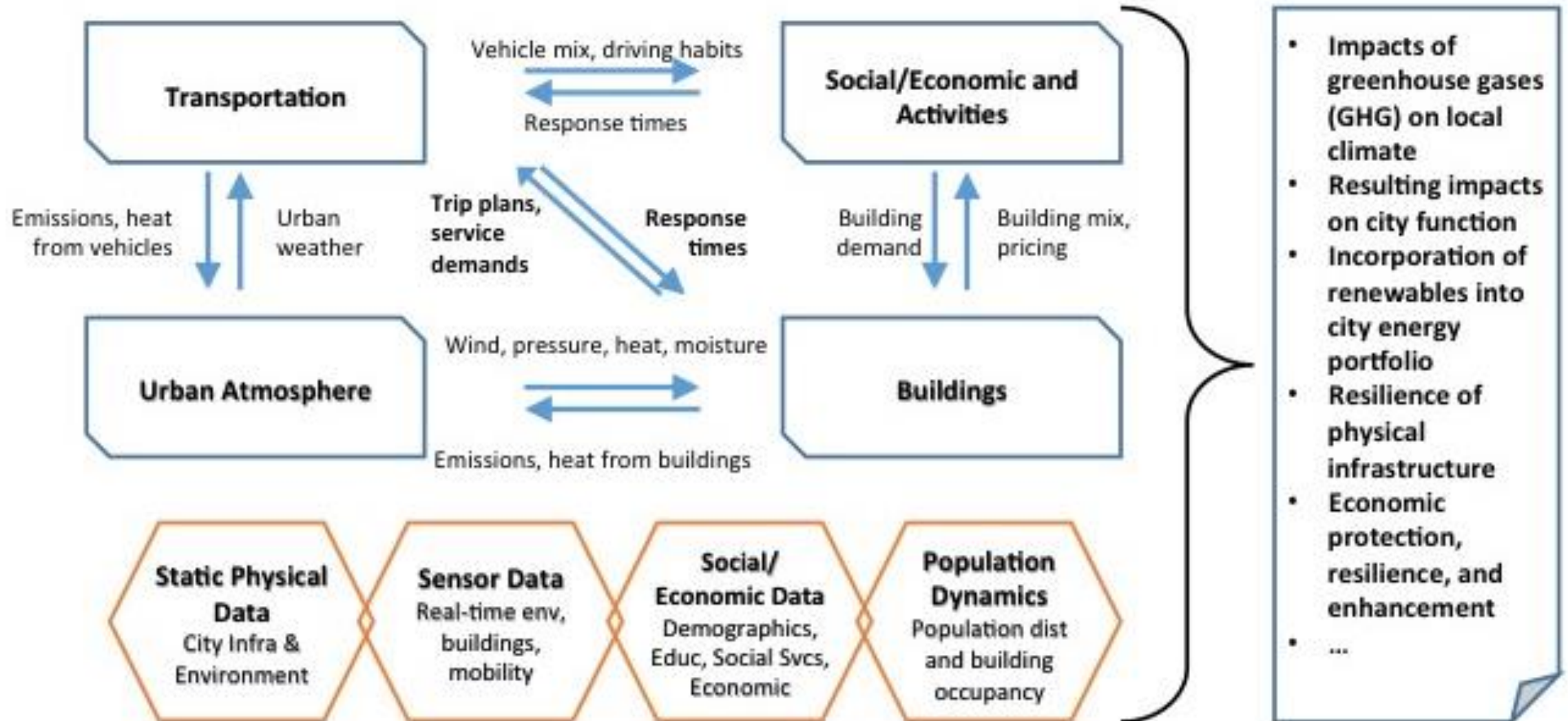


5 Lab effort: ANL, ORNL, LBNL, NREL, PNNL

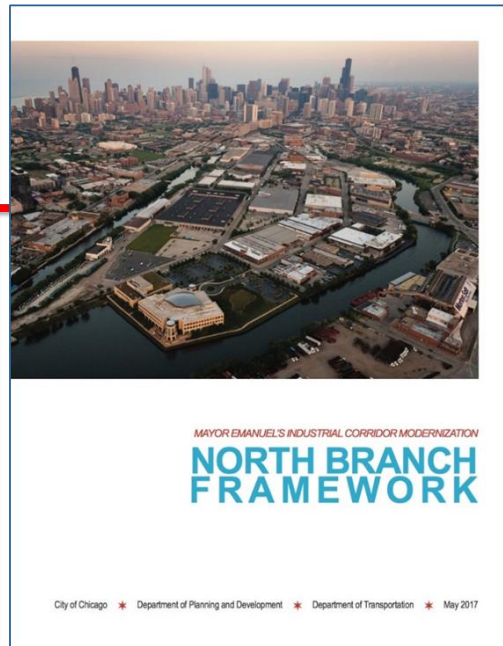
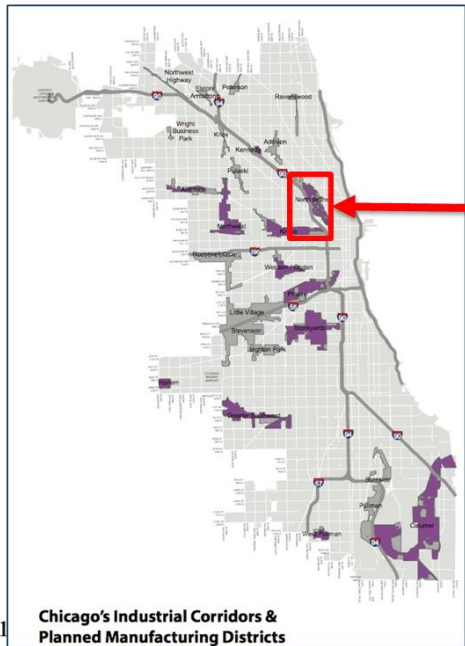
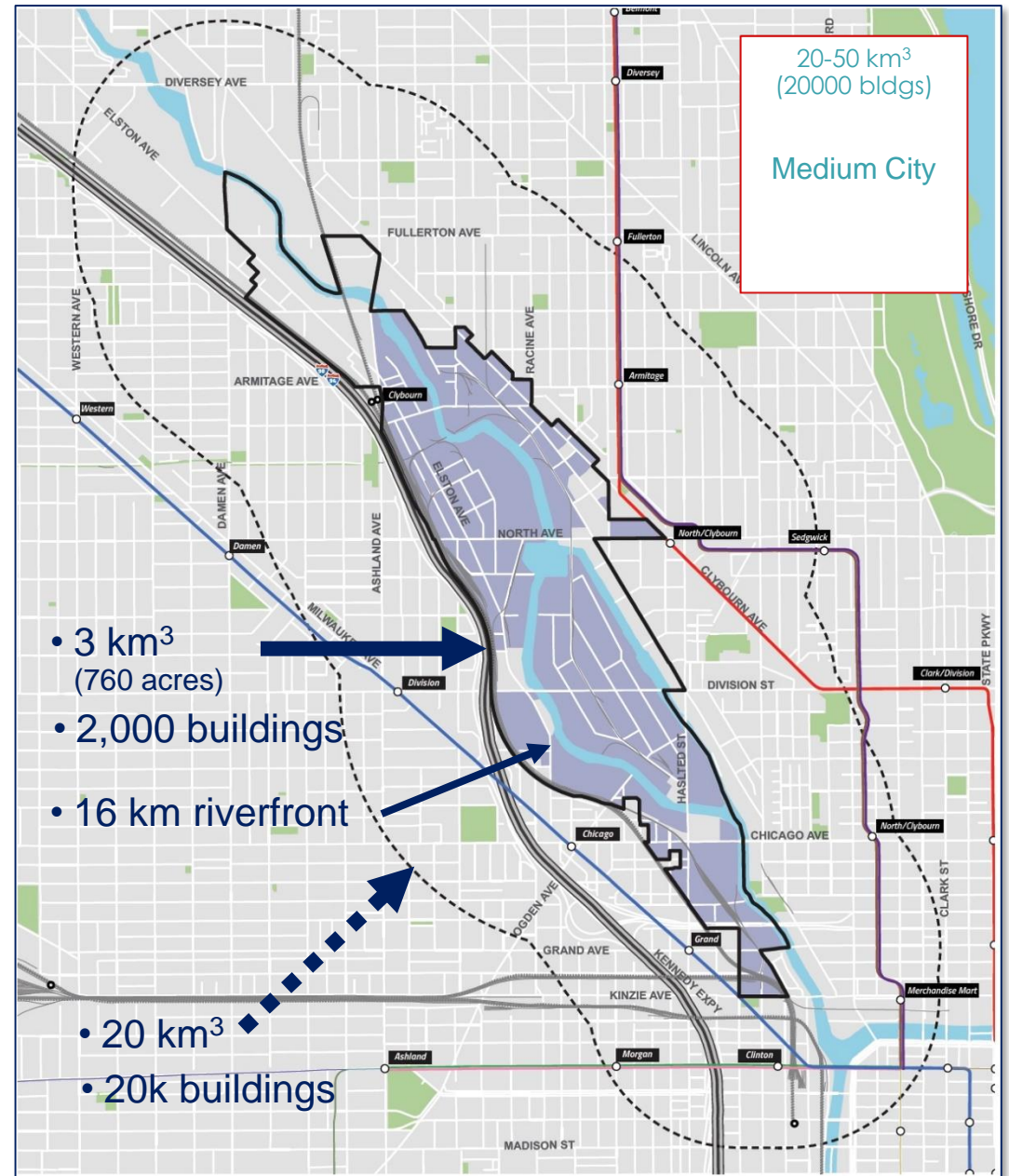
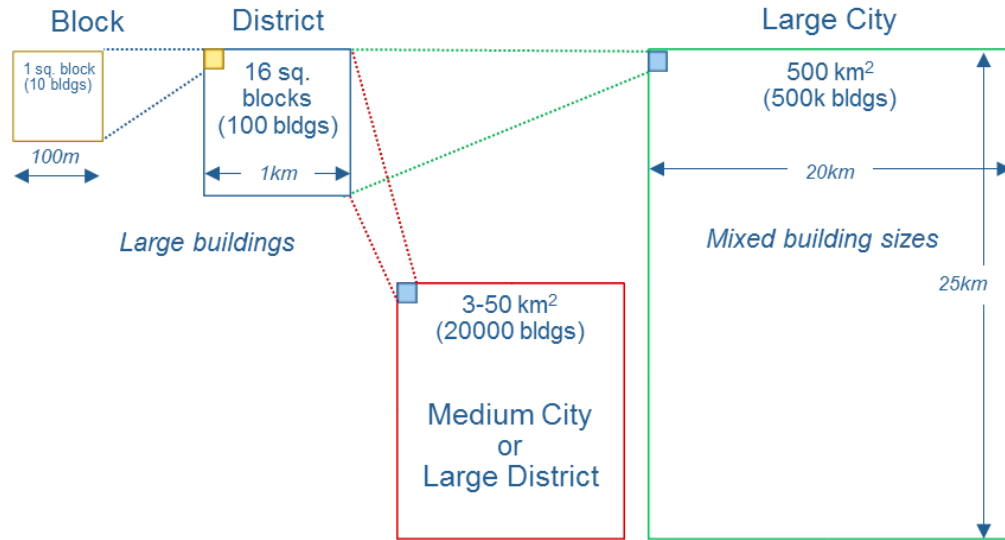
- Coupled **multi-scale** models
- **Three focus areas**
  - Urban weather/micro-climate
  - Socio-economics and transportation
  - Building and district-scale energy
- Characterization and optimization of district performance **over decades**



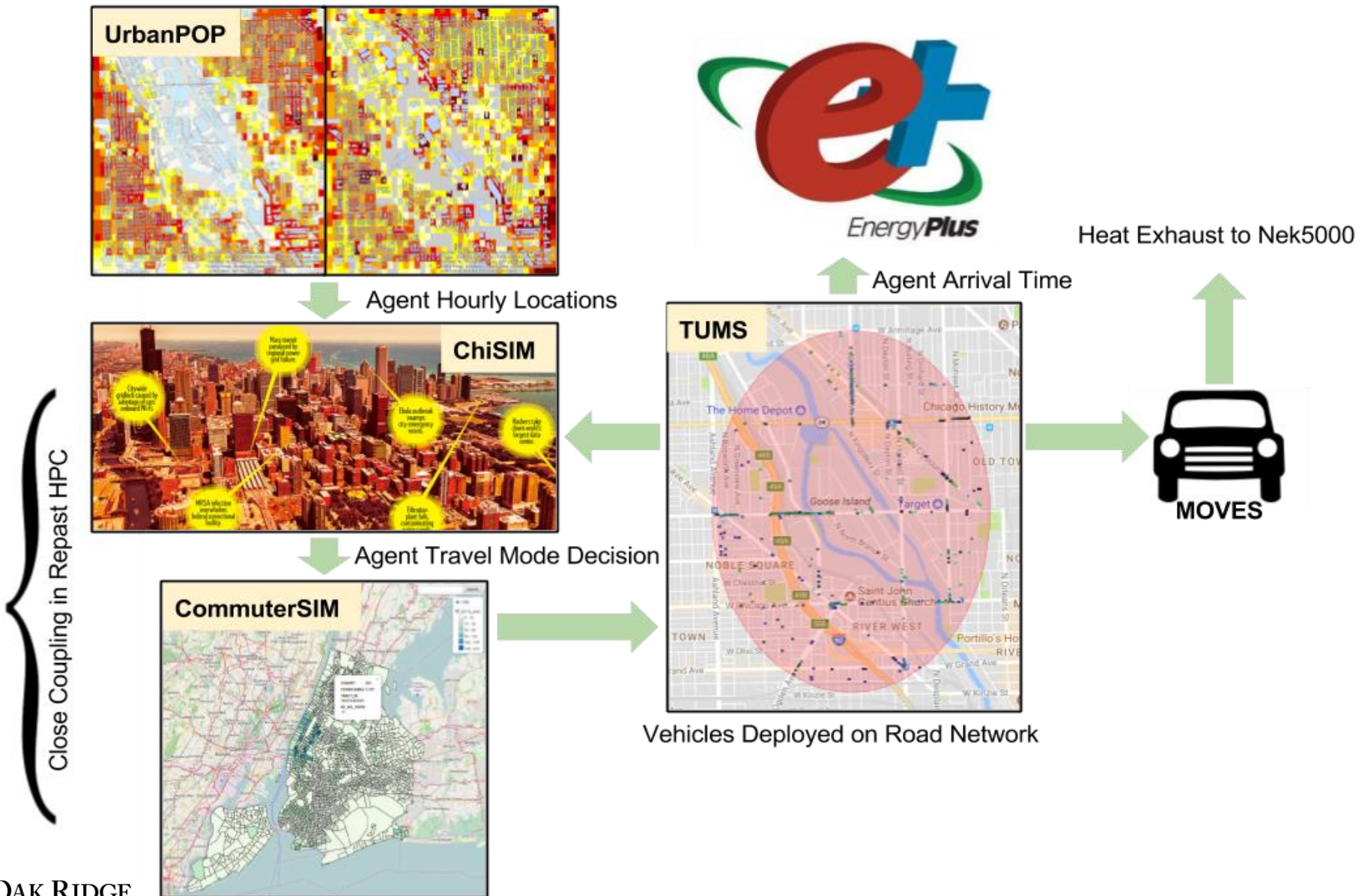
# Interaction of Urban Systems



# Chicago North Branch

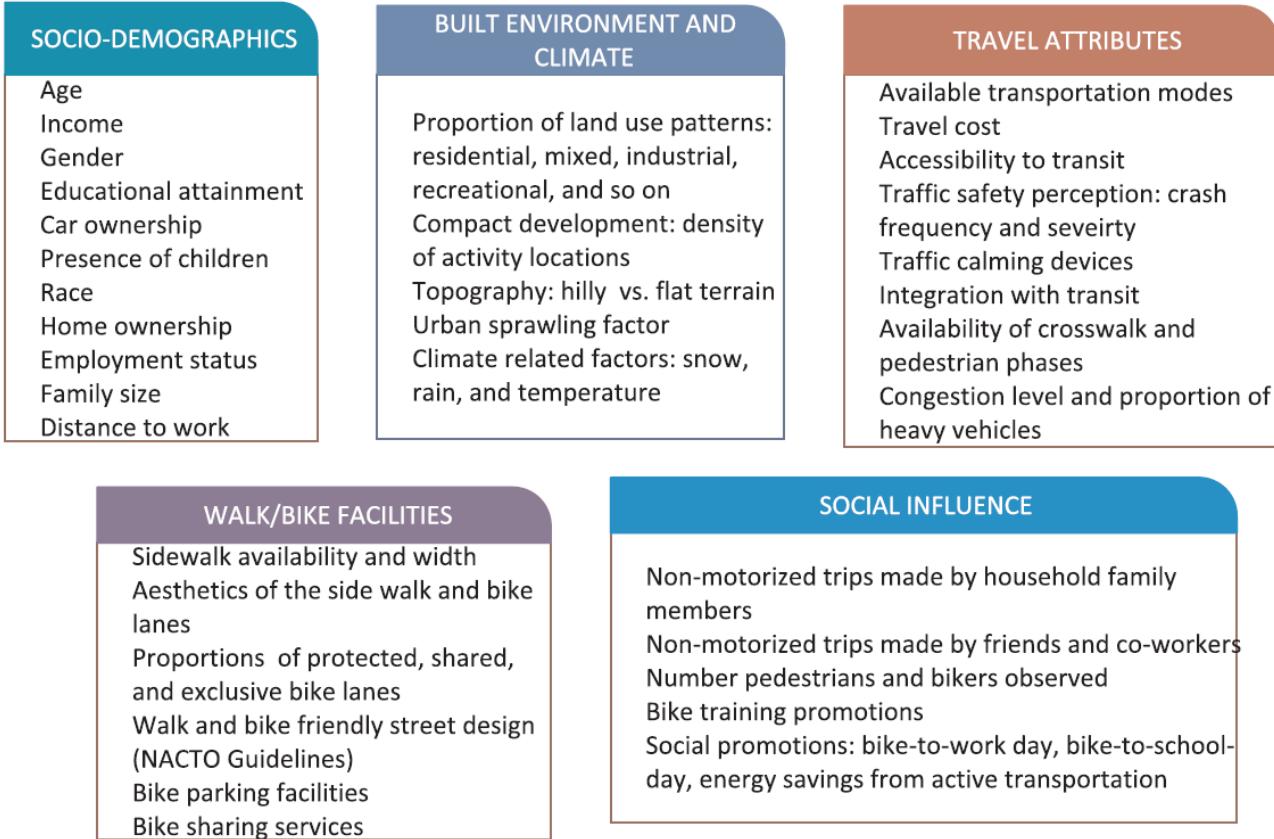


# Socio-Economic Modeling and Data Flow



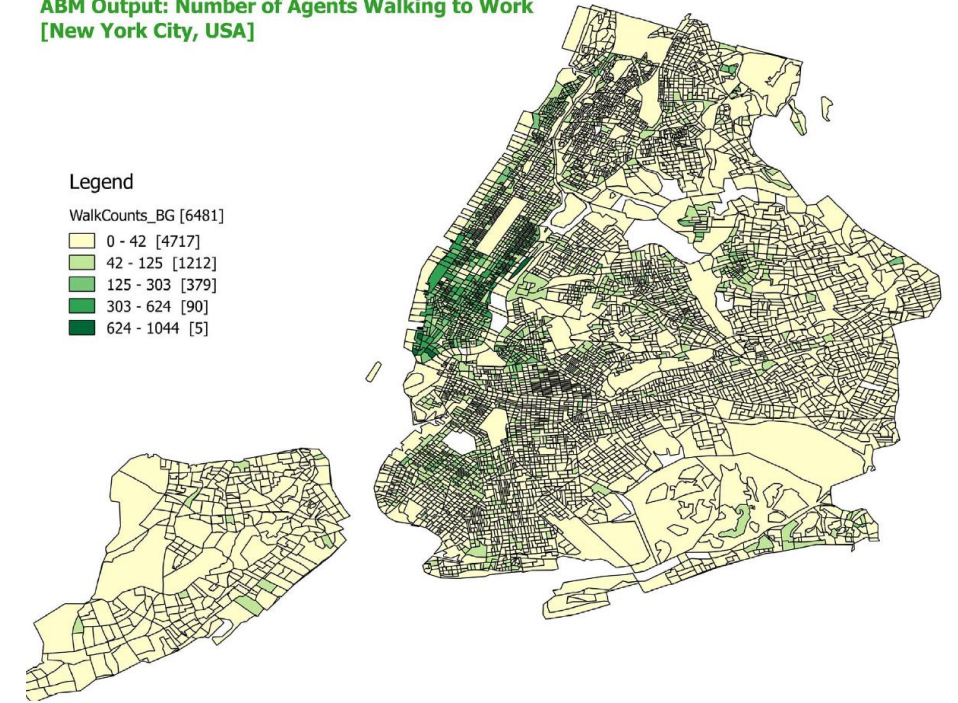
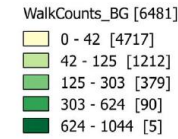
- How will competing district-scale designs, zoning, and transportation changes impact energy use? Water supply requirements? Storm and sewer networks? Microclimate? Traffic congestion? Job growth?
- How will distributed energy storage impact generation and distribution requirements?
- How will green infrastructure (roofs, new parks, etc.) or district-scale building configurations impact urban airflow?
- What is the impact of adding dedicated transit lanes?
- How would energy use change if human behavior with regards to decisions about commute options and commute times are altered?

# CommuterSIM ABM Framework



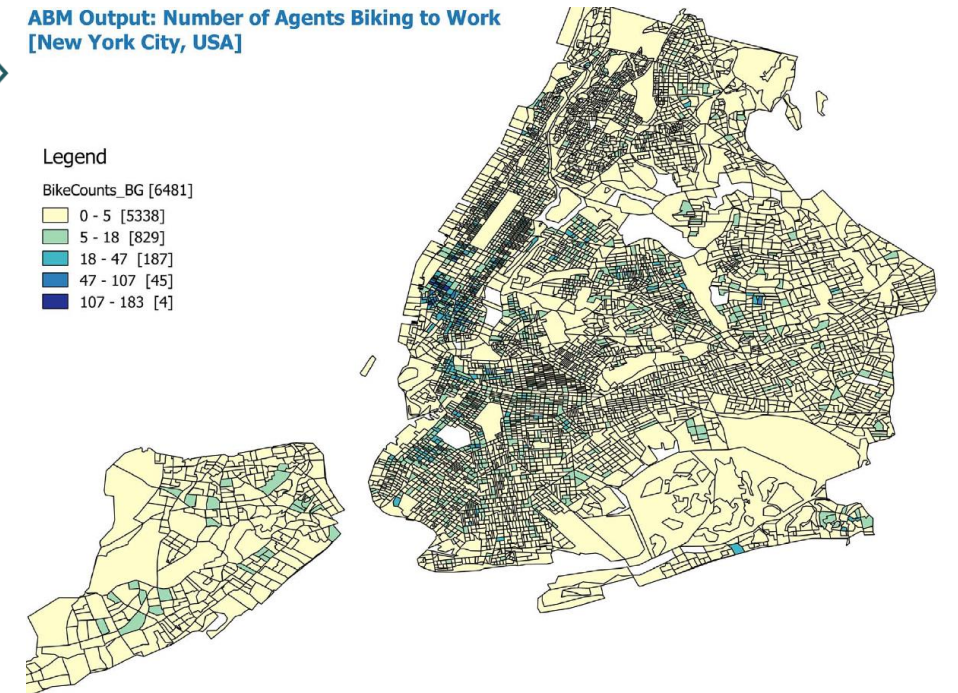
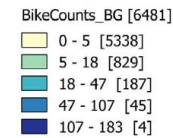
ABM Output: Number of Agents Walking to Work [New York City, USA]

Legend



ABM Output: Number of Agents Biking to Work [New York City, USA]

Legend

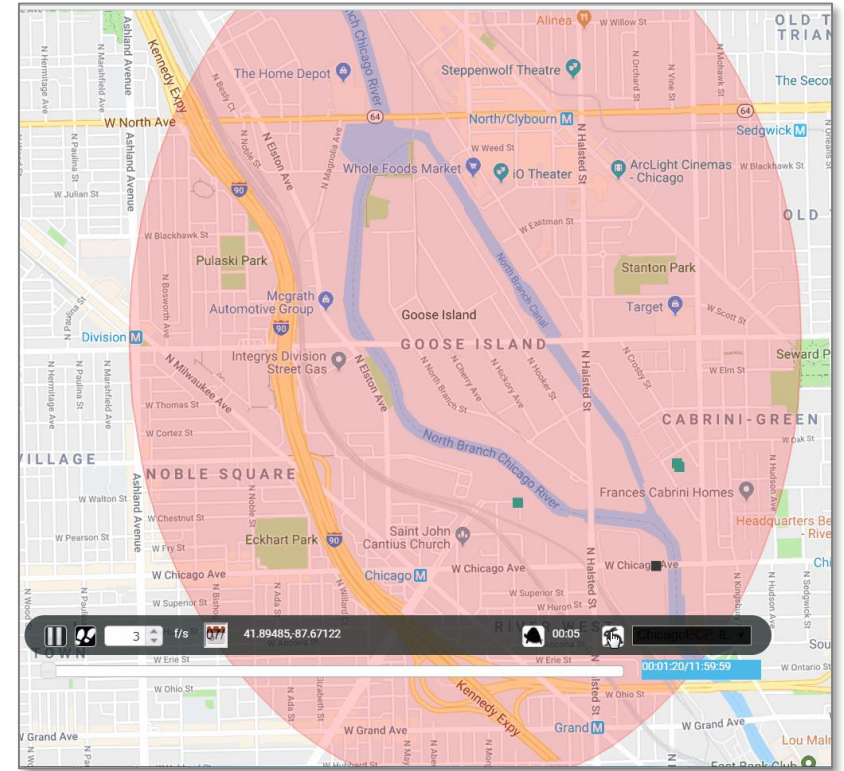
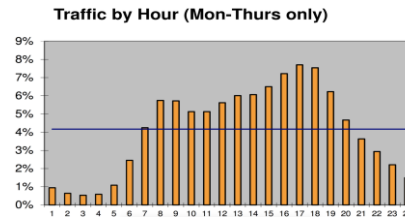


Factors affecting mode choice

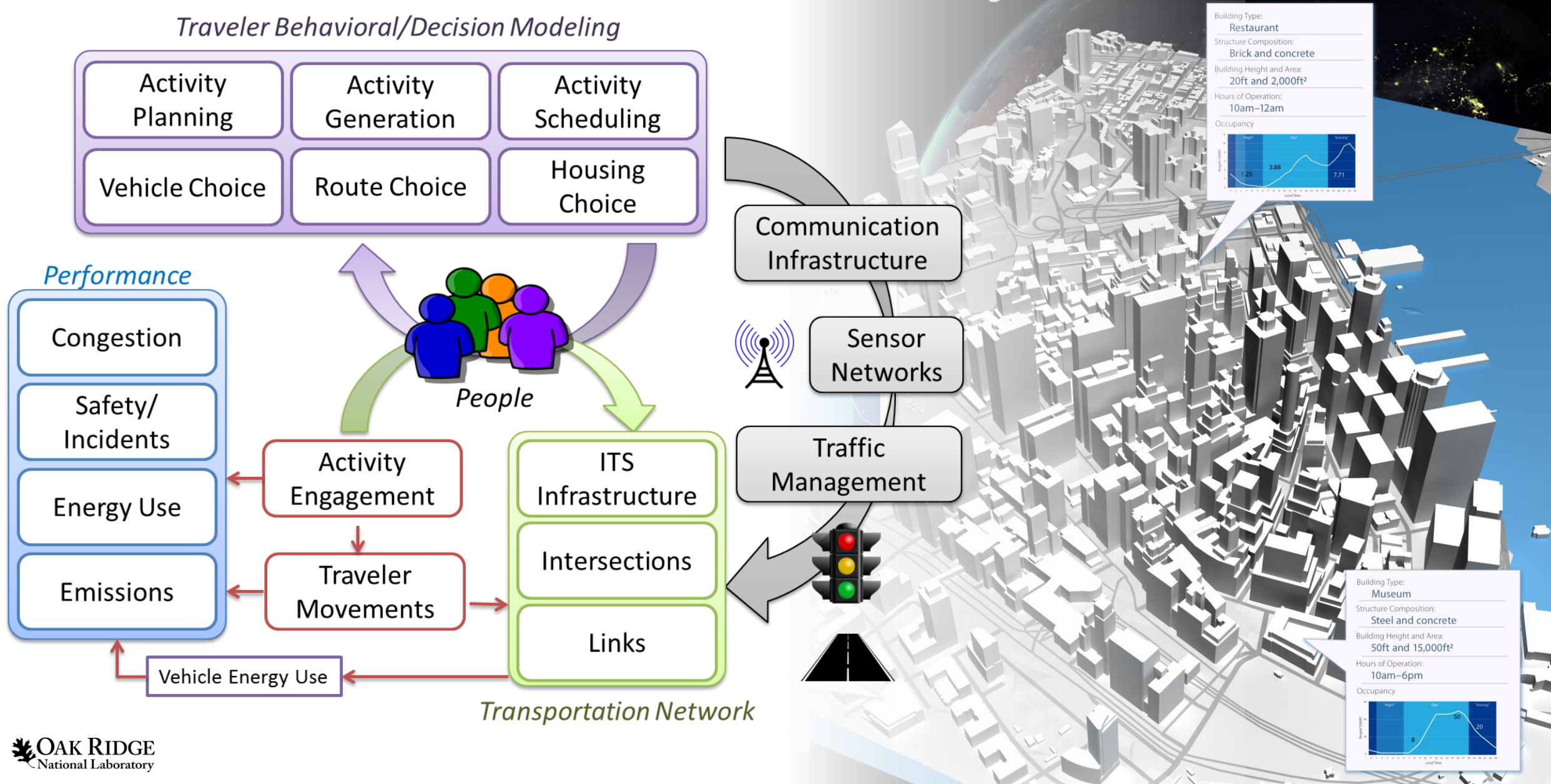


# Toolbox for Urban Mobility Simulation (TUMS)

- Microscopic approach using socioeconomic input to show high-resolution traffic activity
- Chicago North Branch scenario
  - Used LandScan USA 2016 population data
  - Open Street map for Chicago loop and North Branch
- Init data from IL DOT
- Titan runs:
  - Commute and evacuation scenarios
  - Evacuation scenario, runs in **4m 50s**
    - ~300,000 vehicle agents, 2.3 GB, 1 sec resolution output
  - Daily commute scenario for 3 years in, **1 hr 50m**
    - ~300,000 vehicle agents, 40GB, hourly output



# What's next: Integrated Simulation of Travel Behavior



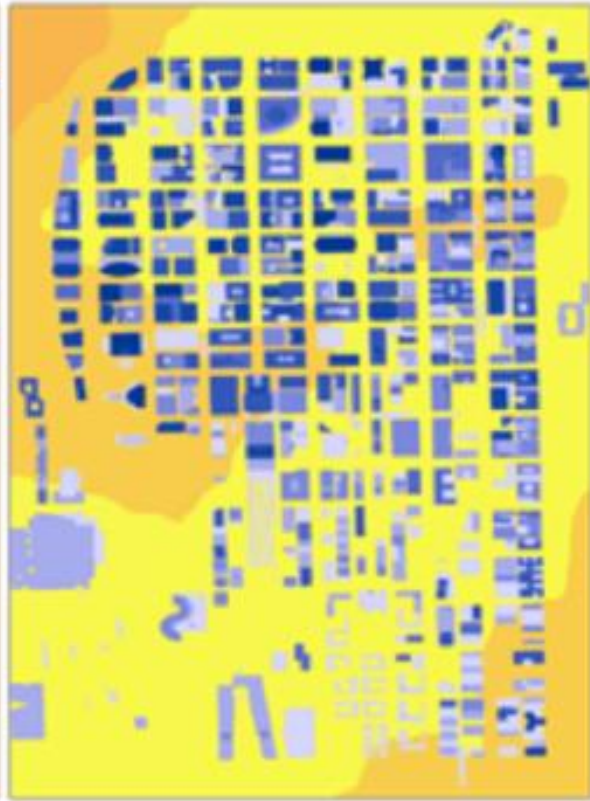
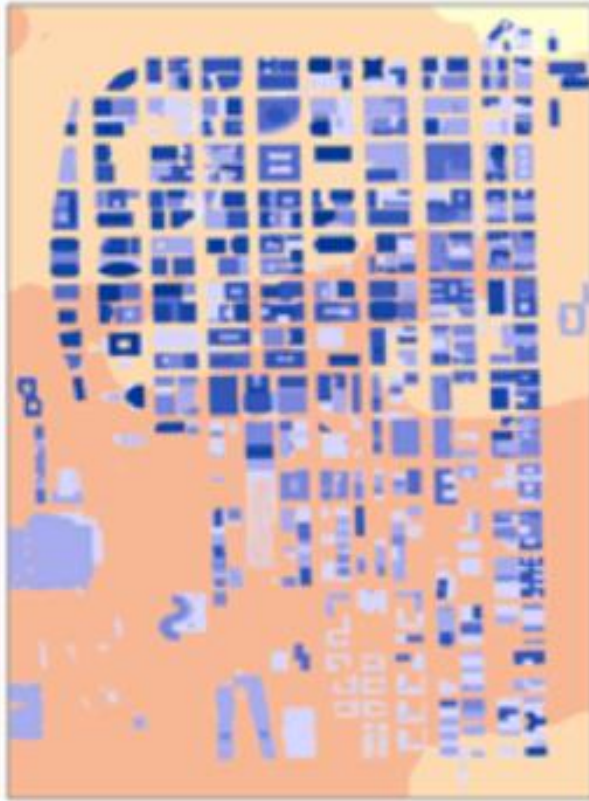
# Acknowledgement



# Discussion







	No. of Bldgs	Area ( $m^2$ )	Elec (GJ)	Gas (GJ)	EUI elec ( $GJ/m^2$ )	EUI gas ( $GJ/m^2$ )
NoMorph	334	19,924,975	5,587,504	3,728,528	0.2804	0.1871
Morph1	361	20,892,217	6,025,625	4,754,649	0.2884	0.2276
Morph2	355	22,996,771	6,414,792	4,989,149	0.2789	0.2169

# MOtor Vehicle Emission Simulator (MOVES)

Accepts from TUMS:

- traffic volume for each link or
- time-dependent speed profiles
- fleet composition for the link volumes

Estimates emissions (including heat exhaust) and energy consumption

Accommodates different fuel types and vehicle processes:

- start and running exhaust
- brake and tire wear
- vapor losses
- spillage losses

