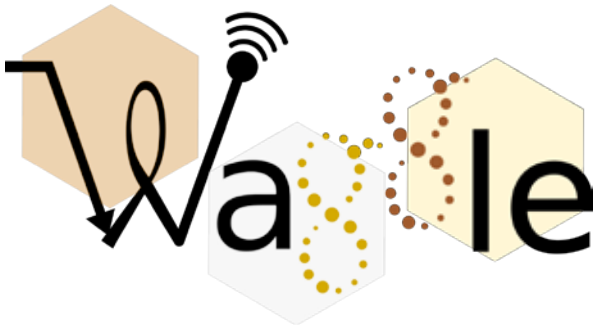
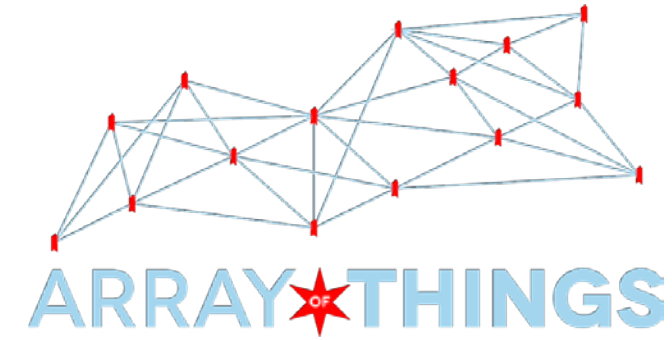




Array of Things & Waggle Sensors and Computing

Pete Beckman

Senior Scientist, Argonne National Laboratory
Co-Director, Northwestern / Argonne Institute for Science and Engineering (NAISE)
Senior Fellow, University of Chicago Computation Institute

The Centrality of Cities

Table 3

The 50 Largest Cities, C40 Cities, and Top 10 GHG Emitting cities[4]

Population (Millions)	GHG Emissions (M tCO_2e)	GDP (billion $ PPP)
1. China: 1,192	1. USA: 7,107	1. USA: 14,204
2. India: 916	2. China: 4,058	**2. 50 Largest Cities: 9,564**
3. 50 Largest Cities: 500	**3. 50 Largest Cities: 2,606**	**3. C40 Cities: 8,781**
4. C40 Cities: 393	**4. C40 Cities: 2,364**	4. China: 7,903
5. USA: 301	5. Russian Federation: 2,193	5. Japan: 4,354
6. Indonesia: 190	6. Japan: 1,374	**6. Top 10 GHG Cities: 4,313**
7. Brazil: 159	**7. Top 10 GHG Cities: 1,367**	7. India: 3,388
8. Russian Federation: 142	8. India: 1,214	8. Germany: 2,925
9. Top 10 GHG Cities: 136	9. Germany: 956	9. Russian Federation: 2,288
10. Japan: 128	10. Canada: 747	10. United Kingdom: 2,176

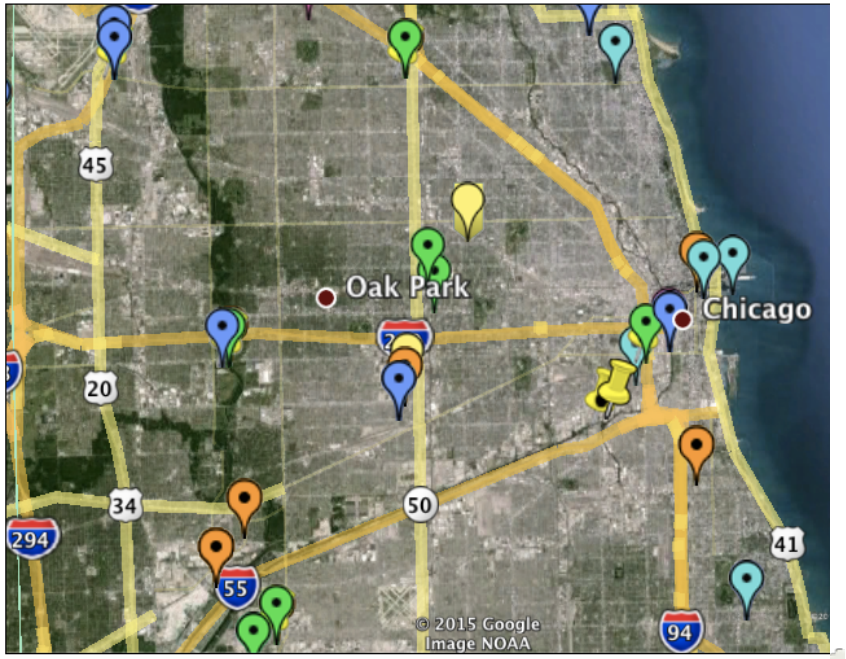
Source: See Annex D. Data for the urban agglomeration associated with each C40 city is used in calculations to maintain consistency with the 50 largest cities, 2005.

"Cities and Climate Change: An Urgent Agenda," World Bank, 2010

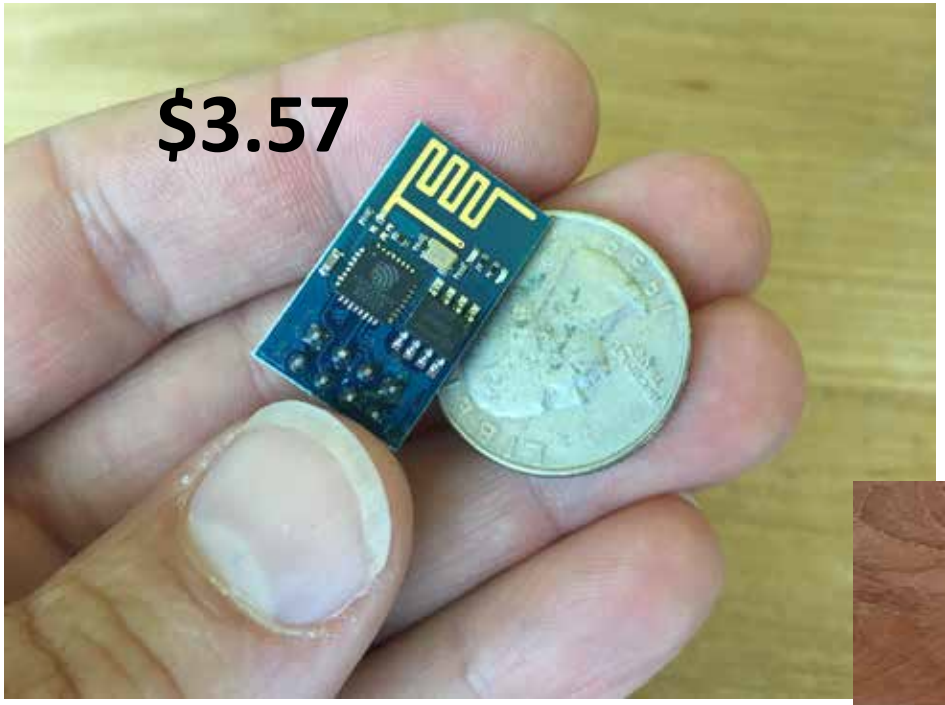
Sensors, Instrumentation, Measurement

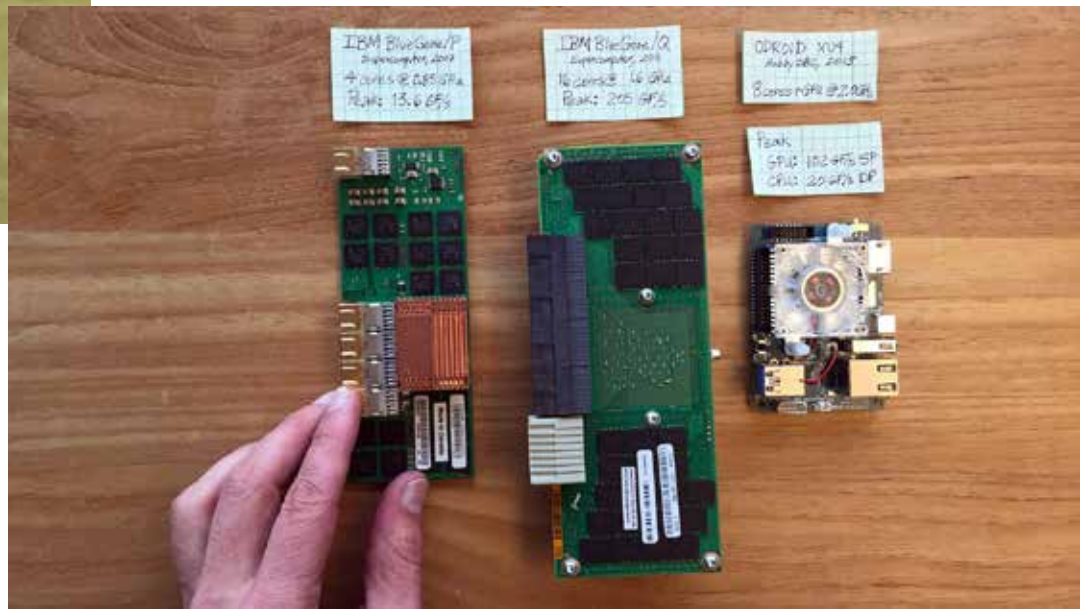
Most topics of urban inquiry require data with greater in temporal and spatial resolution.

- **Energy**
  How can hyper-local weather information improve energy efficiency? Reliability?
- **Climate and Heat Islands**
  What is the impact of the Urban boundary layer on regional climate?
- **Air Quality, Transportation, and Health**
  What are the dynamics of urban air pollutants and how can traffic flow be modified to improve air quality?
- **Social Sciences**
  How might diverse data sources including ambient sensors provide data relevant to predictive analytics w.r.t. disease, public safety/sentiment?



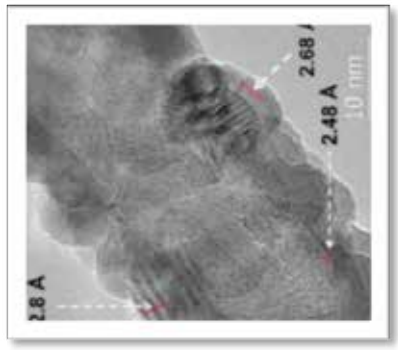
Map of EPA monitoring sites from EPA.


$3.57


IBM BlueGene/P
IBM BlueGene/Q
ODROID XU4

Disruption: Intelligent, Attentive Sensors

- **Sensors**:
  - Explosion of nano & imaging tech
- **CPUs**:
  - Powerful, low-power, embedded with network
- **In-situ/Edge Computing:**
  - Data in flight, can't store it all
  - Sensors+CPUs = new programming model for *in-situ computation*
- **Open Source:** Reusable, extensible software communities



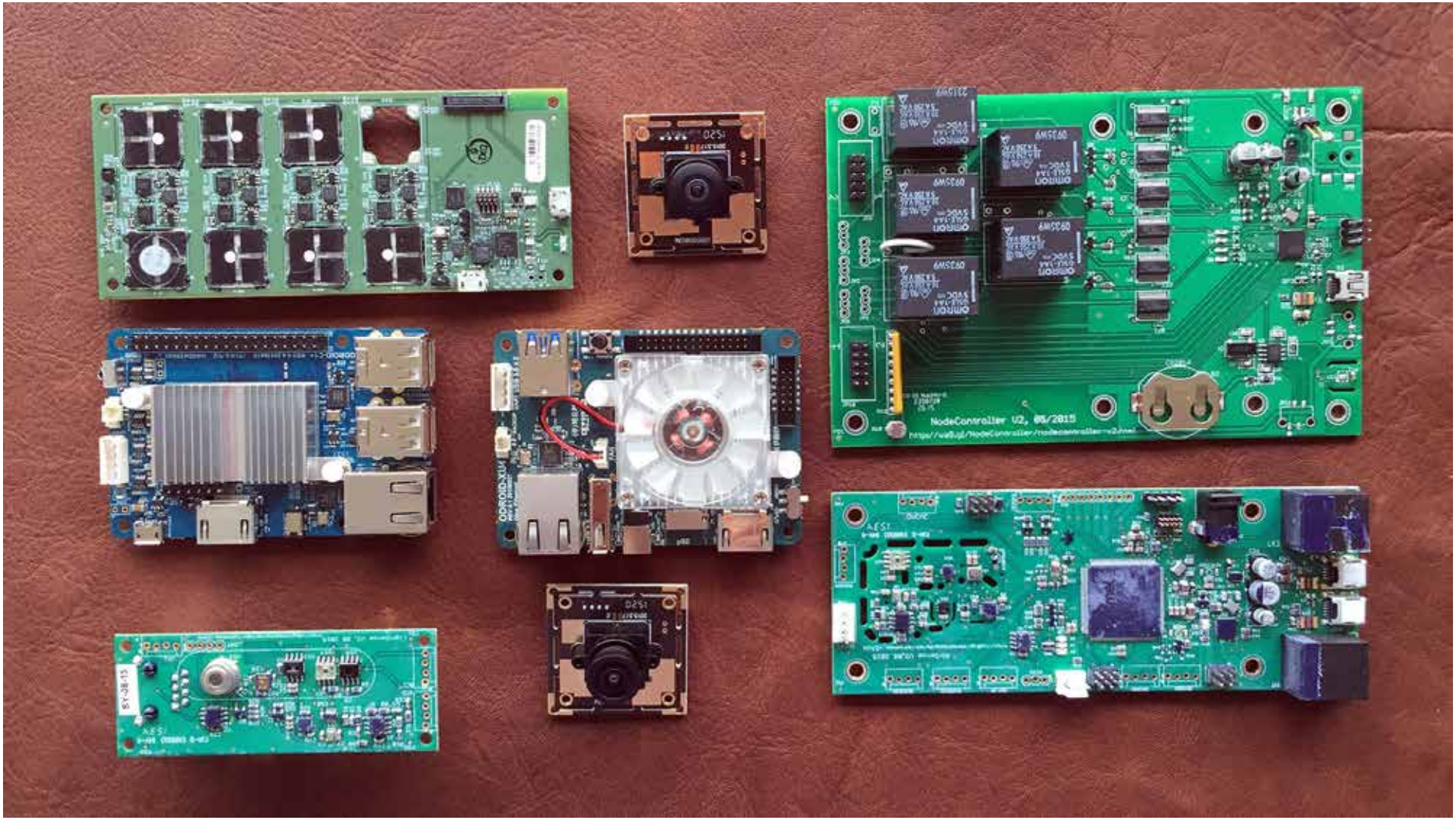
CNM carbon nanotube methane sensor

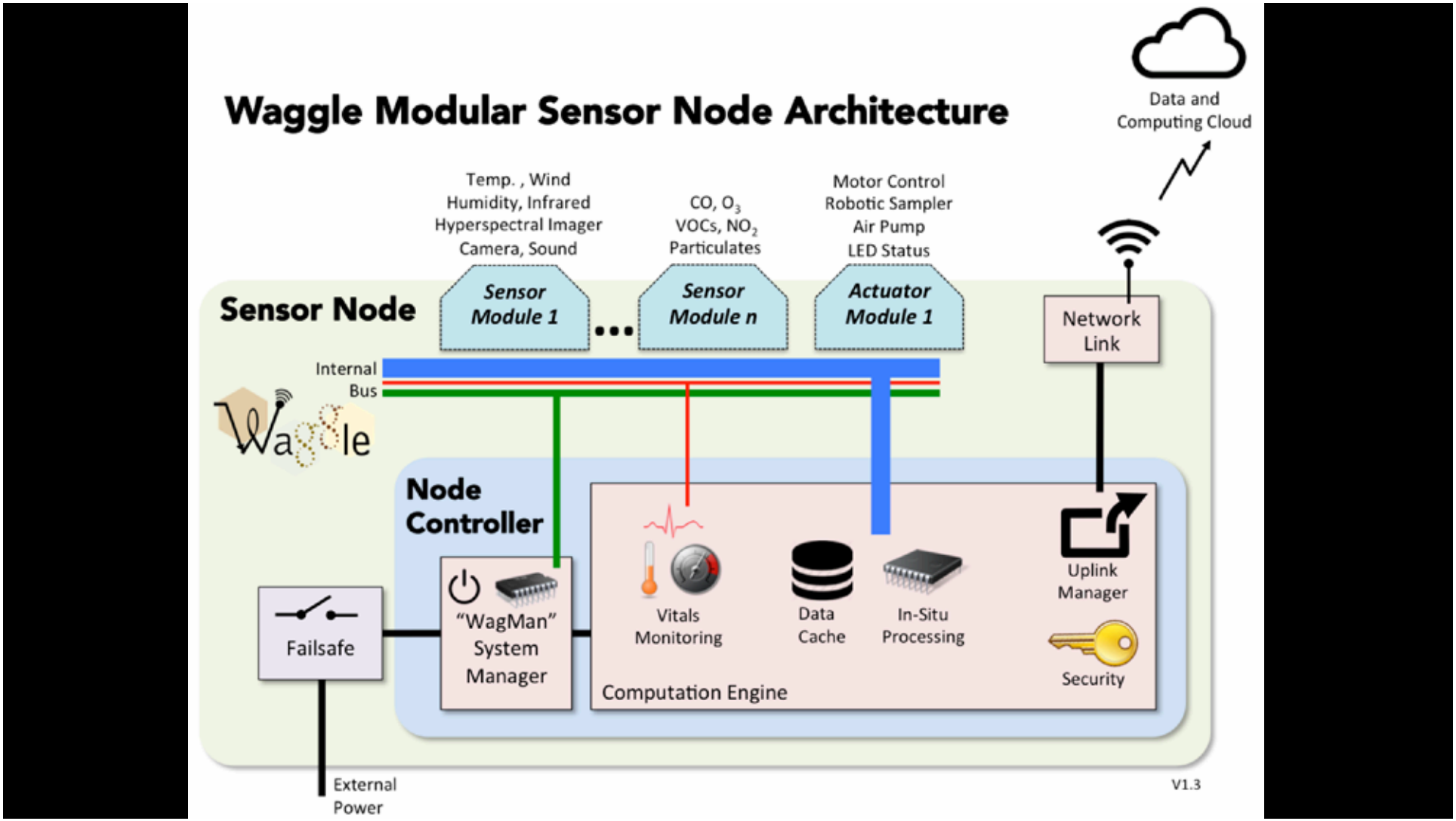
Opportunity: Predictive Models:

Smart Sensors + Supercomputers = predictions and analysis

Introducing Waggle (www.wa8.gl)

- ***Powerful CPU***, accurate sensors
- ***In-Situ Analysis*** for adaptive feature detection, attentive control
- "Deep Space Probe" design for resilience
  - (safe mode, multiple kernels, heartbeats)
- Scalable to 100Ks of nodes; can be linked to supercomputer predictions
- Scalable/hackable Open Source platform adaptable for new science & sensors
  - host active education community


NodeController V2, 05/2015


Waggle Modular Sensor Node Architecture
Data and
Computing Cloud
Temp. , Wind
Humidity, Infrared
Hyperspectral Imager
Camera, Sound
CO, O_3
VOCs, NO_2
Particulates
Motor Control
Robotic Sampler
Air Pump
LED Status
Sensor Node
Sensor Module 1
Sensor Module n
Actuator Module 1
Network Link
Internal Bus
Waggle
Node Controller
Failsafe
"WagMan" System Manager
Vitals Monitoring
Data Cache
In-Situ Processing
Computation Engine
Uplink Manager
Security
External Power
V1.3

A Science-Driven Instrument: The Array of Things

Climate, Environmental and Life Sciences
(Robert Jacob, ANL)

Potosnak (DePaul); Niyogi (Purdue); Gilbert, Graham, Kotamarthi, (UC/ANL); Fernando (Notre Dame)

Urban Infrastructure Systems
(Danie Work, UIUC)

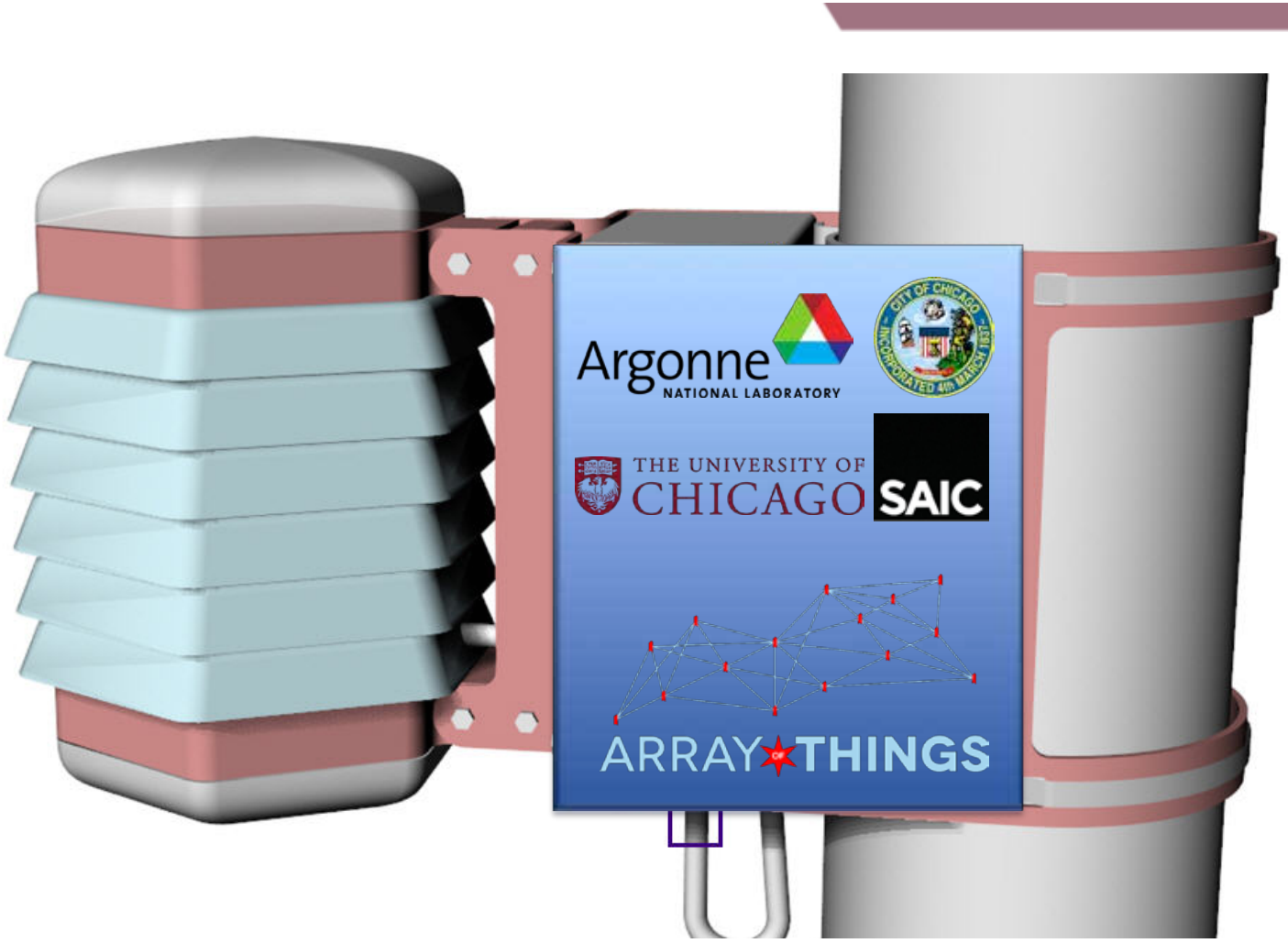
Markoupolou (IaaC); Negri, Snyder (UC/ANL); Buttlar, Peschel, Garcia (UIUC), Gonzales (MIT), Pancoast (SAIC), Guzowski, Rosner (UC/ANL), Claudel (UT); Liu (UMich), Chen (UW)

Education, Health, Social and Behavioral Sciences
(Kathleen Cagney, UChicago)

Diez (UCL/IaaC); Contractor (Northwestern); Epley, Gilliam, Lindau, Meltzer, Hampton-Marcel, Zarraonaindia (UC); Bellingham (Strathclyde)

Computer Science and Cyber-Physical Systems
(Michael Papka, UC/NIU/ANL)

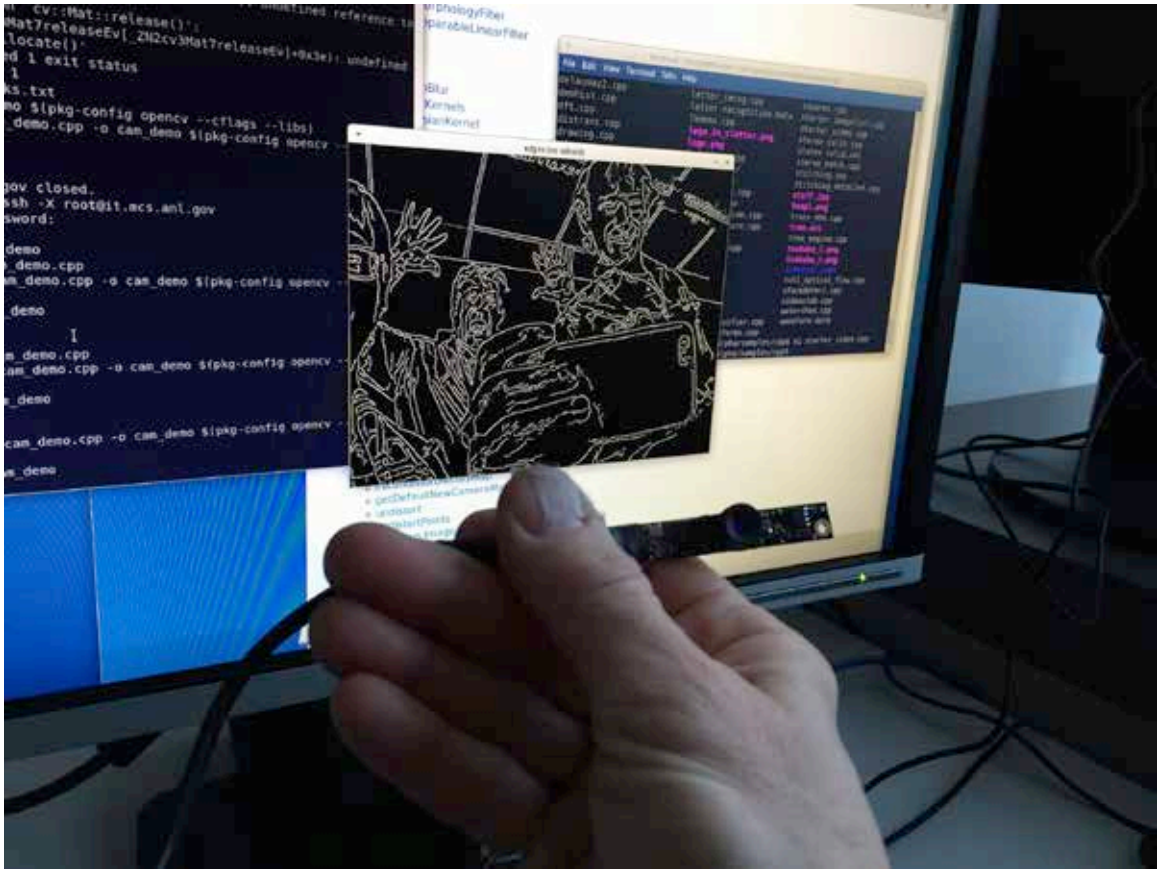
Derrible, Lin, Eriksson (UIC); Alok Choudhary (NU); Beckman, Sankaran, Chien (UC/ANL)


Argonne
NATIONAL LABORATORY
THE UNIVERSITY OF
CHICAGO
SAIC
ARRAY THINGS


3
GERALD


9 FT 6 IN

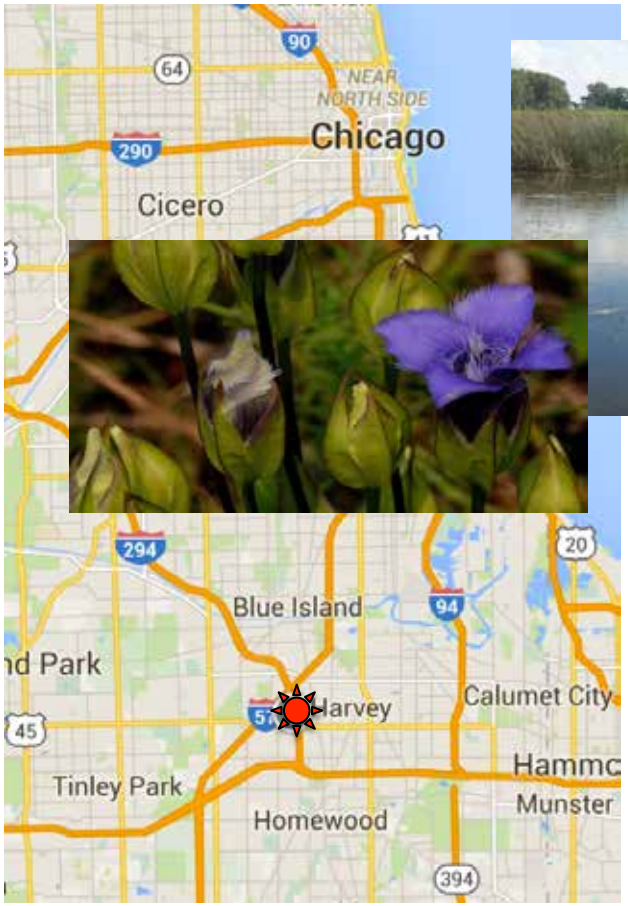
In-Situ/Edge Computing
Analysis and Feature Recognition



Gensburg-Markham Prairie

370 acres, owned/managed by Nature Conservancy and Northeastern IL Univ.
Registered as National Natural Landmark

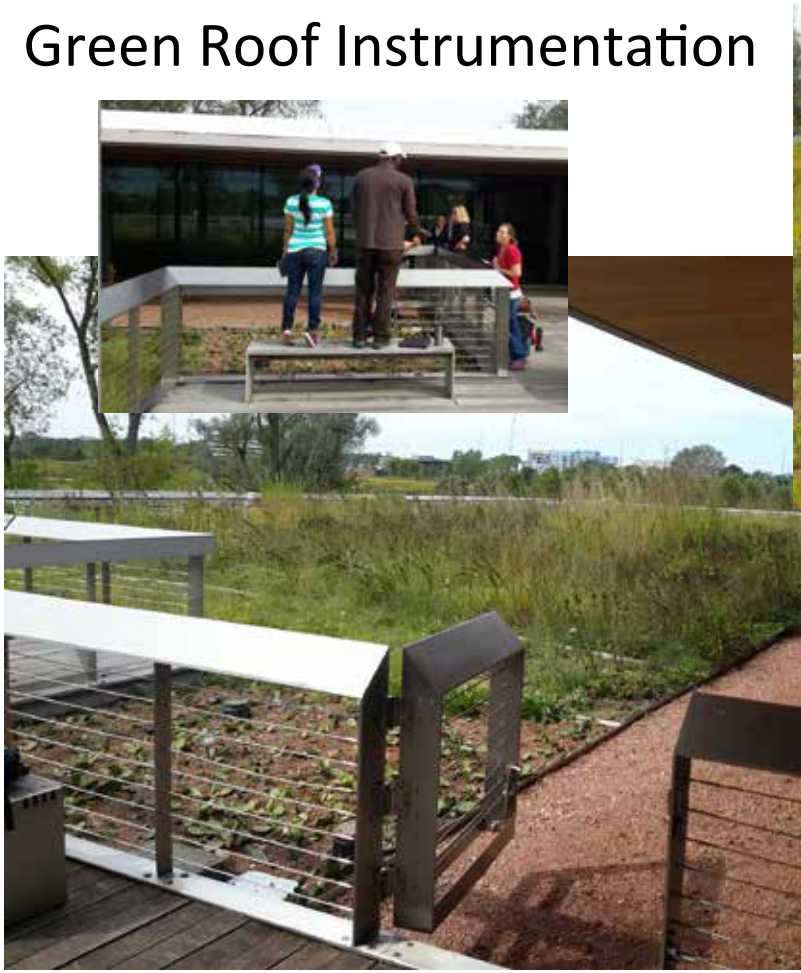
Lead: Aaron Packman@NU
Cristina Negri



Chicago Botanic Garden

Lead: Cristina Negri

Green Roof Instrumentation



Sensors

Edge Computing

O(10K)

Initial QA & Calibration

Live Stream Analysis

On-Demand HPC

STREAM: Research Questions

- STREAMing Data and Analytics.
  - O(10K) Computationally Powerful sensors → limiting network → Live HPC/Analysis
- How do we ***program*** in-situ analysis?
  - Constructing multilayer pipelines for multiple features
  - Building machine learning corpus
  - Dropping in improved classification algorithms?
- How do we leverage machine learning research to build classification libraries?
- How do design large-scale collective management, trust, distributed command and control?
- How will high-performance streaming analytics and simulation be connected to live data?
- Can we use neuromorphic engines or FPGAs to reduce power while streaming?

Waggle Team & Collaborators