Partnering with Cities on Urban Challenges and Opportunities to drive Urban Science

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ARRAY★THINGS

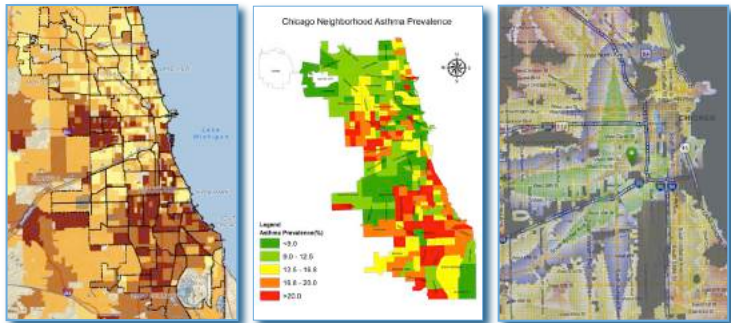Argonne
NATIONAL LABORATORY

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Waggle
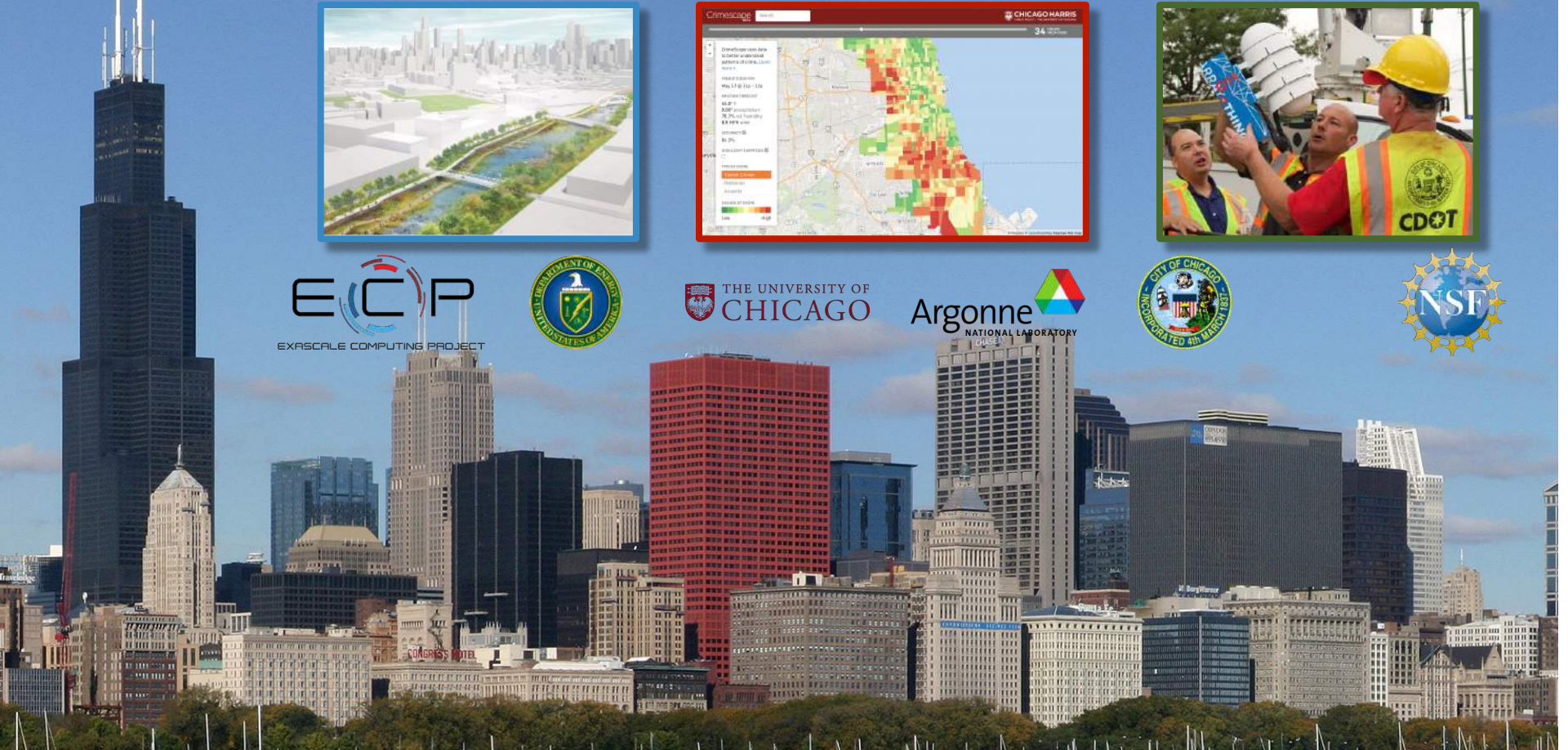
Computational Modeling
(Urban Design & Planning)

Data Analytics and AI
(Urban sciences & optimization)

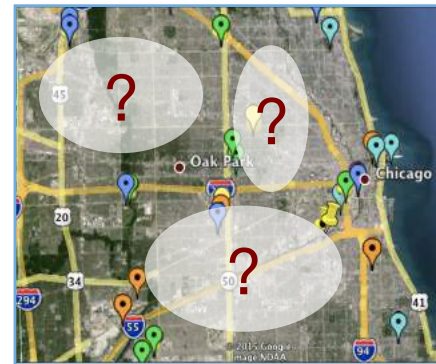**Autonomous Instrumentation**
(Urban measurement & experimentation)

URBAN CENTER FOR COMPUTATION AND DATA

Creating an Instrument for Urban Science

The types of sensors, automated observations, and the placement and density of deployment in Chicago were guided by a series of science workshops beginning in 2013,with communities ranging from atmospheric sciences to transportation, from environmental sciences to social sciences.

Low-Cost Sensor Precision

Urban challenges often present at the neighborhood level, yet traditional *sensing* approaches have been too expensive to provide such dense installations.

Other urban factors—pedestrian or vehicle flow, street flooding, "near miss" traffic collisions—are difficult, if not impossible, to measure with sensors. These require automated *observation*, ideally embedded for real-time response.

Computer Perception

Autonomous operation and remotely programmable Linux computers.

Expandable sensor housing

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AoT is a *Platform* supporting three functions.

1. **Free and open DATA: measurements at high spatial and temporal resolution.**
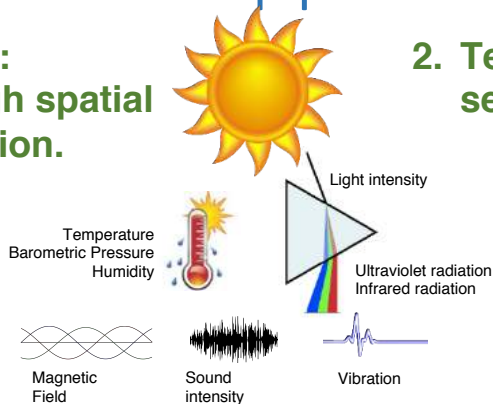
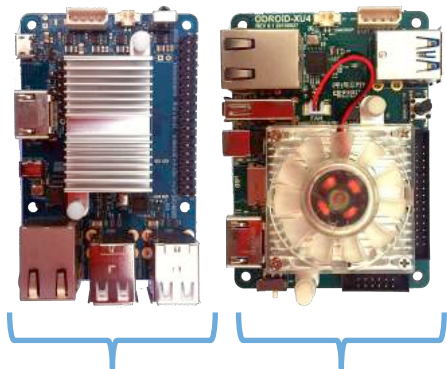2. **Testbed for new sensors**

3. **Testbed for new computer perception-enabled measurements.**

Light intensity

Temperature
Barometric Pressure
Humidity

Ultraviolet radiation
Infrared radiation

Magnetic Field

Sound intensity

Vibration

Total Reducing Gases

Total Oxidizing Gases

PM 2.5
PM 10

Ozone

Carbon monoxide

Pollen

Hydrogen sulfide

Nitrogen dioxide

Sulfur dioxide

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Edge Computing: Waggle Platform

**Computer Vision &
Machine Learning
Has Moved to the Edge**

Security, Control, &
Communications

Edge Computing
(remotely
programmable)

Sensors are intelligent, using advanced,
parallel computing at the edge to
process data

Research Credits
Pete Beckman, Nicola Ferrier,
Ethan Trokie,Zeeshan Nadir
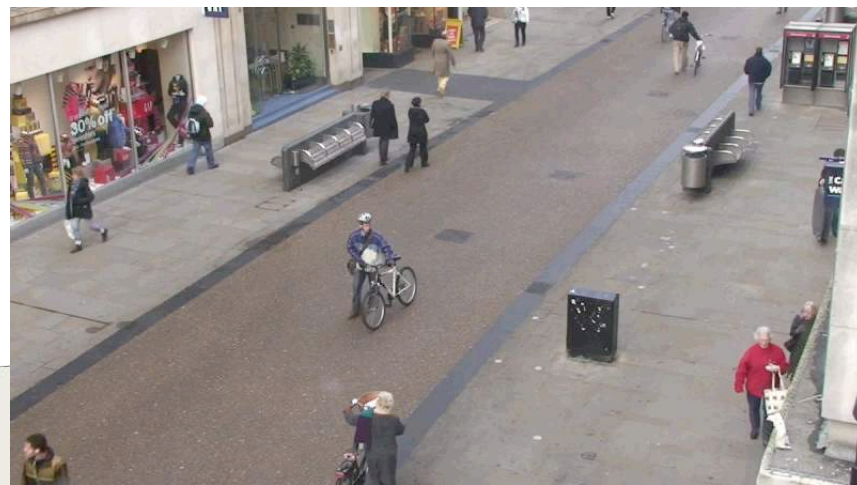
Array of Things
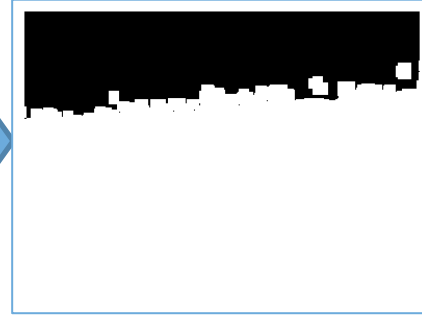## Machine Learning to Understand Cities

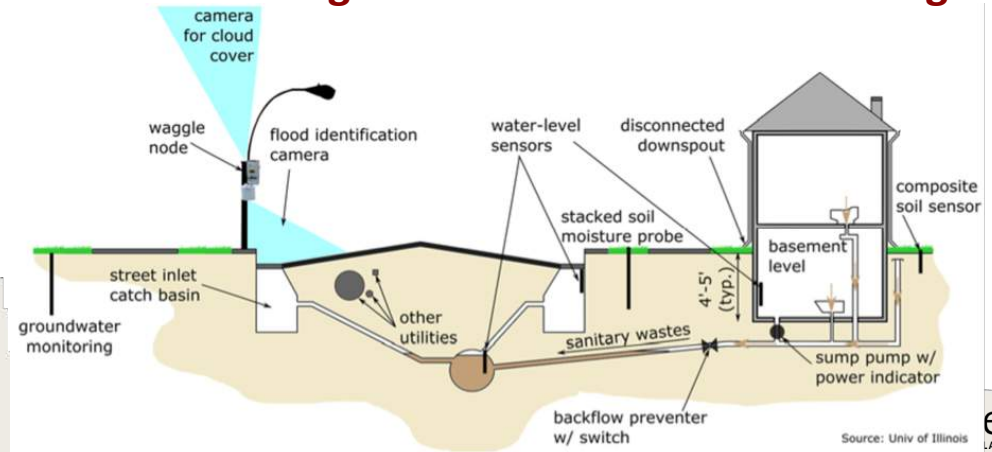**Transforming raw data at the edge into understanding of activities and impacts**

Examples:
- **Cars in intersection**
- **Dangerous car/pedestrian actions**
- **Flooded streets / depth of water**
- **Presence of crowd**
- **Icy roads / sliding cars**
- **Use of bicycle helmets**
- **Disabled vehicles**
- **Birds singing, wildlife detection**
- **Cloud cover / solar load**
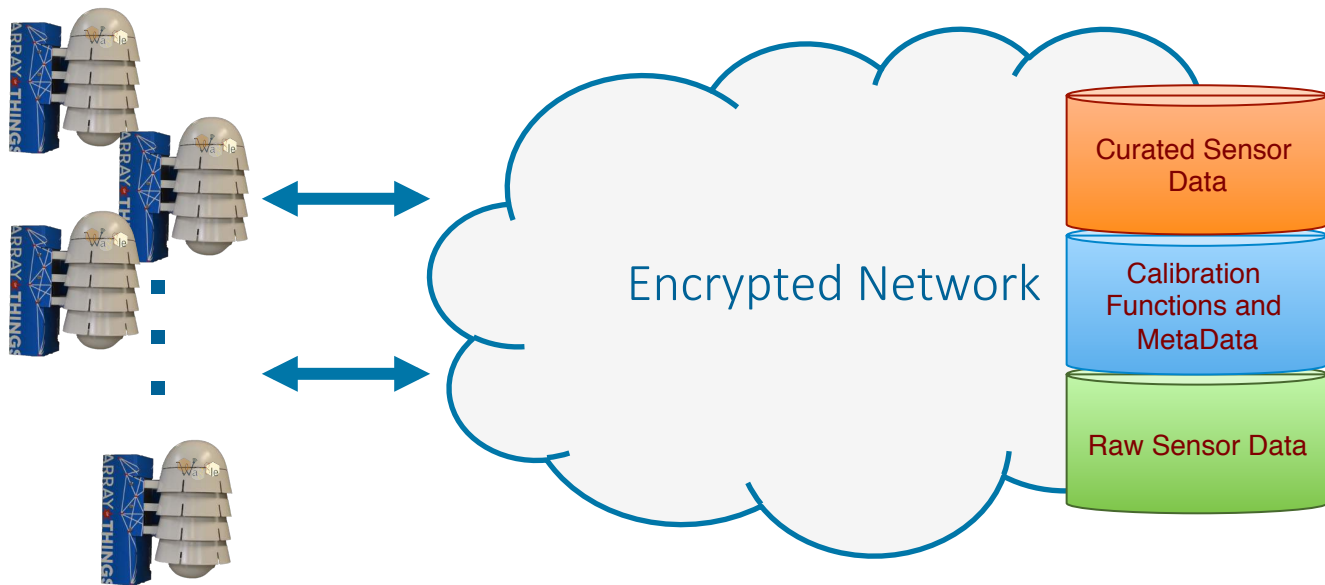- **Truck sounds**

Process 50 frames:

Working to understand urban flooding

camera for cloud cover

waggle node

flood identification camera

water-level sensors

disconnected downspout

composite soil sensor

stacked soil moisture probe

basement level

4'-5' (typ.)

street inlet catch basin

groundwater monitoring

other utilities

sanitary wastes

backflow preventer w/ switch

sump pump w/ power indicator

Source: Univ of Illinois

The Instrument as an open data utility

Encrypted Network

Curated Sensor Data

Calibration Functions and MetaData

Raw Sensor Data

Data Repository: Scientific Analysis
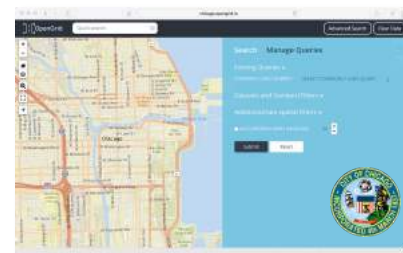
Open Portals: Data Discovery

Streams & APIs: New Applications

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Asking Questions about the City and Communities

Open source hardware and software for measurement

Environment
Cloud cover
Ambient, UV, IR light
Visibility
Magnetic Field
Vibration
Sound level
Temperature
Relative humidity
Barometric pressure

Air Quality
PM 2.5 (PM 1, 10, 40)
Carbon monoxide
Ozone
Sulfur dioxide
Nitrogen dioxide
Hydrogen sulfide
Total reducing gasses
Total oxidizing gasses

Activity/Conditions
Flooding
Pedestrian/vehicle/bicycle flow
Group sizes
"Stickiness" of places
…

?
?
Human decisions
Policy
Investment
Infrastructure
Interventions
Community Programs
Services

.
.
.

Operations
311 services
Inspections
Permits
Licenses
…

Events
Crimes
Traffic collisions
Festivals
…

Infrastructure
Parks
Streets
Buildings
Businesses
…

People
Demographics
Organization
Economics
Health
…

Open data and open source software systems for data discovery and exploration

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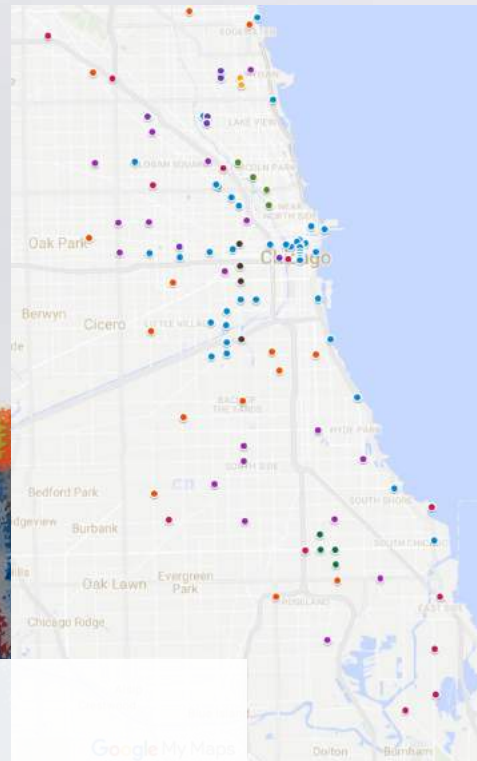**Argonne**
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Chicago Deployment
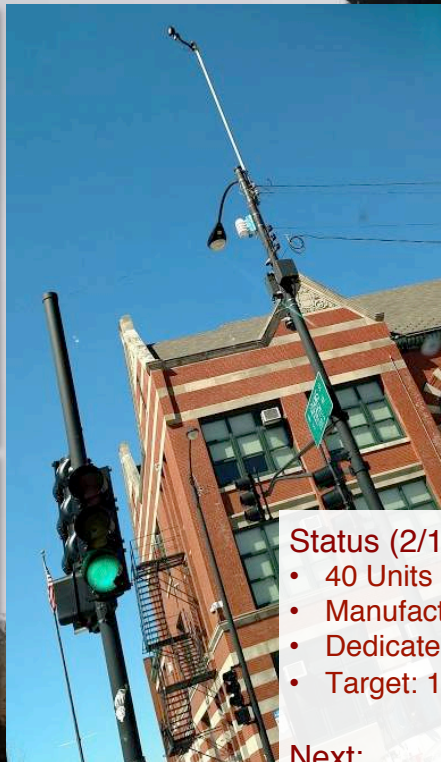
Status (2/16/18):
- 40 Units in place
- Manufacturing 12-16 nodes per week
- Dedicated installation crew deploying 6-8/week
- Target: 150 nodes by June; 200 by August

Next:
- March: Initial data publication
- April: Science/policy workshop to select locations 120-300.
- May: Air Quality Science Community Workshop

An urban-scale instrument—installed in the public way–also requires new policy and public interaction approaches.

Central to the public engagement program is involvement of students. Summer undergraduate and graduate student interns work on the technology, while a high school curriculum has introduced over 450 high school students to data-driven science building wireless sensors, deploying them, and analyzing the data.