Part 2. The Array of Things

AoT Leadership: Charlie Catlett (PI, UChicago/Argonne), Brenna Berman (CIO, City of Chicago), Kathleen Cagney (UChicago), Peter Beckman (UChicago/Argonne), Kate Kusiak Galvin (UChicago), Douglas Pancoast (SAIC), Michael Papka (NIU/UChicago/Argonne), Daniel Work (UIUC)

www.UrbanCCD.org http://arrayofthings.us

Why Instrument Cities?

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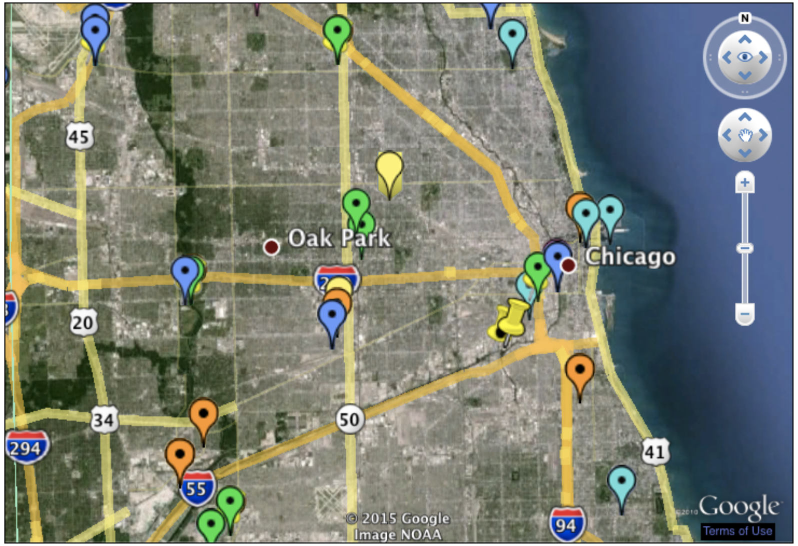
Most areas of urban inquiry require dramatic increases in temporal and spatial resolution.



Monitoring Networks

Click a check box to display a network on the map.

Click the network name to save or open the kmz file.

Note: These layers display all monitors (active or inactive) with data since 1990.

- CO active inactive
- Lead active inactive
- Lead-TSP(LC) active inactive
- Lead-PM10(LC) active inactive
- NO2 active inactive
- Ozone active inactive
- PM10 active inactive
- PM2.5 active inactive
- SO2 active inactive
- PM2.5 Chemical Speciation Network active inactive
- IMPROVE (Interagency Monitoring of Protected Visual Environments) active inactive
- NATTS (National Air Toxics Trends Stations) active
- NCORE Multipollutant Monitoring Network active

- What is the impact of the Urban boundary layer on regional climate?
- What are the dynamics of urban air pollutants and how can traffic flow be modified to improve air quality?
- How might diverse data sources including ambient sensors provide data relevant to predictive analytics w.r.t. disease, public safety/sentiment, energy and emissions, etc.?
- How can new, lower cost sensors fill in the gaps?
- How can new sensors and embedded technologies be rapidly tested and deployed?
- How can applied mathematics and diverse data sources improve insight and measurement?

Map of EPA monitoring sites from EPA.

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

Urban Infrastructure Systems (Daniel Work, UIUC)

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

Computer Science and Cyber-Physical Systems (Mike Papka, NIU)

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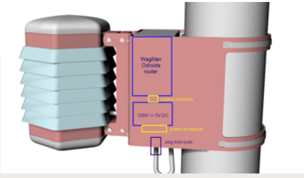
- 2013
- 2014: Resilient Design Field Testing (2 nodes)
- 2015: Sensor Evaluation (12 nodes)
- 2016: Deployment and Field Test (50 nodes); Expanded AQ measurement; Calibration (+150 nodes)
- 2017: Full-scale Instrument (+300 nodes)

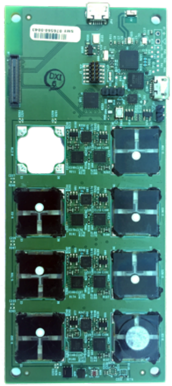
A Science-Driven Instrument



Array of Things "Waggle" Node Configuration

Environment:
Temperature, Humidity, Barometric Pressure, Vibration, Sound, Magnetometer, RF

Air Quality:
NO_2 (Nitrogen Dioxide): <2 ppb
O_3 (Ozone) < 5 ppb
CO (Carbon Monoxide) < 1 ppm
SO_2 (Sulfur Dioxide) < 15 ppb
H_2S (Hydrogen Sulfide) < 2 ppb



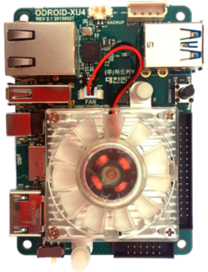
Planned for 2016:
- *TO_X (total oxidizing index) < 1 ppm (CO equiv)*
- *TOR (total reducing index) < 2 ppb (NO_2 equiv)*
- *HCHO (Formaldehyde)*
- *VOC (Volatile Organic Compound)*
- *CH_4 (Methane)*
- *PM 2.5 (Particulate Matter)*
- *Precipitation*
- *Wind*

Light/Visual:
Light, Infrared (surface temperature, cloud cover), 5MP HD Camera*

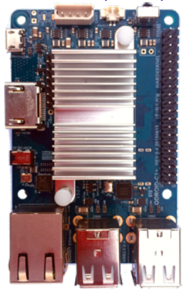
*all images processed in-situ and discarded
No images saved or transmitted.

Sensors
(October 2015)

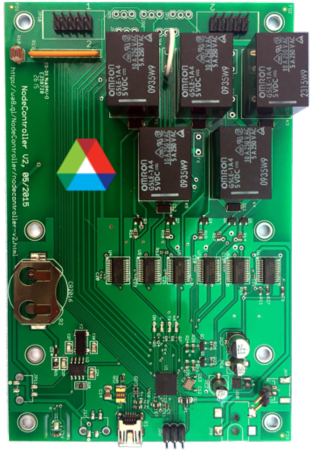
In-Situ Processing*:
Odroid-XU4 (Linux)



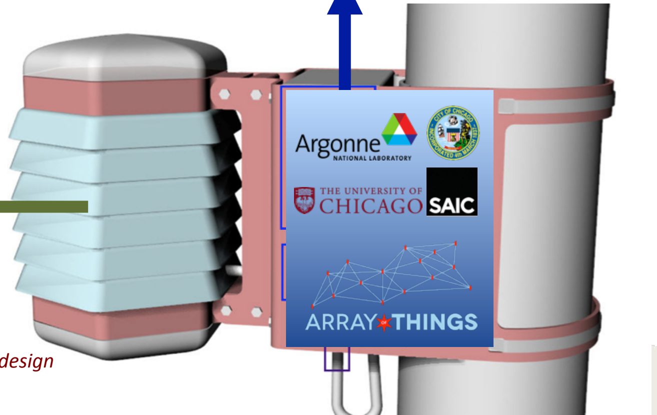
Node Control and Communications:
Odroid-C1+ (Linux)



Power Control and Status Monitor



Open Source Resilient Support Platform



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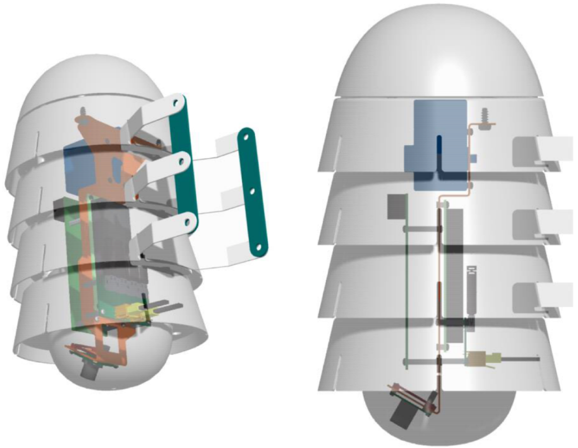
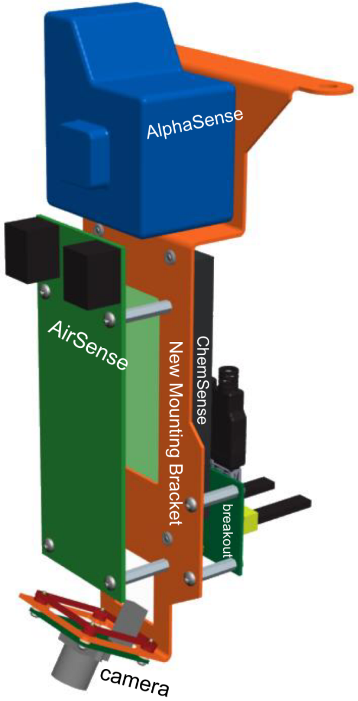
Open source node software and hardware design

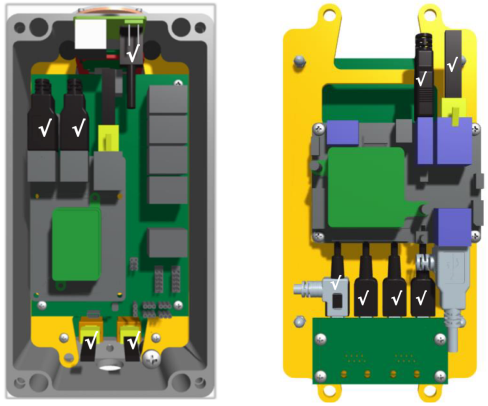
Design Update

Mechanical design updates

- Accommodate AlphaSense in Stevenson Enclosure
- Update for coaxial LightSense
- Breakout boards
- Cable connector clearance verification







URBAN CENTER FOR COMPUTATION AND DATA

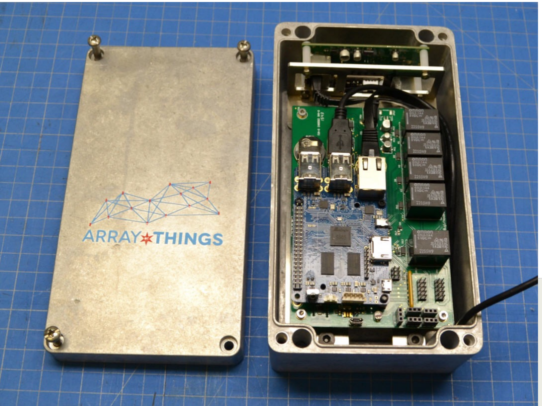
ARRAY OF THINGS

pdt

Manufacturing Status

Open Source Platform for Embedded Sensing/Systems

- *Privacy*. Secure design with privacy policy “baked in” to *prevent* collection, storage, or transmission of data about individuals.
- *Transparency*. All policies, hardware and software specifications, designs, and source code are open source and *published*.
- *Accountability*. Independent security and privacy review process.
- *Public-Private Partnerships*. Low-cost, open, networked, programmable “nodes” that collect, process, and *publish* real-time data on environment, infrastructure, and activity.



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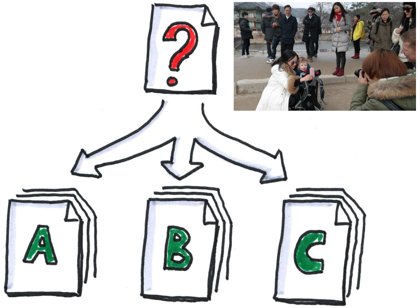
www.wa8.gl

github.com/waggle-sensor



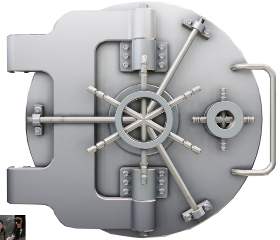
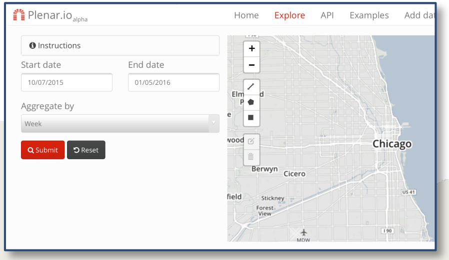


Table 1: Sensor technologies planned for AoT nodes, noting potential for privacy and security risks. Note the initial pilot project in December 2014 at the University of Chicago will not include WiFi or Bluetooth radios.

Sensor	Purpose	Privacy/Security Risk Potential	Risk Mitigation (if applicable)
Prototype Phase			
Temperature	Environmental Conditions	None	
Humidity	Environmental Conditions	None	
Light	Environmental Conditions	None (reports a numeric value for light intensity)	
Sound	Environmental Conditions	None (reports a numeric value for sound volume)	
Vibration	Environmental Conditions	None	
Infrared	Road and sidewalk surface temperature.	None (reports a 4 by 4 matrix of heat values—equivalent to a 16-pixel image with one pixel representing a square foot to a square meter)	
WiFi Radio	Approximation of pedestrian density.	Potential collection of hardware identifiers for devices within range; potential communication channel to mount a malicious attack on devices within range. (approximately 100 meters)	Nodes will be programmed to count unique addresses every 30s, discarding any addresses or identifiers after 30s.
Bluetooth Radio	Approximation of pedestrian density.	Potential collection of hardware identifiers for devices within range; potential communication channel to mount a malicious attack on devices within range. (approximately 100 meters)	Nodes will be programmed to count unique addresses every 30s, discarding any addresses or identifiers after 30s.
Full Pilot Phase			
Air Quality (CO, O_3, SO_2, NO_2 H_2S)	Pollutants (air quality)	None	
Precipitation	Environmental Conditions	None	
Wind	Environmental Conditions	None	
Biological	Environmental Conditions	None	
Particulates	Pollutants (air quality)	None	
Camera	Detect standing water, weather; Count vehicles, pedestrians, bicycles.	Potential capture of images for identification of individuals.	Nodes have insufficient power to perform facial recognition and memory size only sufficient to hold a small number of images. Nodes will be programmed to disallow transmission of images.



Sustainable Green Infrastructure

(air quality, walkability, traffic flow, urban flooding)

Deployment Site Selection Criteria:

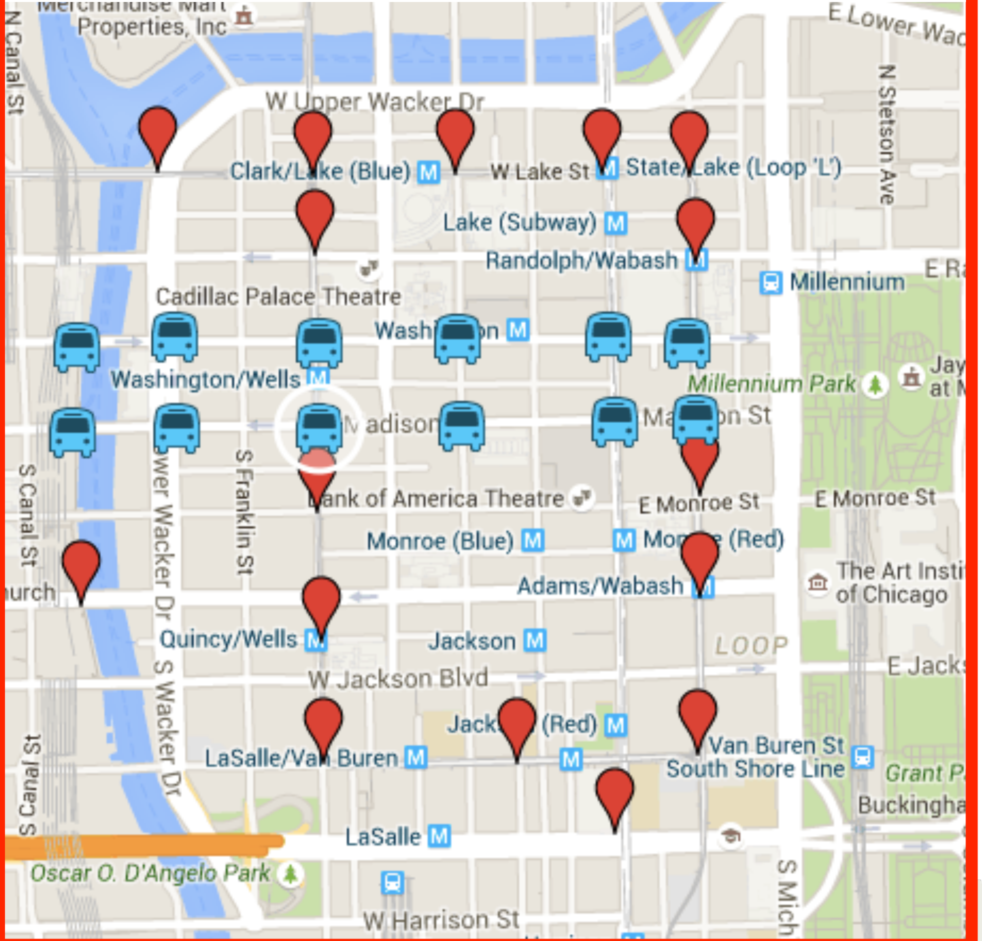
Challenge/Concern of Residents, Visitors, Businesses

Scientists pursuing related research

Related Government policy or action plans

Rapid Bus Transit

(air quality, walkability, traffic congestion)



Creating an International Instrumented Cities Community

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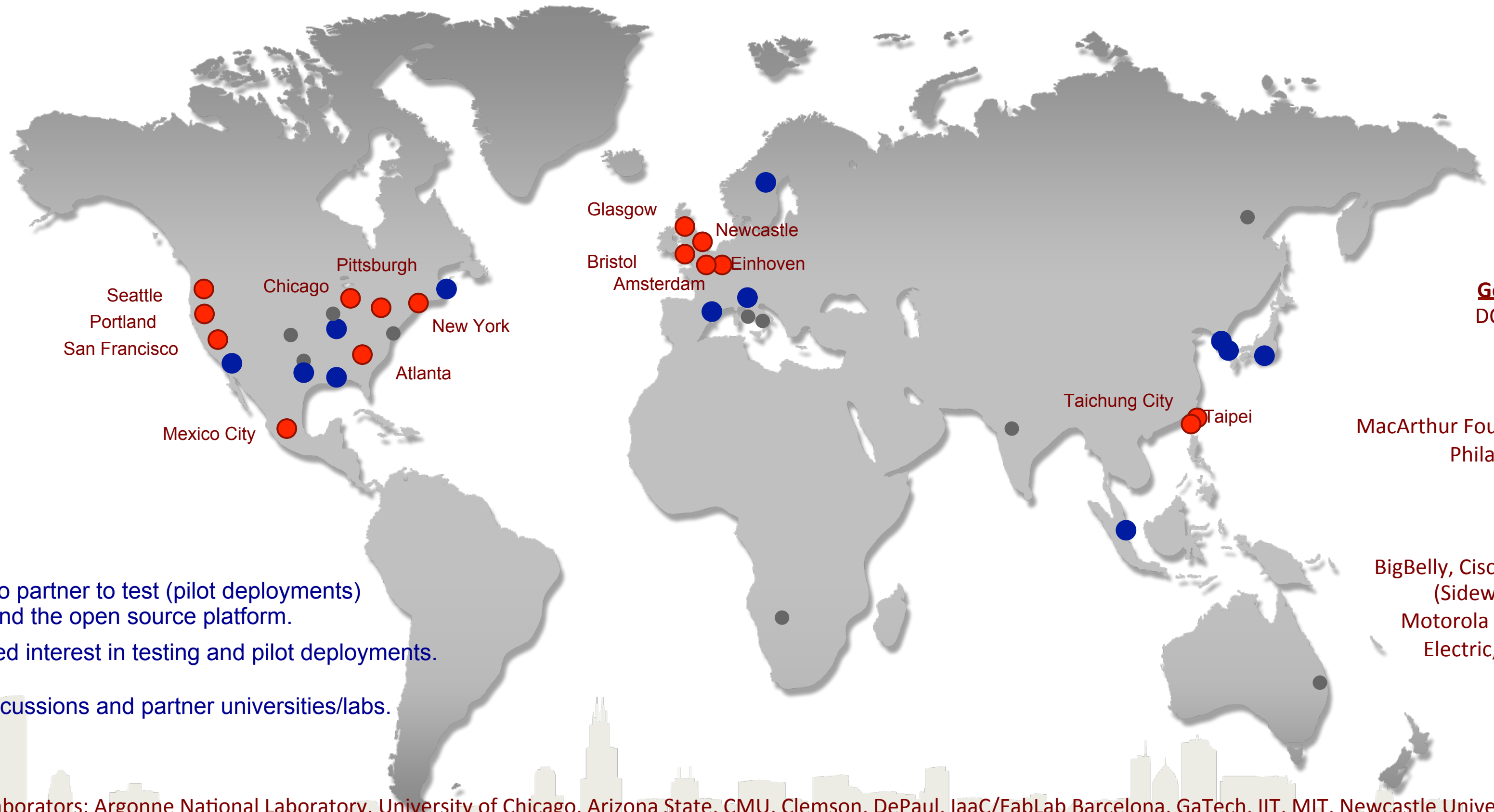

Agreed to partner to test (pilot deployments) and extend the open source platform.

Expressed interest in testing and pilot deployments.

Initial discussions and partner universities/labs.

Government Partners
DOE, NSF, State Dept., City of Chicago

Private Partners
MacArthur Foundation, Bloomberg Philanthropies, Motorola Foundation

Industry Partners
BigBelly, Cisco, Intel, Intersection (Sidewalk Labs), Microsoft, Motorola Solutions, Schneider Electric, Zebra Technologies

Science Collaborators: Argonne National Laboratory, University of Chicago, Arizona State, CMU, Clemson, DePaul, IaaC/FabLab Barcelona, GaTech, IIT, MIT, Newcastle University (UK), NYU, NIU, Northwestern, Notre Dame, Portland State, Purdue, School of the Art Institute of Chicago, National Applied Research Laboratories (Taiwan), University of Amsterdam, University of Bristol (UK), University of Calabria, University College London, Radboud University, Tokyo Institute of Technology, University of Strathclyde (UK), UI-C, UIUC, University of Michigan, University of Texas Dallas, University of Texas Austin, University of Washington