Waggle

A platform for distributed smart wireless sensors and in-situ parallel computation

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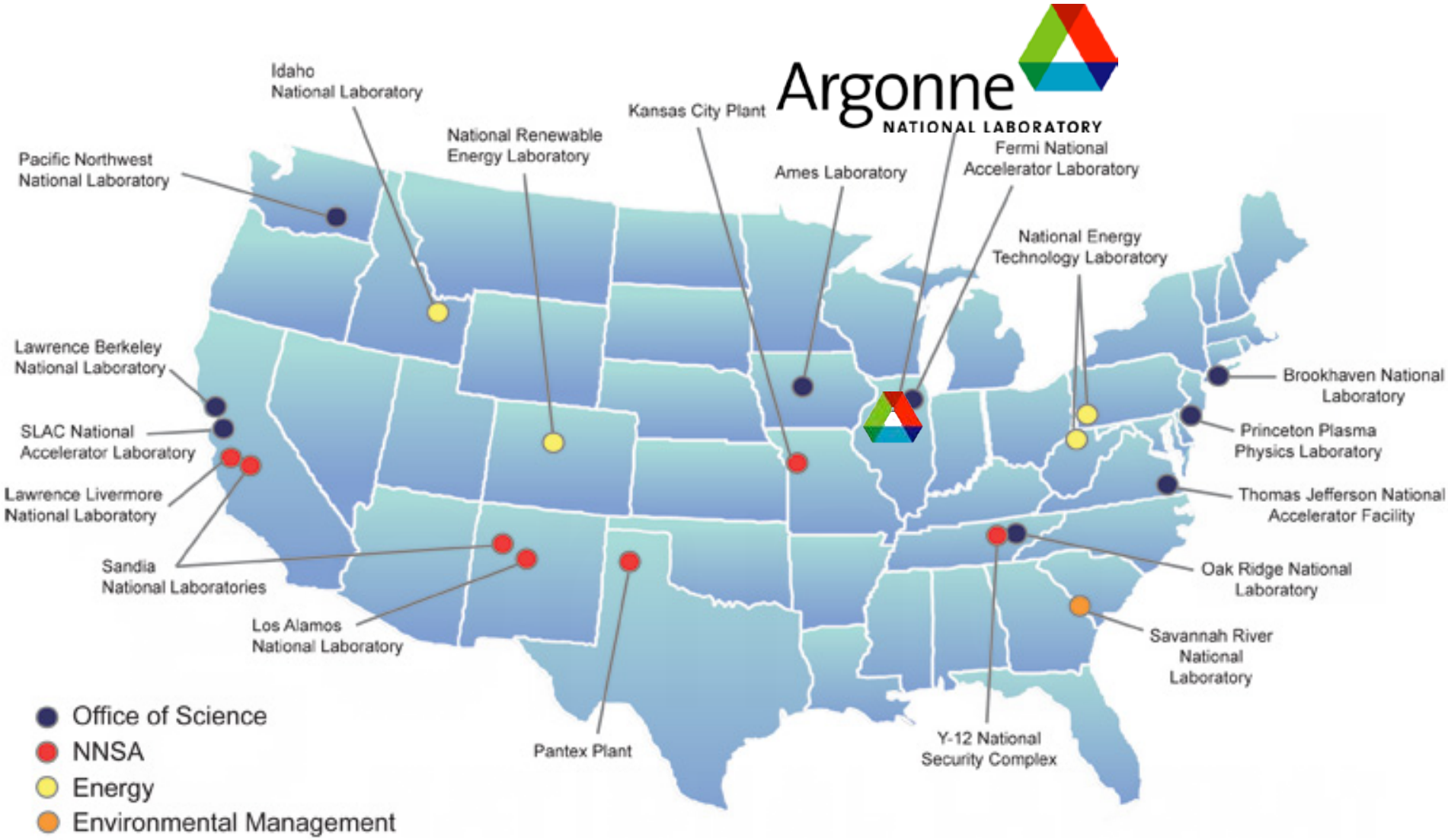
Argonne National Laboratory

- $675M /yr budget
- 3,200 employees
- 1,450 scientists/eng
- 750 Ph.D.s

Argonne: Vital part of DOE National Laboratory System



Direct descendent of Enrico Fermi's Metallurgical Laboratory

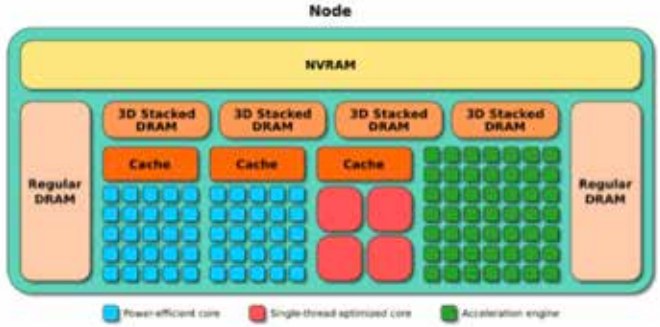
- Opened in Feb 1943 (as new site for Chicago's Metallurgical Laboratory)
- Became Argonne National Laboratory in July 1946 (first national laboratory)

User facilities

Mira: Argonne's Power-efficient Supercomputer

- Blue Gene/Q System
  - 48 racks
  - 786,432 cores
  - 786 TB of memory
  - Peak flop rate: 10 PF
- Storage System
  - ~30 PB capability
    - 240GB/s bandwidth (GPFS)

Argonne: Operating System, File System, Message Layer, etc., System Software Research



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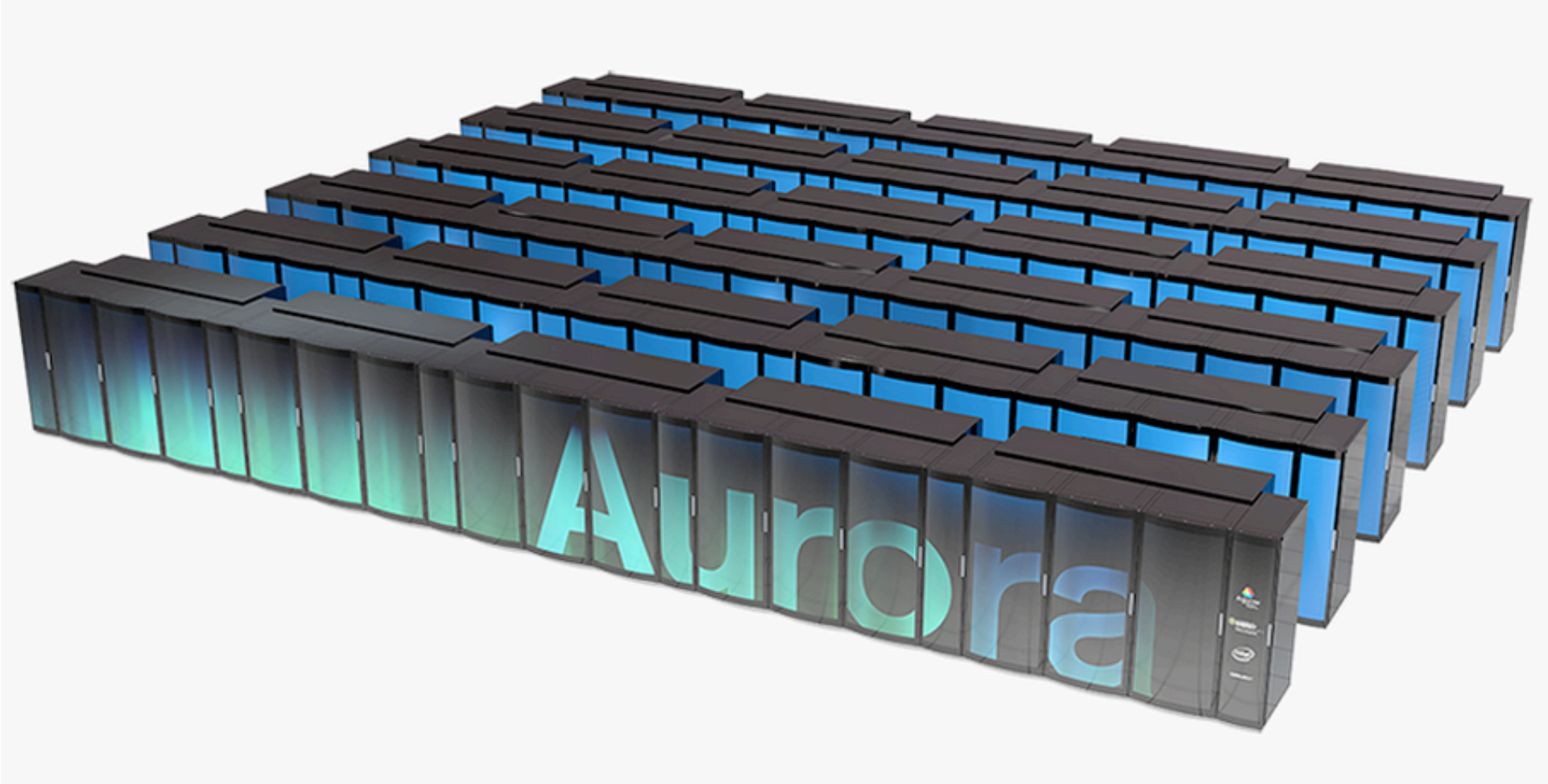
Argonne's Next Big Machine: Aurora

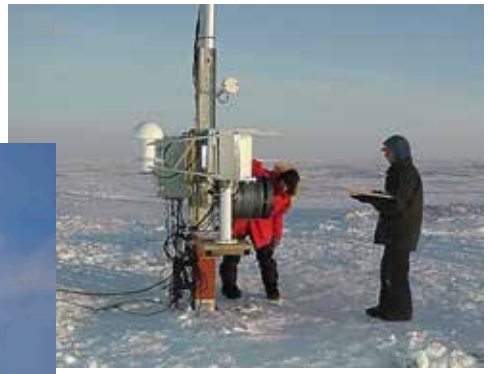


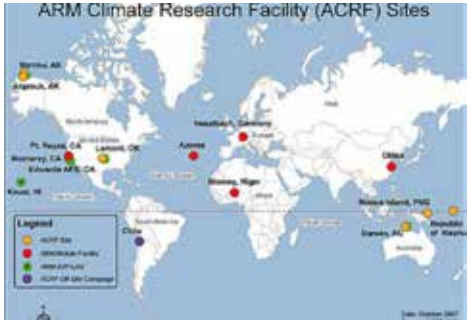
Argonne:

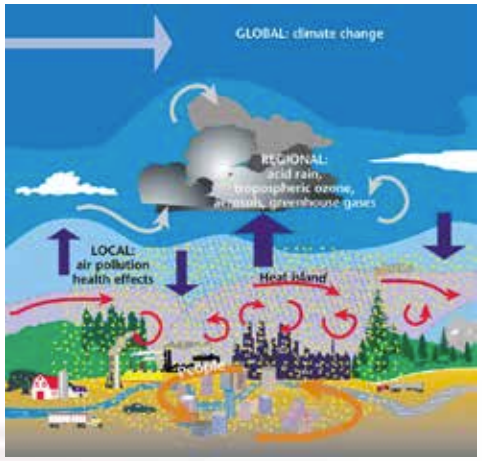
Develops new sensors
Runs large sensor networks
Does climate modeling and simulation

- … chemical, biological, nuclear and explosive materials

Atmospheric Radiation Measurement
Climate Research Facility



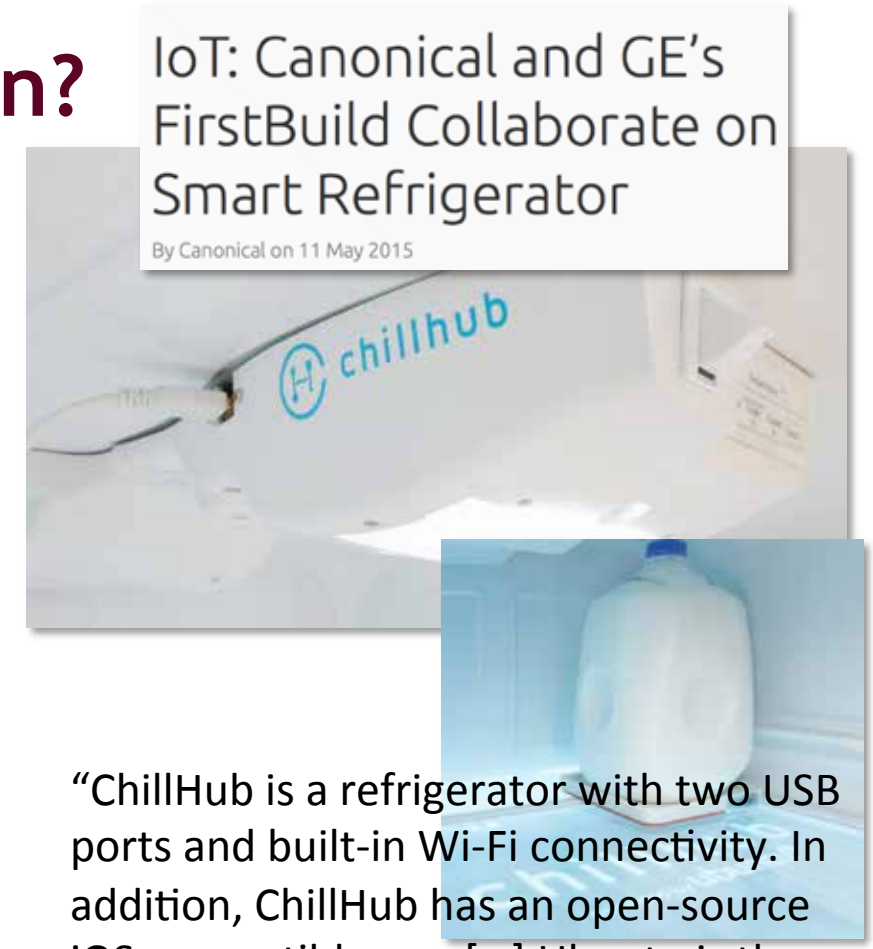




Internet of Things… Yawn?

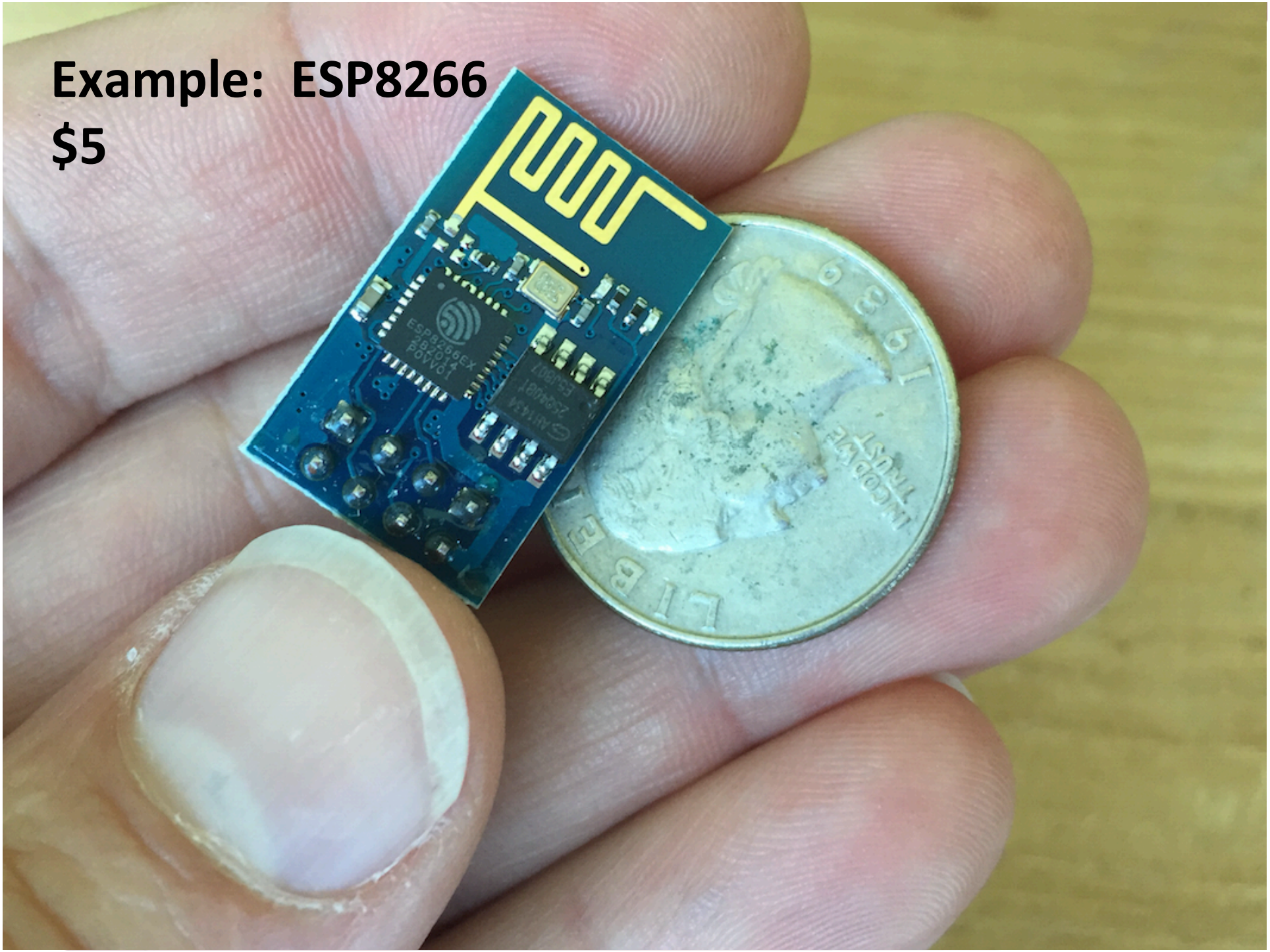
University of Cambridge, 1991

Amazon Dash



"ChillHub is a refrigerator with two USB ports and built-in Wi-Fi connectivity. In addition, ChillHub has an open-source iOS-compatible app […] Ubuntu is the favored platform for developers of all kinds – particularly those innovating around the Internet of Things."

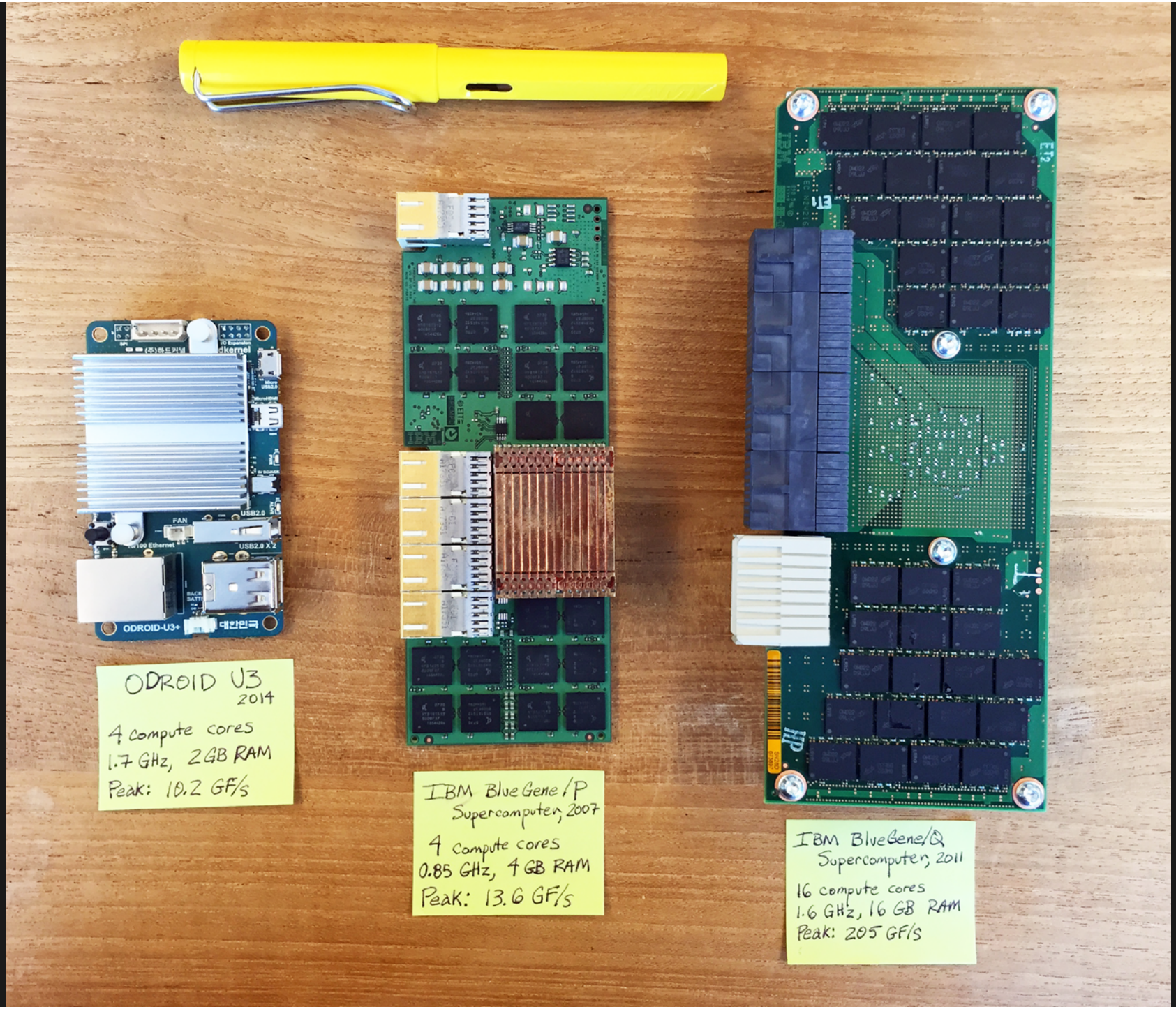
Example: ESP8266
$5



Disruption of Interest: Internet of *SMART* Things

- **Sensors**: Explosion of nano tech (new Moore's-like law)
  - Increasingly smaller, lighter, more accurate, energy efficient
    - Examples: micro GasChrom (NDA), micro air quality sensors, weather, motion, etc.
- **CPUs**: *Capable* low-power CPUs embedded everywhere: cities, people, infrastructure
  - E.g: CPUs we swallow (Freescale K02 prototype), shoes we wear (Nike), to large-scale city water and electrical infrastructure
  - CPUs can be very capable
- **Big Data:** Sensors generate more data than can be stored
  - Sensors+CPUs = new programming model for *in-situ computation*
  - HPC Analysis that can be fused with cloud-based data sets

Opportunity: Move from observing to predicting:
Smart Sensors + Supercomputers = predictions and analysis

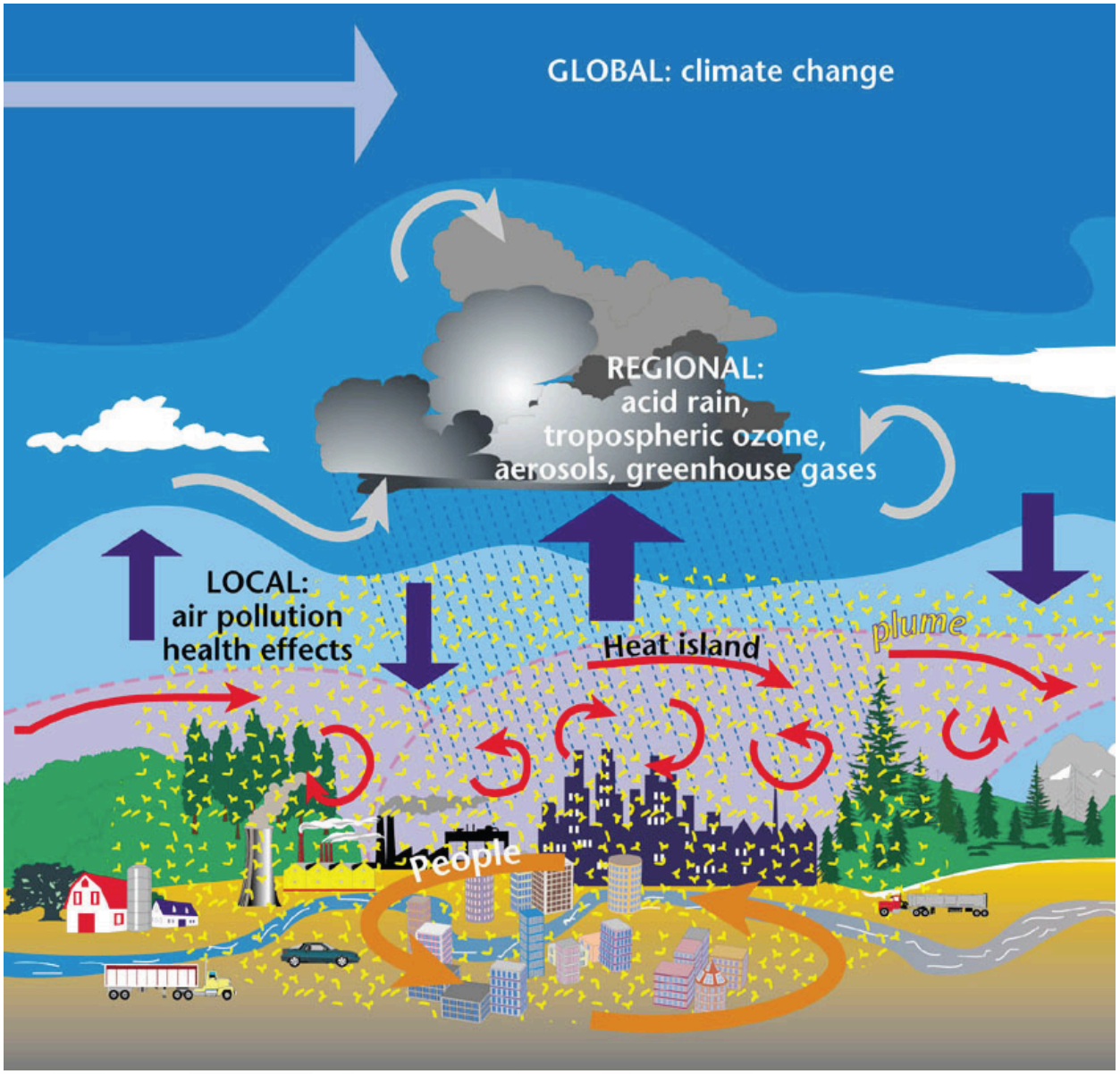

ODROID U3
2014
4 compute cores
1.7 GHz, 2 GB RAM
Peak: 10.2 GF/s
IBM BlueGene/P
Supercomputer, 2007
4 compute cores
0.85 GHz, 4 GB RAM
Peak: 13.6 GF/s
IBM BlueGene/Q
Supercomputer, 2011
16 compute cores
1.6 GHz, 16 GB RAM
Peak: 205 GF/s

Introducing Waggle (www.wa8.gl)

- Open source architecture to leverage disruptive technology
  - A standard building block instead of hack-a-RPi.
- ***Powerful CPU***, accurate sensors
- Supports ***In-Situ computation*** 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 design can be adapted for new sensors or control systems, host active education community

The connection between urban and regional climate

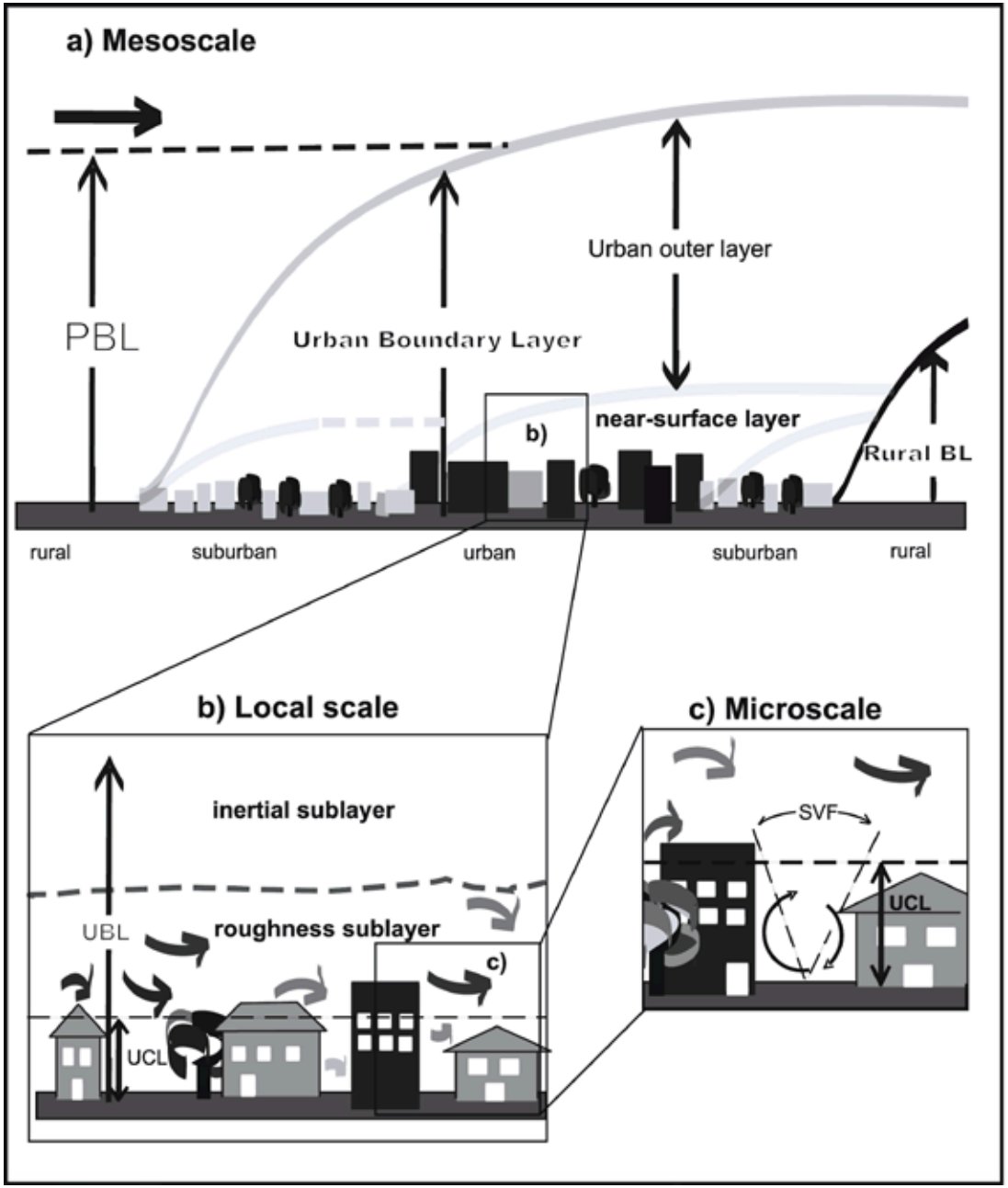
- Cities can alter their local climate through their built environment.
  - Temperature (urban heat island) and precipitation (storm splitting and initiation) are the most widely known examples.
- Cities alter the surrounding regional climate primarily through emissions carried downwind as an "urban plume".
- Predicting urban climate change requires interactive modeling of regional and urban climate systems.



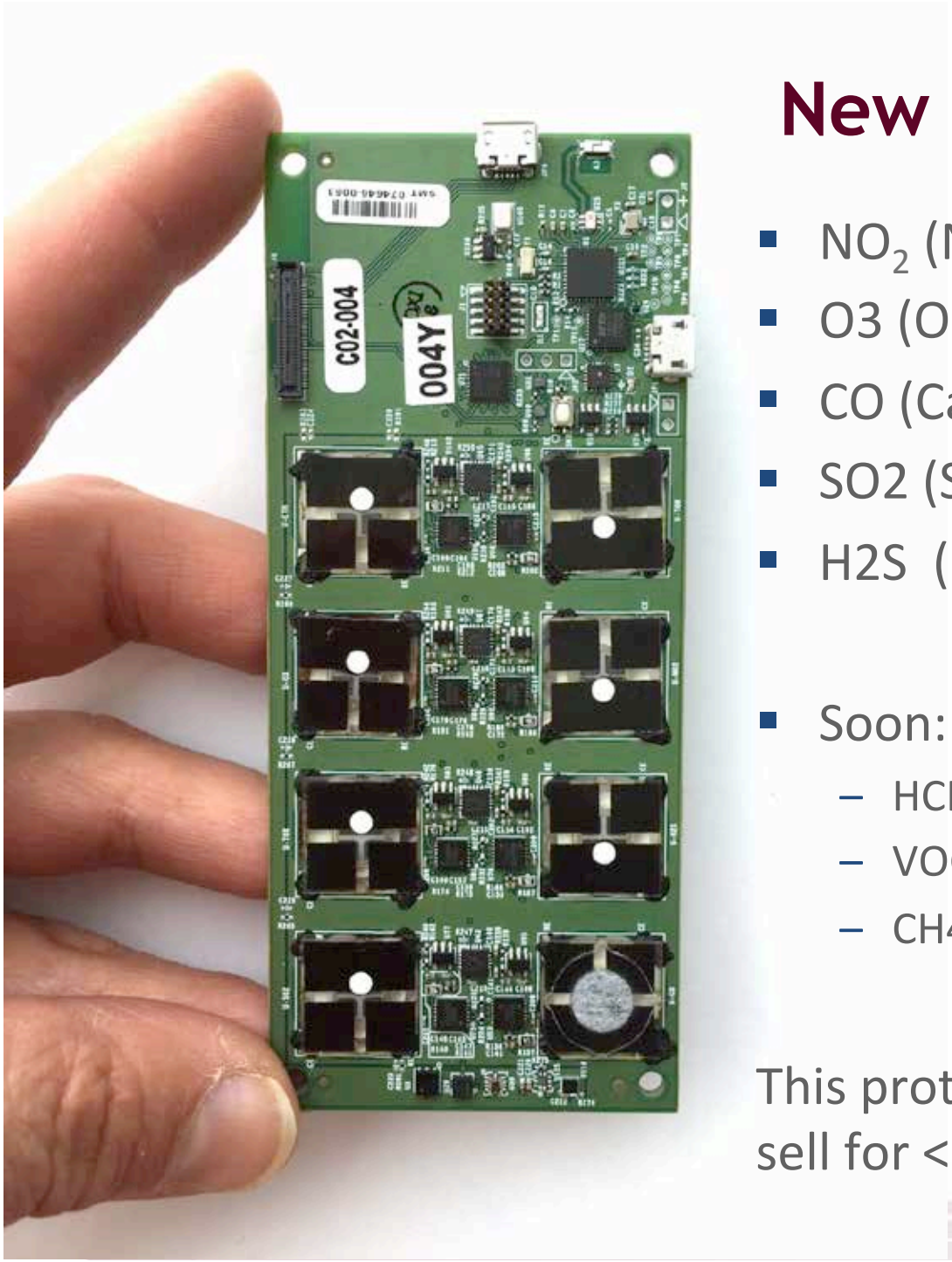
The Planetary Boundary Layer

- Where we live
- After emissions, primary control on pollution levels is interaction between PBL and free atmosphere.
- In Urban areas

  Urban Boundary Layer
  Urban Canopy Layer



Source: NRC "Urban Meteorology: Forecasting, Monitoring, and Meeting Users' Needs"



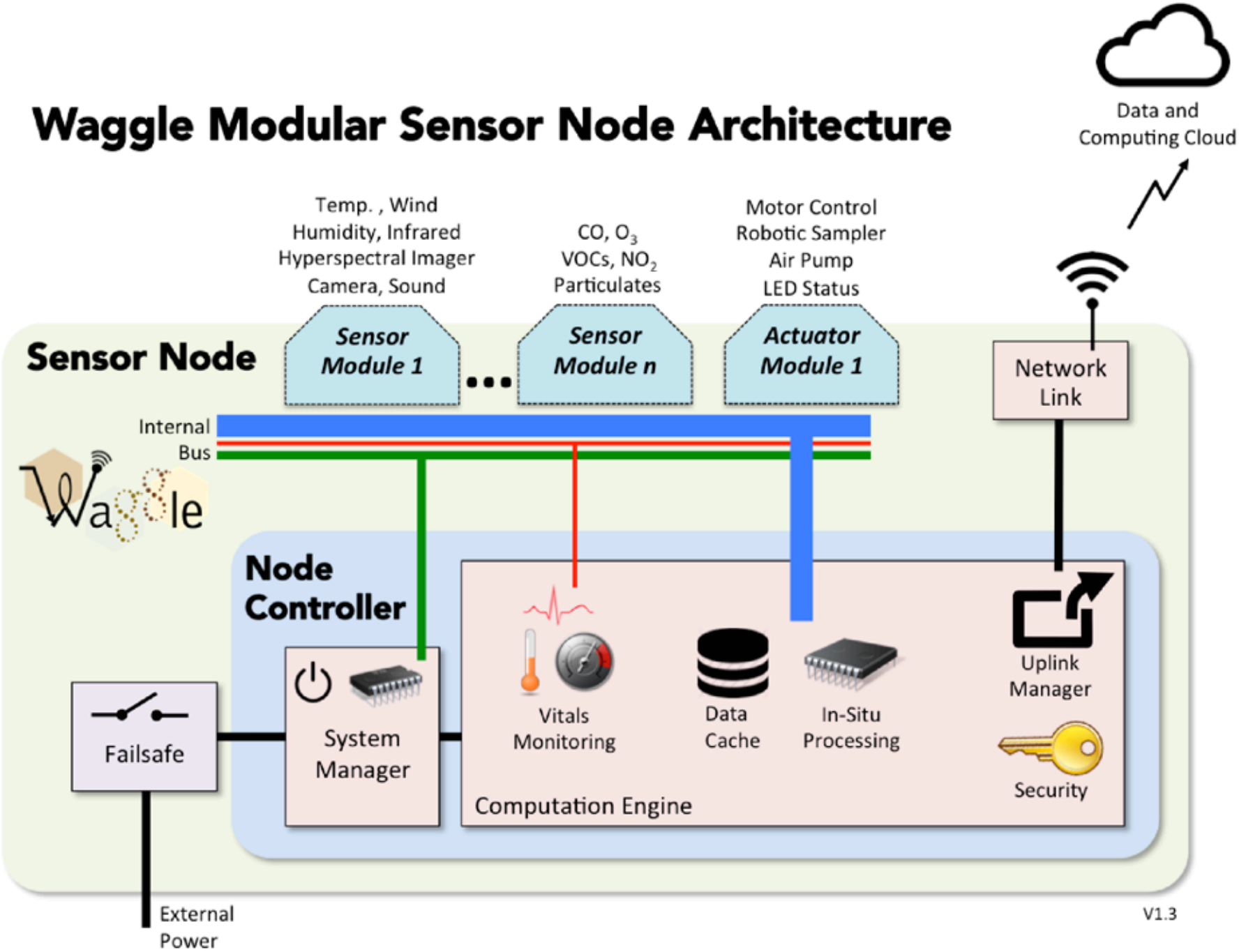
New Advanced Sensors

- NO_2 (Nitrogen Dioxide): <2 ppb
- O3 (Ozone) < 5 ppb
- CO (Carbon Monoxide) < 1 ppm
- SO2 (Sulfer Dioxide) < 15 ppb
- H2S (Hydrogen Sulfide) < 2 ppb

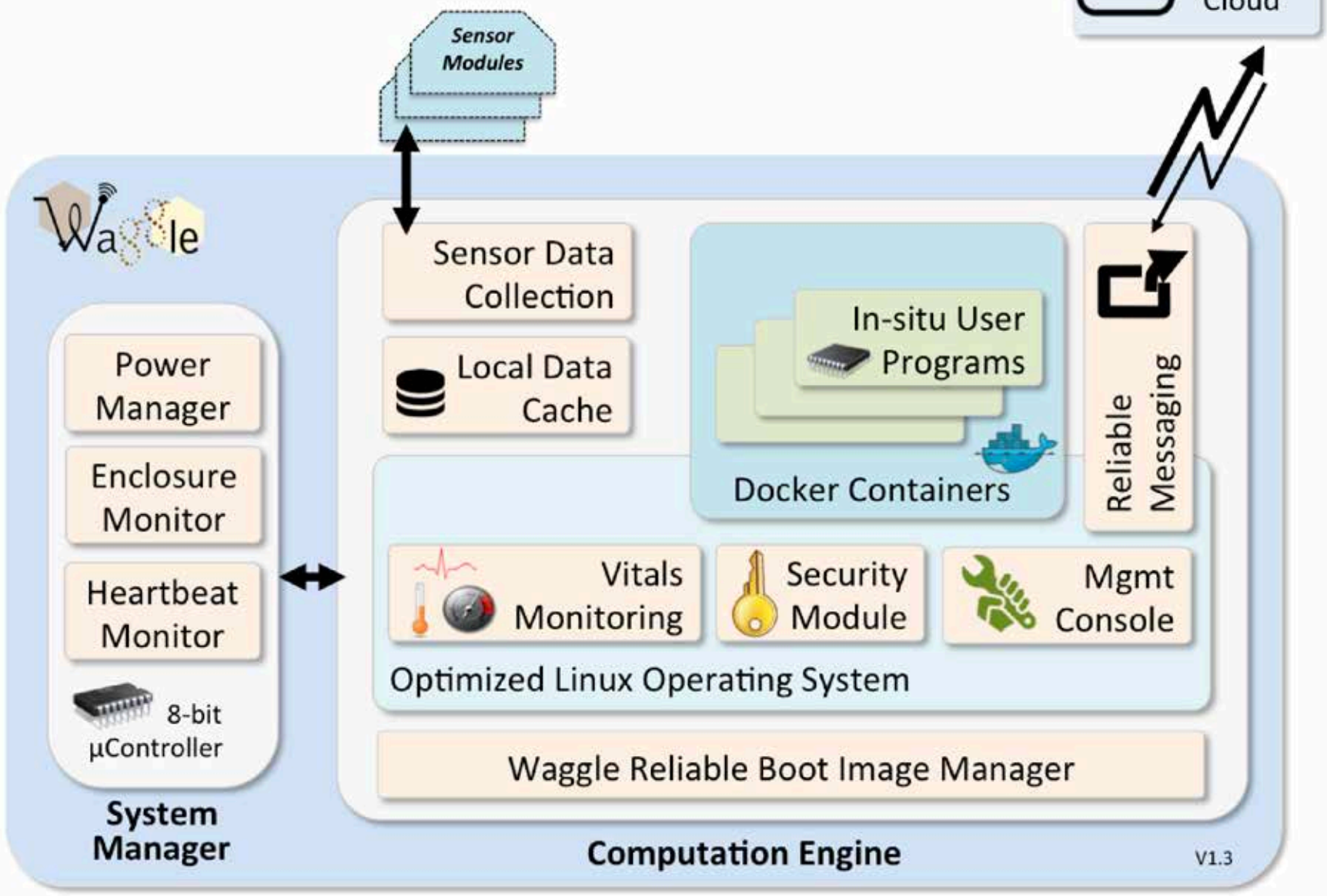
- Soon:
  - HCHO (Formaldehyde)
  - VOC (Volatile Organic Compound)
  - CH4 (Methane)

This prototype board would likely sell for < $75 in production

Waggle Modular Sensor Node Architecture



Waggle Node Controller Software Architecture



Many, Many, Research Questions: Are compute-capable sensors interesting?

- # of devices
  - Parallel in-situ processing? Algorithms? Collectives?
- Ultra-resilient, periodically connected operation
- Control systems for actuators (motors, etc.)
- Embedded secret required, and hard to manage (pairing, Apple HomeKit)
- Assume physical access by mischievous hands
  - Cheap Trojan counterfeits, Report false data, Mod actuators
- How does massive, lower-quality data compare to fewer, high quality data?

Sensors
Waggle EnvSense V1.0 Nov2014 board

1 Overall Packet Structure

The structure of the packet (and the data sub-packet) relies on byte positions and known values, rather than delimiters.

Field	Value	Byte Position	Length
Start	0xAA	0	1
Protocol version	0x00	1	1
Length of data (not whole packet)		2	1
Data		3	194
CRC of data (not whole packet)		197	1
End	0x55	198	1

Table 1: Overall packet structure

Important: If the *length of data* is 0, the packet immediately ends, meaning the *data*, *CRC*, and *end* fields do not exist.

2 Data Sub-Packet

The data sub-packet consists of 32 "chunks" (30 sensors and 2 MAC addresses). Each "chunk" follows one of seven formats.

2.1 Data Formats

Format	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
1	(1 « 7) | integer	(neg « 7) | fractional	-	-	-	-
2	7 MSb	LSB	-	-	-	-
3	Addr5	Addr4	Addr3	Addr2	Addr1	Addr0
4	(1 « 7) | (neg « 6) | (4-bit int « 2) | 2 MSb of frac.	8 LSb of frac.	-	-	-	-
5	(neg « 6) | 6 MSb	8 LSb	-	-	-	-
6	(1 « 7) | (neg « 6) | 6 MSb	Middle 8 bits	8 LSb	-	-	-
7	First 8 "chunks"	8 "chunks"	8 "chunks"	Last 8 "chunks"	-	-

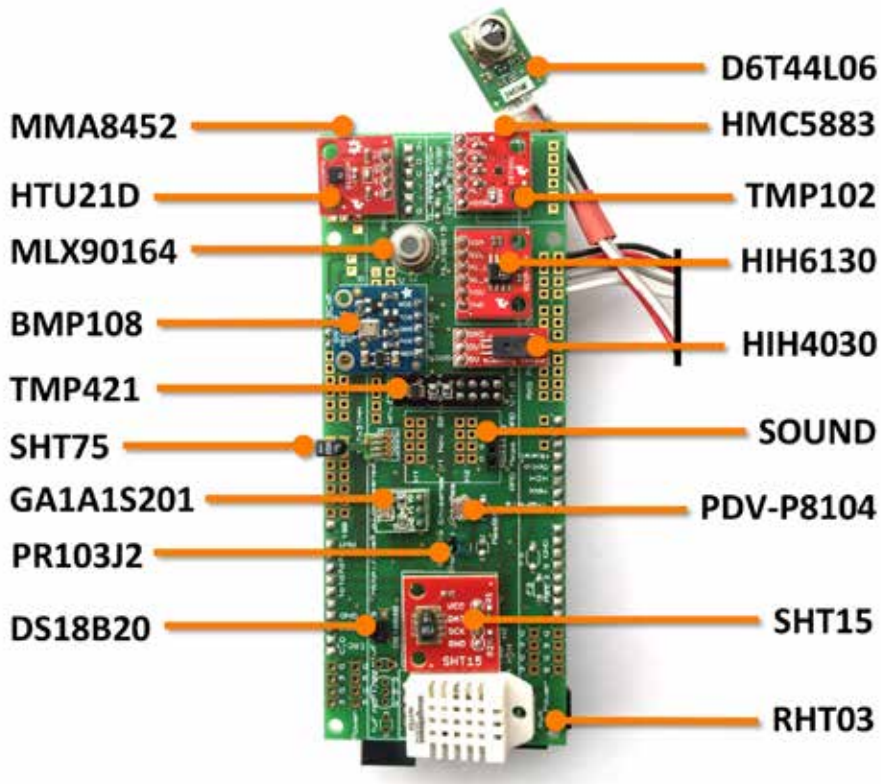
Table 2: Data formats

This version of the Waggle protocol does not use standard representations for floating point numbers. Instead, the location of the decimal point is pre-determined (between the integer and fractional components, if applicable).

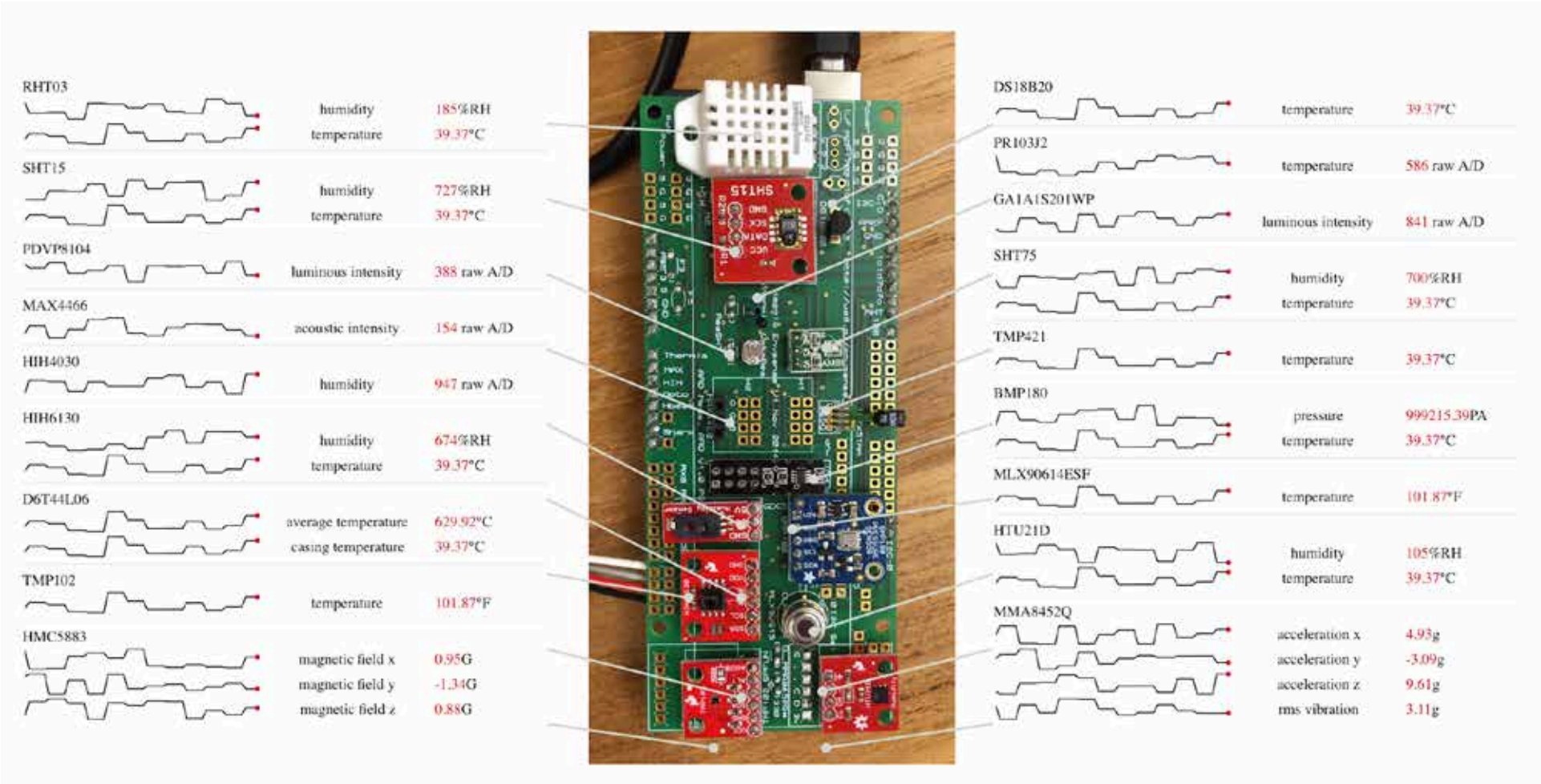
The most significant bit in byte 0 of formats 1, 4, and 6 means the data is already converted. Formats 2 and 5 contain raw data.

Formats 1, 4, 5, and 6 contain a "negative" bit. If this bit is 1, the value is negative.

Air Temperature, Humidity, Infrared Temperature, Barometric Pressure, Ambient Light, Sound Levels, Vibration, Magnetometer, etc.

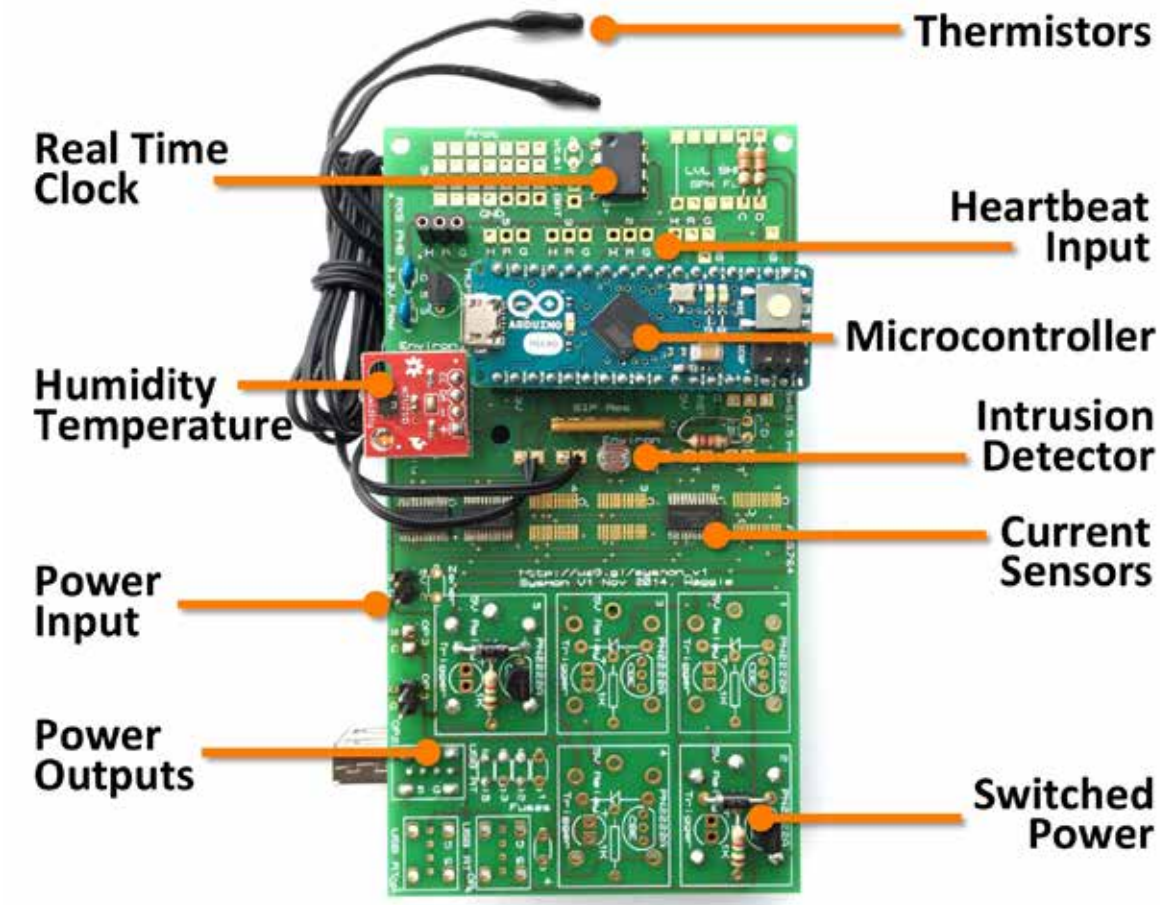


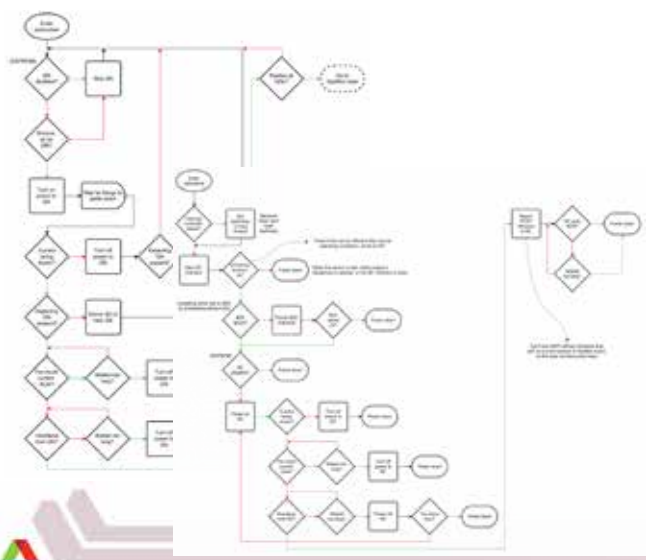
Programmer Interface for Watching



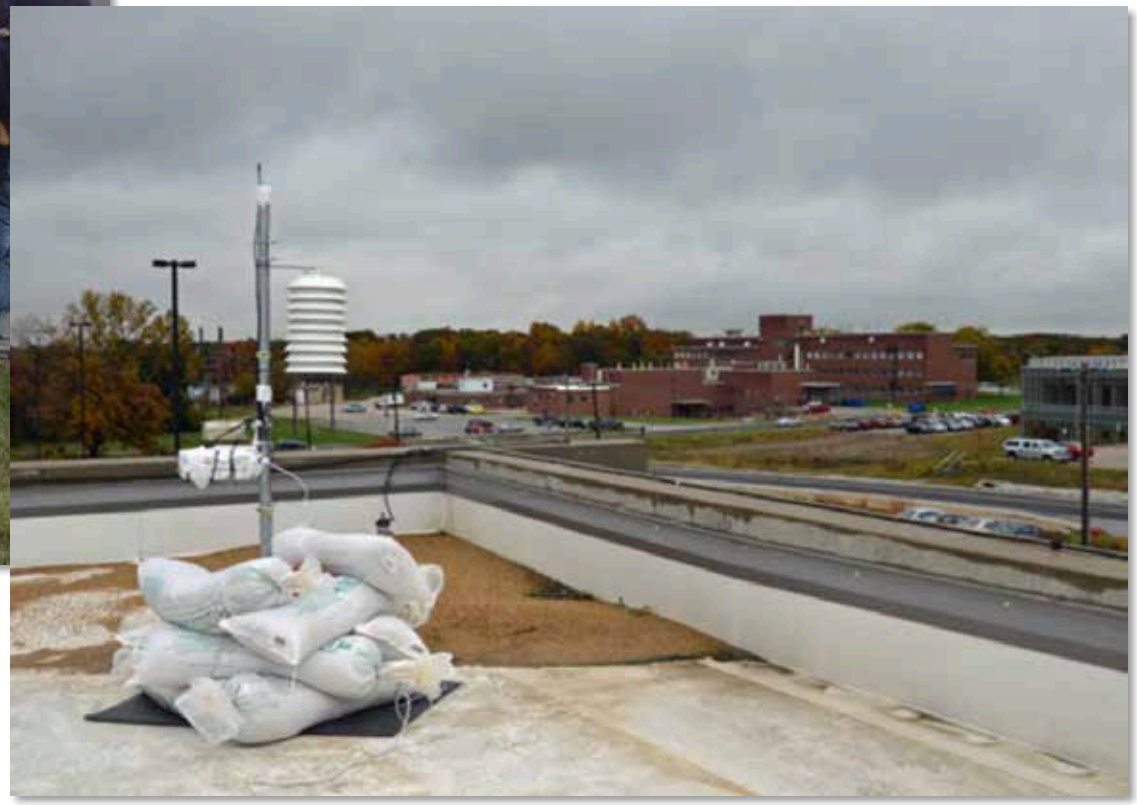
Node Management
Waggle SysMon V1.0 Nov2014 board

- Internal Sensors (intrusion, temp, power (current), etc.
- Provides "Deep Space" operation with heartbeats, safe mode, hard power control, backup kernels, etc.





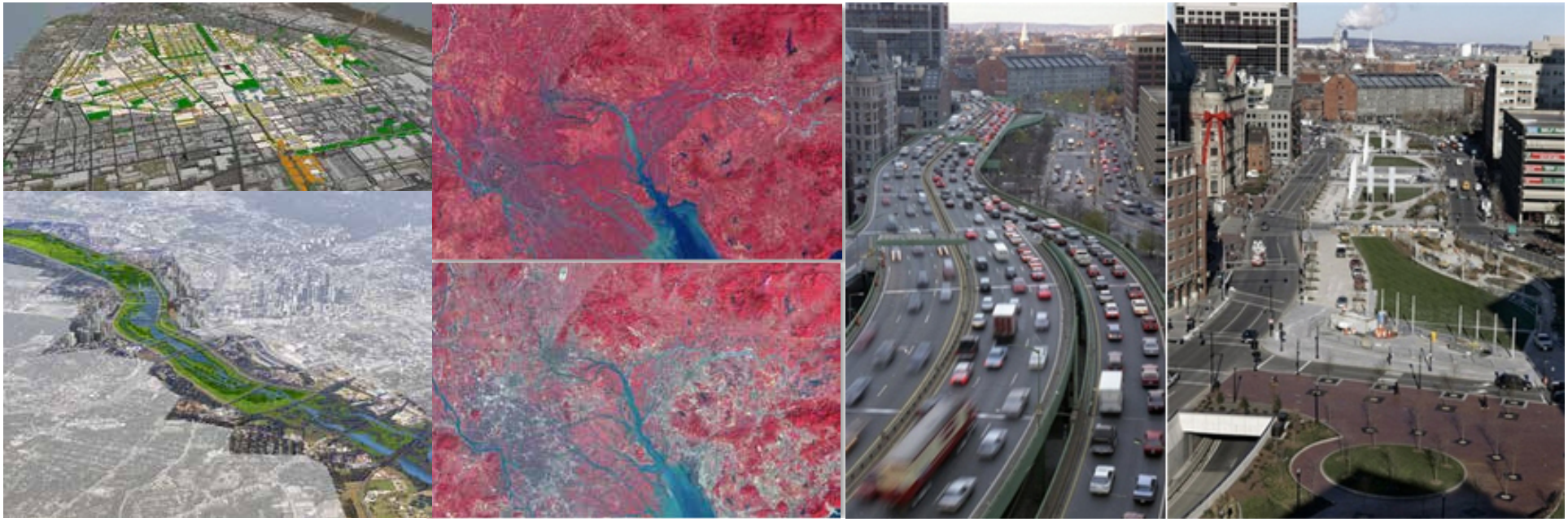
(Chicago Winter Survival Test)…



(old) Version 1 Enclosure

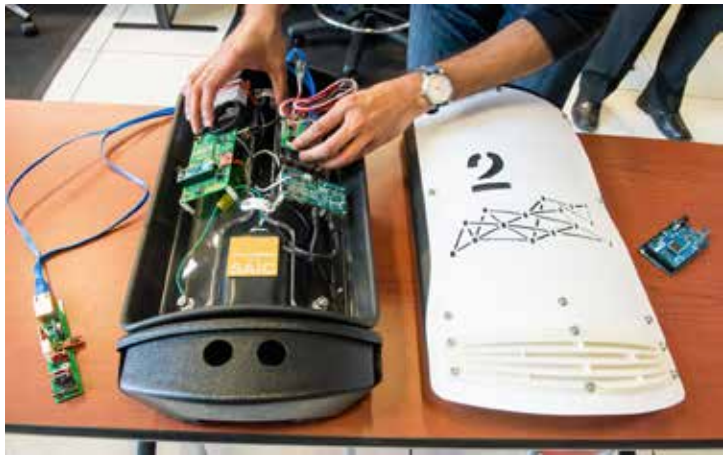
Instrumenting Cities (Preview: Charlie Catlett)

- As cities grow they face increased operational costs and challenges across every area of policy and science.
- There exists no open source, low-cost, general purpose platform to *measure* cities at the spatial and temporal resolution necessary for science and data-driven policy.



Array of Things: Planned Deployment

- Phase 1 (est. 4q2015): 50 Gen3 nodes at CDOT green space “placemaking” project sites.
- Phase 2 (est. 2q2016): 100 Gen3 nodes, Chicago Loop
- Phase 3 (est. 4q2016): 50 Gen4 nodes, Chicago Loop
- Phase 4 (est. 3q2017): 300 Gen4 nodes, mixed density deployment throughout city.

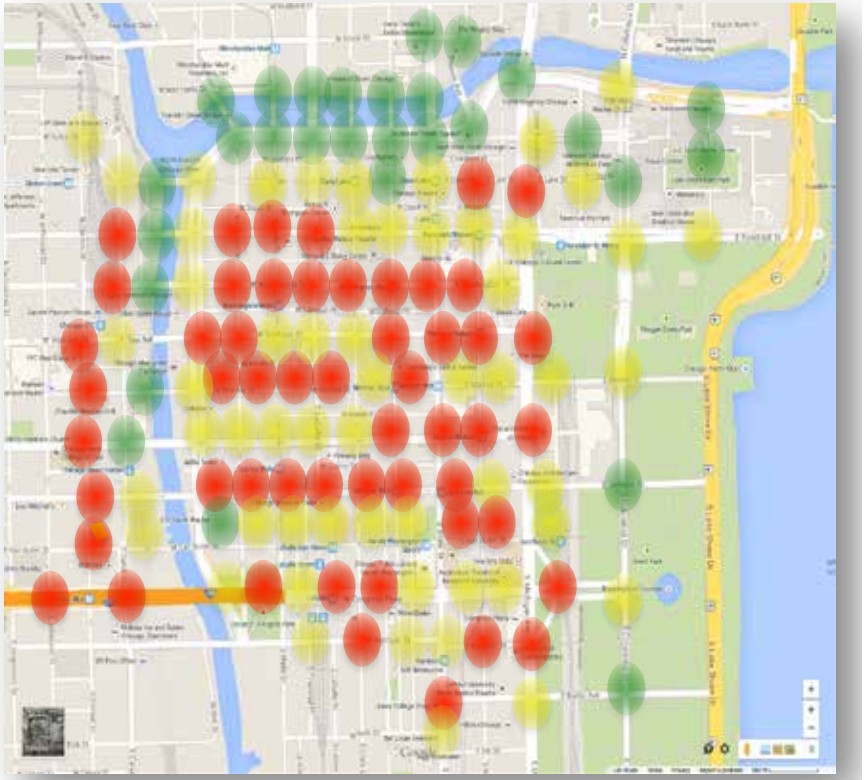


(current) Version 2

Discussions also under way with Seattle, San Francisco, Los Angeles, St. Louis, Boston, Barcelona, London, Bristol, Glasgow, Umeå, Bolzano.


(current) Version 2

Artist Rendition: Version 3



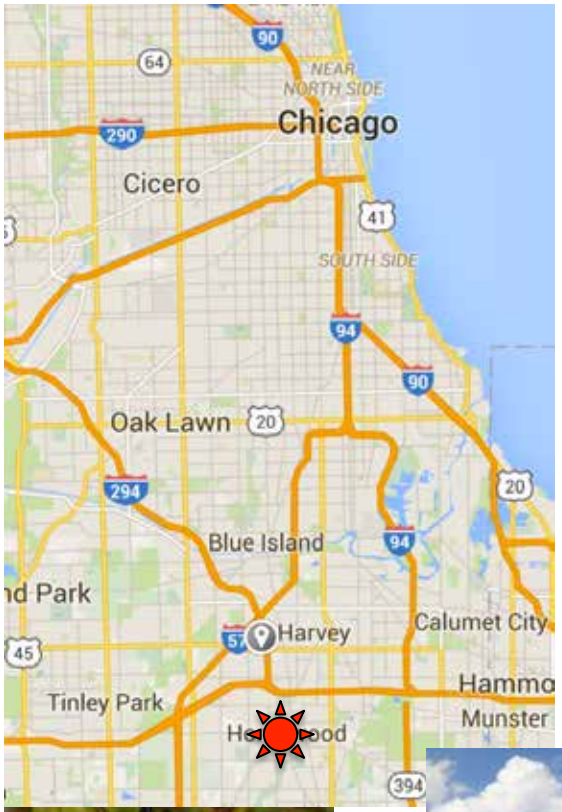
Deployment Map

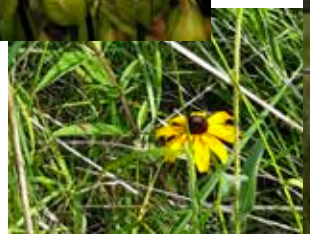

GERALD

Gensburg-Markham Prairie

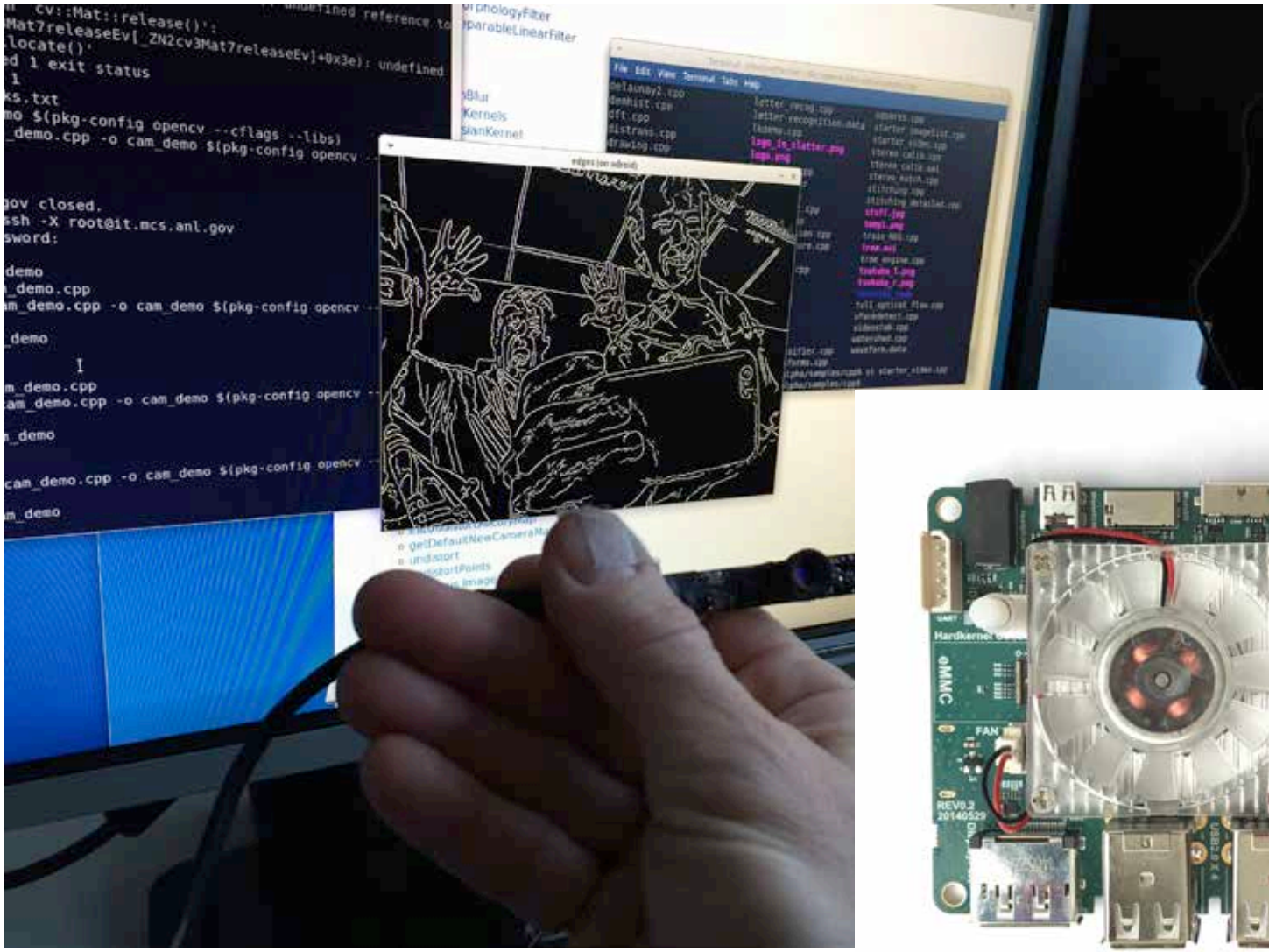
370 acres, owned/managed by Nature Conservancy and Northeastern IL Univ.

Registered as National Natural Landmark

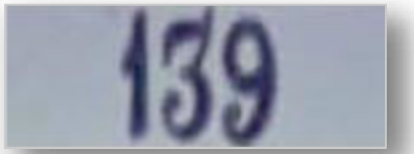




In-Situ Analysis and Feature Recognition



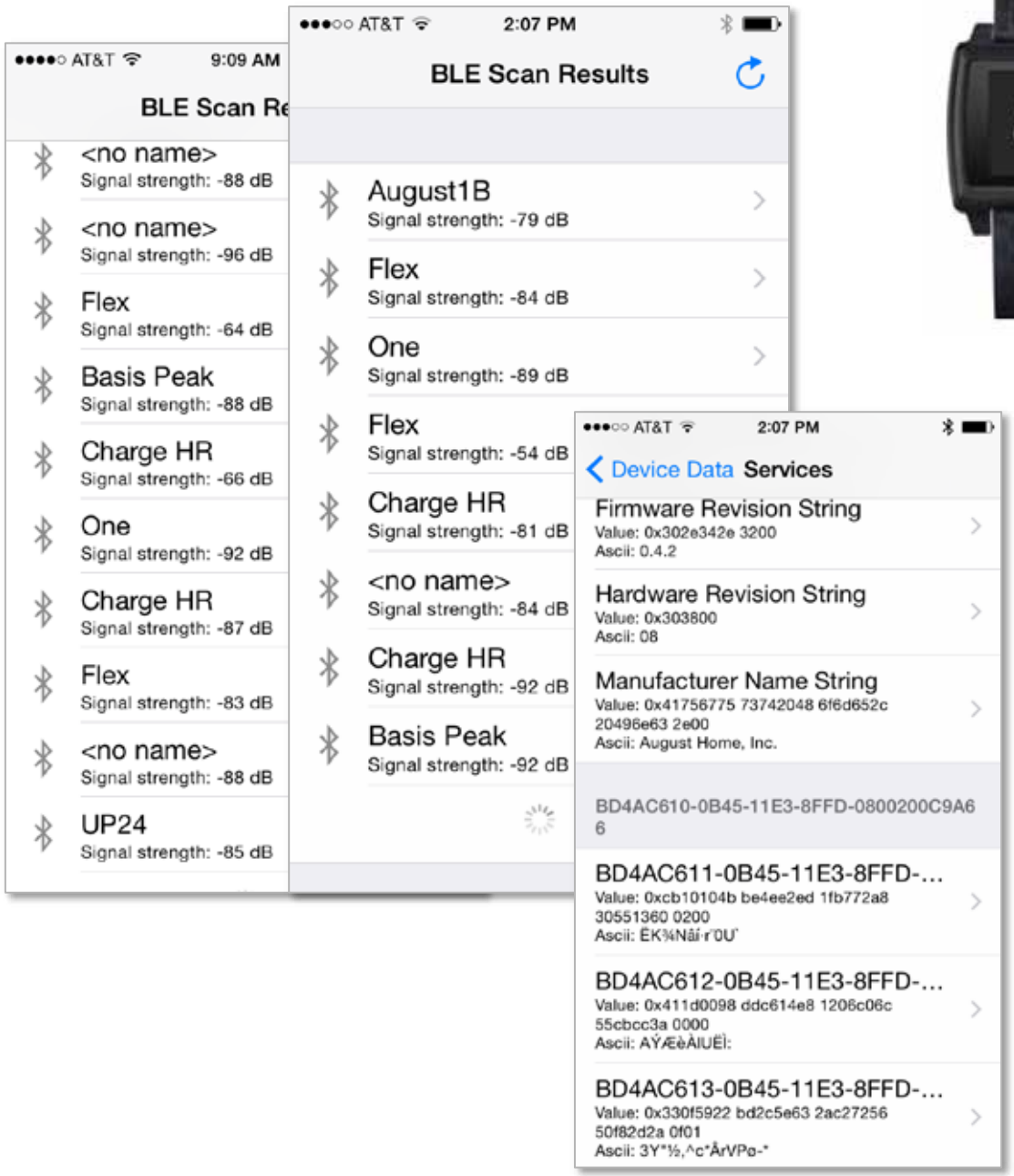
Machine Learning: Cat or Dog?



http://www.flickr.com/photos/thetransitcamera/

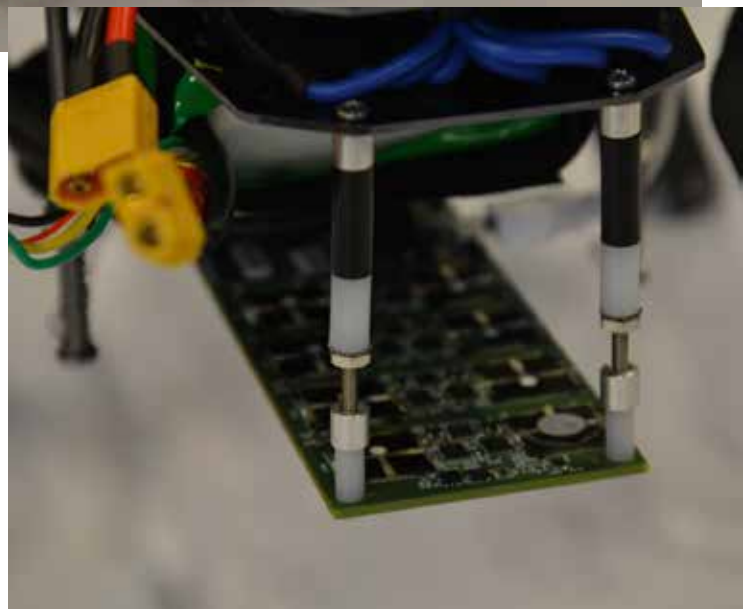
© 2012 J. Mc

Privacy…


AT&T 9:09 AM
BLE Scan Re
<no name>
Signal strength: -88 dB
<no name>
Signal strength: -96 dB
Flex
Signal strength: -64 dB
Basis Peak
Signal strength: -88 dB
Charge HR
Signal strength: -66 dB
One
Signal strength: -92 dB
Charge HR
Signal strength: -87 dB
Flex
Signal strength: -83 dB
<no name>
Signal strength: -88 dB
UP24
Signal strength: -85 dB
AT&T 2:07 PM
BLE Scan Results
August1B
Signal strength: -79 dB
Flex
Signal strength: -84 dB
One
Signal strength: -89 dB
Flex
Signal strength: -54 dB
Charge HR
Signal strength: -81 dB
<no name>
Signal strength: -84 dB
Charge HR
Signal strength: -92 dB
Basis Peak
Signal strength: -92 dB
AT&T 2:07 PM
Device Data Services
Firmware Revision String
Value: 0x302e342e 3200
Ascii: 0.4.2
Hardware Revision String
Value: 0x303800
Ascii: 08
Manufacturer Name String
Value: 0x41756775 73742048 6f6d652c 20496e63 2e00
Ascii: August Home, Inc.
BD4AC610-0B45-11E3-8FFD-0800200C9A66
BD4AC611-0B45-11E3-8FFD-…
Value: 0xcb10104b be4ee2ed 1fb772a8 30551360 0200
Ascii: ËK¾Nâí·r`0U`
BD4AC612-0B45-11E3-8FFD-…
Value: 0x411d0098 ddc614e8 1206c06c 55cbcc3a 0000
Ascii: AÝÆèÀlUËÌ:
BD4AC613-0B45-11E3-8FFD-…
Value: 0x330f5922 bd2c5e63 2ac27256 50f82d2a 0f01
Ascii: 3Y"½,^c*ÂrVPø-*


88
BASIS


135



Looking Forward

- Does community need open platform?
  - Featherweight, middle-weight, CPU-heavy archetypes
- There are good, meaty CS problems in this space…
  - Autonomous decisions, collective behavior, billion-way control, de-centralized mgmt, trusted unprotected hw…
  - Programmable, HPC-style env. with in-situ computation
  - Machine learning, classification, processing audio, etc.
  - Neuromorphic computing
- Selling nodes on SparkFun?
- Privacy? In-situ computation? Air Gap?

An open platform for intelligent attentive sensors

http://www.wa8.gl

Home | About | Team | Design › | News (Blog) | Code & Pubs | Data | Science ›

A customizable, powerful, hackable sensor network platform for science

Waggle Dashboard | Waggle Platform Waggle Nodes Waggle Documentation

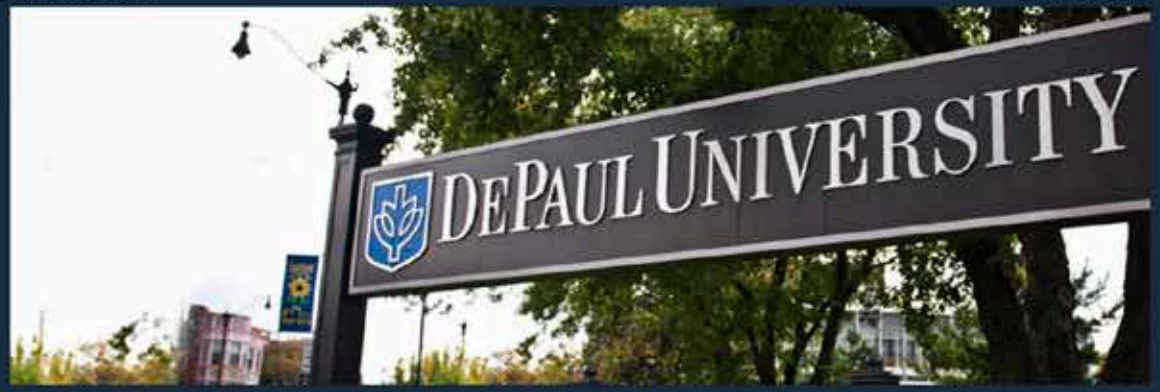
An open platform for intelligent attentive sensors

Name	Group	Location	Coordinates	Status	Current Data
UCAOT01	AoT	Regenstein Library	41.791848, -87.599566	Active	View Data
UCAOT02	AoT	Logan Center	41.785573, -87.604143	Active	View Data
UCAOT03	AoT	Ratner Center	41.793373, -87.602294	Active	View Data
UCAOT04	AoT	Smart Museum	41.793685, -87.600131	Active	View Data
UCAOT05	AoT	Mandel Hall	41.790758, -87.598514	In-active	View Data
UCAOT06	AoT	Oriental Institute	41.789009, -87.597298	Active	View Data
UCAOT07	AoT	Levi Hall	41.789274, -87.600936	Active	View Data
WXSENETDEPAUL01	WxSeNet	McGowan Roof	41.923693, -87.656892	Active	View Data
WXSENETANL01	WxSeNet	TCS 240 Roof	41.717602, -87.982415	In-active	View Data
WXSENETANL02	WxSeNet	Area 460	41.701558, -87.994766	In-active	View Data

DePaul University | McGowan Roof | Data Archive

Lat: 41.923693 Lon: -87.656892

Installed January 20th, 2015



Jul 30, 2015 3:59:14 pm

RHT03

Temperature	NA °C
Humidity	NA %RH

HTU21D

Temperature	NA °C
Humidity	NA %RH

HIH6130

Temperature	31.38 °C
Humidity	31.5 %RH

MLX90614ESF

Temperature	89.49 °F

MMA8452Q

Acceleration x	NA g
Acceleration y	NA g
Acceleration z	NA g

SHT15

Temperature	31.43 °C
Humidity	28.57 %RH

D6T44L06

Avg. Temperature	NA °C
Casing Temperature	NA °C

HIH4030

Humidity	352 raw A/D

TMP102

Temperature	NA °C

PR103J2

Temperature	920 raw A/D

HMC5883

Magnetic Field x	NA µT
Magnetic Field y	NA µT
Magnetic Field z	NA µT

SHT75

Temperature	32.2 °C
Humidity	27.38 %RH

BMP180

Temperature	31.89 °C
Pressure	99383 Pa

DS18B20

Temperature	31.62 °C

TMP421

Temperature	31.37 °C

GA1A1S201WP

Luminous Intensity	710 raw A/D

PDVP8104

Luminous Intensity	1015 raw A/D

MAX4466

Acoustic Intensity	212 raw A/D

More Information

- Waggle
  - http://wa8.gl/
  - Contact: Pete Beckman beckman@anl.gov

- Array of Things
  - http://arrayofthings.github.io
  - Contact: Charlie Catlett c@anl.gov

Funding: Argonne's Laboratory Directed Research and Development program