Community Air Sensor Network (CAIRSENSE) Project: An Evaluation of Low-Cost Air Sensor Technology

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Assessing and supporting new technology

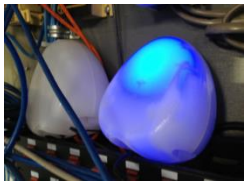
Emerging air monitoring systems (informal classification)

existing

Group 1: Regulatory or regulatory-equivalent air monitoring stations
Cost: $100Ks, Data reliability = A+

emerging

Group 2: Smaller-footprint monitoring systems for community screening and research studies
Cost: $1-10Ks, Data reliability = B+ (target)



Group 3: Very small, very low cost systems enabling dense sensor networks, citizen science
Cost: $0.1-1Ks, Data reliability = ?

CAIRSENSE

Opportunities of lower cost air sensors for EPA Regions

- Ability to conduct monitoring in situations/locations where it is currently cost-prohibitive
- Improved engagement for communities with air quality concerns
- Improved spatial resolution of air monitoring networks
- Better understanding of local-scale air quality issues, such as near-source applications

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Community Air Sensor Network (CAIRSENSE) Project Overview

- **Participants:**

  EPA Regions 4, 1, 5, 7, and 8; EPA Office of Research and Development (ORD); EPA Office of Air Quality Planning and Standards (OAQPS); and Georgia Environmental Protection Division (EPD).

- **Objectives:**

  1. Evaluate in situ the ***long-term comparability of several lower cost sensors of interest*** against regulatory monitors.

  2. Determine the capabilities and limitations of a ***long-term multi-node wireless sensor network applied for community air monitoring***, in terms of operational stability (communications, power) and long-term data quality under ambient conditions.

- **Year 1 Location:**
  - South Dekalb NCore site in Atlanta

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EPA Regional Methods Program

The Regional Methods Program is a mechanism used by EPA Office of Research and Development (ORD) to:

- Respond to high-priority, near-term methods development needs of EPA's regional offices;
- Enhance interactions between regional and ORD scientists; and
- Improve ORD's capacity to bring science to bear on practical environmental issues faced by Regions.

- EPA Region 4 proposed the CAIRSENSE project, with partnering Regions, ORD, and OAQPS

Regional Methods Project Team:

a collaboration across EPA and stakeholders

Lead Organizations:

EPA Region 4

Project coordination, site selection, data analysis

EPA Office of Research and Development (ORD)

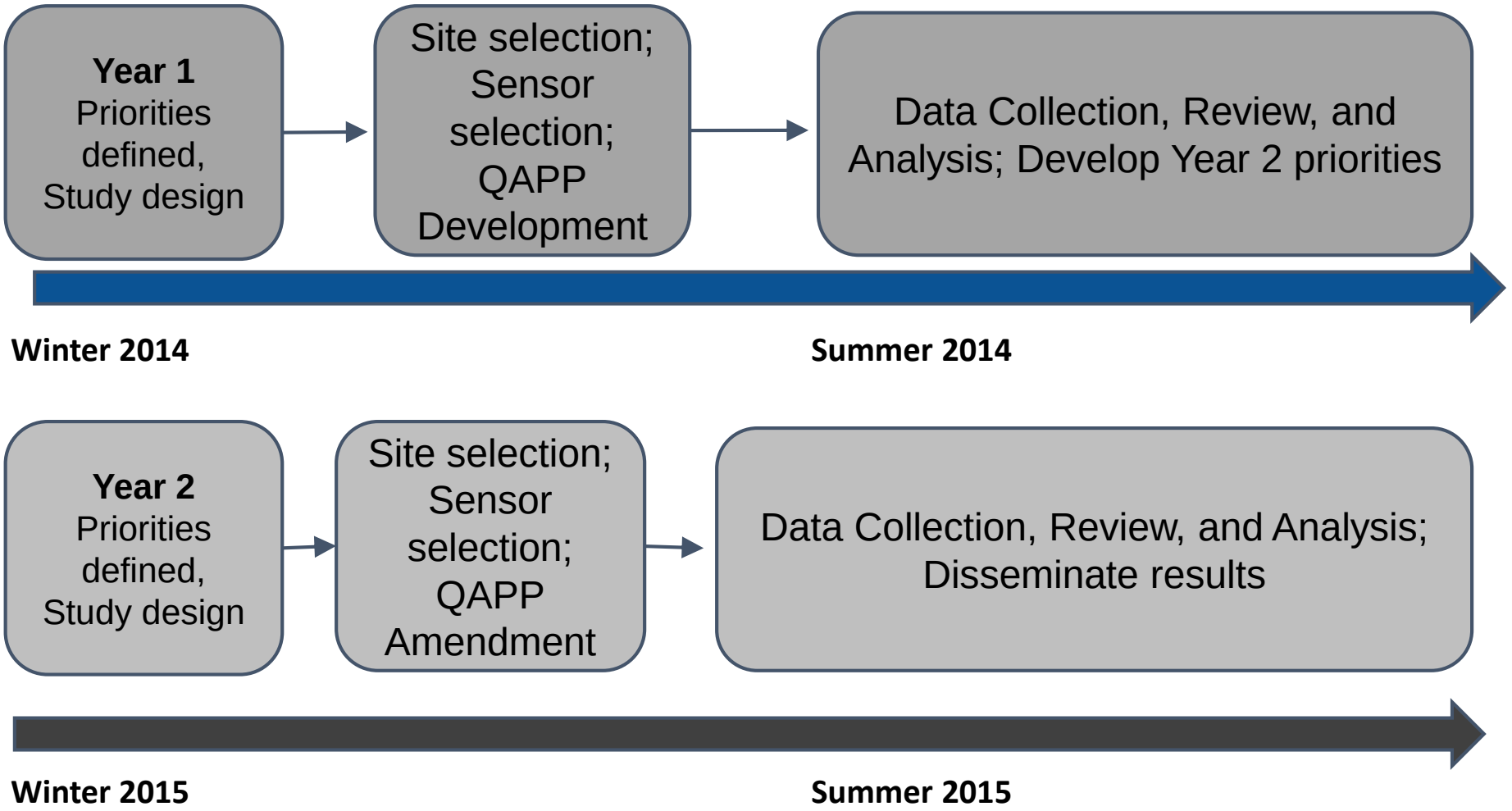
Experimental design, assistance with data analysis, contract management

Partner Organizations:

project input and review of documents
through regular conference calls and e-mail

- EPA Region 1
- EPA Region 5
- EPA Region 7
- EPA Region 8
- EPA Office of Air Quality Planning and Standards (OAQPS)
- Georgia Environmental Protection Division (GA EPD)
- North Carolina Division of Air Quality (NC DAQ)

General Project Timeline



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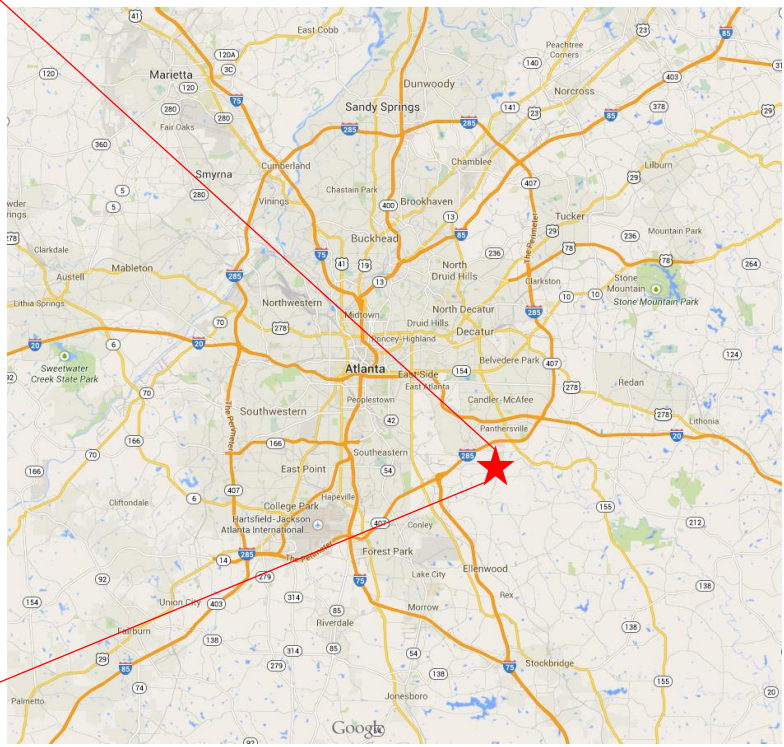
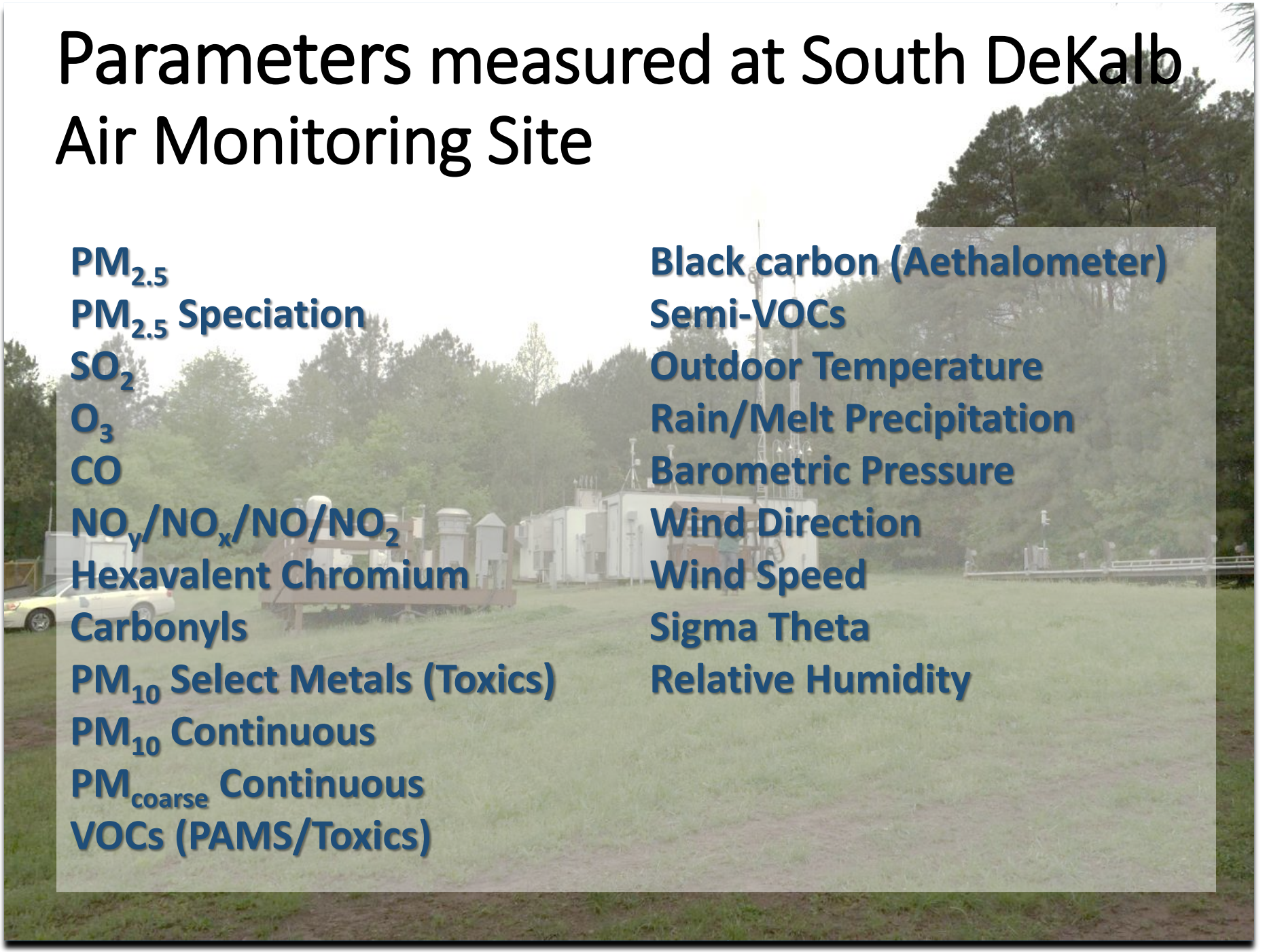
Project Objective 1: long-term comparability of lower cost sensors against regulatory monitors

South Dekalb Air Monitoring Site:

- National Core (NCore) regulatory monitoring site in Atlanta
- Extensive suite of measurements including criteria pollutants and precursors, air toxics, and meteorology
- Long historical data record



Parameters measured at South DeKalb Air Monitoring Site



- $PM_{2.5}$
- $PM_{2.5}$ Speciation
- SO_2
- O_3
- CO
- $NO_y/NO_x/NO/NO_2$
- Hexavalent Chromium
- Carbonyls
- PM_{10} Select Metals (Toxics)
- PM_{10} Continuous
- PM_{coarse} Continuous
- VOCs (PAMS/Toxics)
- Black carbon (Aethalometer)
- Semi-VOCs
- Outdoor Temperature
- Rain/Melt Precipitation
- Barometric Pressure
- Wind Direction
- Wind Speed
- Sigma Theta
- Relative Humidity

CAIRSENSE Sensor Field Testing

Module 1: Wireless sensor network

6 month field test

4 sensor node locations
(1 located at NCORE site)

1 sensor per pollutant, per node

"Point to Point/Star" wireless data streaming of entire network to an off-site server

Operating primarily on solar power

Module 2: Ad-hoc sensor testing

30+ day test

All sensors at NCORE site

Replicates of the same sensor co-located; multiple sensor types for the same pollutant

Data-logging varying by sensor technology

Land power provided

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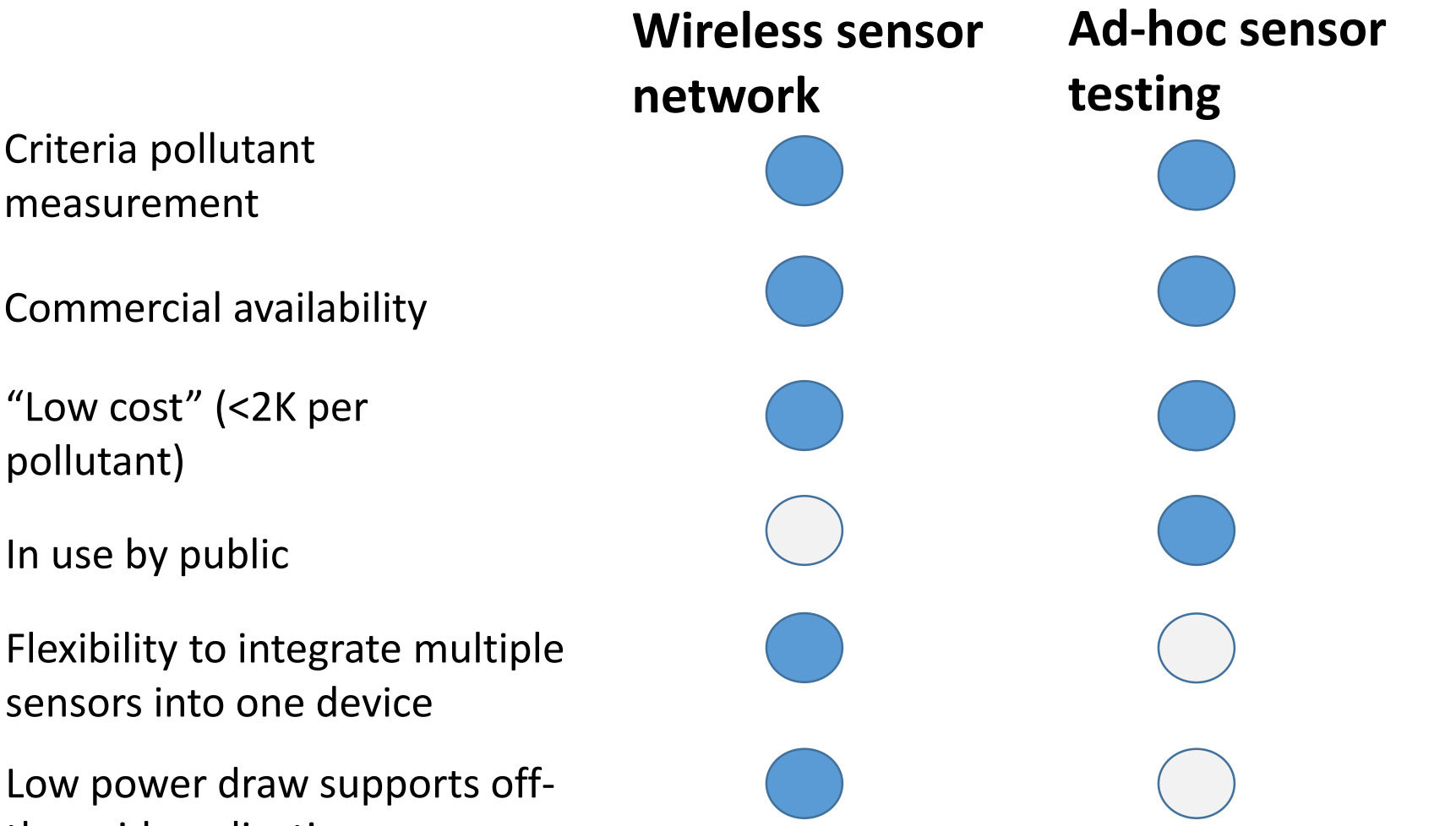
CAIRSENSE Sensor Selection



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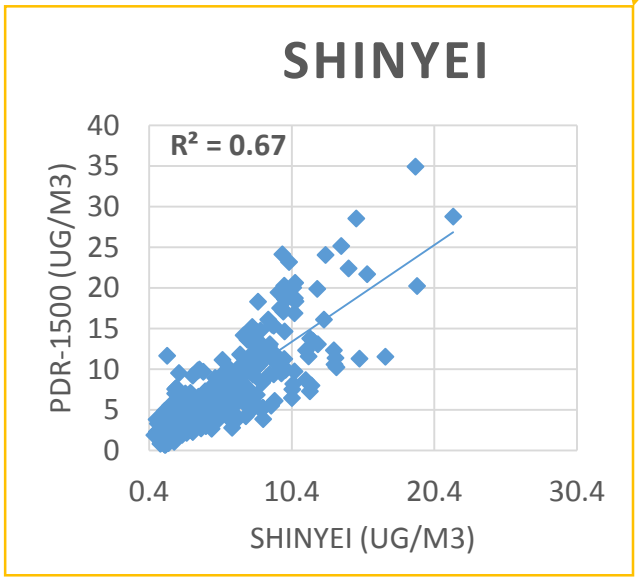
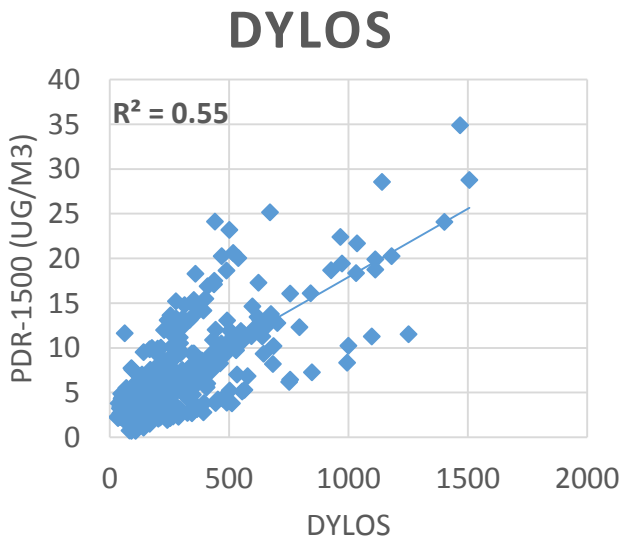
Wireless sensor network: sensor selection

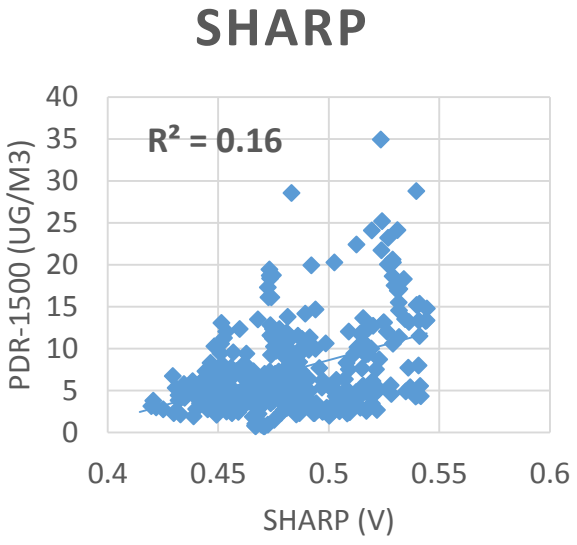
Shinyei PM sensor: light scattering-based detection principle

Week-long field test in Durham, NC determined that the Shinyei PM sensor had promising response, compared to a pDR-1500 (Thermo Scientific)

Also met criteria of being small, low powered, and easy to integrate with other sensors into wireless data stream.







Wireless sensor network: sensor selection

Cairpol NO_2/O_3 sensor: electrochemical sensor

Prior lab-testing determined strong performance when challenged against gas standard.

A key issue for this sensor is the single data output that represents the addition of $NO_2 + O_3$.

To differentiate between the two, a second ozone-only sensor added

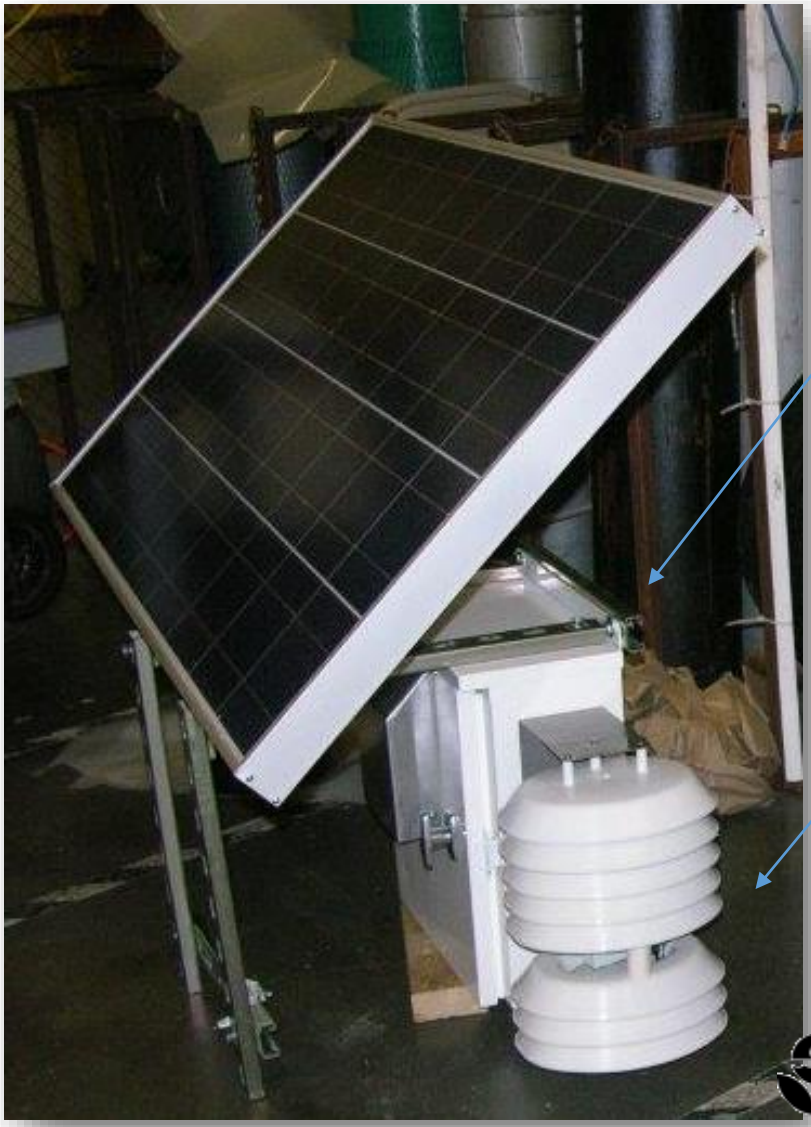
Aeroqual SM50 O_3 sensor: gas-sensitive semiconductor (GSS)

Recent publication by University of Colorado-Boulder researchers noted good performance of this sensor.

Issue with this sensor is higher power draw.

Wireless sensor network nodes

Pole-mountable design



Solar panel, battery, and data communications

Sensors in custom radiation shield for weather protection and exposure to air flow

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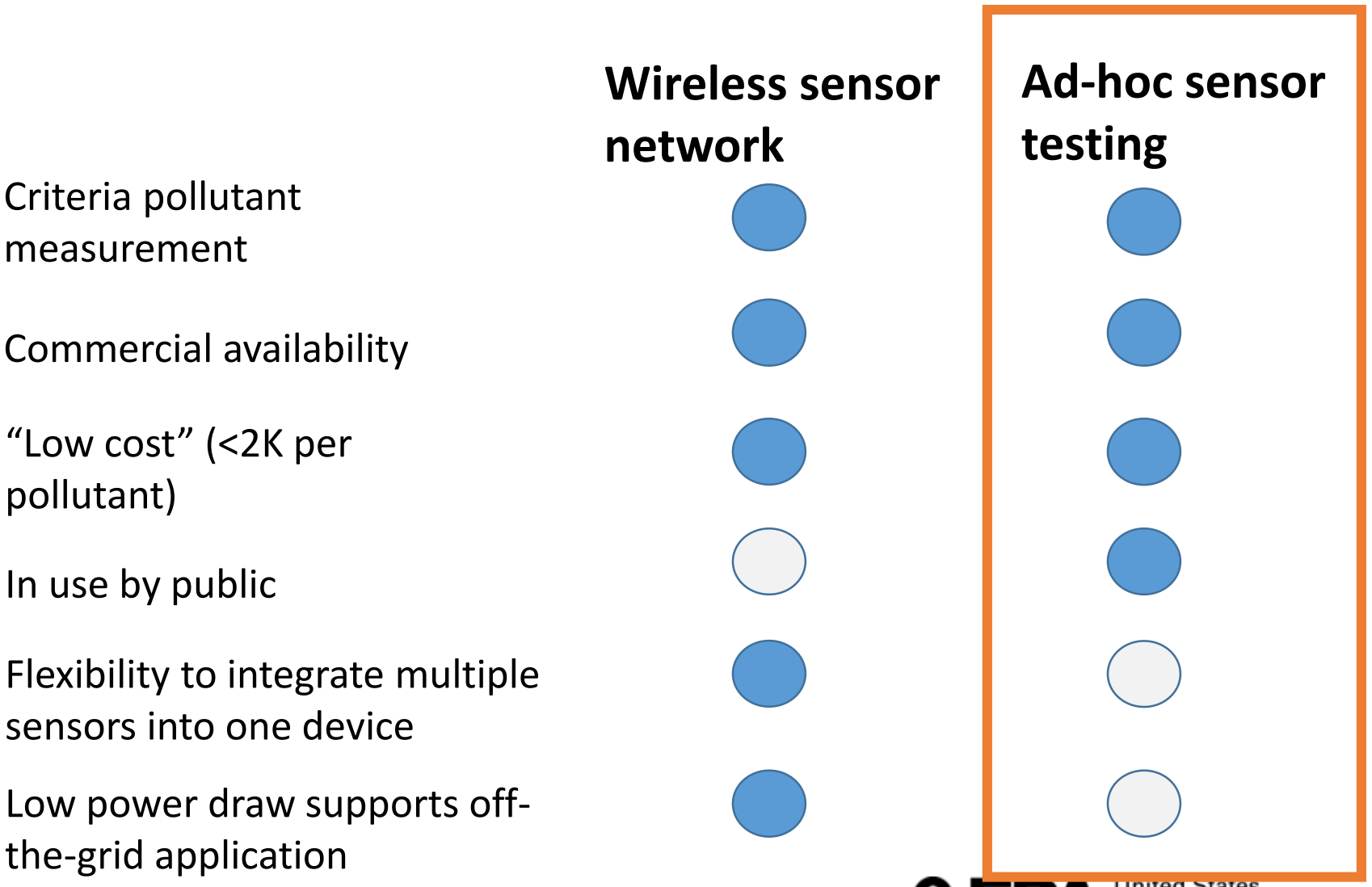
CAIRSENSE Sensor Selection



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Ad-Hoc Sensor Testing

Custom-built shelter to support sensor testing at NCORE site:

Supports air flow from all sides

Weather protection

Power and data-logging support for sensor testing

Sensors to be installed in replicate to the extent possible

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Ad-Hoc Testing: Initial sensors to test

AQMesh: NO_2, NO, O_3, SO_2, CO

MetOne 831 particle sensor

Dylos particle sensor

Shinyei particle sensor

Air Quality Egg (carbon monoxide, nitrogen dioxide)

Aeroqual SM50 ozone sensor

Not shown: Cairpol NO_2/O_3 sensor

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Project Objective 2: capabilities and limitations of a long-term multi-node wireless sensor network

= Regulatory site

B Base station for local wireless network

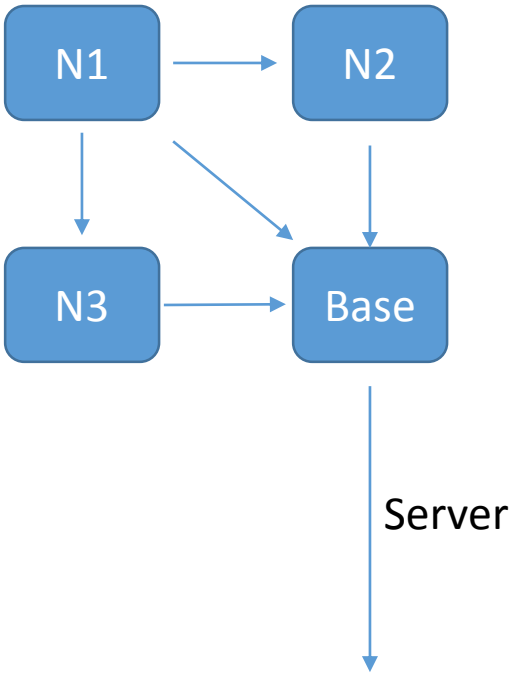
N Small multi-pollutant sensor node stations

AT Ad-hoc testing location for additional sensors

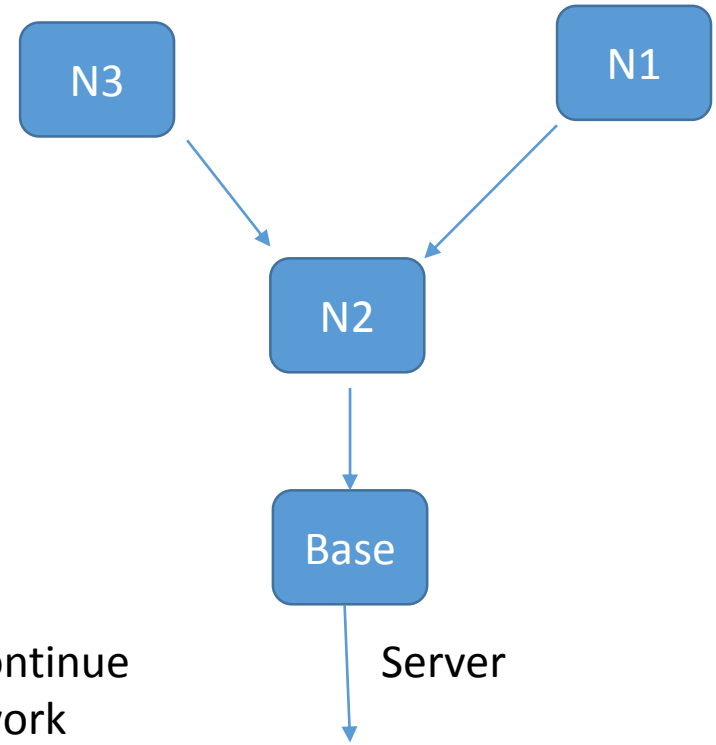
Wireless Communication Formats: mesh vs. direct communication

Mesh network communications: Nodes could transmit data through each other to reach the base station, could allow for extended spatial range

Example: Close configuration



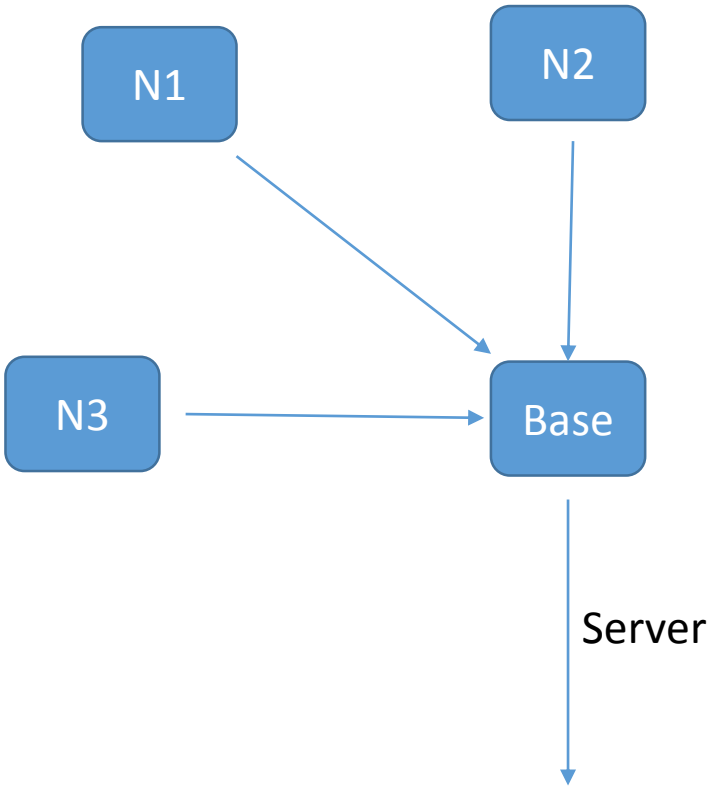
Example: Larger spatial range configuration



*Adding nodes can continue building a larger network

Wireless Communication Formats: mesh vs. direct communication

Point-to-point network communications: Nodes directly communicate to base station – cannot route data through other nodes. Larger spatial range possible than mesh network for node to base communication.



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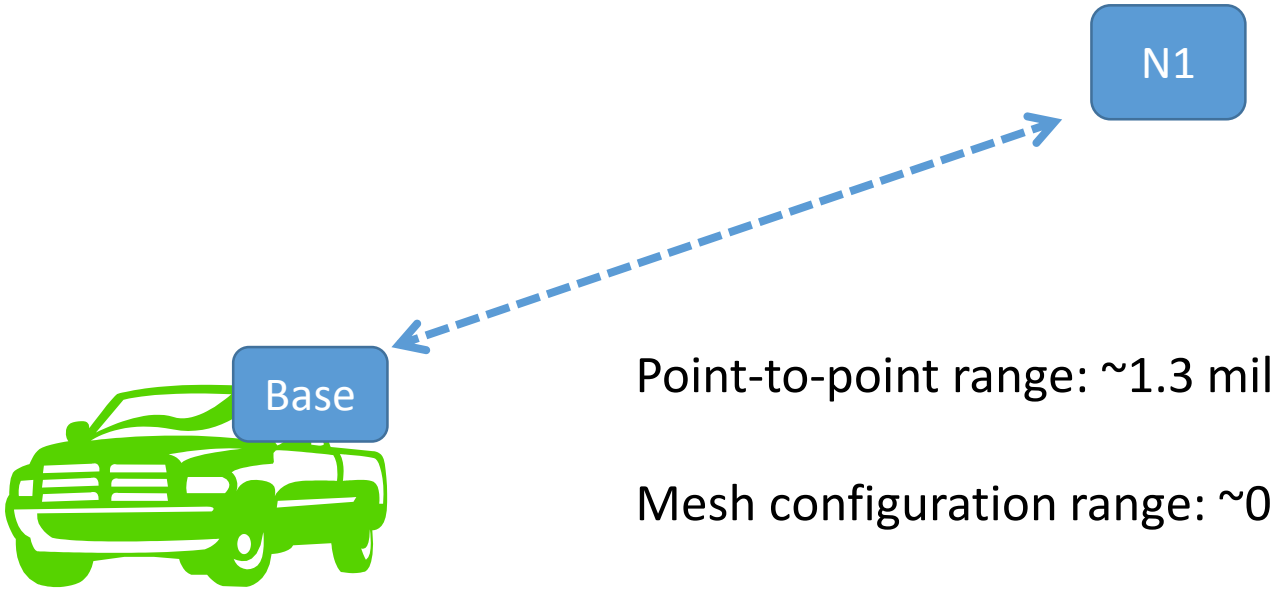
Wireless Communication Testing Results

Communication range tests in Research Triangle Park, NC – suburban environment with office buildings and trees



Point-to-point range: ~1.3 miles

Mesh configuration range: ~0.3 miles

*difference between the two is primarily baud rate and firmware
*range could be extended by adding repeaters (battery plus small XBee antenna)

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Wireless sensor network: ancillary equipment

Sensor network configuration:

Node 2:
Sensors: PM, NO/O_3
Plus: XBee antenna, SD card data storage
SMALL SOLAR PANEL

Node 1:
Sensors: PM, NO/O_3, O_3
Plus: XBee antenna, SD card data storage
LARGE SOLAR PANEL

Node 3:
Sensors: PM, NO/O_3
Plus: XBee antenna, SD card data storage
SMALL SOLAR PANEL

Data via ZigBee communication

Data via ZigBee

Data via ZigBee

Node 0: Base Station at NCORE site
Sensors: PM, NO/O_3, O_3
Plus: XBee antenna, Cellular modem, SD card data storage
LAND POWER

Data to server via cell modem


Sensor Node Locations
The Perimeter
The Perimeter
Clifton Springs Rd
Georgia Perimeter College
Google
Imagery ©2014 Google, Map data ©2014 Google
Terms
Privacy
Report a problem
500 ft


Georgia Regional Hospital Location
~145,000 AADT
The Perimeter
30 meters to nearest traffic lane
Georgia EPD Lead monitoring site
Georgia Regional Hospital - near road loaction ~145,000 AADT
1.2 Miles from the South DeKalb Site
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Google earth

Georgia Regional Hospital/ Near-road Location

Existing GA EPD Lead monitoring site, adjacent to I-285. ~1.25 mi from South Dekalb

Panthersville Stadium Location

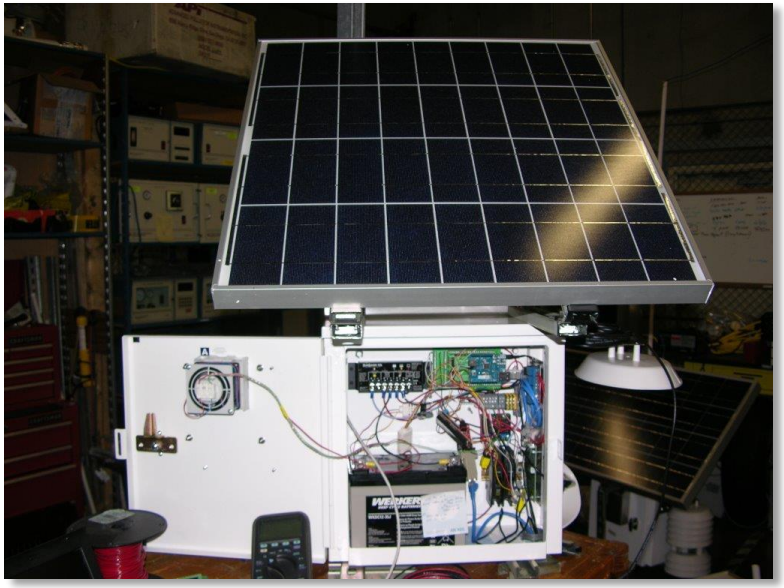
Panthersville Stadium Location

Cedar Grove Middle School Location

~0.2 Miles from the South DeKalb Site – exact distance varies on final monitor location

Next Steps

- Installing equipment this month in Atlanta
- Sampling to continue for approx. 6 months
- After completion of Atlanta sampling, equipment will be moved to another location outside the southeast for further testing



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Questions?

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  EPA Region 4

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  EPA Office of Research and Development

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