



# New Technologies for Air Monitoring

## State-of-the-Science

Peter Preuss

Chief Innovation Officer

Office of Research & Development

U.S. Environmental Protection Agency

# A typical regulatory monitor



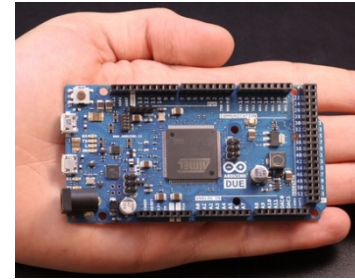
# New low-cost monitor



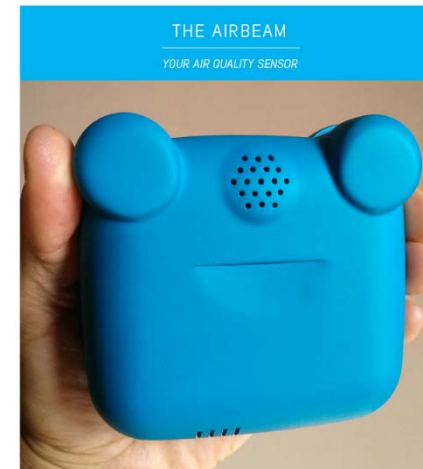
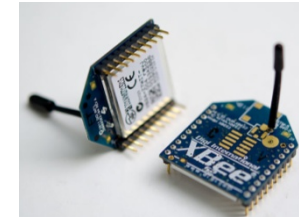
# Many dimensions to sensor technology development

- Smartphone / Tablet in widespread use
- Miniaturized environmental sensors
- Batteries/Alternative power sources
- Introduction of low cost controls and communications
- Crowd-funding supporting do-it-yourself (DIY) innovation

e.g., fitbit activity tracker



e.g., Arduino microprocessor



e.g., Kickstarter

Airbeam

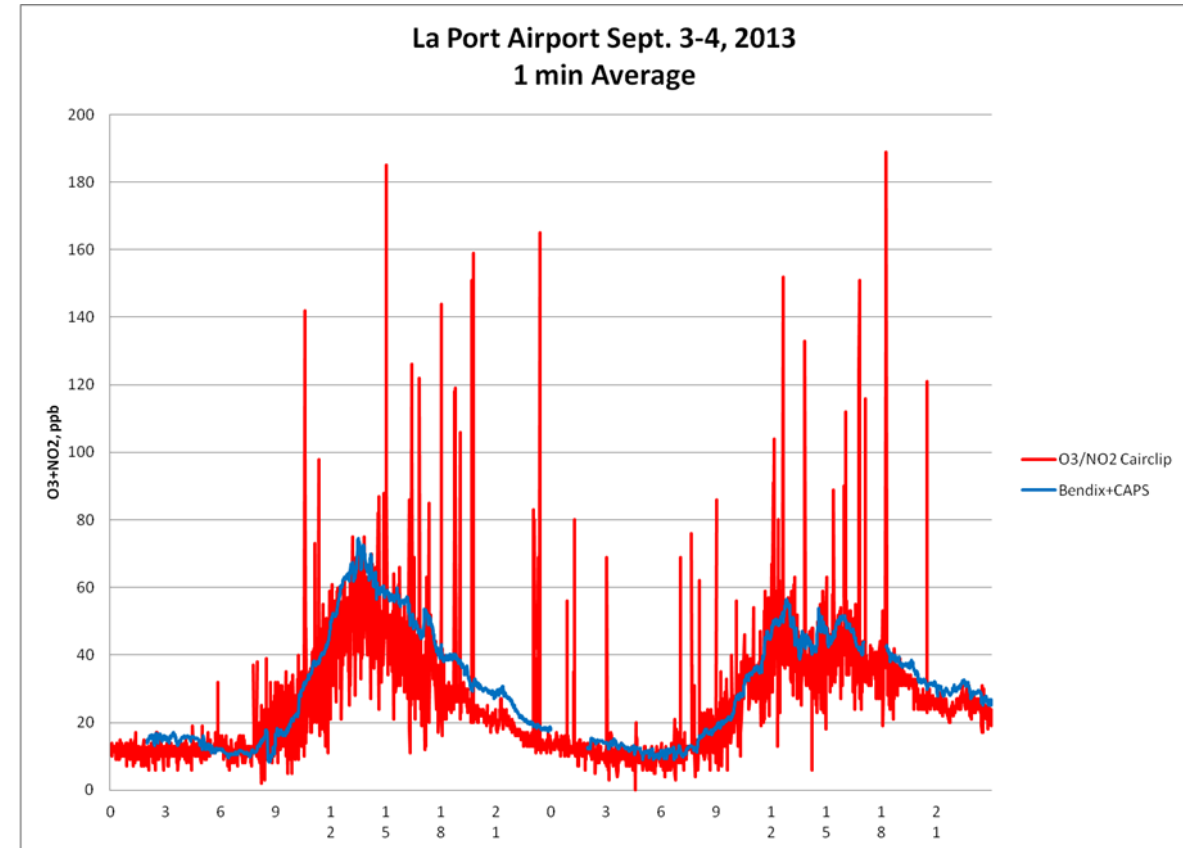
# New Challenges

How to:

- Ensure data quality
- Manage and disseminate data
- Interpret what results mean for public health
- Communicate findings

Whose data is it?

- Privacy, data rights, data policies







# “Village Green” air monitoring park bench

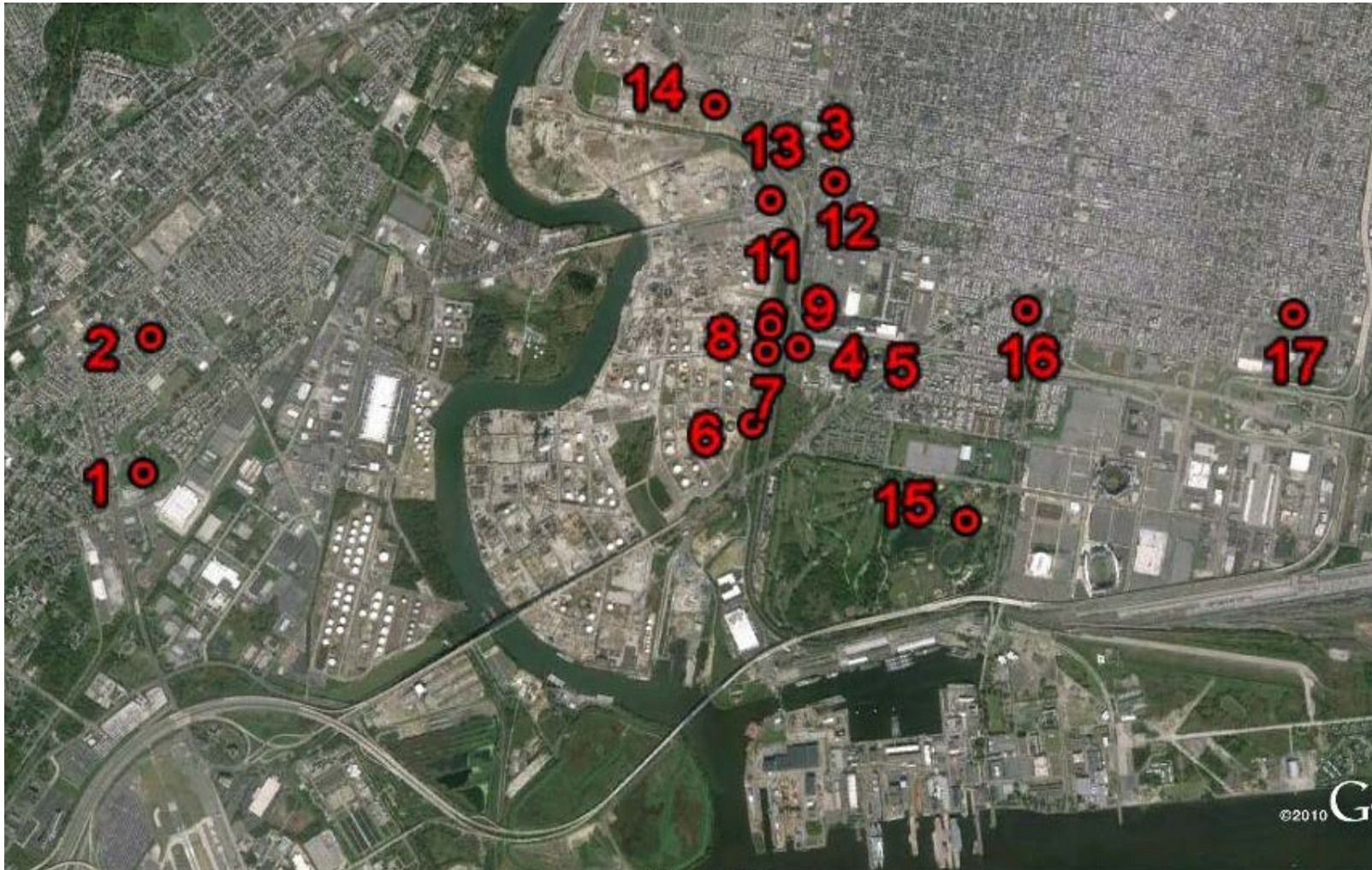
- Measures ozone and PM<sub>2.5</sub>
  - Instruments under the red park bench
- Solar power
- Wireless transmission of data
- Public website updated minute-by-minute
- Engages community
- Installed in Washington D.C., Philadelphia, Durham and more
- On continuum between large stations and low cost sensors



Village Green air monitoring station at the National Zoo in Washington D.C.



# Philadelphia oil refinery fenceline and community monitoring



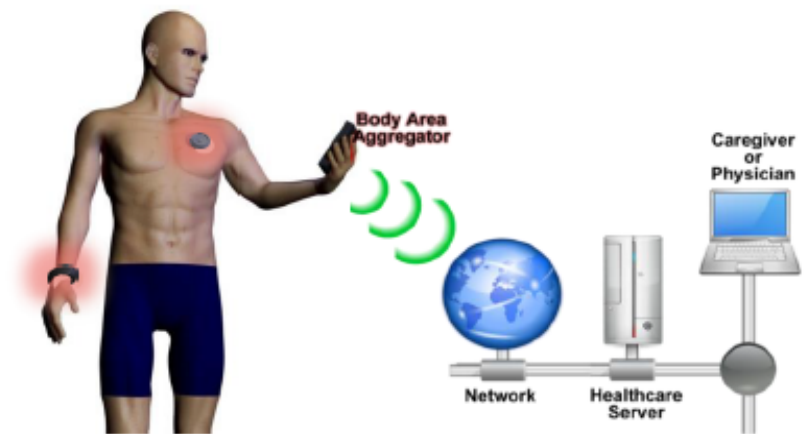




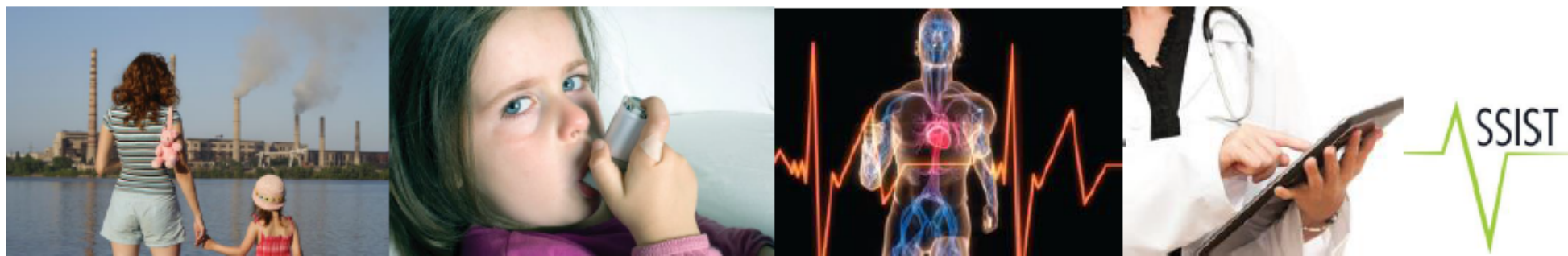
# ASSIST:

## Advanced Self-Powered Systems of Integrated Sensors and Technologies

*An NSF Nanosystems Engineering Research Center*

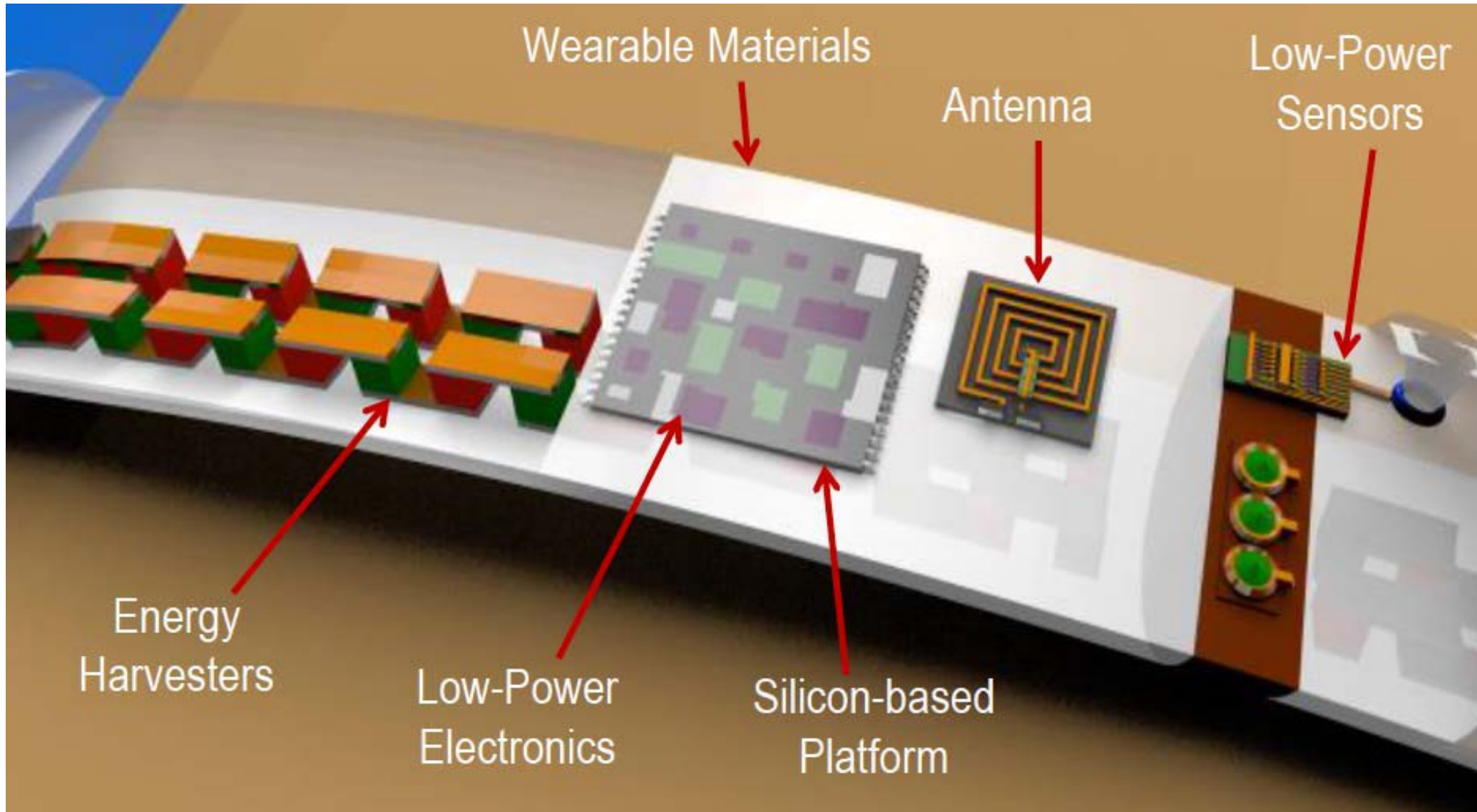


Nanotechnology enabled miniature, self-powered, wireless wearable sensors for **Personal Health** and **Personal Environment** monitoring





Ideally use energy harvesting to completely power wearable sensors



# Sensor Performance Characteristics

- Evaluating sensor performance involves many parameters
- Testing in the lab and field is complex

## Considerations:

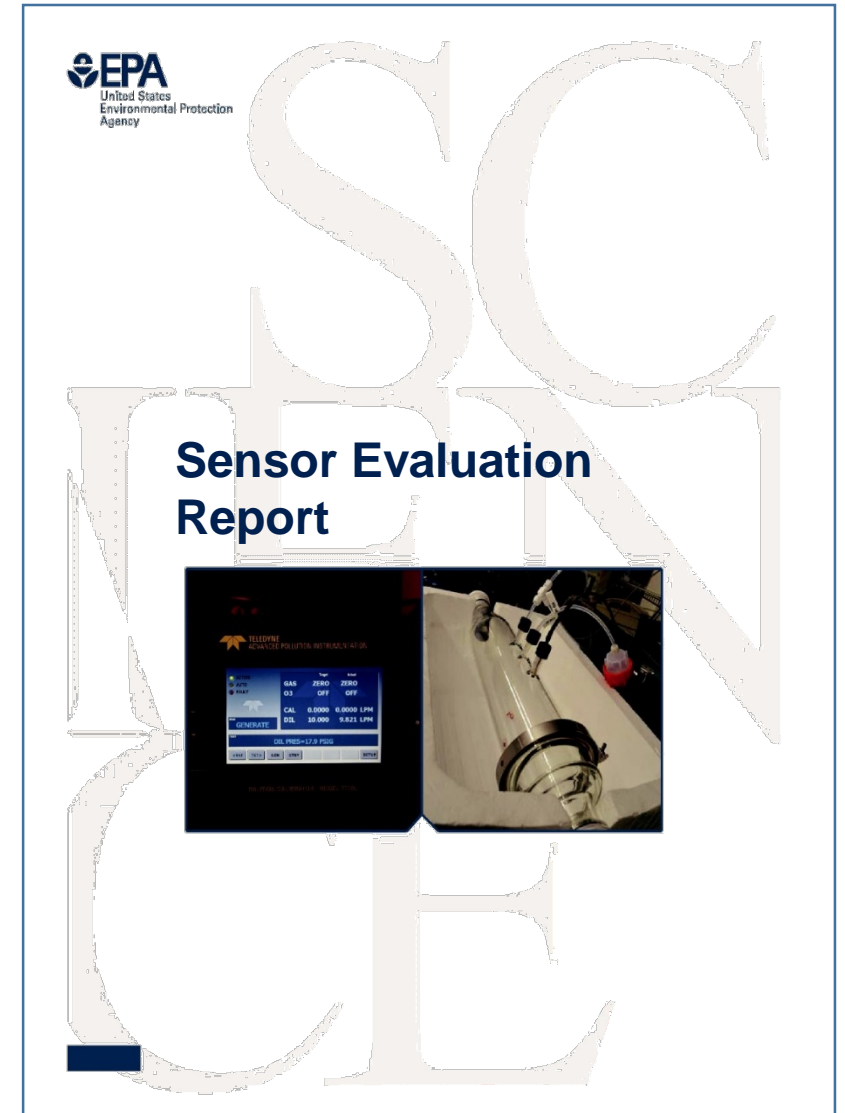
- 1 Linearity (range)
- 2 Precision of measurements
- 3 Lower detectable limit
- 4 Resolution (noise)
- 5 Response time (lag and rise time)
- 6 RH and temperature influence
- 7 Interference equivalent

# Laboratory evaluation of NO<sub>2</sub> and O<sub>3</sub> Sensors

- Open call for potential collaboration (2012-2013)
- O<sub>3</sub> and NO<sub>2</sub> focus
- 9 research groups brought devices for evaluation
- Variety of devices
- Cooperative effort to evaluate devices – evaluation data provided to developers only

Find out more:

<http://www.epa.gov/research/airscience/next-generation-air-measuring.htm>





## AGT Sensor: Ozone FEM Comparison

- Ozone measurement – lab study
  - Highly correlated with Federal Equivalent Method ( $r^2=.98$ )
  - Good precision
  - Maintained good performance under hot, humid and cold conditions

DISCLAIMER Mention of trade names or commercial products does not constitute endorsement or recommendation for use



## Laboratory example

# Cairpol-Cairclip: NO<sub>2</sub> FEM Comparison

- Nitrogen dioxide (NO<sub>2</sub>) measurement – lab study
  - Highly correlated with Federal Equivalent Method ( $r^2=.99$ )
  - Good precision
  - Maintained good performance under hot, humid and cold conditions

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- Technology for PM is more difficult
- 8 different PM sensors tested for 30 days at outdoor location
- Performance varied widely\*
- Best performer in this initial test:

\* Met One 831 ( $r^2=.77$ )

*\* Preliminary results: we have not used replicate sensors and have not repeated this study*



Dylos

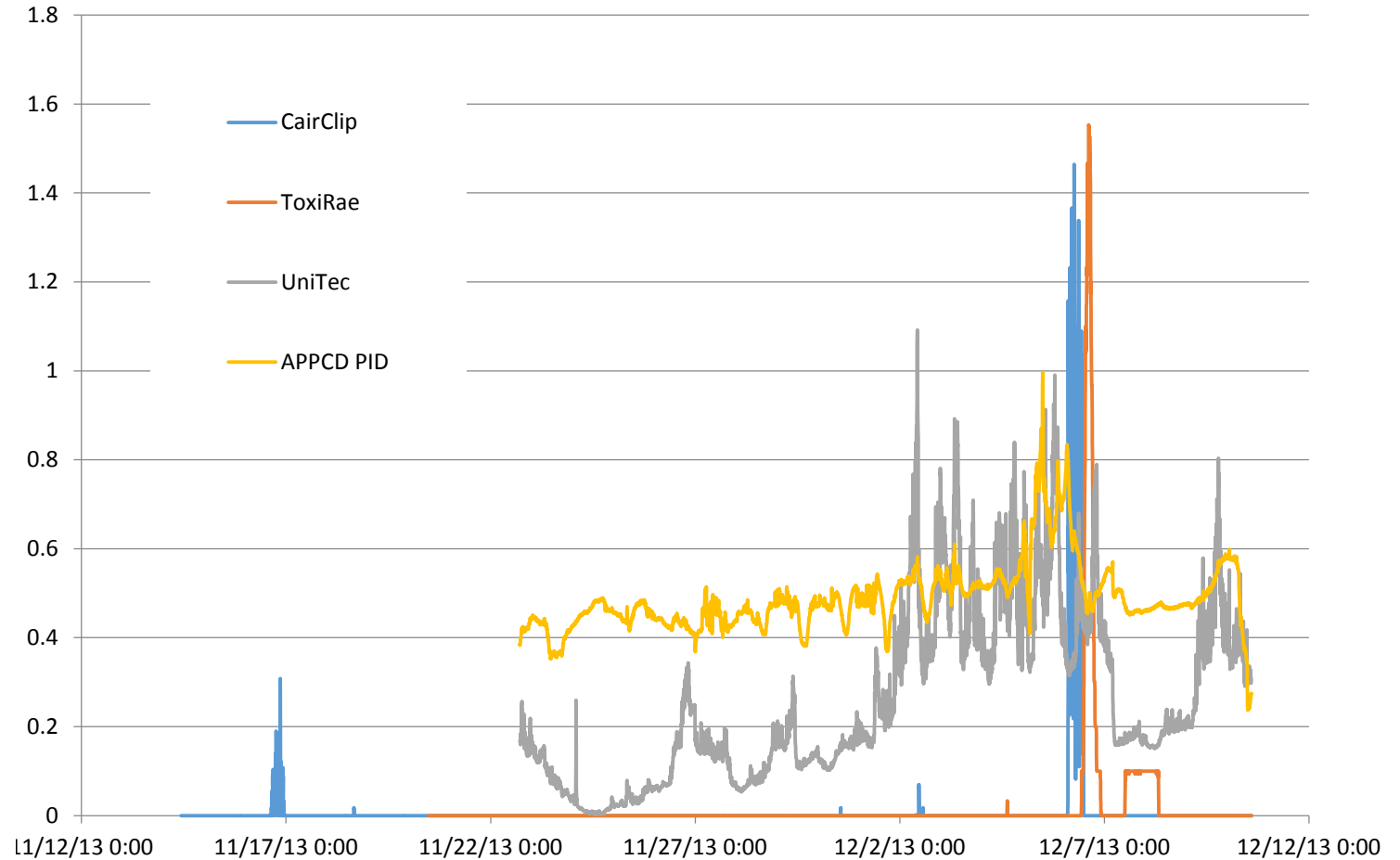
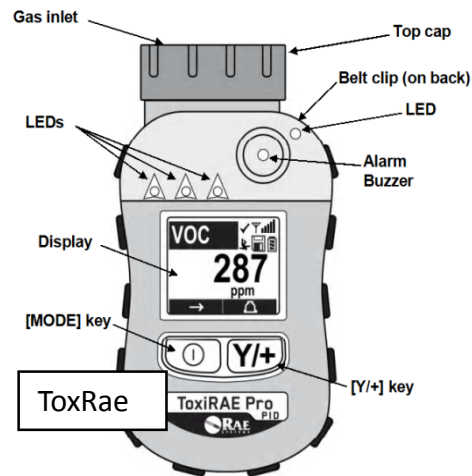
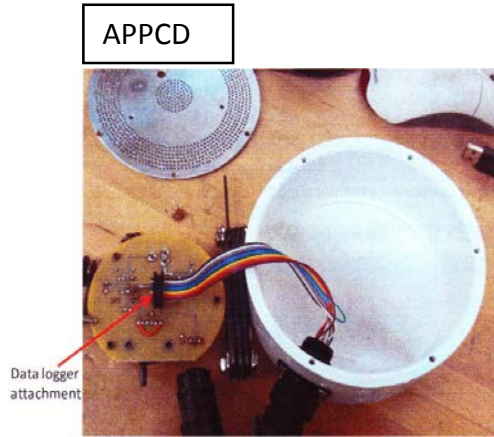


Met One 831



# Examples Volatile Organic Compounds (VOC) sensors

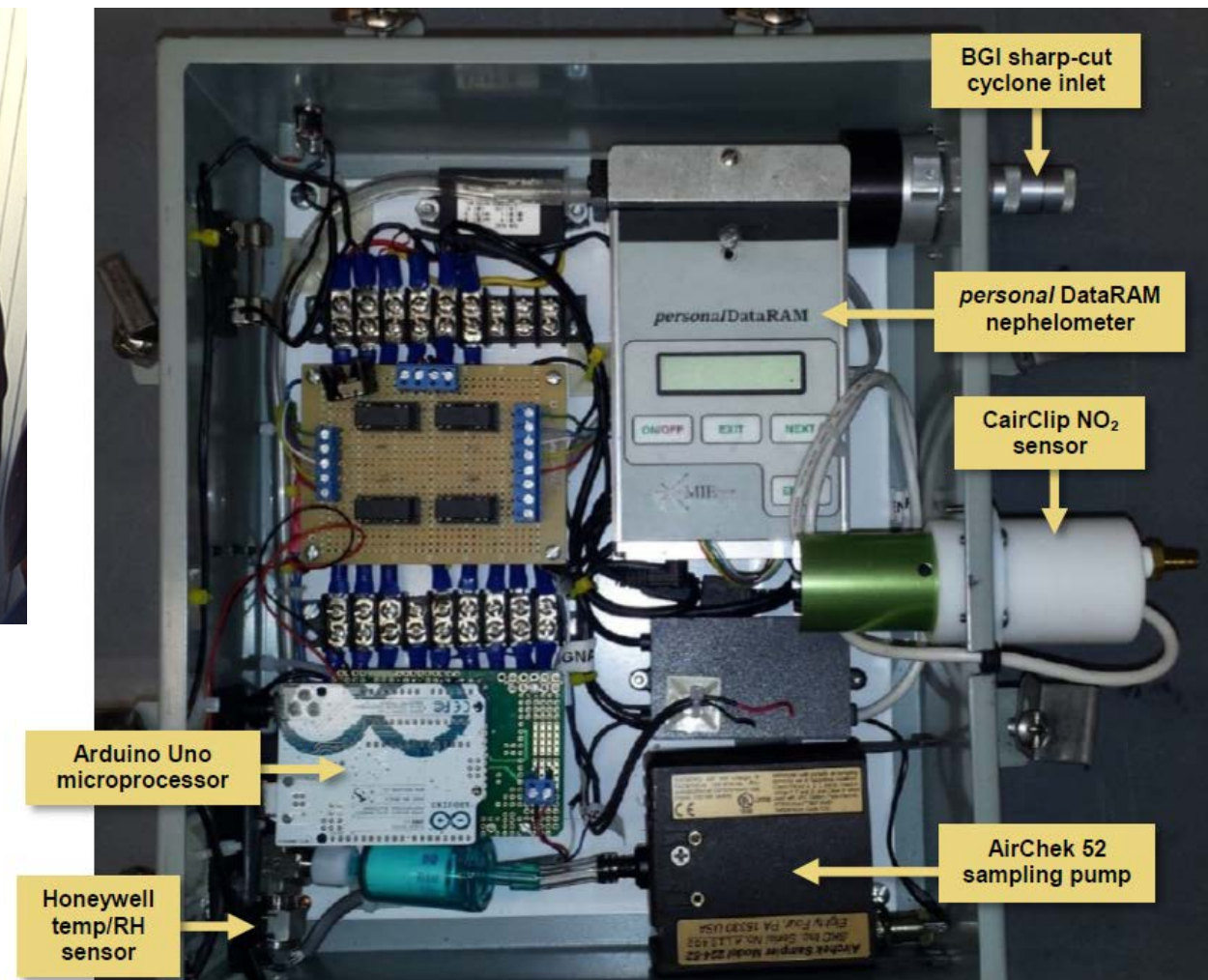
- Preliminary testing of VOC sensors  
– wide range of sensitivities



# Ironbound Community, Newark NJ



- EJ community members conduct air monitoring with EPA
  - NO<sub>2</sub> sensor
  - PM<sub>2.5</sub>
- High quality instruments and data

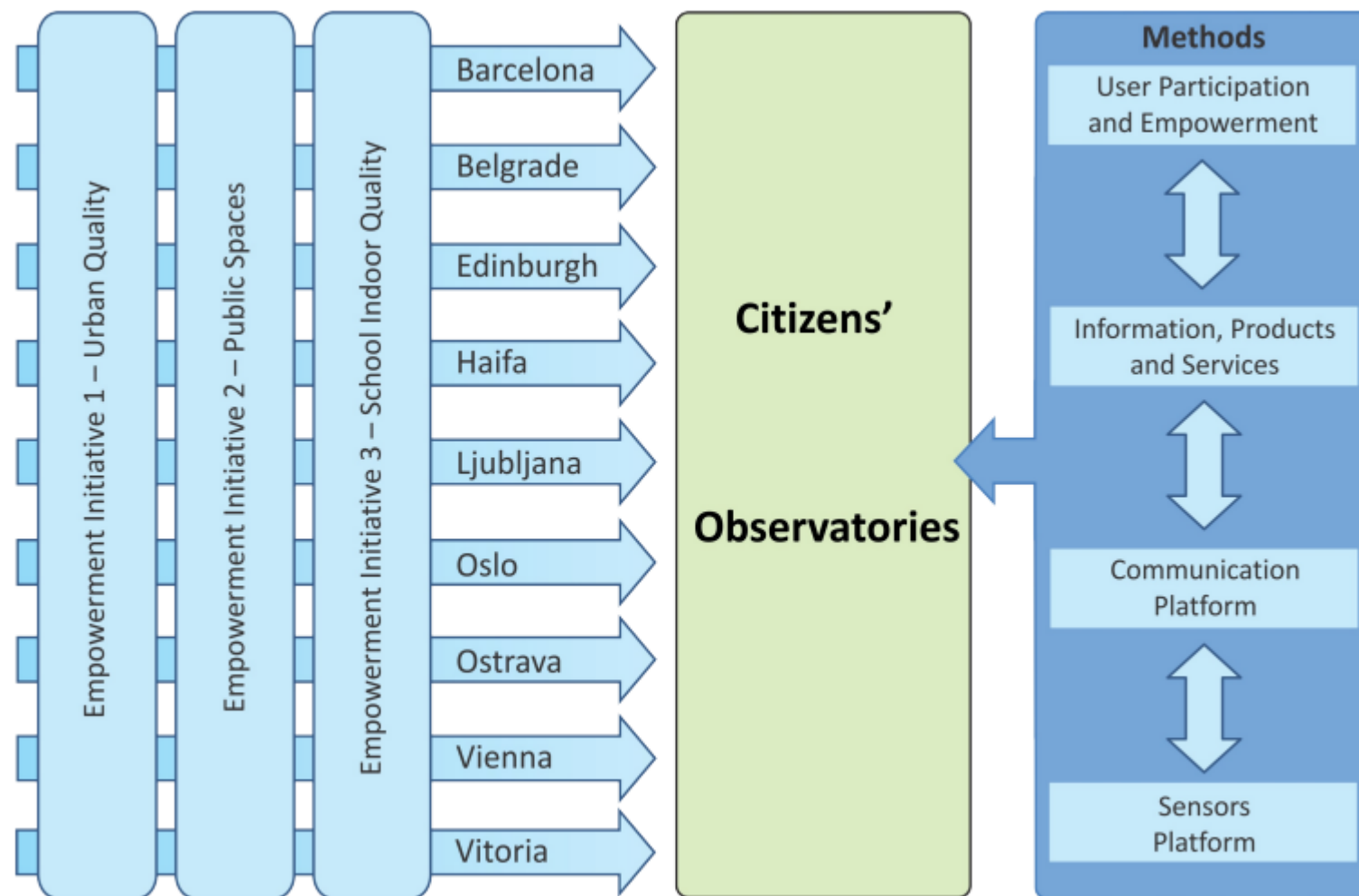


Instruments in "briefcase-sized" package



# CITI-SENSE EU: Development of sensor-based Citizens' Observatory Community for improving quality of life in cities

- Developing Citizens' Observatories with a variety of microsensors
- Integrating data analysis across data types and cities
- Empowering citizens to influence community policy & decision making
- Contributing to GEOSS



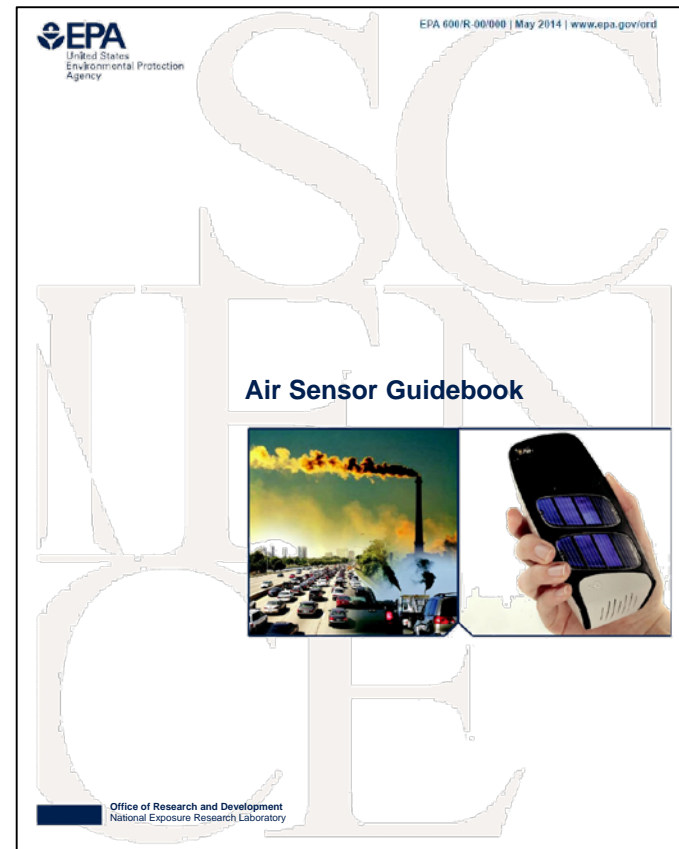




**Citizen Science Toolbox -**  
*Provides guidance for the public on effectively using sensors to collect local air quality data*

**Find out more:**

<http://www.epa.gov/research/airscience/next-generation-air-measuring.htm>



**Air Sensor Guidebook -**  
*Defines what sensor users need to understand if they are to collect meaningful air quality data*

# Challenges in use of low-cost sensors

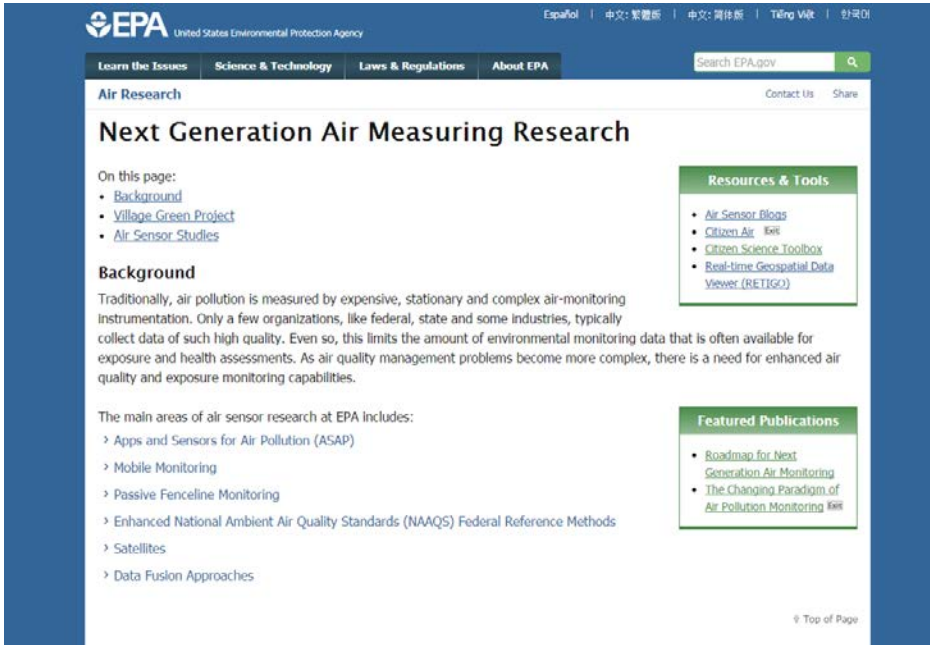
- Moving from sensors to sensor systems
- Privacy issues
- Managing the data
- Visualizing the data
- Interpreting the data
- Communicating results

# What's next?

- EPA STAR grants for community air monitoring (\$4.5M)
- Small Business Innovation Research grants for air monitoring
- Region 2 equipment loan program
- Village Green expansion into more cities
- Water sensors
  - Nutrient Sensor Challenge



# Find out more:



**Next Generation Air Measuring Research**

On this page:

- [Background](#)
- [Village Green Project](#)
- [Air Sensor Studies](#)

**Background**

Traditionally, air pollution is measured by expensive, stationary and complex air-monitoring instrumentation. Only a few organizations, like federal, state and some industries, typically collect data of such high quality. Even so, this limits the amount of environmental monitoring data that is often available for exposure and health assessments. As air quality management problems become more complex, there is a need for enhanced air quality and exposure monitoring capabilities.

The main areas of air sensor research at EPA includes:

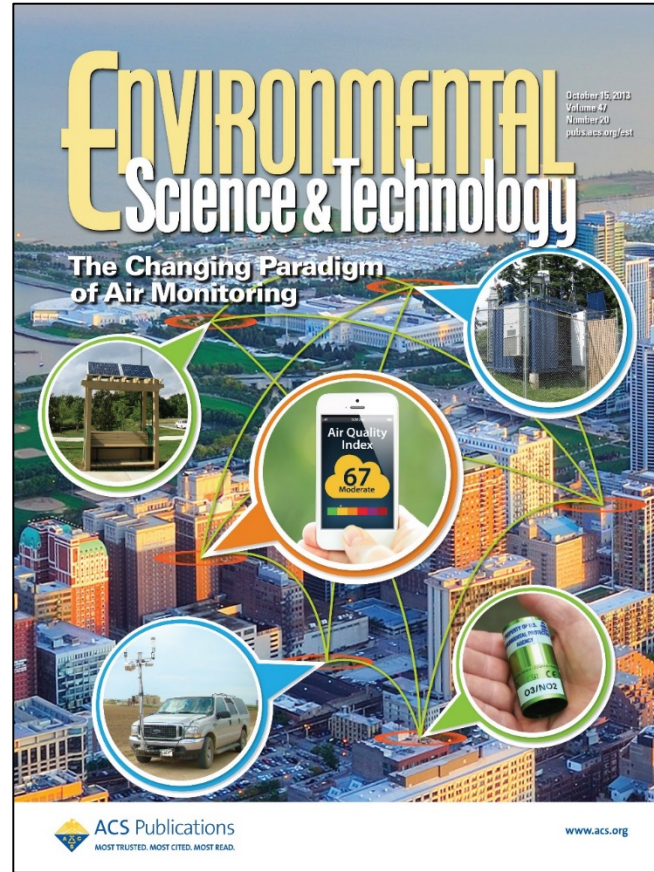
- > Apps and Sensors for Air Pollution (ASAP)
- > Mobile Monitoring
- > Passive Fenceline Monitoring
- > Enhanced National Ambient Air Quality Standards (NAAQS) Federal Reference Methods
- > Satellites
- > Data Fusion Approaches

**Resources & Tools**

- [Air Sensor Blogs](#)
- [Citizen Air IQ](#)
- [Citizen Science Toolbox](#)
- [Real-time Geospatial Data Viewer \(RETIGD\)](#)

**Featured Publications**

- [Roadmap for Next Generation Air Monitoring](#)
- [The Changing Paradigm of Air Pollution Monitoring](#)



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**The Changing Paradigm of Air Monitoring**

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Also in this issue:  
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PM File: Storyboarding Builds Persuasive Presentations

**Air Quality Sensors, Part 1**

Findings from the 2013 EPA Air Sensors Workshop, including emerging sensor technologies (e.g. SmartPhone Apps), data challenges and solutions, and sensor calibration options