EPA's Emerging Low-Cost Sensor Research

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(on Behalf of the ACE EM-2/EM3 Teams)
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EPA's Air Pollution Sensors Team

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  - Stacey Katz, Gail Robarge
- EPA Office of Air Quality Planning and Standards
  - Chet Wayland, Tim Hanley, Joann Rice, Nealson Watkins, Kristen Benedict, Melinda Beaver
- Alion Science & Technology
  - Sam Garvey

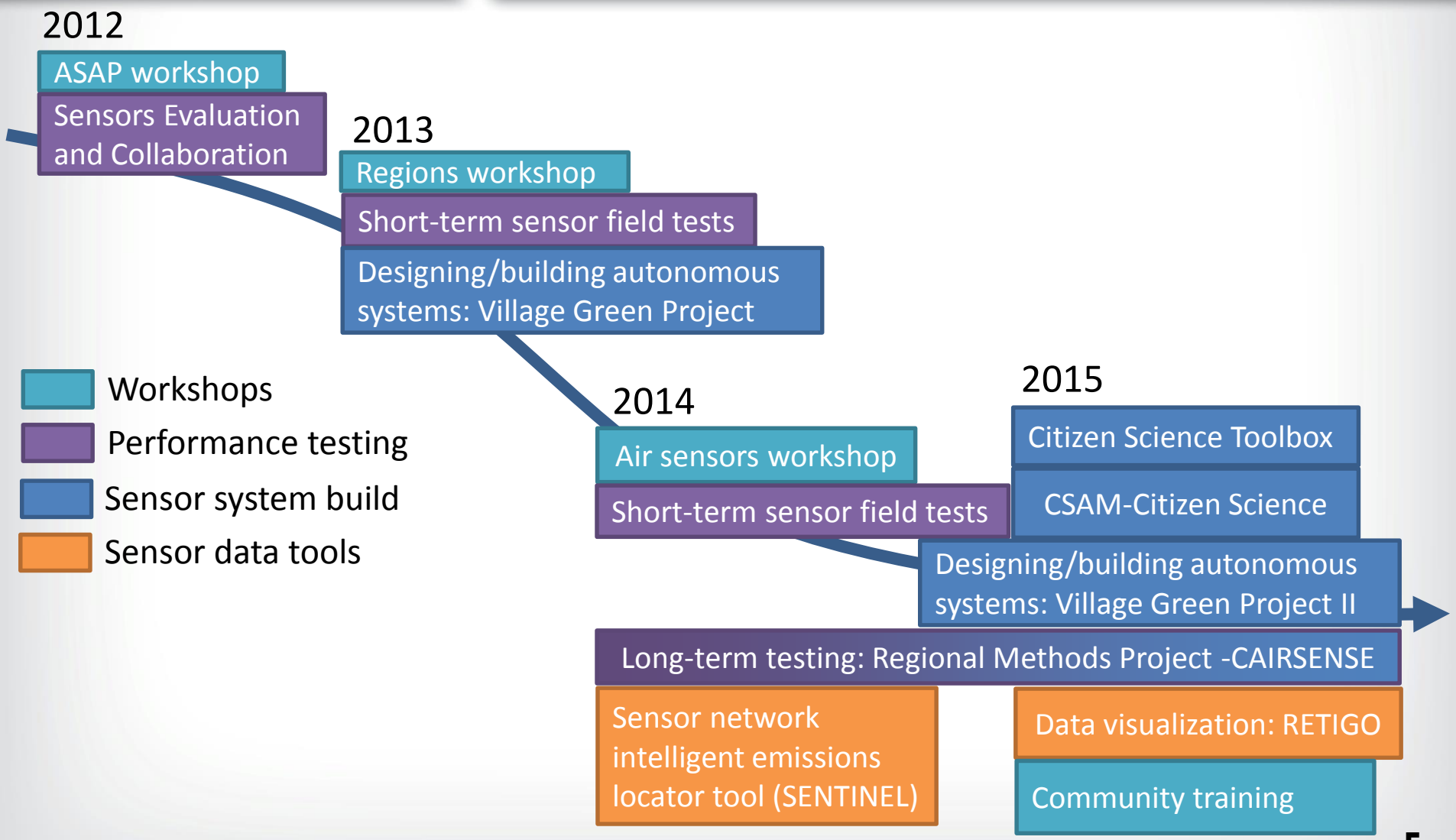
Recognition that Citizen Science is a Reality

Public demand for more personalized information – what about *my* exposure, *my* neighborhood, *my* family – using low-cost sensor technologies

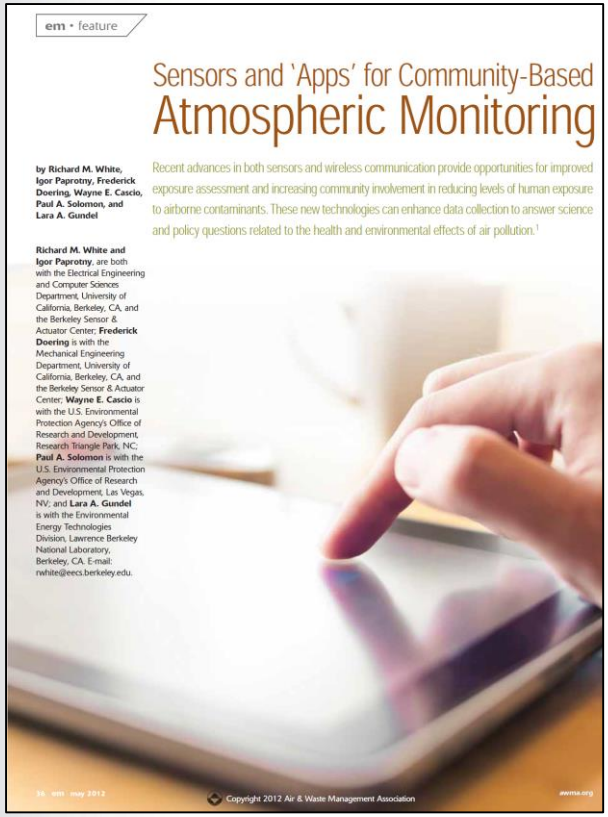
Emerging Technologies Research Agenda

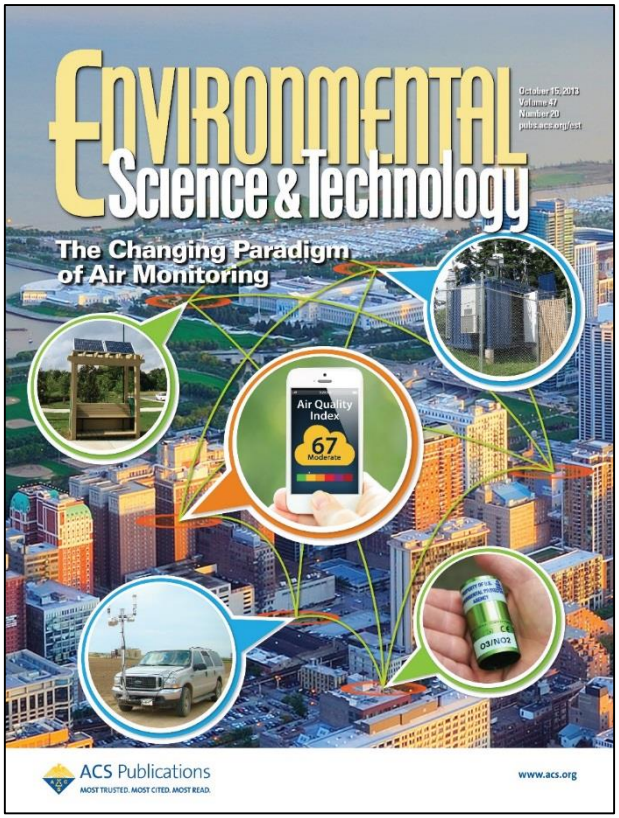
1. Investigate emerging technologies and potential to meet future air quality monitoring needs
2. Establish market surveys of commercially-available air quality sensors
3. Conduct extensive literature survey on the state of sensor technologies
4. Develop sensor user guides
5. Educate sensor developers and users on the state of low cost censors
6. Facilitate knowledge transfer
7. Work with sensor developers to speed up development
8. Support ORD's Sensor Roadmap by focusing on high priority issues (NAAQS, Air Toxics, Citizen Science)
9. Establish highly integrated research efforts across EPA

Timeline of Major Activities



Critical Peer Reviewed Articles Defining Emerging Sensor Technology





Sensor Related Resources

Air Sensor Citizen Science Toolbox

EPA

Measure • Learn • Share

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Online Resources Available at:
http://www.epa.gov/heasd/airsensortoolbox/

Air Sensor Guidebook

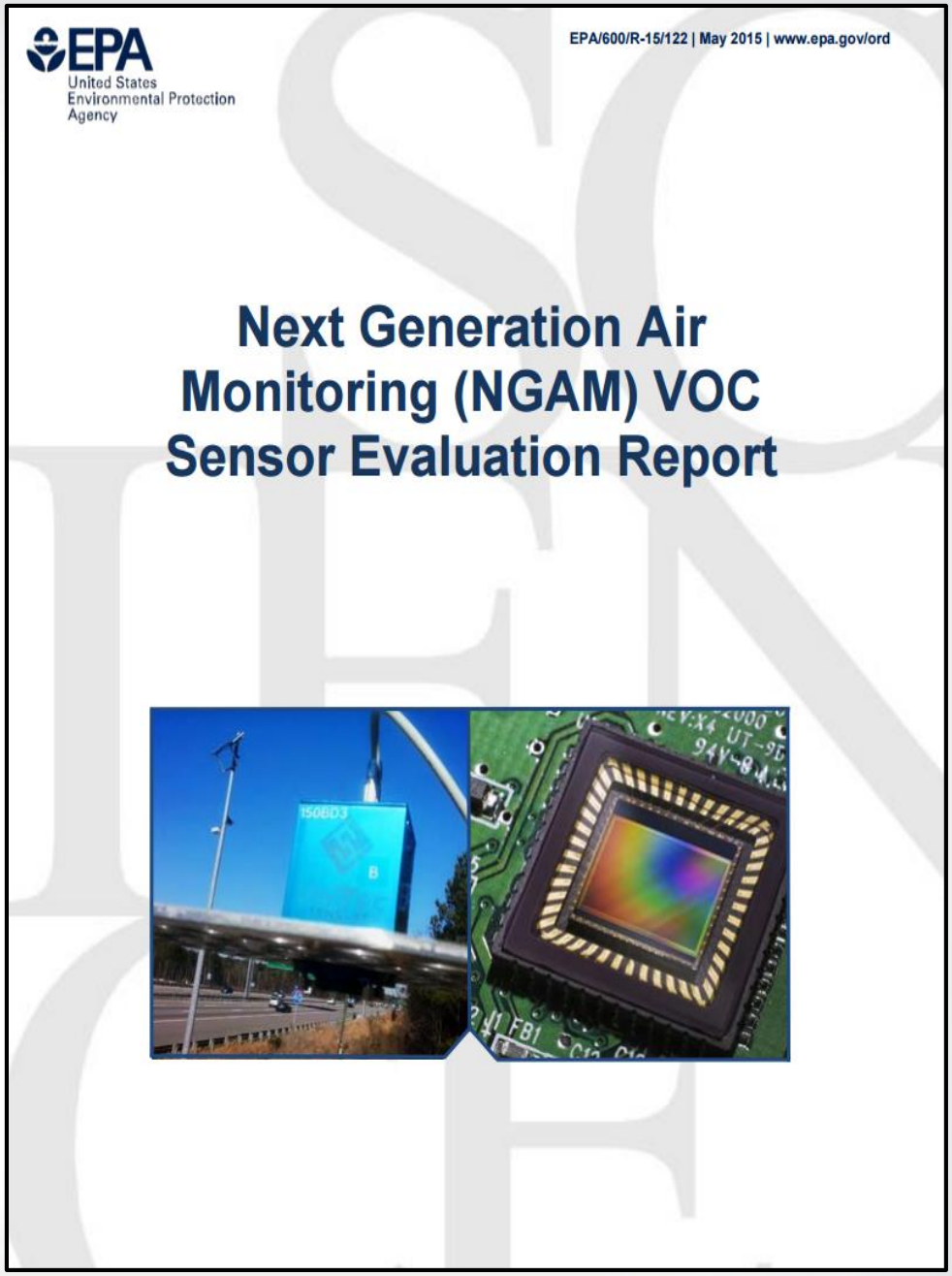
CSAM Operating Procedures

Mobile Sensors & Applications for Air Pollutants

Citizen Science Air Monitor (CSAM): Quality Assurance Guidelines

Evaluation of Field-deployed Low Cost PM Sensors

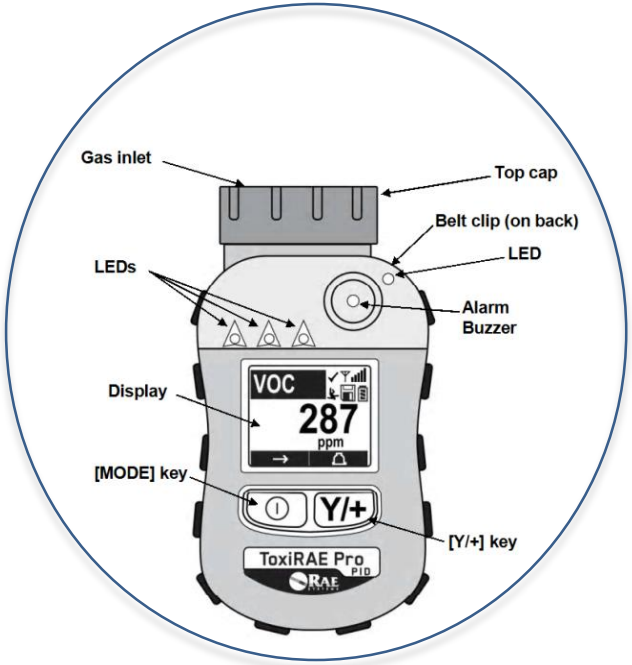
Chamber evaluation of extensive search of low cost VOC monitoring types



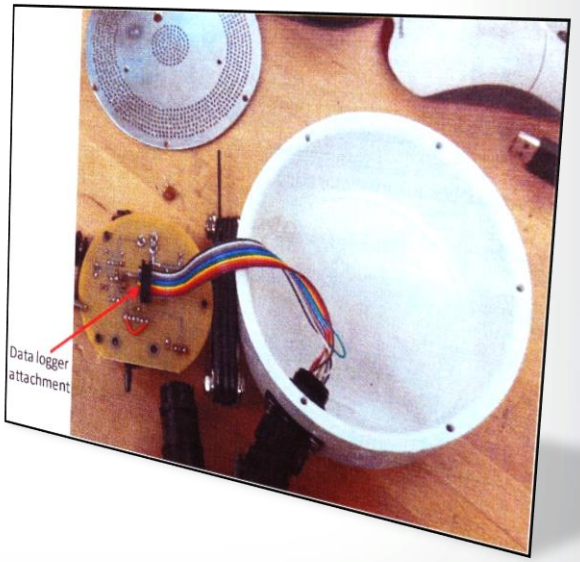
Example VOC Sensors: UniTec, ToxRae, & EPA Devices

UniTech

ToxiRae



EPA SPOD PID



Example-Cairpol (VOC)

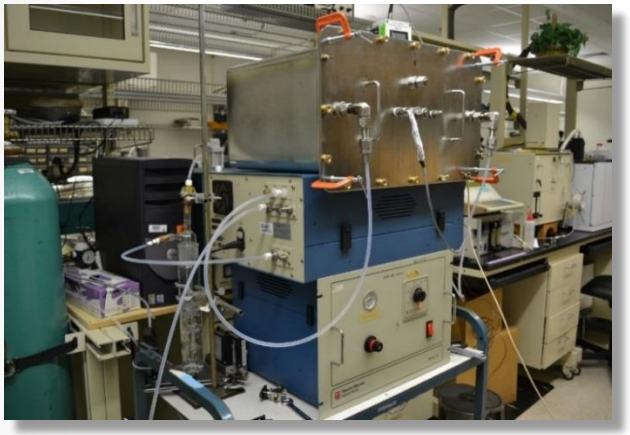
1 inch

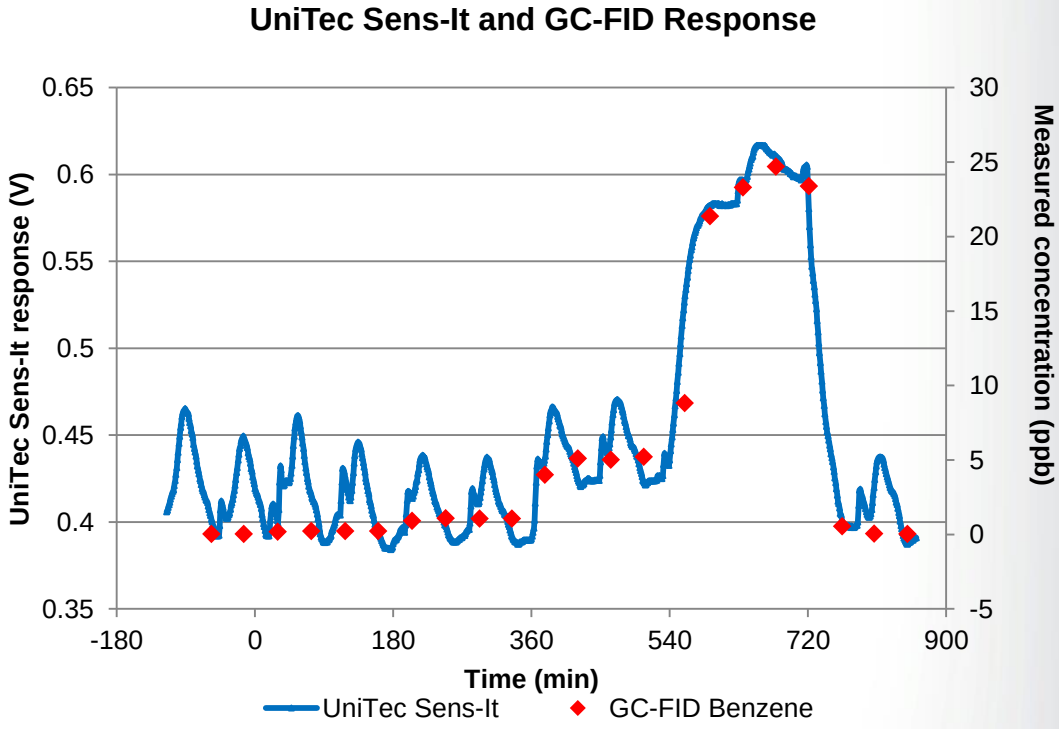
Select Quality Assurance Parameters Involving Continuous Monitoring

- Bias-is it routinely high or low with respect to the true value
- Precision- how repeatable is the measurement
- Calibration- does it respond in a systematic fashion as conc changes
- Detection limit -how low and high will it measure successfully
- Response time -how fast does the response vary with conc change
- Linearity of sensor response -what is the linear or multilinear range
- Measurement duration -how much data do you need to collect
- Measurement frequency -how many collection periods are needed
- Data aggregation -value in aggregating data (1 sec, 1 min, 1 hr, etc)
- Selectivity/specificity -does it respond to anything else
- Interferences -how does heat, cold, effect response
- Sensor poisoning and expiration -how long will the sensor be useful
- Concentration range -will the device cover expected highs and lows
- Drift -how stable is the response
- Accuracy of timestamp - what response output relates to the event
- Climate susceptibility - does RH, temp, direct sun, etc impact data
- Data completeness -what is the uptime of the sensor
- Response to loss of power - what happens when it shuts down

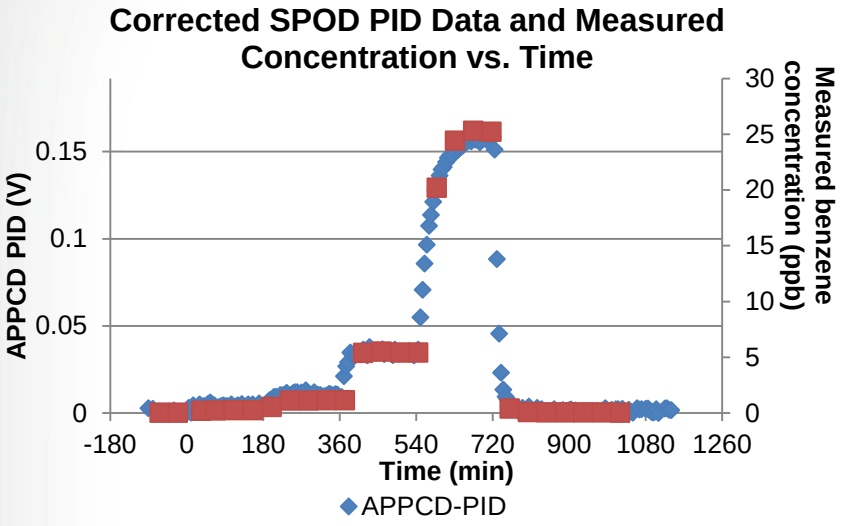
EPA/600/R-14/159 (June 2014)

Laboratory VOC Sensor Evaluation

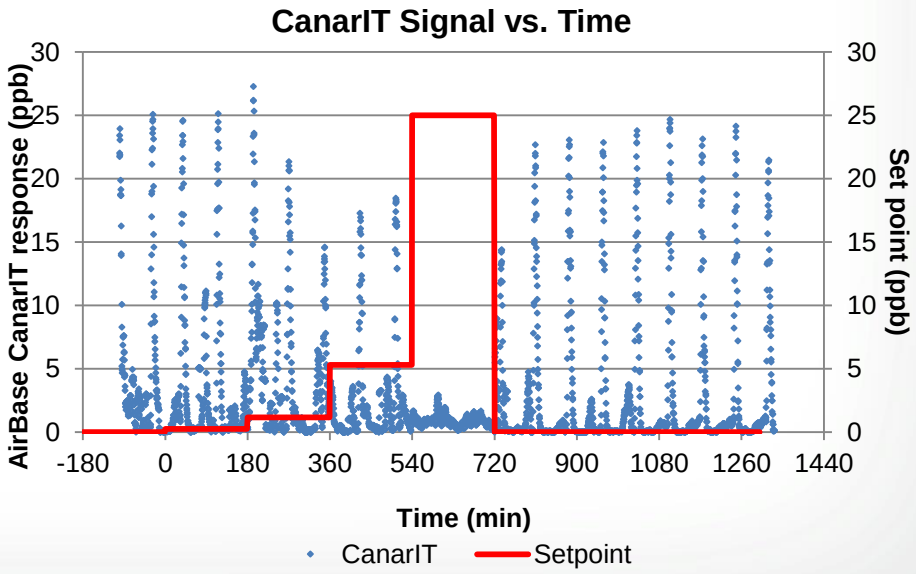




Examples of VOC Sensor Response



Both units are PID-based
But differ widely in response



Generalized Laboratory VOC Sensor Findings

Sensor	Benzene r^2	Three-Component r^2	Benzene Response	Three-Component Response	Three-Component: Benzene Ratio
UniTec Sens-It (V)	0.8973	0.9328	0.0081	0.0213	2.63
AirBase CanarIT (ppb)	NA	NA	NA	NA	NA
CairPol CairClip (ppb)	NA	NA	NA	NA	NA
SPOD PID(V)	0.7799	0.7912	0.0022	0.0060	2.73
ToxiRAE Pro (ppm)	NA	NA	NA	NA	NA

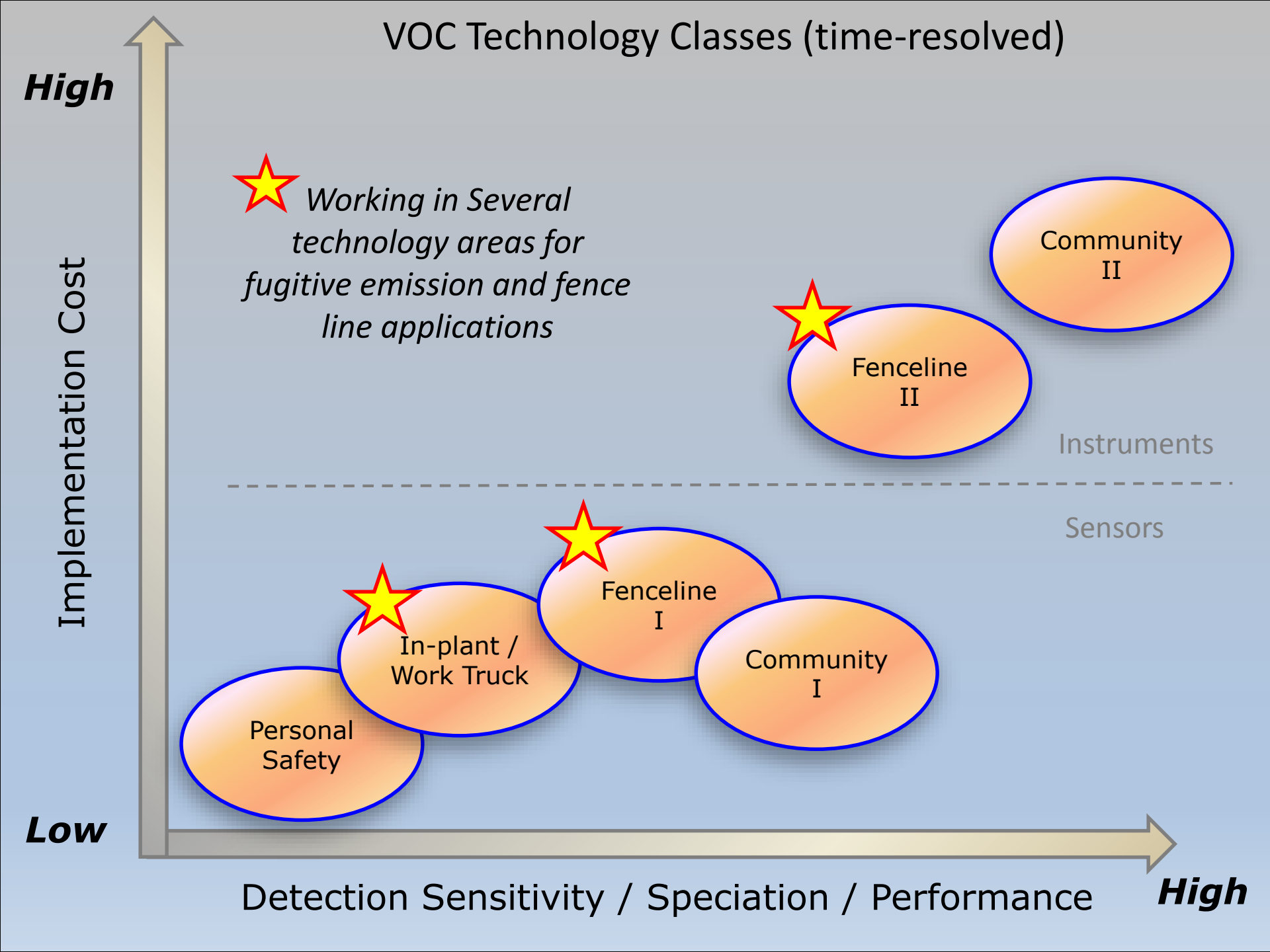
Performance Characteristics of VOC Sensors

Sensor	Uptime	Ease of Installation	Ease of Operation	Mobility
AirBase CanarIT (ppb)	+	++	+++	+++
SPOD PID (V)	++	-	++	++
CairClip (ppb)	+++	++	+++	+++
Sensotran Benzene (V)	unknown	-	-	-
ToxiRAE Pro PID (ppm)	++	++	+	+++
UniTec Sens-It (V)	+	-	+++	-

+ = fair, ++ = good, +++ = excellent

Mid-Tier Research Efforts

- ORD research would suggest that current state of the science for low cost sensors is lacking relative to performance
- Ongoing research investigating higher cost $10-20K (mid-Tier) options


VOC Technology Classes (time-resolved)
High
Implementation Cost
Low
Working in Several technology areas for fugitive emission and fence line applications
Community II
Fenceline II
Instruments
Sensors
Fenceline I
In-plant / Work Truck
Community I
Personal Safety
Detection Sensitivity / Speciation / Performance
High

Automated work truck sensors

In-plant /
Work Truck

benzene leak

Wind

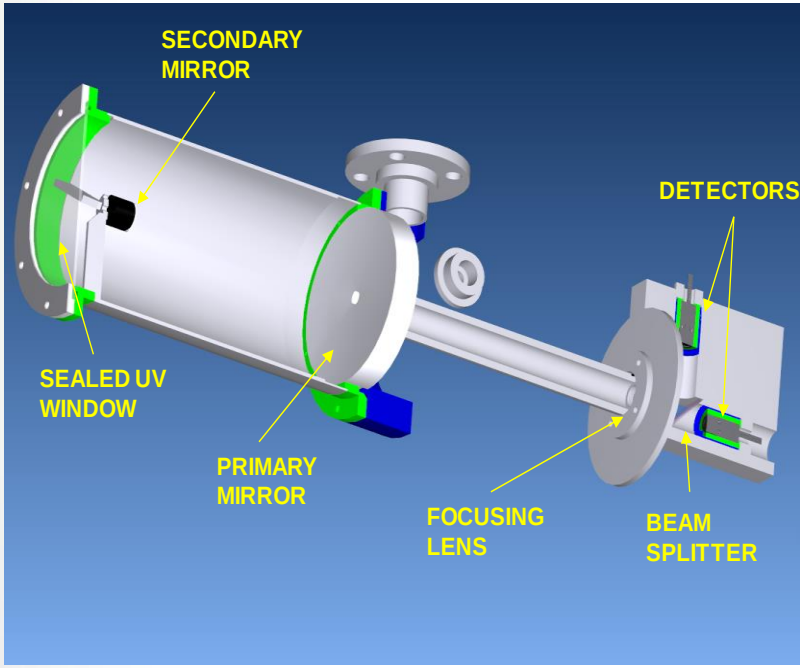
Simplified
GMAP OTM 33

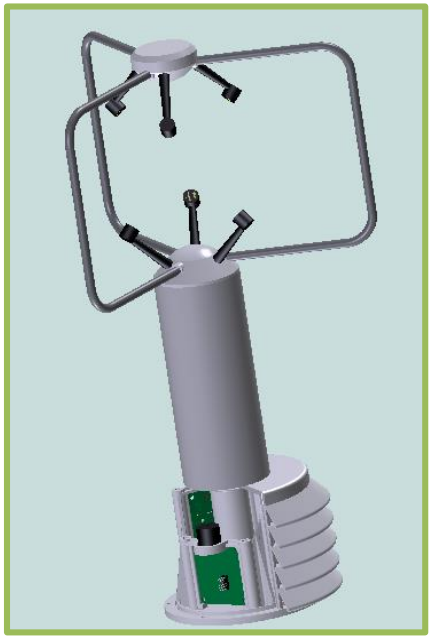
Fenceline I

Non-Speciated measurements at < ppb level

SPods

Deep-UV Optical Sensor





Fenceline II

Speciated measurements at > ppb level

Open-path spectroscopy

Air-inlet compact GC

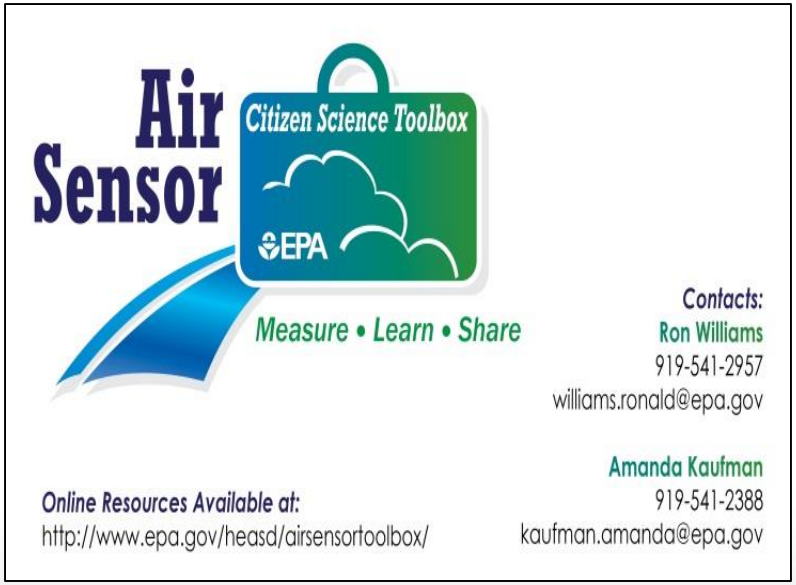
Conclusions

- VOC technologies appear to be lagging behind those for other pollutants
- Lower cost options appear to lack sensitivity at environmentally relevant concentrations
- Sensors reporting to be “specific” have not shown great potential
- Traditional occupational VOC monitors proved to be useful as sentinel sensors
- Mid-Tier options being investigated to examine specificity and LOD for this class of technology

Thank You

One resource for you is the following website:

(http://www2.epa.gov/air-research/air-sensor-toolbox-citizen-scientists)



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