

Advanced Technologies for Measuring Air
Pollution: Status Update on SCAQMD's
AQ-SPEC Sensor Testing Program

Governing Board Meeting
November 4, 2016

Background

- On July 11, 2014 the Governing Board approved funding for AQ-SPEC
- Over \$500,000 investment
- Main Goals & Objectives
 - *Provide guidance & clarity for ever-evolving sensor technology*
 - *Catalyze successful evolution/use of “low-cost” sensors*
 - *Minimize confusion*
- Sensor Selection Criteria
 - *Commercially available on American, European, and Chinese markets*
 - *Criteria pollutants & air toxics*
 - *Real or near-real time*



Field Testing

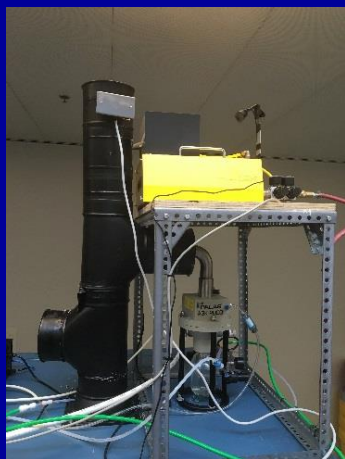
- Started on 09/12/2014
 - *Sensor tested in triplicates*
 - *Two month deployment*
- Locations:
 - *Rubidoux station (main)*
 - *Inland site*
 - *Fully instrumented*
 - *I-710 station*
 - *Near-roadway site*
 - *Fully instrumented*
- Number of (particle and gas) sensors tested to date: ~30





Laboratory Testing

Aerosol Test



T and RH controlled: T (0-50 °C); RH (5-95%)

Gas Test





AQ-SPEC

Air Quality Sensor Performance Evaluation Center

Website (www.aqmd.gov/aq-spec)

The screenshot shows the AQ-SPEC website interface. At the top, it features the South Coast Air Quality Management District logo and the title 'AQ-SPEC Air Quality Sensor Performance Evaluation Center'. A navigation menu on the left includes links for Home, Sensors, Evaluations, Resources, Workshops, Sensor News, Contact Us, and About SCAQMD. Below the menu is a 'Select Language' dropdown and a 'Sign-Up' button. The main content area contains a video player with the title 'AQ-SPEC Air Quality Sensor Performance Evaluation Center' and a play button. Below the video, the 'Background' section explains the program's purpose: to inform the public about the performance of 'low-cost' air quality sensors. The 'Main Goals & Objectives' section lists three points: evaluating sensor performance, providing guidance, and catalyzing the evolution of sensor technology. The 'Sensor Selection Criteria' section lists requirements for sensors, including near-term use, real-time measurements, and measurement of specific pollutants like CO, O₃, NO_x, PM, VOCs, H₂S, and CH₄.

Background

In an effort to inform the general public about the actual performance of commercially available "low-cost" air quality sensors, the SCAQMD has established the Air Quality Sensor Performance Evaluation Center (AQ-SPEC) program. The AQ-SPEC program aims at performing a thorough characterization of currently available "low-cost" sensors under ambient (field) and controlled (laboratory) conditions.

Main Goals & Objectives

- Evaluate the performance of commercially available "low-cost" air quality sensors in both field and laboratory settings
- Provide guidance and clarity for ever-evolving sensor technology and data interpretation
- Catalyze the successful evolution, development, and use of sensor technology

Sensor Selection Criteria

- The sensor shall have potential for near-term use.
- The sensor shall provide real- or near-real time measurements.
- The sensor shall measure one or more of the National Ambient Air Quality Standards (NAAQS) criteria pollutants, air toxics, pollutants of concern and non- air toxics. Examples of the targeted gases and particles are carbon monoxide (CO), ozone (O₃), nitrogen oxides (NO_x), particulate matter (PM), volatile organic compounds (VOCs), hydrogen sulfide (H₂S) and methane (CH₄).



Website (www.aqmd.gov/aq-spec)

South Coast Air Quality Management District

AQ-SPEC
Air Quality Sensor Performance Evaluation Center


Sensor List

Sort By: products

- Dylex - DC1100 PRO
- Smart Citizen Kit
- RTI - MicroPEM
- Shinyei - PM Evaluation Kit
- LANDTEC - AQMesh AQM-5
- Aeroqual S-500**
- Dylex - DC1700
- HabitatMap - AirBeam
- Air Quality Egg

Sensor List

Sort By



Aeroqual S-500

Series 500 - Field Evaluation

General Description

The Aeroqual Series 500 handheld monitor can be used with a wide range of gas sensor heads. The sensor head used in this AQ-SPEC evaluation is the Ozone Ultra Low 0-0.15 ppm sensor head.

Principle of Operation

The device uses a sensitive metal oxide semiconductor that relies on the conductance of heated tungstic oxide (WO₃). In the presence of ozone, surface conductance of WO₃ decreases. Changes in the conductance are calibrated to measure ozone concentrations. During a "flow" state the sensor responds to incoming ozone the sensor conductance decreases. The ozone measurement is proportional to the sensor conductance difference between a no-flow and flow states.


Features

- Dimensions: 105 x 122 x 54 mm
- Weight: <460 g
- Battery: Yes (Lithium 3.1V)
- Power supply: Yes (12V DC (power adaptor/charger supplied 100-250V AC)
- Sensor lifetime: N/A
- Clock function: Yes (Real time)
- Sampling mechanism: Fan
- Environmental operating conditions: Temp: -40°C to 124°C; RH: 0 to 100%
- Internal data logging: Yes (8188 total data points)
- PC data logging: Yes (with provided Aeroqual software + cable)
- Communications: monitor to USB cable
- Weatherproof: No

Applications

- Source and leak detection
- Process control
- Health and safety monitoring
- Indoor air quality



Aeroqual Series 500 Ozone Monitor



Manufacturer's product webpage

Results (Field Testing)

PM Sensors

Sensor Image	Manufacturer (Model)	Type	Pollutant(s)	Approximate Cost (USD)	Time Resolution	Sensor vs FEM/FRM Method ¹
	AethLabs (microAeth)	Optical	BC (Black Carbon)	~\$6,500	1 - 300 sec	$R^2 \sim 0.79$ to 0.94
	Air Quality Egg (Version 1)	Optical	PM	~\$200	1 min	$R^2 \sim 0.0$
	Air Quality Egg (Version 2)	Optical	PM	~\$240	1 min	PM _{2.5} : $R^2 \sim 0.79$ to 0.85 PM ₁₀ : $R^2 \sim 0.31$ to 0.40
	Alphasense (OPC-N2)	Optical	PM _{1.0} , PM _{2.5} & PM ₁₀	~\$450	15 sec	PM _{1.0} : $R^2 \sim 0.63$ to 0.82 PM _{2.5} : $R^2 \sim 0.38$ to 0.80 PM ₁₀ : $R^2 \sim 0.41$ to 0.60
	Dylos (DC1100)	Optical	PM _(0.5-2.5)	~\$300	1 min	$R^2 \sim 0.65$ to 0.85
	HabitatMap (AirBeam)	Optical	PM _{2.5}	~\$200	1 min	$R^2 \sim 0.65$ to 0.70
	MetOne (Neighborhood Monitor)	Optical	PM _{2.5}	~\$1,900	15 min	$R^2 \sim 0.53$ to 0.67
	Naneos (Partector)	Electrical	PM (LDSA: Lung-Deposited Surface Area)	~\$7,000	1 min	PM _{1.0} : $R^2 \sim 0.1$ PM _{2.5} : $R^2 \sim 0.2$
	Perkin Elmer (ELM)	Optical	PM	~\$5,200	1 min	$R^2 \sim 0.0$
	PurpleAir	Optical	PM _{1.0} , PM _{2.5} & PM ₁₀	~\$150	20 sec	PM _{1.0} : $R^2 \sim 0.93$ to 0.95 PM _{2.5} : $R^2 \sim 0.77$ to 0.92 PM ₁₀ : $R^2 \sim 0.32$ to 0.44
	RTI (MicroPEM)	Optical	PM _{2.5}	~\$2,000	10 sec	$R^2 \sim 0.65$ to 0.90
	Shinyei (PM Evaluation Kit)	Optical	PM _{2.5}	~\$1,000	1 min	$R^2 \sim 0.80$ to 0.90
	Speck	Optical	PM _{2.5}	~\$150	1 min	$R^2 \sim 0.32$
	TSI (AirAssure)	Optical	PM _{2.5}	~\$1,500	5 min	$R^2 \sim 0.82$

- Overall, PM sensors showed:
 - *Minimal down time*
 - *Moderate intra-model variability*
 - *Good correlation (R^2) with “EPA approved” instruments*
- However...
 - *Sensor “calibration” is needed in most cases*
 - *Very small particles are not detected*
 - *Bias in algorithms used to calculate particle mass*

Results (Field Testing)

Gaseous Sensors

Sensor Image	Manufacturer (Model)	Type	Pollutant(s)	Approximate Cost (USD)	Time Resolution	Sensor vs FEM/FRM Method ¹
	2B Technologies (PO ₂ M)	UV absorption (FEM Method)	O ₃	~\$4,500	10 sec	R ² ~ 1.00
	Aeroqual (S-500)	Metal Oxide	O ₃	~\$500	1 min	R ² ~ 0.85
	Air Quality Egg (Version 1)	Metal Oxide	CO, NO ₂ & O ₃	~\$200	1 min	CO: R ² ~ 0.0 NO ₂ : R ² ~ 0.40 O ₃ : R ² ~ 0.85
	Air Quality Egg (Version 2)	Electrochem	CO & NO ₂	~\$240	1 min	CO: R ² ~ 0.0 NO ₂ : R ² ~ 0.0
	Air Quality Egg (Version 2)	Electrochem	O ₃ & SO ₂	~\$240	1 min	O ₃ : R ² ~ 0.0 to 0.20 SO ₂ : R ² n/a
	AQMesh (v.3.0)	Electrochem	CO, NO, NO ₂ , SO ₂ & O ₃	~\$10,000	1 - 15 min	CO: R ² ~ 0.75 to 0.90 NO: R ² ~ 0.75 to 0.90 NO ₂ : R ² ~ 0.0 SO ₂ : R ² ~ 0.0 O ₃ : R ² ~ 0.25 to 0.55
	AQMesh (v.4.0)	Electrochem	CO, NO, NO ₂ & O ₃	~\$10,000	1 - 15 min	CO: R ² ~ 0.42 to 0.80 NO: R ² ~ 0.0 to 0.44 NO ₂ : R ² ~ 0.0 to 0.46 O ₃ : R ² ~ 0.46 to 0.83
	Perkin Elmer (ELM)	Metal Oxide	NO, NO ₂ & O ₃	~\$5,200	1 min	NO: R ² n/a NO ₂ : R ² ~ 0.0 O ₃ : R ² ~ 0.89 to 0.96
	Smart Citizen Kit	Metal Oxide	CO, NO ₂	~\$200	1 min	CO: R ² ~ 0.50 to 0.85 NO ₂ : R ² ~ 0.0
	Spec Sensors	Electrochem	CO, NO ₂ & O ₃	~\$500	1 min	CO: R ² ~ 0.84 to 0.90 NO ₂ : R ² ~ 0.0 to 0.16 O ₃ : R ² ~ 0.0 to 0.24
	UNITEC (SENS-IT)	Metal Oxide	CO, NO ₂ & O ₃	~\$2,200	1 min	CO: R ² ~ 0.33 to 0.43 NO ₂ : R ² ~ 0.60 to 0.65 O ₃ : R ² ~ 0.72 to 0.83

- Overall, gaseous sensors showed:
 - Acceptable data recovery
 - Wide intra-model variability
 - CO; NO; O₃ (when measured alone): good correlation with “EPA approved” instruments
 - O₃ + NO₂: low correlation with “EPA approved” methods (potential O₃/NO₂ interference)
 - SO₂; H₂S; VOCs: difficult to measure with available sensors

Sensor Applications: Pilot Study #1



- Monitor fugitive emissions from Rainbow Waste Disposal facility (Huntington Beach, CA)
- 9 sensor “boxes” deployed at facility fenceline
 - \$1,500 per “box”
- Wireless network / remote server
- Real-time PM_{1} , $PM_{2.5}$ and PM_{10} monitoring

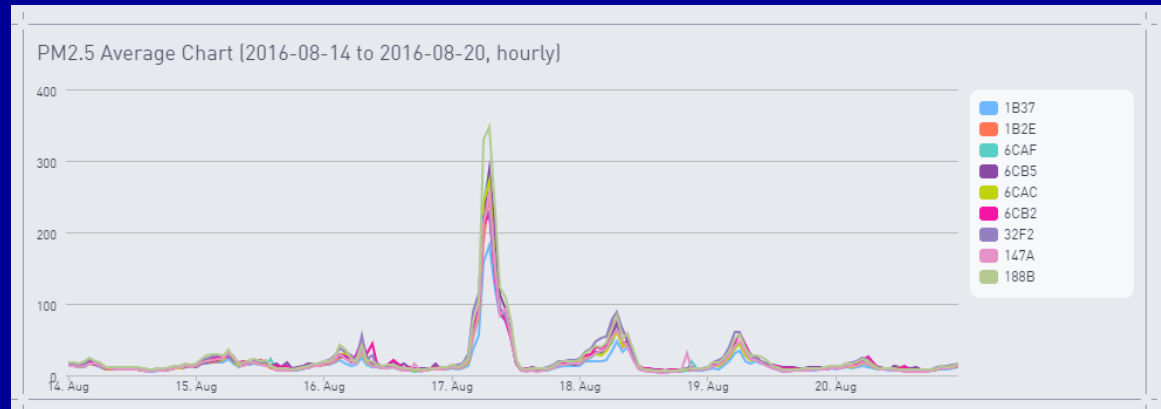




Sensor Applications: Pilot Study #1

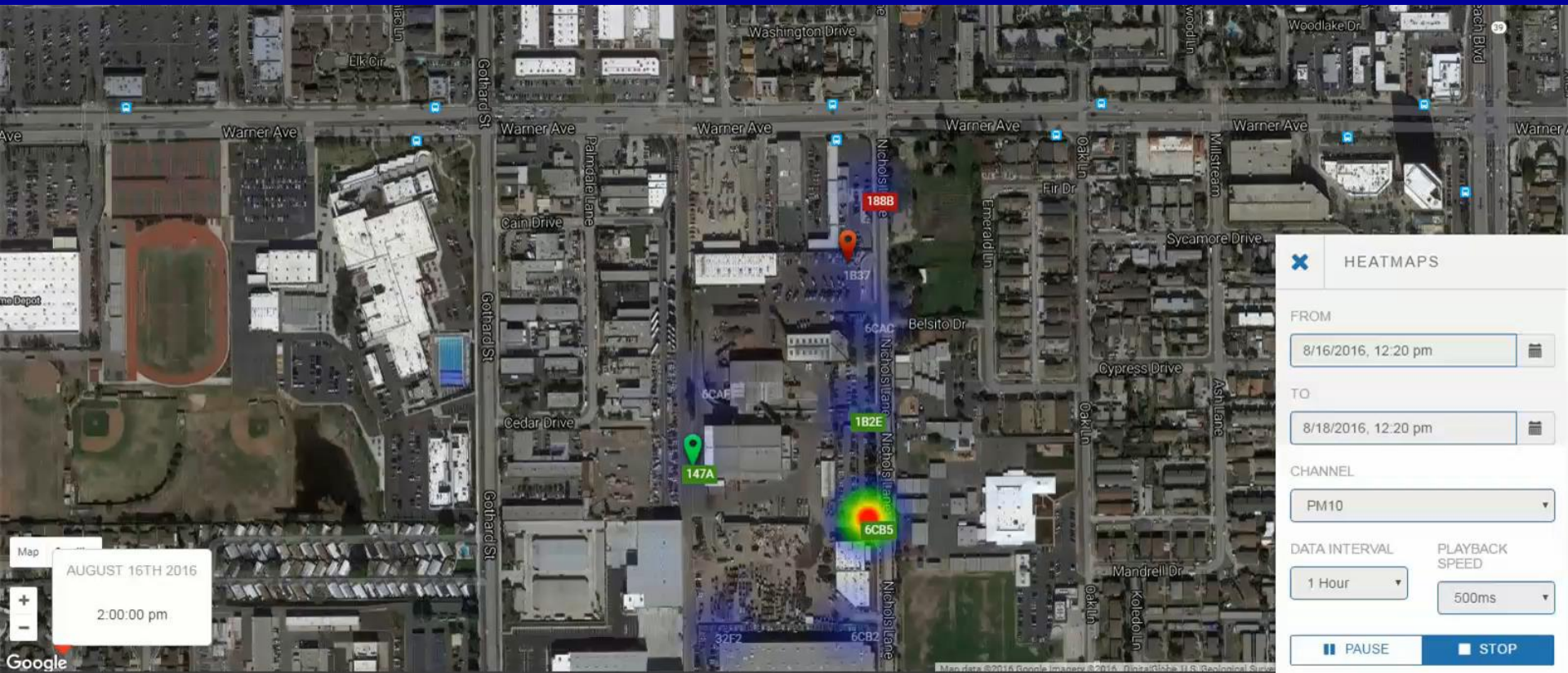


- Dedicated website
 - www.aqmd.meshify.com or www.rainbowes.meshify.com
 - Real-time data logging, display, and mapping
 - Data analytics
 - Email and/or text alerts
- Project benefits
 - Correlate PM measurements w/ on-site activities
 - Measure PM levels before and after facility upgrades

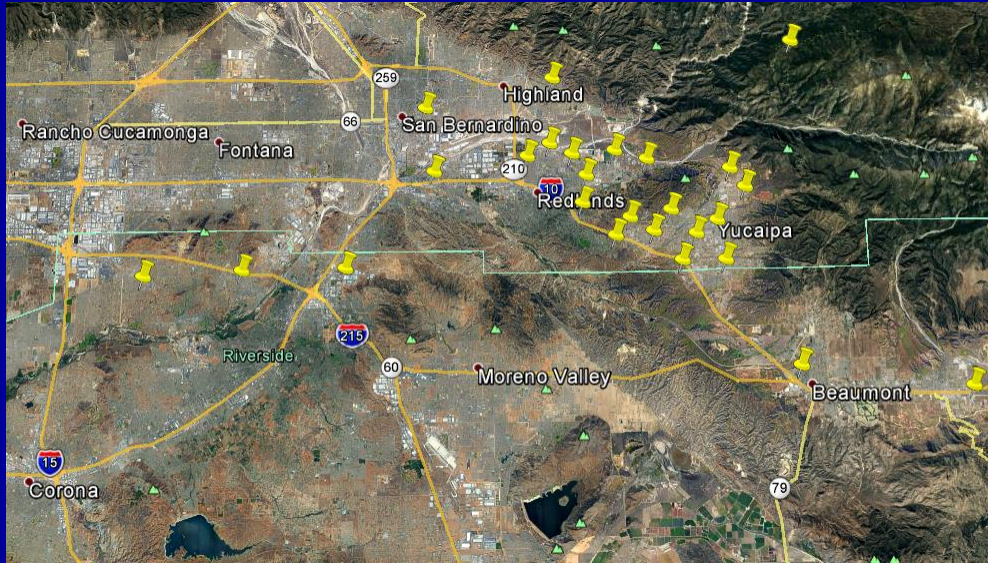




Sensor Applications: Pilot Study #1



Sensor Applications: Pilot Study #2



- 25 “low-cost” PM sensors deployed in the San Bernardino / Redlands area
- Real-time PM_{2.5} and PM₁₀ monitoring
- Wireless network / remote server
 - *Microsoft*
 - *Element Blue*
 - *Sensor Insight*
- Project goals
 - *Test sensor durability*
 - *Show ability to scale up in near future*

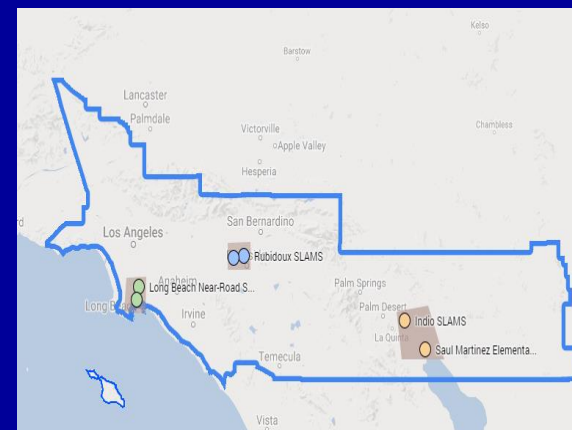


Purple Air Sensors (\$180 / unit)

Ongoing Activities: Sensor Evaluation for EPA

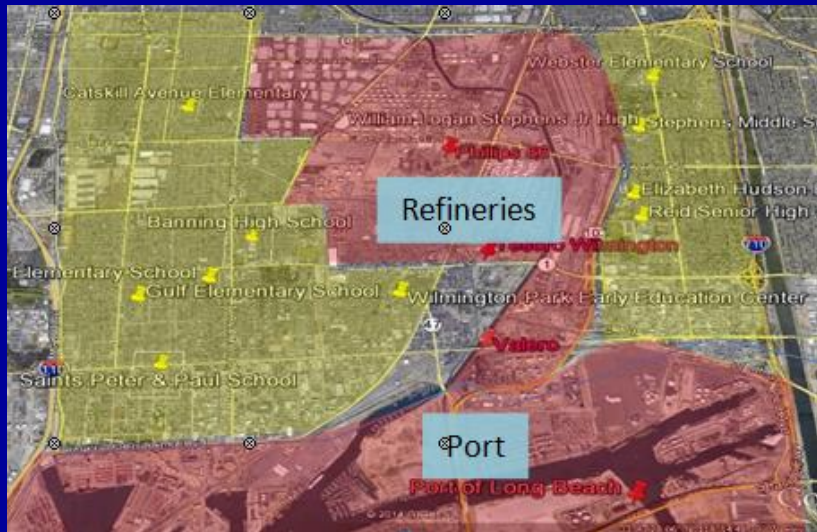
- EPA's National Exposure Research Laboratory (NERL) has developed a Portable Observation Device (POD) to measure PM_{2.5} and ozone
 - *“Low-cost” sensor technology*
 - *Optical particle counter for PM_{2.5}*
 - *Metal oxide sensor for ozone*
 - *Also provides T and RH measurements*

- AQ-SPEC is working on characterizing PODs' performance, reliability, and durability
 - *Detailed field and laboratory testing (2 months)*
 - *Extended field deployment throughout SCAB (8 months)*



Ongoing Activities - EPA Community Scale Study

- Use Optical Remote Sensing (ORS) methods to monitor Hazardous Air Pollutant (HAP) emissions from refineries
- Use of ORS methods and “low-cost” sensors to assess the impact of industrial HAP emissions on surrounding communities
- Two year study





Upcoming Activities – EPA STAR Grant

- Provide California communities with the knowledge necessary to select, use and maintain low-cost sensors and to correctly interpret the collected data

- Four specific aims:

- *#1: Develop educational material for communities*
- *#2: Evaluate / identify candidate sensors for deployment*
- *#3: Deploy selected sensors in California communities*
- *#4: Communicate the lessons learned to the public*

- Three year study in collaboration with:

- University of California Los Angeles (UCLA; Co-PI)
- Sonoma Technology Inc. (STI; Co-PI)





External Funds

- Received (> \$1.5M)
 - EPA STAR Grant: \$750,000
 - EPA Community Scale Grant: \$570,000
 - EPA / NERL POD evaluation and deployment: \$102,000
 - Funds from EPA Region 9 for chamber development: \$75,000
 - PM sensor network @ Rainbow: \$40,000 (NOV)
- Other
 - NASA Citizen Science Proposal (submitted)



E-Enterprise Advanced Monitoring

- Joint EPA, state, and tribe efforts to support innovations in measurement equipment, data analysis tools, and the ability for citizens to collect (and analyze) high quality data
- Key activities needed to prepare for changes in environmental programs resulting from advances in new monitoring technology:
 - Feasibility study for a voluntary 3rd party certification program (Team #1)
 - Technology screening and support network (Team #2)
 - Interpretation of data from advanced monitoring approaches (Team #3)
 - Data standards & data quality tiers (Team #4)
 - Lean EPA technology evaluation parameters (Team #5)
- Dr. Laki Tisopoulos (Steering Committee); Dr. Andrea Polidori (State Lead for Team #1); Dr. Jason Low (Team #3)



The AQ-SPEC Group

- Dr. Andrea Polidori
- Dr. Vasileios Papapostolou
- Brandon Feenstra
- Dr. Hang Zhang

www.aqmd.gov/aq-spec