Speaker: Lisa Matthews

Ok let's go ahead and get started. Thank you again for joining us for the monthly webinar, which was rescheduled from last week. We are pleased to have some of EPA's Air, Climate and Energy research program folks with us today to talk about air quality monitoring and community science. We will go through a presentation and then we'll take some discussion questions. If you have a question, please type it into the chat pod on the webinar screen, and we will answer as many of those questions as we can following the presentation. We will make the slides from today available on the EPA research website under tools and resources webinars, those will be posted shortly, and we will follow that with a recording of today's presentation.

So I want to introduce Dr. Alan Vette who is the Deputy National Program Director for EPA's Air, Climate and Energy research program. Alan is going to give us a short introduction and overview.

[Noise interruption]

Then after Alan finishes, Ron Williams who is a researcher in ORD's National Exposure Research Laboratory will walk us through the presentation, so Alan – thank you.

Speaker: Alan Vette

Sure, hopefully you can hear me. Thanks for joining us. I see there are a number of folks on the webinar, so I want to thank you all for taking the time for this. I think many of you know air pollution sensors are becoming much more widely available and to a broader audience in just a few years' time. Measuring air pollutants has been made more available and affordable, primarily because of the ability to miniaturize the devices and the number of manufacturers of portable low-cost devices has really been blossoming in the past few years. That's driving down prices and offering many more options at a price level that's available to many consumers and community scientists like never before.

Some sensors perform better than others, yet there's not enough information available to provide guidance to identify the few gems among the unfortunately many stones that are available in the marketplace. But there is progress being made, and we in EPA are doing all that we can to work with others in government at the state and local levels and the private sector to nurture this sensor revolution by providing information on evaluation of sensors and how they can be successfully applied to better understand air pollution in communities and really what the data mean. These are things that are vitally important to EPA and communities.

So today Ron Williams will share the wisdom that he's gleaned over the past several years as a leader in this field. Ron has been a pioneer leading research to evaluate sensors in the laboratory and test them further in real world settings. But it's not enough to just understand how well sensors measure air pollutants and the technological advantages and limitations of one sensor versus another. How the sensors are deployed in a given location is also important, and quality assurance measures are important to ensure good quality data is absolutely critical. Ron is a senior scientist in EPA's National Exposure Research Laboratory and brings a wealth of experience – 30 years or so – Ron correct me if I'm wrong – Ron's experience for a number of years has been designing and conducting field studies on sensors to assess human exposures to air pollutants. Today he's going to introduce you to EPA's Air Sensor Toolbox, and talk about his experience and others and some lessons learned about the performance of sensors and some specific projects he's been involved with. So without further ado.

Speaker: Ron Williams

Thank you Alan, good afternoon everybody. I've had a chance to review to see who our participants are today. I recognize some of you by name and reputation and we're very glad that we can participate today and give you an overview of what we've been working on. Basically for the last two and a half years we've had a crash course trying to establish an understanding of sensor technology, as we literally try to change the paradigm of air quality monitoring. Again, we want to welcome everybody today, and I'll look forward to your questions.

I'd like to start very early, for those who are participating today [with the question] what are you going to get out of the time that we share today? We are continuing to look at sensors and evaluate. A lot of what we're doing is market survey - what sensors are available. I get contacted by multiple developers every single week wanting to share with us about devices that they are building or inquiring about what EPA's interest might be in certain devices, so we will share a little of that today with you as we continue market survey. It is an important part of what we're doing. We're trying to evaluate technologies, and when we discover technologies that appear to be valuable to stakeholders, stakeholders include citizen scientists, community groups, regulators and EPA, and [EPA] wants to be able to use these technologies, [since EPA] is a stakeholder likewise. When we can find these types of technologies, we are literally putting them into field campaigns to either work with citizen scientists or conduct research specific to a given task, so we're focusing on low-cost sensors.

Rarely does a week go by where I'm not communicating to a citizen science group or community group, and invariable it will come down to this question, "we want to go there and buy sensors, do you have any recommendations?" Of course we cannot recommend, that's something we legally can't do, so the follow-up question to that is "Ok, what is your capitol expense budget?" Without question, most citizen and community groups say "we have $500, we have $300, and we want the product to be as good as a federal equivalent monitor." Of course that doesn't exist, so we're spending the most of our time looking at those devices that are under $2500 because that's where we see most citizen groups, scientists and we think many in the regulatory field who are looking for a sensible monitor are going to be able to make their investment. So we're focusing on that low-cost area, and that's just a bracket that we've developed locally in our team, there's nothing promulgated. You're not going to find that definition that's agreed upon, it's just that at least within our EPA conversation with many people most citizen groups likewise won't be able to afford $2500.

A lot of capabilities are being mentioned. We look at as many sensors as we can, we have conversations with others trying to glean that information. It's not unusual to see sensors that contain the same base element that is the sensing element that should be doing the job, inserted into one or more different products functioning quite differently. So there's a wide range of capabilities being observed. The dollar amount doesn't necessary drive the capability. We have seen devices in the 200-$300 dollar range outperform devices at the $2500 range, and all along that threshold. If one had to summarize – well Ron, if you had to compare the very best sensors on the market how they relate to reference monitors, is there a short hand? Well, don't quote me on it, but that being said we do see some breakdowns that are occurring. Ozone sensors, electrochemical sensors appear to be very agreeable with co-location monitoring to agreeing with reference data followed by PM monitors, CO, NO2 and SO2 and those last three are really failing in our view because of limits of detection [since] they typically don't have the best ability to get there. There are exceptions though, and I will show you some of those exceptions today.

We're not seeing a lot of movement in the marketplace as far as air toxics. Developers really aren't able to provide anything that have the limits of detection and specificity. I'll talk about what we have seen in that area, but those that are drastically lacking are the VOCs, ammonia, hydrogen sulfide, and methane as well as things like very specific things, like 1-2 Butadiene or a specific VOC. There's just not anything out there I can share with you.

I want to share with you some of the tools we've developed here in EPA. Again we deal with a lot of citizen groups and regulatory agencies that try to figure out how does one use these types of data. Often a problem comes into how can you visualization it? We have a great tool in the RETIGO tool that we've made available at no cost to people, and its undergoing Beta testing right now. We'll have some slides that talk about that. You may also be aware of our Village Green Project, there are some low-tier and mid-tier sensors, and in our book those are sensors that cost about $5000-$6000. We've been evaluating a number of those in our Village Green Project, so I'll include a couple of slides that give you some insight on some of that research, and the fact that we see that this is only an area that's expanding. Literally, my EPA colleagues can tell you that my calendar is scheduled from 7:00 am to 4:30 [pm] every day with conversations like this and in this. Last year we've given 40 presentations to internal groups and external groups about this area of research, it's one of high intensity. I hope you'll be aware of the fact that most recently our colleagues in the Office of Air Quality Planning and Standards have released a tool or at least an application or a messaging as one want to think about it about 'what do you think about, how do you apply, how do you have a conversation about' sensor data of short-term duration. We have the air quality index (AQI), but we know that most people will probably never take the amount of data needed to truly understand an AQI. They may take a 5 minute data point or a 1 hour data point [so] what can one say scientifically about that. You're going to see some great information about released by the Office of Air Quality Standards and Planning, I'll share that with you today. I also want to talk about some of the options communities may want to have available to them in their own research.

There are 10 primary areas that we have been investigating as far as the air sensors draft roadway. That was a document that we in EPA multiple institutions, parts in EPA developed in 2013 to try to figure out what are the areas we need to work on, what the low hanging fruit is considering our resources with FTE and dollars, where can we make the most bang for our buck, where is the greatest needed. I can't talk about all those things today, you can see those 10 primary targets there. I am going to talk about those things today that highlighted in red, again like market surveys and emerging technologies. I'll share with you about how we're trying to apply and transfer this knowledge to others. Certainly we'll go there and talk about how we have worked across all aspects of EPA. This is truly a one EPA type of research function because everything we do ultimately has impacts on so many others. Some of our research is integrated across multiple organizations for both leveraging resources and interests. I'll try to give you some understanding of some of the things we've done and some of the lessons we've learned. One of the things we always want to share with our points contact especially if you're a health based group, if you're working with the public. We often get asked this question, "I want to collect some data, and I want to collect it for meaning and I want to be able to use it for a purpose." We highly agree that data collected should have a purpose, it should have a purposeful study design [and] it should meet some need. But we often have this point of conversation – do you know what it is that you need to measure, and do you believe you can successfully capture it? The vast majority of times in our preliminary conversations with citizen groups and even some regulatory agencies that may not have an

understanding about the specific levels of detection and those devices that are on the market, so we often share this slide with them. For instance, if I'm interested in nitrogen dioxide measurements, and I'm trying to use a lower cost monitor that is one of the sensors that's out there, it's important to know that you want make sure that you have a device that can at least measure 10 parts per billion (ppb) or preferable below 10 ppb because otherwise you can find yourself in many places in the US thankfully at concentrations well below 10 ppb. We don't want people to be confused or lose sight of the fact that if you're collecting data and you're below the threshold of the device, you will be frustrated. Not only will you be frustrated, but in many instances we see the devices give off very erroneous readings at or near their limits of detection. So we have a conversation with others about, let's make sure what you can measure in your local atmosphere can probably at the level that can be detectable by one of these lower cost devices. Of course, they're widely variable across a wide range of pollutants as you see there.

We also want to have conversations with all those we interact with about quality assurance. I cannot stress it enough, it literally is the focus of what we do in the agency [and] we try to make it the focus in community groups and tribal nations. Again, bad data is bad data and it only clouds the conversation. We've been approached many times where data is being collected using a low-cost sensor where the concentrations are not reasonable. In some cases, 2 to 3 orders of magnitude above reality, yet they're being released for public domain and public use. That is not just a matter of confusion, but in some situations it can really cause hardships in cases where some people believe they are being exposed to potentially high levels when in fact that's not reality. It can cause concern if not panic amongst the general population. We've actually had to have conversations with manufacturers about their devices [to] please make sure you're device can provide something of reality. Some of the points that we like to look at are precision, calibration and accuracy. We're not trying to reinvent the wheel here, if you are familiar with federal reference measures and federal equivalence measures that EPA has used for our attainment research all over the world in which our states and others we're working with on attainment issues and regulatory affairs, we don't have to go too far to find out what are the things we should be concerned about understand how stable is a response, that is drift. If we have a sensor operating in a stable environment that really isn't changing, does it hold constant or does it change over time without change in atmospheric concentration. That is important to know because some of these devices we can see can start drifting high or drifting low. You might come into a situation where a device actually is reporting data in an ever increasing fashion but it has nothing to do with reality. We always want to go there and talk about quality assurance features when we're working with individuals.

What about sensors and health? We in the National Exposures Research Laboratory have had a lot of success in working with other parts of EPA and other organizations doing epidemiological studies. We've looked at human exposures whether it's indoors or outdoors, and trying to relate that to a specific health impact. You may be asked that question. Citizens may come to you, health agencies or other parts of your organization [with the question] "how might these sensors apply to what we're interested in or what we might be challenged in." We thought we might go to display a couple of points with you. One, we've taken a lot of personal, residential and indoor/outdoor data, and it's been used successfully in epidemiological study. We've been able to find in some cases significant findings have changed in cardiovascular effects and other types of endpoints. The key point there is quality assurance. Again, bad data is bad data and when you're trying to use a sensor that we're talking about today it must be accurate, precise, repeatable, you have that consideration because you have that human component that is the biological element, that endpoint that you are measuring be it blood pressure, heartrate, and

then you have that exposure potential that you're trying to capture with a sensor. All those areas have to be configured in can you reach something of significance, can you reach something that is statistically of importance, so we always want to remind people that yes this work can succeed. We've done thousands and thousands of personal PM 2.5 measurements using devices just like what I'm talking about today. In the future, these things can already be used, and we have a history of doing that. We see people often negating the fact that you have to understand human activity patterns. There've been a number of devices that we've used and others have used over 10 years that can really do a great job at pinpointing the human activity level, where people are, their energy expenditures, how long their spending in a given space indoors verses outdoors or in some activity. There's been a progression of devices that can do that at a very low-cost so that you can understand human activity pattern. It's often a neglected aspect when we think about understanding health effects, but there is a history especially in the last 10 years of being able to do that. There certainly are some devices on the market now that can assist one in understanding human activity pattern that are very easy to operate.

Sensors can help citizens understand healthy versus unhealthy norms of air quality. Again we have the Air Quality Index, you'll see slides before we finish today about that data messaging. I'm going to keep referring to that because I think it's a fantastic tool that's been developed here, and it's highly scientific in its thought process. What can you say about a 5 minute measurement of NO2? We'll give you some insight into what the Agency thinks might be some good conversation to have with others about that. Healthy versus unhealthy, we'll be able to talk a little about that today.

I often share with people, I have a bicycle, I have a kayak, I have a pickup truck, I have a car [and] each one of those vehicles, if you want to use that terminology, is useful for different things, and sensors are useful for different things. There are sensors that are of course $20, 000 and $50,000 sensors that in reality might be federal equivalent or federal reference measure. We have those low-cost sensors that might be $100 or $500. Each of those different devices have a different means of supporting what I might want to do. There are different things that sensors might be applicable for. If you're interested in doing environmental awareness, working in schools, introducing the citizen tree to the fact that we're constantly being exposed to pollutants, let's try to understand what pollutants we're exposed to today. If you're not necessarily interested in the fact that its 1 microgram per cubic meter or 10 micrograms per cubic meters, well that's an environmental type of awareness campaign. If you're truly interested in defining exactly down to the 1 ppb how much nitrogen oxide you're exposed to, a low-cost sensor may or may not be what you need. Again, sensors can fill a wide-range of needs, and not every sensor can fill every need. Low-cost sensors are starting to be used in a wide variety of issues, from environmental justice and advocacy. I'll show you the ways in which we're trying to do today, and I invite you to that link - you'll have access to these slides following today's broadcast. I invite you to go to that link, and you'll see some of the most recent work that we've been doing with our NCER component within EPA and grants have been released where these low-cost sensors are trying to be integrated into communities for a number of specific mission activities. That's a great happening that's literally just starting to take place.

Often people don't have an understanding of the sensors that are out there. We typically see those things measuring gases like nitrogen dioxide, sulfur dioxide, carbon dioxide, typically are electrochemical in nature. They've existed for 30 or 40 years, many of those on the call that I recognize your names, like I, have been using these sensors since the 1970's, but they've become more miniaturized and the manufacturers have been able to reduce the limits the detection and decrease the noise in many

situations so that they've become more useful to us. The vast majority of devices on the market trying to attempt to measure particulate matter, which of course is a complex mixture, often is using some form of light scattering or particular counting in some nature. There are a lot of different varieties of quote on quote light scattering devices that are there, but they typically fall within a number of different categories, but are typically doing a lot of the same types of optical measurements. You'll see a lot of the same types of devices that are out there. You may or may not be aware of that market survey. Again, this is a vocal disclaimer – we're not trying to guide you to any particular device. If you have a specific need, please contact me after our presentation today, and we'll share with you what we've learned in our publications, or if you have a specific need we might be able to work you through a thought process.

I just wanted to share with you examples today that are out there for PM. All of these have some sort of optical measurement where you're looking at particles through a light beam, either a laser or LED type of situation. These are from multiple places in the US or in the world. The DYLOS is a particle counter, it comes out of clean room technology it sells for $100 to $300. It's used by quite a few community groups because it's so easy to use. You may have heard of the SPECK out of the Carnegie Melon group, which has now been moved to the AirViz component of Creative Laboratories. That's the device that's non-profit, routinely is released for $100 to $150. You can actually go to libraries in the Pittsburg area and get some of these and actually loan them out like a book. That's quite a change in perspective when you think about environmental equipment being on a loaner basis through the public library, but Creative Laboratory has been an advocate of that. The MET ONE comes along more of with the industrial hygiene types of work that we've seen for particulate sensors and sells for $2500 to $2800 category. [Its] very easy to use and one of the varieties of the devices that we see that falls into that industrial hygiene area. It's more robust with a long term manufacturer behind the product development. The SHINYEI is an Asian company that has kind of populated some of the low-cost areas. Their devices typically have to be incorporated into other components - that is they typically don't release a device with its own data portal or power supply, you typically have to add those components in. You may have heard about the AIRBEAM, that's Michael Hindbinder's group out of the New York – New Jersey area supporting citizen science. It's getting quite a bit of use by citizen scientists and others. One of the devices that captured the attention of the Wall Street Journal within the past year is the TZOA. It's a device about the size of a quarter and very small [and] it connects to a number of different portals, but in its base platform is an Android type of output [it's] very small. Again, this is just one of a score of devices to give you a range.

I wish I could offer you page after page of VOC sensors, but there really just aren't a lot of that fall into at least the low-cost category. We see devices coming out of Europe like the UniTech, which you can see is listed as the SENS-IT, and then you see the benzene signature there. I'll explain to you some of the testing that we've done. We're looking for specific VOC sensors. We would love to find a device that's specific to carbon-tec or a device that's specific to benzene. I wish I could to say that I had found such a device at the low-cost range, but we are continuing to look and examining those. You may be familiar with the industrial hygiene types of devices like the ToxiRae. Those are the photo-ionization devices that we've literally had for 40 to 50 years. They are classical industrial hygiene devices, but again they have been miniaturized and improved upon. They still capture the vast majority of what one may call the total VOC detectability range. Those of us even in EPA are developing sensors. We're often trying to again find VOC sensors and incorporating into our own devices. Here you see a device to the far right there (on the Power Point slide) that one of our collaborating laboratories here at EPA actually developed and are trying to use for things like fence-line monitoring or even mobile measurements of VOCs.

Gas based sensors, again the vast majority of those are going to be electrochemical in nature, and they come in wide ranging formats. They capture the majority of the market across the world. The SENSARIS is a product released in France. The Air Casting is part of a citizen science non-profit from Michael Hindbinder's group, you can literally build your own sensor put an order in [it's] great for the classroom setting where you can build a device specific for your need at a low cost in the low $100 range. CAIRCLIP is a company product released out of France [and] it has been used quite a bit for supplemental monitoring around the EU to gain an understanding of complimentary monitoring. This is a device that is about the size of a roll of quarters and sells for around $1500 that measures NO2 or NO2 plus ozone as well as a couple of other products in different formats. It has a wide range of application because it's just so small and easy to use, so it's getting a lot of attention. You may be familiar with some of the work from Australia - the AEROQUAL sensors ozone and NO2. Here you see the ozone sensor. It sells for about $500 it literally is printed circuit board with electrochemical sensor that is attached. I'll give you some understanding of how well it's performing today. You may be familiar with the Air Quality Egg, this was one of the very first citizen science based products released. It first was released in around 2012, they're been a number of iterations of that, you can see it's shaped like and egg and it's really focused on citizen science and environmental awareness types of activities. The NODE is a Scandinavian product, it uses a small device about the size of a roll of quarters that feeds data into a cell phone.

As you can see this is a worldwide phenomenon of companies and others that are making these devices. People often ask, is there a grouping of sensors - we would call that a pod - that would allow us to measure are 4 or 5 things all at once. Well there are, there are a number of companies that release devices like that, such as the ELM [and] you may have heard of the AQ MESH. There are companies that do classical industrial hygiene like SKC, they have a device called the HAZ-SCANNER. Again there are multiple other companies doing that. These often range in cost from $1,500 to $10,000 so there's a wide range in cost of these devices, although in honesty many of these devices are incorporating a lot of the same types of technology so the value added there must really be considered when you're purchasing these.

As I've said we're trying to go there to share with stakeholders as much as we possibly can about what we have learned. In 2015 a number of us here in EPA, Amanda Coffman and others on our team developed the Community Air Monitoring Training Event. Working with our regional partners across the US they've nominated citizen science groups and tribal nations to come to EPA's base laboratories here where we gave them a day's training on the latest sensor technology, quality assurance, what one might need to think about in terms of study design preparation, and some hands-on activities, including things like our RETIGO tools, C-FERST, T-FERST tools, for working with data visualization and integration and it was such a success. We maxed out the total number of people that we could incorporate onsite with the different groups who were invited. We had over 800 people who attended the live event and then we video typed all of the proceedings in the morning's training sensor and those are available online to you. If you're not familiar with that, I really want to encourage you to go to the Air Sensors Toolbox that if you see the next slide, online resources available at – information that's loaded on the Air Sensors Toolbox we've been told was the most downloaded documents in all of EPA last year, that's all of EPA. Obviously, we've struck a nerve there with the types of information we're releasing there. Those training videos are great quality, we certainly encourage you if you are trying to think about working with sensors or working with citizen scientists and you want good starting points, I think we've got a pretty good leg there that you can build upon. We want to encourage you to go to the Toolbox, go to

those training tools made available to you. Those materials include evaluations of specific sensors that we have published, as well as the sensor user guidebook. That sensor user guidebook from what we've been told was the most downloaded document of all of EPA websites last year. We want to encourage you to take advantage of what we're trying to place there.

A lot of what we're learning is side-by-side co-location of sensors with reference monitors. Here you see some of the work that they've done on our campus where we actually have a wide range of regulatory monitors that literally run every day which gives us an opportunity to co-locate. You see that upper right photo - we would just call that a helmet. A vast majority of sensors out there are not weather proofed, so the only way that we can place them in the real environment is to provide some means of protecting them from rain, snow, dew and all the other types of things. So we often go there and use a device like a helmet to allow good air movement into an inlet, which you may or may not be able to see there, but at the same time ensure the device will be protected where we can operate it weeks at a time and collect enough data to really understand it.

We're doing this type of work in multiple places. One of the things we've been doing for the last couple of years is literally long-term evaluation of sensors. Here you can see devices that we had operating in our Atlanta Care-Sense project. That's work we did collaboratively with multiple regions in US EPA as well as the state of Georgia who were interested in understanding how some of these sensors work. You can see we were able to go there and have a large number of sensors in what we call our chicken coop design where sensors where placed operating easily in a trifurcate fashion. We've actually stuffed quite a few in this particular photo just so that you can see it. The chicken coop is like a 7 layer platform where we can separate these out, but this photo just gives an idea or how one might be able to do that.

We do encourage people not to go there and consider examination of just a single version of a sensor to be successful. We have seen multiple times where we've had 3 or more of the same sensor where 2 of the sensors might have worked equally the same and one not function at all. If you happen to be that person who buys that one sensor that's not working, you may not even be aware of the fact that it is not functioning appropriately. We encourage people to go there and look at more than one device, or at a minimum to make sure they are co-located with reference monitoring so you know you have something that is functioning.

Like I said, we are looking at multiple copies of these devices in multiple geographical areas. We were in Atlanta hot and humid for over a year. We moved then to Denver where it is lower humidity, much lower temperatures, you can see in the visual representation of those picture there. It is important to know that these low-cost sensors are going to be affected by relative humidity in many cases, especially the PM sensors. The electrochemical sensors typically are going to be very sensitive to temperatures, especially low temperatures. We've often seen, especially in our chamber work, when we examine these sensors in temperature well below freezing they start to behave very erratically. If you happen to try to be operating these devices in Minnesota, or you happen to be operating a PM device in Seattle where you have a lot of humidity, you need to be aware that this may very well be impacting your data quality. Again, we have tried to shed as much light on that as we can.

A way we're doing that is sharing data in our published reports, go to our Air Sensors Toolbox, you'll see a lot of that output where we try to summarize it. We're looking for the effects of relative humidity. Here you can see a sensor the DYLOS, and when you approach the DYLOS and start challenging it with a relative humidity 85 and higher, you can start to see a very high biased increase in particle number of

particle count. I can tell you that has nothing to do with the density (micrograms per cubic meter) of the particles that are there. In many cases devices are going to do that. Some of the devices that we have examined for PM have the ability to correct for relative humidity, but the vast majority don't, so you need to understand if you're trying to use these devices - is it correcting for relative humidity, and at what point in time in relative humidity should you start thinking about the data being useable or not usable. We see quite a bit a variability, but for the most part once you approach about 85% or higher, you start seeing the impacts of relative humidity for PM.

As I've said earlier, we've been able to examine a number of devices and one of the most successful thing we have been able to uncover was for the devices measuring ozone. This particular device sells for $500, it's from Australia. As I've said we've been able to go there to monitor and use it in a number of cases and in Atlanta as well as Denver. As you can see it provides a very linear function over time, but I also want you to look at the intercept of the equation right there. You can see 0.56 to 0.004 being the intercept with slopes are being in about the 0.5 range. What that means is that we've actually this sensor in the field approximately a year, we brought it back to the laboratory and it still provided a linear output but at a reduced response. That's important, because people often ask us – how long do sensors last? Manufacturers will typically give you a discussion that [it'll] last approximately a year. In all honesty you really don't know, we can't really tell you and the manufacturer probably can't tell you that you're going to get a one year operational lifespan. Here again, you see good response, but it's giving 50% of the response when we first but it in the field. We would not have known that unless we brought the device back and tested it in our laboratories. Likewise we would suggest for others, you need to be constantly looking at response over its lifespan of the device.

We've seen other devices such as their devices from TSI, their Air Assurance PM 2.5, you can see their device which sells for approximately $1000. You can see in our intercept slides that in our work in Denver looking it appears to be very linear with intercepts being very agreeable, especially for citizen science and even some research purposes. Here's a success story you may want to think about where they would appear to have done their homework in engineering. I could easily show you a number of devices that don't work as well but we like to go there and show you some devices that might have some viability for your research functions. This is one of just a number of ones we've seen. Where the work is done at, where you're trying to evaluate, the conditions could have very easily affected the output here. This is not a one size fits all reading, and in fact we would certainly go there and say that if you're testing it on the east coast and using it and also comparing it to data on the west coast say that it would not be unusual to see a far different response because aerosols are different on the east coast and on the west coast you have a different levels of factors if you're looking at a gas based sensors, CO2, NO2 and SO2, so please don't think that just evaluating a devices in one setting is sufficient for another setting that has drastically different environmental conditions.

As I've said we're constantly looking for VOCs and trying to understand how they work. I wish I could say we've found a lot of success. At least I've given you some indication today of some of the devices that are out there. We're trying to apply what we're learning in citizen science studies. Here (picture) you see the EPA Administrator with work that was done in collaboration with our Region 2 partners and a citizen science group. We built a specific sensor pod, we gave it a classy name CSAM, (Citizen Science Air Monitor) where we compiled together a number of sensor pod and made it very easy to use. Literally all the citizens in this community had to do was turn one key to turn the device on and off, then a microbe recovered all the data that was in the SD card that was internal to it. If you're interested in this

particular device, again it was just something we built here in the EPA go to the Air Sensor Toolbox and you can see very specific documents to finding that device. It was a pod because it's multiple devices compiled together. We've been miniaturizing sensors since then. This is our Air Mapper, this is work we've done with our Region 5 collaborators and our Region 5 office in Chicago. It's a device we built specifically for citizen science and for air quality awareness. We've had people as young as 7 years of age be able to operate this device, which measures CO2, PM 2.5 and a number of other environmental measures, metrological impacts, relative humidity and temperature. We've done this so that the data can be outputted specifically to one of the tools we've talked about which is RETIGO.

Ah, and there it is (next slide). I'm hoping you'll take a chance after today's broadcast to go to the RETIGO website. Again, it gives you a lot of opportunities to import your data. This is a site where you can place your data, it's not data owned EPA's data – we don't use the data you place there. You can share your data with others if you get permission to do so. It's a portal that we are making available to you, particularly for data that is highly spatial and highly temporal. That is collecting real-time data in a moving platform, such as on a bicycle or on foot. It's a great tool, it doesn't cost anything to use. There are a lot of tools that are built into this. You can overlay maps, satellite and other types of maps. You can look at local air quality measurements being made by EPA, that is regulatory data and do some comparisons, [and] some statistical data analyses that are allowed to be performed here for you, in a gooey type of interface. We certainly hope you get an opportunity to look at the RETIGO tool. We think it is going to meet a lot of people's needs, and it's undergoing Beta testing. Here's some examples of what some of the output of what some of that looks like. Here you can see where we've actually used the AirMapper, that tool you saw earlier that is being used in the Chicago area where we're doing real-time mapping of air quality PM 2.5 in a given situation. You can look at it on a map or you can look at it in a time sequence, here on the left on the right-hand screen that's been provided to you. Again you have a lot of tools, a lot of ways to go there and look at data there on that tool that's available to you.

Earlier we said that we wanted to go there and make sure that you understand that we are trying to integrate our work in multiple applications. That is not just understanding how sensors are working, but integrating them into communities and into the hands of other scientists. You may be available in different areas, you may have the ability to have conversations with our regional scientists, so I want to give you an understanding of what's going on. Our CAIRSENSE Project it involved 5 different EPA Regions, it involved two state agencies, the state of Georgia and the state of Colorado. We are out of the field now, and we're starting to summarize data. We hope to release data within the next 30 days, at least the preliminary presentation as part of the National Ambient Air Quality Monitoring Conference, where you can see some of this output. We'll be working up a manuscript and output to our Air Sensors Toolbox over the next 6 to 12 months, so stay tuned for that. You want to stay tuned for that because it represents our latest efforts to evaluate as many of technologies as we can versus reference monitors, and give you the good and the bad and what we've learned about it. The CSAM, we had just released a report - literally in the last two weeks that documented the work we did there and the collaboration with community group in the Newark, NJ area and Region 2 collaborators and the process in which we involved ourselves. That is a great insight if you want to do this, you might want to look at the pilot effort to see how you might approach using some of these sensors for your work. CitySpace is a work that we're just starting, again involving multiple EPA Regions where we're going to be doing PM 2.5 monitoring in the Memphis area. It will be a notable distribution where we'll be streaming data live to a web service, and then we'll be taking that data and then summarizing it for spatial and temporal

variability. Monitoring multiple seasons in the Memphis area to meet a specific need of our regional collaborators and local citizen trees who we're already attempting to work with to collaborate. The AirMapper as I've said earlier is already being used in Region 5, our colleagues in Region 10 will also be receiving copies of that for their use for citizen science and air quality awareness campaigns. We'll be getting a new piece of work in Puerto Rico, where we'll be developing a sensor pod specifically for PM 2.5 and total VOCs. Again, I wish we could offer something that was specific for VOCs, we can't but there's a specific interest in one Environmental Justice community in the Puerto Rico Island, so we'll be trying to look at VOCs as some monitoring. We'll try to get summaries of those out in the next 2 years as fast as we possibly can, and we'll try to use the Air Sensors Toolbox as a portal for many things.

What have we learned from some of these studies? Here's an example of an output of our work with the CSAM involving Region 2 and a community group. I want you to focus upon that blue line right there, that blue line is the federally equivalent method that was operating at an end-core site. You can see that there is a purple line, a green line and a red line. We had 4 of these units operating simultaneously at that end-core site, and following regression analyses where we took the raw data from the sensor, the federally equivalent data and then went there and regressed those and normalized the raw data of the sensor. You can see in many instances we were able to get literally duplicated efforts between what the reference monitoring was doing and that sensor. We think that is an important feature in any of this type of work, co-location and comparison because again we've seen a lot of variability in response of these sensors, and unless you know how far away you are from that reference monitors you can literally be multi-fold or multi-orders of magnitude away from reality.

I mentioned on out-set our Village Green Project, and I wanted to touch base about that because there are so many of these stations currently operating across the US. It is data that's available to all citizens and worldwide interests in terms of a solar powered, constantly streaming data portal. We're focusing on mid-tier devices here, the 2B ozone monitor, a thermo 1500 PM 2.5 monitor. This device, when I mean this bench is out in public domain in places of high visibility, interaction with the public, totally supported by solar power, operates on about 30 watts of power – very low wattage, continuously streaming data. We certainly want to invite you if you're interested in what are the components associated with the Village Green Project. We'd love you to just Google "Village Green Project" and that will eventually get you to some of the links I've highlighted here. Some of the things we'd like you to be aware of [is] where is the closest Village Green station to your area, well we're located on the National Mall in Philadelphia, that historic mall very close to the Liberty Bell [it's] a great location. We're located in the Botanical Gardens in Oklahoma City, not too far from the Murray Building - just south of the Murray Building in Oklahoma City at a fantastic location where children and community groups and citizens come every single day to interact in a great garden setting where we can induce environmental awareness. You can see the bench blends in so well there. You may be interested in the fact that a number of schools are now involved in the Village Green partnership, here you see one placed in a school setting in Kansas City. You may be interested to know that in the National Zoo, the Smithsonian we actually have a Village Green station placed there. Other places where we have stations included Hartford Connecticut, here you see a station placed at the science museum, another great port of interaction between the public. New stations will be going into Houston by the end of this calendar year if not before, and we have a station in Chicago that was just released within the last 6 months.

[Interruption]

I do invite you to go to the Village Green website, you're going to see different ways of looking at data from across these different localities. You can understand about the technical features of the portal. I do want to invite you specifically to go to the Village Green website or the Air Sensors Toolbox, and look for indicators associated with the data messaging tool. This is what I highlighted early on in our talk today, about the fact that EPA has been able to go there and do some scientific investigation on ozone and PM 2.5 and what can we say about short-term PM 2.5 and ozone types of measurements. I want to encourage you to go to the portal, [and] it's under Beta testing we want your input on this data messaging, so please take an opportunity to go to those 2 websites and take a look-see.

On our out-set I gave you an indication of some things we wanted to share today. I think we've certainly touched upon all of these, and we'd be glad to take your questions.