EPA WORKSHOP
ON
OPTICAL REMOTE SENSING TECHNOLOGIES

Executive Summary

A Workshop on Optical Remote Sensing Technologies was held in the auditorium of the Environmental Protection Agency's (EPA) Environmental Research Center in Research Triangle Park, NC on July 31, and August 1, 2001. The Workshop was convened by John Bosch of the Emissions Monitoring and Analysis Division of EPA's Office of Air Quality Planning and Standards, and sponsored in part by ARCADIS, an environmental contractor supporting EPA's research on Optical Remote Sensing. Invited participants were technology providers, regulators, end-users and benefactors.

On the first day of the Workshop, the technology researchers/vendors provided brief discussions of the current state of the technology, as well as describing both commercially available instruments and instruments in the developmental stage prior to commercial availability. Generally, the presentations demonstrated that, while some areas continue to require further development, many ORS technologies have advanced well beyond their current level of deployment in the marketplace. In other words, from a technical standpoint, ORS technologies are capable of much broader application than that seen at present. Vendor organizations expressed frustration at their inability to move many technologies beyond the research phase into broader application in the environmental market. Significant advancements and improvements shown are in the following areas:

- Temporal and spatial resolution
- Range (distance) of measurements
- Detection levels
- Number of compounds detectable
- Plume imaging
- Cost effectiveness

A panel discussion, consisting of representatives of various organizations within EPA, convened during the afternoon session to address the direction of marketability for new technology, and its importance in the industry. Panel participants were instructed to emphasize incentives and impediments to the development and implementation of new technologies. The panel's consensus was that focusing technology development on areas of immediate concern and areas where it was possible to implement new technologies to achieve reduced costs (either for the Agency, or more importantly for the end users) provides the best opportunity for future success. Important future needs identified included improved capabilities for continuous monitoring of Hazardous Air Pollutants (for potential cap and trade approaches), as well as mercury and fine particulate matter monitoring.

A second panel discussion, consisting of representatives of prospective end users of ORS technologies, was convened to kick off the second day of the Workshop. Panel participants included staff from the Department of Defense, EPA Regions, and various state environmental compliance agencies. The presenters emphasized the need for technologies to address specific needs in order to have the best chance of success. Several presenters indicated that ORS does offer the potential to address specific needs, but expressed concerns in regards to acceptance of data by all relevant regulatory agencies.

A panel of representatives of funding organizations was convened next. The panel included staff from the EPA, NASA, and various DOD groups. Details of funding mechanisms were provided. A recurring emphasis was cooperation and cofunding between industry and regulatory agencies.

The Workshop concluded with open discussion on how to build and maintain momentum for application of ORS technologies. Approaches identified included the following:

- Increased cooperation and involvement between technology developers, regulators, and end users at the early stages of technology development
- Improved focus on specific issues of immediate concern to the regulated community as opposed to attempting to cure all ills
- Increased technology transfer through actions like additional workshops/presentations

The presence of participants in this workshop does not reflect endorsement for any kind of technology or equipment. The purpose was to bring together interested parties in the field and allow collaboration for potentially expanding remote sensing technology. The workshop represented an economical way to come together to address issues and to learn more about the most current available technologies.

SUMMARY OF TECHNICAL PAPERS (in order of presentation)

Ram A. Hashmonay, ARCADIS

Dr. Hashmonay was the chair of the technical session and the first speaker of the day. Several references on how ORS technologies have developed were presented. Reasons for the current limited applications of remote sensing technologies were discussed. Premature "as is" use, misinterpretation of the path integrated concentration data, disapproval of regulatory agencies, and the use of dispersion modeling assumptions were mentioned as a partial list of "what went wrong".

An overview of the current state of the art was given with emphasis on the technology's maturity and improved capabilities. These advances in detection levels and speed of measurement significantly increase the feasibility of using multiple beams approaches to better account for spatial and temporal variability of measured plumes. Simple multiple beam and innovative tomography approaches developed by Dr. Hashmonay and others caught the interest of the EPA as viable for directly analyzing fugitive emissions of open area sources using ORS. The ability of ORS to provide actual numbers on emissions to regulators, without applying indirect inverse modeling approaches, is a step towards overcoming some of the difficulties with ORS detailed previously.

Robert H. Kagann, EDO-AIL

Dr. Kagann discussed the use and history of Open Path Fourier Transform Infra Red Spectroscopy (OP-FTIR) for emissions characterization. A basic set-up for making OP-FTIR measurements was presented. The very high efficiency of OP-FTIR was emphasized and the advantages were enumerated as follows:

- Fast measurements – a 1 minute measurement interval provides a good instrument sensitivity along a 100 meter measurement path-length
- Remote sensing - can take measurements in inaccessible areas
- Area coverage – typical data is path-integrated concentration. Tomographic techniques, as earlier presented by Dr. Hashmonay, can provide direct measurement of fugitive emission fluxes
- Near real time - a calibration check in the field using TO16 EPA method is needed

This technology was first applied in the laboratory in the late 70's. Since its inception, the Clean Air Act Amendment has promoted more serious requirements. Availability of commercial instruments arose. The compendium TO16 Method was developed, and the Europeans followed suit in developing and promoting optical remote sensing technologies.

Harold Schiff, Unisearch Associates

Dr. Schiff represented Unisearch Associates, which manufactures all types of spectroscopic instrumentation. His presentation focused mainly on Tunable Diode Laser Systems (TDLS).

Laser wavelength depends on the crystal composition and the width of laser line is very narrow, essentially eliminating any interferences. The advantages of using an open path diode laser include:

- Telecommunications spectral range – the instrument can easily be connected with fiber optic cable and be located anywhere
- Can carry out measurements from different locations simultaneously
- System has automatic calibration

Optical sensing using TDLS gives the option of multiplexing combined with high sensitivity. This allows a fast measurement of many beams in few seconds and can apply the tomographic approaches previously discussed. Generally, one laser is utilized for each gas to be measured. However, several lasers can be combined in one unit if required. TDLS is the best way to measure one or a limited number of gases, with higher sensitivity results, quick response time and lack of interference. Several examples of open path TDLS applications along with an example of a hybrid TDLS/DOAS system for fast multiple compound measurements, were presented.

N. Scott Higdon, ITT Industries

Mr. Higdon presented a number of ITT's custom systems that are under various stages of development, including the following:

- LIDAR for detecting particulates or dust (fully developed); this eye-safe aerosol system developed for Hampton University is a powerful mapping tool
- Differential Absorption LIDAR (DIAL) for detection of gases and chemical agents over unprecedented long ranges via receiving signals from distant hard targets. Applying radial tomography will achieve large-scale plume mapping
- Raman Scattering to detect surface molecular contamination and biological agents, most applications being in support of the military
- Hg measurement using the DIAL techniques, including plume mapping

John Otten, Kestrel Corporation

Kestrel Corporation focuses on spectral imaging technology, according to Dr. Otten. The airborne applications are mostly in support of the military (surreptitious surveillance and rocket launching). Leak detection of rocket plumes during testing is very crucial to identify/pinpoint any problem prior to rocket launching, thus averting any catastrophic accidents. These FTIR-based imaging systems may be modified into a simultaneous multiple beam OP-FTIR system that can apply tomographic approaches.

Wynn L. Eberhard, Environmental Technology Laboratory, National Oceanic and Atmospheric Administration

Currently, ETL has 6 aerosol, 3 Doppler, and 2 Ozone Lidar measurement systems in place. Furthermore, ETL is involved in research areas attempting to advance Lidar technology for use in new scientific applications. Issues in air quality in the U.S. and Europe are prompting the research and development of optical methods to better measure

ammonia. ETL has developed and demonstrated NH_3 plume measurement capability with DIAL.

Ting I Wang, Optical Scientific Inc.
Dr. Wang described two path-integrated flow meters. These optical anemometers, which utilize a pair of parallel laser beams and receivers, measure the scintillation from one receiver to the next. Determining the temporal correlation between the two signals is related to the wind speed. In the long path instrument, the air velocity along a 200-900 m long path, such as in an aluminum smelter pot room roof vent, can be measured. Optical flow sensing was approved as an equivalent Method 14 technology for compliance with the USEPA MACT rules. The EPA has applied the optical anemometer technology for other environmental airflow.

The Optical Flow Sensor (OFS) measures airflow in a stack or exhaust duct. The OFS is installed at one level and measures through glass windows across the stack or duct. The data are verified by testing at the NIST Wind Tunnel. The OFS affords advantages, which the other methods do not offer, including:

- Non-intrusive, not directly exposed to the stack flow
- Path averaged measurement for more representative results
- Simple, non-angled installation which lowers cost vs. ultrasonic
- Result independent of temperature and pressure
- Direct cross-stack velocity measurement
- No moving parts, solid-state construction

Cary Secrest, EPA Office of Enforcement and Compliance Assurance
UV/DOAS is the simplest application of remote sensing, yet it can yield powerful results. From a regulatory standpoint open path can help with enforcement and lower costs. Measurement comparisons between UV/DOAS and FTIR were in agreement and demonstrate the utility of using multiple beams to promote better understanding of measured data.

Tom Reichardt, Sandia Labs
Sandia Labs is currently developing a laser-based imaging system for detection of fugitive emissions from refineries. They have also worked on topographical LIDAR. Active Laser-IR is better than conventional leak detection methods (hand-held sniffer). It allows rapid broad range area coverage for easy recognition and source location of plumes. It accelerates the leak detective process, which may decreases costs for environmental compliance.

There are currently several technologies in development. Gas can be seen regardless of temperature because active imaging is not temperature dependent unlike the passive imaging. The disadvantage of the active imaging is it needs a reflective source. Smaller portable systems are necessary. Compliance monitoring will drive future further marketability. The petroleum industry may be first in line to decrease their compliance costs.

Bob Hinnricks, Pacific Advantage Technologies
Their group is working on a gas detection spectrometer primarily applicable to underground leak testing. Infrared imaging can easily detect underground methane leaking to the atmosphere. The flow is not accurate at this time, but good results demonstrated that even low level leaks could be detected. The technique can also be applicable to the propane industry. Propane, other gases and hydrocarbon soots were identified as well. Another application of this technique is for tank leak detection. The instrument may be available by mid-2002.

David Green, Physical Sciences, Inc.
Their company has worked with the EPA/SBIR Program on a tunable diode laser. The goal is to develop a portable device that is affordable and practical. This is very useful in methane detection or any gas leak detection survey. Its sensitivity is in the ppm range. It only weighs 9 pounds and is rugged. To date, 70 devices have been delivered. Passive imaging instrument has been developed as well. The cost is about $10,000 per unit and will be available in 18 months.

Michael Calidonna, US Air Force
Lt. Calidonna discussed a project for opacity test method development. The current method for opacity test is based on EPA Method 9, which is an eyeball calibration. The EPA method is tiring, time consuming, non-reproducible and subjective. The new test method offers a better way of measuring opacity in a smoke stack. It is a digital camera-based method, involving a simple point and click operation after a 10-minute set-up. It has built-in algorithms that are tamper-proof. The results are permanent and reproducible. Litigation costs and fines, etc. can be avoided with this technology. In two to three years time, this new technology will need method validation, which will be followed by a six months certification process. The cost is approximately $5,000 per unit.

EXPERT PANEL FOR NATIONAL REGULATORY PROGRAMS AND POTENTIAL APPLICATIONS

David Mobley, Director of the Emissions, Monitoring and Analysis Division of EPA's Office of Air Quality Planning and Standards (OAQPS)
Introduced the panel and provided an overview of the subsequent discussion. The subjects were incentives and impediments encountered in balancing the need and the desire to develop and use new technologies.

Barrett Parker, Emissions Measurement Center, OAQPS
Mentioned incentives for increased measuring, such as Title V and CAM rules and maximum standards. MACT standards expansion will also drive monitoring needs. Residual risk determinations will also require ambient air toxics measurement. Many sources are apprehensive when it comes to using an advanced monitoring system for fear that the results may be used against them. There is a need for user-friendly instruments that have on-going calibration capability.

Karen Riggs, Batelle (representing EPA's ETV Program)
Focused on the EPA's Environmental Technology Verification (ETV) program. There are about 100 stakeholders of which there are no vendors. The stakeholders advise ETV on how to run the program, what monitoring technology is needed, and which of the technologies are important to be verified. ETV's focus is primarily on field technology. Of importance are mercury contaminants emissions monitoring, multi-metal monitoring and open path systems. ETV is involved in the technology verification but not in technology approval.

Tom Pace, Emission Factor and Inventory Groups, OAQPS
Emission inventories are the fundamental building blocks for doing air quality management. It is impossible to measure everywhere, so some sources are measured and emission factors developed. Open path technologies will be helpful in monitoring emissions from open sources, fugitive dusts, ammonia, all kinds of fires and mobile sources for pollutants. The incentive is to get better information, which with more accurate planning will help avoid repetition that costs time and money.

Cary Secrest, EPA/OECA
EPA faces an impediment to using ORS technology in that there are only minimal funding resources set aside and even less time is available. Legal issues may impede industry from utilizing ORS technologies.

Dan Powell, Technology Innovation Office, EPA's Office of Solid Waste and Emergency Response (EPA/OSW)
While admittedly focusing on cleanup of water and soil, Mr Powell indicated that there should be incentives for employing new technologies and dealings with some of the impediments in trying to develop more defensible data/information. Performance-based measurements could be included in site assessment and site activity.

Barry Lesnik, Economics, Methods and Risk Analysis Division, EPA/OSW
He stressed that EPA SW846 methodologies were not reference methods and could be modified to fit specific applications

J. D. Bachmann, Senior Science Advisor, EPA/OAQPS
He introduced the idea that ORS technologies could play a role in enabling the development of a "cap and trade" approach for air toxics similar to the one that has been successfully employed in the Acid Rain Program. Continuous monitoring methods are the cornerstone for such a program and ORS offers a unique approach. He was very interested in the concept of facility-wide measurements.

END-USER PERSPECTIVES

Rochelle Williams, U. S. Army Forces Command, Atlanta, GA
There is a need for a defensible data for DOD to demonstrate compliance during training activities. It must be done right and scientifically. The U. S. Army does a lot of testing for emission characterization from munitions and artillery and there are limited in what they can adequately measure. At this time, they are unable to characterize a 3-dimensional plume effectively. This 3-D mapping could help in dispersion models for risk assessment based on these air emissions.

Additional needs for characterization include fog oils and other obscurants which have been perceived as potentially hazardous by some state environmental organizations. She added that whatever technologies are developed, it is important that they be "idiot proof" to allow them to be used by enlisted personnel with a minimum of training.

Dennis Goodenow, California Air Resources Board
CARB routinely does two types of air monitoring as follows:

- ambient air quality monitoring (ongoing projects)
- special purpose air quality

He felt that ORS could be an important tool for the latter. CARB is concerned about monitoring impacts to high-risk populations (e.g., schools, hospitals, etc.). Some current areas of concern that may offer applications for ORS include:

- children's emissions initiative – monitoring emissions in homes and playground, etc. to check what chemicals are the children exposed to.
- Pesticide monitoring
- Toxics' control identification – there are 188 HAPS that need to be identified
- Controlled burns in military bases
- Emergency response (toxic spills, tire fires)

Van Shrieves, EPA Regional Office IV, Atlanta, GA
Region IV currently has two DOAS instruments in use for monitoring and they have conducted some special studies. He would like to see additional information exchange to better spread the word about ORS capabilities.

Rick Taylor, Missouri State Environmental Protection Agency
He has successfully applied ORS methods and believes they word well when applied correctly. In 1995, Missouri was able to identify only 6 analytes with the OP-FTIR. This number has greatly increased to 76 identified compounds with the current technology. ORS methods have been or will be applied at sites such as swine farms, landfills, and wastewater treatment plants. Multiple optical measurements (tomography) are non-biased and offer temporal resolution, providing a huge advantage over conventional, "grab" sampling methods such as SUMMA canisters. Furthermore, computerized samples are non-degradable and therefore have better sample integrity.

ACTIONS NEEDED TO CREATE AND SUSTAIN MOMENTUM

Bill Vaughn, Chairman of the AWMA Division on Remote Sensing
AWMA's mission is to assist in professional development and critical environmental decision making to benefit society. AWMA's purpose is to enhance knowledge and provide quality information on which to base environmental decisions. The technologies can provide real time data on multiple pollutants to inform regulators and the public.

Jim Gallup – EPA manager of Small Business Innovative Research (SBIR) programs
SBIR funding is available to companies with less than 500 employees. There is a 1 in 10 approval. There are two phases in the funding program as follows:

- Phase I - $70,000 grant money for six months to prove the feasibility of the technology
- B) Phase II – can be as much as $750,000. Open to competition among companies

The program does a lot of SBIR National Meetings across the country where companies will listen to what is being offered at all agencies. Most of the proposals seen in the measurement or monitoring areas are from companies that have worked with Department of Defense and National Aeronautic Space Administration.

Bob Holst, DOD Manager for SERDP/ESCTP involving environmental compliance projects
This is a 3-Agency partnership (DOD-DOE-EPA). DOD solicitations include basic and applied research/advanced development (SERDP) and demonstration/validation (ESCTP).

Four thrust areas in SERDP include:

- clean-up – cleaning up of unexploded materials
- conservation – to locate endangered species, maintenance and restoration
- compliance area – ensuring that DOD activities meet environmental standards
- HAPS substitution

Fine PM and dust are considered to be major issues looming on the compliance horizon.

Bill Grant, Lidar Applications Group, NASA Langley Research
NASA has interest in the global troposphere and stratosphere. They are mainly interested in the chemistry and dynamics of the radiation budget of the atmosphere. Global airborne measurements characterize background atmosphere at different parts of the world. Asian emissions are being checked out due to increasing concerns. Sea transport is fairly efficient in this part of the world. NASA has no need for further remote sensing, but this is an opportunity for coordination with other EPA groups, NOAA type programs in the US.

NASA is interested in technology/instrument capable of hydrazine detection at the ppb level. At this time, it is very difficult to detect hydrazine leaks from containers at the Cape. Detection of hydrogen leaks from shuttle engines is also of interest to NASA.

Larry Jones – Chief, EPA/ORD/NRMRL/APPCD Emissions Characterization and Prevention Branch

He gave an overview of what his branch does and the technology used. They have used OP-FTIR in radial tomography configuration as earlier presented by Dr. Hashmonay, to measure emission fluxes from animal waste operations (swine regulations and looking into poultry as well).

Susan Thornloe – Scientist, EPA/ORD/NRMRL/APPCD Atmospheric Protection Branch

ORD is looking for better methods for emissions measurements. Joint ventures with industry are highly recommended due to funding restraints. One ongoing project involves a new type of landfill technology. Bioreactors enhance decomposition processes within landfills and produce landfill gas at faster rates, making energy recovery from landfills more cost effective. Increased fugitive emissions are of concern. Applications of the new tomographic approaches are under consideration to address the issue. Other pollutants like mercury should be better understood to determine whether they are an issue for human or ecosystem health. The status of current knowledge is outdated. Partnership with industry is the best way to move forward

Michael Calidonna – Project Manager, USAF Research Laboratory, Tyndall AFB, FL

The USAF has worked on numerous occasions with other governmental organizations. NASA has provided some seed money, and USAF has coordinated partnerships with DOD and EPA. One difficulty discussed was the issues related to getting buy in for technologies from federal and state regulators. This can cost the vendor a lot of invested time. One successful approach involves getting together with regulators in advance to discuss potential issues. Funding for development is available through numerous different channels. Lt. Calidonna expressed his concern that EPA's perceived convoluted chain of command often slows approval processes. It is important for vendors to understand the DOD needs, and to routinely follow up with contacts in order to address the issues. One particular need he expressed involved sensing biochemical and biological hazards to prevent military casualties.