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E-SMART SYSTEM FOR IN-SITU DETECTION OF ENVIRONMENTAL CONTAMINANTS

QUARTERLY TECHNICAL PROGRESS REPORT

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Idaho Operations Office
Idaho Falls, Idaho**

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**GENERAL ATOMICS PROJECT 3719/4450
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Abstract

General Atomics (GA) leads a team of industrial, academic, and government organizations in the development of the Environmental Systems Management, Analysis and Reporting neTwork (E-SMART) for the Defense Advanced Research Project Agency (DARPA), by way of this Technology Reinvestment Project (TRP). E-SMART defines a standard by which networks of smart sensing, sampling, and control devices can interoperate. E-SMART is intended to be an open standard, available to any equipment manufacturer. The user will be provided a standard platform on which a site-specific monitoring plan can be implemented using sensors and actuators from various manufacturers and upgraded as new monitoring devices become commercially available. GA's team members include Isco, Inc., Photonic Sensor Systems (PSS), Georgia Tech Research Institute (GTRI), Science & Engineering Analysis Corporation (SECOR), Biode, Inc (Biode), Rapid Clip Neural Systems, Inc. (RCNS) and the U.S. Air Force Armstrong Laboratory Environics Directorate at Tyndall AFB(AL).

This DARPA TRP project will further develop and advance the E-SMART standardized network protocol to include new sensors, sampling systems, and graphical user interfaces. Specifically, the E-SMART team will develop the following three system elements:

A new class of smart, highly sensitive, chemically-specific, in-situ, multichannel microsensors utilizing integrated optical interferometry technology,

A set of additional E-SMART-compatible sensors and samplers adapted from commercial off-the-shelf technologies, and

A Data Management and Analysis System (DMAS), including network management components and a user-friendly graphical user interface (GUI) for data evaluation and visualization.

In addition, the E-SMART TRP team has signed Articles of Collaboration with another DARPA TRP awardee, Sawtek, to develop an E-SMART-compatible Intelligent Modular Array System (IMAS) for monitoring volatile organic chemicals (VOC's) in the environment. This collaboration will simplify the network development required to field the IMAS sensor, and will encourage the adoption of the E-SMART standard by increasing the number of commercially available E-SMART sensors. The Sawtek team now also includes Perkin-Elmer.

Figure 1 summarizes the vision and goals of the E-SMART TRP project.

E-SMART DARPA TRP

TEAM

General Atomics
Isco, Inc.
Photonic Sensor Systems, Inc.
Georgia Tech Research Institute
SECOR
EnviroNics Directorate, Tyndall AFB

VISION

OBJECTIVES

Develop and promote E-SMART, an open standard for networking smart sensors at environmental sites. Prepare an initial set of E-SMART-compatible devices, including:

- A new class of smart, in situ, chemically-specific multichannel microsensors utilizing integrated optical interferometry technology.
- Sensors and field measurement equipment, based upon commercial off-the-shelf technology, and adapted for E-SMART networks.
- A data management and analysis system (DMAS), including a graphical user interface for data evaluation, data visualization, and network management.

SCHEDULE

ID	Task Name	1996				1997				1998			
		Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1
1	100 DEVELOPMENT												
2	100.100 Microsensors												
3	100.200 E-SMART Integration												
4	100.300 Visualization												
5	200 FIELD TESTING												
6	Preliminary Testing												
7	Integrated Testing												
8	300 PROJ MGMT												

Fig. 1. Quad Chart Summarizing the E-SMART Project

Executive Summary

Program Management

- The PSS/GTRI subcontract was ammended to reflect last year's restructuring of the TRP and to add Rapid Clip Neural Systems to the team.
- An additional subcontractor, Rapid Clip Neural Systems (RCNS) was brought on the TRP project by PSS to aid in development of pattern recognition embedded software.
- Biode, Inc. was added to the project to develop an E-SMART-compatible mercury sensor.

Multichannel Microsensor

- A design review was held in Atlanta to review the overall microsensor head design.
- The chemistry design for the aqueous BTEX sensing was finalized and experimentally verified.
- Selection of the specific BTEX-sensitive polymers for the microsensor is nearing completion.
- An invention regarding sensor protective techniques was made and experimentally verified. Under this method a coating was able to withstand immersion in neat benzene for over an hour without changing its response.
- Rapid Clip Neural Systems was added to the team and began its task of analyzing calibration data for the microsensor.
- Final testing of a cone penetrometer model of the E-SMART microsensor was extremely encouraging.

Sawtek Integrated Modular Array Sensor (IMAS)

- Sawtek plans to work on the E-SMART interface during the first half of 1997.

Other Sensors and Actuators

- A pH sensor was added to the field demonstration site
- Biode, Inc joined the team and is developing an E-SMART mercury sensor
- An improved E-SMART sensor housing is under development to transition the original proof-of-concept design to a commercial version. The improved E-SMART sensor housing design is incorporating lessons learned from laboratory and field testing.

E-SMART Network Management

- A number of emerging technologies are being developed for dynamically linking databases to internet web servers. A web server interface will allow the E-SMART network management program to be controlled remotely by a site owner or representative.
- An internet link was established to the field test site at Tinker AFB

E-SMART Field Testing

- Analysis of data being collected by the E-SMART network is continuing. The sample rate for data collection has been varied by downloading instructions from the E-SMART data management PC to the individual sensors. Each of the E-SMART sensors at the SWTA has taken measurements every 15 minutes nearly continuously since the Phase II installation was completed in late October.

Dual Use and Commercialization

- Armstrong Laboratory is exploring expansion of E-SMART installations and demo sites

1. Work Conducted January - March, 1997

1.1 Multichannel Microsensor (PSS/GTRI)

WBS 100.110 - Develop Requirements and Design Configuration

PSS, GTRI and Isco personnel held an E-SMART microsensor head design review in Atlanta, GA on March 17th and 18th. It is expected that the microsensor head design will be finalized at a follow-on meeting in Atlanta scheduled for May 13th.

WBS 100.120 — Develop Coatings & ID INTERFERANTS

The chemistry design for aqueous BTEX sensing was finalized and experimentally verified. The design incorporates several inventions, and detailed invention disclosures are being prepared for submission to the Dept. of Energy in accordance with contract provisions. Utilizing these inventions, a series of polymer constructs were tailored to give widely varying responses for both the individual BTEX species and the list of standard interferants previously developed by the E-SMART team. Typical results are illustrated in Figure 2, which shows the responses for exposure of three constructs to five different chemical species (benzene, toluene, TCE, chloroform and methylene chloride). The poly(trifluoroethyl acrylate) construct gives positive responses for all five analytes. Conversely, the poly(benzyl acrylate-hexyl methacrylate) construct gives negative responses for all five analytes. The poly (hexyl methacrylate) construct gives positive responses for the two BTEX species and negative responses for the three chlorinated solvents. In addition to this broad class discrimination, detailed pattern differences can be seen for each of the individual analytes. Finally, the polymer constructs all showed minimal or no response to anything other than the BTEX species and chlorinated solvents. Selection of the specific BTEX-sensitive polymer constructs to be used for the E-SMART microsensor will be made over the next three months in conjunction with the development of pattern recognition software (see WBS 100.150).

WBS 100.130 — Design and Develop Glass Waveguides

Analysis of an alternate E-SMART microsensor integrated optic sensing chip design was completed. While the analysis confirmed that the alternate design is feasible and provides several advantages over the baseline design reported last quarter, it was determined that implementation of the alternate is beyond the scope of this project, and a final decision was made to utilize the previously reported baseline design.

Testing was begun on an alternate manufacturing process for the Fresnel beam splitter/combiner in the baseline integrated optic sensing chip design. The default approach use a relatively unforgiving etch process to create the splitter/combiner (i.e.; minor differences in etch conditions or differences in etch times of as little as five seconds can result in functional vs. non-functional elements). The alternate design relies on a relatively forgiving deposition process. If successful, the alternate manufacturing process should significantly improve the yield in fabrication of the prototype microsensors.

Fig. 2. Response of three polymer constructs to five different chemical species (benzene, toluene, TCE, chloroform, and methylene chloride).

In addition, as reported last quarter, an electron-beam, ion-assisted vacuum deposition system installed at GTRI in July is being used to produce tantalum pentoxide (Ta_2O_5) and silicon dioxide (SiO_2) thin films. These films offer the possibility of higher quality waveguiding and protective layers for the integrated optic sensing chip in the E-SMART microsensor. The superior durability of these electron-beam deposited films was demonstrated by exposing them to an extreme base solution (pH 14) for four hours, with no sign of damage. By contrast, exposing a silicon nitride (Si_3N_4)/silicon dioxide (SiO_2) film combination deposited using a traditional plasma-enhanced chemical vapor deposition (PECVD) process to the same extreme base solution resulted in 0.14 μm of material being etched away in four hours.

WBS 100.135 — Develop Sensor Protective Techniques

A method for protecting the BTEX-selective polymer sensing chemistries from environmental attack was developed and experimentally demonstrated. The method involves an invention, and a detailed invention disclosure is being prepared for submission to the Dept. of Energy in accordance with contract provisions. Utilizing this method, a typical polymer sensing construct was able to withstand immersion in neat benzene for at least one hour, and the response to aqueous benzene and methylene chloride before and after immersion was unchanged. In addition, the method provides a low-surface-energy environmental interface that is resistant to grease or other waste accumulation, yet is highly permeable to small organic molecules.

Work was begun on developing a method for patterning the BTEX-selective polymer sensing chemistries on the E-SMART microsensor integrated optic detector. It is currently envisioned that there will be six different polymer constructs arrayed in 381 μm wide strips, with 190.5 μm wide gaps between the strips. Three coating techniques are being considered at present: 1) photolithographic definition of low-surface-energy channels inside high-surface-energy boundaries (into which individual polymers can be wicked), 2) use of ink-jet printer technology, and 3) construction of a multichannel flow cell arrangement. Development of a practical polymer patterning technique will be the focus of this task during the coming quarter.

WBS 100.150 — Design Microsensor Electronics & Packaging

Rapid Clip Neural Systems (RCNS) of Atlanta, GA was awarded a \$75K contract in January to develop pattern recognition software for the E-SMART microsensor, and GTRI and RCNS began collecting and analyzing the calibration data to be used by RCNS.

PSS, GTRI, Isco and RCNS personnel met in Atlanta, GA on February 17th and 18th to flesh out a definitive specification for the E-SMART microsensor controller. This same group plus General Atomics personnel are tentatively scheduled to meet in Atlanta, GA on May 13th for a controller design review.

WBS 100.170 — Build & Test Prelim. Microsensor Model

Final testing of a cone penetrometer model of the E-SMART microsensor built under a companion Small Business Technology Transfer (STTR) program was extremely encouraging. As previously reported, the model uses a four-channel integrated optic sensing chip substantially identical in design to the thirteen-channel sensing chip to be used

for the final E-SMART microsensor and a preliminary BTEX-sensitive polymer sensing chemistry. When buried in a bench-scale soil chamber containing saturated Ottawa sand, the model showed a large, reversible response to contamination of the chamber with ≤ 100 ppm of benzene but no response to contamination of the chamber with $\geq 10,000$ ppm of acetone (which was used as a control).

WBS 100.191 — Microsensor Support (Isco)

Worked with TSL401 sensor array and preliminary laser diode driver design for the microsensor. Studied Hitachi H8/300 processor specifications. Attended LonWorks seminar in Overland Park, KS on Jan. 28, 1997. Held a mechanical review of the microsensor optical design.

Reviewed and approved the Isco Engineering TRP Plan. Reviewed GTRI progress on the microsensor probe. Discussed with GTRI the present optical bench design and ways to make it smaller and easier to assemble/calibrate. Also discussed mechanical parameters that might affect probe stability. Optical bench parts were entered into Pro-E (CAD) to better determine probe housing shape and size. Studied the E-SMART Node Specification and the E-SMART code for a previous probe, converter box and PC as a reference for implementing TRP E-SMART code.

WBS 300.100 — Program Control & Reporting

Two modifications to the PSS/GTRI TRP subcontract were implemented in January. The first modification (adding \$705K) reflected the project-wide restructuring agreed to in early 1996. The second modification (adding \$154K) added responsibility for development of pattern recognition software (see WBS 100.150). Corresponding amendments were made in the contract between PSS and GTRI. Revised monthly expenditure reporting formats were adapted.

1.2 Sawtek Integrated Modular Array Sensor (IMAS)

Sawtek has asked for input from GA on E-SMART SDP form factors and description. That input is being prepared and will be sent to them.

1.3 Other Sensors and Actuators (GA, Biode)

WBS 100.200 — E-SMART Integration

A pH glass electrode sensor was added to the E-SMART field demo site in March. This electrode was connected to the network via a dedicated 100 foot cable which ran from Monitoring Well 1-098 to a standard pH sensor signal conditioner inside the E-SMART trailer. A long cable was chosen to reduce the chance that a bad connector or interim connection would interfere with the low-level signal for the sensors. The signal conditioner current output was connected to a modified PSI/SDP board to form an E-SMART node within the trailer.

Several lessons were learned during installation of the glass electrode and its long cable which tended to validate the modular design of E-SMART sensors. For instance, the BNC connector at the far end of the cable had to be cut off and a new connector attached in order to snake the cable from the well through various pvc pipes, fittings, and holes to get from the well into the trailer. The labor required to manipulate the sensor was substantially higher than for the other E-SMART sensors since raising and lowering the sensor into the groundwater could not be easily accomplished without manipulating 40 feet of cable.

An additional problem arose after the sensor was calibrated and lowered into the ground. The E-SMART node reading changed substantially (several pH units). It was found, after some diagnostic work, that a ground loop (anomalous current path) was created between the pH sensor and other E-SMART nodes when the pH sensor contacted the groundwater. An isolation circuit is being developed for the E-SMART node to fix this problem. This node will be reinstalled next quarter. Meanwhile, the electrode will be evaluated for problems due to submersion in the SWTA groundwater. It was noted that about 2 inches of a light green free product were seen in bailed water from the well where the sensor was installed (MW 1-098). However, no immediate impact was seen on the pH electrode after recalibration.

Work continued on improving the E-SMART sensor housing. The new sensor housing design will transition the original prototype design to a manufacturable version. A major improvement is the elimination of the potting process for sensor components, which will make E-SMART sensor fabrication quicker and easier. Another improvement realized by the new design will allow transducers to be more easily interchanged.

Biode continued design efforts on their microcontroller and ASIC electronics for their SHAPM and STW transducers. The control ASIC will monitor the frequencies of up to four piezoelectric transducers. BIODÉ is performing a review of current electrochemical techniques and is planning a second ASIC for the control of up to four electrochemical cells. This ASIC would be functionally similar to the frequency control ASIC with respect to its computer interface.

BIODE has been evaluating sensor-specific circuitry for the shear wave transducer, as well as performing specific research into improving the shear-wave sensor technology. Low power oscillators have been tested with per oscillator current draw of only 5 to 10 mA dependent on the specific transducer.

Biode is performing a review of current electrochemical techniques and is planning a second ASIC for the control of up to four electrochemical cells. This ASIC would be functionally similar to the frequency control ASIC with respect to its computer interface. This second chip would provide the full functionality of an industrial grade potentiostat and could replace such instrumentation in commercially-relevant "throw-away" applications within the nuclear industry. Biode will prepare performance specifications and implementation budgets next quarter.

The quartz Shear Horizontal Acoustic Plate Mode (SHAPM) transducer effort is yielding stable baseline frequency. Sensor tests are being performed. Quartz Surface Transverse Wave STW prototypes are nearly complete. Sensor tests have been performed and provided extremely anomalous responses to electrochemical excitation in the presence of mercury. Quartz STW prototypes have been received; however, the pulse-DC sputtered film provided undesirable acoustic properties at 1 micron film thickness. Thinner film devices are being measured.

1.4 E-SMART Network Management (GA)

WBS 100.230 — E-SMART Network Management

E-SMART network management software provides the ability to talk to nodes and to display data. The development of algorithms for characterizing each individual sensor for influence of temperature, pressure, and other environmental effects continued.

Problems experienced with the database from the Tinker Field Test were looked at by Sybase, however no cause for the problem was identified. The most likely cause appears to be associated with breaking ODBC links unexpectedly for instance during a Windows 95 crash. In this case the database rolls back all uncommitted data. However, the program was set to autocommit data which should have minimized this effect to perhaps a few data points. The data was recovered following a procedure recommended by Sybase. The E-SMART staff is continuing to investigate what caused the problems.

Development of the E-SMART graphical user interface (GUI) continued. Resources required to investigate the database problem and delays in receiving the production version of the Echelon Network Management software, problems with the c++ development system, and major revisions in the structure of this software delayed the evolution of the E-SMART network management program. It is now expected that the next revision will not be ready until June.

A number of emerging technologies are being developed for dynamically linking databases to internet web servers. This is the intended approach for providing remote access for E-SMART data. In addition a web server interface will allow the E-SMART network management program to be controlled remotely by a site owner or representative. Several software packages and systems are being evaluated for use in E-SMART. The internet connection established to the field site in December continued to prove useful for controlling the E-SMART network and transferring data.

1.5 Field Testing (GA, SECOR)

WBS 200 — E-SMART Field Testing

The Tinker AFB field test is sponsored in part by the Air Force Air Logistic Command in Oklahoma City, Oklahoma (OC-ALC) under contract number F34601-95-D-0374, Task Order 14, SDRL A025. The goal of the testing is to deploy an E-SMART network in the Southwest Tank Area (SWTA) site, to evaluate system performance, and to identify opportunities for system improvements. The E-SMART network has a graphical user interface tailored to the SWTA site and allows OC-ALC Environmental Management & Restoration (EMR) Division personnel remote access to data from the site.

Last quarter, the Phase II installation at the SWTA was completed. This brought the total number of installed sensors to 22. Thirteen new sensors were installed and nine existing (Phase I) sensors were removed from monitoring wells, upgraded, and reinstalled.

During the quarter, five sensors were removed for additional testing and inspection and 1 (pH) was added. The remaining sensors, which measure pH, free oxygen, hydrocarbon vapor, water level, and barometric pressure, were installed in six monitoring wells. The barometric pressure sensor will be used to correct the readings from the water level sensor (which is based upon readings from a pressure transducer) to local atmospheric conditions. The installed sensors are listed in Table 1.

The DMAS network management software utilizes an SQL database to retain data and implements a more flexible interface for installing and communicating with nodes on the network. The previous software package was limited to 12 nodes. The current software approach will be able to handle hundreds or thousands of nodes. The network management software will eventually be enhanced to include such features as data presentation, periodic backups, web access, and additional E-SMART functionality.

Analysis of the data being collected by the E-SMART network continued. The sample rate for data collection has been varied by downloading instructions from the E-SMART data management PC to the individual sensors. Initially, data was being collected at one measurement per minute, which for 22 sensors yields 31,680 measurements per day. The ability to sample at this rate will be useful for applications such as slug testing of wells, and in situ calibration of sensors, but is not necessary for ground water monitoring. Each of the E-SMART sensors at the SWTA has taken measurements every 15 minutes nearly continuously since the Phase II installation was completed in late October.

A major issue concerned the ability of PC-based tools to handle datasets with greater than 100 MB of data. Several database systems were investigated and custom programing efforts were examined in the effort to deal with this amount of data.

Table 1. Phase II Installation of E-SMART Sensors		
Monitoring Well	Sensors	Depth (ft)
MW I-99	B013	9.8
	P014	30.01
	P015	30.17
	P10	33.31
MW I-116	B012	9.96
	P009	29.98
	P030	31.69
MW I-123	O2003	9.74
	VOC001	9.74
	B027	11.48
	P026	30.59
MW I-119	O2005	9.75
	VOC004	9.75
	B025	11.63
	P028	30.61
MW I-109	O2001	9.81
	B021	11.52
	P024	33.8
	P029	35.45
MW I-98	PH01	23

The E-SMART demonstration employed pressure and gas sensors for simple measurements at Tinker AFB. The pressure sensors recorded changes in liquid level in several monitoring well, taking measurements four times per hour. The gas sensors measured oxygen concentrations and relative VOC levels; the hydrocarbon sensor was not specific. The DMAS logged over 7,000 samples and temperatures from each sensor for the period 27 October, 1996 to 27 January, 1997.

Liquid level measurements use one pressure sensor in the headspace to get barometric readings, while another pressure sensor underwater records the combination of liquid head and barometric pressure. Figure 3 shows corrected measurements from five barometer nodes with good agreement on air pressure. Figure 4 shows the liquid level above pressure sensor[30] during this four month period. The liquid level remains fairly constant through this period, with small changes that correlate with the weather. The water level dropped a few inches when a high pressure system moved into Oklahoma City, and rose again when the barometer fell. Since pressure[30] was installed at a depth of 31.7 feet, the water table lies about 22 feet below the wellhead.

The gas sensors monitored the headspace in several wells. Figure 5 shows the oxygen concentrations measured by oxygen[1]. The typical oxygen concentration for fresh air is 21% by dry volume, equivalent to the maximum value observed. The lower concentrations come from some source of stale air, presumably lower from biologic activity. Since the oxygen values go up and down the same as the barometric pressure, the changes represent "barometric pumping", where rising barometric pressure forces fresh air into the well, and falling barometric pressure draws vadose air from the soil surrounding the well. Two oxygen sensors in different wells showed even lower oxygen values, perhaps the result of higher activity.

Figure 6 shows more detail on barometric pumping, covering one week in November. The oxygen levels start to fall shortly after the barometer goes down. The hydrocarbon levels become significant after the barometer falls below 29.9 in. Hg, the mean value. After midnight on the 17th the barometer rises and fresh air pushes out the stale. This cycle repeated twenty times over the four month period. Note that the hydrocarbon value gets big for a short time; the peak width is less than six hours. Even daily sampling could miss the maximum concentration! The peak concentration extrapolates to the equivalent of 500,000 ppm ethane. Since this sensor is twenty to fifty times more sensitive to BTEX (benzene, toluene, ethylbenzene, and xylenes), the VOC's could still be more than 10,000 ppm BTEX. Although these metal-oxide semiconductor (MOS) sensors also respond to small oxygen levels, this particular MOS showed very small response to a 10% oxygen calibration mixture, so the hydrocarbon levels are significant.

Five barometric sensors in Tinker AFB demo

Figure 3. Five barometric sensors agree about the weather. The barometric sensors serve as references for the liquid level measurements.

Liquid level sensor [30] in MW 1-116

Figure 4. The liquid level sensors change with the weather even after correction for barometric pressure. The water stays fairly constant, 22 feet below the wellhead, but changes slightly when high pressure pushes water out of the well.

Oxygen sensor [1] in MW 1-109

Figure 5. The oxygen sensor varies as barometric pumping changes the source of air in the well. The air temperature drops in the wintertime.

Tinker AFB SWTA MW 1-123

Figure 6. During one week at the site, falling barometric pressure draws vadose air into the well, while rising pressure eventually introduces fresh air.

1.6 Visualization

WBS 100.300 — E-SMART Visualization

SigmaPlot software was acquired from Jandel Scientific for use in charting E-SMART data for detailed analysis. The utility and ease of use of this software was investigated for subsequent incorporation into the E-SMART Data Management and Analysis System (DMAS). One of the advantages of SigmaPlot is its ability to quickly manipulate and plot large quantities of data. However it has been found that it does not handle time-date values and large data sets as well as had been hoped. Therefore alternatives will be investigated.

1.7 Program Management (GA)

WBS 300.100 — E-SMART Program Management

Two modifications of the PSS/GTRI TRP subcontract were made in January. The first implemented the project restructuring agreed to last year by adding \$705k to the PSS subcontract. A second amendment added responsibility for pattern recognition to PSS and its subcontractor Rapid Clip Neural Systems. This amendment added \$154k to the PSS subcontract. A \$4k modification was also made to Isco's subcontract as agreed by GA, PSS, Isco, and RCNS. Biode, Inc. was given a \$20k subcontract and will contribute \$300k of cost share to the team to produce an E-SMART compatible version of their mercury sensor.

1.8 Dual Use and Commercialization (GA, Armstrong Lab)

WBS 300.200 — Dual Use and Commercialization

Armstrong Lab has identified several potential E-SMART demonstration sites in addition to Tinker AFB. Candidate sites are Port Hueneme, CA (USN), the Puget Sound Naval Shipyard (USN), and the Groundwater Restoration Field Laboratory (GRFL), Dover AFB, NJ. They have also arranged an E-SMART briefing at Brooks AFB in April for the Air Force Center for Environmental Excellence (AFCEE) and the Armstrong Laboratory Occupational Health and Safety Group.

2. Problems

Isco has had internal problems generating required monthly expense reports and SF270 invoices. They have advised us that these problems should be resolved by the end of April.

3. Plans for the Next Quarter

Update E-SMART Node Specification based on October 1996 and subsequent comments.

Optimization of pattern recognition and improvements to waveguide quality and fabrication techniques for microsensors will continue.

Microsensor coating chemistry development will continue, focusing on screening of BTEX-selective polymer coating materials.

Advances in E-SMART network management, data management, and visualization will continue, including continuation of system upgrades.

Biode will continue work mercury sensor development.

Support for SAWTEK will be increased.

The Tinker AFB field test will continue.

4. Milestones and Deliverables

E-SMART System for In-situ Detection of Environmental Contaminants - Quarterly Technical Progress Report, Quarter 4, Calendar Year 1996 - completed and delivered per contract requirements.

Financial Status Report-Standard Form 269A, Reporting Period 10/1/96-12/31/96 - completed and delivered per contract requirements.

5. Papers and Conferences

Steve Leffler attended the EPA Field Methods Conference in Las Vegas in January.

6. Financial Status Report

Per contractual direction, DOE form SF-269A, "Financial Status Report", has been completed by GA for this quarter and has been distributed to the following individuals at DOE-Idaho:

- Patrick Trudel, Program Manager
- Chief Financial Officer, Financial Management Division
- Rebecca Rich, Accounting, Financial Management Division
- Wade Hillebrant, Contract Specialist

7. Distribution List

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