*Stephen Billets[1] and Amy Dindal[2]*

# History and Accomplishments of the U.S. Environmental Protection Agency's Superfund Innovative Technology Evaluation (SITE) Monitoring and Measurement Technology (MMT) Program*

**ABSTRACT:** This manuscript presents a detailed narrative of the history, accomplishments, and evolution of the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Monitoring and Measurement Technology (MMT) Verification Program. This includes a discussion of how fundamental concepts of a performance testing/verification program were developed in response to the 1986 Congressional legislation that was enacted to bring together technology developers, users, and EPA's credibility in a national testing program. One impetus for the program was the technology developers' need for a cost effective and technically credible program for showcasing the performance of their technologies to EPA regions, other federal agencies, and other clients. The SITE Program was EPA's first technology verification program and it has served as a model for subsequent evaluation programs. The performance characteristics of 70 technologies have been verified by the SITE MMT Program. A survey of developers that have participated in the program indicated their overall satisfaction and a summary of their observations is presented. The outcome of the program and its legacy represents an important contribution to the EPA Superfund Program and the use of field analytical technologies.

**KEYWORDS:** U.S. EPA, SITE Program, monitoring technologies, technology evaluation

## Introduction and Program Background

The U.S. Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, in 1980 [1]. The creation of this law provided broad federal authority to respond directly to releases or threatened releases of hazardous substances that might endanger public health or the environment. The 1986 Superfund Amendments and Reauthorization Act (SARA) amendments to CERCLA provided legislation which mandated that the U.S. Environmental Protection Agency (EPA), through its Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD), create the Superfund Innovative Technology Evaluation (SITE) Program. Among other activities, SARA called for an "Alternative or Innovative Treatment Technology Research and Demonstration Program" (U.S. Code 2004). This demonstration program was to include technologies that permanently altered the composition of hazardous waste through chemical, biological, and physical processes, as well as technologies that characterized and assessed the extent of contamination. Prior to enactment, the draft legislative language focused only on remediation, but the pressing need to test field analytical measurement technologies prompted the EPA to recommend the expansion of this legislation to include monitoring, which led to the formation of the Monitoring and Measurement Technology (MMT) arm of the SITE Program. This legislation was also intended to assist technology developers and users who believed that an EPA testing program was needed to accelerate the acceptance and use of new technologies that were coming into the commercial market as possible alternatives to traditional laboratory methods. These field technologies were not intended to replace conventional laboratory-based methods, but rather to act as alternative, complimentary techniques. The partnership between field measurement technologies and on-site remediation activities was expected to reduce overall clean-up costs and provide timely characterization data that allowed better decision-making regarding the removal of contamination.

Technical staff in EPA's ORD National Exposure Research Laboratory, at the Environmental Sciences Division facility in Las Vegas, NV, has managed the MMT Program since its inception. The early years of the program (1986–1992) focused solely on EPA ORD-sponsored projects, by evaluating the performance of field monitoring technologies that were developed as part of ORD contracts or cooperative agreements. Reports were produced for internal use only based on developer-directed technology evaluations. These demonstrations were viewed as an extension of the research and provided an opportunity for additional testing of the monitoring device. A list of the demonstrations conducted during this timeframe is provided in Table 1.

During the 1986–1992 timeframe, the MMT Program Manager was gathering information about how to better execute and expand the program. A number of important outcomes emerged from this effort. The most significant finding was that the program could provide more value if it was applied broadly across other EPA pro-

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[1]Chemist, U.S. Environmental Protection Agency, 944 E. Harmon Avenue, Las Vegas, NV 89119.

[2]Project Manager, Battelle, 505 King Avenue, Columbus, OH 43201.

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TABLE 1—*SITE MMT Program Technology categories and significant program enhancements.*

| Report Publication Year | Technology Category | Developers | Significant Program Enhancements |
|---|---|---|---|
| 1987–1992 | Pentachlorophenol Immunoassays<br>Benzene-toluene-xylene Immunoassays<br>Long-path Infrared Spectrometry Mobile Mass Spectrometer<br>Portable Gas Chromatographs<br>Ion Mobility Spectrometers<br>Sorbent Tubes<br>Bioaerosol Samplers<br>Electromagnetic Geophysical Equipment | Not available[a] | Established direction and goals for the program. |
| 1993 | Field Portable Gas Chromatographs | Analytical and Remedial Technology, Inc.<br>Bruker Instruments, Inc.<br>HNU Systems<br>PE Photovac International, Inc.<br>Sentex Sensing Technology, Inc.<br>SRI Instruments | Realization that program could be valuable to a wider user community if the scope of projects was extended beyond EP's Office of Research and Development. |
| 1995 | Cone Penetrometers | Fugro Geosciences<br>U.S. Army Environmental Center | Greater use of technical panel in demonstration planning, including conducting a Visitor's Day during the demonstration. |
| 1995 | Test Kits | Bio Nebraska Inc.<br>Dexsil Corporation<br>Hanby Systems<br>Radiometer American Strategic Diagnostics, Inc. (previously Ensys, Inc.)<br>Strategic Diagnostics, Inc. (previously Millipore Corp.)<br>Strategic Diagnostics, Inc. (previously Ohmicron Corp.)<br>Westinghouse Bio-Analytic Systems | Increased involvement from EPA quality assurance (QA) staff that broadened the scope of demonstration plans. |
| 1998 | Field Portable X-ray Fluorescence | HNU Systems<br>Oxford Instruments (previously Metorex Inc.)<br>Thermo (previously NITON)<br>Keymaster Technologies (previously EDAX) | Utilization of developer as operator of the technology (rather than operator trained by developer running the technology). |

TABLE 1— *(Continued.)*

| Report Publication Year | Technology Category | Developers | Significant Program Enhancements |
|---|---|---|---|
| | | Thermo Noran (previously TN Spectrace) | |
| 1999 | Soil and Soil Gas Samplers | AMS, Inc. (previously Art's Manufacturing and Supply)<br>Aquatic Research<br>Clements & Associates, Inc.<br>Geoprobe® Systems, Inc.<br>Quadrel Services, Inc. (previously Beacon Environmental Services, Inc.)<br>Simulprobe®<br>W. L. Gore & Associates, Inc. | Recognition that, in addition to monitoring technologies, sampling technologies were an important component of site characterization. |
| 2001 | Total Petroleum Hydrocarbons in Soil | CHEMetrics, Inc.<br>Dexsil Corporation<br>Environmental Systems Corporation<br>Horiba Instruments, Inc.<br>SiteLAB Corporation<br>Strategic Diagnostics Inc.<br>Wilks Enterprise, Inc. | Shift in philosophy that testing design should be focused on evaluating technology performance rather than simulating field conditions. |
| 2004 | Mercury in Soil and Sediment | Milestone, Inc.<br>MTI, Inc.<br>Ohio Lumex Co.<br>Oxford Instruments. (previously Metorex Inc.)<br>Thermo (previously NITON) | Significance of pre-demonstration study in evaluating technology maturity realized. |
| 2005 | Dioxin and Dioxin-like Compounds in Soil and Sediment | Abraxis<br>CAPE Technologies<br>Eichrom Technologies Inc. (formerly Hybrizyme)<br>Wako Chemicals USA<br>Xenobiotic Detection Systems | Implementation of pre-demonstration analytical characterization of environmental samples to assist with sample selection. |
| 2006 | Field Portable X-ray Fluorescence | Innov-X Systems, Inc.<br>Oxford Instruments (previously Metorex Inc.)<br>Thermo (previously NITON)<br>Oxford Instruments Analytical<br>Rigaku, Inc.<br>RONTEC USA Inc.<br>Xcalibur XRF Services Inc. | Repeat of previously evaluated technology category due to significant technological advances. |

grams and technology users. The program was therefore expanded to include technologies that were developed outside of ORD and the first publicly available documents were published in 1995. This change began the transformation of the MMT from a research program to one of technical support. Another significant change was based on the finding that the program was spending considerable effort testing technologies that were later found to not be ready for commercial use. This observation led to a change in the selection process and to the requirement that, for all post-1992 testing, every technology participating in the program would be commercially available.

Since the early efforts were essentially in-house, an expansion of the program identified a need for another mechanism for choosing the technology category to be tested. Consequently, the program began enlisting the support and input of EPA Program offices and regional laboratory staff who suggested technology categories for evaluation. The staff in these organizations were aware of the technology gaps associated with site characterization and remediation. They were also in a better position to understand the user's data needs and could make suggestions as to how the results should be reported. The most influential EPA organization in this evolution was EPA's Technology Innovation Office (TIO) (which is now part of the Technology Innovation and Field Services Division within EPA's OSWER). This organization was well-integrated with the user community based on its charter and served as an excellent liaison to the practitioners who would be buying and using the technologies being tested. Building a relationship with TIO brought Regional awareness and a broader interest in the program. This relationship also lent considerable credibility to the emerging program and provided access to both technology developers and end users. This began the expansion of the MMT Program into a new phase of client partnership.

As additional examples of the visibility and need for a national testing program emerged by the mid-1990s, it became clear that the objectives of the MMT Program were shared by the Department of Defense (DoD) and the Department of Energy (DOE). On this basis, EPA integrated the MMT Program into the Consortium for Site Characterization Technology (CSCT). The CSCT brought federal agencies with a common need for faster, cheaper, and better monitoring technologies together with end users of these technologies to facilitate unbiased, third-party performance verification testing [2]. In 1995, the CSCT and a newly formed EPA program called the Environmental Technology Verification (ETV) Program collaborated jointly on technology verifications. The CSCT was one of twelve pilot programs under ETV. Some of the other ETV pilot programs included air pollution control, drinking water systems, and greenhouse gas emission technologies. During this period, the SITE MMT Program through the CSCT and the ETV Program was leveraging resources to verify monitoring and site characterization technologies in the areas of soil and sediment monitoring technologies for polychlorinated biphenyls (PCBs) and field portable gas chromatographs for volatile organic compounds. Eventually, the collaboration ended in 1999 with the SITE MMT Program focusing on soil and sediment technologies that could be applied to Superfund sites (more closely related to the original mission) while the ETV Program focused on monitoring technologies for air and water. The primary product of the CSCT partnership was the development of a guidance manual that captured the process by which technologies were to be demonstrated and evaluated [3]. The

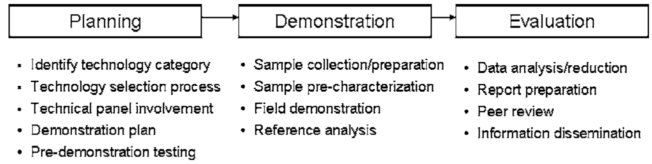


FIG. 1—*Key elements of the SITE MMT Program demonstration concepts.*

guidance manual was a critical milestone because it provided the SITE MMT Program and other technology evaluation programs with a defined process for testing field characterization and monitoring technologies.

## SITE MMT Program Verification Process

As initially formulated, the SITE MMT Program was created to provide reliable performance and cost data for field characterization and monitoring technologies in support of the Superfund program. The goals of the SITE MMT Program are summarized as follows:

- Test the performance of commercially-available field sampling and analytical technologies that claim to offer advantages over existing methods. (One of the findings of this program was that many technologies did not live up to these claims.)
- Identify the performance attributes of technologies that address field sampling, monitoring, and characterization problems in a more cost-effective and efficient manner.
- Prepare reports, guidelines, methods, and other technical publications or presentations that enhance acceptance of these technologies for routine use.

The key steps in SITE MMT demonstrations are summarized in the flow chart in Fig. 1. Each element in the figure is described below, including the initial premise for how each was implemented and how it evolved as the program gained experience with the technology evaluation process. A list of the technology developers that participated in the MMT Program and their corresponding technical categories is presented in Table 1 along with a timeline of the significant program enhancements that are also described in this section.

### *Identify Technical Category*

The first step in the SITE MMT process is to identify a technical need area. In the pre-1992 years of the program, this was determined by the EPA Program Manager based on input from a small group of ORD colleagues. As the staff completed the testing and began to disseminate the performance information results at internal meetings, the Program Manager realized that it would be beneficial to explore broader areas of technical need. Consequently, recommendations were solicited and received from EPA regional laboratories and program offices. Once the technical need area was identified, commercially available technologies were solicited to participate in the demonstration. Prior to the current dependence on the use of the Internet, common techniques for identifying technologies were by announcements in *Commerce Business Daily* and

[a]Information available as EPA for internal use only reports.

trade journals, as well as a review of technical conference proceedings. In spite of these efforts, the most successful avenue for identifying technologies was through discussions with other EPA offices, and in particular EPA's TIO. This organization was aware of a broad range of site characterization technologies which were eventually included in databases on the TIO web site (www.clu-in.org) including REACH IT (Remediation and Characterization Technology Database) and FATE (Field Analytic Technologies Encyclopedia). These databases became a valuable resource for identifying the technologies that would be invited to participate in the demonstrations. As shown in Table 1, the technology categories evaluated in the SITE MMT Program primarily involved monitoring or measurement technologies. However, in 1999, the program recognized that sampling technologies were also an important component in the site characterization process so a demonstration of soil and soil-gas sampling technologies was conducted.

## *Technology Selection Process*

In order to have the broadest impact and to achieve certain efficiencies of scale, a requirement of the selection process was to include three or more technologies in a given demonstration. A demonstration of multiple technologies also offered users more information on the comparison of prospective technologies. Generally, the demonstration involved a specific type of monitoring or sampling technology, but could also involve testing different techniques that accomplished the same analytical objective (e.g., measure a specific organic contaminant in sediment). The SITE MMT category that included the greatest number of different technology types was the demonstration of field technologies for the measurement of total petroleum hydrocarbons (TPH) in soil, which included the techniques of immunoassay, colorimetry, infrared analysis, and ultraviolet fluorescence spectroscopy. The program also was designed to test technologies multiple times if significant technological advancements suggest a need for re-testing. For example, verification reports evaluating the performance of seven X-ray fluorescence (XRF) instruments for the analysis of metals in soil were posted on the SITE Program web site (www.epa.gov/ORD/SITE) in March 1998. A few months later, in May 1998, EPA's SW-846 Program announced the release of a new method (Method 6200) for using field-portable XRFs for measuring metals in soil and sediment, predicating final approval of this method largely based on the results of the SITE MMT demonstration [4]. The publication of the demonstration reports and the SW-846 method opened up an entirely new market for the commercial manufacturers and vendors of XRF equipment. Software enhancements and the expanded use of X-ray tubes rather than radioactive sources prompted a re-evaluation of these field-portable XRF instruments, with eight new reports posted on the SITE web page in early 2006.

## *Technical Panel Involvement*

Because the program strived to execute demonstrations that were relevant to users' data and information needs, a technical panel of key stakeholders was formed once the technology area was identified. Initially, the technical panel consisted of an informal group of a few interested EPA experts, including those who had presented the technical need to the MMT Program Manager. The concept of making technical experts aware of the demonstration evolved with the 1995 demonstration of cone penetrometer systems by actively engaging a panel of experts in developer selection, experimental design, sample collection, demonstration execution, and report review. The technical panel for the cone penetrometer demonstration also suggested that the program have a Visitor's Day during the demonstration. The Visitor's Day opened the field site to the general public and was designed to educate anyone who wanted to learn more about the participating technologies and the testing program. Visitor's Days were conducted from this point forward as part of each demonstration. In addition to engaging knowledgeable technical experts on specific demonstrations, the SITE MMT Program was also working with a panel of regional advocates that the EPA's TIO had identified. By the mid-1990's, this panel included representation from each EPA region. These regional advocates advised the SITE MMT Program Manager of technical gaps with national significance and helped prioritize testing areas for subsequent demonstrations. The technical panel could have as few as a five or more than 20 contributing members, the majority of whom were EPA staff, but the number and organizational affiliations were dependent on the scope of the technology category, the demonstration site, and the interest in the topic. The character of each demonstration was driven by this panel that helped to define the scope, identify sampling locations, and promote the results. A recent example of an active technical panel was the group involved with the demonstration of monitoring technologies for dioxin and dioxin-like compounds. This demonstration's technical panel consisted of 25 members, with representation from seven EPA regions, the technology developers, the reference laboratory, and the demonstration site hosts (Michigan Department of Environmental Quality and U.S. Fish and Wildlife Service). An example of the panel's influence on the dioxin demonstration was the addition of co-planar polychlorinated biphenyls (PCBs) to the experimental design. According to the needs identified by EPA OSWER and EPA's Draft Dioxin Reassessment Team, this project was originally intended to only focus on targeted chlorinated dioxins and furans. However, the panel suggested including World Health Organization (WHO)-designated dioxin-like PCBs in the determination of the total toxicity equivalent (TEQ) concentration. Expanding the scope of the demonstration to include the contribution of the WHO PCBs provided a more complete representation of the TEQ. This change significantly increased the time and cost of the demonstration, but it was an investment that broadened the scope of the project to better meet the needs of the user community.

## *Demonstration Plan*

The experimental design for each evaluation is described in the demonstration/quality assurance project plan (D/QAPP). Initially, these plans were brief highlights (<20 pages) that outlined the key elements of the demonstration because they were for internal use only. With the development of the EPA Guidance Manual [3] the plans evolved into 150 to 200-page documents. The development of the Guidance Manual was significantly influenced by EPA QA staff who stressed the need for the demonstration plans to include separate sections on QA and health and safety, and for the plans to follow a standard format. The formation and involvement of the technical panels also influenced the level of detail that was included in the plans. These demonstration project plans are published as EPA documents and were subjected to a well-defined peer review process. These plans also required the signature approval of each technology developer since prior experience demonstrated that written documentation of the developer's approval was a way to ensure that developers thoroughly read the plan and understood what would be expected of them during the demonstration.

Another important component of the D/QAPP is a description of the data evaluation process, including the statistical methods that would be employed to interpret the results. Early SITE studies relied upon post-demonstration statistical analyses based on whatever data had been generated in the field. One of the primary limitations of this approach, in retrospect, was that the type of interpretation selected could weaken confidence in the conclusions. It was learned that if the demonstration data were derived for an intended purpose, describing how the data would be analyzed after the demonstration and what the performance objectives would be simplified the data interpretation. This approach closely followed the data quality objective process that was gaining favor during this timeframe.

The pre-1992 days of the program involved testing a limited number of samples, but with experience it was realized that a statistically rigorous experimental design should be implemented that included as many analytical samples as possible (usually, more than 200). In 2001, there was a shift in philosophy during the TPH demonstration where the technical panel and MMT Program Manager agreed that the experimental design should focus on technology performance rather than on simulating field conditions. Prior to 2001, samples would be collected randomly throughout the demonstration site with 10 % analyzed in duplicate as was typical for a field characterization study. This approach led to numerous nondetects for the collected environmental samples and often limited the number of replicates for the determination of precision. In the TPH demonstration, the number of replicates was increased to three for environmental samples so that technology precision could be more rigorously assessed. The Program Manager also learned that it was important to test the performance of the technologies with certified samples that were of known concentration, as well as environmental samples with various matrix compositions. The new experimental design now included both environmental and certified samples in the demonstration. The analysis of these samples was shown to provide a more statistically robust dataset within the quality control guidelines of the demonstration.

Prior to 1998, EPA's technical support contractor operated all of the technologies included in the demonstration. As the demonstrations involved more complex technologies, it was difficult for the technical support contractor to find a sufficient number of qualified, well-trained operators for each technology. To eliminate any perceived or real bias due to the technical operator and following the XRF demonstration in 1998, each technology developer was expected to operate his equipment and to analyze the demonstration samples in the field. EPA's technical support contractor would now conduct audits during the demonstration so that operational conditions could be observed and documented. This change led to greater participation in the demonstration by the developers and improved the overall testing process while reducing costs to the government. The field demonstration proved to be a great learning experience for many of the developers who would now gain first-hand experience on how their technology would be used under field conditions. The demonstrations often led to improvements in the logistical operation of the technology with enhancements or modifications to practical aspects of the technology's use. Examples include the use of trays to organize solvents, converting from recyclable glassware to expendable supplies, better labeling of reagents, preweighed reagents, and changes in operator training.

### *Pre-Demonstration Testing*

By 1995, the EPA Program Manager realized that some of the nominated technologies were not ready for rigorous field testing and that many had never been used in the field prior to the demonstration. The solution to this problem was to require a preliminary step to assess the readiness of each technology and other elements of the experimental design. This pre-demonstration sampling and analysis event would also be used to confirm that the samples from the proposed site were appropriate for the technology and to ensure that the reference method was correct [3]. The pre-demonstration step allowed the developers to refine their technologies, if necessary, for the particular samples that were to be analyzed in the demonstration. It also provided an extra level of quality control for evaluating the procedure for sample homogenization. The pre-demonstration evaluation also applied to the readiness testing of the reference laboratory and method. It was assumed that technologies that had difficulties with the analysis of the pre-demonstration samples lacked maturity and after receiving the results, each developer was given an opportunity to decline further participation in the demonstration process. An example of an unusually large number of developers leaving the program after the pre-demonstration testing occurred during the demonstration of mercury analyzers for soil and sediment. Twelve developers participated in the pre-demonstration study, but eight removed themselves from the program after the pre-demonstration, citing maturity and performance issues. This large number of developers who left the mercury program after the pre-demonstration was not typical, but it is a good example of the utility of the pre-demonstration study which ultimately saved resources for the developers and the government.

### *Sample Collection, Preparation, and Pre-Characterization*

In the early years of the program, the demonstration experimental design involved evaluating a number of samples (usually $<50$) from one environmental site. Beginning in 1995, the demonstration was performed at a minimum of two sites using the site characterization model. During this period, the field portion of the demonstration often took a month or more to complete and variations in performance at the different locations compounded the interpretation of results. This two-site model was seen to be costly and inefficient. As a result of these difficulties, in 2001, a variation of the original one-site model was implemented. In this version, samples were collected from multiple sites, no less than three and on one occasion from ten different sites. The number of sites selected was dependent upon the recommendations of the technical panel, the number of readily available sampling sites, and the performance objectives to be accomplished. This design maximized the information regarding different sample types, minimized travel expenses, and although it increased the period of performance at one site, it allowed more focus on the performance of each technology under well defined field conditions.

To ensure that each participant analyzed samples that were statistically similar in concentration, environmental samples were homogenized prior to sample aliquoting. The early demonstrations involved collection and field homogenization of samples at the site during the demonstration. Other federal programs (such as DoD's Environmental Security Technology Certification Program) were following a similar approach, so EPA was consistent with these programs. Although the sampling plan was guided by the site history, this approach often resulted in a large number of nondetect samples included in the design, even though the samples were collected in areas of known “hot spots,” sampling would often miss the plume of contamination. There were also concerns about splitting samples that were often heterogeneous in analyte concentration using in-field homogenization techniques that were not as rigorous as laboratory-based procedures. This may have resulted in an inability to directly compare the field technologies with conventional methods, or at a minimum, raised questions as to whether the discrepancies between the field and conventional results were due to differences in analytical accuracy or to sample composition. During the 2006 dioxin demonstration, samples were collected prior to the demonstration (as opposed to during the demonstration) to allow for laboratory homogenization, pre-characterization, and selection of the samples that were to be used in the study. Since the homogenization process involved oven drying and mixing, the samples were no longer representative of the actual site conditions; but the EPA Program Manager decided that this was the appropriate approach since the overriding objective was to mitigate heterogeneity, reduce the number of nondetect samples, and challenge the dynamic range of the technologies.

Homogenization procedures can be found in D/QAPPs posted on the SITE Program’s web site [5]. This pre-demonstration characterization process increased the cost of the demonstration, but better ensured that the performance objectives were adequately addressed. This approach dramatically changed the quality and nature of data obtained from the demonstration and re-established the focus on technology performance, not site characterization. In previous demonstrations, the design was to mimic a field characterization study, assuming the appropriate technology had been selected. This design is intended to provide the performance data so that the correct technology (i.e., one that meets the user’s needs) would be chosen. This model is thought to best represent the goals of the program as originally intended.

## *Field Demonstration*

The field demonstration of the technologies is the heart of the verification process. As noted, the selection and function of the location for the demonstration is one of the concepts that changed frequently over the course of the program. Prior to 1992, all testing was conducted in an EPA or contractor laboratory. The regional advocates advised the MMT Program Manager to take the technologies to the field for the demonstration, so that testing would be conducted under realistic operating conditions. Consequently, beginning with the cone penetrometer demonstration in 1995, testing was conducted in the field but only at one location. This provided a thorough evaluation of the technology’s application to samples from one contaminated site, but was limited in that the results could not be applied to other sites. In response to this concern, demonstrations were conducted in two locations, each for a one-week period [3]. The sites were selected from different parts of the country to allow for differences in climate, soil matrices, etc. This change increased the span of environmental conditions that might be encountered when using the technology. However, mobilization at two field locations was a significant financial and resource burden on the participating developers and the government. It is now the policy that demonstrations be conducted at a single field site known to contain the contaminants of interest with multiple environmental samples brought from other contaminated locations to this core site. This approach also allows for the collection, homogenization, and pre-characterization of environmental samples from multiple contaminated sites prior to the field demonstration. As an example of these different approaches, the XRF reports that were published in 1998 were based on data collected at two demonstration sites, while the 2006 reports were developed from a single core testing location with samples analyzed from nine different collection sites. The amount of usable data collected during the 2006 demonstration was significantly greater. The analyses were better targeted with fewer nondetects. Sample management was better organized and performance measures, like sample throughput, was more accurately determined.

## *Reference Analyses*

In each demonstration, a conventional laboratory was selected to serve as the “reference,” and would analyze replicate splits of the demonstration samples using a conventional EPA laboratory-based method. The quality of the reference analyses is one of the most critical components of the SITE MMT demonstration since the results generated by the reference method are viewed as the benchmark against which the performance of the technology would be measured. In the pre-1992 days of the program, the laboratory results were considered to be “correct” if there was a discrepancy between the laboratory and field technology data. During most of the program, the reference laboratory data were viewed as superior to that provided by the developers. However, it was seen in a number of demonstrations that this assumption was not necessarily correct and that data generated using standard, laboratory-based EPA methods were not always of higher quality than data generated by the field technology. This may be due to a number of factors, (e.g., analyst skill level, sample matrix, analytical conditions, etc.), that affected the quality of results. For example, during the 2001 TPH demonstration, the reference laboratory results generally exhibited a negative bias (based on a comparison to the certified sample results). Because the reference laboratory data met other quality control requirements and the precision of the results were good, the reference laboratory data were deemed acceptable for use. However, this demonstration prompted the SITE MMT Program Manager to begin conducting pre-demonstration testing and accuracy/precision checks of the reference laboratory and method concurrently with the participating technologies so that the quality of the results that were used for comparison with the technologies would be independently established. The relationship between the reference laboratory and the SITE MMT Program has also changed over the years. Initially, the reference laboratory was not represented during any of the technical panel’s experimental design discussions. This approach was based on the premise that the reference laboratory should be able to analyze unknown samples with little or no site history or context, or both. However, it was discovered that it was counterproductive to not include the reference laboratory as part of the demonstration panel. The reference laboratory was now expected to engage in discussions regarding the experimental design, data quality objectives, and other factors that would establish performance and comparison criteria at the same level as the technology developers. So, while samples are still analyzed as received, the reference laboratory is now included as part of the technical panel. The reference laboratory results continue to be used as the benchmark for comparison. However, since the methods are different, certain bias remains. For example, many field technologies are designed to provide a high bias so comparison to accuracy is often problematic. Key to all comparisons is precision and even the most experienced laboratory can have performance problems. The high level of QA imposed throughout the demonstration has minimized these problems; however, an independent confirmation of results is an important element in establishing data usability.

### *Data Analysis/Reduction*

Nearly all demonstrations since the inception of the program involved evaluation of the classic "PARCC" parameters—precision, accuracy, representativeness, comparability, and completeness [3]. As described in the Demonstration Plan section, the number of replicate samples in a demonstration design increased as the program learned the value of the use of a balanced number of replicates, which resulted in a more robust dataset to evaluate the PARCC parameters. Feedback from the regional advocates and TIO indicated that, in addition to evaluating these data-quality indicators, other key performance criteria were important to evaluate and report. These criteria included both quantitative metrics (such as frequency of false positive/negative results, cost of equipment and supplies, and sample throughput) and nonquantitative ones (such as ease of use and operator skill level required). The parameters evaluated by quantitative measures were referred to as the primary objectives of the demonstration; those addressed by qualitative means or by observation of the technology (factors such as user friendliness, operator skill level, health and safety aspects of the technology) were called secondary objectives. The D/QAPP provides a detailed description of the evaluation criteria for each primary and secondary objective. Where possible, the most simplistic and commonly used statistical analysis methods are used in the evaluation of the demonstration data. This policy was undertaken in direct response to the input received from users, who indicated that the reports must be written so that a novice can understand the results of the evaluation.

### *Report Preparation*

A separate report is prepared for each participating technology since it is the policy of the program to not judge, compare, or advocate any individual technology based on the results of the demonstration. The reports are prepared from the statistically reduced data and follow a standard EPA publishing format. The original name for these reports was an innovative technology evaluation report (ITER). The SITE MMT Program Manager recognized that there was special significance to the word "verification" which indicated that the performance results represented a snapshot in time, and subsequently modified the title to innovative technology verification report (ITVR). A frequent recommendation from users was to reduce the length of the report and every effort was made to follow this advice. Within each report are a short abstract and a four-page verification statement that summarizes key findings. Also a complete data evaluation record of the raw field data is prepared and is available for auditing purposes. This document is not peer reviewed or published but is maintained by the MMT Program Manager as a final record of the demonstration.

### *Report Review*

To be published as an EPA document, the report must be cleared following the EPA's peer review process. The draft reports prepared by the technical support contractor are first reviewed by the EPA Program Manager and technology developers. The revised reports were then reviewed by the technical panel, as well as independent EPA and non-EPA technical expert peer reviewers. Finally, the report received internal EPA administrative review. The review process typically takes four to six months to complete. Once finalized, the reports receive EPA report numbers and are published through ORD newsletters and on the SITE and National Exposure Research Laboratory (NERL) web sites. Since these are public documents, each developer is also encouraged to add a copy of the report to its company web site.

### *Information Dissemination*

As described previously, the reports generated before 1995 were for internal use only and were available only to EPA staff and only in hard copy. Once the external value of the reports was realized, the distribution procedure changed to make them publicly available in hard copy. Today, the final, approved reports are posted on the SITE Program's web site (www.epa.gov/ORD/SITE). In addition, the results of the demonstration are presented in various forums, such as technical conferences, manuscripts, and internet seminars, to ensure that the performance information is widely disseminated. The information is intended to help the developer market the technology and to provide the user/customer with an objective evaluation. The reports are marketed to reach a broad audience and represent the well-documented outcome of a SITE verification study.

## Developers' Perspective on SITE MMT Program

To date, the performance of 70 technologies have been verified through the SITE MMT Program. In 2005, the developers that have participated in the program since 1995 were contacted to update their contact information in the SITE MMT developer database. Contact information for the eleven technologies tested prior to 1995 was not available and, given the considerable changes in the program, was not considered relevant to the current performance verification process. The developers were asked several questions about their experiences during and after their participation in the SITE MMT Program. Of particular interest was whether or not they believed their participation was valuable and worthwhile, and what impact participation may have had on their businesses. The responses to the key questions in Fig. 2 are described in more detail below.

Approximately 22 % of the developers are no longer in business, or they no longer sell the technology that was tested. Of the 78 % that still sell the technology, 60 % of those are still marketing it under the same name. Over 70 % of the developers are small businesses and the majority of the developers that responded (83 %) had participated in a SITE MMT demonstration in the past five years.

Some supporting and improvement area comments from the developers are summarized in Table 2. When asked if participation in the SITE MMT Program helped their products, twelve developers indicated that there was an increase in the visibility of their product and eight indicated that the SITE MMT Program improved the quality of their product. CAPE Technologies dioxin verification indicated that their SITE MMT Program involvement significantly contributed to them receiving increased business with a specific customer. Another developer, siteLAB PAH verification, indicated that participation directly resulted in four straight years of quadrupled sales, and that its participation was mentioned more than once per month by inquiring customers. siteLAB also indicated that

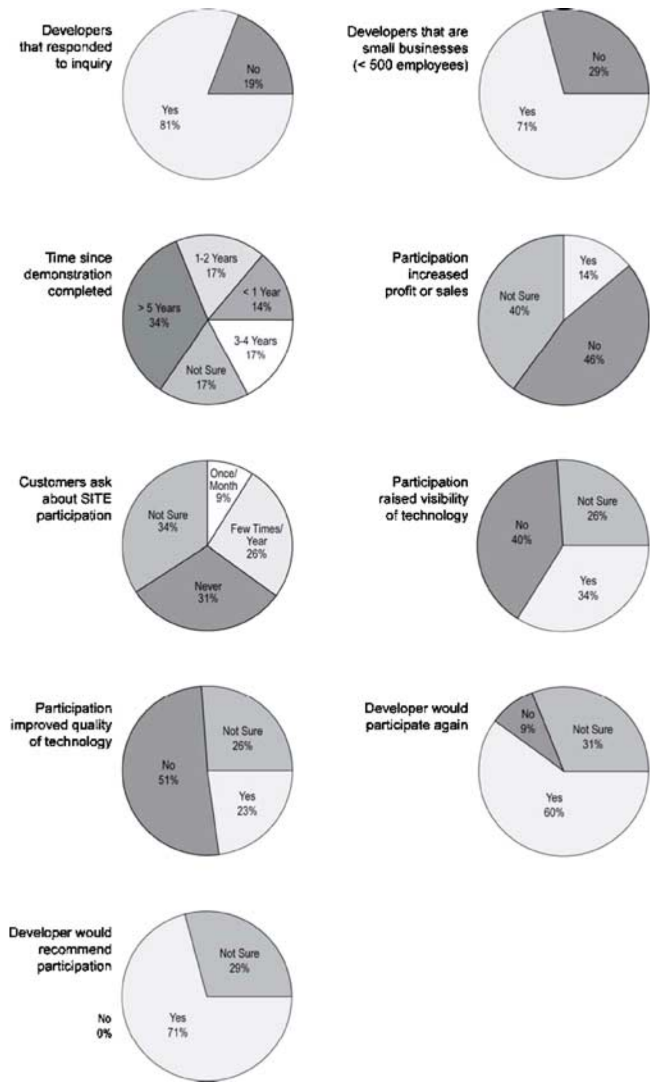


FIG. 2—*Summary of developer responses to key questions.*

the SITE MMT verification was recognized by state verification programs, so its technology was accepted by the state based on the SITE MMT report, without the need for additional independent verification.

While many developers indicated that the demonstrations were fundamentally well-executed, some improvement areas that were suggested included reducing the time between test completion and report finalization; disseminating more information after the reports are published to promote the demonstration results; and establishing a grant program to fund participation of developers (particularly those that are small businesses, which make up the majority of participants in the program). Only three developers said that they would not participate in another SITE demonstration, and none of the developers said that they would not recommend the program to others.

## Conclusions

The future of the SITE Program is undergoing evaluation by the EPA. One possibility under consideration involves folding the program into a new developing organization within ORD whose focus will be the continued development and testing of innovative technologies. Regardless of its future directions, the establishment and successful execution of the SITE MMT program over the past 20 years is evidence that this program has been a legislative and technical success. Developer claims of quadrupled sales as a result of participation in the SITE MMT Program demonstrate the program's contribution to the acceleration and use of innovative technologies. In addition to meeting the goals set forth under SARA, the SITE Program was a model for other EPA technology evaluation programs, such as the Environmental Technology Verification (ETV) Program (www.epa.gov/etv) and the Technology Testing and Evaluation Program (TTEP) (http://www.epa.gov/NHSRC/tte.htm). While these programs were created by EPA to address other areas of technology evaluation (e.g., the ETV Program addresses environmental technologies across a broad range of areas such as air pollution control, drinking water systems, and greenhouse gas emissions; TTEP evaluates homeland security related technologies); principal features and mechanisms developed and tested by the SITE MMT Program have been incorporated into these EPA testing programs. The SITE MMT Program impacted demonstration programs in other federal agencies as well; it was the catalyst for joint technology evaluations with the DOE and DoD through its CSCT. Also, the fundamental concepts of the SITE MMT Program formed the basis of one of the three critical components of Triad, which is a systematic decision-making approach that EPA uses in support of site characterization and remediation [6].

TABLE 2—*Supporting and improvement area comments.*

| Supporting Comments | Improvement Area Comments |
|---|---|
| (Participation in SITE MMT Program) did help company definitely, especially with name recognition. | (Developer would like to see) more help marketing their technology via the SITE MMT Program. |
| Company is recognized overseas all because of the (SITE MMT Program) report. | (Developer would) like to see tests completed more quickly. |
| Sales quadrupled and have consistently remained at that level. | (It is hard for customers to grasp that) verifications are just snapshots in time and products are constantly improving. |
| SITE (MMT) tests have led to increased acceptance of the technology in the industry. | Tests should compare like instruments. |
| Having the products verified has lent credibility to the products. It was worthwhile. | (Developer would like to see) funding for participants. |

## *Acknowledgments*

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## References

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