LIMS and the Mine Site Lab
Essential Features and Implementation Notes

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Abstract

Once the exclusive domain of billion dollar biotech and pharmaceutical labs, Server-based Laboratory Information Management Systems, (LIMS), are increasingly deployed in laboratories serving other sectors, such as mining and environmental. These laboratories continue to take a larger share of the $400 million North American LIMS market. Nevertheless, many surveys indicate widespread customer dissatisfaction with LIMS and LIMS vendors. Some sources suggest that up to 60% of LIMS installations fail.

This paper lists the essential features for a Minesite LIMS, and examines the reasons behind LIMS project failures. It offers mineral analysts a guide to help them choose the right product for their facility.

LIMS Benefits

Over the last two decades, automation and computerization within the mining industry have focused on areas such as geological modeling mine planning and process control. Laboratories, largely, have been ignored. This is sometimes the result of the "black box" syndrome. Mine management, often with little or no background in mineral analysis, tend to see the laboratory as a "black box"; samples go in on one end, and results come out the other. What goes on inside the box is not their concern, (except when the numbers stop coming out the other side). Thus, capital funding to implement a data management system is often not available. "Don't fix it if it ain't broke". The problem is, how do you know that it isn't broke? A LIMS can help to determine this, as we will see later on.

In contrast, most analysts do understand the benefits a LIMS can bring. Among the more obvious ones, a LIMS

- Allows better utilization of staff by reducing the amount of time spent keying in data or calculating results.
- Reduces or eliminates data transcription errors.
- Improves turnaround time.
- Provides a clear picture of the work-in-progress status of the laboratory at any point in time, to identify and eliminate bottlenecks
- Assists in laboratory accreditation by meeting the data management requirements for regulatory agencies.
- Allows for rapid analysis of large datasets for statistical Quality Control and Assurance.
- Gives real-time data access to other departments, such as Processing and Mining.
- Allows ancillary record keeping, such as calibration and maintenance records for instruments and equipment, sample storage and disposal, invoicing, inventory tracking and more.

Most are difficult if not impossible to quantify, explaining, perhaps, why Laboratory Managers often find it so difficult to get funding for LIMS.

We will examine some of the benefits above in a little more detail.

REDUCING DATA ENTRY TIME AND TRANSCRIPTION ERRORS

Data transcription errors are amongst the most insidious of all errors in laboratory data. They are notoriously difficult to detect since, unlike a persistent analytical bias, they are random and sporadic. Consider a gold facility, producing some 400,000 Oz / year of bullion. In one month, the laboratory is likely to have analyzed 40 to 50 bullion samples by gravimetric fire assay. If they follow a standard bullion assay, five aliquots would be taken from each sample, weighed to at least 0.01 mg and recorded to five or six significant figures. Each aliquot will generate a prill or cornet for final weighing, another six significant digits. Before calculations, we have 60 digits transcribed per sample. Add to this the weights for check samples, the intermediate calculation results and the final calculated finenesses, and you are looking at 100 or so digits per sample – 4,000 to 5,000 per month. The potential for error becomes enormous. Moreover, this takes into account only one of the many types of analysis undertaken by a typical minesite lab.

With a suitable LIMS, the entire assay is automated. Weights are transferred directly from the balance to the LIMS. All calculations are performed internally, and the final analysis report or certificate is printed directly.

IMPROVING TURNAROUND TIME AND PROVIDING A PICTURE OF WORK IN PROGRESS

One of the most critical parameters in many Minesite labs, turnaround time is often the major yardstick against which a lab is measured. This is not only because of its importance to a 24/7 operation. Turnaround time is also the one parameter whose measurement is simple and immediate. A LIMS can improve turnaround time in several ways. Firstly, by automating many data entry tasks, the LIMS frees up staff for other activities. Pre-defined templates for sample entry and analysis setup mean that routine created in seconds. A LIMS allows managers to prioritize samples, so that non-essential ones are not analyzed at the expense of critical ones.

Many labs include sample turnaround statistics in their month-end reports. Without a LIMS, this can involve spending the better part of a day with a heap of sample submission records, analysis reports and a calculator. Lab Managers generally approach turnaround-time reports with the same reluctance that they would performance appraisals. This need not be the case. A suitable LIMS allows Managers to generate these reports simply and quickly, and to view trends over longer periods. Furthermore, the LIMS permits several filtering and grouping options, so that Managers can identify problems within particular areas, such as sample preparation, or with certain analytical methods. This type of information is invaluable and allows Managers to make informed decisions to improve the efficiency of resource allocation.

ASSISTING IN LABORATORY ACCREDITATION

Tougher standards are making it increasingly difficult, if not impossible, to meet accreditation or certification guidelines without some form of computerized data management. In the environmental field, this has certainly been the prime mover toward LIMS implementation, and most of these labs now operate a LIMS.

For Minesite labs that analyze environmental samples, accreditation is a pre-condition for acceptance by Regulatory agencies. Even for mineral analyses, many lenders are now demanding accreditation as part of their loan conditions. A LIMS that is designed to conform to national accreditation standards therefore allows lab manager and QA officers to concentrate on other areas, knowing that the data management requirements are fully met.

DATA ANALYSIS AND QUALITY CONTROL

If the benefits above are areas in which a LIMS is superior to a manual system, then data analysis is an area in which a LIMS excels. Modern, server-based relational databases can access and process data with phenomenal speed and perfect accuracy. A well-designed LIMS allows managers to extract pinpoint datasets from amongst millions of records, and to analyze those datasets with unparalleled speed. With a set of built-in QC/QA tools, the LIMS lets analysts review quality control charts before submitting results for approval. It allows QA officers and managers to examine long-term trends, answering questions such as “Is our quality improving”. Finally, it provides auditors with documentary evidence that the laboratory is in control.

REAL-TIME DATA ACCESS

It’s no good processing samples within twenty minutes if the results then sit on the managers desk until the following morning. By providing plant operators with up-to-the-minute analytical data, a LIMS allows them to adjust process conditions in a timely manner, and to respond to process changes and upsets with the minimum of delay. Whether it is the particle size distribution of a classifier overflow, tailings grade from a concentrator or the sulfur content of a roaster product, operators need this vital information as soon as possible. Delays can cost many thousands of dollars, which is why online access to analytical data is often of paramount importance.

Geologists and mine planners also benefit from electronic data retrieval. Samples can be logged in by the client instead of at the lab, and results can be downloaded to spreadsheets or even directly into the database supporting the mine model. All of which speeds data access to those who require it, while at the same time reducing or eliminating typographical data entry errors.

Some LIMS incorporate web-based data access, allowing authorized personnel to view results from any PC with an Internet connection, in a nearby town or on the other side of the world. Lab managers retain absolute control over the data; deciding who can access what.

Feature list for a Minesite Lims

The design of commercial LIMS packages has been shaped largely by the markets they serve. Traditionally, this has meant labs in the food and pharmaceutical industries, or generic LIMS, often developed by instrument manufacturers. Meanwhile, mineral analysis laboratories have specific requirements that need to be met, a consequence of the types of analyses they perform.

The following list outlines some of the more important of them:

- Batch login of samples, with ability to combine products from different batches into an analysis.
- Expanded sample preparation section, including preparation-specific Quality Control.
- Ability to handle multiple sample products and to back-calculate the original sample assay.
- Ability to receive routine samples and set up routine analyses automatically.
- User-defined calculations for intra- and inter-test, and intra- and inter-sample results.
- Automatic generation of worksheets based on user-defined criteria for insertion of blanks, replicates, reference material and other QC samples.
- Ability to handle multiple analytes and methods for a group of samples

BATCH LOGIN OF SAMPLES

Batch sample login is essential in a Minesite lab, and many LIMS packages offer this functionality. Logging in or registering samples in this manner allows users to attach much of the attendant information, such as sample type or client department, to the batch instead of to the individual samples. This reduces dramatically the amount of data that must be entered, thereby speeding data entry. If batch login is the only type of login allowed in the LIMS then there will be another, less obvious advantage. The database is no longer required to store any extra information as part of the sample – it may instead be attached to the batch. Apart from reducing storage space, this may also speed data access somewhat, since the database engine must search through fewer bytes of information to get to the data it needs.

EXPANDED SAMPLE PREPARATION

Virtually unique in analytical chemistry is the attention that must be given to sample preparation protocols in a minerals lab. Lab managers understand well that they ignore sample prep at their peril.

The variance of an analytical result is composed of the intrinsic variability of the orebody, the variance introduced in the field, in preparation, in sub-sampling and in the actual analysis. Since these variances are additive, it is possible, by calculating them individually, to arrive at an estimate for the total variance of an analysis on a mine sample. This number is often critical in the mine planning operations – sometimes to the extent of determining which mining method is to be used.

Lab Managers need a LIMS that lets them estimate the variance introduced at each stage in sample preparation. This allows them to make informed decisions about preparation methodologies, including such things as optimal sample size, number of size reduction stages, and number and type of splitting stages. Information about preparation variance is normally gathered using split samples, taken at various stages along the preparation route.

Many labs introduce QC samples during preparation, as distinct from those introduced at the analysis stage. An example is the use of barren quartz washings to identify equipment contamination. The LIMS should be able to independently track and report on all these samples.

WORKING WITH MULTIPLE PRODUCTS

A central feature of the workflow in a minerals lab is that, very often, it is sample products and not the samples themselves that are ultimately analyzed. In the case where a sample pulp is assayed once only, this is not an important distinction. Very often however, the lab must analyze multiple products from a single sample and then report a re-calculated, weighted assay. Typical examples of this type of analysis include the metallics fire assay for gold, and screen assays of separate size fractions for metallurgical recovery tests.

If the LIMS cannot perform these calculations as part of its design, users are required to transfer results to another format, such as spreadsheets, for further calculation. Besides the extra time and effort involved, there is the added danger of introducing errors. There is also the added complexity of having separate data storage for analytical records, since the spreadsheets will have to be maintained and archived as part of the data management system. The LIMS should be able to set up, calculate and report a screen-fire, a metallics assay or a bullion assay, easily and without any arithmetical juggling.

ROUTINE SAMPLES AND ANALYSES

Most of the sample received by a Minesite lab will be routine in nature. Grade control samples, mill feed samples, crusher heads samples and tailings samples. All of these sample types, and many more, are run through a typical minesite lab during a normal working day. Many are processed several times per day. Not only are the sample types and identities regular in nature; so too are many of the tests that must be performed on them. The LIMS should allow users to select these routine samples from pre-defined lists, and then register the samples automatically. Moreover, the LIMS should also be able to complete all of the sample preparation and analysis functions that would normally be performed manually.

The LIMS also needs the flexibility to allow changes “on the fly”. If a sample is missing, or if a non-standard test is suddenly required, the LIMS users need enough control to be able to make these changes quickly and painlessly. The workflow in a Minesite lab often dictates that samples from different client departments be analyzed together. The LIMS must allow this, all the while retaining internally the correct ownership of each sample.

USER-DEFINED CALCULATIONS

User-defined calculations are commonly divided into four types; inter-test, intra-test, inter-sample and intra-sample. Different LIMS packages will support these types to widely varying degrees. In addition, some systems allow the use of intermediate results, such as sample weight or sample moisture, to be included within the calculation.

The first stage in deciding which types of calculations are required is to carefully examine the needs of the laboratory. All of the analyses, both routine and non-routine, that are carried out in the lab must be examined to see whether the LIMS can accommodate the calculations involved. A set of Standard Procedures helps enormously. The LIMS vendor should be provided with copies of the standard methods for the lab, and should be able to set up a demo of the LIMS using the methods in the manual as examples. The demo should show the steps involved, firstly in profiling the different methods and then in generating results based on them.

Other calculation options that a lab may consider important are:

- Detection limit calculations,
- Blank corrections
- Instrument calibration and curve fitting
- Correction for weight, moisture, final volume and dilution factor.

Some tests do not provide a numeric result. In this case, the LIMS package should provide support for user-defined parameters or analytes. Instead of entering numeric values, users can select a result from pre-defined lists. such as "Positive", and "Negative". The lists should be simple to set up and maintain, so that new entries can be added during results entry if desired.

AUTOMATICALLY CREATING WORKSHEETS

Most production laboratories have developed templates for generating analysis worksheets. These templates, which should be defined within the Standard Operating Procedures, specify how the individual racks of a bench job are to be set up; the number of samples per rack, number and frequency of replicates, blanks, QC samples etc. If the LIMS is to generate worksheets automatically, it must be able to store all of this information internally, and apply it each time the worksheet is created. The time savings that can be realized from this are considerable, particularly in labs that routinely handle and process large batches of samples.

It is important, however, that the LIMS does not become too rigid. Analysts need the flexibility to be able to add or drop samples as required, change their position within the racks, and to select which QC samples they will use. Furthermore, analysts must be able to combine samples from different batches, and even from different clients, within the same worksheet.

MULTIPLE ANALYTES AND METHODS

Almost all LIMS packages allow users to configure tests with multiple analytes. However, displaying those analytes simultaneously is often problematical. Once readings are entered and calculated, users need to be able to view the results for all analytes at once. This is particularly important for labs that perform multiple element scans, for example by ICP spectroscopy.

This philosophy should be carried through the entire program, from results validation to report generation and quality control and assurance. Ideally, users should be able to custom craft the reports themselves – adding and removing analytes from different tests as they see fit. Analytes should be grouped into libraries pertaining to individual methods, so that selection does not involve wading through heaps of un-related parameters. The program must be able to store multiple reporting parameters for each analyte. These should include the number of decimal places or significant figures, units of measure, and information about the instrument detection limit for the parameter. Automatic scaling of units is often a good idea, especially in labs that deal with exploration samples where analyte concentrations can change by orders of magnitude between samples. An example from the gold industry would be a method that reported gold concentration in parts per billion, but which scaled up to parts per million at higher concentrations.

If a batch of sample is analyzed by several different methods, it is essential that the program is flexible enough to allow all results to be combined and displayed in one report. Consider the case where a client department requests a series of check analyses by a different method. In gold labs running aqua regia digestion, a common request is for five or ten percent fire assay checks. It is likely that the aqua-regia results will be available before the fire assays. Users should be able to issue interim reports for these. Later, when the check assays are ready, users should be able to generate a second report showing, for each sample, the original aqua-regia result alongside the fire assy.

Implementation issues

The LIMS is how the laboratory tracks and manages its information resources, particularly the data that represents the laboratory's product. Any change in the data-handling system, therefore, engenders some potentially traumatic changes in the way the laboratory operates. One LIMS consultant puts it this way.

There has never been a LIMS project whose implementation has not been marked by a "trail of bodies".

Changes in information management processes are also traumatic because the laboratory staff has to adopt new routines, and the laboratory management has to accept, support, and encourage change. These changes are generally costly, disruptive, and unwelcome to those who have to deal directly with them in the short term. The long-term payoff, one hopes, is improved effectiveness and efficiency. However, the laboratory must be willing to devote the necessary time and resources to planning, selecting, and implementing the new system. In addition, the LIMS has to be compatible with and integrated with the quality and business objectives of the laboratory.

LIMS COMPONENTS

Three major functional areas of the LIMS illustrate the relationship between the information management system and the other management processes in the laboratory. The first, sample tracking, demonstrates that the appropriate work is properly completed and that the workload is properly managed. This can be as simple as correlating a sample container to an entry in a notebook, or as complex as a multistage custody chain tracked with sophisticated bar-coding equipment. Second, the sample analysis must be documented, and sufficient raw data must be maintained to reconstruct and defend the result. Finally, these results must be organized and reported in a manner that is understandable and meets the requirements of the end user.

Five key actions form the core of the automated LIMS application. First, data is captured or entered into the system. This data may be entered manually or captured electronically through such mechanisms as RS-232 or RS-435 communication links, importing from data files such as spreadsheets and text files, or by manual entry. Second, the data is analyzed and organized. This process includes performing calculations, adjusting for significant digits, and checking against limits. Third, the data is reported. Fourth, the LIMS provides support for lab management functions such as sample tracking and workload assignment. Finally, the LIMS contains a number of system management functions, such as the audit trails and archival functions.

The various functions will exist to some extent in all automated LIMS; however, the breadth of functionality varies from system to system. In a Minesite lab, it makes sense to review the available options with the vendor and decide which are to be included and which omitted. These options include such things as invoicing and costing, inventory control, instrument interfacing, sample scheduling and sample storage. A quality control module is another important feature.

Features that have emerged recently include Internet protocols such as hypertext transfer protocol (http) or "sendmail". Applications include the transfer of reports to clients via e-mail and online access to data through a web interface. Some LIMS allow client departments to pre-register samples through the Internet..

Hardware components of the LIMS cannot be neglected. The Minesite LIMS will typically operate using a server computer running an operating system such as Windows NT or Windows 2000, and through a number of PC workstations. We recommend a robust server with plenty of memory and redundancy. Inadequate servers harm system performance with slow transaction speeds and unreliable performance. The server needs to be fast and reliable.

We use dual processor machines with redundant power supplies and hard drive arrays. The servers should be protected by uninterruptible power supplies and adequate data backup systems. We use digital audiotape drives for short-term backup and archive the databases to CD-ROM for permanent storage. Although a 10-Mbps network is generally adequate for a LIMS application, 100–Mbps LAN’s provide ten times the speed for very little extra. Remember, however, that in a well-designed Client/Server LIMS, the network is unlikely to be the major speed bottleneck. Installing the network and cables can be a major issue depending on the laboratory's physical layout. The building's architecture often does not allow easy paths for cables between floors or rooms.

Some laboratories look for systems that will run on existing hardware. This decision can be a serious mistake. The rapid evolution of computer hardware and software means that existing hardware may not be able to adequately support future upgrades. We recommend that the laboratory invest in new, more powerful hardware at the time of implementation.

IMPLEMENTATION

Planning is the first step in implementing a new LIMS, and the first step in this process is to evaluate the laboratory's information resource needs. If there is already a LIMS, how does it operate? How does it interface with other business and quality systems? What works well, and what weaknesses are observed?

Users, including analysts, client departments, and management, need to be involved from the beginning. They are the people who will have the best perspective on how the new system should work. Additionally, early involvement can help build user acceptance of the change. Resistance to change may be the biggest cause of failure in implementing a new system. The planning stage provides an opportunity to anticipate problems and educate the users on the project.

Client departments should be involved in the LIMS specification, since they are the ones most likely to benefit from its’ implementation. They should be asked about the concerns they have with the present system, and what features they would like to see in the new one.

Management commitment is an absolute requirement. Managers need to clearly delineate the goals to be obtained by implementing the LIMS; communicate that the change is desirable; encourage cooperation and coordination among the users, clients, and system implementers; and ensure that adequate financial and staff resources are available to implement the system. The project will fail without these commitments from the laboratory manager.

A key decision for the laboratory manager is the assignment of the project manager. Responsibility and authority must be clearly delineated. In most Minesite laboratories, the project manager is probably the system administrator who will manage the LIMS. The project manager needs to be familiar with laboratory operations and information technology, and, in the early stages of the project, be able to translate data management objectives into specifics that will have little adverse effect on laboratory operations. Planning requires a good understanding of the laboratory operations and the culture. The project manager must clearly communicate the project goals and status to the laboratory managers and other users.

The system administrator needs to be sufficiently trained in information technology to be able to install, configure, and manage the LIMS and supporting hardware. Ideally, system administration should be a full-time position. However, we realize that in a small, Minesite lab, this is often not practical. In this event, it is essential that the LIMS be self-maintaining as far as possible, and that a vendor representative is available who can liaise closely with the part-time administrator. Ideally, the vendor representative should have an in-depth knowledge of the laboratory operation.

The general operation of a computer-based LIMS requires knowledge of computer networking and database administration. When a laboratory analyst is assigned to administer the system, computer training is essential. In addition, the administrator must know the culture and business practices of the laboratory.

PLANNING FOR CHANGE

Planning for the LIMS involves clearly defining the information flow, the structure of the generated data, and the user requirements. Flowcharts showing where and how data is generated, transferred, and stored in the system are very useful. These charts should include decision points in the process, such as QC data evaluations, or requirements for supervisory approval before the release of reports. Existing infrastructure, such as the computer hardware, instruments, and computer network, needs to be inventoried to gauge the scope of the project. This evaluation also helps the laboratory define the new system requirements and better understand its business processes. Failure to do this will likely result in the design or purchase of a LIMS that does not meet the laboratory's needs.

The second step is to define the expectations for the system. It is very easy to imagine ways in which the lab workflow can be automated. However, ensuring that expectations stay in line with what can reasonably be achieved is difficult. At this step, budgetary and personnel considerations are projected. In drafting the specifications, the laboratory should identify the issues and features that are critical and distinguish them from desirable but nonessential features. The laboratory will probably need to make tradeoffs between cost and features. Flexibility is essential because every unachieved goal provides a focus for doubters to object, which can delay and disrupt implementation. Nevertheless, the laboratory must ensure that it allocates sufficient resources to implement a workable solution. Inadequate funding could lead to a system that cannot meet expectations, lacks essential features, and delays implementation.

VALIDATION AND DISASTER PREPAREDNESS

LIMS validation is an important issue for many laboratories, and a requirement for regulated ones. The laboratory should develop a formal plan for validating the system, including the test data and acceptance criteria. The validation plan should be established before purchasing the LIMS and include how the validation will be documented and how the records will be retained. The LIMS must be extensively tested to ensure that it processes and stores the data properly. Evaluation is an ongoing process to ensure that configuration changes work and that data have not become corrupted. The system needs to include a change control procedure and audit trail to document changes.

The first step in testing the system is to use normal, boundary value, and invalid data sets. Outlying data must be handled properly, and invalid data should be trapped by the software. Data validation is generally conducted with an off-line system using simulated data, which protects the integrity of the online system and databases. The validation plan should test all input and output points, such as data entry screens, printers, and data import routines, to ensure that the data is transferred properly by the system. Before implementation, the laboratory should perform a system "stress test", which is a dynamic test using large data sets that focuses on possible weak points in the system. Records must be retained and labeled with what was being tested and whether the results met the test specifications.

The laboratory will need to establish a backup and data recovery plan to assure system security in case of an emergency. We protect the electrical components of our network and servers with an uninterruptible power supply and line-conditioning equipment. We have built redundancy into our servers, including RAID (redundant array of inexpensive disks) drive technology to protect against short-term loss due to a hard-drive failure. We use a tape system with off-site storage for short-term backup protection, and we archive databases to CD-ROM for long-term storage. (Recent price drops in writer technology have made CD-ROM storage particularly attractive.) Another solution is to ensure that the LIMS source code is held in escrow to protect the laboratory against the possible loss of support by the vendor.

CONFIGURATION ISSUES

Once the LIMS is installed, it will require additional work before it is ready for use. The administrator will need to populate static data tables, configure interfaces, design reports, and test the system to ensure that it functions properly. At this point, detailed information on lab processes and the feedback from the users becomes most important. We recommend that the laboratory installing a new LIMS discuss these issues with the vendor. If the vendor representative has a background in mineral analysis, he may be called upon to assist or even carry out this task. In any event, it is vital to involve the administrator fully at this stage.

Populating the static data tables is a sizable task. The laboratory must define items such as sample types, tests, instruments, user IDs and passwords, and much more. Any item that the lab desires to be accessible through a "pick list" must be entered into the appropriate table.. The benefit of configuring these tables beforehand is that is that uniformity is achieved in the data, but maintaining the tables is a major task.

Data definitions will also be critical in the migration of data from older systems to the new LIMS. Data conversion can add significantly to the complexity of implementing a LIMS project, particularly if the older system is not well documented. Converting the older data and the semantics of the data will require a thorough understanding of the underlying structures of the old system. Data migration services are often available as a part of the vendor's implementation support package.

Connecting the LIMS with other computer systems can be very difficult with proprietary systems, and, therefore, we recommend the purchase of software components that have open architecture and are widely available. The vendor should also provide a fully documented definition of the LIMS database structure, which is essential for accessing the stored data. Moreover, the data definition provides a glimpse of how the software works and greatly aids in solving problems. In many cases, it enables the lab to determine why an error occurs and fix it by "tweaking" the configuration. In others cases, the lab will be able to clearly identify a problem to the vendor's technical support staff and solve it quickly.

Interfacing instrumentation to a LIMS can be a complicated process. Since most modern instruments are PC-driven and are able to export data as text or spreadsheet files, we recommend a LIMS package that is able to read and import these files easily, without having to call up the vendor each time a change is made. Some packages allow even tighter integration of the LIMS and instruments. A potential problem with tightly integrated systems is that instruments not supported by the LIMS vendor cannot be interfaced.

The laboratory will want to review and modify any vendor-provided reports or create a series of custom reports. The real power of the automated LIMS is the ability to query and organize the data rapidly. Programming and reporting tools, such as InfoMaker and Crystal Reports, have made this an easy task..

Training on the LIMS is best done in increments. Because a modern LIMS contains a bewildering array of features, we have found that it is best to teach the users to master the basic data entry and retrieval functions and then move on to more advanced features. The system administrator conducts a demonstration, and then personnel are assisted through their initial attempts to use the system using simple checklists and flowcharts for reference. Training and documentation are particularly critical when implementing a new system, because the user cannot obtain assistance from an experienced colleague. Similarly, we implement a new system test-by-test and laboratory-by-laboratory to allow more interaction with and support for the unfamiliar system. Support and training will be major ongoing issues throughout the life cycle of the LIMS.

In the process of installing and implementing the system, even the best prepared laboratory can expect to encounter unforeseen delays and interruptions in the normal workflow. Planning can minimize these problems. The laboratory management must expect that these problems will occur and be ready to take an active role in mediating the disputes that will arise. The laboratory management has to maintain this commitment throughout the lifecycle of the LIMS. A successful LIMS implementation will involve an ongoing process of evaluation and modification. With careful attention and a sincere commitment, implementation should result in significant improvements in the way the laboratory does business.