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An Information System to Support Calibration

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Abstract

The National Institute of Standards and Technology (NIST) performs calibrations that achieve the highest level of measurement quality for the makers and users of precision devices. The information system that administers these calibrations should be of the same high quality and reliability. The devices that NIST calibrates cover a wide spectrum, ranging from physical measurement standards to software algorithms. Such a diverse set of equipment types put a tremendous strain on the development of any supporting software, having to cover a wide variety of extremes. This paper describes the information system used by NIST to support their calibration program. It describes the processes used to design and implement the system along with details of its use by the technical and administrative staff. Although the system was initially designed for a single calibration program, it has been readily extended for use throughout the entire NIST calibration program. The system is World Wide Web (WWW) based using an Standard Query Language (SQL) database and the Practical Extraction and Reporting Language (PERL), and therefore not reliant on any particular commercial product.

Background

NIST has performed calibrations of precision instrumentation and standards for many years. The system maintained by the Calibration Program, the central office for administrative support of calibrations, was a System 2K (S2K) database, and administratively kept track of items sent in for calibration. Since it was designed over fifteen years ago and had surpassed its intended useful life, a new system was needed.

There are fourteen different divisions at NIST that perform calibrations, with each division averaging two or three separate calibration groups. Each division informally maintains their own financial and historical calibration data which is vital to the fiscal and technical management of a division. Each group implemented their own systems, with no regard for consistency or interoperability. This led to a wide variety of software used by each division to track and maintain their calibrations, along with the Calibration Program's System 2K (S2K) database. The Calibration Program's database focused primarily on the needs of NIST as a whole and not on the individual needs of the divisions. An updated system was needed to meet the technical requirements of the individual calibration programs.

One of the divisions, the Electricity Division, performs approximately 20% of calibrations at NIST. In May of 1995, this division formed a committee to explore ways to improve the quality of the calibration process within the Electricity Division. This team was part of a Total Quality Management (TQM) effort within the Electronics and Electrical Engineering Laboratory (EEEL). A Calibration Process Improvement Team (CPIT) was formed and comprised of a facilitator, and representatives from Management, the Calibration Program, and from each of the calibration areas within the division. The calibration areas of the division include Resistance, Impedance, Voltage, Precision Ratio, Phase Meters and Power and Energy. The CPIT met frequently over the next year. The goal of the CPIT was to identify problems with the calibration process and recommend solutions to rectify the identified problems. This effort served to strengthen the calibration process, making it acceptable to the division staff, the Calibration Program personnel, and the calibration customer.

Identifying the Problems

The first problem identified by the CPIT was the time the technical calibration personnel were spending on administrative requirements of calibrations. Too much time was being expended on administrative functions rather than on the calibration itself. Responsibilities of the technical personnel included submitting cost information and a calibration report for each item calibrated. Most costs are fixed (i.e., have a set price), but many are "at cost" and the final price must be computed after the calibration is done. The calibration personnel determined the cost of the calibration by computing a "time and

materials" cost using a special form, which accounted for all overhead costs incurred by NIST. This form could take a considerable amount of time to fill out, with much of the time spent tracking down the overhead rates. The submitted forms had to be hand typed, sent to the Calibration Program, and then on to Accounts Receivable for billing.

Generating the calibration report also presented problems. To prepare a calibration report the technical staff used a plethora of text preparation packages. These packages ranged from simple FORTRAN programs to complex word processors. And once the report was generated, the technician archived a copy on their local system for future reference. Each report was either generated from a template of a previous report or generated from scratch. As technical people left, their replacements used the existing system to generate reports or developed their own style. The reports themselves carried no specified format. Each calibration service maintained its own style, with no consistency across groups, much less across the division. Some services were inconsistent from calibration to calibration.

The CPIT felt that this process could be automated, relieving the calibration staff from some of the administrative duties. In the process, the calibration reports could be "standardized" so that reports from the Electricity Division would maintain a common look and reporting style. Most reports contained information explaining the measurement process used, the uncertainties, temperature and other ambient conditions. The reports were modified to include a "fact sheet" to explain the measurements and other factors, resulting in clear, concise reports for the calibration customer.

Historical data on the equipment being calibrated was stored with previous calibrations, usually on three by five index cards in a filing cabinet. This meant no readily available means to regenerate calibration reports. Also, historical information on a item sent in for calibration was not readily accessible. Using a database, historical data could be maintained and easily retrieved. Calibration personnel could have quick and easy access to prior results for use in the current calibration. Backups would prevent data loss or inadvertent destruction. Historical data would not be affected by changes in personnel.

The last area identified, and the most major, was in customer service. The calibration process can be viewed as a business, and as in any business, one of the major goals is customer satisfaction. Under the old system, customers knew little, if anything, about

their instrument sent in for calibration until it was returned. The CPIT felt that increased communication with the customers was vital for the calibration services. A technical contact at each company could be identified and information on the calibration sent to them directly. Communications with the customer was "a must" in order to better serve them.

Some other areas noted by the CPIT were: 1) reduce effort needed for administration, 2) store customer addresses and contact information in the database, 3) improve workflow tracking, 4) notify staff of new work via email, and 5) fiscal and workload reports.

Design Goals

As a result of the CPIT meetings, it was recommended that a database be developed to support the entire calibration process. Such a database would have to use industry standards, be easy to use, provide access to all types of computers and operating systems (e.g., not be system dependent), use email for notifications, provide protection to calibration data and print to any networked printer. A simple task by any means!

Another recommendation from the CPIT was to focus on improving customer service. The calibration system would have to provide status information to the customer on their equipment in for calibration.

With very little internal funding available, the design process did have the added constraint of "little to no " software costs. With as many as 60 users in one division alone, any added "per user" license costs would make the software goal unobtainable.

The first goal of zero costs, but great software, was achieved by using the database provided by the NIST Information Technology Laboratory (ITL). Using overhead funding, ITL had purchased an SQL database for use by the laboratories. With the database in place, we needed to provide access via the network to all types of computers, running differing operating systems. To avoid having to port any client software to each harware and software platform, we chose a WWW browser as the interface to the database. Browsers were available for every machine, and we would not expend any

effort porting the application. Browsers are available to all NIST personnel, and only older versions of the browsers would present a problem (e.g., we took full advantage of new capabilities in newly released versions). Personnel were advised to upgrade to the latest versions of their browser for best results.

The WWW interface saved us numerous hours of development, and allowed us to build our software as new developments to the WWW were being made in parallel. The Common Gateway Interface (CGI) provided the ability to access the database and dynamically generate the resulting page using HTML. The WWW was a new and exciting technology that fit the requirements of our database perfectly. The database also put a new spark into the mundane part of the calibration process.

System Implementation

The system has been in development for three years now, mostly part-time by two people, programming as time allowed. We have expanded it vastly, taking advantage of developments in HTML and WWW technologies as they occur (e.g., tables did not exist when we started, but were incorporated after a few months of development). The most time consuming task is the CGI programming, which is done in PERL. Each page is programmed individually, but common routines are in a library and accessed by many pages. We have divided the system into four major areas and can allow access independently to each. The administrative area is for managers and Administrative Officers, and provides numerous revenue reporting facilities. The data entry area is for the maintainers of the database. All purchase order information is entered and changed in this section. Access to this area is restricted to the few who perform this task, making the data more reliable and limiting unwanted changes or mistakes in the database. The third section is for the Technical Personnel, who can check on waiting calibrations, enter calibration data and generate calibration reports. The last area is for Customers, who can access a status page for each current calibration. This area will be discussed in a later section.

Dividing the database into discrete sections allows us to maintain proper security controls on the data contained within it. Each person has a specific function in the calibration process, be it entering purchase order data, or submitting calibration data, or running fiscal reports. Using the security mechanisms, we can allow access by personnel

only to the areas they need to perform their function. (e.g., administrative staff cannot enter technical data or print calibration reports, and technical staff cannot generate administrative paper work, other than the NIST Form 77 for time and materials costs they require.) This separation of powers is a fundamental principle of a database, and ensures proper controls and data integrity.

The last two years have been spent generating pages for the technical and administrative staff to perform their specified functions. The pages are designed and implemented, used by the staff, feedback provided to the programmers, refinements made and the pages changed, then the process started again. Using this process we have developed an information system designed specifically for the NIST staff, providing both technical and administrative support in a single database. Each page has been finely tuned to the technical and ergonomic needs of the staff, a feat not possible with a contract programming exercise.

Security

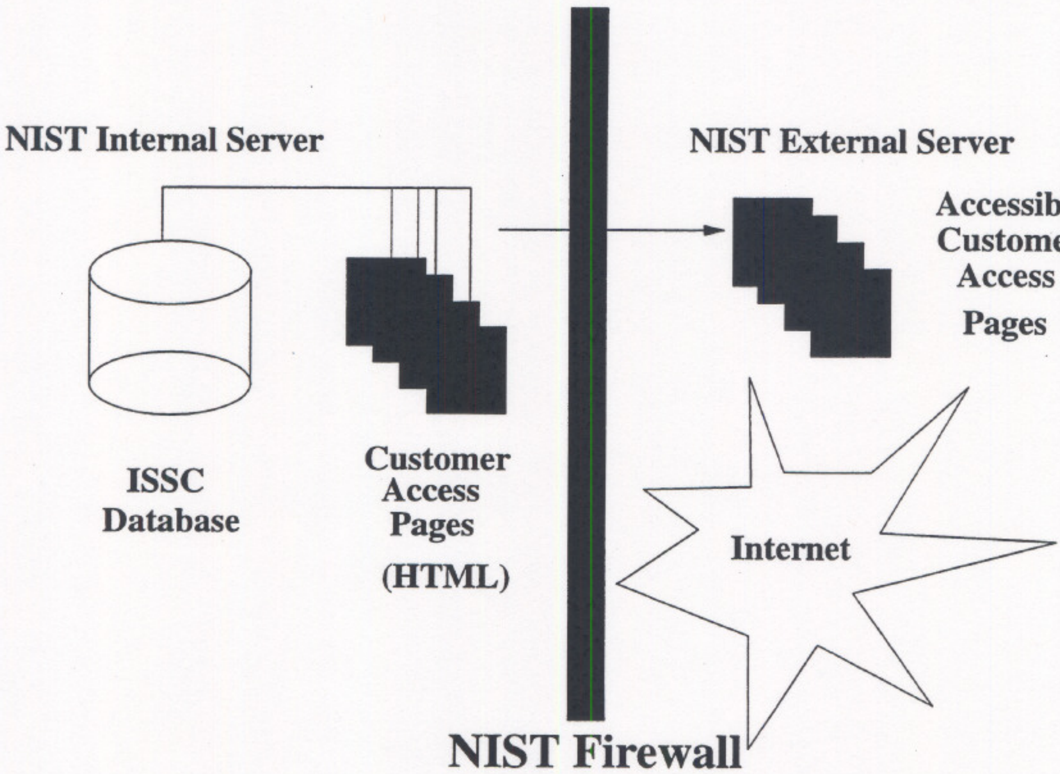
As we mentioned above, the calibration process is a business, and we could not allow any one customer to see another customer's calibration data. In fact, one customer is not permitted to know another customer had an item in for calibration. So, limiting access to the database to unauthorized users was a top priority.

The database was an "Intranet" resource, so only NIST personnel on the campus needed access. The first security step was NIST's installed firewall around the campus restricting access to the database from the Internet. The second security measure, each instance of the database can be further restricted by limiting access to the database by subnet. This prevents users in one lab from gaining access to another lab's version of the database. The last tier of the security triad is the username and password. Each user is issued a username and password to gain access to the database. These three security measures, firewall, domain restriction, and username/password provide suitable security for the database. The username/password is implemented via the web server security mechanism and is undergoing constant development and upgrades, as is the firewall. The last problem was to provide internet access for customers to calibration status information, while maintaining the high level of security.

Internet Access by Customers

Since the database sits behind an internet firewall, providing access to customers was not as easy as just generating a web page for them to view.

Figure 1. External Customer Access



Internet firewalls require a pass key for access and are quite complicated. Since the customers could not access our internal pages, we had to make the pages accessible outside the firewall. Every hour, on the internal server behind the firewall, a job is run that generates a web page for each open calibration and for each calibration closed within the last thirty days. This allows customers access to shipping information while the item is in transit. The pages are then propagated to the external server. The web page details the status of the calibration, whether it is awaiting calibration, in progress, or in the review

process. Relevant dates are also available, including among others the date the report was printed, the date the calibration was finished and the date the equipment was shipped back to the customer. NIST technical personnel responsible for the calibration can be reached via the provided phone number or email address. The latest shipping and billing addresses are also available for customer verification. In order to ensure that a customer has access to only their web page, a username and password is required. When an item is received for calibration, a NIST form 64 acceptance letter is mailed to the customer. This form contains the estimated cost of the calibration, verifies receipt of the item for calibration, and provides the NIST technical contact(s) responsible for the calibration. A machine generated password, along with a username is provided on this form. After receipt of the NIST 64 acceptance letter, the customer can then access the Universal Resource Locator (URL) of their status page, 24 hours a day, seven days a week. This web page is accessible to the company who submitted the respective equipment for thirty days after the calibration is completed.

Expansion to NIST Calibration Program

Once the ISSC was in use by our division, other calibration divisions at NIST heard of its existence and requested demonstrations of the system. After a few demonstrations, one other division wanted to know if there was any way possible for them to use it. The administrative requirements for each division across NIST are identical, with the only differences in the items being calibrated. Since the only differences were in the information stored in the database, replicating the system involved populating the database with their initial cost information, item descriptions, and staff listings. Having separate instances for each division was just a distributed database implementation, with none of the data replicated among databases. Each division can run fiscal and turn-around time reports, that only gather data from their calibrations, reporting on only their data. We also had to build new templates for calibration reports that differed from our own. For example, thermodynamic calibration reports were very similar to ours, only different wording in the report. This let us start a few services in other divisions printing calibration reports immediately. Again, the reporting style and format of the reports would spread across NIST.

The Calibration Program requested an interface to the Information System to

Support Calibrations (ISSC). The ISSC contained all the administrative information they needed, so their S2K database would be discontinued, and the ISSC would become the NIST standard. Since each division was generating reports, we needed to create "Views" for the calibration program that looked at all the divisions as a single entity. This would allow the calibration program to generate reports combining all the divisions, and report on the NIST calibration program as a whole. Each division would be autonomous, control their own data, and the calibration program would oversee the fiscal reporting for NIST.

The last area that needed to be addressed was the Accounts Receivable and billing functions. The old S2K database fed data weekly to the main NIST accounts receivable database to enable customer billing. The Chief Financial Officer's (CFO) personnel are the only ones that have access to the billing functionality. We designed a WWW based front-end for them, which allows them to bill folders as soon as the technical divisions close them out. We improved the quality of the bills by generating Portable Document Format (PDF) versions of the bills, based on customer type. The correct bill is generated, and a PDF version sent back to the browser for printing and mailing.

Committee Support - the ISSCOC

Once the system was in use by other divisions, a committee was formed to oversee operations and upgrades to the system - The Information System to Support Calibrations Oversight Committee (ISSCOC). One member from each calibration division, the CFO's office, the Calibration Program and ITL comprised the committee. The committee prevented any influence from any single division, and made the database truly a NIST resource. The committee meets monthly, and new issues are discussed and voted upon. Changes and bug fixes are discussed, and only approved on majority approval. The committee also discusses items related to calibrations, and not necessarily to do with the ISSC. It has developed into an excellent forum to discuss many calibration issues.

Future Goals

The main thrust of the next year will be creating templates for calibration reports. Data already exists in the database, generating calibration reports will be an ongoing programming project. We start with divisions that have reports similar to ones already being generated, and will then move to the more difficult reports. The goal is to have everyone wishing to print calibration reports doing so by the end of the next fiscal year.

Another area of research uses iButton technology. An iButton resembles a watch battery, with a physical size about that of a nickel. The iButton contains a small JAVA virtual machine, and about 6K of available non-volatile memory. Information, such as a calibration report or calibration data can be written to the iButton, and physically stored with the artifact. Access to the iButton is protected by a username and password controlled by the JAVA virtual machine. Data required by the ISSC such as model number, serial number, and manufacturer can be stored on the iButton and read electronically when the item is received for calibration. Customers could also be provided readers and have access to all information stored on the iButton. The costs of the iButtons is minimal, and the readers are inexpensive as well.

Summary

The ISSC will be in use across NIST by the start of fiscal year 2000. All calibrations done at NIST will be entered, tracked and billed using the ISSC. The customer access pages will be available by August 1999, as soon as the NIST firewall is complete.

We did achieve the goal of "minimal software costs", using shareware (PERL), and the ITL ORACLE database. The only cost was the staffing to initially design and build the ISSC. With no recurring software costs, future funding can be spent on upgrades to new web technology, greatly extending the useful life of the ISSC. Some programming tasks can be assigned to summer students, who have proven to be an excellent source of programming expertise.

To access the ISSC, a staff member needs a "vanilla" browser. All documents returned to the browser are in the PDF. After viewing the document, the user can print a

hardcopy version to any available printer.

The complexity of the ISSC prevents it from being purchased as "off-the-shelf" software. Contracting out this work would have been relatively expensive. The in-house development of the ISSC brought together the many people involved in the calibration process to work together towards a common goal. The end product is a high-quality calibration program, supported by the NIST community.