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DEVELOPING A SYSTEMS INTEGRATION TOOL FOR UTILITY DATA

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ABSTRACT

The Facility Resource Energy Data (FRED) project first started in 1993 as a project team assessing the needs of the utility system at the U.S. Department of Energy's Hanford Site. It was decided that the amount of manual data entry and use of Lotus 1-2-3 spreadsheets (in DOS) was inadequate to continue producing Site electric bills. A tool was sought to integrate and control the stand-alone metering systems, analyze, and distribute utility-related data.

The team quickly realized that the number of meter points, diverse data streams, and redundant metering systems precluded the use of "off-the-shelf" utility management software. A systems integration tool was needed that could utilize existing software and add needed features without re-inventing existing ones. The solution was a systems integration tool called FRED.

FRED is really a suite of unique software modules and tools wrapped around existing software. In addition to its own features, FRED utilizes analysis and/or graphics from PCDAS data logger configuration, Adobe Acrobat™, Microsoft® Excel, Microsoft® Access, SRC's Metrix, and the Whole-Building Diagnostician (WBD). Having full control of the native code allows on-site programmers to make changes to the software when needed.

Various technical and organizational hurdles were encountered during FRED's implementation. Existing software was upgraded to communicate with FRED via DDE and OLE. Y2K compliance testing drained some of FRED's resources. Training was also needed to get the utility group's computer skills up-to-date. Each set of contractors at Hanford expressed different data needs. To meet these needs, FRED had to provide the greatest level of detail for those with in-depth needs as well as summary-level reports for the more casual user. The most difficult task was to get data producers, data users, and financial folks to accept this new way of doing things.

FRED's scope recently expanded to include an Internet-based module, with complete implementation occurring by the end of fiscal year 1999. The lessons learned during FRED's development will be useful to others who face similar problems, especially Federal sector sites.

INTRODUCTION

The U.S. Department of Energy's Hanford Site in Richland, Washington, once a nuclear weapons production center, is now dedicated to environmental cleanup of waste from its former mission and energy research. The Site consists of

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1,350 buildings scattered over 1,476 km^2 (570 mi^2). Many of the facilities are over 40 years old, and only recent history has seen an effort to install metering at the building level. Although one might presume that our predecessors were short-sighted to meter only the Site total, the metering met the needs at the time.

The history of metering at Hanford represents a path similar to other large, Federal facilities. Initially only total metering was provided, and additional meters were installed piece-meal over time. Thus, facilities are faced with a lack of either detailed energy data or an affective means of handling data from a variety of meter sources.

Today, the Energy Policy Act, Executive Order 12902, and Executive Order 13123 requires Federal facilities to reduce energy use. These orders dictate that facilities install more metering to document progress towards reduction goals and to better understand energy use at a facility. Additional trends in the Federal sector include a greater participation by sub-contractors, external organizations, and out-sourcing of activities to reduce costs. Each of these activities require more detailed energy data for cost reimbursement. Now with the cost justification for metering, we are seeing an explosion of metering points at Federal facilities.

With a renewed push for metering, facilities also experience a new problem – getting different metering systems to work together and provide accurate, reliable data in a timely fashion. Very few facilities have the luxury of purchasing complete turn-key automated metering systems. Therefore, facility managers are faced with the task of integrating, often outdated, metering equipment into an efficient data collection system.

The utility data tool developed for Hanford represent a solution to a set of problems that may also exist at other large Federal facilities.

SITE SPECIFICS

After 1998, the primary utility at the Hanford Site is electricity. To a lesser extent, steam, potable water, fuel oil, and vehicle fuels are available. The distribution of energy use by fuel type is shown in Table 1. Note that Hanford's coal plants, a major energy consumer, were retired in 1998.

TABLE 1. ENERGY USE BY FUEL TYPE

Fuel Type	FY1996 Fuel Use, MBTUs
Electricity	3,739,420
Fuel Oil	243,187
Natural Gas	20,807
LPG/Propane	1,279
Coal	7,460,390
Gasoline	220,175
Diesel	1,248

Electrical Metering

In the early days, electrical metering existed only at the substation level. Metering was necessary because the electrical system wheeled power for Bonneville Power Administration (BPA). Routine electrical metering of buildings and processes began in earnest during the late 1970s. Many, but not all, facilities are currently metered. Facilities that aren't metered require loads to be distributed and/or estimated.

Hanford electrical service is provided by Hanford Electric Utilities, the City of Richland, Benton County Public Utility District (PUD), and Benton

TABLE 2. HANFORD ELECTRIC PROVIDERS

Provider	Meter Type	Count	Reporting Method
Hanford Electric Utilities	Automatic Data	283	Electronic Time-Series Data.
Hanford Electric Utilities	Manual Meters	531	Hand-held meter reader generated report.
City of Richland	Manual Meters (some automatic)	85	Monthly paper bills. Monthly electronic download.
Benton County PUD	Manual Meters	10	Monthly paper bills, yearly electronic data.
Benton County REA	Manual Meters	3	Monthly paper bills.

County Rural Electrification Association (REA). The Site contains approximately 912 electric meters, with about 5 new meters installed monthly. (see Table 2)

Hanford Electric Utilities operates two separate metering systems; manual meters and automatic data loggers. The manual meters are read monthly by a meter reader who enters the readings into a hand-held computer, which downloads these data to a database on a dedicated computer. The automatic meters are connected to electronic data loggers that communicate with a central computer nightly via shared phone lines. The data loggers were developed by Pacific Northwest National Laboratory for a large, regional end-use monitoring program in the mid-1980's and recycled for use by the Hanford's metering program. Each logger has analog and digital channels capable of recording time-series data for 16-32 metering points.

The two metering systems are pseudo-redundant - that is they partially overlap each other. The automatic meters were installed to supplement the poor quality and unreliability of manual meter readings. A complete switch to the automatic meters has never occurred because the communication mechanism, shared phone lines, is not completely reliable either. The incomplete overlap of metering systems, the unreliability of those systems, and the unmetered and estimated loads make the Hanford electric system a difficult one to monitor.

Water

Less than one dozen water meters are present on Site, located only at the main pump houses. Buildings served by Hanford utilities are not charged directly for water usage since building-level water usage is unavailable. Buildings served by the City of Richland are charged for actual use as shown on the monthly billing.

Steam

In 1998, the two coal plants providing space heating and process steam were replaced with smaller oil and natural gas boilers, installed and operated through an Energy Savings Performance Contract (ESPC). The ESPC contractor purchases natural gas from Cascade Natural Gas and produces steam for the Site. The ESPC project has produced a dramatic cost savings through reduced energy use.

Other

Several facilities use natural gas provided by Cascade Natural Gas. Fuel oil is also used in very small quantities. Fuel for vehicles is provided at two contractor run service stations and reported on a yearly basis.

THE PROBLEM

In 1993, with the growth in metering and downsizing within the Department of Energy, management began looking at the way utilities were metered, data processed, and reports generated. (Hadley, 1995) A study was commissioned to assess data needs and how they were addressed. A team representing the various contractors on Site, undertook the task of identifying options for a new data processing tool for Hanford.

The first criteria for a new tool, would be to reduce the number of manual tasks involved in collection, processing, and validation of utility data. The tool could also save manpower by providing an automated mechanism for responding to data requests. Secondly, the new tool would need to work with the current manual and automatic metering systems, to eliminate the cost of replacing those systems. Most importantly, the tool would need to handle Hanford's redundant metering systems, selecting data from the most accurate source, and allocating energy use or providing estimates where metering of facilities was incomplete.

These issues precluded the use of "off-the-shelf" utility management software. In 1993, the software simply didn't exist that could meet all of Hanford's requirements. The most sophisticated tools couldn't handle Hanford's "two meters on a single point, choose the best value." Even today's software (circa 1999), would require a great deal of customization and additional programming to handle Hanford's complex set of tasks and reports.

The decision was made to develop a systems integration tool that could utilize existing software without having to re-invent functionality currently existing in other software. The tool would need to automate data collection and validation tasks, handle redundant meter systems, and produce custom reports. It also had to be flexible and modular so features could be added directly applicable to different organizations. (Chvala, 1995) Developing

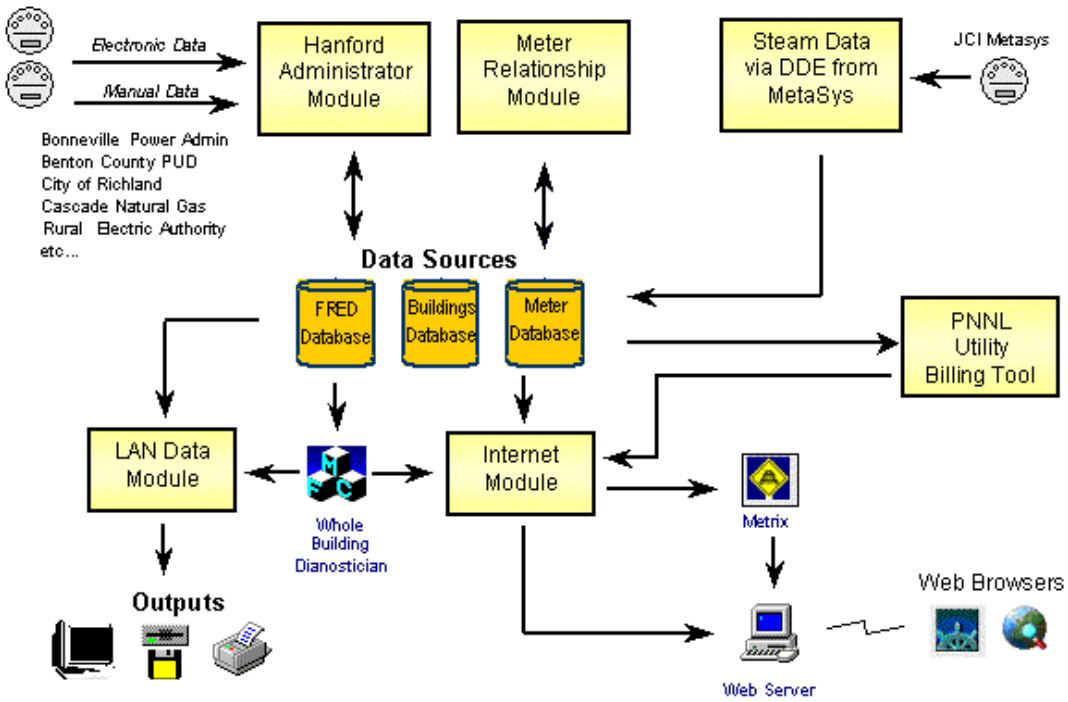

FIGURE 1. SIMPLIFIED FRED SCHEMATIC

the tool in-house meant greater control over current and future development.

THE SOLUTION

The solution to Hanford's problem was found in a systems integration tool to provide pre- and post-processing of data from existing software, and manage other software modules with distinct functionality. Its goals were to be accessible to a large number of people on Site at no additional cost, have the ability to automate data tasks and reporting, be able to link to databases or import data stored on various servers, and be flexible to accommodate changing needs.

A development environment used for multi-media energy-related kiosks, Asymetrix Toolbook™, was selected as the development environment for Hanford's tool. Toolbook™ addressed the defined development goals allowing maximum flexibility and distribution at the lowest cost. It allowed programmers to utilize Microsoft® Windows® features like Dynamic Data Exchange (DDE), Object Linking and Embedding (OLE), and query databases using Structured Query Language (SQL) via Open Database Connectivity (ODBC) calls. Linking to databases across the Hanford Site ensures access to the most up-to-date data available. The tool's most important aspect is that it interacts with other software – the data logger configuration software, Microsoft® Excel, Microsoft® Access, and SRC's Metrix™.

Hanford's tool is named Facility Resource Energy Data (FRED). It is constructed of a series of interconnected modules, each performing a distinct task. Its modular nature allows new tasks or routines to be added as needed. Figure 1 shows a simplified schematic of the modules.

The Administrator Module and the Meter Relationship Module are designed for system administration tasks. The Administrator Module allows utility staff to manage the data collection, validation, billing, and reporting of utility data. The Meter Relationship Module maintains and tracks the meter relationship hierarchy, meter configuration information, and handles the important task of by generating usage equations used to determine energy use for buildings .

The Local Area Network (LAN) Data Module and the Internet Module provide utility data and reports to a wide range of users via the Intranet or the Hanford Local Area Network (HLAN). Both

TABLE 3. TEN OBSTACLES

	Problems	Difficulty	Solution	Type
1	Redundant Metering	"Off-the-shelf" software not applicable.	Hanford "virtual" meter denotes real-life manual and automatic meters.	Technical
2	Organizational Momentum	Difficulty moving from the way things have "always been done." Out-of-date computer equipment and skills.	New system built to look like the old way of doing things at discrete points. Upgraded equipment and skills.	Technical / Management
3	Differing Contractors Needs	Some contractors want more detail, some less, others custom reports and analysis.	Build for the lowest level of detail and aggregate up. Modular nature of tool allows parties to add their own features.	Technical
4	Existing Software	Not efficient to reinvent existing tools.	Structured as a systems integration tool.	Technical
5	Steam Data	Unwillingness to provide data by ESPC contractor.	Only solution is contract modification. Lesson learned: "Write it in the contract."	Management
6	Providing Data Access	Data provided manually on request.	Data access provided free via Intranet or LAN.	Technical
7	Bill Reconciliation and Reporting	BPA data, wheeling power, billing, and reporting.	Reconcile all costs to BPA total cost and automate reporting.	Technical
8	Scope Creep	Development continually identified additional functionality or reports.	Manage scope creep and provide for contingencies.	Management
9	Software Implementation	Difficulties training, testing, and implementing.	Long development time and subcontractor facilitated implementation.	Technical
10	Year 2000 compliance	Difficult to test a complete set of inputs. Dependent on many providers of data whose systems could fail.	Construct complete set of dummy data and test for future years.	Technical

modules provide access to usage, cost, and various reports, while the LAN Data Module also includes a rate schedule analysis feature.

Additional modules have been added to accommodate unique needs. PNNL developed a Billing/Forecast Module focused on budgeting, financial tracking, and load forecasting. Another module is currently being tested that uses the Whole-Building Diagnostician (WBD), a building energy diagnostics model developed by PNNL, to provide on-going feedback of building operation to building managers.

System Requirements

FRED is designed to run on a Pentium personal computer running Microsoft® Windows95 or WindowsNT and must be connected to the HLAN. The runtime version can be distributed freely and no additional licensing is required. The only software requirement is that the users have access to Microsoft® Office which is provided by site license at Hanford. All other data and database functions are accomplished using ODBC links to databases on other Hanford servers from within the Windows environment. To access data using the Internet Module, the user needs an Internet connection and a browser such as Microsoft® Internet Explorer (version 3.0 or greater) or Netscape® Navigator (version 3.0 or greater).

DIFFICULTIES AND ISSUES

Satisfying Hanford's needs didn't happen quickly. Over three years, the tool's architecture changed several times to account for difficulties encountered during development. Table 3 lists the ten most difficult obstacles encountered during development. A detailed discussion of each obstacle and the developers' solution is provided for a better understanding of how the tool addressed Hanford's needs.

Problem 1: Redundant Metering

The incomplete overlap of metering systems, the fact that neither is completely reliable, and the number of unmetered and estimated loads complicates the

allocation of energy usage. Most utility management software packages expect a single meter on a single building, although some allow users to distribute loads to a group of buildings based on some criteria. However, none that we could find could take two meters, provide some checks to see which were the preferred, and determine if it fit historical trends.

To handle somewhat overlapping metering, a Hanford "virtual meter" was created to represent a metering point. Each point then could have various meters attached to it – manual, automatic, or both. When the Administrator Module collects these data, it checks the validity of all readings and selects the best value and records that value for the virtual meter. If the value is outside of an adjustable threshold or any other problem arises, it generates an error message, which a staff member must address and correct if necessary.

The Meter Relationship Module was developed to track the relationships between buildings and meters. Its main function is to allocate the energy use to the various buildings and other loads by linking to the electric line diagrams for the Site. The result is a usage equation for each building that determines electric usage. The equation can be a single meter, sum of several meters, subtraction of several meters, percentage split based on square footage, or a user-defined estimate. Figure 2 shows an example of the usage equations determined from the actual electrical line diagram. Each equation is saved in the database with an effective date, so that changes can be tracked over time.

Problem 2: Organizational Momentum

Change, although inevitable, never comes easily. Shifting the organizational momentum to a new software tool and way of doing things proved difficult. In addition to the normal stresses of changing an organization's business paradigm, staff found themselves moving several generations forward in computer technology.

To facilitate acceptance, the software was designed with outputs and discrete points that mimic the steps that existed previously. Although the software could be designed to go directly from points A to D, going step-by-step from A to B to C to D provided a level of familiarity to the tool and allowed users to view the results of each step gaining confidence in the software.

The long development time for the software – three years – helped expose future users to the software and aided in its acceptance. The long development time also gave users the opportunity to improve their computer skills from DOS-based Lotus 1-2-3 era to Microsoft® Office and Windows. The software itself is very user friendly and graphically oriented. Only a few administrators need advanced computer skills to track down problems during data processing.

Problem 3: Differing Contractor Needs

The Hanford Site is served by various contractors all of whom have different needs. Some want utility data by building, some by project or program, and others want a single total. In addition to utility data, PNNL wanted the fully burdened cost of energy (including overheads) to help manage declining budgets.

To meet a diverse set of needs, FRED was built for the highest level of detail, with tools to quickly aggregate these data. The modular nature of the tool also allowed users to pay for custom features or modules specific to their needs. The Billing/Forecast Module and the Internet Module were funded by organizations other than our prime funding source. As long as it's understood that all new modules, even though they are funded separately, become part of the suite of tools, the project as a whole benefits.

Problem 4: Existing Software

Not many facilities have the luxury of replacing the entire metering infrastructure with new hardware and software that performs all system tasks. Developing a tool that worked with existing hardware and software was a necessity at Hanford. As a systems integration tool, controlling the existing data collection software was a low cost solution to extending the life of the metering systems without reinventing capabilities. The other unique feature was designing the software to work with other tools at the backend. By providing data and connections to existing software like SRC's Metrix™, advanced features can be utilized without having to build them from scratch. Links to other front end or backend software tools could easily be added as either modules or functions.

Problem 5: Steam Data
When the coal plants were replaced with natural gas boilers, the ESPC contractor took over all purchases of natural gas and, in turn, provides steam to the Site. Time-series data are collected through an energy management and control system. The monthly figures for the first year were delivered six months after the year ended.

Unfortunately the ESPC contract did not clearly spell out the data requirements. The amount and timeliness of these data failed to meet the minimum of Hanford's quarterly reporting requirements. Building energy managers and engineers would also benefit from analysis of the time-series data to better understand their facilities. The ESPC contractor treats these data as business sensitive, even though they are collected in Hanford facilities.

The bottom line is to clearly define all requirements in the contract. Get the financial, contractual, and the engineering staff together and speaking the same language. Hanford found that the requirements for steam data from its ESPC contractor weren't clearly defined in the contract, and the only solution is to modify the existing contract.

Problem 6: Providing Data Access
Providing access to utility data for building managers is the first step towards energy use accountability. Secondly, charging for energy use lower in the organizational structure will also encourage conservation. Even at Hanford, where facilities are fairly well metered, one contractor is proposing to lump all the energy charges in a "pool" for funding and pay for it through overhead accounts.

FRED's two data access modules allow users to access up-to-date utility information at the building level. Decisions of how utilities are billed are made at a higher level than this project.

Problem 7: Bill Reconciliation and Reporting
Because of the structure of Hanford's electrical system some unique features were developed in FRED. First, Hanford Electric Utilities does not have a fixed electric rate it charges customers. The financial system dictates that all electric charges match exactly what BPA charges the Site each month. Therefore, site usage is computed, and charges are allocated so that the sum of all charges reconciles with the BPA charge. The result is a sliding rate that ranges from $0.01124/kWh to $0.03363/kWh for energy use and $2.441/kW and $1.806/kW for demand. FRED automatically computes the BPA charges, finds the usage for each load on Site, reconciles the charges, and determines what the electric rate is. Overhead charges for items such as operations and maintenance are added to these costs by the financial system in a later step.

The reporting requirements for the Site, specifically the quarterly report, provided an additional incentive for an automated tool. Energy cost and consumption must be reported quarterly in detail. The reports consist of a breakdown by fuel type, area, contractor, and use type (building, metered process, or vehicles). To construct the reports, the tool categorizes each load by use type during the billing process. These data feed into the quarterly report generation feature which also includes non-electric fuel inputs. The most difficult quarterly reports to generate compares current use to usage during the previous year and the 1985 base year. If the percent change is significant, a comment must be provided to explain the difference. For each entry, the tool provides suggested comments determined by frequency of occurrence in previous years. Users can select one of the recommend comments or provide a new one.

Problem 8: Scope Creep
Scope creep, the gradual increase in expectations or deliverables, is a problem in most projects and should be actively managed. This project was no different. To combat scope creep, clearly define deliverables and provide for a reasonable number of contingencies. The long development time and redesigning of the tool was mainly caused by previously unidentified issues causing a re-evaluation of the tool's architecture.

Problem 9: Software Implementation
Hanford's tool presented a challenge to implement because of the complicated set of tasks that were replaced and the wide variety of reports generated. The tool went through several iterations in development, with future users having input into the tool's architecture at each step. The long development time provided additional familiarity which aided in its acceptance.

Testing of the software occurred both during the development stage by programmers and by utility personnel in parallel with current data processing

procedures. The existing methods and FRED were operated simultaneously for approximately six months. Although this was longer than planned, it was necessary to work out software bugs and train utility personnel.

The software developers established a subcontract with an employee who had previously worked at Hanford and had intimate knowledge of utility operations. During the development stage, she acted as a project consultant, spending more time with the software developers than Hanford utility personnel could spare to help them understand utility operations. During software implementation, her good working relationships with existing utility employees helped facilitate software testing and implementation. She also represents a low-cost resource to Hanford Electric Utilities in the future to provide training or other assistance with the software.

Problem 10: Year 2000 Compliance

Additional tests were required, because of the concern over computer failures in the year 2000. The tests were a significant task, requiring generating dummy input files and databases to simulate future data. The complete processing was performed on these data at significant dates. Hopefully this is a problem future projects won't have to face.

A tool like FRED, which utilizes other software packages, databases, and data input files, is in a vulnerable position. It is dependent on each piece to perform its specific task. The year 2000 compliance testing took into account each individual piece by contacting the company or developer of the tool. However, the number of interconnected pieces represents some increase in risk for the project. On a smaller scale, FRED is also dependent on each input file or database to remain the same. Small changes to input files will require some small changes in FRED.

CONCLUSIONS

Legislation passed in the last 5 to 10 years now provides cost justification for end-use metering of utilities. Rather than installing metering simply to meet requirements, facilities should utilize this metering to increase accountability for energy use. Where metering exists, facilities should take the higher road and discourage lumping energy costs into "pools." Rather, making individual organizations responsible for their energy costs and providing quick access to these data provide an effective tool to encourage energy reduction.

To handle these data, a custom application doesn't always make sense. Some Federal sites may be better served with an off-the-shelf utility data management package or by out-sourcing metering activities through an energy services company. All out-sourcing activities must be clearly defined by contract. Hanford found that the requirements for steam data from its ESPC contractor weren't clearly defined in its contract, and a solution has yet to be found. Certainly there are more options available than ever before and these should all be explored.

In Hanford's case, and many others, an in-house tool can provide the greatest flexibility and control for addressing specific problems. Experience at Hanford has shown that it's not necessary to replace or re-invent existing software. An architecture of systems integration allows the new tool to communicate with and control existing software. Viewing the tool as a suite of distinct modules can also help to fund development, where organizations only want to pay for functions that directly affect their tasks.

The lessons learned during FRED's development should be useful to others – especially large Federal facilities – who face similar problems.

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