PANSOPHY, A JLAB SRF ENGINEERING DATA MANAGEMENT SYSTEM, SUPPORTING DATA COLLECTION, RETRIEVAL AND ANALYSIS UTILIZED BY LCLS-II

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Abstract

Pansophy is an engineering data management system composed of a collection of technologies that together provide a comprehensive solution for managing information in the production and testing of cavities and cryomodules. It is especially suited to support the Data & Quality Management Systems for large projects, including LCLS-II and the Jefferson Lab (JLab) 12 GEV upgrade, in addition to ongoing CEBAF Upgrade projects. With the extensive amounts of data collected for an individual project, data retrieval to facilitate feedback and enhancement of production and processing activities is a high priority. The priority shares importance with the needs of managing the project, including production status, Non-Conformance Reports (NCR), and Quality Management reports. Pansophy was introduced and first utilized in 2002. Since then, many enhancements have taken place. More recently, the focus has shifted to Data and Quality Management reports and statistical analysis. Such enhancements include a database driven menu system, extended MSWord macro pre-processing of travelers, and an extensive reporting system. The reporting system allows managers and group leaders to respond quickly to the needs of the project in areas of cavity and cryomodule production, data collection, NCR, Quality Management and schedule. Extensions include integration with the inventory system, allowing traceability from the receiving of manufactured parts to the final cryomodule product.

BACKGROUND

Pansophy was first introduced in 2002 as a system for the collection of production and test data of cryomodules for Jefferson Lab. The first large scale project that utilized Pansophy was the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory in 2004, with the initial focus being on travelers and the collection of data. Since then, the focus has turned to quality management and data mining and analysis (Figure 1).
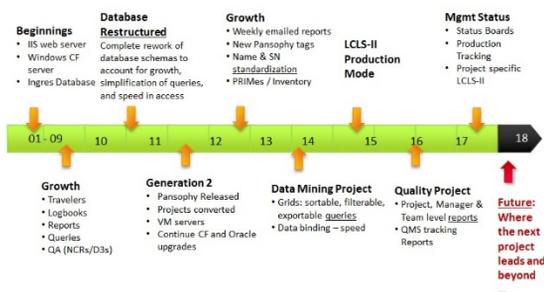

Figure 1: Pansophy Timeline.

Pansophy is a web-based engineering data management system (EDMS). The initial concept was to create a series of programs that would collect data produced during the manufacturing and testing of cavities and cryomodules. This includes such parameters as serial numbers, measurements, alignment, leak tests, cavity and cryomodule performance measurements and date of assembly. The system is a custom integration of several commercial software utilities, including DocuShare™, ColdFusion™, Oracle™, as well as, some common desktop programs, such as MSWord™ and MSExcel™. Users range from process managers, shop-floor technicians, and test engineers to after-the-fact data miners. Important quality assurance elements include procedural control, automated data accumulation into a secured central database, prompt and reliable data query and retrieval, and online analysis tools, all accessed by users via their platform-independent web browsers.[1]

The basic vehicle used for data collection in Pansophy is the traveler. Travelers are used to define and control a process and to gather data particular to the fabrication, assembly, or performance verification of components and completed cryomodules. Travelers are version controlled and tie directly to procedures, safety documents and drawings to give the user a complete picture and data set of the process of manufacturing and testing.

WHY EDMS?

During the production and testing of a cryomodule, over 13000 data points are collected. Multiply that by the 18 cryomodules as in the LCLS-II project and the data becomes unmanageable, especially if collected in spreadsheet format. To manipulate and analyse data across cryomodules within a project or to compare between projects would be impossible without additional functionality. Therefore, collecting data systematically into an online database with a cohesive user interface becomes a necessity for today's production environment (Figure 2).
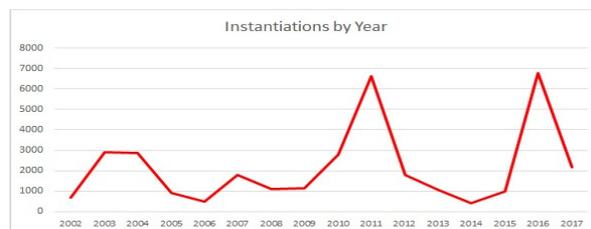

Figure 2: Number of Travelers by Year.

Pansophy, a JLab EDMS, is utilized for both large production runs, such projects including SNS, CEBAF 12 GeV upgrade and the current LCLS-II, but is also a useful system for monitoring and collecting data for research projects (Figure 3).
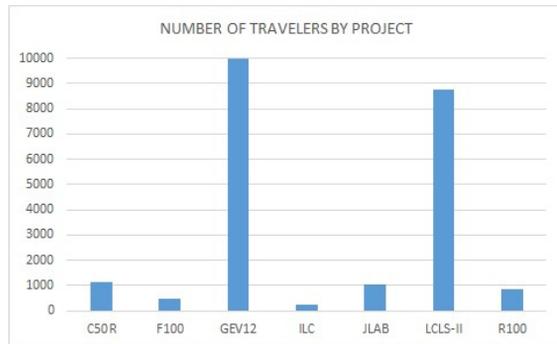

Figure 3: Number of Travelers for Major Projects.

Having data in an EDMS allows for the capability of part traceability throughout the assembly process and it permits the notation of conformance issues or discrepancies in processing, such items that previously may have been overlooked or lost. Additionally, reporting becomes a simplified process. Reports are readily producible for daily progress of a production line, comparisons of cavity tests results and Project Management weekly and monthly reports. Another benefit is the comparison of key performance metrics across all projects, e.g. Q_0, FE, etc.

MENU SYSTEM ENHANCEMENT

Part of an EDMS is the cohesiveness of a user interface so that users of the system can readily find projects, data and reports. For Pansophy the menu system is an in-house design, utilizing a single database table that stores all the individual menus for the various functional Pansophy areas. The data dynamically builds a Hyper Text Mark-up Language (HTML) structure to create the menu. The table is based on a parent and child method, meaning the table includes an item ID column that acts as the parent, and a parent reference column that acts as the child, subsequently putting the child under the parent in the menu, creating a tree structure. In addition, the table includes additional columns, such as the display name and hyperlink. A hierarchical query filters the data based on the functional area selected from the main menu, which acts as the highest parent (Item ID 0) in the table.

HTML tags for unordered and ordered lists (<ul> and <li> tags) are used to build the HTML structure of the menu as the query data is processed in an algorithm. The algorithm allows for n-depth of any members and assigns class attributes for headers and hyperlinks. Cascading Style Sheets (CSS) are used to provide an easy to use visual presentation of menu items. With improvements to Pansophy happening dynamically, updates to the menu system can be made to the database and are immediately

available to the user without requiring a system restart or downtime.

TRAVELERIZATION ENHANCEMENT

With travelers being the base unit of the Pansophy system by which processes are defined, and data to be collected is called out, it is important that the subject matter expert (SME) be the author of the traveler. The use of MSWord and a series of macros aid the SME in writing the traveler, thus simplifying the process and making it feasible for more SMEs to write travelers. These macros are embedded in a Pansophy ribbon on an accessible template in which traveler procedures are clearly defined and consistently written. Once the traveler is written, it is then sent to the programmer for processing.

The Pansophy format for a traveler is a series of ColdFusion HTML form pages, written in ColdFusion Mark-up Language (CFML), allowing the traveler to have increased ability to interact with the database. To expedite and simplify the achievement of this format from the SME-written MSWord traveler, the programmer converts the document using an MSWord macro, a Java pre-processor, and a script program. The MSWord macro saves the document into the necessary formats, including the HTM file that the Java pre-processor reads and converts. A web based CFML form page on Pansophy allows the programmer to select the traveler HTML file to be processed, removes MSWord styling, and runs the Java pre-processor. The pre-processor checks for errors, such as duplicate variable names, special characters and ensures that all necessary fields are populated. It then generates a series of CFML form pages that represent the pages of the traveler, creates configuration files containing the SQL to create and update necessary tables in the database and moves the created pages and files to the appropriate folders. The programmer finishes the process by running a predefined script command that runs the SQL configuration files, thus creating the database tables and making the traveler available for use on the Pansophy system.

Time required to convert an MSWord traveler written by the SME to production in the Pansophy system has been reduced from hours to minutes of processing time.

REPORTING ENHANCEMENTS

Traveler Filtering and Sorting Features

The addition of filtering and sorting capabilities are recent enhancements to report functionality. Initially, values returned for a report were displayed in a tabular format and have since been modified to a grid format with additional functionality.

The primary field for a traveler is the unique sequence number, however it is often more useful to sort by the part serial number, inspection date, or other key field of interest. The new formatting utilizes an AJAX enabled grid to present information. The grid allows users to sort and filter information as needed on any column. The grids also allow the use of hyperlinks, which allows the user to

open traveler pages and to access documents directly, and with the use of CSS coding, color and other formatting enhancements are possible. The grid gives a quick and consistent look and feel to all generated reports and thereby aids the user by focusing their attention to data and not the user interface itself. The filtered data in the grid is exportable to Excel, which provides a useful way to enable users to do additional formatting and analysis work.

Non-Conformance Reporting (NCRs)

When a part goes through inspection and testing, it may not meet the specifications called for; this then results in a Non-Conformance. A specialized traveler has been adopted to produce a Non-Conformance Report or NCR. The NCR allows managers and SMEs to monitor the acceptability of manufactured parts and permit immediate feedback to head off possible additional problems [2].

The NCR traveler describes the non-conformance or specification that was not met and then it automatically issues an email to the responsible engineer(s) or SME for disposition. Dispositions include Return to Vendor, Reject, Use as Is, Rework, Remeasure and Continue to Next Workstation. The NCR can be tracked and traced back to the inspection/testing traveler in which it originated and the NCR can be monitored through a series of Report Functions to complete the feedback loop.

Detours, Deviation, and Discrepancies (D3)

When processing a part or during an assembly process there may be cause to deviate from the prescribed process and/or procedure. When this happens a D3 traveler is filled out. This specialized traveler maintains information that otherwise may be lost during a production run or testing. This could be something like a machine failure, power outage, or a process had to be restarted for some reason. These insights are conveyed to the SME in order to adapt any necessary changes to processes or procedures.

A D3 differs from a NCR in that the NCR is used when a part or test does not meet prescribed specifications, such as a measurement and stop non-conforming parts from entering production. A D3 is utilized when a process is modified to meet the immediate needs of an assembly, process or test and provides notes for the SMEs.

Status Boards (schedule/status)

Status Boards, utilized by team leaders and project management, show a timeline progression of assembly. Each can show steps within a single traveler or show assembly across several travelers, like in the chart below, which demonstrates a Cryomodule Assembly Status Board [4]. This is very helpful for schedule planning, determining where work is being held up or where more hands are required. These status boards are used heavily to monitor the progress of the LCLS-II project and are being utilized in weekly and monthly status report meetings (Figure 4).

Figure 4: Cryomodule Status Board.

Serial Number (SN) Searches (part based)

The Serial Number Search allows users to select project(s), a serial number acronym, and serial number(s). The report searches through all travelers related to the selected project(s) and returns a list of travelers where the acronym and serial number(s) match, providing a complete document chronology for the selected part.

This also provides and displays a cross-analysis usability of a part previously noted in an NCR or D3, in relation to a traveler. Open / Close status of travelers are also displayed making the engineer(s) aware of current state of part. A single part's entire history is displayed in a simplified user friendly, filterable and sortable listing which can be exported to MSExcel.

User Defined Query (UDQ)

A User-Defined Query enables a user to define ad-hoc queries of the database. Presented with a list of travelers and the data parameters stored with the selected traveler, the user can select what they wish to view and under what conditions. For example, all FEONSET >= 14 will query the database for all field emission onset values greater than or equal to 14. A tabular display is generated from the selected parameters and presented to the user. The user then has the option to export to Excel for further processing or plotting. This puts the search power into the hands of the SME without requiring the knowledge of programming or database queries.

FROM MANUFACTURING TO COMMISSIONING: DRILL-DOWNS

Traceability of a part within a cryomodule is valuable information for the LCLS-II project. Knowing which cavities were installed in which cryomodule and what the key parameters are for testing, aids in the operation of the accelerator. This traceability is accomplished via a visual drill-down/drill-up reporting system. The drill-down system allows a user to navigate thru levels of data from cryomodule (highest level) to the cavity RF test (lowest level) seeing both summarized data (drill-up) and more detailed data (drill-down). One advantage of these reports is to present an over-view and summary of the key parameters, by cryomodule and by cavity string [3].

The Drill-Down reports present a visual representation of a cryomodule with related stored data parameters and travelers with point and click capability to drill-down to the cavity string assembly layer or drill-out to a specific traveler. This allows traceability from cryomodule (Figure 5) to cavity string (Figure 6) to cavity testing down to inspection and receiving of a part, presenting all associated travelers. This traceability was developed and

highly utilized during the CEBAF 12GeV upgrade and is currently being utilized by the LCLS-II project.

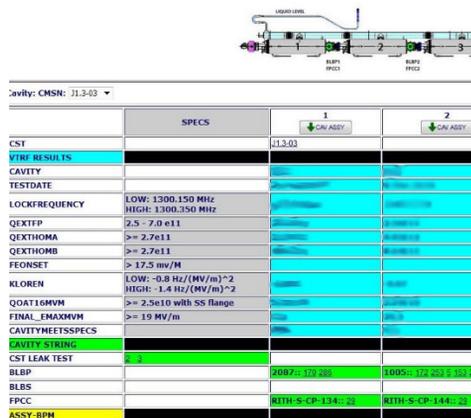Figure 5: Cryomodule Drilldown and Summary Report.

Figure 6: Cavity String Drilldown and Summary Report.

ADDITIONAL ENHANCEMENTS

Hold Points in Assembly Line

Hold Points have been added to the traveler system to aid LCLS-II managers/team leaders to verify system processing, procedure and data have been collected and followed up to a certain point in the assembly process. This hold point pauses the assembly process until an approver signs off. Hold points are used at the end of cavity string assembly and at workstation changes within the cryomodule assembly process. Thereby ensuring data is collected and specifications are being met.

Vendor Supplied Hold Point Data

A useful addition for the LCLS-II project has been the collection of vendor data. During cavity production, JLab receives, collects and processes vendor hold-point data

for the cavities into a traveler. The data is sent to Jefferson Lab from the manufacturer in the form of Excel spreadsheets and PDF files. A series of VBA scripts and macros combine all of the spreadsheets for a particular cavity and hold-point into a single workbook, all while collecting important data from each spreadsheet and presenting it in a summary sheet in the workbook. The data presented in the summary sheet are key parameters that are necessary to release the cavity for further processing by the manufacturer. The data is automatically uploaded into the proper hold-point traveler so the SME can see the parameters in a consistent traveler format and report user interface.

Excel Macro Process of Cavity Test Data

Excel macros and java programs have also been added to the system to pull raw cavity RF test data into excel spreadsheets. The macros automatically select the appropriate performance data, perform the prescribed set of calculations and produce graphs of the cavities key performance parameters. Cavity testers now have an expedited way to process raw data into useable reports. A cryomodule version is in progress.

CLOSING REMARKS

The Pansophy Database and reporting continues to be a key element for effectively managing the large amounts of data for the LCLS-II project, including Production Status, NCR (Non-Conformance Reports), and Quality Management reports. This System supports not only large external projects, but also our ongoing improvements to JLab CEBAF accelerator, which includes the recent 12 GeV Project as well as ongoing CEBAF cryomodule refurbishments.

We have used feedback to continuously improve the Pansophy System at JLab. In particular, since 2002, we have enhanced the reporting capabilities developing Summary, and "Drill Down" reports, as well as Quality Management Reporting for use by management and other stakeholders.

Finally, the Pansophy database insures a final record at project completion for all of the LCLS-II cryomodules built at JLab.

ACKNOWLEDGMENTS

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