

Light Water Reactor Sustainability Program

Seamless Digital Environment – Data Analytics Use Case Study



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Seamless Digital Environment – Data Analytics Use Case Study

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SUMMARY

Multiple research efforts in the U.S Department of Energy Light Water Reactor Sustainability (LWRS) Program studies the need and design of an underlying architecture to support the increased amount and use of data in the nuclear power plant. More specifically, the three LWRS research efforts (Digital Architecture for an Automated Plant, Automated Work Packages, Computer-Based Procedures for Field Workers, and Online Monitoring) have identified the need for a digital architecture and more importantly the need for a Seamless Digital Environment (SDE). An SDE provides a means to access multiple applications, gather the data points needed, conduct the analysis requested, and present the results to the user with minimal or no effort by the user.

During the 2016 annual Nuclear Information Technology Strategic Leadership (NITSL) group meeting the nuclear utilities identified the need for data-analytics-focused research. The effort was to develop and evaluate use cases for data mining and analytics for employing information from plant sensors and databases for use in developing improved business analytics.

The goal of the study was to research potential approaches to building an analytics solution for equipment reliability, on a small scale, focusing on a single system. The analytics solution consisted of a data integration layer, predictive and machine learning layer, and the user interface layer that displayed the output of the analysis in a straight forward, easy-to-consume manner. This report describes the use case study initiated by NITSL and conducted in a collaboration between Idaho National Laboratory, Arizona Public Service – Palo Verde Nuclear Generating Station, and NextAxiom Inc.

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ACRONYMS

CR	Condition Report
EAD	Equipment Anomaly Detection
LWRS	Light Water Reactor Sustainability
NITSL	Nuclear Information Technology Strategic Leadership
PI	plant information
PVNGS	Palo Verde Nuclear Generating Station
SDE	Seamless Digital Environment
SIG	special interest group
WMS	work management system
FY	fiscal year

SEAMLESS DIGITAL ENVIRONMENT – DATA ANALYTICS USE CASE STUDY

1. INTRODUCTION

Nuclear industry is moving toward the use of more advanced technology to extend the operational life, to once again become a competitive energy option, and to attract and retain new workforce. This technology is becoming more integrated in the workers' daily routine as both the use of data and the amount of data collected are increasing. The need for easy access to relevant and meaningful data has become a priority. The data is commonly collected and stored in the utility's legacy systems or other software applications, and is essentially grouped by work function (i.e., which system collected and stores the particular type of data). Most applications also only offer access to the data through the application's dedicated user interface. Hence, in many cases the worker has to look at several systems to gain all the information needed for a particular task or analysis.

A well-designed digital architecture is needed to support the increased data demands. However, to ensure the data is adequately utilized to improve and support the plant operations an easy, quick, and reliable method must be created to access the data. A common method is to create a "one stop shop" application that the worker can go to access the data needed. A key to this approach is a method to integrate the data stored in multiple applications, such as the work management system (WMS) and plant information (PI) databases. In other words, there is a need for a Seamless Digital Environment (SDE). Without any effort by the worker, the SDE will access all applications, gather the data points requested, conduct the analysis requested, and present the result to the worker.

The vast increase of accessible data can support well-informed plant decisions and management, but it can also become overwhelming and unruly if not handled properly. To support decision making and improve operational efficiency it is important to ensure that the data is both accurate and relevant by utilizing both quantitative and qualitative techniques to analyze the data. For example, data analytics can facilitate faster identification of and response to potential issues such as equipment failure or other issues that could cause delays in work completion.

The different data collection needed depends on the purpose and use of the data. An analytical model should be developed that will verify the collection of the desired data for the task or analysis. The model should be developed and used on gathered data to test its accuracy. The model, and possibly the data gathered, is revised and tested again in a process known as training the model until it functions as intended and is proven to provide the desired analysis.

The Digital Architecture for an Automated Plant effort is a part of the U.S Department of Energy's Light Water Reactor Sustainability (LWRS) program. The main goal of the effort is to provide the nuclear industry guidance and recommendations for how to best design a digital architecture that can support the growing data supply and demand. The main outcomes of the research conducted 2015–2016 are a requirements report (Thomas and Oxstrand 2015), a gap analysis (Oxstrand, Thomas, and Fitzgerald 2015), and a planning model (Oxstrand et al. 2016). The digital architecture planning model is the methodology for mapping power plant operational and support activities into a digital architecture that unifies all data sources needed by the utilities to operate their plants.

Research conducted in both the LWRS *Computer-Based Procedures for Field Workers – FY16 Research Activities* and the LWRS Automated Work Packages efforts indicates an increased interest by the industry to implement electronic work packages and computer-based procedures to improve system efficiency and reliability as well as increase human performance related to activities conducted in the plant (Oxstrand and Bly 2016; Oxstrand 2016). The deployment of electronic work packages and computer-based procedures will create a new source and demand of data that needs to be incorporated

into the SDE. The addition of these types of digital processes add more near real-time data, which can be used to support the operational efficiency improvements at the utility.

A study conducted by Oxstrand et al. in 2015 in the LWRS Automated Work Packages effort demonstrated the means for automatic and wireless acquisition of plant process and components status information into the work order on a mobile device. To enable this automatic acquisition of data, a prototype platform for data exchange between the field instruments and the mobile devices was designed and evaluated.

Other research efforts in the LWRS program studies online monitoring of both active and passive components using multiple types of sensors. The research conducted shows the value of leveraging the advancement in sensors and wireless communication technologies to further improve operational efficiency (Agarwal et al. 2017). The same publication also highlights the use of sensor data for a variety of plant engineering, maintenance, and management applications.

The outcomes and findings from these LWRS research efforts along with ongoing activities conducted by the nuclear utilities themselves identifies the increased amount of available data and new use of the data to support plant operations. Based on this, members of the Nuclear Information Technology Strategic Leadership (NITSL) group identified the need for an effort focused on data analytics.

NITSL is an organization that brings together leaders from the nuclear utility industry and regulatory agencies to address issues involved with information technology used in nuclear power utilities. NITSL strives to maintain awareness of industry information technology related initiatives and events and communicates those events to its membership.

The suggested focus of NITSL was to develop and evaluate use cases for data mining and analytics for employing information from plant sensors and databases for use in developing improved business analytics. Hence, the Data Analytics initiative is organized by the NITSL and facilitated by LWRS researchers as a part of the Digital Architecture for an Automated Plant effort.

The goal of the Digital Architectures for an Automated Plant is to develop a methodology for mapping power plant operational and support activities into the digital architecture. Due to the close relationship between digital architectures and digital environments, it is beneficial to leverage the insights from both research efforts in any future activities. Hence, it was strongly recommended that the Data Analytics' use case study be conducted in close collaboration with the Digital Architecture research.

The goal of the Data Analytics initiative is to support the adoption of the SDE concept in the nuclear industry. As a first step, fiscal year (FY) 2017 was dedicated to provide a proof of concept through a use case study. This report describes the use case study, its impacts, and the path forward.

This report addressed Milestone: M3LW-17IN0603123 – Complete report documenting the evaluation of use cases for data mining and analytics for employing information from plant sensors and database for use in developing improved business analytics.

2. DATA ANALYTICS USE CASE STUDY

As mentioned, the Data Analytics initiative is organized by the NITSL and facilitated by LWRS researchers as a part of the Digital Architecture for an Automated Plant effort. For the initiative to be a success, the researchers had to collaborate with both utilities and vendors. Arizona Public Service Palo Verde Nuclear Generating Station (PVNGS) volunteered to both host the study and to take an active part in the team. PVNGS uses middleware technology from NextAxiom Inc.; hence, it made sense to leverage this relationship for the use case study as well.

Over the year, PVNGS, NextAxiom, and Idaho National Laboratory worked together to identify use cases, develop the technology, and evaluate the design.

2.1 Goal, Purpose, and Objective

The main goal of the use case study was to provide proof of concept of a data analytics solution. The use case study should demonstrate both benefits of data analytics and how to present aggregated or analyzed data to the worker in a meaningful way. The study should also address potential benefits of using machine learning.

The purpose of the study is to research potential approaches to building an analytics solution for equipment reliability, on a small scale, focusing on either a single piece of equipment or a single system. An equipment or a system with sufficient amount of quality historical data was to be selected for best results.

The objective is to research potential approaches to building an analytics solution where analytics on data from multiple locations is conducted and the result is provided to the worker in a way that enhances the productivity and/or ability to make well-informed decisions. Although many commercial software products exist that may be able to provide such an analysis, the use case is intended to be referenced as a more cost effective and nuclear-industry-tailored approach.

2.2 Identification of Use Cases

A large set of potential use cases was identified in the early stage of the effort. For example, tracking design implementation work orders to get real-time status updates related to specific plant design modifications, and tracking work and equipment status by accessing data logged during operator rounds in the plant as well as in the main control room.

It was decided to use the following two use cases for the FY 2017 study: an equipment anomaly detection (EAD) use case and an engineering work management use case.

The EAD use case looks at detecting, evaluating, and dispositioning potential equipment anomalies. These anomalies are deviations from the standard operating parameters of the equipment and can indicate the beginning of an equipment failure. Successfully implemented, this analytics would help identify early indications of equipment failures and improve equipment reliability by tracking the anomalies, allowing for preventative action to be taken before the failure could cause an issue that could lead to worker injury or shutdown of the reactor.

The engineering work management use case aims to provide a portal that would gather data from several systems and utilize the data to more accurately help assign work based on availability. The portal would then update the source systems about the work scheduled.

2.3 Back-End System Development

The analytics solution developed consists of a data integration layer, predictive and machine learning layer, and the user interface layer that displays the output of the analysis in a straight forward, easy-to-consume manner. NextAxiom's *hyperService* platform was used for the data integration layer between

different plant applications, such as the work management system and the plant information database. The researchers used a statistical programming language in the predictive and machine learning layer.

The research team decided to focus on the EAD use case and study the engineering work management use case if time permits.

This system in the EAD use case consist of three parts:

1. A system for detecting equipment anomalies
2. A dashboard for engineering and operations to review and disposition these equipment anomalies
3. An integration layer for both retrieving contextual data and updating data according the anomaly disposition.

While systems for detecting equipment anomalies based on time-series process data have existed for some time, these systems are expensive and labor-intensive to maintain. As mentioned, a part of the study was to determine benefits of using new machine learning techniques; more specifically, to investigate if much of the manual effort can be automated and scale anomaly detection more efficiently.

The machine learning techniques provide a method of data analysis that automates analytical model building. Using algorithms that iteratively learn from data, the machine learning techniques allow computers to find hidden insights without being explicitly programmed where to look. As the algorithms are tuned to find the correct data through an iterative process, it is expected to see high false-positive rates, where many anomalies that are detected are mistakenly found and are inconsequential. By using an integrated dashboard, there is hope to improve the efficiency of screening anomalies as well as improve the ability to act on anomalies by efficiently generating condition reports and other work mechanisms. An integrated dashboard consists of information from various disparate data sources presented in one graphically intuitive user interface. Interactive organization and drill down capabilities allow quick access from the dashboard oversight down to an equipment's anomalous detail. This brings all the information into one location for a user to be able to make more informed decisions by having the correct information at the right time.

Engineers at PVNGS had in the past developed a system implementing these machine learning algorithms, which shows strong historical sensitivity to equipment anomalies. Data fed to the system is not real-time and access to the system is difficult. Unfortunately, due to the design of that system, it is not a reliable or sufficiently flexible tool to allow users to have immediate access to the data. Hence, this system was not feasible for the use case study.

A small near real-time system was developed, which provides an easier access point to any job function that could benefit from the data. NextAxiom *hyperService* Platform was used to gather the data from the various source systems to mitigate the facts that many systems are not updated frequently and could have issues with providing access to all potential users.

Figure 1 illustrates the relationships between the different components involved in the use case.

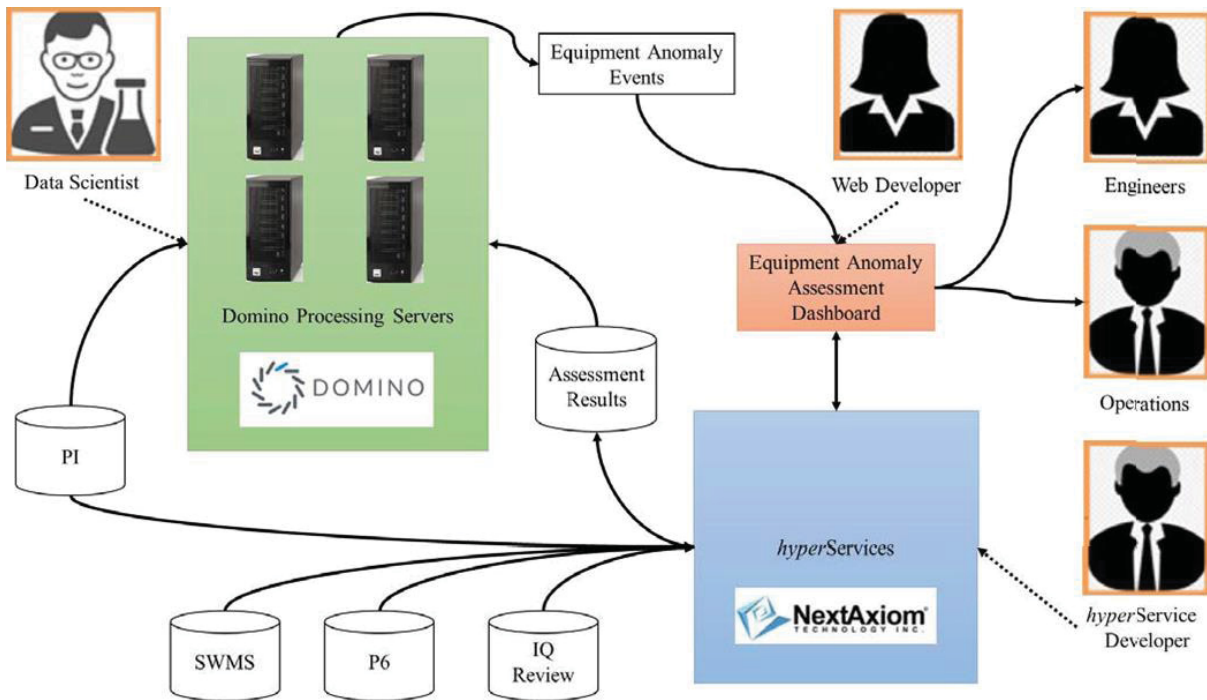


Figure 1. The relationships between the different components involved in the equipment reliability use case.

2.4 User Interface Development

The users, in this case engineers and operators, use an integrated dashboard to access information important to their job functions. The information presented on the dashboard comes from the PI database, the scheduling tool, and the WMS. The *hyperService* Platform is used to access the data to determine what to present to the user and how to do so. Also the *hyperService* Platform is used to log what specific information is accessed most by the users. This log will be used to adjust the data gathered to provide predefined data sets to the users.

As the engineers use the dashboard, they will be able to disposition the anomaly events into three categories: Acknowledge, Watch, and Condition Report. Acknowledging the anomaly is used by the engineer to state that he or she has seen the anomaly and does not believe there is a cause for further investigation. Setting the anomaly in the Watch state informs other engineers that there is a possibility for a concern and to continue watching the event. The Condition Report (CR) state allows the engineer to create a CR automatically from the information gathered by the EAD system with just a click of a button. This frees up the engineer to continue investigating other anomalies. The states are fed back to the Domino processing servers where the data is incorporated back into the data analysis to train the algorithm on how to detect if future anomalies are actually real or may be a false positive event. The research team will collect and analyze data from the development and use of the architecture, described in Figure 1, to report on the resulting lessons learned.

The researchers designed the functional aspects of the user interface for the EAD use case by creating wire frame mockups. Mockups were demonstrated to potential users to receive feedback on what the potential users think is needed in the dashboard to determine the course of action accurately on the events reported. The team updated the designs after feedback from several focus groups each reviewed the mockups. This design process allowed the users to give their opinion on how the dashboard would function and what data they need to perform their roles.

Figure 2 shows the mockup of the dashboard’s home screen. As shown on the top section of the dashboard, the users have the ability to filter and refine the list of anomalies they are seeing. This allows the engineers to focus on the systems for which they are responsible. The engineer can select an anomaly event from the list to view more details regarding the event.

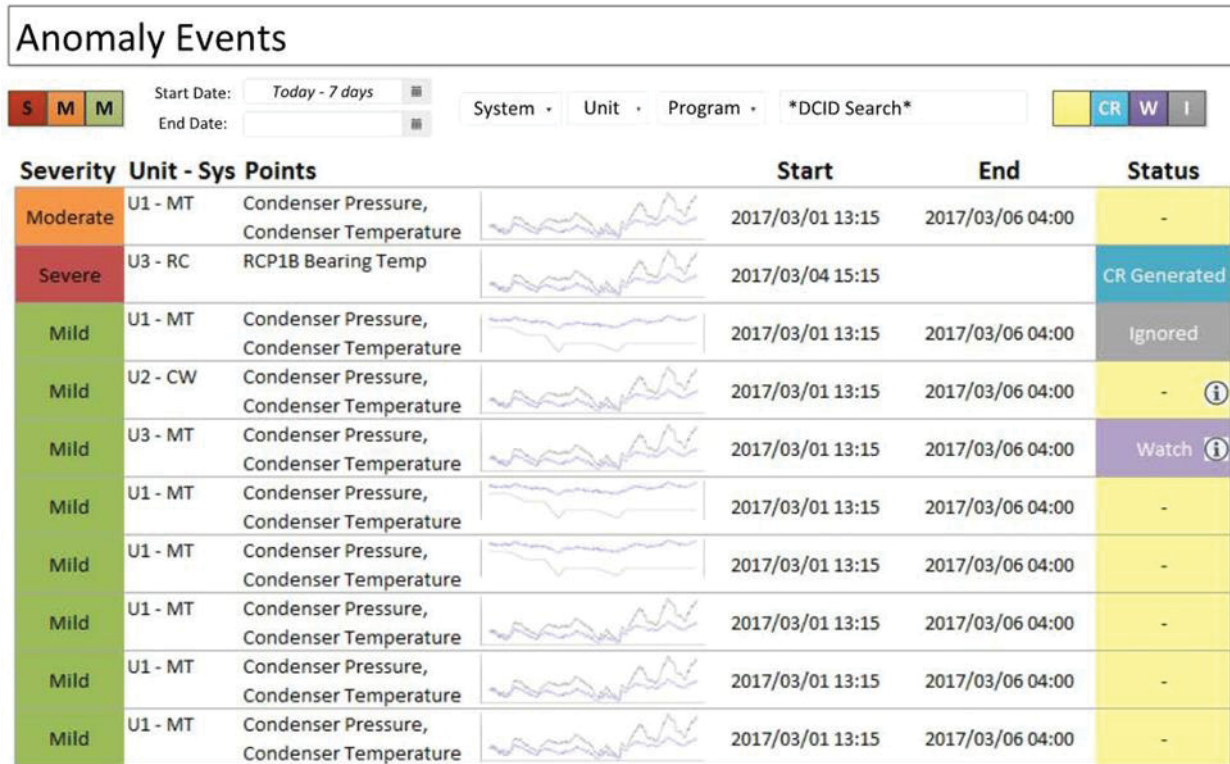


Figure 2. Equipment anomaly detection home screen mockup.

Figure 3 shows the details page mockup of the event. The details screen allows the user access to the data located in various silo systems seamlessly. The source systems that provide the details are captured in the in the upper-right-hand corner of the screen. The initial systems include the PI database, the scheduling tool, the WMS, the review system, engineering modifications repository, and a file repository where reference material can be found (e.g., design documents). Each button on the details screen displays the number of records found regarding the equipment on which the anomaly is occurring. The underlying data in the system can be accessed by clicking the respective buttons.

When the user has reviewed the information, a decision can be made whether to acknowledge the event, put the event on a watch list, or generate a CR.

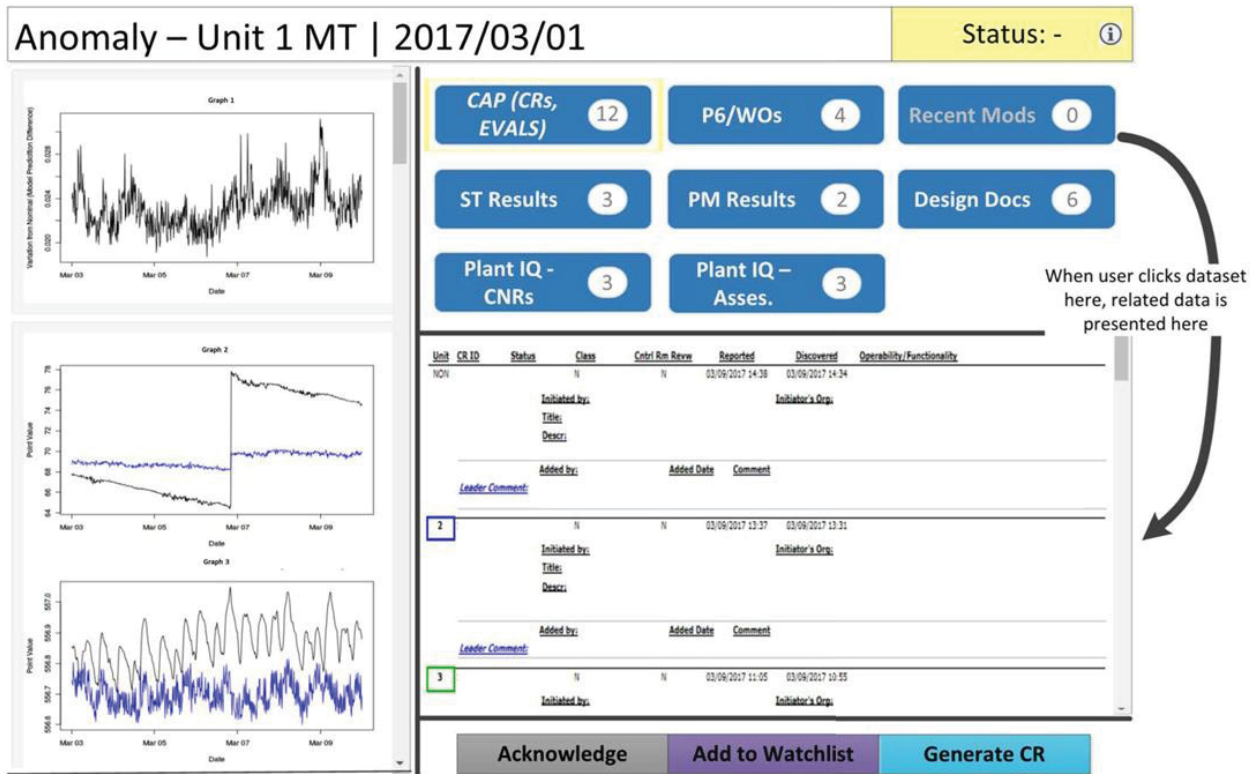


Figure 3. Equipment anomaly detection detail screen mockup.

When the users choose to generate a CR a popup is displayed to the user, as seen on the left of Figure 4. The data presented to the user is a very small summary of the CR that will be generated: Title, Description, and optional Suggested Disposition. The title and description are auto-generated with the information needed, but the system allows the user to modify the fields if desired. Once the user clicks “Generate CR,” the system automatically fills out a condition report and submits it. The right side of Figure 4 displays some of the data that is automatically filled out with the data already gathered in the background. The user never sees the right side of Figure 4. As the users look at the detail data and categorize the events, their actions are recorded to train the analytic model to have the ability to report accurate anomaly events.

Title

Potential equipment anomalies identified in Unit X System X

Description

Anomalies detected on (list DCIDS) for the parameters (list parameters/PI Points) starting on (start date).

Suggested Disposition

Optional

Generate CR

Condition Report Search

VINCENT JERROLD J Select a Unit *Discovery Date/Time 3/22/2017 9:35 AM

Classification Eq Deficiency # EQ DEFICIENCY # Suggested Owner Group Ex: 1231, Operations, Engineering, Security

*Industrial Safety? Y N Originator Eval Review? Y N

*Equipment Related? Y N Auto-attach equipment

*Procedure Related? Y N

*Other Controlled Docs? Y N

Anomaly start time

Title & Description Actions Taken Suggested Disposition

*Title: PROVIDE A BRIEF DESCRIPTION OF THE CONDITION.

Help On (fill in the date)
 While (what was being done, performed, etc)
 Who (was doing it, organization, title, etc)
 *Description Discovered (or found, observed, etc)
 That (describes the "thing" that is not what it should be)
 How (if it should be)
 Why (sequence of the condition that was not correct)

Upload files (max 10MB) Only PDF & Images allowed

Upload PDFs of anomaly charts? Select files

Anonymous? Y N

Route to Control room

Submit Condition Report Clear

Figure 4. Condition report one-click creation mockup.

3. IMPACTS AND PATH FORWARD

The use case study was presented at the annual NITSL conference in San Francisco, California, July 17–20, 2017. In addition, the researchers conducted an SDE and data analytics workshop during the conference. The outcome of the FY 2017 activities in the Data Analytics initiative was well received. NITSL decided to continue the initiative in FY 2018. More specifically, next year the initiative will identify a common definition for data analytics and define the skillset needed to conduct data analytics. This skillset will be contrasted to the skillset of a traditional information technology specialist.

The initiative will survey the industry to identify the current maturity of the data analytics movement. In other words, gather information about conducted and ongoing data analytics activities within the utilities. A list of use cases being considered or already addressed will be consolidated. As a follow on, the initiative will facilitate the sharing of lessons learned from these activities. Information such as what risks (e.g., quality of existing data) have been identified and how they have been mitigated as well as what makes a data analytics effort successful. The utilities will also be encourage to share feedback on what tools and approaches were used to set up their data analytics environment. This includes the discussion about why specific tools or approaches were selected over others.

The main outcome for the FY 2018 Data Analytics initiative will be an additional implementation of an advanced data analytics solution. Advanced data analytics in this case means the use of machine learning to gather relevant data points. The implementation will be demonstrated at the 2018 NITSL conference. The goal is for another plant than PVNGS to implement the next solution.

The special interest group (SIG) for data analytics, which was established early on in the Data Analytics initiative, is expected to be the main forum for information sharing and discussion. The SIG focuses on broader questions related to data analytics and how/when it should be used to support the Nuclear Promise. The purpose of the SIG is for members to share insights and lessons learned from related activities in their organization and learn from others' experiences. The SIG provides feedback on the use cases study and feeds the results from the study back to their organizations. As of February 2017, the SIG currently consists of 30 members. Fifteen of the members represent four U.S. nuclear utilities (Arizona Public Service, Southern Nuclear Company, Dominion, and Duke Energy) and one international utility (EDF Energy). The other 15 members represent Idaho National Laboratory, Sandia National Laboratory, the Institute of Nuclear Power Operations, and six vendors.

The researchers will continue to refine the design of the EAD system based on feedback from users. The design and data gathered is expected to change as the research continues. The hope is to fine tune the features in the dashboard that improve work efficiency and tune the data feedback to the analytics model to improve anomaly detection. Also user feedback on the use of the dashboard will steer the any design updates.

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