PRACTICAL OBSERVATIONS REGARDING KNOWLEDGE MANAGEMENT FOR A NUCLEAR WASTE MANAGEMENT PROJECT

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Abstract

The purpose of the paper is to share practical observations regarding knowledge management based on experience following the suspension of the proposed Yucca Mountain Project (YMP) in the United States. After its suspension in 2010, custody of YMP information systems was transferred to the U.S. Department of Energy (DOE) Office of Legacy Management. Meanwhile, Sandia National Laboratories was directed to maintain, on its own systems, the technical basis supporting the postclosure component of the 2008 Yucca Mountain Repository License Application. Because of increasing costs of hardware maintenance and increasing risks of obsolescence of some of the database software used at the YMP, the DOE has directed Sandia to develop a cloud-based information management system to serve as a generic template for any future nuclear waste management and disposal project. Generally, IT systems for large, long-term programs are developed incrementally, as needed, by separate organizations for their specific purposes. Opportunities to restructure and integrate these various systems are rare because of the disruption caused. This cloud effort is being developed using the experience and the information systems from the former YMP and its requirements while there is no ongoing scientific and engineering work, providing a unique information management opportunity to analyze, define, and potentially integrate an information architecture that meets all its needs and requirements efficiently. Key observations relevant to knowledge management include:

(a) Observations on opportunities and challenges of migrating information to a cloud platform.
(b) Thoughts on efficiently managing and structuring information to meet separate requirements and needs.
(c) Observations on capturing tacit knowledge from experts and using it in information management.
(d) Observations on knowledge recovered from legacy project software itself.
(e) Implications on long-term management of information and records to meet regulatory requirements and to maintain useful knowledge and lessons learned for other programs and purposes.

1. INTRODUCTION

Generally, IT systems for large organizations and long-term programs are developed incrementally on an as-needed or as-funded basis, to meet requirements as project priorities arise, and developed by separate organizations for their specific purposes. Opportunities to restructure and integrate these various systems are rare because of the disruption involved, as well as the costs. The need to update long-dormant information systems from the DOE's Yucca Mountain Project (YMP) to capture project knowledge for future waste management work presents a unique information management opportunity in that it is (1) being developed using the experience and the information systems from the former YMP and its requirements, but (2) there is no ongoing scientific and engineering work, providing a rare opportunity to analyze, define, and integrate an information architecture that meets all those needs and requirements efficiently. This paper offers observations and lessons learned from this effort relevant to information management, information architecture and requirements structures, and knowledge management.

2. BACKGROUND

As the program progressed from the 1980s through license application submittal in 2008, the DOE YMP developed, updated, and replaced information systems to meet program needs, reflect changing requirements, implement new technology, and support new tasks and improve processes. The systems reflected the project's

quality assurance (QA) requirements, so they reflected the categories and structures of those requirements: records requirements were fulfilled in a records management system; document control requirements were fulfilled in a separate document control system, and so on.

In 2010, when the DOE shut down the YMP, it transferred custody of YMP information systems from its Office of Civilian Radioactive Waste Management to its Office of Legacy Management. This included the project records management system as well as information systems that supported licensing efforts and technical work under QA controls, including document control, impact review and design control, and corrective actions.

The information systems have been maintained in their original state, without software updates (because there has been neither funding nor authority to update applications) and with hardware updates that have been infrequent and increasingly expensive and complicated because of the software constraints. Many of the systems in this collection had initially been developed in the 1990s and, with the additional 8 years since shutdown, many of them are at risk of functional obsolescence. Because the software has not been updated, they lack up-to-date cybersecurity controls required for any internet-connected information system and are maintained on an isolated local network by Legacy Management, and the systems are not available to users in other offices of the DOE or to national laboratories.

Meanwhile, since 2010, at the direction of the DOE, Sandia, as the Lead Laboratory for Repository Systems with responsibility for postclosure science, has maintained the technical basis supporting the postclosure component of the 2008 LA. Recently, the DOE has asked Sandia to develop a cloud-based information management system to serve as a generic template for any future nuclear waste management and disposal project.

3. STRUCTURE OF PAST HIGH-LEVEL WASTE MANAGEMENT INFORMATION SYSTEMS

Nuclear waste management information at the YMP and the IT systems that managed it reflect the structures embedded in its regulatory and QA requirements. Information systems were developed to support work conducted under the system of QA outlined in the DOE *Quality Assurance Requirements and Description* [1]. Thus, information is collected and managed separately in a records management system, a document control system, technical inputs configuration control system, a site characterization sample management system, a corrective action program information system, and others, each reflecting the particular characteristics, requirements, and controls appropriate for that information in that context. The systems archived by legacy management included:

- RISweb, the project records management system;
- CDIS, the document control system;
- TDMS, the technical data management system;
- CSITS, the site characterization project sample management system;
- CAP, supporting identification and management of condition reports for the Corrective Action Program;
- DIRS, the technical inputs management system, which supported impact analysis;
- The LSN screening and submittal system, which provided input to U.S. Nuclear Regulatory Commission's License Support Network;
- The LA database, which managed license application development and review;
- RAIRS, which supported the regulatory response process for U.S. Nuclear Regulatory Commission requests for additional information.

The systems were developed over time, and they were updated and modified as funding allowed and as changes were required. The requirements also developed over time. For example, in the late 1990s, the project decided that its existing practices did not provide sufficient information and controls for managing technical inputs in support of impact analysis and design control so a new information system, DIRS, was developed.

Because of this development history, these systems were not built on a seamlessly integrated information architecture. Though there is some information automation between systems, the systems are focused on the purposes and definitions that derived from the QA program. With hindsight, with current technology now progressed more than 20 years since most of the systems were developed, with a QA program that was structured with information architecture in mind, and with greater flexibility to adapt regulatory and QA requirements to an integrated information architecture, these information systems would be developed

differently. The Sandia team's goal is to realize this opportunity by moving these nuclear waste management information systems to a cloud platform. However, recognizing the imperative to preserve the regulatory and requirements precedents represented by the information systems and seeing the need to preserve the organizational knowledge embedded in the application workflows and controls, we found that the goal of an ideally integrated information architecture was in conflict with the need to preserve requirements and process and maintain the knowledge embedded in the systems.

4. OPPORTUNITIES AND CHALLENGES OF MIGRATING INFORMATION TO A CLOUD PLATFORM

As described previously, the redevelopment of these systems on a cloud platform was motivated largely by the looming obsolescence of the systems. But the costs of preserving those near-obsolete, marginally functional, and isolated systems was just as much a factor motivating a move to the cloud. Hardware maintenance, including periodic replacement, is still required for the systems maintained by DOE's Office of Legacy Management. Hardware upgrades for Legacy Management may be even more complicated and costly, in comparison to current technology, due to the aging operating systems and software that supports the information systems. The cost proposition that identified migrating the information systems to the cloud strongly favor the cloud platform.

In addition to eliminating hardware and maintenance costs, a cloud platform is also ideally suited to the goal of developing a system of applications to serve as a generic template for any future nuclear waste management and disposal project because such a system is highly portable. Instead of shutting down all the hardware, transferring ownership, shipping the equipment, and then restoring it to operation in a new location, systems on the cloud can be transferred contractually with no additional logistical burden. It could potentially be replicated for use by more than one organization.

In the USA, the Federal Risk and Authorization Management Program (FedRAMP) provides standardized requirements and processes for procurement and security authorization of cloud services. Use of FedRAMP made procurement, selection, and contracting with a cloud services vendor much more transparent and simple and helped minimize or eliminate some of the risks involved in migrating on-premise systems to a cloud platform. FedRAMP provides an independent trust mechanism that prequalifies vendors for consideration, provides standardized cybersecurity requirements, standardized authorization packages and contract language that reflect requirements and best practices without which a relatively small project like this probably could not have progressed successfully through the complicated and risky decisions and judgments otherwise to be reached without guidance or support.

At the time of writing, not all costs involved in migrating these applications to the cloud platform have been realized, so it is too early to assess in their entirety the accuracy of the cost estimates. There are some applications that, because they run on obsolete operating systems or software licensed from companies that don't exist anymore, can't be migrated to the cloud without extensive additional effort, potentially including buying new replacement tools and migrating the old data into them or developing software from scratch to fit prior data structures. However, many of these costs would be incurred by any approach to modernize them to current technology meeting current cybersecurity requirements and to make them available for use on an internet-connected network. To this point, the team has discovered no option to be cost-prohibitive or to be foreclosed or predetermined by the cloud platform.

5. EFFICIENTLY MANAGING AND STRUCTURING INFORMATION TO MEET PARALLEL BUT SEPARATE REQUIREMENTS AND NEEDS

As outlined above, the information architecture of the existing YMP systems was not developed from integrated information management principles. Fundamentally, the information architecture reflects the organization of QA requirements, rather than ideal information management structure. The requirements of the DOE *Quality Assurance Requirements and Description* treat document control, management of technical inputs, and design change control as separate functions and requirements. Therefore, a calculation document might be represented by the same document identifier (1) in the document control system (with change revisions and change documents linked to the "parent"), (2) in the records system (potentially in multiple draft versions required to be captured as records, even multiple versions of the same draft with review annotations required to be captured as records), then (3) in inputs management system (with an additional unique identification number just for this system), and then (4) identified and in other systems for corrective actions and other purposes. In the context of each system, that same data label (Document ID number, in this example) has slightly different significance. In contrast, the ideal design from an information management perspective would have one document with a unique identifier to which all requirements and functions attach, with unique, unvarying relationships in universal categories.

There has been a strong desire to rebuild these systems in this ideal data model; indeed, as indicated previously, it was among the initial aspirations of the project. However, the prior YMP information architecture successfully implemented all the regulatory and QA requirements, which means that the prior data model was the best available representation of high-level waste management information system requirements. Abandoning its accepted precedent and reinterpreting the regulatory and QA requirements to develop a new information model might require a wholesale restructuring of the project procedure set and perhaps the QARD itself, work that was well outside the scope of this effort. Even if it could be accomplished, such change would increase regulatory uncertainty rather than decrease it. The DOE and its regulator, the U.S. Nuclear Regulatory Commission, would have to start over in establishing that the information systems and the processes they support meet requirements.

Therefore, reorganizing those requirements to fit the ideal data model is not a genuinely available option. The redevelopment of information systems could not improve the information architecture implicit in the requirement, even where efficiencies could be identified in theory. The value of precedent, of reviewed and accepted information systems that have been shown to meet regulatory requirements, is greater than theoretical information integration and efficiency. While the path forward for the nuclear waste management program is uncertain and the law provides no opportunity to explore alternative approaches to information management, the only requirements basis is the past systems.

One lesson derived from these observations is that achieving an ideal data model for information systems for a nuclear waste management project requires that QA requirements are structured on a parallel model. The best—and perhaps only—opportunity to meet that ideal is to establish parallel QA structures and information management structures at the outset of establishing the nuclear waste management project. Partial success in accomplishing that ideal might be attained by continually associating QA requirements to information management requirements like the two sides of the same coin, and always considering both aspects when changes and updates to requirements, processes, and systems are required.

6. CAPTURING AND USING EXPERT TACIT KNOWLEDGE RELEVANT TO INFORMATION MANAGEMENT

The cloud project was able to gather expertise from the YMP that could illuminate the general history of the program and how it is reflected in the information systems being migrated to the cloud platform. The tacit knowledge from their program experience helped contextualize the development history of some of the systems. For example, some of the experts could recall that citation-formatting features of the inputs management system (DIRS) were developed in response to DOE's performance measures for their management and operating contractor and not from regulations or quality assurance requirements, making that feature less important to migrate and maintain for a future waste management organization.

However, the effort frequently presented questions where such tacit knowledge was unavailable and perhaps is now lost, where a value of a feature, a workflow, control, or database module was no longer understood and could not be reliably determined by review of program records. Such features of indeterminate importance will generally be retained and migrated into this cloud platform. A future nuclear waste management program will have a better opportunity to draw experts, whereas this project with its relatively narrow scope and limited duration is less able. Regaining that dispersed experience will need to be a priority for any new organization in order to prepare them to use the information tools and adapt to them successfully.

7. KNOWLEDGE RECOVERED FROM PROJECT SOFTWARE ITSELF, FROM HOW INFORMATION IS STRUCTURED WITHIN IT AND WORKFLOWS AND CONTROLS ARE DESIGNED

As noted incidentally throughout this paper, the initial thinking was that information management for a future nuclear waste management program could be developed fresh, guided primarily by best practices from information design. But as actual regulatory and QA requirements are being analyzed, it has become clear that those requirements weren't always compatible with ideal efficiency in design. Instead, the effort demands understanding of requirements that derive from review of the library of QA documents and program procedures and from the explicit and tacit knowledge of experts to understand how the applications need to function and how data of various kinds needs to be managed. However, even with that basis, the software itself serves as an additional form of knowledge that guides analysis and decision making.

In review of the LA database, which was used to manage development and review of the repository license application document and other licensing information, a licensing manager, who had supervised the development of the database, discovered that the database also contained the program's licensing Commitment Management System. For many years, the Commitment Management System was an independent tool, and the manager had forgotten that it was added to the LA database at about the same time that the RAIRS system (the system that managed the process for responding to NRC's requests for additional information) was being developed. The requirements and procedures identified the Commitment Management System as a required tool, but the documentation didn't identify it as a component of the LA database. In cases where experts were unavailable, the gaps filled by review of the software was even more significant.

Some work instruction documentation provides a rich source of information regarding the functions of the information systems, but this is highly variable. Where some processes had desktop instructions and users' manuals for systems, others did not. And even regarding a single application, a desktop instruction containing screen captures of the user interfaces might only cover part of the system for one type of user or for one use case among several supported by the system. Generally, the documentation provides only general process steps, and review of the software itself is needed to deeply understand the processes, workflows, and controls provided by the application. Where there as a gap in detailed understanding of information system requirements, the software itself could be used as a reliable default definition of features, functions, and contents for information systems that adequately supported processes for nuclear waste management.

It should be noted that the shutdown documentation for YMP included detailed information that would help IT professionals restore and restart the mothballed system, and this information has, of course, been indispensable in this effort. However, no rigorous knowledge management effort was made to capture the tacit knowledge of experts, owners, and users of the systems, to document the purposes, important features, secondary or perhaps obsolete, unused, or unnecessary features and components of the systems, or to provide advice to potential future users on changes or improvements that might be implemented.

8. IMPLICATIONS ON LONG-TERM MANAGEMENT OF INFORMATION AND RECORDS TO MEET REGULATORY REQUIREMENTS AS WELL AS MAINTAIN USEFUL KNOWLEDGE AND LESSONS LEARNED FOR OTHER PROGRAMS AND PURPOSES

Cloud computing, because of its "portability," may be an ideal solution for long-term management of information and records. Nuclear waste organizations beginning to develop their information systems may consider a cloud approach, and, if requirements and QA structures are not already deeply institutionalized,

perhaps those structures and an integrated data model might be developed while there is flexibility to accomplish it.

Organizations concerned with recovering knowledge should consider information systems as a source of knowledge, not just for the obvious content of the systems but for implicit information they contain regarding processes and program requirements. Organizations actively engaged in knowledge management and knowledge preservation should include in their collections expert discussions of the history of information systems, their use, and their relationship to project requirements and processes.

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REFERENCES

[1] U.S. Department of Energy, Quality Assurance Requirements and Description, DOE/RW-0333P, Rev. 20, Office of Civilian Radioactive Waste Management, Washington DC (2008).