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Knowledge Preservation for Repository Systems

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Abstract

The management and preservation of knowledge is essential to ensure the long-term safety of a radioactive waste repository throughout its lifecycle (planning, site selection, licensing, construction, emplacement operations and post-closure). While *recorded documentation* of technical and scientific information such as documents, media, software code and data is fundamental for the long-term safety assessments of a repository, there are additional categories of knowledge that need to be managed and preserved. These additional categories include *cultural considerations* such as history, social context, values, folklore, processes and procedures, plus the *memories* of staff, retirees and stakeholders in general. The preservation of knowledge for a nuclear waste repository is challenged by the long time scales involved and require management practices of *recorded documentation, cultural considerations* and *memories* that are robust and, as far as possible, future-proof technologically. Robustness also requires resiliency to future operational and societal changes, such as the advent of new organizational structures and evolutions in the decision making environment as well as the changing perceptions of stakeholders over time.

This paper discusses issues associated with the management and preservation of knowledge, including consideration of approaches that are expected to mitigate the inevitable changes in organizational structures and changing perceptions of stakeholders over time. Three case studies are presented, one associated with knowledge management and preservation for the Waste Isolation Pilot Plant radioactive waste repository. A second case study is that of the knowledge management and preservation program at Sandia National Laboratories (Sandia) associated with the maintenance of nuclear weapons. In the late 1990's, Sandia recognized the need to capture, maintain, catalog and store knowledge associated with the development, improvement and maintenance of nuclear weapons. Many of these weapons have been designed as early as the 1950's and there is a requirement to maintain them to ensure they perform as designed, and, most importantly, to remain safe while in storage. A third cases study illustrates knowledge preservation efforts attendant to the shut-down of the Yucca Mountain Project.

As repository development continues to advance in many countries, several disposal programs began to examine means for passive oversights to enhance the long-term safety of the future disposal facilities. In 2011, the Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) Radioactive Waste Management Committee (RWMC) launched a project on the "Preservation of Records, Knowledge and Memory (RK&M) across Generations". The RK&M Project aims at formulating and developing knowledge preservation methods that endure the longest possible timeframe (i.e. including the post-closure phase). This paper reports on the progress of RK&M as well as an initiative connected to RK&M entitled REPMET (repository metadata). The aim of this initiative is to identify sets of metadata that can be used by national programs to manage their repository data, information and

records in a way that is both harmonized internationally and suitable for long-term management and utilization. It will also formulate a consistent set of guiding principles for capturing and generating metadata. The RepMet project fills a unique and important niche in the broader programs on knowledge management that are conducted nationally and internationally. The REPMET initiative includes European, Asian and North American participants.

Introduction

Knowledge management is a comprehensive term generally meant to encompass efforts directed at compiling, organizing, and leveraging an organization's knowledge to support organizational goals, (continuity, profitability, efficiency, etc.). The term includes a diverse range of efforts to identify, analyze, optimize, and apply information that the organization deems important. In the context of repository systems, it spans matters ranging from the purely technical, well understood (certain), physical/chemical characteristics (waste packages materials, waste forms, corrosion, and waste locations); to less well understood (uncertain) characteristics, (natural fluid flow, volcanism, other low probability events); to very poorly definable characteristics, (cultural influences, societal characteristics).

Knowledge preservation is an element of knowledge management. For long term social artifacts, like nuclear waste repositories, its focus is different from that customarily applied, which is largely directed at important information necessary to maintain or improve current business models. Applied knowledge management as generally practiced would be very useful in the operation of a repository system. An example would be using knowledge management techniques to maintain the continuity of procedural processes (technical culture) over the decades of repository operations. However, knowledge preservation consists of efforts to safeguard our understanding of important issues for continuing long-term safety of the repository system by avoiding the loss of institutional and societal knowledge long after its closure.

Knowledge preservation for repository systems envelops both classic subdivisions of knowledge; explicit knowledge, and tacit knowledge. Explicit knowledge is information that is readily codified into a tangible form[1], i.e., documentary material (reports, analyses, memos, videos, email, databases, etc.) that may be retained in a wide variety of media (paper, film, electronic, etc.). This knowledge is most readily identified and retained, although it is still subject to the customary difficulties associated with dissemination, poignancy, searching, and technological obsolescence. In our societies, development of a nuclear repository is driven by overwhelmingly regulatory (technical / engineering) considerations. So, recording and preserving the explicit recorded knowledge required to convince a regulator to allow repository operation secures at least a core set of information requiring preservation. However, regulatory submittals likely constitute less than one percent of the recorded information necessary to produce it.

Tacit knowledge is knowledge that we as individuals possess, but is not readily codified. Skills like playing musical instruments, woodworking and welding are examples, as are inherent personal abilities like writing and mental arithmetic. Tacit knowledge is much more difficult to codify, if possible at all. However, this knowledge class also includes information that is not clearly explicit, but can be codified to a certain extent. Examples are technical, societal, or cultural processes that pertain to substantial organized efforts (large engineering projects). This knowledge can be captured by interrogating participants and transcribing or recording the conversations. Some examples are discussed in the case studies below.

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[1] Hilsop, D. 2013, Knowledge management in Organizations: A Critical Introduction, Oxford University Press, pg23

Notably, the form of the preservation media is a pervasive problem that overshadows all attempts at knowledge preservation, especially those attempting to preserve knowledge for centuries or even millennia[2] as in the case of repository post-closure information. Paper objects have traditionally served as the media for important information. However, our technological advances are clearly directing preservation efforts to electronic forms. In the U.S., the National Archive and Records Administration (NARA) accepts records in electronic formats[3]. Yet advances like these are not without their own obsolescence related issues. For example, while the ease of web-based publishing has greatly enhanced the dissemination of information, the inevitable changes in the web construct have led to international efforts to secure continued access to scientific and technical literature in the nuclear field[4]. This illustrates the difficulty of maintaining accessibility to electronically preserved knowledge, even over a time span as short as a few decades.

CASE STUDY: Sandia National Laboratories' Knowledge Preservation for Nuclear Weapons

Sandia emerged from World War II's Manhattan project.[5] During July, 1945, the site that is now Sandia National Laboratories (SNL) in Albuquerque, New Mexico, was chosen for the newly established Z Division of Los Alamos Laboratory. The site selected for the Z Division was part of land acquired by the U.S. military in January 1941 to establish a training facility for bomber pilots, as well as a training center for aircraft mechanics and air depot personnel. The Z Division, SNL's forerunner, gathered the ordnance engineering, testing, assembly, and military liaison activities into one group. In 1949, Sandia Corporation, a wholly owned subsidiary of Western Electric, took over management of Sandia Laboratory at the request of President Harry Truman (the name was changed much later from Sandia Laboratory to Sandia National Laboratories). In 1993, the management of Sandia Corporation was transferred to Martin Marietta (now Lockheed Martin) where it currently is as of this writing.

In the late 1940's, the nuclear stockpile was small, consisting of a few hand-crafted devices modeled on the Fat Man design used in World War II. However, as the cold war progressed from the 1950's through the end of the 20th century, the United States developed a larger stockpile of nuclear weapons of multiple designs. A primary mission of SNL has been and continues to be to provide the science and technology to maintain and certify the nuclear stockpile. The facilities and expertise used to fulfill this mission over the last 60 years are even more critical as the stockpile ages, the total number of weapons decreases (greatly increasing the relative worth of each remaining weapon), and the security threat to the stockpile changes. The capability to certify the safety, security and operational capabilities of the stockpile are made even more difficult since the banning of nuclear weapon testing in 1996. This means that the stockpile must be certified for safety and surety based on the understanding of the weapons systems in the absence of physical proof. Consequently, the knowledge of a weapons system, and how and why it was developed, becomes even more crucial.

In the early 1990's, it was recognized that with no new weapons designs on the horizon and with the designers of the weapons over the prior 40+ years leaving SNL and entering retirement[6], it would be challenging to maintain the expertise required to sustain the nuclear stockpile and the capability to respond to changes in the threat environment. While laboratory and DOE processes require the storage and maintenance of all design and test drawings and documents, it had no way of capturing the tacit

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[2] Cloonan, M.V., 1993, The Preservation of Knowledge, Library Trends, Vol. 41, No. 4, Spring 1993, pp 594-605.
[3] Code of Federal Regulations, Electronic records, Title 36 Section 1228.
[4] IAEA, 2008, Web Harvesting for Nuclear Knowledge Preservation, IAEA Nuclear Energy Series No.NG-T-6.6, Vienna.
[5] Johnson, L. 1997, Sandia National Laboratories, A History of Exceptional Service in the National Interest, SAND97-1029, pp. 3-5
[6] Sandia Lab News, July 8, 1994, p. 1

knowledge of these departing individuals. With this in mind, in 1994 a SNL Defense Program Vice President initiated the Knowledge Preservation Project with the goal of capturing and then offering the experience base of this generation to those yet to be hired. Through the rest of the 1990's and into the early 2000's, there was significant effort to gather as much of this tacit knowledge of retiring weaponeers as possible. In excess of 1,500 hours of video was recorded and placed on the Sandia Classified Network. Painstakingly, many of these videos were manually transcribed to allow for text searching but unfortunately, finding and accessing useful knowledge was both tedious and time consuming and therefore seldom attempted. For over a decade, this captured knowledge resided on servers, available but unused.

To remedy this problem, a new effort was initiated in 2012 that utilized the expertise of on-roll retirees to review these lengthy tapes, identifying and categorizing short (5-10 minute) synopses (video clips) of these exit interview videos for inclusion into a web based "YouTube" like application. The development of keywords for each clip allows for both effective searching and allows the system to use these keywords to create a sidebar search for related clips with the hope of encouraging a browsing by the users. The system, titled the Sandia Weapons Channel, is in use today and provides current weapons engineers with the history and context of why and how design and program decisions were made associated with the development of nuclear weapons.

Figure 1 is an un-classified screen capture from the Sandia Weapons Channel. The video dip appears in the top left section of the screen, and there are related clips on the right side of the screen. The value of the system might become evident if, for example, one of the solutions the weapons designers had 40+ years ago but couldn't be implemented, but could easily be implemented today with today's technology, providing a better solution. What is more likely to be of highest value are the lessons learned and philosophical approaches that are so willingly discussed throughout these interviews. In almost all cases, it is not the technical details that the retirees want to convey to these unknown future generations, but the approaches that worked and did work – the "gotcha's" that happened that they'd like to talk about – all the things that they wish someone had warned them about and all the tricks that they wished they'd learned earlier. That is the kind of information that, before the Knowledge Preservation Project, would have left with the departure of these early weapon designers.

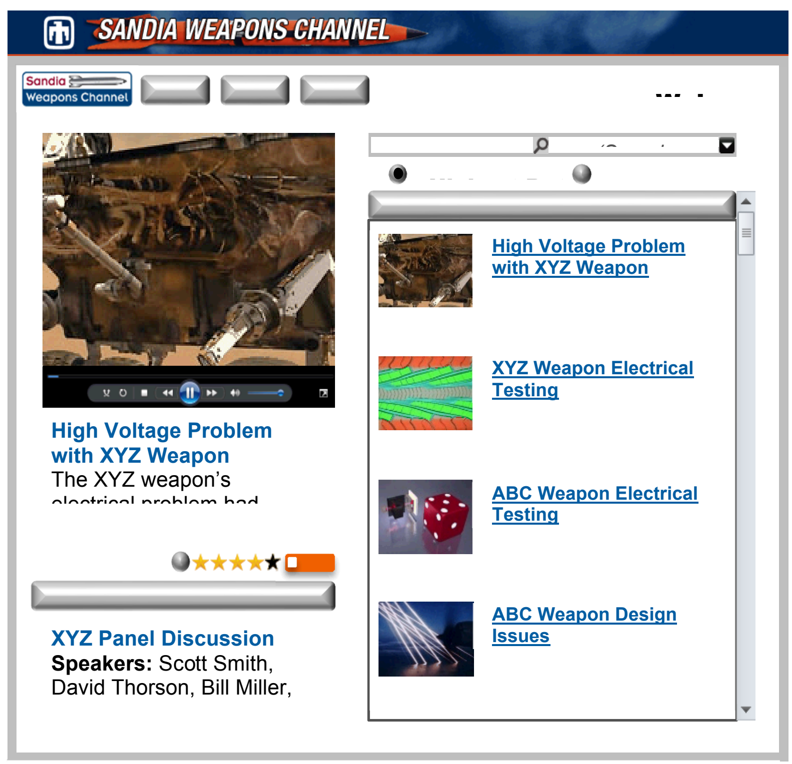

Figure 1 Sandia Weapons Channel screen capture
Image by Diane Miller, Sandia National Laboratories, 2014

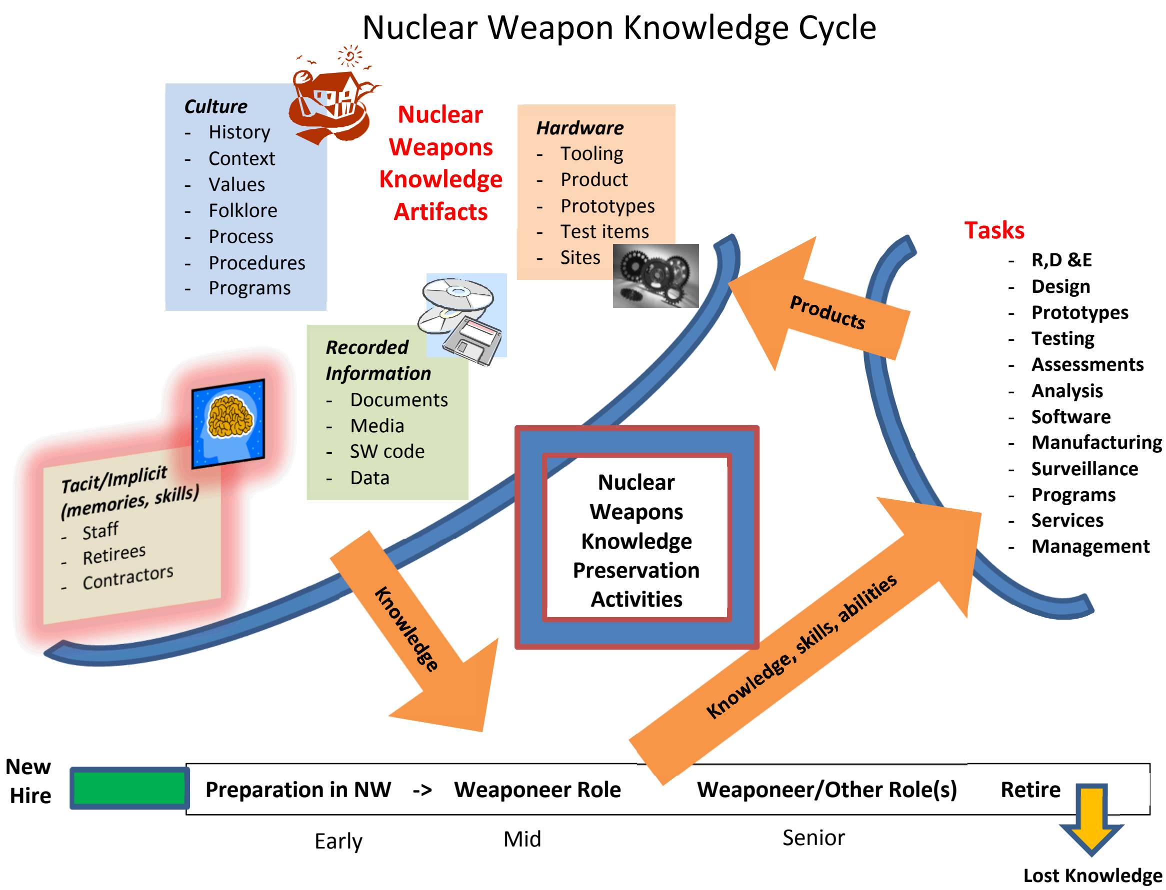

Figure 2 Nuclear Weapon Knowledge Cycle
Image by John Whitley, Sandia National Laboratories, 2014

The Sandia Weapons Channel, while an important component of the knowledge preservation at SNL, is not the only component. SNLs responsibility associated with nuclear weapons requires the continuing transfer of decades of nuclear weapon-related knowledge and experience to new generations of nuclear weaponeers, critical to the success of nuclear stockpile stewardship. Today, SNL approaches knowledge preservation for nuclear weapons by addressing the preservation needs through a Nuclear Weapon Knowledge Cycle. (Figure 2).

All phases of the Nuclear Weapon Knowledge Cycle are currently being addressed in SNL's knowledge preservation activities. The cycle begins after a new hire starts his or her preparation in nuclear weapons. Throughout an individual's career, knowledge, skills and abilities are applied to tasks such as research, development, engineering, and design. The knowledge, skills and abilities applied to these tasks find their way into explicit products that include the nuclear weapons artifacts of hardware, recorded information and culture, and the tacit artifacts embedded in personal skills and memories. The NW knowledge preservation program creates and sustains a flexible, on-demand set of programs that continually feeds these knowledge artifacts back into the workforce, effectively "recycling" this continually evolving knowledge base. As the weaponeer (the title given to the nuclear weapons engineer) passes through early, middle and senior stages of their career, the cycle repeats itself. When a weaponeer retires, the goal is to minimize the lost knowledge that would be leaving the organization.

Classroom based instruction is a key element of this knowledge cycle. The laboratory offers about 80 different instructor-led classes on various aspects of nuclear weapon operation, design, engineering, and testing, varying in length from two to forty hours. The program does not utilize a professional teaching corps but instead relies on either active or retired weaponeers for instruction. The basic philosophy is for legacy systems and subjects to be taught, as much as possible, by those who did the original work (usually retirees), while instruction on current systems is taught by those currently doing the work. Over the course of a year, this corps of over 250 instructors will reach over 1500 students and generate over 30,000 student-contact-hours.

In addition to this specialized nuclear weapon curriculum, Sandia also provides an extensive education experience to not only Sandia employees but to other DOE nuclear weapon sites and the military. The Weapon Intern Program (WIP) brings together a relatively small group of about 20 early career engineers and scientists and provides an intense, comprehensive exposure to nuclear weapons and nuclear deterrence. The first class of the WIP was established in 1998, with the first graduating class in September of 2000[7]. The WIP involves eleven months of classes (~500 hours), one-on-one encounters with senior weaponeers and nuclear weapons pioneers, site visits and rotational assignments[8]. Since the first graduating class of the 1998 WIP class, 353 weaponeers have successfully completed the WIP. The WIP continues to this date with 35 weapon interns currently enrolled.

Rounding out the weapon related knowledge activities are the efforts to preserve and utilize classified legacy hardware and components for educational purposes. Large numbers of prototypes, models, and test hardware was created during the course of these activities, and the program is actively collecting, cataloging, and offering these items for study and instruction.

Knowledge preservation for nuclear weapons stockpile stewardship is managed through the Weapons Engineering Professional Development Department (WEPD) and is closely coordinate with the laboratories' corporate learning activities. The WEPD continues to address the Nuclear Weapon Knowledge Cycle and advances the preservation of knowledge by employing current technologies that provide professional development forums, capabilities, educational programs, and products to enhance the skills of SNL's weapons engineers. WEPD has developed the capabilities to process archival media and make it accessible using today's technologies. They are processing motion film as well as ¾ inch, Beta and VHS video tape. A stand-alone PC which contains drives that read Bernoulli, Jaz, 5.25 inch and 3.5 inch drives has been made available. This knowledge preservation activity managed by WEPD represents a robust effort that continues to implement current technologies and multiple approaches for the preservation of nuclear weapons stockpile stewardship knowledge, as well as making sure older technologies and the decades of lessons learned remain accessible.

CASE STUDY: Yucca Mountain Knowledge Preservation

In June of 2008 the U.S. Department of Energy (DOE) submitted a license application (LA) to the U.S. Nuclear Regulatory Commission (NRC) for a high-level waste repository located at Yucca Mountain, Nevada. This culminated more than 20 years of scientific investigations into the feasibility and safety of disposal of high-level radioactive waste and commercial spent nuclear fuel at this location. On February 1, 2010, the U.S. Administration announced its Fiscal Year 2011 Budget Request to the U.S Congress reflecting discontinued support for the Yucca Mountain Project (YMP) LA submitted to NRC. DOE began to terminate YMP activities in March, 2010. By the end of July 2010, all YMP site-related technical studies had ended. Because the licensing proceeding had not come to a clear cut conclusion, several involved organizations, including Sandia National Laboratories, moved to preserve the scientific, technical and procedural information from the project.

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[7] Sandia Lab News, October 6, 2000, p. 11
[8] Sandia Lab News, October 17, 2003, p. 4

One advantage YMP had over most similar projects was that NRC's rules[9] required population of a Licensing Support Network (LSN) to facilitate legal discovery for the adjudicatory licensing hearing. The LSN is an electronic system, established by the NRC and operated by the NRC's Atomic Safety and Licensing Board (ASLAB) panel. Its purpose was to provide internet access to documents that may be used as evidence in the NRC's review process and associated licensing proceedings. This meant that the information to support the licensing hearing was preserved by the regulator, in addition to the licensee and its support organizations.

Another advantage was the rigorous records management provisions imposed by DOE on participants throughout the project. The collection of information maintained by DOE's Legacy Management office is the most comprehensive YMP collection. It contains about two million project documents and other artifacts (computer programs, etc.) related to research conducted in DOE's Civilian Radioactive Waste Management program over at least two decades.

Knowledge Preservation Systems for the Yucca Mountain Project are:

- NRC ADAMS (Agency Document and Management System) Collection
- NRC ASLAB LSN (Licensing Support Network) Collection
- DOE Legacy Management Collection
- Sandia National Laboratories (Yucca Mountain Project Lead Laboratory)
- Other Proceeding Participant Collections

Sandia National Laboratories is DOE's lead national laboratory for the project principally responsible for post-closure analyses of the YMP repository system. Sandia archived project information in a more integrated fashion than the project systems allowed. Figure 3 illustrates the general YMP Lead Lab information relationships. The shaded boxes represent independent project information systems that were largely isolated from each other. Without understanding the relationships among these information systems one would be unable to interpret the coding and metadata that relates the knowledge preserved (documents, data files, etc.) to the process from which it originated.

[9] Code of Federal Regulations, Procedures Applicable to Proceedings for the Issuance of Licenses for the Receipt of High-Level Radioactive Waste at a Geologic Repository. Title 10 Section 2, Subpart J.

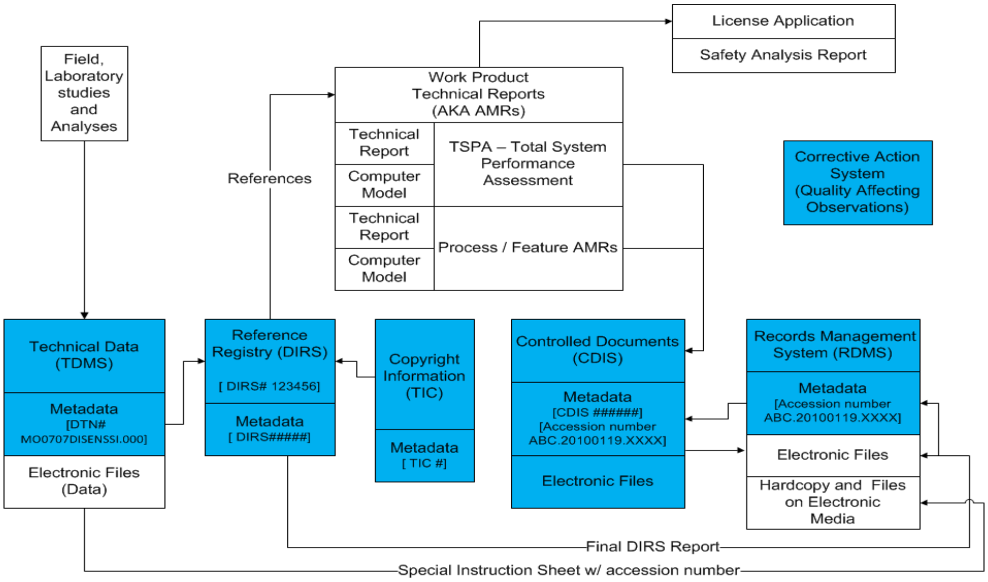

Figure 3 General YMP Information Relationships

Using SharePoint© technology, conventional file storage, and the general information model shown in Figure 4, Sandia developed two integrative tools to access project information; the Licensing Support Warehouse (LSW) and the Search and Report Center (SRC). LSW allows searches of an electronic warehouse for data and documents collected from YMP information systems. SRC allows creating, distributing, and managing business information from information systems using existing or tailored reports.

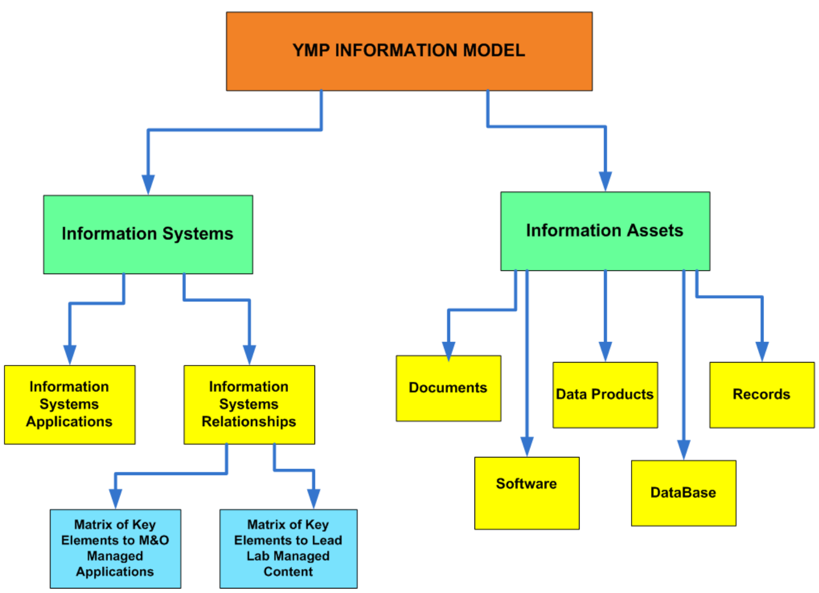

Figure 4 YMP Information Model

These tools provided several benefits with respect to accessing project information:

- Access to information that was scattered among multiple diverse project systems, often not operated by SNL
- Access to large collections of documents that are more conveniently searched collectively

- Access to multiple tracking systems (databases) addressing the same or similar subjects
- Reduced time to establish the traceability of information
- Reduced time to find needed information
- Results that provided access to available content
- Assist memory capabilities of participants

The approach described above did make SNL's post-closure analyses of the YMP repository system information readily searchable and available. Similarly efforts were made before project closure to retrieve physical samples and test specimens from various research locations and return them to the YM Sample Management Facility. Custody of this facility was returned to DOE in mid-2010.   Unfortunately, time constraints did not permit any collection or preservation of the intrinsic knowledge of the hundreds of participants.

Records, Knowledge and Memories – REPMET

There is international consensus that geologic repositories represent the best known method for permanently disposing of used nuclear fuel and high-level radioactive waste, without putting a burden of continued care on future generations.[10] Although geologic repositories are conceived to be intrinsically safe, there should be no intention to forgo, at any time, knowledge and awareness of the repository or waste that it contains.[11] Preservation of records, knowledge and memories (RK&M) need to be integral parts of the phases of repository development process from pre-siting all the way through site characterization, licensing, operations of waste emplacement and post-closure monitoring and management. The challenge to knowledge preservation for repository development phases is exacerbated by the time frames from start to finish, which may extend over hundreds of years.

The OECD\ sponsored "Project on Preservation of RK&M Across Generations," initiated in 2010, identified specific products and actions over the years 2010-2014 in three phases.[12]

<u>Phase I (2010 – mid 2011): Scoping of the issue</u>:

Surveys to participants will be administered, a glossary of terms will be started to provide common vocabulary and a draft collective statement will be produced on fundamental questions that are faced in the waste area.

<u>Phase II (2011 – mid 2012): Improving our understanding</u>

Based on two project workshops, one in October 2012 and one in April 2012, the glossary of terms with more work on short-, medium- and long-term issues, a bibliography and additional questionnaires to participants will result in the finalization of the collective statement and a progress report.

<u>Phase III (2012 – early 2014): Consolidating the lessons learned and reaching out to different communities</u>

The goal is to produce a menu-driven document that will allow identification of elements of a strategic action plan for RK&M preservation.

[10] USDOE, January 2013, Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Waste http://energy.gov/downloads/strategy-management-and-disposal-used-nuclear-fuel-and-high-level-radioactive-waste

[11] NEA-OECD , October 2011, Vision for the RWMC Project on Preservation of RK&M Across Generations, NEA/RWM(2011)6/REV2, http://www.oecd-nea.org/rwm/docs/2011/rwm2011-6.pdf

[12] NEA-OECD, October 2011, Ibid

In October, 2012, at the Integration Group for the Safety Case of Radioactive Waste (IGSC) 14th Annual Meeting in Paris, a presentation[13] that included a proposal for data management was made. The presentation recognized the RK&M project aims of formulating and developing knowledge preservation methods that endure the longest possible timeframe. However, also identified was the usefulness of a review of the data types and preservation methods that different national programs are currently using. This review would allow a meta-database, similar to the NEA Features, Events and Processes (FEP)[14] database, to be developed. From this proposal, the data management (DaMa) project was initiated.

At the first meeting of DaMa, held in Paris during September, 2013, a review of existing approaches adopted by waste management organization's from the participants was conducted. Participating representatives of waste management organizations from Belgium, France, Germany, Hungary, Japan, Spain, Sweden, the United Kingdom and the United States provided input through presentations and discussions. The following vision statement was developed:

> *"…Aim of this project is to create a metadata registry that can be used by national programmes to manage their repository data and records in a way that is harmonized internationally and is suitable for long-term management…"*

After continued collaborations and communications following the first meeting of DaMa, it was decided to rename the project RepMet (for repository metadata). The vision statement was rearranged to improve clarity, but the changes were mostly on how the material is presented than in the substance.

In January of 2014, the first RepMet meeting was held in Paris. A Summary Record of the First Meeting of the Radioactive Waste repository Metadata Management (RepMet) Initiative[15] was published. Topics addressed in the January RepMet meeting included:

- Standards in the field of metadata,
- INSPIRE[16] Infrastructure for SPatial Information in Europe, was considered for adoption by RepMet as an organized approach to defining and structuring metadata,
- CASPAR[17], Cultural, Artistic and Scientific knowledge for Preservation, Access and Retrieval, developed a set of methods and tools and applied them in diverse areas of scientific data, cultural heritage and performing arts
- RK&M project and the status of the phases (discussed above)
- Additional waste management presentations were made from countries not presenting at the DaMa meeting

The scope of the RepMet project is the:

- Identification of methods and protocols for the data and metadata gathering and management;
- Justification of the sufficiency of the set of metadata describing the identified data.
- Relationship to safety assessment models. The metadata required for the information captured 'in the field' will differ from that required for the analyzed and derived data that are often used within safety assessment models.

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[13] Nagy, Zoltan, Leader Geologist, PURAM, Hungary, "Proposal for Data Management" presented at IGSC 14th Annual Meeting
[14] NEA FEP database, https://www.oecd-nea.org/rwm/igsc_coprojectactivities.html
[15] NEA-OECD. 20-21 January, 2014, Summary Record of the First Meeting of the Radioactive Waste Repository Metadata Management (RepMet) Initiative, NEA/RWM/IGSC(2014)3
[16] INSPIRE, http://inspire.ec.europa.eu
[17] CASPAR, http://www.casparpreserves.eu/

- The role of metadata in 'handshake' between data providers (e.g. site characterization or waste producers) and data users (e.g. modelers or strategic decision makers).
- Identification of methods, protocols, etc. to guarantee the persistence of the above procedures in time.
- Feasibility of the identified procedures;
- Guideline for proposed data/metadata management.
- Discussion, and possibly joint recommendations, on critical terms that are used by the member organizations.
- The role of controlled vocabularies and policy as a means of ensuring consistency and reliability of data and its cataloguing.
- Data auditability, verification methods and if needed modification.

Following the January 2014 RepMet project meeting, a questionnaire regarding metadata collected for waste packages in storage and ready for disposal was distributed to the participants in June of 2014 for completion by August 15, 2014. The questionnaire implemented comments received from RepMet participants. The purpose of the questionnaire was, in Phase-I of RepMet, to develop a common list of metadata for waste packages in storage and ready for disposal, using an agreed and shared terminology as well as to understand commonalities and differences in practices among participating organisations. The questionnaire will be a basis for discussions at the next RepMet meeting, scheduled for September 2014 in Paris.

RepMet is affiliated with the NEA IGSC and maintains a strong connection to the RK&M Project. The RepMet project fills a unique and important niche in the broader programs on knowledge preservation that are conducted nationally and internationally.

Conclusion

The preservation of knowledge related to an eventually successful nuclear repository project will be of inestimable value. This aspect of the effort should be planned from the very beginning. Projects like this require a historian or knowledge management entity that is explicitly responsible for Knowledge Management and Knowledge Preservation, as well as, a defined process for capturing intrinsic knowledge from participants. We should not leave future generations wondering: ‘How did they move those enormous stones into place to build the pyramids?

Acknowledgement

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