NUCLEAR KNOWLEDGE MANAGEMENT STRATEGIES IN CANADA

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Abstract. An effective knowledge management strategy must encompass three basic elements; a sound resource management and training strategy to maintain nuclear competency in the face of accelerated retirements of current generation of experts and the development of advanced products, effective engineering tools to preserve the current technology and design basis and effective information management systems to facilitate pooling and sharing of information amongst different entities. The Canadian Nuclear Industry and its regulatory agency, the Canadian Nuclear Safety Commission (CNSC) recognized the importance of nuclear knowledge management and have already implemented a number of initiatives, in order to maintain competency, capture and preserve existing knowledge, advance the nuclear technology, develop future nuclear workers and maintain a critical R&D capability. The paper describes activities and initiatives undertaken or in progress in Canada in order to ensure a smooth transition of nuclear knowledge to the next generation of nuclear workers. Although this paper intends to address the Canadian scene in general, special emphasis will be placed on activities currently underway at Atomic Energy of Canada Limited (AECL) as the design authority and guardian of the CANDU technology.

1. Introduction

Over the past few years, plans have been developed at AECL and in other sectors of the industry to identify critical core competencies, potential and timing of future retirements and prioritize core competencies to be tackled first. Development of future nuclear workers received a boost through the University Network of Excellence in Nuclear Engineering (UNENE) program in Canada that was launched in 2002. UNENE is an alliance of six Canadian universities, nuclear power utilities, AECL and the CNSC. Capturing / preserving existing knowledge is taking place in Canada through a number of activities, notably the CANTEACH program.

Canadian utilities, such as Ontario Power Generation (OPG), Bruce Power, New Brunswick Power and Hydro Quebec have been continuously updating their documentation on plant configuration and introducing new training programs to enhance nuclear technology knowledge amongst staff.

Sustainability of research and development capabilities was also addressed by the CANDU Owners Group (COG) through a review of R&D capability in Canada and issued recommendations on necessary actions. Since then, AECL has undertaken a supplementary R&D program in support of new features of the Advanced CANDU Reactor (ACR) design.

The following sections provide more insight on all the above elements.

2. Maintaining Competency

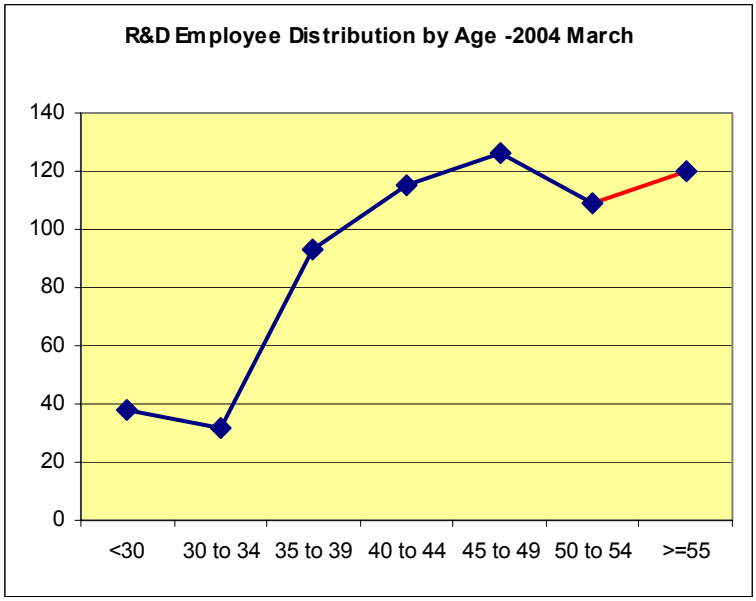

Figure 1: R&D demographics in a specific R&D group

With the ongoing rate of retirements of nuclear workers, resource management, succession planning and continuous technical training are of paramount importance. A human resources capability maintenance study has been undertaken at AECL to evaluate existing capabilities, impact of retirements, required resources to support corporate objectives and to identify high-risk areas for immediate action. A typical analysis for R&D demographics in a certain group is demonstrated in Fig 1. Further analysis of potential retirements by skill category has been also undertaken. In response to these studies and similar ones for all other skill categories, a succession plan has been established at AECL for all of its professional, technical, managerial staff and singleton experts. A hiring, training and mentoring strategy was then developed. Staff development through continuous training and mentoring is of crucial importance to maintaining competency. A company wide career development and training guidelines document for centrally managed resources that identifies skill categories, designates responsible skill managers and defines required training has been issued and the strategy is being implemented. Demand-supply forecast is being monitored and updated annually to ensure on-going commitments are met.

The AECL recruitment plan includes a short term, medium term and a long term focus. The short term focus includes an annual new graduates program in addition to the standard hiring program to meet immediate needs. The medium term focus includes hiring co-op and summer students, in an effort to screen and attract the best to join the company in future.The long term focus relates to collaboration with universities and technical colleges through the UNENE program. This program is an alliance of Canadian universities, nuclear power utilities, AECL and the CNSC and its purpose is to assure a sustainable supply of qualified nuclear engineers and scientists to meet the current and future needs of the Canadian nuclear industry. In addition to full-time under-graduate and graduate degrees, UNENE, through 6 major Canadian universities offers part-time programs designed for students currently employed in the industry. Courses are offered in flexible formats, generally at nuclear sites and at AECL for the convenience of the students. Some teaching modules are delivered by experts from the

industry in addition to university professors. More information on UNENE will be presented at this conference through a different paper (Reference1).
The industry also supports a number of Industrial Research or University Chairs in addition to a number of Adjunct Professors at numerous universities to enhance faculty and students awareness about nuclear energy and resource requirements. This helps to enhance the profile of the nuclear industry through arranging visits/tours for student groups, definition of research topics for post graduate studies and pre-selection of good candidates for full-time employment at AECL.
In order to support all the above human resources initiatives, it was imperative to develop numerous services and tools to enable effective human resources management. Examples, include E-cruiter, a web based recruiting tool, an information package for potential immigrants, a hiring case procedure/template, new grad hiring campaign, supply/demand forecasts and tracking of trends. Metrics are being continuously developed and updated to ensure proper resource management.
The Canadian regulatory agency, the CNSC approaches knowledge management as a continuous activity that is addressed in the implementation of its core regulatory processes. It is an inherent part of the regulatory framework, and of activities in the licensing and compliance inspection programs. CNSC considers knowledge transfer and learning as lifelong processes and is committed to the training and development of its employees to enhance the efficiency and effectiveness of its operations, achieve its mission objectives and permit the ongoig development of a professional, competent, versatile and motivated workforce.
In order to promote systematic knowledge transfer, the CNSC has established a Learning Management System that automates the administration, tracking and reporting of training activities. This system enables management to plan and budget for employee training and supports the organization in the acquisition, creation and transfer of information and knowledge.
On another front, the CNSC has also developed an internship program to recruite young engineers and scientists as one of a number of strategies aiming at rejuvinating its aging workforce in a very competitive market. The young recruits commence with a structured program that accelerates knowledge transfer with a number of short term individual work assignments, and common training and group activities. The objectives for both work assignments and training activities are developed in consultation with regulatory business line management. The interns are evaluated after each work assignment and are required to demonstrate proficiency during training courses. Following the successful completion of the program, they are placed in entry level generalist positions in the regulatory operations branch.
All Canadian utilities, particularly OPG, have in recent year been focussing on development and implementation of detailed staffing / recruitment / training plans for the major functional areas (operations, maintenance and engineering) to address potential retirements and general attrition. As indicated earlier, utilities also partnered with colleges and universities to provide a sustainable supply of qualified staff (apprenticeships, internships, UNENE). New training programs were also intruduced to enhance the technical / operations knowledge of the existing staff and managers. Utilities also implemented significant improvements in the areas of documentation and accessibility of technical plant information.

3. Capturing / Preserving Existing Knowledge & Advancing CANDU Technology

Maintenance, preservation and advancement of CANDU technology have received significant attention in Canada. “CANTEACH” is one of the recent successes in the area of preservation and dissemination of CANDU technical knowledge. This project was initiated a few years ago with a mission to preserve the technical knowledge of CANDU nuclear power plants for use

by current and future members of the CANDU community. AECL, Canadian Nuclear Society Universities Committee and Canadian Industry Partners sponsor this project. Its main objectives are to, a) provide a permanent record of CANDU technology, b) provide a source of education and training material and c) capture and share existing documentation before it is lost. The CANTEACH project continues to record current CANDU plant knowledge, capture and leverage existing technology information and document the bases and design considerations of CANDU plants.

The need for CANTEACH was prompted by the absence of a central repository of large amounts of information available at CANDU plants and AECL that captured design legacy and evolution and an integrated archival system required to provide a consistent and complete record of CANDU development. Information is made available through a dedicated web server that is being administered by the CANDU Owners Group (COG). More information on CANTEACH program can be found in References 2 and 3.

In parallel to CANTEACH, fully computerized engineering tools (AIM/TRAK) have been developed by AECL and used to document the complete design of CANDU 6 plants. This encompasses all plant design, analysis and licensing knowledge including engineering drawings, design manuals, design reviews, analysis reports and all licensing documentation. The same system is being also used today to document the development of the ACR design, analysis and licensing knowledge. TRAK has been designated as the sole repository for the company's intellectual property. A consolidation process is underway at present to capture information from other systems and migrate these to TRAK. In addition, a comprehensive system for feedback of experience is used to document all operational issues to ensure lessons learned from operating plants are shared widely within AECL and with CANDU owners.

Examples pf current knowledge sharing systems at AECL are:

Operating Experience (OPEX): OPEX is a Nuclear Laboratories process that captures operating experiences and assists in sharing lessons learned.

Feedback Monitoring System (FMS): FMS is a feedback database which conforms to CSA N286.2 requirements regarding systematic collection, recording, evaluation and distribution of design, construction, commissioning and operating feedback information to AECL groups for the purpose of improving the safety and reliability of AECL products.

Project Reporting Systems (PRS): Various PRS tools are used to allow users to share knowledge about projects. Such a tool is essentially a dashboard that captures data about a specific project such as schedule, budget, milestones, risks, resources, status reports, etc.

Customer Connect: Although implemented primarily for customer relations purposes, this tool allows users to share knowledge about our customers, including issue tracking and resolution, financial performance, profiles, etc.

Others: Other systems exist for specific purposes such as the Action and Issue Management System (AIMS) for tracking regulatory issues, the Quality Information System (QIS), etc.

AECL has also developed the *SMART CANDU*^{TM} that transfers knowledge from people to computer systems. Such technology enables nuclear operators in monitoring station conditions, converting measured data into useful information, analyzing the information intelligently and providing recommendations to support decision making. An example of such a system is the System Health Monitoring Tool (SHM tool). A SHM tool provides both past and present views of plant conditions. Plant data are sorted and displayed according to specific functions or degradation mechanisms with which they correlate. Out-of-spec conditions are flagged and their impact on system or component health is then assessed using on-line analysis codes. Predictive tools that are part of the SHM tool suite enable staff to target when and where to inspect, and assist in the planning of remedial maintenance activities

to avoid equipment failure or plant de-rating. Such tools can be used to assist in plant control and testing, operations and maintenance and configuration management.

An important aspect of maintaining the technology is AECL's continuous development and innovation of "maintenance technology" in support of Plant Life Management. This aims at reducing maintenance outages and radiation doses to workers through increased use of automation and robotics since as a nuclear power plant ages, the amount of maintenance and inspection work, generally increase, as does preventive maintenance work. At the end of plant life, a massive effort is spent on either plant life extension or decommissioning. This spurred the development and innovation in the field of "nuclear maintenance technology". Three technologies that have been implemented successfully by AECL are:

Robotics and remote technologies: As plants age, the need for more intelligent, flexible and durable robots increase dramatically. AECL has been using advanced robotics and remote technologies in field services for a number of years. A dedicated robotics group with significant field experience has been established to focus on the development and application of this technology at CANDU plants. It should be noted that robotics applications are not stand alone technology. The human in the loop plays a major role and robots will not function without key human participation

3D simulation or virtual prototyping: At AECL, almost all maintenance projects are first modelled and tested on 3D simulation systems. This offers maintenance personnel the opportunity to visualize their systems working in a virtual environment without the need to build costly mock-ups and physical systems.

3D laser scanning: Laser scanning uses time of flight laser principles that builds a geometric model of the environment and produces photo-quality images to replicate a full 3D environment as a maintenance outage planning and preparation tool.

The on-going design and development of advanced CANDU systems is another essential element in AECL's efforts in preserving knowledge. Over the past decade alone, AECL developed the CANDU 3 and CANDU 9 designs (as GEN II along with CANDU 6) and is now developing the ACR design (GEN III)). AECL is also an active participant in the GEN IV program with a focus on the Supercritical Water Reactor design (SCWR). As shown in Fig.2, the company has a long-term outlook and started the thought process for post-Gen V and beyond (CANDU X) technologies.

The evolutionary approach AECL follows aims at minimizing the risk to utilities seeking the CANDU technology as well as ensuring continued AECL support of maintenance and field service requirements. The continuous development mode for new products and maintenance technology has been the most instrumental aspect in preserving AECL's design and analysis competency as well as improving analysis methodologies and tools. This development mode enabled the company to retain experienced design, analysis and R&D staff, to further develop, improve and verify advanced computer codes and to attract new and young employees. This preservation and maintenance of expertise enabled AECL to successfully complete 2 CANDU 6 units in China and to participate in the construction of Cernavoda unit 2 in Romania.

The effectiveness in capturing and preserving nuclear knowledge by any organization is dependent to a large extent on the existence of appropriate Quality Management Systems. AECL has formalized a company-wide Quality Management System and has adopted the Canadian Framework for Business Excellence to guide its operations (Reference 4).

Finally, AECL succeeded in maintaining an extensive network of CANDU suppliers, as there has always been at least one CANDU plant under construction at any given time over the past 40 years.

4. Maintaining Research and Development capabilities

Maintaining R&D capabilities is the backbone of any overall program to maintain competency and advance the nuclear technology. As reported in the IAEA meeting on knowledge management in June 2002, the CANDU Owners Group (COG) undertook a review of R&D capability and issued a recommendation that "the industry must implement, in the near term, an increase in funding to R&D programs to ensure that adequate core capability is maintained in key areas". This is still an issue industry-wide and the appropriate level of funding is still being debated. Nevertheless, AECL is undertaking a supplementary R&D program in support of new features of the ACR design. Major facilities in support of CANDU development are still available, notably the full-scale RD-14 thermal-hydraulic facility at Whiteshell Laboratories.

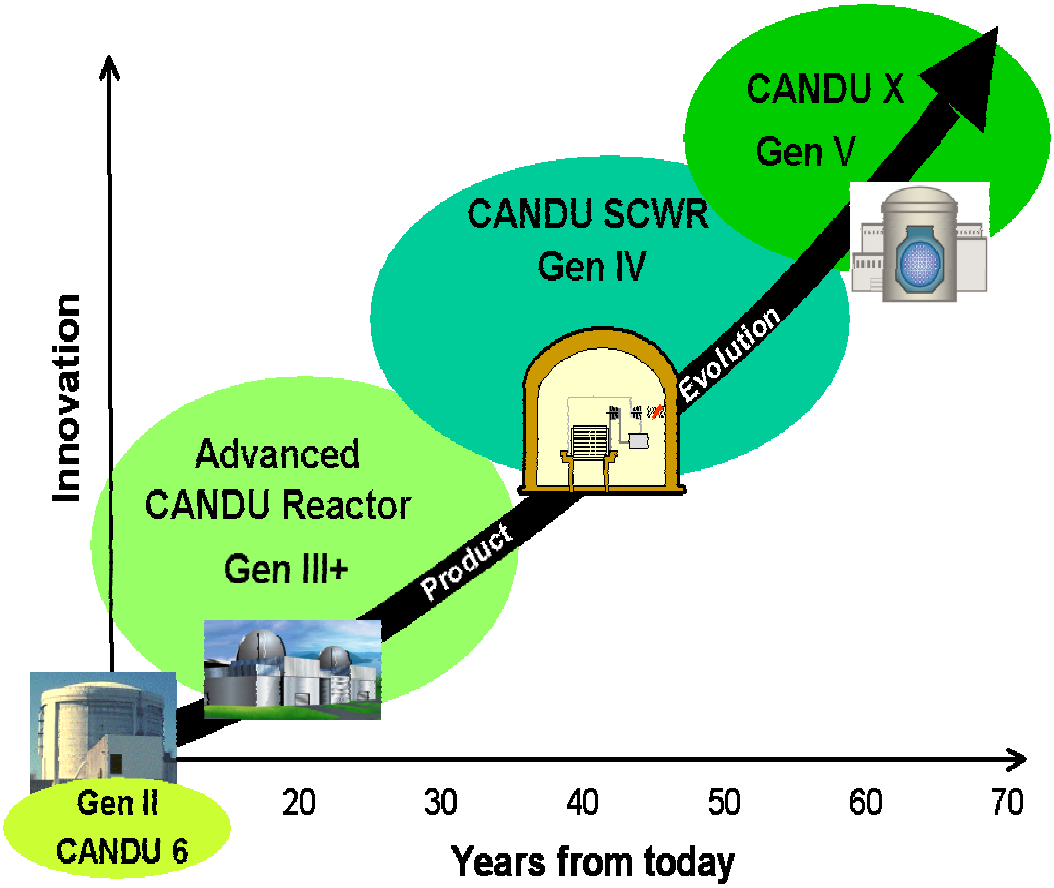

Fig. 2. Evolution of CANDU systems

Plant life management also requires significant R&D activities. Tables 1 and 2 provide information on such R&D work that is supported in Canada by AECL as well as nuclear utilities through the COG program. More information on Canadian R&D efforts in support of plant life management can be found in References 5-7.

In conclusion, there is much awareness in the Canadian nuclear industry on the importance of knowledge management to the sustainability of nuclear technology as a major source of energy. CANTEACH program aims at capturing and preserving nuclear information and knowledge, while UNENE program aims at generating high quality professionals. Specific human resources and information management programs and training activities supplement these across the nuclear industry as well as the CNSC. Many issues have been addressed but much still to be done to ensure smooth transition of knowledge to a new generation.

Table 1. Summary of COG Specific R&D Programs

CANDU Components	*Degradation Mechanisms*	*Ageing Data*	*Life Prediction*	*Maintenance Guidelines*	*Obsolescence (subcomponents)*
Fuel Channels	**X**	**X**	**X**	**X** (fitness for service guidelines)	
Steam Generators	**X**	**X**	**X**	**X** (fitness for service criteria)	
Process & Safety Related Components (pressure vessels, heat exchangers, rotating machinery, etc.)	**X**		**X**	**X**	**X**
Plant piping/ Elastomers	**X**	**X**			**X**
Concrete Structure		**X**		**X**	
Nuclear Cables	**X**	**X**			

Table 2. Inspection and Monitoring R&D Programs

	Capability Development	*Efficiency Improvement*	*Component Life Prediction*
Fatigue Monitoring	**X**		**X**
Valve Diagnostics	**X**		**X**
Motor Monitoring			**X**
Defect Sizing	**X**		
Pump Monitoring	**X**		**X**
Erosion-Corrosion Susceptibility	**X**		**X**
ET Fretting Wear	**X**		
Pipe Flaws - Gauging		**X**	**X**
ET (for wide range of CANDU materials)	**X**	**X**	

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