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Basic Principles

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Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation

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COMPARATIVE ANALYSIS OF METHODS AND TOOLS FOR NUCLEAR KNOWLEDGE PRESERVATION

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FOREWORD

The important role which the IAEA plays in assisting Member States in the preservation and enhancement of nuclear knowledge and in facilitating international collaboration in this area has been recognized by the General Conference of the IAEA in resolutions GC(46)/RES/11B, GC(47)/RES/10B, GC(48)/RES/13, GC(50)/RES/13 and GC(52)/RES/12. Today, nuclear knowledge management has become an important element and tool for the nuclear community. The IAEA has published a number of reports on nuclear knowledge management in the areas of guidance, applications, lessons learned and terminology.

Knowledge preservation is part of the larger process of knowledge management. The IAEA is continuing to focus on nuclear knowledge management activities to support Member States in analysing their needs for nuclear knowledge preservation, to estimate the current status of existing problems and to suggest common approaches towards preserving their existing nuclear knowledge and specialist expertise. In general, preventing the loss of vital technical and historical information is starting to be recognized as being of strategic importance to the nuclear industry and, in particular, to nuclear facilities. In recognition of this need, the IAEA initiated a coordinated research project (CRP) in 2006 on Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation to assist Member States in the selection and implementation of appropriate, cost effective, knowledge preservation solutions, and to facilitate awareness of new methods and best practices in the preservation of critical nuclear sector knowledge.

The CRP has resulted in technology transfer meetings and the publication of several reports. Each year, a Research Coordination Meeting has been held to discuss the progress of tasks. The reports from each of these meetings, along with this final report, describe all of the activities carried out by the coordinating organization under this project. The final report provides guidance and recommendations for the development and implementation of knowledge preservation systems in Member State organizations.

This publication represents the final report of the CRP. The reports of national organizations are presented on the attached CD-ROM.

The IAEA officers responsible for this publication were I. Kitaev and A. Kosilov of the Department of Nuclear Energy.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Long term nuclear energy scenarios have created awareness of the need to preserve and maintain accumulated knowledge in the areas of nuclear science, industry design and operating experience. These scenarios have highlighted the problems arising from an ageing workforce and a sharp decline in the number of entrants to education and training programmes for nuclear science and engineering. Preserving existing nuclear knowledge, specialist expertise, and in general prevention of the loss of vital technical and historical information is starting to be recognized as a mission of strategic importance to both nuclear and nuclear supporting organizations.

The challenge of the IAEA is to enhance the capacity of Member States to maintain and preserve information and knowledge resources related to the peaceful uses of nuclear energy. As such, the development of knowledge preservation approaches and tools based on innovative methods, including the use of modern information technology, is becoming a necessity. To begin to tackle the problem of nuclear knowledge preservation, different types of information capture, transfer and management need to be considered, including databases, expert systems, multimedia, intranets, portals, etc. A need also exists to investigate various methods of tacit knowledge sharing, enhancement and codification.

In recognition of this need, the IAEA initiated a coordinated research project (CRP) entitled Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation in 2006 to address the topic of knowledge preservation (KP).

The main objectives of the CRP were:

- To assist Member States in the selection and implementation of appropriate KP solutions;
- To facilitate awareness of new methods and best practices in the preservation of critical nuclear sector knowledge. In particular, methods and tools to capture, interpret, analyse and disseminate data and information, as well as the knowledge ultimately derived from them, were explored.

Following an announcement by the IAEA in 2005 that the CRP was to be undertaken, six countries and one international organization agreed to partake in research in support of the project. These were: Bulgaria (United Technical College, Technical University of Sofia), Canada (Atomic Energy of Canada Ltd.), Jordan (Water Authority of Jordan), Philippines (Philippines Nuclear Research Institute), Romania (Institute for Nuclear Research), the Russian Federation (Inter DCM Corp., a subsidiary of the RRC Kurchatov Institute) and the European Commission (Institute of Energy, DG Joint Research Centre). Pakistan (Pakistan Nuclear Regulatory Authority) joined the CRP at the beginning of its second year.

As part of the CRP initiative, a survey tool on the Current Status of KP in Nuclear and Supporting Organizations was developed and undertaken in 2006–2007. An analysis of the results from this survey helped to support the formulation of recommendations and conclusions on good practices in knowledge preservation.

This report is based on the results of the CRP, which include the results of CRP participants' research projects and joint studies of KP methods and tools as well as findings from the above mentioned survey.

1.2. OBJECTIVE

This report discusses KP in the context of nuclear knowledge management (KM) in nuclear facilities. The specific objectives of this publication are to:

- Increase awareness of methods and best practices in the preservation of critical nuclear sector knowledge. In particular, methods and tools to capture, interpret, analyse and disseminate data and information, as well as the knowledge ultimately derived from them are explored;
- Summarize the findings of a benchmark survey conducted to determine the current status of nuclear KP in Member States;

- Document various commonly used KP methods and tools and provide guidance on their typical uses and potential benefits;
- Examine specific case studies of KP initiatives to provide useful examples of current best practise in knowledge preservation.

1.3. STRUCTURE

Section 2 discusses KP in the context of nuclear knowledge management. It explains why KP is important to nuclear facilities and summarizes the important role of KP and the perspective it can provide. The basic knowledge processes and key knowledge attributes that influence approaches to KP are explained. Widely used KP methods and tools are enumerated and described. Finally, useful criteria are presented to help categorize and understand the domain of use of each method and tool, and provide a framework for the remainder of the report.

Section 3 provides useful guidance on the formation of KP strategy and implementation plans. It outlines basic factors to be considered and an effective method to identify threats to knowledge loss in an organization. This is based on an assessment of the effectiveness of current KP processes in meeting an organization’s KP needs and any gaps that result. An approach to planning a balanced KP initiative and an effective implementation plan are described.

Section 4 discusses KP in the context of each of the basic knowledge processes: knowledge identification, capture, organizing and processing, storage, access and retrieval, etc. It provides guidance on the range of application and usefulness of each method and tool.

Section 5 provides assessment criteria to evaluate the status of KP in an organization.

Section 6 summarizes several examples of KP ‘best practice’ initiatives based on input from Member States involved in the CRP. Conclusions and recommendations are also provided.

Appendix I summarizes the findings of the survey on KP that was conducted as part of this CRP. Appendix II provides examples of successful IAEA KP programmes. Finally, Appendix III summarizes the individual participants’ reports, which form part of this CRP.

Annex I reproduces the IAEA survey questionnaire on current status of knowledge preservation in nuclear and supporting organizations. An accompanying CD-ROM presents the reports of national organizations.

2. KNOWLEDGE PRESERVATION IN A KNOWLEDGE MANAGEMENT CONTEXT

Nuclear knowledge has been developed and accumulated over decades. This knowledge base stems from both research and development and the industrial application of nuclear technologies, and includes both energy and non-energy applications. In response to an increased awareness in many countries of the importance of managing nuclear knowledge, the IAEA has published a number of guidance and technical documents, including a document outlining high level issues and objectives for nuclear KM [1]; it is widely agreed that these are relevant and applicable to activities in the nuclear sector as a whole. This section draws from and builds upon these IAEA publications to provide a general summary introduction to the subject of KP in the context of nuclear KM (for further information see Ref. [1]).

2.1. KNOWLEDGE AND NUCLEAR KNOWLEDGE

Before any meaningful discussion about KP can be undertaken, it is important to first clarify what is meant by ‘knowledge’. Many definitions of the term are used in literature, but they do not all agree. Table 1 [2–7] provides some of the more widely cited definitions found.

TABLE 1. DEFINITIONS OF KNOWLEDGE

Definition	Author(s)
Knowledge is a mix of different experiences, values, contextual information, and expert insight. It provides a framework for evaluating and incorporating new experiences and information.	T.H. Davenport and L. Prusak, 1998 [2]
Knowledge is information that is contextual, relevant and actionable.	F. Soliman and M. Youssef, 2003 [3]
Knowledge is a justified true belief.	I. Nonaka, 1994 [4]
Knowledge is a person's experience gained over time (it can be communicated and shared).	V. Allee, 1997 [5]
(Organizational) Knowledge is what the firm knows in terms of best practices.	G. Szulanski, 1996 [6]
Knowledge is placing information in some type of context. It brings information together and helps understand its 'know-why' and 'know-how'.	A. Brooking, 1996 [7]

In general, academics agree there are three different types of knowledge: explicit, implicit and tacit. Explicit knowledge is contained and conveyed in documents, drawings, calculations, designs, databases, procedures and manuals. Explicit knowledge is knowledge that has already been codified (i.e. written down) or declared. In contrast to such relatively accessible information, implicit knowledge is difficult to reveal, but it is still possible to record. It is generally feasible to convert implicit knowledge into explicit knowledge through a knowledge conversion processes generally referred to as 'codification' or 'transformation'. The third type of knowledge, tacit knowledge, is the most difficult to recall and to articulate, and thus to transfer. Tacit knowledge cannot be completely explained, since it is wholly embodied in the individual, rooted in practice and experience, expressed through skilful execution, and transmitted through apprenticeship and training by watching and doing. Tacit knowledge can be observed; however, it is doubtful that all of this knowledge can be converted into explicit knowledge. Thus, the saying developed, "We know more than we realize we know." Tacit knowledge includes skills, experience, insight, intuition and judgment. It is the 'know-how' accumulated in an individual's mind.

In this report, knowledge is defined to include tacit, implicit and explicit knowledge, meaning it encompasses everything from technical information laid down on paper or in electronic media to insights or capabilities and skills embodied in people. Knowledge then clearly extends beyond just information. It includes the expertise required to turn raw data or information into understanding (i.e. the ability to find a meaningful interpretation of relevant issues using information). Knowledge may be applied for such purposes as problem solving and learning; forming judgments and opinions; decision making, forecasting and strategic planning; and generating feasible options for action so that action can be taken to achieve desired results. Knowledge also protects intellectual assets from decay, augments intelligence and provides increased flexibility.

Nuclear knowledge is knowledge specific or relevant to nuclear related activities. Nuclear knowledge is owned today by many different organizations at all levels. Wide varieties of different stakeholders claim interest in managing, using, applying, developing and sharing such knowledge — each with specific objectives, requirements, and limitations. These stakeholders include:

— Governments, including regulators;
— Designers, vendors, utilities, operators, suppliers, consultants, and support organizations;
— Training and academic institutions;
— Research and development (R&D) organizations;
— The general public and non-governmental organizations (NGOs);
— International organizations.

The resources required to sustain nuclear knowledge, which was often developed with government support, may exceed current available resources and as a result may face the risk of being permanently lost. There is also often a lack of effective planning and mechanisms are not in place to transfer knowledge from one generation to the next. Given the significant impact nuclear technology has had over the past century, there is widespread consensus that the need for nuclear knowledge will increase in the future, and in particular with respect to the following three important areas:

- The continued secure and safe operation and eventual decommissioning of existing nuclear facilities;
- The design and building of new nuclear facilities;
- Acceleration of the growth of new nuclear applications.

Finally, it is important to recognize there are various perspectives on knowledge that need to be considered. Knowledge can be considered at the individual level, at the group level, at an organizational level, or at the industrial level. Further, knowledge considerations may be quite different depending on time perspective. For example, our ability to identify, retrieve, interpret, transfer, and apply knowledge to a task at hand may be very immediate and knowledge flow and stores that facilitate the speed of utilization may be the primary focus. Conversely, it may be important to consider knowledge accumulation or loss within an organization or across the industry over long periods of time, and in the context of societal needs and technology changes. Finally, knowledge must be considered within organizations.

2.2. KNOWLEDGE MANAGEMENT

Various definitions of 'knowledge management' also exist in literature, however most are consistent with the notion that a coordinated approach is required to manage an organization's knowledge and improve organizational performance, and that this is achieved through knowledge creation, structuring, and dissemination processes [8]. B. Newman defines KM as "…the processes that govern the creation, dissemination, and utilization of knowledge" [9]. M. Alavi and D.E. Leidner define KM as "…the process to acquire, organize, and communicate knowledge of employees so others may be more effective in their work." [10]. For the purposes of this report, the definition put forward by D. Andriessen that KM is "…organizing and optimizing knowledge processes" [11] is deemed to be the most appropriate. KM processes are defined in many ways by different authors using various analogous terms. G. Hedlund describes KM processes as knowledge capture and storage, transfer and sharing, transformation, creation or generation, and representation [12].

The IAEA defines KM as "an integrated, systematic approach to identifying, acquiring, transforming, developing, disseminating, using, and preserving knowledge, relevant to achieving specified objectives." KM consists of three fundamental components: people, processes and tools [13], and can be clarified in this way:

- KM focuses on people and the organizational culture required to stimulate and nurture the sharing and use of knowledge, on processes or methods to find, create, capture and share knowledge, and on the technology needed to store and make knowledge accessible and to allow people to work together without being together;
- KM focuses on processes or methods which find, create, capture and share knowledge. Established operational processes are essential to safely operating and maintaining nuclear facilities. Nuclear facilities must rely on strict adherence to procedural requirements in order to assure safe operation and process integrity. Although there are companion procedures through which those processes may be changed, it is imperative in the nuclear industry that any changes to established procedures and processes be rigidly controlled. KM must be integrated into strategic planning, analysis and decision making, implementation of plans, and evaluation of results;
- KM focuses on technology to store and make knowledge accessible, which allows people to work together without being at the same location. Thus, technology is an important enabler to the success of KM.

Thus, nuclear KM is an integrated, systematic approach applied to all stages of the nuclear knowledge cycle, including its identification, sharing, protection, dissemination, preservation and transfer. It affects and relates to human resource management, information and communication technology, process and management approaches, document management systems, and corporate and national strategies.

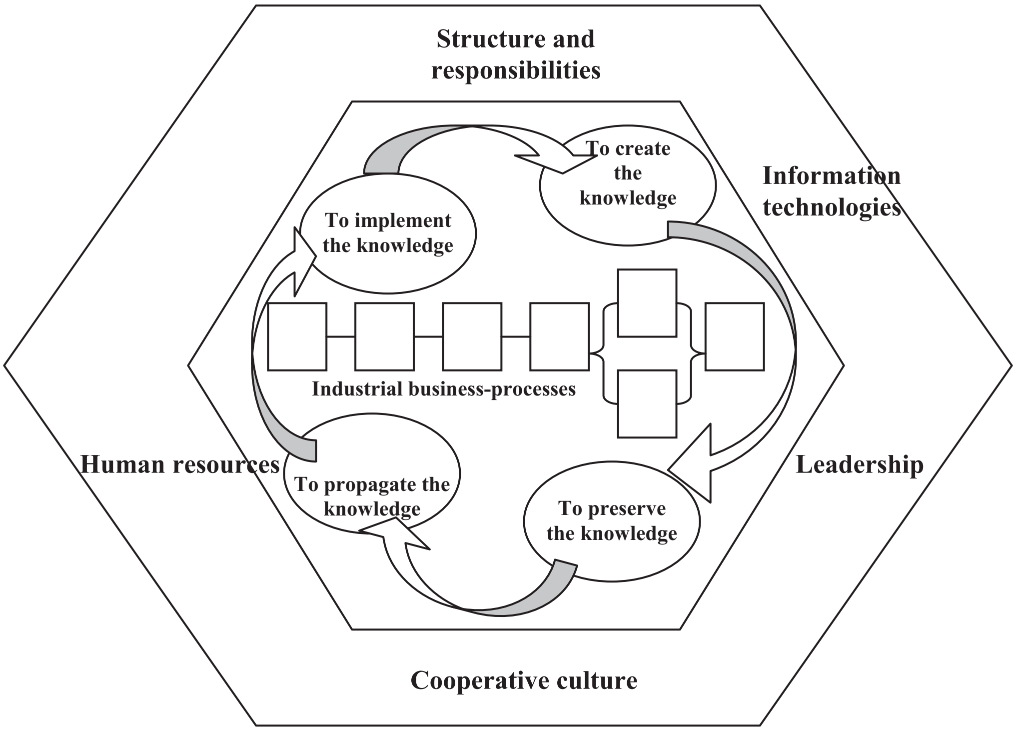

FIG. 1. Fraunhoffer's model of KM.

2.3. KNOWLEDGE PRESERVATION

Within the KM context, it is obvious that nuclear KP plays a vital role. Preserving existing nuclear knowledge, specialist expertise, and in general preventing the loss of vital technical and historical information is starting to be recognized as strategically important to the nuclear industry, in particular for nuclear facilities. As such, the development of KP approaches and tools based on innovative approaches, including the use of modern information technology, are becoming a necessity.

The IAEA has formalized the definition of knowledge preservation to state (see Refs [1, 13]): "a process of maintaining an organizational system of knowledge and capabilities that preserves and stores perceptions, actions and experiences over time and secures the possibility of recall for the future."

In this report, KP is viewed as including the processes required to capture, understand, archive, retrieve and protect explicit and tacit knowledge and to maintain accessibility and readability of it as technology evolves for as long as the knowledge remains useful. KP can be seen as a process of maintaining an organizational system of knowledge and capabilities that preserves and stores perceptions, actions and experiences over time and secures the possibility of recall for the future. The preservation of knowledge is an important phase within the KM cycle, from creation to implementation (see Fig. 1). KP, as a component of KM, plays an important role in supporting the entire management system, which ensures the effectiveness of industrial business processes. The main factors and driving forces of such a management system are human resources, organizational structure and responsibilities, IT, leadership, and cooperative culture.

Organizations that intentionally manage their experiences for them to be available for the future have to master three basic processes of knowledge management:

— Select from the large number of organizational events, persons or experts and processes only those worth preserving;
— Store their experience in a suitable form;
— Ensure the setting up and operation of organizational memory.

The preservation of tacit knowledge assumes the maintenance of core competencies, specialized expertise, and experience within an organization or industry. This is often referred to as knowledge retention and focuses on the human aspects of KM. The preservation of explicit knowledge, on the other hand, by definition assumes a knowledge repository or organizational memory system (OMS). A knowledge repository is a place to store and from which to retrieve explicit knowledge. A set of file folders are an example of a low technology knowledge repository. A high technology knowledge repository might be an OMS in the form of a database. Thus, KP underlies all aspects of KM, including the creation or generation of new knowledge (e.g. capturing knowledge as it is produced).

2.4. IMPORTANCE OF KNOWLEDGE PRESERVATION IN NUCLEAR ORGANIZATIONS

Organizations that do not pay attention to KP may face negative consequences (such as suffering losses or even worse, bankruptcy) if critical knowledge required by an organization is not preserved. In the case of the nuclear industry, if critical knowledge associated with regulation, construction, design, maintenance, operation and decommissioning is not preserved it can lead to incidents, accidents and other significant events. An example is the Okiluto-3 EPR NPP currently being constructed in Finland. The project experienced construction and welding problems because critical knowledge associated with methods and quality assurance had been lost among local contractors in Finland. This resulted in delays in construction.

One of the questions being raised concerning the ‘nuclear renaissance’ is the availability of critical knowledge required to forge large pressure vessels and steam generators. Recent surveys of suppliers indicate this capability has been lost in many countries because there was a long period of time in which no new reactors were built. It is believed that organizations which pay attention to KP and make it a part of their objectives tend to keep a competitive edge. This is likely the reason that more mature organizations are now concerned about the preservation of institutional memory. An underlying benefit of KP is that it helps to improve work processes and therefore aids in transforming a regular organization into a ‘learning organization’.

Depending on an organization’s level of KM maturity (i.e. the phase of development in KM processes), it may need to embark on KP as a means of preserving critical knowledge to secure its future. At first, the primary objective of an organization is to preserve its most explicit knowledge in archival form. As an organization matures, the preservation of implicit and tacit knowledge will become more dominant, leading to preservation of process knowledge (work flow). The main objective of all KP efforts is to develop a KP mechanism in which knowledge is being preserved as it is created. In this way all types of knowledge — including explicit, implicit and tacit — will be captured. In order to achieve this, different methods and tools must be employed.

First, the nuclear industry is a maturing industry within which recent high attrition rates have highlighted the vulnerability of nuclear organizations[1] to the loss of critical tacit knowledge, indicating that measures aimed at knowledge retention are needed. There is concern in the industry over the ‘pipeline’, or supply, of new and adequately skilled workers due to a lack of university level programmes specifically targeting nuclear knowledge and skills. There is also the recognition that it takes many years of on-the-job training to build the competencies and expertise needed to perform in many positions within the nuclear industry. Second, many ageing nuclear facilities will soon require either refurbishing or decommissioning, and this need will arise at the same time that new projects are being planned and launched, creating a high demand for specialized nuclear skills. Third, there is recognition that licensing basis information, including design basis information, and plant configuration information is critical to the continued safe and economic operation of many nuclear facilities (meaning such material must be kept up to date, accurate and correct). Finally, there is a keen awareness that other industries are doing more in the area of KP and have thus been benefitting from these initiatives and best practices.

Nuclear facilities and institutes constitute a particularly challenging environment from a KP perspective. Some of the issues faced by the nuclear industry include:

[1] In the context of this report, a nuclear organization is any organization the primary activities of which are directly related to nuclear energy and/or nuclear material, such as NPP fuel fabrication and/or reprocessing, nuclear research and/or research reactor facilities, radioactive waste management organizations, etc.

- A complex technology base and infrastructure (i.e. both from a design basis perspective and from an operations and management perspective);
- Lengthy technology and facility life cycles;
- Regulatory requirements that change over time;
- Highly capital intensive assets;
- A reliance on multidisciplinary technologies and expertise;
- Competing operational objectives involving safety, economics, and production;
- Potentially high hazards that must be systematically managed to remain demonstrably and tolerably low risks;
- The ongoing need for coordination of complex physical and human systems.

Furthermore, stringent requirements for safety, environmental qualification, nuclear quality assurance, nuclear security and non-proliferation safeguards, as well as equipment/design configuration management must be met, all within the context of a regulated industry environment.

For example, KP in nuclear facilities is complicated by the need to maintain knowledge over many decades and thus ensure the safety of longer term nuclear waste fuel management facilities. Another example is the need to establish and respect creative and flexible intellectual property license arrangements that allow owner–operators, design organizations, multilateral research organizations, and technical support organizations to innovate and share technical information on reactor designs (which are highly proprietary). Existing designs must be maintained, modified and adapted over time to ensure reliability and safety, to extend equipment life, or to introduce improvements offered by new technology. Thus proprietary designs and design information must be shared amongst these parties and must evolve over time. This involves legal issues regarding knowledge utilization, transfer and generation. Finally, everything is further complicated by the threat of cyber attacks. Knowledge flows or stores must also address the increased need for security. For these reasons, the role of KP within the nuclear industry is both particularly important and particularly challenging and underscores the need for an improved KP strategy. Nuclear KP is relevant to all nuclear organizations and supporting bodies (nuclear power plants, nuclear research institutes, research reactors, nuclear programmes and research in universities, nuclear regulators, nuclear design organizations, and nuclear support service organizations).

2.5. COMMON PERSPECTIVES ON KNOWLEDGE PRESERVATION

Different KP processes can be readily identified within most organizations. Non-experts in the field can usually relate to and understand these, whether or not their organization has any formalized KP strategy or programme in place. Most people have a perspective of KP based on the business or work systems and processes (and their inherent knowledge process needs) that they work with and with which are familiar. Some examples include:

- The archival perspective: this view of KP is based on objectives and processes associated with traditional digital or paper based documents or records of archival and storage processes and systems (such as library and records services in many organizations);
- Business process re-engineering (BPR) and the transaction theory perspective: this view of KP emphasizes on-line information systems (also referred to as OMS) such as enterprise application software (EAS), enterprise resource planning (ERP) systems, information systems (IS), information and communications technology (ICT), and information management systems (IMS) collectively. These systems enable integrated work flow and cross-functional processes in organizations and support institutional memory by capturing and preserving the transactional history of work flow and business processes within a firm;
- Human resource and organizational learning perspective: this view of KP focuses on those programmes, processes, and initiatives within a firm that ensure human resource capability is maintained and core competencies are sustained (such as formal training programmes and supporting methods, processes, and technology that facilitate tacit knowledge retention via knowledge transfer and sharing mechanisms);
- Project based perspective: this view of KP focuses on the processes and tools needed to ensure adequate capture of design detail and rationale, project records and documentation, and to safely preserve this information in a repository that will be accessible (and hopefully maintainable) in the future. Most project

groups focused on design and engineering use this view. The knowledge preserved will be important and utilized throughout the life cycle of a facility;

- Production process data perspective: this view of KP focuses on operational history data (e.g. data collected from real time monitoring and control systems, system health monitoring data, laboratory information systems, on-line monitoring systems, statistical process control systems, etc.) and is used to support information and knowledge needed for sustained equipment or production reliability, economics and safety;
- Design basis information maintenance perspective: this view of KP focuses on the ongoing maintenance and configuration management of design data, requirements, constraints, assumptions and rationale, change history, etc., as changes are required to maintain a plant (such as maintenance of design manuals, drawings, licensing submittals, safety requirements, safety cases, equipment qualification records, etc.).

It is not uncommon for individuals within an organization that has not implemented any coordinated, company wide KP policies and programmes to view KP quite differently (and sometimes quite narrowly), depending upon which of these processes primarily involve them, and the associated perspectives.

2.6. BASIC KNOWLEDGE PROCESSES

The following basic processes are the focus of KM activities and must be considered from a KP perspective in the organizational context:

- Identification;
- Capture;
- Generation or creation;
- Processing and transformation;
- Storage and retention;
- Search and retrieval;
- Representation;
- Transfer and exchange;
- Maintenance and updating.

These processes may occur in different sequences. A brief definition of each of the basic knowledge processes follows:

Identification: The process of distinguishing which knowledge should be or has been captured, processed, maintained and preserved. It considers how such knowledge will be identified, and how changes over time will be identified. Bibliometric tools (such as citation analysis) are often useful for such analysis.

Capture: The process that brings data, information, or knowledge into the organizational knowledge base. Knowledge capture may be either internal or external knowledge in any form (for example, tacit know-how or explicit technical information). Capture processes should consider the life cycle and may need to address factors such as media, format, speed, costs, volume and intellectual property issues. Capture may also need to include alternatives for source capture and guidelines for hard copy publication (to enable subsequent imaging), preservation of historical documents, as well as standards and quality control procedures.

Generation or creation: The process of deriving new knowledge. This may take place through processes of analysis, interpretation or incremental learning, or be based on entirely new ideas or innovations.

Processing and transformation: Any sorting, filtering, structuring, organizing, simplifying, compiling, interpreting, correlating, or manipulation that alters data, information, or knowledge into a form that adds value, utility, or additional meaning.

Storage or retention: Any process which allows data, information, or knowledge to be kept in the organizational knowledge base. This may be in any form (for example, tacit or explicit). Alternatives in media technology should consider longevity, robustness, cost, conversion, volume, standards, existing formats, historical data and other factors. This process is often related to the capture function in the KP life cycle.

Search and retrieval: Any process that facilitates the location of and access to data, information, or knowledge in the organizational knowledge base. This is primarily seen as a process pertaining to explicit knowledge but may be interpreted to apply to the search and retrieval of tacit knowledge as well. Explicit knowledge may pertain, for example, to the retrieval of relevant 'documents' (including text, data, drawing, videos, 3-D models, etc.) regardless of their location, format and language. Important factors to consider here include ensuring the ability to use advanced retrieval software, interoperability across heterogeneous databases and systems, multilingualism, etc.

Representation: Any process that improves understanding, comprehension or conceptual presentation of data, information, or knowledge through audio and visual means.

Transfer and exchange: Any process that facilitates the sharing of data, information, or knowledge. This may apply to knowledge in any form (for example, tacit or explicit). Explicit knowledge may involve, for example, data exchanged between databases. Tacit knowledge is any knowledge sharing between individuals or groups of people, whether direct or indirect.

Maintenance and updating: Any process that helps to sustain the organizational knowledge base. As knowledge is contextual, its correctness or completeness may change over time. There are also many factors that may deteriorate or diminish the quantity, value, or quality of data, information, and knowledge over time. This process may be human centric in the case of tacit knowledge, or include methods and tools for tracing and managing the currency of data, documents, drawings, software codes, procedures, etc., or updating and recording changes as appropriate in the instance of explicit knowledge.

2.7. KEY KNOWLEDGE PROCESS ATTRIBUTES

There are several generic knowledge process attributes that are important for KP. These include:

— Multilingualism;
— Quality assurance;
— Security;
— Safety;
— Version control.

Each of these key attributes is described below.

Multilingualism: is the ability to support cross language information retrieval (CLIR). Multilingual tools (for example, ontology) should be considered part of the KM and KP process. This will impact several other areas such as retrieval and standards.

Quality assurance: focuses on the reliability and integrity of data, information, and knowledge. Developing and managing data and information systems, methods and tools for assuring data reliability and integrity are critical when considering long term preservation. Tools and technologies available to facilitate the process of assuring data quality in systems must consider data completeness, correctness, clarity, consistency, and conciseness. Quality assurance measures need to be considered for effective knowledge preservation.

Security: refers to the protection of knowledge from unauthorized, intentional, unintentional or malicious access, distribution, alteration, corruption or loss from an asset protection perspective.

Safety: refers to the protection of knowledge from unauthorized, intentional, unintentional or malicious access, distribution, alteration, corruption or loss from a nuclear and industrial safety protection perspective.

Version control: refers to the ability and/or need to uniquely identify and control access to data and alteration of each and every revision of explicit data or information. It may also include the ability to trace changes between subsequent revisions, to revert to prior revisions, or to maintain multiple parallel versions.

2.8. KNOWLEDGE PRESERVATION METHODS AND TOOLS

Some known KP methods and tools currently being used in the nuclear industry are listed in Tables 2 and 3 [14]. The methods and tools include human resource practices, approaches based on information technology or tools,

TABLE 2. KNOWLEDGE PRESERVATION METHODS

KP methods	Comments
Action reviews, pre/post job reviews	Action reviews are quick and simple team learning processes held while work is being performed, usually during a break in the task or activity. A post-job briefing is a retrospective review of a recently completed work assignment, task, or activity to clarify or establish and reinforce lessons learned. A pre-job briefing is a preparatory review in advance of a work assignment, task or activity to familiarize, clarify or re-establish required knowledge and reinforce past lessons learned. The intent is to reinforce on-the-job learning during the experience.
Coaching and mentoring	The interactive transfer of knowledge from more experienced to less experienced staff. A dynamic and reciprocal relationship that may take the form of managerial, group/team, or one-on-one coaching and mentoring.
Computer based training (CBT)	Computer systems and software and training content that supports e-learning, usually at the user's own pace.
Concept maps, knowledge maps, ontological models	Graphical (diagrammatic) techniques which show associations, linkages, structure, and inter-relationships between concepts or knowledge domains.
Cross-functional teams, team learning approaches	The formation of project or work teams comprised of members from different disciplines and/or departments and/or production phases to facilitate knowledge sharing.
Decision summaries	Documents or reports that capture the rationale behind a decision (such as criteria, circumstances, or justification). They record the context of a decision for later use.
Design basis information management	Specifically for production facilities, systems and tools to enable effective configuration control, modification and maintenance of design basis information. This may involve the integration of several engineering tools such as CADD, electrical wiring databases, parts management, equipment reliability databases, etc.
Informal staff training strategies	Informal approaches focused on developing specialized skill sets needed to meet local organizational unit needs.
Document production and management	Methods and processes to support the creation and systematic archiving and retrieval of documents, artefacts, drawings, etc.
Data collection and management	Database applications with intelligent user guidance for data entry, retrieval and evaluation.
Equipment reliability and nuclear asset management	Methods and tools to support the life cycle management of facilities and equipment. Condition and risk assessment, equipment reliability, surveillance and health monitoring, and maintenance strategy are all aspects of this.
Formal training and human resource development programmes	Formal training programme development and delivery, typically with specific quality and performance objectives.
Information processing and management	Methods and systems to support information management processes, including records and data management practices.
Use of intranet portals	Internal organizational web site to provide a common communication port and ease of access to various company resources, including links to various repositories, databases, document archives, etc.
Involvement in peer communities of practice and benchmarking	A voluntary group of peer practitioners who share lessons learned, methods and best practices in a given discipline or for specialized work. Benchmarking methods and tools for self-assessment of the relative effectiveness of KM practices or processes (at a point in time or over time) and against industry best practices.
IS/IT infrastructure	Design and implementation of IS and IT tools and infrastructure in an organization to facilitate KM processes (capture, transfer, storage, etc.)
Knowledge elicitation interviews (such as employee exit interviews)	Most often in the form of exit interviews, they are a form of tacit knowledge capture from subject matter experts.
Knowledge loss risk assessment and management	Method and process of assessing critical knowledge and resources in a firm and their risk of being lost due to attrition.

TABLE 2. KNOWLEDGE PRESERVATION METHODS (cont.)

KP methods	Comments
Resource locators	On-line databases or lists that help to locate human or other knowledge resources (such as a subject matter expert locator).
Operations logs, event reports	Efforts by an individual to document knowledge as acquired. This may be either to capture experience and insights in a very general sense or it may be related to a specific task or work process.
OPEX review and/or corrective action process	Formal mechanisms to report, capture, assess, and correct organizational failures or shortcomings. Typically the focus is placed on identifying root causes and implementing corrective actions to ensure organizational learning and improvement.
Peer assisted team visits	Peers from different teams or organizations share their experiences, insights, and knowledge with a team that has requested assistance.
Process and procedure documentation	The explicit documentation of knowledge for methods or processes that attempts to capture lessons learned from past experiences and tacit know-how (for example for design documentation, guidelines, and procedures).
Storytelling	To transfer experience, values, and lessons learned through the recollection of previous incidents, past circumstances or events.
Systematic approach to training (SAT)	Formal training programme development and delivery, typically with specific quality and performance objectives based on the 'systematic' approach.
Use of retired or retiring specialists	Initiatives that tap into the expertise of recently retired employees. For example, as trainers or mentors, or to codify specialized knowledge in the form of guidelines.
Training simulator programmes	Hands-on computer simulation models that permit users to experience, through direct interaction with a virtual (modelled) environment, a representation of a real world system and its behaviour, possibly in an interactive life-like manner.
Use of Wikis	The collaborative creation of knowledge content through on-line media.
Workforce or succession planning	Methods and tools to assess requirements for specific skills.

TABLE 3. KP TOOLS

KP tools	Comments
Database (records management)	Records management (RM) is the practice of identifying, classifying, archiving, preserving, and destroying records. The ISO 15489-1: 2001 standard [14] defines it as "The field of management responsible for the efficient and systematic control of the creation, receipt, maintenance, use and disposition of records, including the processes for capturing and maintaining evidence of and information about business activities and transactions in the form of records."
Intranet portals	Internal organizational web site to provide a common communication port and ease of access to company resources including links to various repositories, databases, document archives, etc.
Search engines	A search engine is an information retrieval system designed to help find information stored on a computer system. Search engines help to minimize the time required to find information and the amount of information which must be consulted, akin to other techniques for managing information overload. The most public, visible form of a search engine is a Web search engine which searches for information on the World Wide Web.
Metadata	Metadata (metadata, or sometimes meta information) is 'data about data', of any sort in any media. An item of metadata may describe an individual datum, or content item, or a collection of data including multiple content items and hierarchical levels, for example a database schema. In data processing, metadata is definitional data that provides information about or documentation of other data managed within an application or environment.

TABLE 3. KP TOOLS (cont.)

KP tools	Comments
Taxonomy	Taxonomy is the practice and science of classification. The word comes from the Greek τάξις, taxis (meaning 'order', 'arrangement') and νόμος, nomos ('law' or 'science'). Taxonomies, or taxonomic schemes, are composed of taxonomic units known as taxa (singular taxon), or kinds of things that are arranged frequently in a hierarchical structure. Typically they are related by subtype–supertype relationships, also called parent–child relationships. In such a subtype–supertype relationship the subtype element has by definition the same constraints as the supertype element plus one or more additional constraints.
Thesaurus	A hierarchical arrangement of related words and phrases often displayed in systematized lists of synonyms.
Descriptor	A descriptor in Symbian OS is a text string. There is a library of descriptor classes incorporating the usual string manipulation methods. Descriptors come in two main types, 8 bit and 16 bit. An 8 bit descriptor stores ASCII text or binary data, a 16 bit descriptor stores Unicode text.
Data mining	Data mining is the process of sorting through large amounts of data and picking out relevant information.
Enterprise resource planning /enterprise application software (EAS) systems	Advanced enterprise business software that integrates various information sub-systems such as procurement, work management, resource planning, inventory management, production planning, and finance. Such systems typically embed knowledge of business processes and facilitate information and work flow.
Groupware	Collaborative software (also referred to as groupware or workgroup support systems) is software designed to help people involved in a common task achieve their goals. Collaborative software is the basis for computer supported cooperative work.
Document management systems	Document management systems (DMS) are computer systems (or a set of computer programmes) used to track and store electronic documents and/or images of paper documents.
Content management systems	Content management systems (CMS) are computer applications used to create, edit, manage, and publish content in a consistently organized fashion.
Concept mapping tools	Concept maps are diagrams showing the relationships among concepts. Concepts are connected with labelled arrows, in a downward branching hierarchical structure. The relationship between concepts is articulated in linking phrases, such as 'gives rise to', 'results in', 'is required by', or 'contributes to'. Concept mapping is a technique for visualizing the relationships among different concepts.
Multimedia tools	Multimedia tools like video, audio, photo, text scanning and OCR.
Graphics and image editing software	In computer graphics, graphics software or image editing software there is a programme or collection of programmes that enable a person to manipulate visual images on a computer, including screenshots from the vector graphics editor Adobe Illustrator. A screenshot from the raster graphics editor Adobe Photoshop Computer graphics can be classified into two distinct categories: raster graphics and vector graphics. Before learning about computer software that manipulates or displays these graphics types, you should be familiar with both.
Simulation	Simulation is the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviours of a selected physical or abstract system. Most current simulation tools are based on applications for computing technologies and mathematical models.
Computer modelling	A computer simulation, a computer model or a computational model is a computer programme, or network of computers, that attempts to simulate an abstract model of a particular system. Computer simulations have become a useful part of mathematical modelling of many natural systems in physics (computational physics), chemistry and biology, human systems in economics, psychology, and social science and in the process of engineering new technology to gain insight into the operation of those systems, or to observe their behaviour.
Historical data systems	Libraries of historical book or document archives.

TABLE 3. KP TOOLS (cont.)

KP tools	Comments
Nuclear asset management systems	Nuclear asset management (NAM) covers implementation models for long range planning and project portfolio evaluation, effective/efficient analytical methods and tools to support the NAM process and adequate measures of NAM performance and business value.
Equipment reliability models	Equipment reliability models deal with studies of reliability: the ability of a system or component to perform its required functions under stated conditions for a specified period of time. It is often reported in terms of a probability.
Decision support systems	Decision support systems constitute a class of computer based information systems including knowledge based systems that support decision making activities.
Wikis	The collaborative creation of knowledge content through an on-line media.
On-line safety monitors	Software programmes related to industrial processes or plants to monitor and guarantee safety in fabrication or plant processes.
PSA/PRA models	Probabilistic safety analysis/Probabilistic risk assessment models.
Training simulators	Application of computers and simulation technology in technological processes for operation and maintenance.
3-D CADD	Three-dimensional computer aided drafting and design.
IS/IT infrastructure	Design and implementation of IS and IT tools and infrastructure within an organization to facilitate KM processes (capture, transfer, storage, etc.).

training approaches, operations and/or maintenance approaches, approaches that apply to technical units or engineering support organizations, and finally general approaches that apply to all or many areas of the organization.

2.9. CATEGORIZING KNOWLEDGE PRESERVATION METHODS AND TOOLS

KP methods and tools may be categorized in many ways. Some of the more common (and more useful) schemes include categorization by:

(1) Nature of the knowledge being preserved (tacit, implicit, explicit);
(2) Level of knowledge domain (individual, group, organization, or industry);
(3) Range or focus of knowledge domain (processes/methodologies, product/design, project, technology);
(4) Stage in the KM life cycle phase (knowledge identification, capture, processing, etc.);
(5) Application or usage (such as supply chain management, HR or personnel data, etc.);
(6) Time horizon (short, medium, or long term).

3. KNOWLEDGE PRESERVATION PROCESS, STRATEGY AND GENERAL APPROACHES

Nuclear industry and supported organizations have their own specifics resulting from policy and strategy principles, organization history, operation expertise, human resources and performance. KM, and in particular KP philosophy, is focused on extracting the positive contents of these aspects through the development of a valuable knowledge application culture.

Additionally each organization possesses its own specific vision, mission, goals and action plans, depending on the nature of the organization, political and economic environment, organizational capability and culture.

Business vision operates at a high level of abstraction, and systems development at a low level of details and specifications. A KP system design should be compatible with the level of business strategy and pull strategy down to the level of systems design without undermining either. Establishing an organizational capability that supports such an interpretation of KP requires using a variety of approaches depending on the context of the organization, existing practices, and short and long term objectives.

3.1. BASIC CONSIDERATION

Top management, with its macro view of an organization's processes, can play a decisive role in prioritizing KP activities critical to an organization through undertaking risk assessment of its processes. The first step is to identify core functions (processes) and/or competences within the organization. The next step is to assess the risks and chances when dealing with these processes and/or competencies, then determine the impact of each risk within the organization's operation and decide upon actions required to mitigate its influences. Risks may come in the form of:

— Loss of tacit knowledge;
— Danger of competent staff leaving the organization;
— Loss of documents (hard copies);
— Loss of data and electronic documents.

The use of knowledge process maps, critical analysis and knowledge trees allows organizations to identify sources of, as well as the presence or absence of key knowledge, which leads to filling in identified gaps and protecting sources.

3.2. PROCESS

KP is one of the most lengthy and labour intensive processes of knowledge management. Separate subprocesses branch out from this main process. The most popular model presents KP as a unity of two categories — KP processes and resulting valuables in the form of generated knowledge or information. Each KP process is associated with specific phases of a KP life cycle (see Section 4). The preserved information should be available to current and future users.

Most executives today recognize that their organizations' ability to manage knowledge effectively is a strategic imperative. As is the case in most other areas of management advice, there is no shortage of different types of suggestions to choose from. These solutions are usually presented as applicable in any and all situations, but unfortunately this is not the case and managers are left to make their own mistakes as they use one tool or another to limited effect.

Generally, KP structure is based on useful frameworks, checklists, standards, programmes or virtual models and workflows. However each category should follow the principle that useful, effective and valuable KP should be aligned with an overall organization strategy.

The proper choice of strategy depends on organizational specifics, but there are examples in the area of nuclear that could be used as good practices.

The KP process structure illustrated in Table 4 is adapted from practices of the Kansas City Plant and fits into the KP life cycle of the plant. It could be used as a point of reference for organizations considering how to best leverage their knowledge assets.

TABLE 4. KANSAS CITY PLANT KP PROCESSES STRUCTURE

Basic process/ plant KP life cycle phase	The associated process
	Knowledge identification
Identification and prioritization of knowledge to capture	— Analysis of knowledge used or generated in routine processes — Analysis of risk of knowledge loss and identification of knowledge areas — Analysis of workforce ageing and loss of key personnel — Analysis of knowledge used or generated in non-routine processes, process shutdown, relocation or restarting after long break
	Knowledge capture
Gathering service documentation for respective processes	Gather all available or necessary documents and information which support or explain a process
Knowledge mapping using different applicable methods	Selected tools used for specific activities
Capturing multimedia information	Determining and applying suitable media to capture critical steps — video clips (people, places, equipment), audio clips, animations, text documents, graphics, etc.
	Knowledge generation or creation
Knowledge generation	— Routine processes: operation, maintenance, experience exchange, training, etc. — Non-routine processes: shutdown, relocation or restarting after a long break, design changes and modernization — Processes of research and development
Knowledge creation	— Conversion of tacit knowledge forms to explicit forms — Development of analysis, reports and other applicable documents
	Life cycle
	Knowledge processing and transformation (organizing knowledge)
Data processing	Processing captured data with the goal of bringing it in line with organization specific requirements
Data conversion	Selection and application of methods and tools for conversion of knowledge related data types according to specific needs and destinations
	Knowledge storage and retention
Data storage	Determining the applicable methods and technology for storage of processed knowledge
Data archiving	Determining the procedures, methods and medias for archiving knowledge
	Knowledge search and retrieval (including interoperability)
Data access	Process of guaranteed and controlled (depending on security conditions) access to all relevant knowledge units
Data search	— Deliver information on a web platform: Development of a specially designed intranet portal (with search and retrieve engines), potential access through Internet — Timely retrieval of available knowledge units
	Representation and visualization
Knowledge presentation	— Process of training material development for all kinds of training, including classroom, practical, simulator, on-the job — Process of computer based courses, multimedia applications, and e-learning implementation
	Transfer and exchange
Knowledge transfer/exchange	Process of data communication between different database structures and/or applications
Knowledge usage	The process of direct use of preserved knowledge or dissemination between potential users
	Maintenance and updating
Updating and redundancy	Providing version control and regular assessment of actuality and redundancy

3.3. STRATEGY

An organizational strategy originates from an organization's mission and overall policy. A strategy is generally articulated through general objectives. From that point of view, an effective KM strategy should be aligned with organizational policy and respective initiatives. A strategy should be a unity of principles and management factors.

Designing a KM implementation strategy for an organization should be the first step before moving towards total KM implementation within an organization. This strategy must be aligned with the organization business strategy and strategic objectives to accomplish goals that are tangible to the organization. The KP strategy should provide a clear understanding of the overall context of an organization — internal and external environment, strategic objectives, SWOT (strengths, weaknesses, opportunities and threats) analysis results. The strategy should define general areas of KP actions and identify applicable management factors for successful performance.

The following principles should be taken into account during the process of strategy development and implementation. The strategy should:

- Be publicly declared and strongly supported by management;
- Have explicit and visible structure, governance and funding;
- Be described in depth through documents at all levels of the organization's document tree;
- Include the clear understanding that KP is not solely a technology problem; it is a balanced combination between IT and managerial solutions;
- Be focused on the preservation and management of valuable knowledge and information; the organization cannot and should not keep and manage everything;
- Consider that KP is not a single initiative; it is a process which needs attention and resources over a period of time and in spite of results;
- Take into account the following management factors:
  - Knowledge mapping;
  - Tacit knowledge retention;
  - Regulations and requirements;
  - Workflow;
  - Knowledge systems integrity;
  - Human resources.

Based on the above considerations, a model of KP strategy could contain (but not be limited to) the following elements:

- Improving human performance;
- Succession planning;
- Developing methods and tools for knowledge preservation;
- Making KP part of an organizational culture;
- Investment in information systems technology;
- Formal (mandatory) KP procedures;
- Informal (voluntary) KP practices.

One of the methodologies which can be used for developing a KM strategic plan is as follows:

- SWOT analysis: this includes a thorough study of an organization's past and current status, identifying knowledge strengths and weaknesses of the internal environment and opportunities and threats of the external environment. Internal and external stakeholders should be included in a SWOT analysis process;
- Identification of KM challenges and risks: identified KM challenges should be considered during formulation of an institution's KM vision and strategic objectives;
- Formulation of a KM vision and mission statements;
- Defining drivers and strategic levers based on the institution's vision and mission;
- Defining strategic KM objectives. These objectives should be SMART (systematic, measurable, achievable, relative, and time bound);

— Defining key performance indicators (KPI) of strategic KM objectives: each of these indicators should have a baseline and targeted values, and relate to a certain pinch mark. Each strategic objective could have several KPIs. These KPIs are the key factor in KM monitoring and assessment;
— Risk assessment and management plan: risk analysis and assessment should be carried out for a KM strategic plan and associated objectives. The risk assessment should cover knowledge assets (both explicit and tacit), and there must be an associated contingency plan;
— Development of a KM implementation action plan;
— Assessment, monitoring and evaluation of plan implementation effectiveness.

3.4. APPROACHES

Implementation of an accepted KP strategy requires different approaches and resources. The proper choice depends on organization specifics, but in any case it should be related to applicable practices and processes and should cover necessary human resources, knowledge selection, knowledge sharing, knowledge recovery, knowledge usage and respective IT applications.

These requirements generate a set of methods, tools, techniques and practices that have a different nature and weight but as a whole assure and support implementation of KP initiatives.

Special attention should be paid to implementation of information management systems. The use of advanced information technology is a strategic approach, not just an option. Information management tools provide a means for data/information management or conversion, aid in knowledge generation (capture and learning, innovation), and can capture tacit knowledge in 'decision support' or process, procedure, and task support tools.

General and widespread approaches to KP are listed below:

— Assessing knowledge loss risk assessment and management;
— Providing training for all processes;
— Providing recruitment and employee development;
— Providing access to portals, resource locators, info repositories;
— Arranging coaching and mentoring of new staff by senior specialists;
— Providing appropriate human resources;
— Providing appropriate financial resources;
— Getting all levels of management involved;
— Establishing systems for encouraging individual contribution;
— Defining clear criteria and standards;
— Creating a formal maintenance programme for KP systems;
— Formalizing KP procedures and processes;
— Planning organization-wide KP systems.

Obviously such a list could be even more comprehensive and each organization should use its own preferred combination of options.

4. METHODS AND TOOLS FOR KNOWLEDGE PRESERVATION

KP efforts go through a cycle of: identification, capture, processing and organization, storage and retention, search, retrieval and representation, transfer and exchange, and maintenance and updating. In each stage, various methods and tools are available which can be used to support such work.

4.1. IDENTIFICATION

Knowledge identification refers to activities that involve what knowledge should be captured, processed, maintained and preserved and how to conduct such activities regularly.

Top management can lead in prioritizing KP activities critical to the organization. Individually, each department can evaluate the procedures being developed and their results can be validated by top management and/or QM departments.

The use of knowledge process maps, critical analysis and knowledge trees allows organizations to identify sources, as well as the presence or absence of key knowledge which leads to filling in identified gaps and protecting sources.

Some organizations formulate and/or adapt selection criteria, which serves as basis for identification of critical knowledge for preservation. Some adapt a graded approach in deciding what is critical while others set requirements for management of various kinds of documentation and information.

Identification of key knowledge for preservation can be carried out for example through:

— Scientific meetings;
— Technical–economic and scientific committees composed of experts;
— Research groups or teachers/students, depending on what type of knowledge is being taken into consideration.

The development of knowledge domains can be based upon an organization's functions and processes, including documents, publications, technical reports, thesis, maps and soft copies which are stored in databases. Domains may also be selected using mere common sense, studying previous experiences, evaluating usefulness of knowledge and/or current information required to fulfil certain tasks.

The process of verifying the reliability, quality and authority of a knowledge source is an important step in the context of KP. Sources of knowledge include not only documents and data but also key personnel/staff with tacit knowledge critical to an organization's success.

4.2. CAPTURE

After having identified key knowledge and sources of knowledge, the next step is to formulate procedures to capture them. Capture is related to processes that bring data and information into a knowledge system. The processes will consider the KM life cycle and should address factors such as media, format, speed, costs, volume and intellectual property issues. They should also include alternatives for source capture and guidelines for hardcopy publication, preservation of historical documents, standards and quality control procedures. This stage of the process includes two groups of activities; the first being the capture of tacit knowledge and the second involving the capture of explicit knowledge.

4.2.1. Tacit and implicit knowledge

The capture of tacit and/or implicit knowledge is a more challenging task because such knowledge resides in a person's capabilities and expertise. It is an accepted truth that people are not always so open to sharing what they know, and sometimes they simply do not have time to teach other people. Some good practices used by various organizations to capture tacit knowledge include:

— Conducting interviews of employees which may be critical to an organization's functions;
— Formulating questionnaires that successfully capture the tacit knowledge of employees;
— Using knowledge mapping;
— Using photography and video recording in capturing actual activities conducted by experts, such as in workshops, seminars, lectures, experiments, etc.;
— Conducting exit interviews with employees leaving the organization about how they carry out their tasks and duties;
— Conducting mentoring/coaching by experts or senior personnel with younger or newer personnel;

— Shadowing by younger/new/subordinate staff of experts and/or senior staff;
— Encouraging informal communication between experts and novices within an organization;
— Implementing a culture of working in teams inside the organization;
— Conducting self-assessment of each staff member's achievements;
— Collaborating with communities of practice;
— Implementing on-line collaborations, in which research or projects are done through e-workgroups and for which procedures are available on-line;
— Using process mapping;
— Using laddering techniques.

4.2.2. Explicit knowledge

The capture of explicit knowledge, though a less challenging task, can be very laborious because of its enormity. Still, with advances in computer and Internet technologies, most, if not all the explicit knowledge can be captured in electronic formats. This can be in the form of ASCII text files, MS Word, MS PowerPoint, PDF, HTML, XML, scanned images, PSD, RTF, Comma Separated Values (CSV), etc. For image files, standards such as JPEG, GIF and TIFF are used. Video formats can be in raw format VOB or in MPEG, AVI, etc. Size and portability of video files are factors that should be considered when selecting which video format to use. The following methods and tools may be used individually or in combination to preserve explicit knowledge:

— Digitization of hard copies;
— Use of relational databases;
— Storage of photos and/or sound and/or video files in databases;
— Development of computer models and simulations;
— Creation of editable source files available to concerned personnel, such as wikis;
— Creation of 3-D models;
— Document management;
— Use of decision support systems as a tool, like data mining.

The capture of explicit knowledge should be followed by validation to ensure that correct and key knowledge resources are those which have been captured. Some validation techniques include inspection, peer review and checks against data constraints.

4.3. PROCESSING AND ORGANIZATION

KP requires information be stored in a format in which it is easily accessible and can be reused. This process considers different programming languages as well as software packages, open source or proprietary, for the development of databases and systems. Organizing knowledge involves the creation of metadata, as well. Data processing can be carried out using the following techniques:

— Data analysis;
— Data structuring;
— Digitization;
— Compression of data for storage size consideration;
— Creation of metadata;
— Statistical processing for valuable information;
— Visualization for verification;
— Format conversion;
— Verification of information correctness;
— Use of open sources.

4.4. STORAGE AND RETENTION

The next stage of KP is storing the knowledge identified, captured and processed in robust and reliable devices to make it available for a long period of time. Storage practices by Member States, as revealed in a survey, mainly consist of archiving hardcopies and saving digital information in electronic formats.

Electronic or digital formats can be stored on hard discs, optical media (CD, DVD, etc.), streamers (magnetic tapes) and/or in a film library. These could be read-only or editable, full text or just abstracts. For information stored in databases, database design should consider ease of retrieval in the future using metadata, thesauri, taxonomies, ontology, etc. Integrated information systems provide interoperability of different knowledge formats, including text, data, drawings, videos, and/or 3-D models. The information can be classified by author, release number, date of production, subject and/or keywords. Computer aided metadata creation tools can also be used to create metadata automatically for knowledge resources. A combination of the following software/system tools can be used in the implementation of electronic or digital archives:

- Commercial relational database management systems (RDBMS), such as ORACLE, MSSQL, SYBASE, etc.;
- Intranet technology;
- Custom in-house RDBMS systems;
- Open source RDBMS, such as MySQL.

Some organizations are planning to upgrade their current storage formats, which involves enhancement of tools and technologies.

The IAEA's INIS, undertaking preservation of nuclear knowledge for several years now, offers a very good example of data storage methods and tools, as shown in Appendix II.

4.5. SEARCH, RETRIEVAL AND REPRESENTATION

The main dynamic factor of KP is the ability to reuse knowledge for future undertakings or decision making requirements. Accessibility and retrieval covers all activities associated with determining, administering and utilizing nuclear knowledge. Central to this is the timely retrieval of all 'documents' (text, data, drawings, videos, 3-D models, etc.), regardless of their location, format and language. Important concepts to consider include preserving the ability to use advanced retrieval software, interoperability across heterogeneous databases and systems and multilingualism. Approaches to processing retrieved information through the development of user interfaces may include value added techniques such as visualization, modelling, simulation, and analysis programmes (predictive models in different application areas).

Knowledge can be reused through access and retrieval of stored knowledge. Access to knowledge in an organization can take different forms. Some knowledge can be made freely available to all stuff members, but some may require access control, which is especially necessary and important in nuclear organizations.

Some control can be implemented to limit retrieval of knowledge that is confidential in nature. Access control to stored knowledge is implemented through passwords and user identification, data encryption, limited network accessibility to authorized users, and/or installed physical security measures at storage facilities. Network accessibility can be limited in the form of IP authentication.

Access control can be achieved by imposing certain restrictions at different levels. Users are limited to access only certain knowledge in carrying out their tasks and responsibilities within an organization. They can be given rights, such as read-only, write/modify, delete, cannot-delete, copy, backup, and/or execute.

An organization must ensure that data integrity is maintained. False information or contaminated data can result in major misunderstandings between different entities of an organization.

4.6. TRANSFER AND EXCHANGE

Collaborations in which knowledge exchange occurs can cross organizational and even state boundaries. Informal collaborations normally do not require official agreements between entities, and the free exchange of information and knowledge is possible. But when a more critical exchange of knowledge is required, states and/or organizations usually undertake to make bilateral agreements beforehand. Other types of exchanges can even be commercial in nature, when collaborations require payment for imparted knowledge or expertise.

The requirement to rapidly disseminate and provide access to nuclear knowledge is dependent on alternative communication systems which are particularly critical, considering the technological differences in different States. These alternatives will vary from nearly instantaneous knowledge transfer to reliance on postal services. The alternatives will shrink over time, and it is anticipated that in the long term most facilities will have faster communications due to rapid advances in communication technology.

Standardized protocols, formats and techniques are required for the exchange and use of data residing in the databases of complex structures and/or between different parts of applications which interoperate with each other.

The exchange of knowledge can take place in an electronic format. The media used for exchange of explicit knowledge are:

— Mail;
— E-mail;
— Internet/intranet;
— E-learning;
— Simulation software.

For the exchange of tacit/implicit knowledge, the media used are:

— Interviews/questionnaires;
— Conferences/meetings;
— Mentoring/training;
— Communities of practice;
— Simulation.

4.7. MAINTENANCE AND UPDATING

KP is a never-ending task. As new knowledge is identified, created and/or enhanced within an organization, it goes through the entire KP cycle again and again. One of the stages in KP is handling the maintenance and updating of knowledge base systems. This involves activities which validate and implement version control mechanisms.

Version control includes software tools for tracing and managing the currency of data, documents, drawings, software codes, procedures, etc., and automatically updating and recording changes as appropriate. Revision control (also known as Version Control System (VCS), Source Code Management (SCM)) is used for the management of multiple revisions of the same unit of information.

4.8. KNOWLEDGE PRESERVATION APPROACHES

A summary of KP approaches covering methods and tools appropriate for each process, whether tacit, implicit, or explicit knowledge is involved, whether it exists at an individual, group/department, organizational or industry level, and whether it is focused on project, technology or process, can be found in Tables 5–7.

TABLE 5. METHODS FOR KP

KP methods	Knowledge Type			KP Processes							Level				Focus		
	Tacit	Implicit	Explicit	Identification	Capture	Processing and transformation	Storage and retention	Search and retrieval and	Transfer and exchange	Maintenance and updating	Individual	Group/department	Organization	Industry	Project	Design/technology	Process
Action reviews, pre/post job reviews	X	X	X		X		X		X		X	X			X		X
Coaching and mentoring	X	X							X		X						X
Computer based training (CBT)		X	X	X	X	X	X	X	X	X	X	X					X
Concept maps, knowledge maps, ontological models		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Cross-functional teams, team learning approaches	X	X	X		X				X	X		X			X	X	X
Decision summaries (analysis, rationale and assumptions)		X	X	X	X		X	X	X		X	X			X	X	X
Design basis information management			X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Informal staff training strategies	X	X	X	X	X	X	X	X	X	X	X	X			X		X
Document production and management			X		X	X	X	X	X	X	X	X			X	X	X
Data collection and management			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Equipment reliability programmes and nuclear asset management	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Formal training and human resource development programmes		X	X		X	X	X	X	X	X	X	X	X	X	X		X
Information processing and management			X	X	X	X	X	X	X	X	X	X	X	X	X		X
Use of Intranet portals			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Involvement in peer communities of practice and benchmarking	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
IS/IT infrastructure			X		X	X	X	X	X	X	X	X			X	X	X
Knowledge elicitation interviews (e.g. employee exit interview)	X	X	X	X	X	X	X		X		X				X	X	X
Knowledge loss risk assessment and management	X	X	X	X	X		X		X		X	X	X	X	X	X	X
Resource locators	X	X	X	X					X	X	X	X	X	X	X	X	X
Operation logs, event reports		X	X	X	X		X	X	X	X	X	X			X	X	X
OPEX review and/or corrective action processes		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Peer assisted team visits	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X
Process and procedure documentation		X	X	X	X				X		X	X	X		X		X
Storytelling	X	X			X				X		X	X				X	X
Systematic approach to training (SAT)		X	X	X	X	X		X	X	X	X	X	X			X	X
Use of retired or retiring specialists	X	X	X	X	X				X		X	X	X	X	X	X	X
Training simulator programmes	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Use of Wikis			X		X		X	X	X	X	X	X		X	X	X	X
Workforce or succession planning	X	X		X			X		X		X	X	X	X			

TABLE 6. KP TOOLS FOR PROCESSES

KP tools \ Processes	Identification	Capture	Processing and organization	Storage and retention	Search and retrieval and representation	Transfer and exchange	Maintenance and updating
Database (records)	X	X	X	X	X	X	X
Portals	X	X		X	X	X	X
Search engines	X				X		
Metadata, taxonomies, thesauri, descriptors	X	X	X	X	X		X
Data mining	X		X		X	X	
ERP/EAS	X	X	X	X	X	X	X
Group-ware	X	X	X	X	X	X	X
Document management systems			X	X	X	X	X
Content management systems			X	X	X		X
Knowledge mapping tools	X		X	X	X	X	X
Multi-media tools		X	X	X	X	X	X
Graphics and display software			X		X		X
Simulation and models		X	X			X	X
Historical data systems	X	X	X	X	X		X
Nuclear asset management systems		X	X	X	X		X
Equipment reliability models		X	X				X
Decision support systems		X	X		X		X
Wikis		X	X	X	X	X	X
On-line safety monitors		X	X		X		X
PSA/PRA models		X	X		X		X
Training simulators		X	X		X		X
3-D CADD		X	X	X		X	X
IS/IT infrastructure	X	X	X	X	X	X	X

TABLE 7. KP TOOLS FOR APPLICATION DOMAINS

Applications domains / KP tools	Facility operating data	Design basis data	Work-flow and transactions	Financial data/info	Technical documents	Group or team work	Project based info/knowledge	Training info/modules	Resource location	Visualization/presentation	Analysis/interpretation/diagnostics	Work process/procedures	Taxonomy/ontology	Safety case	Regulatory compliance	Supply and procurement	Operating experience	Maintenance records	HR data	Standards	Design processes
Database (records)		X	X	X			X	X	X				X	X	X	X	X	X	X	X	X
Portals		X		X	X		X	X	X	X		X	X	X	X		X		X	X	X
Search engines					X		X	X	X				X	X		X	X	X	X	X	X
Metadata, taxonomies, Thesauri, descriptors		X			X		X	X	X				X	X		X	X	X		X	X
Data mining		X	X		X			X						X		X	X		X	X	X
ERP/EAS			X	X							X	X				X			X		X
Group-ware			X		X	X						X					X				X
Document management systems		X	X		X		X	X	X			X	X		X	X	X	X		X	X
Content management systems		X			X		X		X			X	X		X	X	X	X		X	X
Knowledge mapping tools						X	X						X				X				
Multi-media tools							X	X		X											
Graphics and display software	X						X	X		X											X
Simulation and models						X	X				X			X	X						X
Historical data systems	X							X	X		X			X	X	X	X	X		X	X
Nuclear asset management systems	X			X								X				X					
Equipment reliability models	X										X			X	X	X					X
Decision support systems											X	X				X					X
‘Wikis’							X		X				X								
On-line safety monitors	X									X	X										
PSA/PRA models		X					X				X			X							
Training simulators						X		X		X	X				X		X		X		X
3-D CADD		X					X			X											X
IS/IT infrastructure	X	X	X	X	X	X	X		X	X	X	X				X		X	X		

5. IMPLEMENTATION AND ASSESSMENT OF KNOWLEDGE PRESERVATION METHODS AND TOOLS

Effectiveness of KP processes within an organization depends not only on the implementation and availability of various methods and tools for KP but also on organizational policies, strategies, managerial factors and workforce culture. Section 5.1 provides guidance on some key criteria to consider in choosing and implementing KP methods and tools. Section 5.2 identifies and discusses many of the criteria needed to assess the effectiveness of KP processes in organizations and provides useful guidance for the establishment of KP benchmarks based on known good practices.

5.1. IMPLEMENTATION OF KNOWLEDGE PRESERVATION METHODS AND TOOLS

There are many factors to consider when selecting and implementing KP methods. Section 4 identified many characteristics or attributes of more commonly used KP methods and tools which aid in understanding their usefulness and range of applicability. However, there are many more important factors to be considered that serve to guide the implementation decision and process. Table 8 classifies for each KP method identified in Section 4 the following implementation factors/questions and criteria:

- Does the given method require an external expert to be implemented (yes or no)?
- What is the relative complexity of the implementation project effort for the given method (high, medium, low)?
- What is the typical time duration needed to implement the given method (hours, days, months, years)?
- What is the budget required to implement the given method (high, medium, low)?
- What are the potential area(s) of impact of the given method within an organization (safety or effectiveness)?
- What is the magnitude of the potential benefit to an organization of implementing the given method (high, medium, low) in the potential area(s) of impact?
- What are the potential consequences to an organization of not implementing the given method (high, medium, low) in the potential area(s) of impact?
- Is the implementation of the given method a one-time, periodic, or continuous effort or initiative?
- What is the risk of encountering issues or problems with implementation of the given method (high, medium, low)?
- Are changes required to an organization's work methods or procedures to implement the given method (yes or no)?
- Are changes required to an organizational culture to implement the given method (yes or no)?
- What is the typical level of management support required to successfully implement the given method (high, medium, low)?

5.2. ASSESSMENT OF KNOWLEDGE PRESERVATION METHODS AND EFFECTIVENESS OF TOOLS

A successful KP programme depends on how effectively the methods and tools which are available and implemented are used in each particular organization. For this reason, it is useful to periodically assess the effectiveness of a KP processes within an organization and to make benchmarking assessments based on known good practices.

A representative set of relevant criteria for assessment of KM processes has been developed by the IAEA [15] and based on good practices of international organizations and industries. These criteria are presented in the form of simple questions and were developed for specific use in IAEA KM assistance missions. They provide a basis for self-assessment of knowledge management in nuclear utility organizations. A subset of these applies specifically to KP and can be reformulated as questions for organizations to conduct KP self-assessment. This section summarizes these to guide KP self-assessment.

TABLE 8. IMPLEMENTATION CRITERIA FOR KP METHODS AND TOOLS

KP method/tool	Implementation criteria											
	Method expert required to implement (yes or no)	Complexity of implementing method (high, med, low)	Duration needed (hours, days, months, years)	Budget required (high, med, low)	Potential area of impact (safety or effectiveness)	Potential benefits (high, med, low)	Potential adverse effects of not implementing (high, med, low)	One time, periodic, or continuous initiative	Risk of implementation problems (high, med, low)	Changes to methods procedures (yes or no)	Changes required to culture (yes or no)	Level of management support required (high, med, low)
Action reviews, pre/post job reviews	N	L	H	L	S	H	L	P	L	N	Y	L
Coaching and mentoring	N	L	M	L-M	S	H	M	P	L	N	Y	L
Computer based training (CBT)	Y	M	M	M	S+E	M	L	P	L	N	N	L-M
Concept maps, knowledge maps, ontological models	N	L	D	L	E	L	L	O	L	N	N	L
Cross-functional teams, team learning approaches	N	L	M	M	S+E	H	M	C	L	Y	Y	M
Decision summaries (analysis, rationale and assumptions)	N	L	D	L	S	M	M	P	L	Y	Y	L
Design basis information management systems	Y	H	Y	H	S+E	H	H	C	M	Y	Y	H
Informal staff training strategies	N	L	D-M	L	S+E	M	L	P	L	N	Y	L
Document production and management processes/systems	Y	H	Y	H	S+E	H	H	C	M	Y	Y	H
Data collection and management processes/systems	Y	M	M-Y	M	S+E	M	M	C	L	Y	Y	M
Equipment reliability programmes and nuclear asset management	Y	H	Y	H	E	H	H	C	M	Y	Y	H
Formal training and human resource development programmes	N	M	M-Y	M-H	S+E	H	H	P	L	N	Y	H
Information processing and management	Y	M	M-Y	M-H	E	M	H	C	L	Y	Y	M-H
Use of intranet portals	Y	H	Y	M-H	E	M	M	C	L	N	Y	M-H
Involvement in peer communities of practice and benchmarking	N	M	M	L-M	S+E	H	M	P	L	Y	Y	H
IS/IT infrastructure (e.g. ERP/EAS)	Y	H	Y	H	E	H	H	C	H	Y	Y	H
Knowledge elicitation interviews (e.g. employee exit interview)	Y	L	D-M	L	S+E	M	M	P	L	N	N	L
Knowledge loss risk assessment and management	N	M	M	L	S+E	H	H	P	L	Y	N	H
Resource locators	N	L-M	D-M	L	E	L	L	C	L	N	N	L
Operation logs, event reports	N	M	M	L	S+E	M	H	C	L	Y	N	M
OPEX review and/or corrective action processes	N	M	M	L-M	S+E	H	H	C	L	Y	Y	H
Peer assisted team visits	Y	M	M	L-M	S+E	H	H	P	L	Y	Y	H
Process and procedure documentation	N	H	M-Y	M	S+E	H	H	O	M	Y	Y	M-H
Storytelling	N	L	D	L	S	M	L	P	L	N	N	L
Systematic approach to training (SAT)	Y	H	Y	H	S	H	H	C	M	Y	Y	H
Use of retired or retiring specialists	N	L	D	L-M	S+E	L-M	L	P	L	N	N	L
Training simulator programmes	Y	H	Y	H	S+E	H	H	C	M	Y	Y	H
Use of Wikis	Y	M	M	L-M	E	L	L	C	L	N	Y	L
Workforce or succession planning	N	L	M	L	E	M	H	P	L	Y	N	M

5.2.1. Policies, strategies, managerial factors and workforce culture

The following statements may be used to guide assessment of the effectiveness of policies, strategies, managerial factors and workforce culture:

- Top level policies and associated procedures that provide an integrated strategy and implementation approach for KP, including the identification of roles, responsibilities, and priorities for KP within an organization;
- A communications strategy that supports an organization's KP goals and changes initiatives through identification of objectives, approaches, and tactics for communicating with organization employees and key stakeholders;
- A workforce planning strategy that ensures staffing needs for the life of the organization are identified and tracked. (This strategy addresses areas such as risks associated with losing critical knowledge, succession planning, and developing leaders and managers.);
- An organizational culture that promotes the preservation of knowledge, particularly tacit knowledge among personnel. (Managers serve as role models for others to emulate regarding knowledge retention. Methods are in place to periodically assess the status of this culture.);
- Managers who personally ensure that a KP programme is developed, implemented, continuously improved and integrated within an organization's overall management system;
- A strategy that rewards and recognizes people for their contributions to keeping and expanding the knowledge assets of their organization;
- Benchmarking to improve performance, and emulate best industry practices, thus integrating identification and correction of problems and operating experience as well as self-assessment into an organization's culture.

5.2.2. Knowledge identification, capture, transfer, storage and retrieval

The following statements may be used as a guide to assess the effectiveness of knowledge identification, capture, transfer, storage and retrieval:

- KP methods that are built into management processes, rather than being separate, add-on tasks, in order to increase effectiveness and reliability of knowledge identification, capture, transfer, storing and retrieval;
- Effective use of knowledge elicitation tools that assist in identifying critical knowledge held by experts and to present this knowledge in a manner that facilitates its transfer to others;
- Organization personnel who document and transfer information accurately. (Organization activities, conditions, and decisions are documented in sufficient detail to enable personnel to recreate and address organization problems or events.);
- Managers who frequently observe work and training activities to ensure that KP methods are effectively applied and to identify needed improvements;
- Design calculations, drawings, analyses, procurement specifications, and other design documents that are readily retrievable and that clearly describe the bases for the function of organization systems and components;
- Well defined, documented, controlled and retrievable licensing and design requirements;
- Procedures, drawings, training lesson plans, and related documentation that are promptly updated following implementation of configuration changes;
- Information technology (IT) that is used broadly and effectively to identify, capture, transfer, storage and retrieval of the knowledge critical to the organization's mission. (Up-to-date IT tools like portals, intranet, and relational databases, are to be developed/purchased and used taking into account the current needs of KP in the organization.)

5.2.3. Human factors/tasks resource management, training and performance enhancement of personnel

The following statements may be used as a guide to assess the effectiveness of human factors/tasks resource management, training and performance enhancement of personnel:

- Managers who ensure that future staffing needs are identified and tracked through an ongoing workforce planning process. (This planning process includes a knowledge loss risk assessment to identify knowledge that is critical to the organization's mission and that could be lost in the near future.);

— Competences that are established and used for key jobs and for the identification of candidates for leadership positions;
— Succession plans that are in place for key positions. (A succession plan should include rotational assignments, project assignments and other means to develop staff for advancement.);
— Human resource personnel who work as a team with line managers to anticipate personnel needs and to recruit sufficient knowledgeable and skilled personnel;
— A systematic approach to training that is implemented to achieve, maintain and improve personnel knowledge, skill, and performance to support organization safety, performance goals and KP process;
— Managers who feel accountable for the training, qualification, and performance of their personnel. (They should use appropriate tools like qualification matrix to assist them in determining whether they have adequate numbers of qualified persons.);
— Continued training that ensures maintenance of organizational job specific knowledge and skills;
— Training materials and examinations that are up-to-date, accurate and of high quality;
— Change initiatives that are well managed and coordinated. (The potential effects of organizational changes and staff reductions should be considered and addressed before such changes are initiated.);
— A feedback process, including post job reviews and management observations, that improves human performance and knowledge transfer;
— The composition of operating crews and other teams that takes into account individual experience and attributes to enhance knowledge transfer.

5.2.4. Effective learning from experience

The following statements may be used as a guide to assess the effectiveness of learning from experience:

— Personnel involved in maintenance, operations, engineering who play an effective, integrated role in monitoring plant performance, learning the lessons and in documenting this knowledge in such a way that it can be effectively retrieved and utilized when needed;
— A process that is in place to encourage, monitor, and address employee feedback on KP and other organizational initiatives;
— Organization personnel who are self-critical and frequently provide feedback to improve KM processes, plant performance, processes, plans, procedures, and training. (The personnel should willingly report problems, near misses, error-likely situations, and safety hazards.);
— Lessons learned from operating experience that are systematically institutionalized through changes to station processes, procedures, equipment, and training programmes;
— Computerized systems (databases) that are used for tracking operational performance, events causes, corrective actions implementation and lessons learned.

6. EXAMPLES OF KNOWLEDGE PRESERVATION INITIATIVES

The following sections describe several examples of current KP best practices in organizations participating in the CRP.

6.1. TACIT KNOWLEDGE PRESERVATION AT THE INSTITUTE OF NUCLEAR RESEARCH, ROMANIA

A questionnaire based investigation was performed in January 2007 at the Institute of Nuclear Research (INR) in Pitesti, Romania, in order to study, understand and analyse the status of the institute’s knowledge transfer and preservation. The investigation was focused mainly on tacit knowledge transfer and preservation.

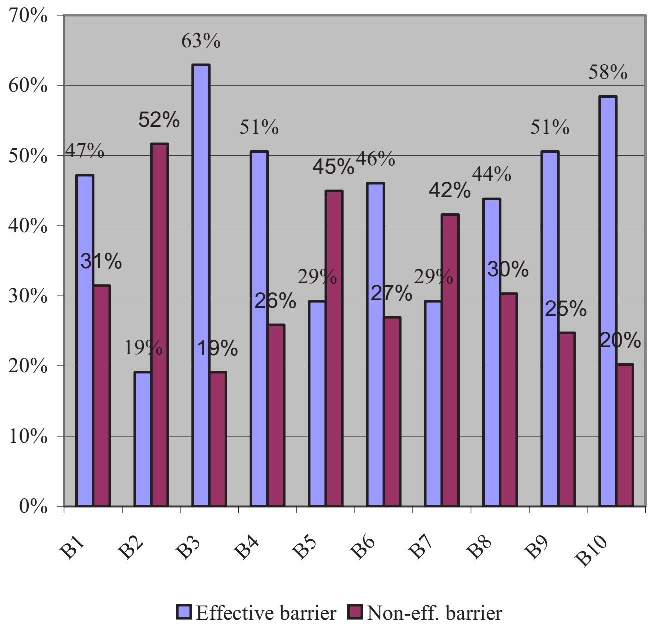

FIG. 2. Effectiveness of the barriers against knowledge sharing at the Institute of Nuclear Research (INR).

The main objective of this investigation was to answer the question 'What are the motivations for an expert to transfer his/her experience before retirement?' The method of gathering information was face-to-face interviews, and around 100 people were investigated, each of them with more than 20 years of experience.

Some important results are listed below:

(1) Regarding the time interval needed for optimal knowledge transfer (KT):
— 48% of respondents said 4–6 years;
— 30% of respondents said 1–3 years;
— 7% of respondents said 7–9 years;
— 3% of respondents said more than 9 years.

(2) Related to the efficiency of methods and tools used for KT and KP:
— Very efficient — documents (reports, procedures, users' manuals, computer codes, articles/papers);
— Efficient — community of practice;
— Somewhat efficient — mentoring;
— Not very efficient — expert–newcomer tandem teams and continuous training of successors.

(3) Concerning the importance of barriers against knowledge sharing, the results (accumulation of positive and negative concerns) are presented in Fig. 2.

Legend:

B1 Lack of time (or productivity and deadline pressure);
B2 Lack of trust (use of knowledge out of its original context, lack of source recognition/acknowledgement);
B3 People grouping in functional departments/buildings;
B4 Poor means of knowledge capture;
B5 Internal competition;
B6 Top–down decision making;
B7 Lack of awareness of how useful particular knowledge is to others;
B8 Low interest among knowledge receivers;
B9 The 'knowledge is power' syndrome;
B10 Lack of discussion/social events/working in teams (individualism).

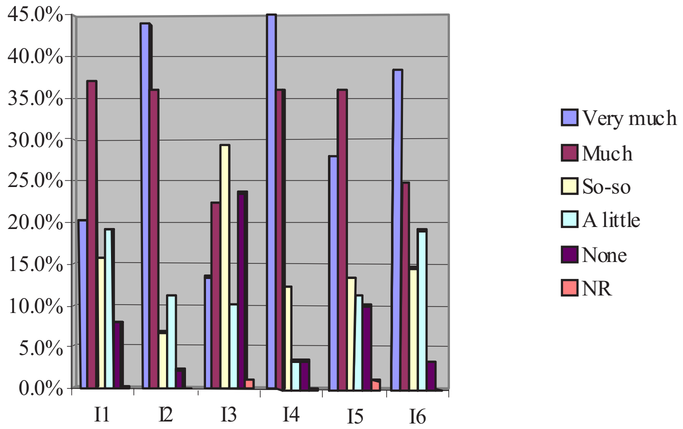

FIG. 3. The importance of interest in knowledge sharing at INR.

(4) Related to the efficiency of some motivation increasing factors in tacit knowledge transfer, the importance of the following factors were measured:
- — Retirement awards depending on the effective transfer of knowledge (57%);
- — Additional earnings for KT tasks (80%);
- — Post-retirement collaboration contracts depending on the number and quality of prepared newcomers (81%);
- — Support for future publications (64%);
- — Free access to INR social/team building activities (63%);
- — Clearance form completion, only undertaken after a relevant exit interview (47%).

An illustrative matrix of the importance of retiring experts' interests is presented in Fig. 3.

Legend:

I1 Retirement awards dependant on effective KT;
I2 Salary increasing in the last years depending on KT;
I3 Clearance form completion after a relevant exit interview;
I4 Post-retirement collaboration contracts depending on the number and quality of prepared newcomers;
I5 Support for future publications;
I6 Free access to INR social/team building activities.

The tacit knowledge investigation resulted in the conclusion that in the next 5–10 years a significant number of experts will retire and their expertise will be lost, therefore the institute board decided to take appropriate measures to increase both the amount and the quality of KT and KP by:

- — Hiring young, new personnel in order to compensate losses incurred through the retirement process. It was decided that newcomers should be hired at least four years before the retirement of existing experts. An important recruitment method could be the selection of candidates directly from universities, based on study contracts supported by the institute;
- — Improvement in the efficiency of tools and methods, especially for tacit knowledge transfer, primarily through fast liquidation of barriers against tacit knowledge sharing (see above) and at the same time by using the most efficient ways and means to stimulate sharing (mainly including financial incentives and through definition of a collaboration policy between retired employees and the institute).

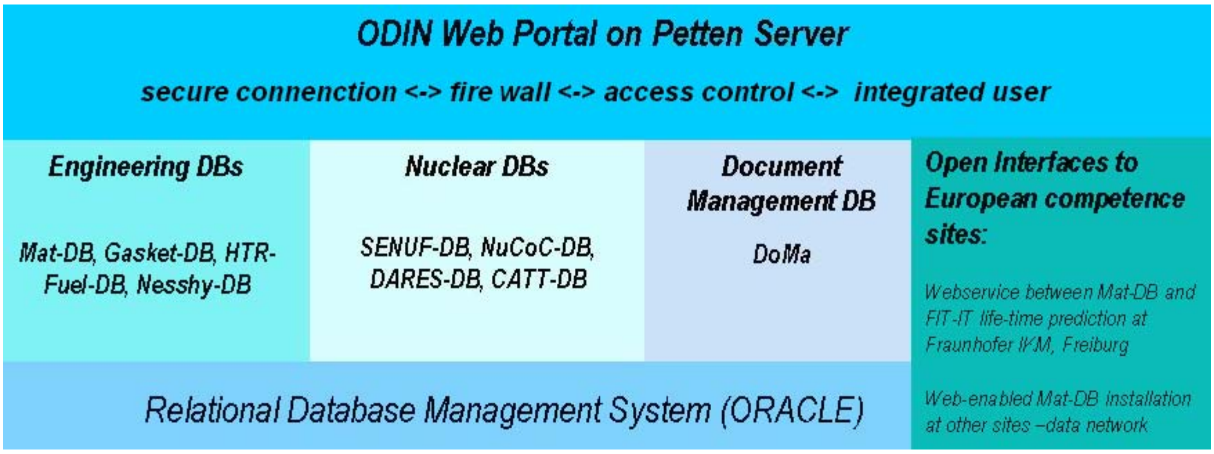

FIG. 4. ODIN databases.

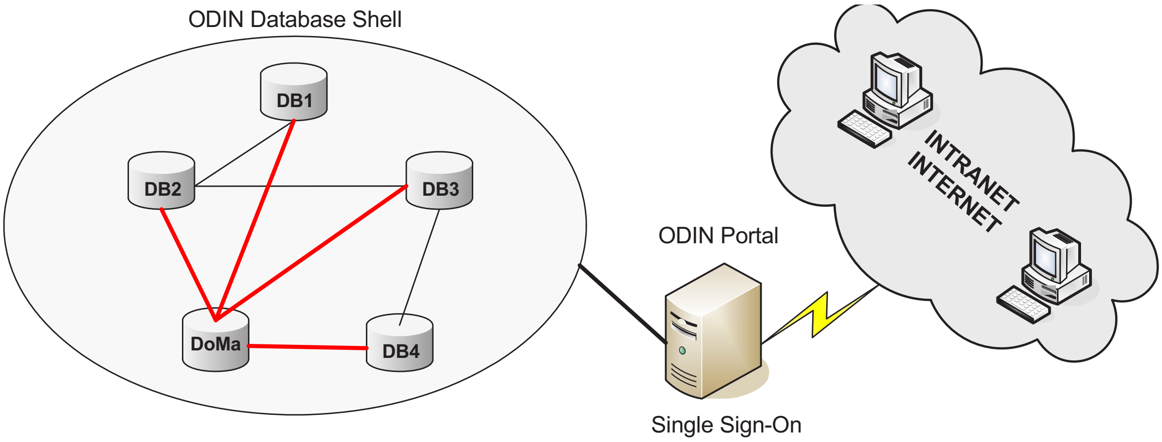

FIG. 5. ODIN architecture.

6.2. EXPLICIT KNOWLEDGE PRESERVATION AT THE EC JOINT RESEARCH CENTRE, PETTEN

The secure on-line data information network (ODIN) portal (http://odin.jrc.ec.europa.eu) has been built up to organize data management and dissemination for the EC Joint Research Centre (JRC) at Petten. The ODIN portal provides access to various web-enabled energy related database applications (see Fig. 4). The applications share fast cabling, firewall, secure connection, redundancy to guarantee high availability, central data and user management, professional hardware and software infrastructure in order to facilitate maintenance and further development, such as ORACLE[2] as a powerful RDBMS, and professional database servers with high capacity Raid Arrays for the storage of data and documents. These are continuously maintained and updated. A single-sign-on server controls the access rights of Internet/intranet users (see Fig. 5).

Final reports of R&D projects, drawings in any format, and entire project documentation, including minutes of meetings, can additionally be stored in a structured manner (such as in public and confidential areas) in the related web-enabled documentation database DoMa[3] and linked to project specific data sets. Some of the databases (DB1–DBn) directly interact with each other, whereas DoMa interacts with all of them.

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[2] The ORACLE database (commonly referred to as ORACLE RDBMS or simply ORACLE) consists of a relational database management system (RDBMS) produced and marketed by the Oracle Corporation. Since 2008, ORACLE has been a major presence in database computing.

[3] The web enabled document management system DoMa is designed to enhance the dissemination of information amongst R&D community sectors.

One of the motivations for developing various energy related databases and DoMa was to provide fast access to public and confidential data sets as well as to other documentation on the Petten Server, and to help in conservation, management and analysis of data from European R&D consortia in the area of nuclear and conventional energy. Just by opening their browsers, any authorized partner can immediately access and evaluate data sets entered and validated by other partners.

Where relevant, JRC Petten provides the full cycle of data entry, retrieval and analysis over the Internet. Furthermore, a network with partners in order to increase both the amount of available data and the tools for analysing this data is in the planning stages.

On-line help assists in using JAVA programmed web-enabled user interfaces and evaluation routines. Manuals for describing databases and analysis tools, including such things as descriptions of image and text thesauri, curve file structures, and definitions of test types, are available for database users on the ODIN portal.

The ODIN portal of EC-JRC Petten, with access control, database interaction and analysis routines is foreseen to be a major step from explicitly KP to KM.

6.3. TACIT AND EXPLICIT KNOWLEDGE PRESERVATION AT UNITED TECHNICAL COLLEGE AND KOZLODUY NPP, BULGARIA

Within the framework of this research project, the United Technical College at Sofia carried out a knowledge acquisition study based on risk analysis of knowledge loss and use of concept map methodology. The task was performed with the valuable contribution of the Kozloduy Nuclear Power Plant (KNPP).

The goal of this study has been to identify the most important job positions related to key persons who possess unique subject matter related knowledge, to analyse the risk of knowledge loss, and to create a model of crucial tacit knowledge held by key experts. Creating a knowledge model requires organizing the various existing concept maps into a structured and consistent system which clarifies various aspects of experts' knowledge and corresponding relationships.

For the purpose of this project, this study has been focused on the personnel responsible for activities associated with ensuring or monitoring of nuclear safety and radiation protection (the classification is in compliance with national nuclear regulations). The target group includes six positions in the 'top management' category (six persons), seven positions in the 'operational management' category (nine persons) and four positions in the 'operational personnel' category (64 persons). The scope of the study contains a formal risk analysis of a total of 79 individuals.

The study was performed on the basis of a general approach described in an IAEA publication (see Ref. [1]), however the methodology was adapted to reflect plant specifics.

The total risk factor was defined as a combination of three types of threats — attrition, position and personal. A specific weighting rate was assigned to each threat.

The attrition threat consists of two components: planned and predictive attrition dates.

The position threat includes three components: job experience requirements, education degree requirements and specialized training requirements.

The personal threat is a conditional assessment of complex personal rating. That rating has been assigned by research experts and considers the professional file of an employee (including informal roles and soft skills), evaluation of direct managers, and opinions of colleagues and key partners.

The total risk factor is a normalized sum of components enumerated by a modified exponential distribution function. Such an approach allows for tuning of the results depending on the λ parameter value (for more details see the full paper on the attached CD). Based on the applied risk analysis of knowledge loss, a knowledge retention pilot study was carried out.

The main goal of the study was to demonstrate the validity of proposed methodology and to prove its applicability. Knowledge retention work involved elaborate interviews with two experts — the plant shift supervisor, who has 18 years' experience in KNPP, and the chief reactor physicist, who has 15 years of experience. The total risk factor of these experts is placed at around 7–8 on the risk chart.

In this pilot study, concept maps were used to capture, represent, and preserve specific professional knowledge held by the above mentioned experts. Knowledge elicitation sessions were conducted by two elicitors. The team was designed with one member designated as a moderator and the second as a recorder. The role of the moderator was to interact with the experts, to keep the conversation moving and on-topic, and to ensure that the recorder is keeping up with the conversation. The recorder created the concept map as the discussion unfolded. The recorder created the arrangement of items in the map and potential connections between items. When necessary he/she created submaps; in this particular case study there were four submaps.

By applying this technique, information was obtained that could be used for different purposes. One result of this work has been the transformation of a package of licensed training courses. The course Neutron and Reactor Physics Processes has been updated and expanded. The project team proposed the development of two new courses — Training of Operating Personnel on SBEOP[4] [16] for WWER-440 and Training of Operating Personnel on SBEOP for WWER-1000'.

Project results have also been applied to establish knowledge retention plans and succession planning. The pilot study has limited scope and only provides principle information for such work. Nevertheless, three different templates for the development of knowledge retention plans have been submitted to plant management for assessment, selection and approval for future implementation.

6.4. PRESERVATION AND DISSEMINATION OF CANDU TECHNICAL KNOWLEDGE — THE CANTEACH PROJECT, CANADA

There is a critical need to preserve CANDU technical knowledge and to provide a means of disseminating that knowledge to the nuclear community in a convenient and cost effective manner. The CANTEACH project aims to fulfil those needs. CANTEACH is a knowledge repository that provides high quality technical documentation relating to the CANDU nuclear energy system. This information is public and is intended for use in various aspects of education, training, design and operation. The CANTEACH project aims to provide an information preservation mechanism and exchange network for people interested in the CANDU energy system. Contributors are industry experts who hold valuable knowledge and experience in diverse aspects of CANDU technology and its applications, and unique expertise in the areas of science and technology, nuclear power design and construction, project management and the development of engineering tools.

CANTEACH uses a web based process to capture know-how and know-why from within the nuclear industry. It is sponsored by Canadian nuclear power utilities Atomic Energy of Canada Limited (AECL) and Canadian universities, and is administered by the CANDU Owners Group (COG). As an example of a successful Canadian KP initiative, this appendix describes the project model and current web site content, discusses how the site is used and the role it plays in the successful capture, preservation, and dissemination of CANDU technical knowledge. This summary describes the logical structures and processes of the CANTEACH data filing and recovery systems.

CANTEACH is a recently devised and ongoing project with the purpose of preserving technical knowledge of the CANDU nuclear–electric generating system for use by present and future members of the CANDU community. Sixty years have passed since nuclear energy research began in Canada. Fifty years have passed since the founding of AECL and the start of efforts to commercialize nuclear power production. Since that time, tens of thousands of dedicated people have worked within the Canadian nuclear industry to forge a new and successful primary energy supply. CANDU technology is well into its second century. Within the world's fission technology power reactor community, CANDU pressurized heavy water reactor (PHWR) technology is quite unique, first because it was established as a separate effort very early in the history of world fission energy, and second because it grew in an isolated environment in its early years, with tight security requirements. As with any commercial design, intellectual property restrictions on proprietary design details have considerably limited the accessibility and degree of open dissemination of CANDU reactor design information. Thus the CANTEACH initiative is intended to capture the published and available design legacy of the CANDU reactor in a form that is readily accessible to current and future generations of professionals involved with CANDU reactors, be they students, designers, operations staff, regulators, consultants or clients.

Prior to establishing CANTEACH, young students and graduates entering the Canadian nuclear industry had to make do with one or two textbooks and a huge collection of diverse technical papers augmented by limited scope education and training materials. Those employed within various parts of the nuclear industry rely mostly on a

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[4] SBEOP: Symptom based emergency operating procedures.

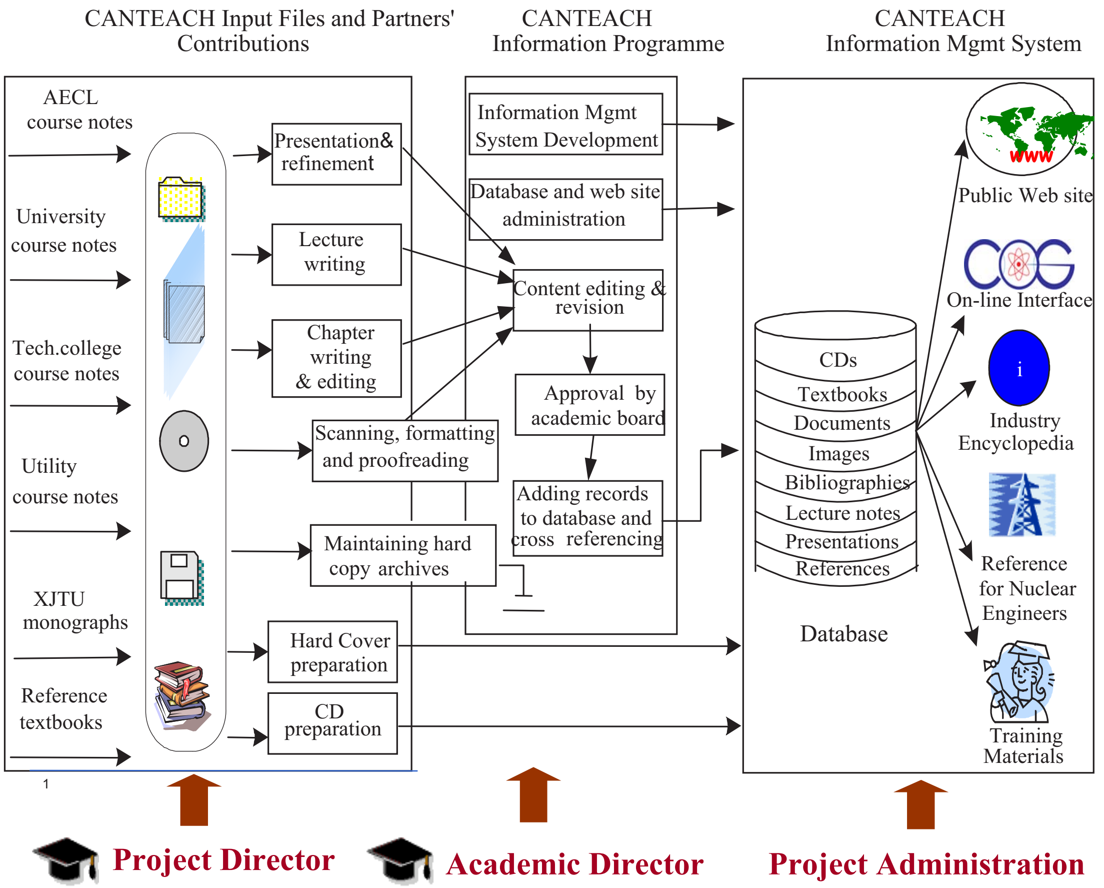

FIG. 6. The CANTEACH process (as originally designed).

smaller set of CANDU related documents available within their own organizations; documents that sometimes are rather limited in scope. University professors often have even more limited access to in-depth and up-to-date information. In fact, they often depend on literature published in other countries when preparing lectures, enhanced by guest lecturers from various parts of the industry. Because CANDU was developed mostly inside Canada, few of these text materials contain useful data describing processes important to the CANDU system. For many years it has been recognized that a comprehensive CANDU 'technical reference manual' and training materials are needed. There is, in fact, a large volume of existing documentation that describes CANDU systems and operations. Much of that documentation is repetitious and more superficial than desired. Very few of the documents detail why CANDU is designed the way it is, how the design has evolved, and how and why existing plant retrofits and design changes have been implemented. Much of the tacit and implicit knowledge of retired or about to retire industry experts (such as experiential knowledge, historical knowledge, and overall technical design 'wisdom') is not being captured and passed on to the next generation of nuclear industry workers. The CANTEACH project is striving to capture this knowledge and fill in current gaps in available materials.

CANTEACH captures and disseminates CANDU nuclear knowledge utilizing a four-step process, illustrated in Fig. 6:

(1) Obtain documentation from any of many sources;
(2) Store current CANDU knowledge in a document management database;
(3) Categorize and cross-reference records and documents;
(4) Retrieve documentation through a dedicated web server.

Figure 6 illustrates the information flow and products of the project. Donors (organizations and individuals) send contributions to CANTEACH staff, who then arrange the documents into a consistent format and review material to ensure a high level of quality. The main activities of staff to date relate to development and refinement of the information management system. Results may be judged by browsing the web site. In some cases, several documents covering the same subject are available; eventually this diversity will be reduced through the merging or rejecting of some materials.

The dissemination of CANTEACH material is achieved via the World Wide Web. It provides convenient and easy access to a virtually unlimited volume of information with negligible distribution costs. Documents on the web are searchable electronically and, if attention is given to detail, the page layout of original documents in printed copies is reproducible.

The CANTEACH project is an excellent example of a successful KP project. It has shown that industry can collaborate to build a significant technical repository and knowledge base at minimal cost. The web site is accessed by many different users including educational instructors (such as university professors and high school teachers), technical trainers, industry professionals, utility staff and management, and even as an information resource for prospective new CANDU customers. The CANTEACH project exists to provide access to existing legacy education and training documents and images, to distil the essence of these documents, and to prepare new documentation. The task of populating the CANTEACH library with seminal documents is ongoing. The underlying philosophy of an open, free, and cooperative exchange on basic CANDU design and operation information has proven to be sound and effective. The CANTEACH web site can be found at http://canteach.candu.org/.

The CANTEACH administration operates under the auspices of the CANDU Owners Group Inc. (COG). COG is a non-profit corporation that is dedicated to providing programmes for the cooperation, mutual assistance and exchange of information to successfully support, develop, operate, maintain CANDU technology as well as keeping it economically feasible. Membership in COG is open to all CANDU/PHWR owners/operators worldwide, as well as to AECL. Other entities interested in furthering the objectives of the CANDU Owners Group may be considered for membership by the group’s members. For further details go to the public web site www.candu.org or email cog@candu.org.

6.5. AN INTEGRATED LIFE CYCLE APPROACH TO TECHNICAL KNOWLEDGE RETENTION, AECL AND CANADA

AECL is responsible for the design and construction of CANDU PHWRs. Through designing and building CANDU reactors over the past 40 years, AECL has established a strong project management delivery capability. Over the last decade, AECL has designed, built and delivered six CANDU-6 reactors to international customers on or ahead of schedule, and on budget. This success has been achieved largely due to effective KM practices that ensure sharing, retention and preservation of technical knowledge so that it is available for reuse at each subsequent project. Each completed CANDU-6 reactor project evolves from those previously built, and incorporates improvements in design, fabrication and construction based on previous experience.

Part of AECL also includes the nuclear laboratories at Chalk River, where much of Canada’s nuclear research and development is conducted. AECL also has a full services reactor engineering division that engages in commercial service work to maintain, refurbish, and decommission existing CANDU plants and related nuclear facilities. KM in general and KP in particular are an important ongoing requirement of AECL’s business. Given AECL’s long history in research and development, as well as design and service work related to CANDU reactors, it has always been recognized within AECL that design information management and feedback from operating experience are essential components of AECL’s business, enabling design improvements and the development of future opportunities.

AECL takes a life cycle view of design, meaning that the information and technical requirements of successive phases of a design project are fed back from previous projects and are considered early in the next phases of a new reactor project. For example, design requirements for manufacturability, for constructability, for maintenance, for operations, and for decommissioning are identified from operating experience, customer and supplier feedback, and prior project experiences, and are incorporated in the early phases of a project. For each successive phase of the project, technical information evolves; it is created, transferred, transformed (often between individuals and organizations), and utilized in different ways and at different times. To facilitate the capture, organization, integration, configuration control, and dissemination of design information, AECL relies on a suite of

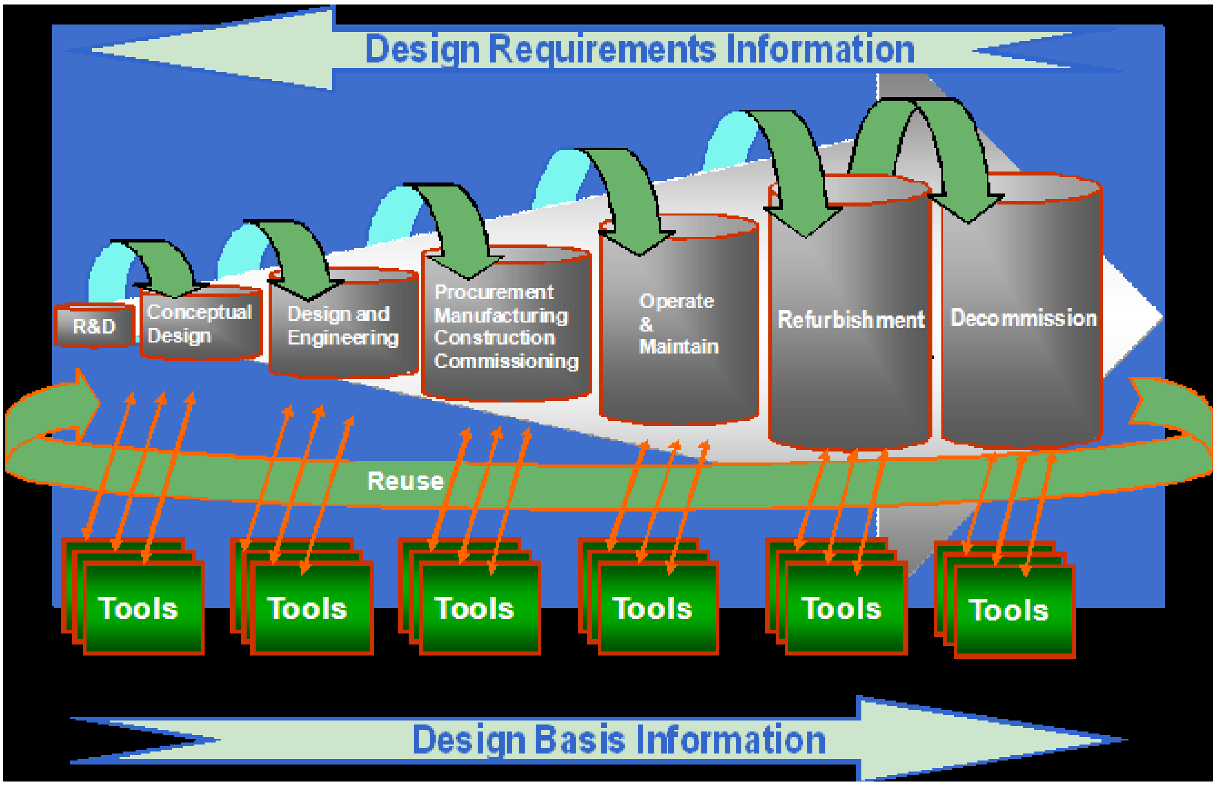

FIG. 7. life cycle view of design basis knowledge.

tools which support various design processes and enable effective knowledge capture processes. Figure 7 illustrates these concepts. These tools help to maximize knowledge capture, retention, and subsequent utilization within and between phases. Knowledge captured at an early phase may be used in a much later phase, sometimes decades later, and for reasons not initially anticipated. This approach is also applied to consultations, analyses and component improvements provided to CANDU utilities as part of AECL's services.

AECL's knowledge retention and preservation strategy is built around the following basic understanding:

— Processes need to be in place to correctly identify, capture, transfer, and retain nuclear knowledge;
— Human resource skills, experience, and specialized knowledge need to be sustained and available in several core competency areas to support the Canadian nuclear industry;
— Retention and management of research and development (R&D) knowledge is essential to support operating facilities and advance nuclear technology;
— Tools need to be available for effective and efficient capture, preservation, and retrieval of nuclear knowledge in a way that makes it readily available for reuse or future utilization (for example, for innovation and development);
— A culture is needed which creates and sustains awareness of knowledge sharing, transfer and retention processes within the organization;
— A life cycle view of knowledge management and knowledge processes is required for projects, technology and products.

The capture, transfer and management of knowledge require tools to be in place, and these tools need to be compatible with the organization's information management strategies across all departments, from design, marketing, procurement, and R&D to finance. Several examples of the tools currently used by AECL to support knowledge retention and preservation will be outlined in more detail in the following sub-sections.

6.5.1. Use of operating experience and project feedback

AECL maintains a feedback monitoring system (FMS) which helps staff involved in design, engineering and R&D activities to be aware of and have access to available feedback information as part of their work. The FMS is an internal database that supports AECL's operating experience feedback and design improvement programme in conformance with Canadian Nuclear Standard CSA N286.2-00 [17] requirements. The FMS database and process enables the systematic collection, recording, evaluation, and distribution of design, construction, commissioning and operating feedback information to AECL technical groups for the purpose of improving the safety, cost competitiveness and reliability of AECL products and services. The FMS database supports formal internal assessment and review for the following key processes:

- Feedback for design;
- Plant operations feedback to design;
- Feedback from construction;
- Regulatory feedback;
- Commissioning feedback;
- Supply and procurement feedback;
- Engineering experience from built projects;
- Feedback from R&D into CANDU products;
- Design feedback database;
- Market feedback;
- Information bulletin to CANDU operating stations;
- Advisory notice to CANDU operating stations.

The feedback management system and process provide an important mechanism to capture, store, filter, correlate, prioritize, and make accessible vital technical information, lessons learned, event summaries, and experiential knowledge related to all aspects of the business. The FMS database is available to all staff on AECL's internal web site. The AECL operating experience feedback group is the custodian of the feedback management process and is responsible for the design feedback and improvement programme as well as ensuring that the ongoing process of feedback information collection, logging, categorization, communication, and record management is effective. The group organizes initial reviews performed by various teams and technical reviews performed by technical experts. The group also acts as the operations feedback team. Various feedback procedures and operating instructions are available in-house which define AECL's feedback processes. A 'What's new' page on the corporate intranet summarizes significant feedback received including monthly summaries, newsletters, and quarterly FMS output documents. Individual staff members can also submit feedback issues and evaluations via the internal FMS web site. A link is provided to the CANDU Owners' Group operating experience (OPEX) database. FMS forms a key part of AECL's technical organizational learning system.

6.5.2. Use of engineering tools and information technology support

AECL has developed a suite of integrated engineering and project management tools to provide electronic delivery of all design, procurement, building and commissioning data for new CANDU projects. Use of these engineering tools has helped AECL to complete new reactor projects within schedule and under budget. Electronic tools have become, in effect, a repository of AECL knowledge and CANDU design and engineering technology. By using the experience and knowledge base retained from previously built projects, engineering tools also serve as an effective means of knowledge transfer and reuse from one project to the next. For example, AECL's tools include systems that provide strong configuration control of design and construction. These include an electronic document management system ('TRAK'), 2-D and 3-D CADDS models, an integrated cabling and wiring system database and manager ('IntEC'), and the CANDU materials management system (CMMS), which includes modules for demand/supply/release and inventory control.

Engineering tools are used by all parties involved in a construction project (including subcontractors, site construction teams, and utility customers) to ensure efficient data exchange, accurate information capture (as it is produced), and tight version control. AECL also has access to a large number of other information sources, such as the IAEA, US NRC, EPRI, the Canadian Nuclear Safety Commission (CNSC) and CANDU Owner's Group (COG) reports and databases, and maintains close relationships with these institutions, as well as universities and other nuclear organizations in order to ensure that its technical documentation and operating experience data is complete.

Another key knowledge retention tool AECL has developed is the Requirements Management System. This database captures information elements within a document and checks the consistency of this information across documents. It is used to establish and manage relationships and links between information objects. Changes to these information objects are either automatically updated in related documents or the need for changes is flagged. This enforces information consistency, improves traceability and compliance verification and enables more effective knowledge reuse.

The evolution of the 3-D CADD modelling suite has allowed AECL to build on a 'data-centric' view of integrated design information. The SmartPlant Enterprise software suite from INTERGRAPH is used to achieve greater design consistency, for example from flow sheets through to piping isometrics and bills for materials. This permits improved configuration management and revision control. Design and operating data are readily accessible to procurement and project management applications and better support of work group data sharing is achieved. A standards based data interchange between engineering tools, SmartPlant design data repositories, and simulator tools is being developed and will further enhance the tool suite capability for design knowledge capture, management, and retention.

AECL is developing a suite of operations and maintenance (O&M) support applications to assist in tracking the health of plant systems and components, and assist in making proactive maintenance decisions by providing diagnostic tools to identify and correct problems before they result in a loss of performance. AECL's so-called SMART CANDU[5] applications combine process, chemistry and inspection data to provide up-to-date assessments of the current status of key plant systems and components. Nuclear plant and facility process data are stored in a life-of-plant historical data system (HDS) or 'historian', where they can be easily retrieved and displayed to compare current plant status with past behaviour. Where feasible, plant data are interfaced with analytical models based on knowledge developed through AECL's R&D programme to simulate expected current or future performance or operating behaviour based on operating data.

Finally, additional tools and technology to aid in project communication, coordination, and information management such as project (and customer) correspondence databases, work/task scheduling, budgeting and control, procurement, progress reporting, risk assessment and tracking, and records management are employed.

6.6. UNIVERSITY NETWORK OF EXCELLENCE IN NUCLEAR ENGINEERING (UNENE), CANADA

The University Network of Excellence in Nuclear Engineering (UNENE) is an organization that was established in 2002. It is an industry driven alliance of prominent Canadian universities, nuclear power utilities, and research and regulatory agencies. UNENE was created to secure a sustainable supply of qualified nuclear engineers and scientists for innovation in nuclear generation while ensuring nuclear safety and performance excellence. The primary means of reaching these goals include supporting university education and research and university based training and by encouraging young people to choose careers in and gain relevant experience within the nuclear industry. Through funding from its industrial members and the Government of Canada (under the Natural Sciences and Engineering Research Committee (NSERC)), the UNENE is reinvigorating university based mid to long term nuclear research and expanding its academic basis. The current members of UNENE are listed in Table 9.

Funds are provided to faculty members for nuclear research and to graduate students. Courses and expertise imparted at one university are made available to students from other universities. In addition, UNENE member universities offer a joint, course based Masters of Engineering degree for the professional development of industry employees, in particular those newly hired. Eleven three year projects are being funded at a cost of approximately CDN $90 000 each by UNENE. These funds are matched by NSERC money through collaborative research and development grants. In addition to research output, these projects will support Masters and PhD graduate students.

[5] SMART CANDU is a registered trademark of Atomic Energy of Canada Limited.

TABLE 9. CURRENT MEMBERS OF UNENE

Industry	University
Ontario Power Generation	McMaster University
Bruce Power	Queen’s University
Atomic Energy of Canada Limited	University of Toronto
The CANDU Owners Group	University of Waterloo
The Canadian Nuclear Safety Commission	University of Western Ontario
Nuclear Safety Solutions	University of Ontario Institute of Technology
	Ecole Polytechnique
	University of New Brunswick
	The Royal Military College
	University of Guelph

NSERC and UNENE are currently sponsoring Industrial Research Chairs (IRC) at the following universities with the listed research topics:

- Queen’s University NSERC/UNENE IRC in nuclear material.
  Research topics include: control of microstructure/texture of zirconium alloy tubes; experimental study of anisotropy and deformation of zirconium alloys; modelling anisotropy and deformation of zirconium alloys; effects of deformation on plastic instability and failure; improvements in measurement of crystallographic texture; micro-structural characterization and qualification; experimental study and modelling of macroscopic and microscopic stress and strain developments during manufacture and evolution during service; and theories of radiation damage and in-reactor deformation;
- McMaster University NSERC/UNENE IRC in nuclear safety analysis.
  Research topics include: best estimate and uncertainty based nuclear safety analysis; vapour generation and boiling heat transfer; modelling dry-out, post dry-out and quench processes; thermal–mechanical behaviour of reactor components at high temperature accident conditions, and; computational fluid dynamics models for two phase flow;
- University of Toronto NSERC/UNENE IRC in nano-engineering of alloys for nuclear power systems.
  Research topics include: mechanisms of oxidation cracking in hot water under reducing conditions; alloy design for corrosion resistance; building on atomistic understanding to promote favourable interface structures; exploiting alloy corrosion processes for the fabrication of useful nano-structured materials, and; corrosion and stress corrosion research for the Canadian nuclear industry;
- University of Ontario Institute of Technology (UOIT) NSERC/UNENE IRC in health physics and environmental safety.
  Research topics include: characterization, through real time modelling and measurements, of sources of ionizing radiation; experimental and theoretical investigation of techniques to minimize total radiation fields coming from sources; development of specialized radiation detection devices, such as microdosimeters and real time extremity monitors; monitoring and modelling the environmental impacts of ionizing radiation produced as a result of the operation of a nuclear facility, and; on-line dynamic health physics and environmental protection information management system;
- Waterloo University NSERC/UNENE IRC in probabilistic-based life cycle management.
  Research topics include: assessment methods; probabilistic models of load and resistance variables; mechanically based failure models; digital image analysis for condition assessment; reliability estimation models and computation methods.

— University of Western Ontario NSERC/UNENE IRC in control, instrumentation and electrical systems. Research topics include: fault detection/isolation and control loop stability monitoring/enhancement; probabilistic based maintenance optimization for control and instrumentation systems; applications of distributed control systems in CANDU power plants; load following control of CANDU power plants, and; enhancement of training simulators for engineering applications.

UNENE can be accessed through its web site at http://www.unene.com.

7. CONCLUSIONS

KP in nuclear organizations has not yet reached maturity. This is clearly shown by the results of this study, including survey results (see Appendix I). Barriers to a sustainable KP culture could include lack of motivation and trust by the staff, limited time or other organizational factors.

KP is important, and organizations that ignore it may suffer stark consequences (including losses or even bankruptcy) when required critical knowledge is not preserved. In the case of the nuclear industry, when the critical knowledge associated with construction, design, maintenance and operation is not preserved, it can lead to incidents, accidents and other adverse events.

There are several important, interrelated issues associated with knowledge and information management characteristics of nuclear organizations. These include proprietary knowledge and information protection, knowledge and information security, safety and non-proliferation of nuclear knowledge and information and data integrity. Collectively, these characteristics often complicate the flow and storage of data, information, and knowledge, and must be considered carefully. The implementation of KP, including information management systems, organizational memory systems (or repositories), process oriented KM approaches, and the KM culture of an organization, should address these additional challenges.

The implementation and interaction of explicit, implicit and tacit KP as an integrated process is vital to achieve an overall KM objective. Sustainable and optimized KP processes (such as organizational memory and information flows) can guarantee fast access to data, documentation, images, videos, analysis and CADD software and know-how, which supports fast decision making and training of staff. KP processes can improve operational procedures and overall performance. They can also support organization configuration management and identify pathways and gaps in information.

It is often necessary to capture explicit knowledge related to past artefacts. Modern scanning techniques to capture hard copy documentation, together with optical recognition techniques, allow for efficient recapture (such as in the INIS example in Appendix II). Even when such a KP effort is too costly or manpower intensive, an organization should consider establishing and improving its KP initiatives and culture according to its needs and opportunities.

KP is vital to achieving the overall objective of optimal and sustainable knowledge processes, such as organizational memory and information flows. Furthermore, KP improves availability and utilization of technical and operational knowledge in nuclear organizations, which ultimately improves the safety and economics of nuclear facilities.

Many cost effective methods and tools are available to support KP in nuclear organizations. Mentoring, training and knowledge retention activities have been undertaken mostly by older, more experienced specialists or experts. However, this tends to be done on a voluntary or ad-hoc basis. This may be because of a lack of KP culture in these organizations. To guarantee preservation of implicit and tacit knowledge, an organization has to ensure adequate resources and an ongoing commitment to provide training and mentoring to new staff. In addition, time periods between retiring experts and new employees should sufficiently overlap for critical knowledge to be passed on through coaching, mentoring, and hands-on experience. Finally, to facilitate effective generational knowledge transfer, it is important for management to motivate the experts by providing recognition and rewards for the sharing of their tacit knowledge during this period.

8. RECOMMENDATIONS

Nuclear organizations should make efforts to become fully aware of their ongoing and future reliance on core nuclear knowledge and expertise. In organizations where no formal KP programme has been introduced, it is recommended that a knowledge loss risk assessment be conducted from a KP perspective. If findings from an assessment show there is a need for new or improved KP initiatives, the organization in question should pay additional attention to establishing adequate measures to ensure that both short term and long term KP needs and obligations are adequately addressed.

Nuclear organizations should ensure appropriate management awareness and the presence of an organizational culture that recognizes KP as an important ongoing requirement. Appropriate policy and procedures should exist in each organization to establish which KP measures are needed and ensure that they are implemented as standard practice.

Strategic planning by nuclear organizations should take KP into consideration. Effective KP often demands ongoing financial investment, but it is certain to pay off in the future through saving additional costs to reinvent lost knowledge and solve problems caused by lack of know-how, which can be reduced if not totally eliminated. Furthermore, avoiding lost profit caused by production delays because of an absence of KP compensates the costs needed to sustain KP. KP plans should recognize that to be effective, KP should be implemented in the context of specific organizational needs and constraints. Integration, accessibility, interoperability and maintainability are important general objectives in achieving KP. The technical infrastructure of an organization needs to support KP and any necessary hardware and software must be implemented and maintained.

As a minimum, basic KP measures should be taken in nuclear organizations to ensure that key tacit and explicit knowledge is identified and retained. Successful KP measures can often be achieved via commonly used, inexpensive, and widely available technology such as word-processing, imaging and multi-media tools that are typically already in use in most organizations. Simple but effective measures to capture and archive data, information, and knowledge can often be implemented at minimal cost and should be considered. For example, many organizations have already been successful in setting up multi-user networks and shared resources that enable employees to organize data, documentation, etc. in repositories or databases which are readily accessible.

Once the most immediate KM needs of an organization are addressed, a longer term and more comprehensive KP programme should be considered. Several methods and tools have been discussed in this report. Organizations can select those which meet their needs. Important issues such as security, maintainability, accessibility, usability, presentation, translation, validation, and retrieval need to be evaluated. Although technical solutions exist for many of these issues, data exchange and interoperability between complex and multiple data repositories remains a challenge, and carefully planned implementation is required.

Appendix I

SUMMARY OF A SURVEY ON THE CURRENT STATUS OF KNOWLEDGE PRESERVATION IN NUCLEAR AND NUCLEAR SUPPORT ORGANIZATIONS

I.1. INTRODUCTION

This appendix presents an analysis of the results from a survey conducted between December 2006 and September 2007 to determine the current and anticipated status of nuclear knowledge preservation in Member States.

The survey aimed at obtaining information on:

- The status of nuclear knowledge preservation in Member State institutions;
- Methods and tools applied in the knowledge preservation life cycle;
- Management approaches and practices used in knowledge preservation.

A Questionnaire on Current Status of Knowledge Preservation in Nuclear and Supporting Organizations was developed for this benchmark survey on knowledge preservation. The first CRP meeting was held from 13 to 17 November 2006 in Vienna to review the survey questionnaire, entitled The Current Status of Knowledge Preservation in Nuclear and Supporting Organizations. Considerable effort was spent on reviewing and revising the Knowledge Preservation (KP) questionnaire which was drafted at the CRP Consultancy Meeting, held from 21 to 25 November 2005 in Vienna. The questions were edited for clarity, redundancy, and appropriateness of location in the document.

This questionnaire was sent to more than 350 selected Member State institutions. In addition, an on-line questionnaire was made available on the Agency's INIS and NKM web site. By the end of September 2007, 41 responses from 25 Member States and one international organization had been collected. Survey analysis reflects the current status of knowledge preservation in nuclear organizations from Argentina, Austria, Brazil, Bulgaria (2), Canada (2), Colombia, Croatia, El Salvador, France, Ghana, Jordan, Lithuania (2), Mexico, Montenegro, Niger, Pakistan, the Philippines, Poland (2), Romania (6), the Russian Federation (2), Serbia, Slovakia, the United Kingdom (2), Ukraine (3) Uzbekistan and the Joint Research Centre of the European Commission.

CRP participants felt that the survey results must be used with caution and should only be interpreted as an indication of the current status of knowledge preservation in Member States due to the limited response rate.

I.2. ANALYSIS OF THE IAEA SURVEY QUESTIONNAIRE

I.2.1. Policy and strategies

It should be mentioned that different types of organizations (educational, governmental, research and commercial) tend to focus on different policies (Fig. I.1). However every responding organization has developed its own strategy to support knowledge preservation. Improving human performance and investment in information system technology are the most common policies in organizations, and have been adopted by almost 65% of

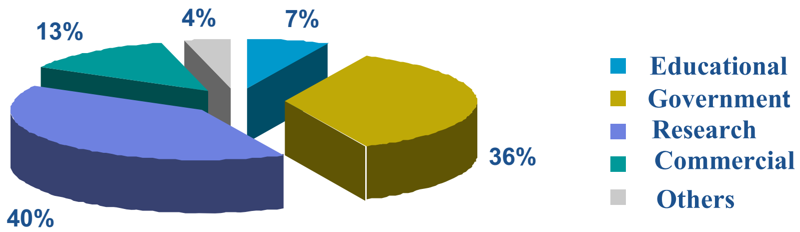

FIG. I.1. Distribution of the different types of organizations.

TABLE I.1. TYPE OF POLICY OR STRATEGY APPLIED BY ORGANIZATIONS (IN PER CENT)

Improving human performance	63
Investment in information system technology	61
Informal (voluntary) KP practices	61
Succession planning	49
Making KP part of the organizational culture	49
Developing methods and tools for KP	46
Formal (mandatory) KP procedures	24
Other	24

respondent organizations. A combination of these policies is common, especially for the educational organizations and some of the governmental organizations which participated in the survey. KP is a prevalent part of the organizational culture in Canada, Romania, Lithuania and at the JRC Institute of Energy. In other responding countries, an official KP strategy is used relatively seldom; 61% of responding organizations had developed informal KP practices on a voluntary basis. The EC indicated that in its new framework programme, knowledge preservation will be introduced for all GIF activities.

The extent to which different strategies are used can be seen in Table I.1.

The vast majority of responding organizations use various combinations of suggested strategies. About 40% of them join more than three types of policies together.

Some respondents do not have formally named KP procedures and processes, but they have some strategies in place, such as succession planning for key positions, Human Performance Improving Programmes etc., to support the preservation of knowledge.

In some Romanian institutions, for example, different aspects of KP and knowledge transfer are described in non-specific procedures. These are defined at a lower level, with each division having specific training programmes. A similar situation exists in some research centres in Montenegro.

In general, KP activities are decentralised and only 30% of responding organizations have a nominated person/group responsible for knowledge preservation. Usually responsibilities are placed on several persons from different departments who are in charge of separate KP elements.

Figure I.2 indicates which approaches are being applied to achieve KP objectives.

Clearly the most used approaches at responding organizations provide for appropriate human and financial resources and training for all processes. Approximately 50% of responding organizations recognize the importance of getting all levels of management involved, and establishing systems to encourage individual contribution. On the other hand, formal KP maintenance programmes had been rarely (12%) implemented at responding organizations. KP procedures and processes are formalised at some responding organizations in Argentina, Bulgaria, Romania, Slovakia and Ukraine. In some Ukrainian scientific and research centres, knowledge bases for expert and scientific activities have been elaborated.

I.2.2. Management factors

In most cases, respondents broadly use general sources of explicit nuclear knowledge depending on organizational needs, such as scientific nuclear publications, national and international standards, rules and guides, licensee information, IAEA publications, patents, etc. Sources of tacit knowledge include materials with records of personal experience exchanges from meetings, workshops, training sessions, etc. Employee interviews are prevalent in Argentina, Canada, UK, Ukraine and Poland.

Knowledge maps are not widely used. This management tool is only practiced in 27% of organizations. A further 17% of responding organizations have started knowledge map development projects, selecting, classifying and storing their documents in technical archives. In enterprises which use mapping tools, the update frequency is usually based on each department's individual plans.

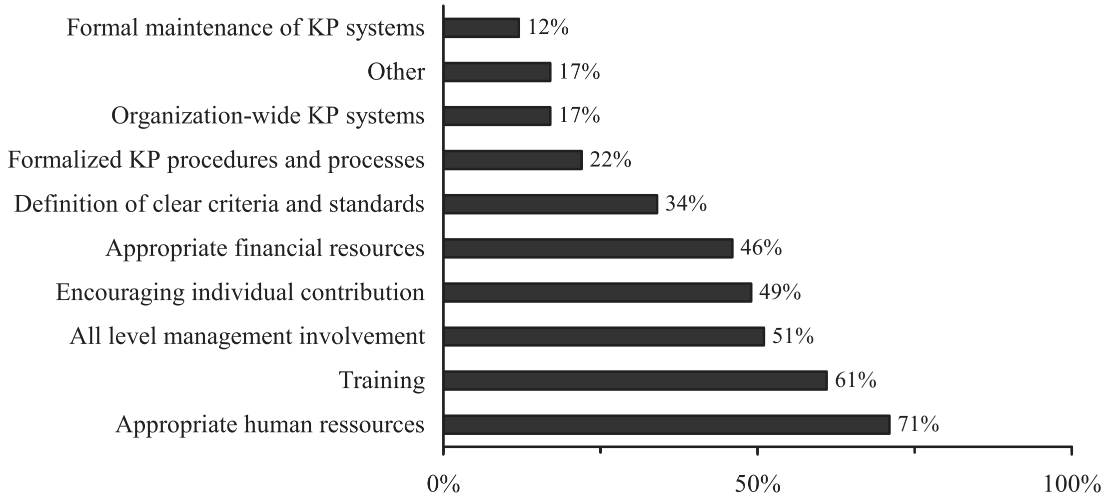

FIG. I.2. Approaches applied to achieve KP objectives.

In 41% of cases, KP is a part of quality management systems. Lack of integration between knowledge management and quality management systems is a well known deficiency. Lithuanian and Romanian respondents planned to integrate these two systems in the near term. In most responding Member States organizations, KP is not strictly a part of QMS, but the quality policy of regulatory bodies includes some statements regarding the maintenance of regulatory staff competence. ISO and IAEA regulations are broadly used in responding organizations from Western and Eastern Europe.

Based on results of the survey, we can observe that knowledge system integrity (23%) is very weak. Only a few responding institutions in Colombia, the Philippines, Romania, Slovakia, Ukraine, Uzbekistan and the European Commission have a system administrator for KP (14%). The survey indicated that any specific procedures developed address almost all parts of system administration, such as system security, authentication, and access rights.

One of the most important tasks of KP is to maintain corporate knowledge and transfer it to newcomers. As a rule, experienced staff are assigned to be coaches or lecturers at various workshops and courses.

Generally speaking, respondents have not yet implemented detailed succession planning, including knowledge loss risk assessment, identification of key positions which should be monitored with respect to KP, etc. Currently only a few British, Bulgarian, Canadian, Colombian, Romanian, Russian and Ukrainian organizations have implemented all these steps to avoid knowledge loss and to ensure timely succession in key positions. Some responding organizations have neither the funds nor the human resources required to undertake such activities. In other institutions, these functions are not formalized. Some research organizations in Romania nominate one to three persons for each key position requiring succession planning. Potential candidates are included in a dedicated training programme. However, this advanced practice is relatively rare.

I.2.3. Methods and tools to sustain the knowledge life cycle

Only 39% of organizations questioned in Member States apply a graded approach to evaluating knowledge significance. Sometimes grades are defined by subjective opinion. In some Romanian organizations they are based on previous experience and annual evaluation of personnel, and clearly defined methods are used to identify the knowledge that should be captured, processed, maintained and preserved. As an illustration they are, for instance, based on an evaluation by the Techno-economic and Scientific Committee. The UK respondent indicated a graded approach is used for the organization's knowledge identification process. In other cases, methods are based on common sense and previous experience.

The vast majority of responding organizations use various combinations of suggested methods and tools. About 12% use three or more methods for capturing tacit knowledge and 80% use three or more methods for capturing explicit knowledge. The use of various methods of knowledge capture is presented in the charts below (see Figs I.3, I.4).

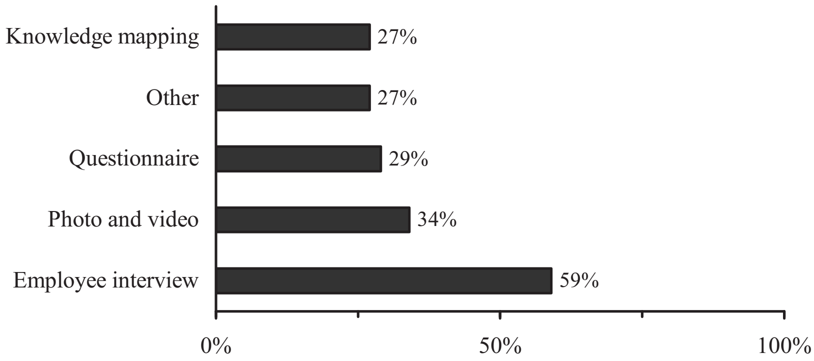

FIG. I.3. Methods and tools for capturing tacit knowledge.

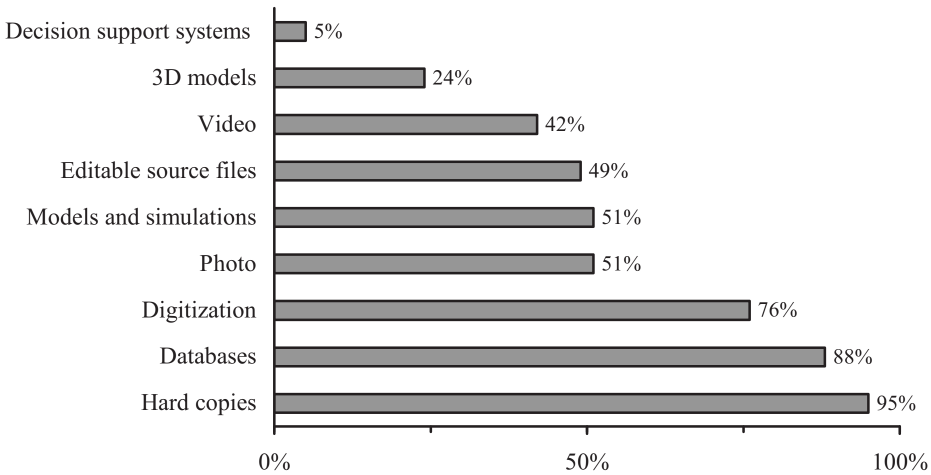

FIG. I.4. Methods and tools for capturing explicit knowledge.

As can be seen from Figs I.3 and I.4, methods and tools for capturing explicit knowledge are more widespread than those for capturing tacit knowledge.

The most commonly used e-forms for information capture among respondents are MS Word (80%), PDF (85%), ASCII (24%) and XML (24%). Some organizations also use RTF, PSD, CSV and relationally structured data (MS Access, SQL). In general, the content of electronically captured information remains searchable. The same forms are usually used for information storage on hard discs, CDs and DVDs. Streamers and film libraries are used in Bulgarian, Canadian, Lithuanian, United Kingdom and Ukrainian organizations. However, about 60% of responding organizations plan to upgrade their storage format. With the exception of a few organizations in France, the Slovak Republic, Uzbekistan and Romania, respondents generally use hard copy archiving parallel to e-storage.

Seventy-six per cent of questioned organizations use commercial software for data processing. Only some respondents in Argentina, Brazil, Ghana, Mexico, the Philippines, Poland, Ukraine and the European Commission do not use this approach. Techniques for data processing such as digitalization, data analysis and data structuring are common for almost all respondents in Eastern Europe. The distribution of these and other techniques can be seen in Table I.2.

In addition to the techniques mentioned above, various nuclear (especially gamma) spectrometry data processing is applied. For statistical processing of data, some NPP operating organizations have developed special databases and software tools.

About 42% of questioned organizations use thesauri, taxonomies, ontology or other organizational structures and 46% apply computer aided metadata creation tools. Within responding organizations, commercial document management systems and intranet technology (56% for both) are applied more frequently than custom in-house database management systems (27%) and other tools for archive management (20%).

TABLE I.2. TECHNIQUES USED FOR DATA PROCESSING

Digitalization	90%
Data analysis	78%
Data structuring	66%
Creation of metadata	54%
Statistical processing	55%
Compressing	54%
Visualization	49%
Format conversion	41%
Verification of correctness	10%

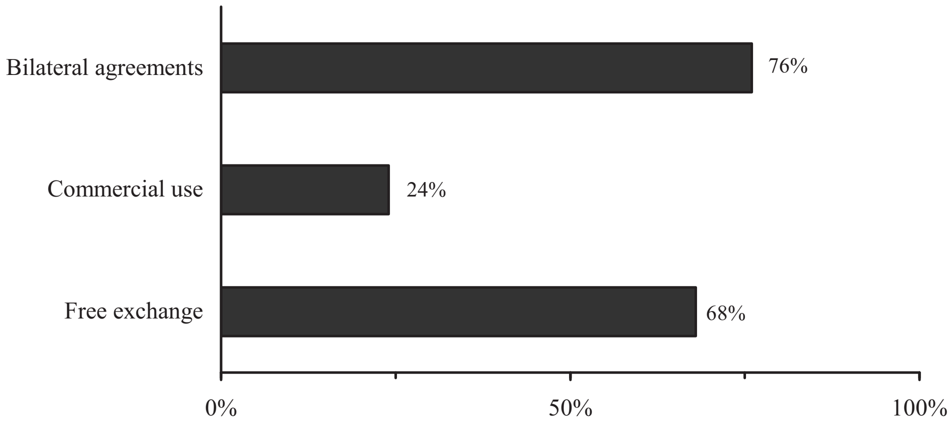

FIG. I.5. Terms for knowledge exchange.

With few exceptions, most responding organizations control access to knowledge stored and 49% have an integrated information system which provides interoperability of different types of knowledge.

Nearly 80% of responding institutions exchange stored knowledge with external organizations. The terms for such exchanges can be seen in Fig. I.5.

Commercial use of stored knowledge is common practice for less than one third of questioned nuclear and nuclear support organizations, with free exchange and bilateral agreements being much more frequently applied. The same e-formats are used for knowledge exchange as for knowledge capture and storage, including MS Word, PDF, ASCII and XML. Some organizations use also RTF and PSD.

E-mail (88%) is used almost everywhere in responding organizations for explicit knowledge exchange. Mail, Internet/intranet, e-learning and simulation are adopted by 59%, 76%, 34% and 20% of questioned organizations respectively. The majority of responding organizations try to use combinations of different media.

Methods of tacit knowledge transfer are shown in Table I.3. Setting up mentoring programmes, organizing training sessions, attending conferences and holding meetings can be regarded as the most popular activities for transferring tacit knowledge.

Knowledge preservation in responding countries is usually implemented in national and English languages. Only 27% of respondents use computer aided translation and 29% utilize special means (such as thesauri) to assure the multilingual use of information.

Only 32% of questioned organizations have special procedures for version control, updating and knowledge redundancy. For these reasons, tools and methods are selected individually depending on specific goals.

TABLE I.3. METHODS OF TACIT KNOWLEDGE TRANSFER

Mentoring/training	78%
Conference/meeting	76%
Interviews/questionnaire	51%
Communities of practice	39%
Simulation	22%
Others	5%

Appendix II

DIGITAL PRESERVATION AT THE IAEA

This section outlines digital preservation activities and ongoing projects in the IAEA's INIS programme. It provides general information about technical methods and standards used, describes processes related to scanning, quality control, workflow, OCR, verification, and other related issues.

This report does not offer precise recommendations or guidelines for digital preservation, since such guidance is available elsewhere or will develop through experience. As technology and industry standards improve and change, digitization techniques also evolve.

The aim of the INIS programme is to ensure a consistent, high level of image quality, interoperability and accessibility of digitized materials as well as the long term preservation of these digital resources for future generations in Member States.

II.1. MAJOR DIGITIZATION INITIATIVES AT INIS

There is a wide range of digital preservation initiatives in which INIS actively participates, both at the IAEA and in Member States. Some of the major projects (ongoing and/or completed) are listed below.

II.1.1. Microfiche to digital

The most significant project in digital preservation is the conversion of INIS Non-Conventional Literature (NCL or grey literature) from microfiche to digital media. INIS has a unique collection of grey literature gathered since the early 1970s. The collection from the period 1970–1996 is available on microfiche and consists of over 600 000 documents. INIS started to convert the collection prior to 1997 from microfiche to digital media in 2004. To date, digitization of almost 40% of the microfiche collection has been completed and full electronic texts uploaded to the INIS on-line database.

Before starting these major tasks, INIS carefully considered the pros and cons of outsourcing conversion of the microfiche collection to digital media as opposed to conducting it in-house. The final decision favoured a combination of both, which means that conversion from 'microfiche' to 'TIFF image only' is outsourced while image enhancement, OCR, verification, quality control and compression are performed by INIS in-house specialists.

In close cooperation with Member States, INIS continues to identify material that is highly relevant for digital preservation. Some of the most prominent digitization initiatives are listed below.

II.1.2. Within the IAEA

(1) IAEA General Conference documents:
All General Conference documents from the past 30 years were digitized and are now being made available on-line on the IAEA web site. As agreed with IAEA Policy Making Organs (PMOs), the integration of these documents into the INIS database with indexed metadata and full text are ongoing;

(2) Board documents:
All documents from the IAEA Board of Governors for the past 50 years were digitized and are now available on-line on the IAEA GovAtom web site;

(3) INDC series:
The digitization of archival documents from the International Nuclear Data Centre is an ongoing project. Within the last three years, over 850 documents containing 55 000 pages of textual and numerical information were converted into digital form;

(4) IAEA Bulletin, back issues:
One hundred and eighty two the IAEA Bulletin in six official UN languages have been digitized and published on the IAEA web site;

(5) IAEA Library technical reports:
Another major undertaking in this area is the digital preservation of Member State technical reports, which are kept at the IAEA Library and which date back to the 1940s. The collection includes over 50 000 printed reports, mainly text based material containing illustrations, graphics and photos (black and white). The digitization project started in late 2006 with the support of library staff and is expected to last for several years.

II.1.3. In collaboration with Member States

(1) CEA:
The historical French CEA-R microfiche collections were converted into digital form in close cooperation with the French INIS National Centre. A total of 2721 reports with over 150 000 pages have been digitized, OCRed, converted to searchable PDF and optimized for web access;

(2) Serbian RA type reactor knowledge base:
The Serbian knowledge preservation project for the RA type reactor was successfully completed in the summer of 2007. Documents on design, analysis, construction, operation, and decommissioning were included in the INIS Database with indexed metadata and digitized full text. The digitization of oversized design and engineering plans for the reactor plant were a great challenge. The project continues with knowledge preservation at the Serbian RB type reactor;

(3) Topical subsets:
The IAEA produces special topical CD/DVDs for particular scientific events. Usually each topical CD/DVD contains bibliographic references and full text related to a specific subject. A special procedure for the development of topical products was elaborated and includes all aspects of digital preservation from document selection to CD/DVD publishing.
Over the last two years topical products were developed on the following:
- International Conference on Area-Wide Control of Insect Pests: Integrating the Sterile Insect and Related Nuclear and Other Techniques, May 2005, Vienna, Austria;
- IAEA General Conference Scientific Forum 2005 on the topic of Nuclear Medicine;
- International Symposium on Trends in Radiopharmaceuticals, November 2005, Vienna, Austria;
- International Conference on Management of Spent Fuel from Nuclear Power Reactors, June 2006, Vienna, Austria;
- RRFM Conference: Research Reactor Fuel Management (full collection of RRFM conference papers for ten years), May 2006, Sofia, Bulgaria;
- The Chernobyl Accident and its Consequences is in the INIS Database, (including key materials, references, and full text documents), August 2006. This DVD was developed in cooperation with INIS National Centres in Belarus, the Russian Federation, Ukraine and the IAEA's Department of Nuclear Safety.

II.2. INIS GENERAL PRINCIPLES

To ensure the creation of consistent, high level quality images, INIS has adopted some general principles including:

- Performing benchmarking for image quality and resolution;
- Scanning at a level appropriate to the original source content;
- Creating and storing a master image file;
- Using formats that conform to standards;
- Applying standard compression techniques;
- Creating backup copies;
- Ensuring that media is stored in an appropriate environment;
- Creating bibliographic metadata for digital resources;
- Integrating image files with bibliographic metadata to the INIS database.

II.3. TECHNICAL INFRASTRUCTURE AT INIS

The components which make digital imaging possible are usually referred as the technical infrastructure, which mainly consists of the network, hardware, software, standards, policies, procedures for workflow, maintenance, etc. This falls into the category of technical infrastructure at INIS.

II.3.1. Applications and software

The applications and software utilized by INIS for image creation, document processing and workflow management are the following:

- From 1997 to 2003: the Jouve system, which was developed especially for processing INIS NCL full text documents. The system allowed for the scanning of documents and importing of TIFF/PDF images, enhancement of images, recognition of barcodes, quality control, setting of links to INIS bibliographic metadata, maintenance of cumulative indexes, as well as production of INIS NCL CD-ROMs conforming to the format of the INIS NCL browser (INISIR). The Jouve system could only operate in black and white mode, so it was phased out in 2003;
- From autumn 2003 onwards, INISIS2K has been used. It is based on InputAccel (IA) with PrimeOCR. This highly powerful main imaging system operates with open architecture and has been integrated with LiveLink, which is the IAEA’s standard document management system. IA allows for the performance of a number of vital processes, such as defining and monitoring workflow, scanning, importing, enhancing, quality control, OCR, export and several other special functions;
- PixEdit is primarily used for special image enhancements. The system can also be used for imaging documents;
- Abby FineReader is used for the OCR of multilingual documents, including those in Cyrillic languages, with an accuracy rate of close to 98%;
- Adobe Acrobat 8.0 is used for the OCR of script languages (mainly Korean and Japanese).

II.3.2. Hardware

- Scanners: there are five types of digital capture devices, including flatbed scanners, sheet fed scanners, drum scanners, cameras, and film scanners. As scanners have the most impact on image quality in digitization projects, INIS has exercised great caution is selecting quality scanners. The current INIS imaging/OCR infrastructure consists of seven scanning stations, three servers, four high performance scanners, three flatbed scanners, one high performance microfiche scanner and a digital camera. The technical characteristics are indicated in Table II.1;
- Computers**:** one of the most important tasks is selecting the correct computer for digitization work. INIS has carefully considered issues relating to memory, processor speed, rate of data transfer between components, disk storage device size, and audio and video cards. Computers purchased have a balance of reliable components and facilitate increased productivity and overall effectiveness;
- Monitors: large display monitors provide the possibility to better view and evaluate images. Monitors interpret and display values differently based on their type, size and quality, thus special care is devoted to the adjustment and manipulation of images. INIS has upgraded most of its scanning stations with LCD monitors having a minimum display of 19 inch. In addition, some special CRT monitors (Iiyama) are used at QC stations.

II.3.3. Creation of digital objects

Based on experience gained over the years and through benchmarking, INIS has dedicated special attention and applied different measures to a variety of material being digitized.

TABLE II.1. TECHNICAL CHARACTERISTICS OF SCANNERS

Scanner	Type	Paper size	Resolution (dpi)	Bit-in-depth	Speed (A4, 200 dpi)
Fujitsu fi-5750c	Colour; flatbed	A5–A3	Up to 600	24	100 p/min (simplex) 55 p/min (duplex)
M4099D	B&W (colour CCD); ADF	A7–A3	200, 240, 300, 400	10	90 p/min (simplex) 180 p/min (duplex)
M3099G	B&W; ADF	A7–A3	200, 240, 300, 400	8	50 p/min (simplex) 100 p/min (duplex)
M3096EX	B&W; ADF/flatbed	A5–A3	200, 240, 300, 400	8	30 p/min
M3092DC	Colour; ADF/flatbed	A5–A3	Up to 600	16–48	15 p/min (mono) 5 p/min (colour)
Kodak i260	Colour; ADF/flatbed	A5–A3	Up to 600	16–48	60 p/min (simplex) 120 p/min (duplex)
SunRise 2000	Microfiche scanner	A0–A4 reductions 7x–50x	CCD 3600–8800 True resolution		Up to 2500 frames/hr

II.3.4. Benchmarking

INIS considers this a first and most important step in the digitizing effort. The results of document/imaging and equipment benchmarking considerably affect all further steps (scanning, enhancement, format, etc.). The purpose of document benchmarking is to define and clarify the following:

- — Can the informational content of the original material be adequately captured in digital form?
- — Do the physical format and condition of material correspond to digitizing requirements?
- — What is the document type?
- — Which resolution should be applied?
- — At which bit-depth should it be applied?
- — Which compression parameters should be set?
- — What is the estimated level of accuracy for OCR?
- — Are there any other considerations?

(1) Capture modes:
Digital images may be captured in three modes:
— Bitonal (1 bit) — represents two tones, black and white;
— Greyscale (8 bit) — represents 256 colours/shades of grey;
— Colour (24 bit) — represents 16 million colours/shades of grey.
Owing to the large variety (quality and quantity) of text based material digitized by INIS, the benchmarking process is essential. For example, a black and white typed document may have annotations in different colours, such as red ink. Although normally black and white (bitonal) scanning is used for typed documents, scanning in colour may be preferable in such particular cases;

(2) Optical resolution:
Optical resolution is normally expressed in scanner specifications, such as ‘dots per inch’ (DPI) or ‘pixels per inch’ (PPI). While increasing the resolution enables the capturing of finer detail, it results in larger file sizes. For determining the resolution necessary to capture all significant details present in the source document, INIS follows a special formula, called the digital Quality Index (QI). This formula was developed by Cornell University and can be used as a guide for calculating optimal resolution;

(3) Bit depth:
The amount of information that a sensor in an array can capture is represented by 'bit depth'. Greater bit depths result in a more accurate digital representation of the original.
The final decision about resolution and bit depth depends upon the goal of digitizing**.** INIS applies a resolution of 300–400 dpi for bitonal scanning to documents of A4–A5 size, and 200–300 dpi with an 8 bit depth (256 colours/tones) for greyscale/colour scanning;

(4) File formats:
There are several standard file formats and they vary in terms of resolution, bit-depth, colour capabilities, etc. Although there is no clearly recommended archival format in use today, the most commonly used format for master digital images is the Tagged Image File Format (TIFF).
INIS stores uncompressed master digital images in TIFF Group IV, which ensures longevity and the production of a range of delivery versions (for example, for screen, for print, or for web access). For purposes of delivery to Member States, customers, users, and access via the INIS on-line database, files are converted to PDF (portable document format) and compressed (see below);

(5) Compression:
A process used to mathematically reduce image file size for storage, processing and transmission. Compression techniques can be either lossless (no information discarded in the process) or lossy (where the least significant information is averaged or discarded). Uncompressed or compressed files using the lossless compressing technique are clearly preferred. There are several standard and proprietary compression techniques available for resolution reduction, which is often necessary in order to create images for web delivery. INIS has chosen the JBIG2 standard for web optimization of digital resources.
Table II.2 below, created at Cornell University, provides detailed information about common compression techniques.

(6) Source material types:
Paper and film based source material may be categorized, but not limited to, the following:
— Printed text/simple line art: distinct edge based representations that are cleanly produced, with no tonal variation, such as a book containing text and simple line graphics;

TABLE II.2. ATTRIBUTES FOR COMMON COMPRESSION TECHNIQUES (CORNELL UNIVERSITY)

Name	ITU-T.6 (formerly: CCITT Group 4)	JBIG/JBI2	JPEG	LZW	Deflate	Wavelet	ImagePac
Standard/ proprietary	Standard	Standard	Standard	Proprietary	Standard	Standard/ Proprietary	Proprietary
Lossless/ lossy	Lossless	Lossless or Lossy	Lossy	Lossless	Lossless	Lossless or Lossy	Lossy
Bit depths supported	1-bit	1-bit up to 6-bit typical	8-bit or 24-bit	1-bit up to 8-bit typical	8-, 16- and 24-bit	varies	24-bit
Multi-Res	No	No	No	No	No	Yes	Yes
File formats + applications associated with	TIFF, PDF, fax	TIFF, PDF, ax	JPEG/JFIF, TIFF, FlashPix, SPIFF, PDF	Zip, TIFF, GIF, PDF, Postscript	PNG, Zip, PDF	JP2, LuraWave, MrSID, ER Mapper, DjVu	Photo CD
Web support	Plug-in or helper application	Plug-in or helper application	Since Explorer 2, Navigator 2 for use in JPEG/JFIF files only	Since Explorer 3, Navigator 2 for use in GIF files only	Since Explorer 4, Navigator 4.04 for use in PNG files only	Plug-in or helper application	Java applet or helper application

— Rare or damaged printed text: items that convey intrinsic information beyond the printed text or those in which the text may be obscured by surface dirt, stains, or other damage;
— Manuscripts: soft, edge based representations that are produced by hand or machine, but which do not exhibit the distinct edges typical of machine processes, such as letters or line drawings;
— Maps, architectural drawings: oversized materials that contain fine details, line drawings, and text, either hand or machine produced;
— Halftones: reproduction of graphic or photographic materials represented by a grid of variably sized, regularly spaced patterns of dots or lines, often placed at an angle. Including some graphic art as well, such as engravings;
— Continuous Tone: items such as photographs, watercolours, and some finely inscribed line art that exhibit smoothly or subtly varying tones;
— Microformats: microfilm, microfiche;
— Mixed: documents containing two or more of the categories listed above, such as illustrated books.

The majority of the digitized items at INIS are text based material containing illustrations, graphics, photos (black and white, colour), as well as oversized materials with fine details, line drawings, etc., falling mainly into the categories of printed text or mixed items.

II.3.5. Quality control (QC)

QC is as an integral part of the digitization process to retain original value, utility and integrity. QC consists of a set of procedures and techniques to verify the quality, accuracy and consistency of digitized objects.

INIS applies a wide range of QC measures to ensure that quality expectations have been met. QC is conducted through a visual inspection of images on-screen, concentrating on resolution, colour, tone, and appearance. It is important to mention that this assessment may be highly changeable according to the viewing environment and monitor characteristics.

(1) Equipment: INIS equipment is calibrated and maintained regularly. Special methods, including scanner test charts, are used for checking resolution, dynamic range, tone and colour reproduction;
(2) Image enhancement: is any process applied to a raw scan to improve quality or legibility of the resource. INIS applies several procedures and techniques to verify the quality, accuracy, consistency and integrity of digital products, such as despecking deskewing, noise reduction, black border removal; adjusting for colour and tone, etc.

II.3.6. Optical character recognition (OCR)

In order for printed text to become fully searchable electronic text (full text), the letters on the original pages must be translated to machine processible ASCII. This is done using an OCR programme.

INIS uses Abby FineReader to apply OCR to text printed in Latin and Cyrillic characters and achieves nearly 98% accuracy. Recent tests have provided satisfactory results using Adobe Acrobat 8.0 for OCR of script languages (mainly Korean and Japanese).

II.3.7. Storage

Digital files must be stored in a reliable, controlled environment. Master files should be stored on high quality, industry standard devices, such as CD-R, DVD, or other contemporary reliable media. Backups of master files must be created and stored off-site in a secure location. Digital files should be refreshed onto new media regularly. Refreshing involves copying files from one storage medium to another to mitigate media obsolescence. After media refreshing, a verification procedure should be applied (such as checksum) to ensure the authenticity and integrity of the files. Another process in the preservation strategy is migration, for example transferring digital information from one hardware and software setting to another or from one computer generation to subsequent generations. Migration can also be format based, involving moving image files from an obsolete file format to a new format. Emulation involves re-creation of the technical environment required to view and use a digital resource. This is achieved by maintaining information about hardware and software requirements so that a system can be reengineered.

II.3.8. Workflow

— Document benchmarking;
— (Pre) Scanning;
— Quality check;
— Image enhancement;
— Metadata validation/creation;
— Export including compression;
— Final quality control;
— Backup;
— Post-production.

II.3.9. Metadata

Metadata plays a key role in describing, processing, managing, tracking, accessing and preserving digital resources.

When integrated with the INIS Database, digital images are accompanied by detailed bibliographic metadata which is carefully reviewed by bibliographic specialists and automatic processing programs. QC at INIS verifies accuracy and completeness of components, data integrity, and correctness of metadata including its form and validity as well as the accurate matching of metadata and image files.

Appendix III

SUMMARY REPORTS OF THE PARTICIPANTS IN THE COORDINATED RESEARCH PROJECT

III.1. ANALYSIS OF METHODS AND TOOLS FOR NUCLEAR KNOWLEDGE PRESERVATION IN BULGARIA

III.1.1. Introduction

The current situation in the Bulgarian nuclear power sector is complicated. Two WWER-440 units are in decommissioning, another two are in shutdown condition. Two WWER-1000 V320 units are in operation and two WWER-1000 V466 units are under construction. Additionally, projects in relation to the national radioactive waste repository and dry spent fuel storage are ongoing. Under the circumstances, a substantive and lasting investment in nuclear knowledge management is needed to collect, preserve and disseminate existing nuclear scientific and technological information. Many national organizations and companies are involved in maintaining comprehensive nuclear infrastructure, but the major player remains Kozloduy NPP (KNPP). Over its more than 30 years of operation, KNPP has accumulated a huge amount of specific data, knowledge and experience. Some of this highly valued information is documented, but there is a lot of specific undocumented knowledge and skills, performance techniques or just useful information only stored in the minds of experienced workers. There is a potential risk of loss for such knowledge due to the retirement of employees and staff turnover. Therefore strong emphasis should be placed on the development of comprehensive systems for identification, elicitation and preservation of available corporative memory.

III.1.2. Objectives

The overall objective of the project is to determine the scale of knowledge management systems (KMS) at KNPP and the feasibility of setting up a new KMS within the plant's current infrastructure.

Specific research objectives focus on:

- Classifying the existing and most important information in relation to plant industrial memory, identifying information sources; establishing a comprehensive 'knowledge data map' of available information;
- Overview and assessment of the current information infrastructure. This overview should cover corporate and administrative, operational and maintenance, and scientific and technological areas, including training and qualification;
- Performing a formal risk analysis of potential knowledge loss for safety critical positions/individuals. Risk assessment can help the plant to assess existing risks and decide what actions need to be taken to minimize disruptions to plant management plans. It would also help the plant to decide whether the strategies it could use to control risk are cost-effective;
- Performing a knowledge acquisition study, based upon applying the Concept Map Approach. The goal of this work is to create a knowledge model of critical knowledge for key expert positions.

III.1.3. Scope

The first step in the successful deployment of a comprehensive and user friendly KMS should focus on knowledge preservation as part of a lengthy process of knowledge management. The general scope of the project emphasizes implementation and performance of knowledge preservation processes, most especially these from the initial phase — identification, selection, capturing, data processing and storage. The remaining knowledge preservation elements are not included in this project.

To reach project goals, an analysis of available methods and tools for institutional memory preservation has been performed as well the selection and experimental application of the most appropriate tools and methods.

The project scope also includes a pilot knowledge acquisition study focused on the personnel responsible for activities associated with ensuring or monitoring of nuclear safety and radiation protection (the classification is in compliance with national nuclear regulations). The study has been performed on two selected individuals in two critical job positions.

III.1.4. Approach

The project is planned to run over two years. On this basis, task performance has been structured over two one year phases. The programme is oriented to initial processes of knowledge management — identification of primary knowledge resources and storing in a suitable form as well as selecting out only the events, processes and persons which are worth being preserved.

The work plan of each phase is developed on the basis of sequential performance of separate tasks (the step-by-step approach). The possibility that respective achievements and results could be ready for independent use has been taken into account.

The tasks include investigation of all existing sources of knowledge related to information, systematization and classification on the basis of used taxonomy.

The following tasks have been performed:

— Development of an information sources inventory (a general knowledge location) for KNPP. The task includes investigation of all existing sources of knowledge related information, systematization and classification on the basis of used taxonomy;
— Analysis and recommendation of the methods and tools required for knowledge preservation suitable for KNPP. Recommendations on the most applicable approach for development of a knowledge preservation system, in particular the methods and tools needed for tacit knowledge elicitation on the basis of worldwide practice and existing plant specifics;
— Identification of key plant positions and an overview of the knowledge base related to them. The available knowledge information has been analyzed and the valuable data has been defined. After separating the protection worthy part of organizational knowledge from the less important information, a suitable form for data storage has been developed;
— A risk analysis regarding the loss of key plant positions and identification of ‘critical’ individuals has been undertaken. Staff members holding at least two key positions have been examined and the potential consequences caused by the loss of those experts have been analysed. The different options for preservation of such tacit knowledge have been considered and their applicability to plant specifics has been evaluated;
— The knowledge mapping process is based on the concept map approach. The WinCmapTools software package has been implemented as a specific tool for corporative memory preservation. Structured and personalized exit interviews will be developed for nominated individuals. The interviews will be conducted and critical knowledge will be elicited through a set of concept maps.

Recommendations have been made for the use of captured information and the further processing of available data. The captured information could be used directly to train ‘successors’, but a more effective method is to transform and document this knowledge.

III.1.5. Main achievements

According to the technical requirements of the project, its performance provided the plant with an alternative conceptual plan for a knowledge preservation system and possible options for the implementation of such a system. A practical application of different methods and tools for these specific activities has also been demonstrated and lot of examples have been provided.

The project output is presented briefly below:

— List of available information sources listed with extended analysis and comments;
— Inventory overview done of current information infrastructure;

— Analysis and assessment carried out of existing IT infrastructure's ability to cover requirements of comprehensive KMS, and corresponding recommendations;
— Applicable tool found for risk analysis of critical workforce and respective tacit knowledge loss;
— Identification of key plant positions and critical individuals made;
— Experimental application of concept mapping approach for nuclear industrial memory preservation completed;
— A set of concept maps for two experts in key positions designed;
— Analysis and recommendations for use of obtained results made;
— Transformation of captured tacit knowledge to suitable explicit forms undertaken.

KNPP maintains and manages a large number of information sources. The scope of information includes all major and auxiliary activities. Nearly each plant department generates knowledge related information. However, there are three main structures which have specific responsibilities meant to coordinate and manage such activities.

The Personnel and Training Centre division prepares, organizes, conducts and records all the activities of TC as well as the training of personnel who work with nuclear installations, in order to guarantee safe, reliable and efficient operation.

The Production directorate of the Operations division has been authorized to classify and store incoming information from the IAEA, WANO and technical and scientific periodicals. The division also obtains presentations, reports and other documents from different types of events — seminars, workshops, conferences, business trips and missions.

The Safety and Quality directorate of the IT department and the Quality division manage electronic services and maintain all national and international standards and regulations that are applicable to the KNPP.

Information is stored in server based databases. This data has also been duplicated onto portable electronic mediums and paper copies.

The Kozloduy NPP intranet portal is a standard information access tool for all plant personnel. The purpose of the portal was to provide access to staff of general and frequently used information necessary for the routine and daily work of the plant.

Portal architecture was designed using a module principle and follows the general structure of the plant. The home page (see Fig. III.1) contains general, publicly accessible and frequently used information and corresponding links. Each major division maintains its own subportal, which services the specific needs of that division's personnel. Hierarchical structure, pull-down and shortcut menus facilitate navigation and provide a user friendly interface.

As a result of project performance, specific technology for risk analysis of knowledge loss has been developed, critical job positions have been identified, and a set of concept maps has been created to fix elicited information.

The developed risk analysis tool, applied concept map methodology and results achieved are described briefly in Section 6.3 and comprehensively in corresponding reports which have been submitted to the IAEA.

III.1.6. Conclusions

The results of activities carried out during project years can be summarized in the following conclusions:

— A huge quantity of specific and knowledge related information has been generated at KNPP during its 33 years of operation. This information has been accumulated and stored;
— Due to historically established circumstances, the information has been distributed over many different databases. Nevertheless the plant uses a well structured system for integration and provides relatively quick search engines and easy access;
— From a knowledge management point of view, available information can be segregated into two groups. One is data sets, drawings, instructions and other documents, which can be interpreted as direct sources of corporate memory. The second group includes information, which has been adequately processed and transformed into formal explicit knowledge forms, including all types of training materials;
— The national nuclear sector and KNPP in particular have no clearly defined strategy for the assessment of risk of nuclear knowledge loss. Thus there are no well defined activities for succession planning and nuclear knowledge retention. The project work could be used as an initial phase for broader activities in this respect;

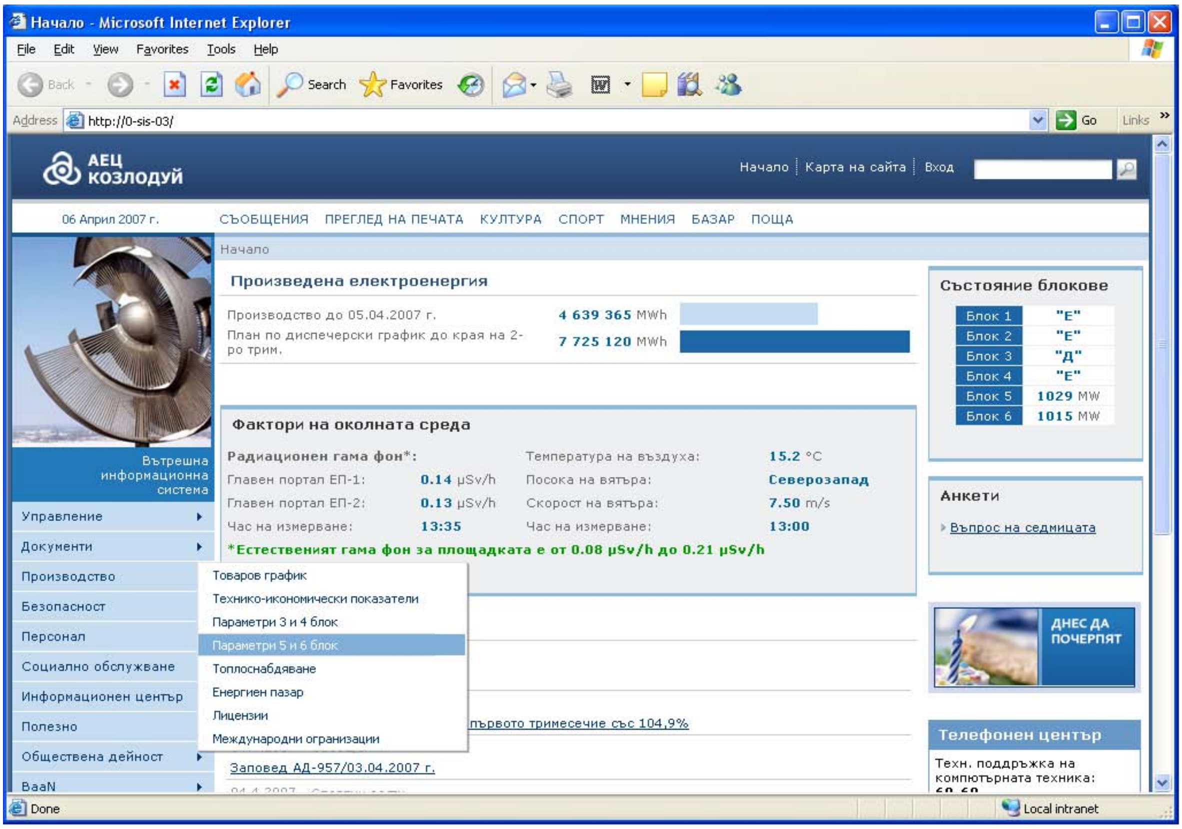

FIG. III.1. KNPP intranet portal home page.

- The risk management strategy for nuclear knowledge loss technology developed by the IAEA is generally applicable to the entire nuclear sector. However, modifications should be implemented to address national and organization specifics;
- Project results acknowledged that knowledge mapping and more precisely the Concept Map methodology is an appropriate and powerful tool for the elicitation of tacit knowledge. Nevertheless the process is resource consuming and expensive. In certain cases the use of alternative approaches (like self-assessment, targeted job assignments, etc.) could be recommended;
- The main objective of research activities is focused on the design of knowledge management systems depending on existing specifics. The areas of training and qualification are obvious beneficiaries of achieved results, though obtained information can also be used in other fields of application. In this specific case, the study has supported plant recruitment policies as well as the maintenance of documentation operations.

III.2. KNOWLEDGE MANAGEMENT IN NUCLEAR POWER PLANT ORGANIZATIONS, CANADA

Atomic Energy of Canada Limited (AECL) has undertaken a research project to investigate knowledge management in NPPs. This project formed part of an IAEA coordinated research project (CRP) entitled Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation. The project is funded by AECL and included the following activities: conducting a literature review, development of an industry survey, peer review and trial of the survey, administration of the survey, and preparation of a summary report. This project was expected to be completed in 2010. The following text highlights some preliminary findings of the research to date.

Knowledge management practices have long been cited as an important factor in achieving overall organizational effectiveness. Many authors in academic literature have studied the links between KM best practices and firm performance, but few empirical studies have been conducted on the subject, and none specifically on the nuclear power industry. Nuclear power plants around the globe have begun to recognize the strategic importance of

KM initiatives in achieving sustained overall operational performance. This includes consideration of the impact of IT and IS and their impact on information flow and storage in an NPP organization. Awareness of the need to manage knowledge and ensure its effectiveness in the NPP organizational context varies from plant to plant. Several NPPs were early adopters of KM theory and practice, and have been proactive in implementing KM initiatives. However, at other NPPs the concepts and benefits of KM are only beginning to be understood and applied. The various approaches taken to KM and the benefits obtained vary from station to station. A better understanding of how KM practices improve operational performance is needed.

NPPs have been performing elements of KM for a long time without explicitly recognizing it as or referring to it as KM. There are many examples of this such as: equipment reliability programmes, systematic approaches to training, configuration management of design basis information, documented operational procedures, plant work management systems, outage planning systems, pre-job briefing practices, document management systems, etc. Despite the long history of specific KM activities, KM has not been managed in any integrated or strategic manner in most NPPs.

Recently, KM has become a 'hot issue' for NPPs for several important reasons. First, the nuclear industry is maturing, and recent high attrition rates have highlighted the vulnerability of NPPs to the loss of critical tacit knowledge — measures aimed at knowledge retention have been needed. There is a concern in the industry over the lessening 'pipeline' or supply of new graduates and adequately skilled NPP knowledge workers available due to a lack of university level programmes specifically targeting nuclear knowledge and skills. There is also recognition that it takes many years of on-the-job training to build the competencies and expertise needed for many NPP positions.

Second, the aging fleet of nuclear plants will require either refurbishment or decommissioning and at the same time new projects are being planned and launched, creating a high demand for specialized nuclear skills. Third, there is recognition that licensing basis information, design basis information, and plant configuration information are critical to the continued safe and economic operation of NPPs (i.e. must be kept up to date, accurate and correct). Fourth, there is strong pressure to achieve the next level of productivity gains in NPPs, and this is driven by factors such as deregulation and competition, rising operating costs, a move towards 'lean' operations and maintenance (reduced staffing levels), and opportunities arising from new technology. Finally, there is a keen awareness that other industries are doing more in the area of KM and benefiting from these initiatives and best practices.

NPPs provide a particularly challenging environment from a KM perspective. Some of the issues faced by the nuclear industry include: a complex technology base and infrastructure (both from a design basis perspective and from an operations and management perspective); lengthy technology and plant life cycles; regulatory requirements that change over time; highly capital intensive plant assets (and thus the need for risk informed asset management decision processes); a reliance on multidisciplinary technologies and expertise; competing operational objectives of safety, economics, and production; potentially high hazards that must be systematically managed to demonstrably low tolerable risks; and finally, the ongoing need for coordination of complex physical and human systems. Furthermore, stringent requirements for safety, environmental qualification, nuclear quality assurance, nuclear security and non-proliferation safeguards, as well as equipment/design configuration management must be met, all in the context of a regulated industry environment.

For these reasons, the role of KM is particularly important in the nuclear industry. It is gradually becoming recognized that knowledge management practices, if effectively applied at nuclear power plants, enable operational and safety performance improvements, including reductions in operational and personnel safety risk, and opportunities for plant design improvements. Clearly, introducing and maintaining effective knowledge management processes (such as a KM system) in a nuclear plant is difficult and challenging. Many utilities are making progress towards the implementation of different knowledge management processes and support systems, but in general, progress lags behind many other industries and a higher than expected implementation effort is being experienced. Further, feedback from several nuclear utilities indicates they are not always able to determine the effectiveness of KM processes, and in some cases are not able to clearly identify key areas in need of improvement. As a result, knowledge management initiatives may not always provide all of the expected benefits. This underscores the need for improved KM strategies, implementation, measurement, and alignment of knowledge processes in NPPs.

Preliminary findings from a literature review and from NPP site visits support the notion of a direct link between KM and organizational performance. The remaining tasks in this programme will focus on the implementation of a NPP KM survey and compilation of survey results. It is hoped the nature and strength of this relationship will be established with empirical evidence. Furthermore, it is desirable to identify some of the contingency factors that may influence this relationship and to quantify their effect. KM is seen as an important strategic issue for NPPs; however, it is difficult and challenging. It is recognized in literature as an important driver of sustained organizational performance. Information management tools and infrastructure are seen as important contributors in leveraging knowledge processes and achieving better knowledge creation, retention, and utilization. An integrated approach to KM is needed and KM thinking and principles must become an embedded part of the organizational culture. Finally, a better understanding of the link between KM practices and organization performance is required.

Qualitative research findings to date indicate the successful and efficient operation of any NPP is dependent on effective knowledge and KM processes. KM processes are believed to help build and maintain the corporate knowledge base and promote organizational learning. This enhances knowledge utilization, enables organizational effectiveness, and promotes better decision making. In an NPP operational context, this facilitates proactive problem resolution and avoidance. By better enabling utilization of industry, organizational, departmental, and individual knowledge, NPPs with effective KM programmes achieve better decision making and higher work process efficiency by establishing and leveraging a knowledge enabled workforce in a stronger knowledge sharing culture.

III.3. KNOWLEDGE PRESERVATION MANAGEMENT AT EC-JRC (PETTEN), EC

III.3.1. Introduction

Extensive material programmes are often necessary for new international energy related facilities, such as fusion or GEN IV reactor systems, to qualify new or modified materials. This is associated with high costs which one partner is rarely willing to invest in. The exchange of experimental data between partners is probably the easiest way to reduce costs.

Due to traceability, experimental test results are combined with complex metadata such as source information, chemical analysis, heat treatment, specimen dimensions or coating layers, test environment and service exposure, and in-pile or out-of-pile irradiation. Due to the fact that partner organizations have heterogeneous databases, data exchange via EXCEL or SQL files is complicated and very time consuming. Internationally agreed upon exchange platforms and formats have to be established to ease the mapping of database structures.

III.3.2. Objective

EC-JRC Petten's objective within the IAEA CRP Comparative Analysis of Methods and Tools for Nuclear Knowledge Management was the definition of such an internationally agreed upon exchange of formats, including units and determination of mandatory metadata for the experimental mechanical properties surveillance data of WWERs and Reactor Pressure Vessels (RPVs) to harmonize nuclear safety data management and dissemination practices. Exchange formats have been established within the EC-JRC Petten materials database Mat-DB, which is an integrated part of the ODIN portal.

III.3.3. ODIN portal

Explicit Knowledge Preservation at the EC-Joint Research Centre, Petten (Section 6.2)

III.3.4. EC-JRC Petten Mat-DB

One of the engineering databases within ODIN is Mat-DB. Mat-DB safeguards and manages experimental materials data resulting from European research projects undertaken over the last 20 years. Because of its intelligent user guidance and accessibility via Internet, Mat-DB also hosts the IAEA RPV materials database, a confidential tensile and impact surveillance data pool of WWERs and RPVs with irradiated and non-irradiated specimens from IAEA associated Member States.

The emphasis of Mat-DB is on data from experimental tests which comply with existing or pre-normative standards and which are delivered by laboratories in defined formats and qualities. The data can be entered, stored and accessed using typical database routines and can be evaluated with integrated analysis tools.

Mat-DB covers mechanical and thermo-physical properties data of engineering alloys at low, elevated and high temperatures for base materials and joints. It includes irradiation materials testing in the fields of fusion and fission, tests on thermal barrier coatings for gas turbines and mechanical properties testing on corroded specimens. Corrosion refers to weight gain/loss data from high temperature exposed engineering alloys, ceramics and hot isostatic pressed powder materials and covers corrosion tests such as oxidation, sulfidation and nitridation.

In order to conserve as much information as possible, the database contains detailed meta-information and the entry of information into many fields is mandatory to increase data quality. Thesauri are provided for many text and image fields facilitating and improving data entry and retrieval. All entities contain additional fields (customer internals), which can be used for company specific purposes. In addition to numerical and alphanumerical data, all types of binary files can be stored within the database, for example the final reports of research and development activities, drawings, or large amounts of raw data (unfiltered curve data, the basic output of strain gauge measurements).

In total, the database structure for base materials contains more than 130 tables and 1850 fields, which are grouped into logical entities: data source, material, specimen, test conditions and test results. The entities are linked within a relation table. For tests on dissimilar joints, such as weldments, a joining and also a second material entity are added. The entity ‘test result’ is divided into different areas, which contain tables for storing test type specific mechanical (23), thermophysical (10) properties and corrosion data.

Mat-DB provides the full cycle of data entry, retrieval and analysis over the Internet. JAVA programmed user interfaces and evaluation routines are further developed and improved. On-line help provides assistance in using applications. Manuals which describe databases and analysis tools including, for example, descriptions of image and text thesauri, curve file structures, and definitions of the test types are available for Mat-DB users from the ODIN portal.

Procedures such as the selection of pre-defined thesauri and images for specimen and welding techniques and positions as well as the control of mandatory fields and constraints have been established to assist Mat-DB users during data entry. Test data available in EXCEL and correctly formatted in the requested Mat-DB formats can be directly uploaded or copied and pasted into the data entry interface. Another data entry feature is the XML interface, which allows users to convert their data into XML. Once correctly formatted in XML, uploading into Mat-DB is fast and easy because the data are correctly identified and transferred to Mat-DB. The same is valid for machine post processing tools, which are extended to export into the defined XML format. This technology supports direct web enabled data entry from a machine into Mat-DB.

III.3.5. Conclusion

The XML related data entry procedure could prove to be useful for future data exchange with GIF (Generation IV International Forum) partners or with IAEA associated Member States for uploading reactor pressure vessel materials surveillance data. Utilization of XML techniques is seen as a necessary step towards more powerful methods of incorporating semantics into data exchange used by heterogeneous databases.

III.4. NUCLEAR KNOWLEDGE MANAGEMENT IN THE WATER SECTOR, JORDAN

III.4.1. Introduction

The Water Authority of Jordan (WAJ) is the only institution in the nation with accumulated knowledge in isotope hydrology measurement techniques and applications in water resources management; it has been involved for more than 25 years and is regionally recognized as one of the centers of excellence in that field.

At the same time, the water sector is especially confronted by the impact of aging staff in the field of isotope hydrology, with personnel leaving for better opportunities, a lack of effective mechanisms for knowledge preservation and information sharing between staff working in the same field at different locations. It was found that at these dispersed locations, research and studies were often repeated, and scientists and experts were occasionally not updated on work carried out on common topics.

Knowledge threats, including the loss of tacit knowledge, are present as little effort has been made to capture or manage knowledge at an organizational level. Knowledge management can put in place a structured mechanism for capturing, preserving and transferring such knowledge within the organization.

III.4.2. Study objectives

The objective of this applied study is to build an appropriate, up to date model for nuclear knowledge capture, preservation, interpretation, analysis and visualization in the field of isotope hydrology. This can, in turn, be added to existing nuclear knowledge assets and create links and communication channels between people and nuclear knowledge sources. The project also aims to create a register of existing explicit knowledge in isotope hydrology using appropriate technology which optimizes knowledge preservation and sharing.

III.4.3. Approach taken (methods and tools used)

To achieve the study's objectives, the following approach was taken:

- Develop and implement a KM strategy in the field of isotope hydrology, including vision, mission and strategic objectives;
- Define the most appropriate methods and tools for knowledge preservation and sharing;
- Develop knowledge risk management plans for knowledge management strategic objectives;
- Develop a conceptual knowledge management model based on the main isotope hydrology knowledge processes.

The goals of the strategic plan are to:

- Create and preserve a knowledge repository;
- Improve knowledge assets;
- Enhance the knowledge environment and build trust for knowledge sharing in that regard;
- Manage knowledge as an asset.

The approach followed in the development of the Isotope Hydrology Knowledge Management Strategic Plan is as follows:

- SWOT analysis;
- Identification of challenges and risks;
- Formulation of vision and mission statements;
- Defining drivers and strategic levers based on the institute's vision and mission;
- Defining strategic KM objectives and goals;
- Defining the KPIs of strategic KM objectives;
- Uncovering knowledge risks (assessment and management);
- Creating an action plan for implementation;
- Assessing, monitoring and evaluating effectiveness of the plan's implementation.

An example of the SWOT analysis is shown in Table III.1.

III.4.4. Knowledge management strategic objectives

(1) Improve the knowledge reservoir in the field of isotope hydrology, through:
  (a) Identification of knowledge sources and creating a knowledge inventory;
  (b) Improving knowledge content through capturing, organizing and sharing knowledge in the field of isotope hydrology;
  (c) Provision of a supportive learning environment.

(2) Increase the value of processes (process performance) in isotope hydrology through:
   (a) Identifying knowledge sensitive processes;
   (b) Mapping of processes and addressing knowledge gaps;
   (c) Increasing the value of processes by filling required knowledge gaps.

(3) Increase the efficiency of knowledge preservation and communication systems in isotope hydrology, through:
   (a) Establishing a communication system and policies to share, retrieve and search for required knowledge;
   (b) Defining the appropriate tools and technologies to support effective knowledge exchange and sharing.

(4) Achieve stakeholder satisfaction in isotope hydrology services by:
   (a) Providing required credible and accurate information and quality service on time;
   (b) Running the required knowledge process in a proficient, efficient manner.

The knowledge risk management plan determines risk significance through measuring frequency of occurrence and risk impact. Table III.2 offers an example of a risk analysis assessment.

A conceptual knowledge management model was developed based on a conceptual knowledge map, for which existing knowledge sources, types, knowledge locations, processes and paths were determined. The model contains these main knowledge elements: people, technology and content and deals with both explicit and tacit knowledge sources. The main process contains a series of functional sub-processes. Each sub-process consists of several layers of interdisciplinary knowledge assets and resources. Knowledge preservation and sharing takes place within each sub-process.

TABLE III.1. SWOT ANALYSIS

	Opportunities	Threats
Strength	S – Long serving and front line staff in isotope hydrology in Jordan have a depth of knowledge that is relied upon by other staff O – There is an international interest in isotope hydrology capacity building that is mainly lead by the IAEA Combining S and O will lead to continuous capacity building and knowledge transfer in the field of isotope hydrology in Jordan's water sector	S – There are knowledgeable experts in the field of isotope hydrology in Jordan's water sector T – Jordan's water sector is currently not providing an attractive working environment especially in comparison to that provided by Gulf countries, which drives such experts to leave S – There is a national Isotope Hydrology Laboratory that is recognized as a regional analytical and training centre T – There is a lack of funds and financing received by the lab to continuously update and upgrade analytical facilities
Weakness	W – Isotope experts are often very dispersed geographically, with limited communication channels among them; there are also few mechanisms for sharing information between staff working in the same business area W – Databases are not compatible, which inhibits ease of data sharing W – Databases are not commonly accessible by a wide range of data users O – Many projects exist now in Jordan that are funded by donor parties which aim to develop credible, easy to access databases through a well designed portal that will link people to each other and to information	W – The public sector is particularly confronted by the impact of an aging workforce W – There are barriers between head office, directors and researchers and working staff in this field T – In general there is little effort made to capture, preserve or manage knowledge at an organizational level

Notes:
S – strengths
T – threats
O – opportunities
W – weakness

TABLE III.2. EXAMPLE OF THE RISK ANALYSIS

Risk	Indicator of risk occurrence	Reasons	Impact 1–10	Freq. 0.1–0.9	Weight 0.1–9	Actions to mitigate the influence
	loss of tacit knowledge					
Retirement and immigration of experts and key persons	— the high turn over factor — improper decision making in water resources management — decrease in the number of studies and reports delivered	— low income of government employees compared to those in the private sector and in neighbouring countries — low motivation and self esteem and lack of appreciation	9	0.9	8.1	— adoption of initiatives to improve the work place environment — successive planning — HR programmes — attracting experts leaving or who have already left the organization — motivation schemes — training programmes, meetings — storytelling — informal meetings
	loss of explicit knowledge					
Loss of documents (hard copies)	— poor referencing system — duplication of work — low quality output — decrease in the number of new documents relative to a good year bench mark	— poor archiving and improper asset mapping — theft — fire — intentional damage	9	0.7	6.3	— adopt a plan for the protection and security of institution information systems — document control and proper archiving system (library) — capture and preservation of all available documents (scanning of old yellow paper documents, etc.)
Loss of data and electronic documents		— hackers — viruses and worms — disasters — poor document control and ineffective backup	8	0.7	5.6	— document control system and backup policies — proper maintenance, antivirus software and system updates. — security of important software, data basis and information systems against problems that could arise
Lack of interest in using isotope hydrology in water resources studies	— poor infrastructure — old technology tools and methods	— overall change government and donor agencies' priorities — change in organization priorities	6	0.8	4.8	Provide socio-economic feasibility studies to prove the high return vs. the investment in the field. An example is an isotope investigation into dam safety, leaks and seepage that can save millions of dollars compared to measures taken based on physical evidence only

Achievements:

— Development and execution of a knowledge management strategy;
— Development of a register of existing isotope hydrology assets;
— Completion of a mind map and a conceptual knowledge map;
— Development of a risk management plan;
— Development of a conceptual model for KM processes;
— Development of an action plan for isotope hydrology KM strategy;
— The implementation of knowledge preservation actions is in progress.

Some methods and tools used:

- Successive planning;
- On-the-job training;
- Expert and senior staff interviews;
- Formulation of focus groups and team work;
- Success stories;
- Electronic archiving and development of a KM database;
- Identification and filling of some knowledge gaps;
- WAJ portal development (still in process).

III.5. KNOWLEDGE PRESERVATION ACTIVITIES AT THE PAKISTAN NUCLEAR REGULATORY AUTHORITY, PAKISTAN

III.5.1. Background

The Pakistan Nuclear Regulatory Authority (PNRA) participated in subject coordinated research to explore methods and associated techniques of knowledge preservation to address the expected future loss of knowledge due to departing knowledge experts. The development of a fully functional knowledge management portal is seen as an important element in addressing the difficulties associated with knowledge loss. The portal would provide a method for preserving and categorizing knowledge obtained within the organization either in documented form or through interviews, discussions and classroom learning. The knowledge portal would gather all knowledge resources on a single platform and link them together.

III.5.2. Objectives

- Developing a PNRA Nuclear Safety Knowledge Management portal which would be the key knowledge repository;
- Disseminating knowledge within the organization;
- Sharing KM experiences with other Member States and learning from them.

II.5.3. Scope

The following are the major outcomes wished by PNRA through participation in the subject CRP:

- Identification of internal resources possessing knowledge;
- Collection of explicit knowledge from those resources at a central point;
- Extraction of tacit knowledge (for example through socialization and mentoring);
- Implementation of appropriate and easy to use methods of knowledge classification;
- Definition of mechanisms for the distribution of knowledge;
- Increased collaboration between workers;
- Effective search/navigation through available knowledge material;
- Continuous addition of valuable information and timely updating of stored knowledge.

III.5.4. Activities of the first year

Prior to participation in the CRP, PNRA made knowledge management incentives part of its corporate policy and developed a fully functional web site, an independent email system and an intranet site to be used within PNRA offices. After taking part in the CRP, new activities commenced in order to accomplish its objectives, briefly described as:

— Initiation of a process to identify knowledge experts and resources;
— The holding of interview sessions by the KM team with some senior PNRA experts in order to get their opinions on the implementation of knowledge management activities;
— Steps were taken to increase socialization between employees through formal and informal interactions;
— Strategies were put in place to capture tacit knowledge as it is being generated and convert it into explicit knowledge;
— Explicit knowledge was then organized among thematic knowledge areas or domains. A project based approach was used in identifying knowledge domains. Each project generating knowledge capital is represented as an individual domain;
— A PNRA nuclear safety knowledge portal was developed to be the primary repository of stored and disseminated knowledge, meant to replace the current intranet site upon completion. The identified knowledge domains were incorporated in the portal (Fig. III.2);
— The hardware and software needed to facilitate knowledge management activities were procured.

In addition to the aforementioned activities, the PNRA instigated programmes to improve organizational performance and human resource capabilities. Though not directly related to knowledge management, these programmes help to create good managerial examples. They include:

— Self-assessment exercises in order to check the effectiveness of processes and overcome performance gaps;
— Initiation of a leadership development programme to form a young workforce team with full leadership talents and decision making skills to replace current leaders in the future.

III.5.5. Results achieved

(1) A prototype version of the knowledge portal has been finalized and is currently being used by selected personnel for evaluation and feedback. It provides personal login IDs to users, allowing them to have their own personalized interfaces. In addition, there is a general access area in the portal which can be used by anyone. A mechanism to search portal contents is currently under development. To gain the best outcome, PNRA chose Microsoft® SharePoint Portal Server 2007 to be the development platform for the final version of portal.
(2) PNRA has developed two separate forms for knowledge resource identification:
— The specialization form**:** To be filled out by all PNRA senior personnel. It contains information about the experiences of senior resource people and the specialization areas in which he/she could mentor;
— Training Needs Assessment (TNA) form**:** to be filled out by juniors, providing their received and planned training details and the areas in which they are expected to be a knowledge resource in the future.
(3) Valuable suggestions were drawn from interviews conducted with senior personnel. Some propositions were chosen for immediate implementation, such as:
— Affiliating junior engineers/scientists with senior experts for two to three year periods as part of a succession management plan;
— Compilation of technical text by experts in the form of working materials, manuals, etc.;
— The rehiring of retiring personnel as consultants under special packages and incentives;
— The invitation of university professors, regulatory affairs experts and intellectuals with proven experience in the nuclear industry and supporting organizations to deliver guest lectures and hold seminars/workshops;
— The education financing of young PNRA engineers or scientists studying nuclear subjects at masters or doctoral levels.
(4) The conversion of tacit knowledge into explicit knowledge is being achieved through the recording of interviews/seminars/lectures on DVD media, the maintaining of minutes of formal interactions and the distribution of classroom lectures among course participants. Recorded DVDs are being preserved in the PNRA library for future reference.
(5) A survey has been conducted by the KM team to obtain employee feedback regarding the PNRA web site and gather their proposals regarding functional changes in order to improve user friendliness and content quality. The results of the survey are currently being analysed.

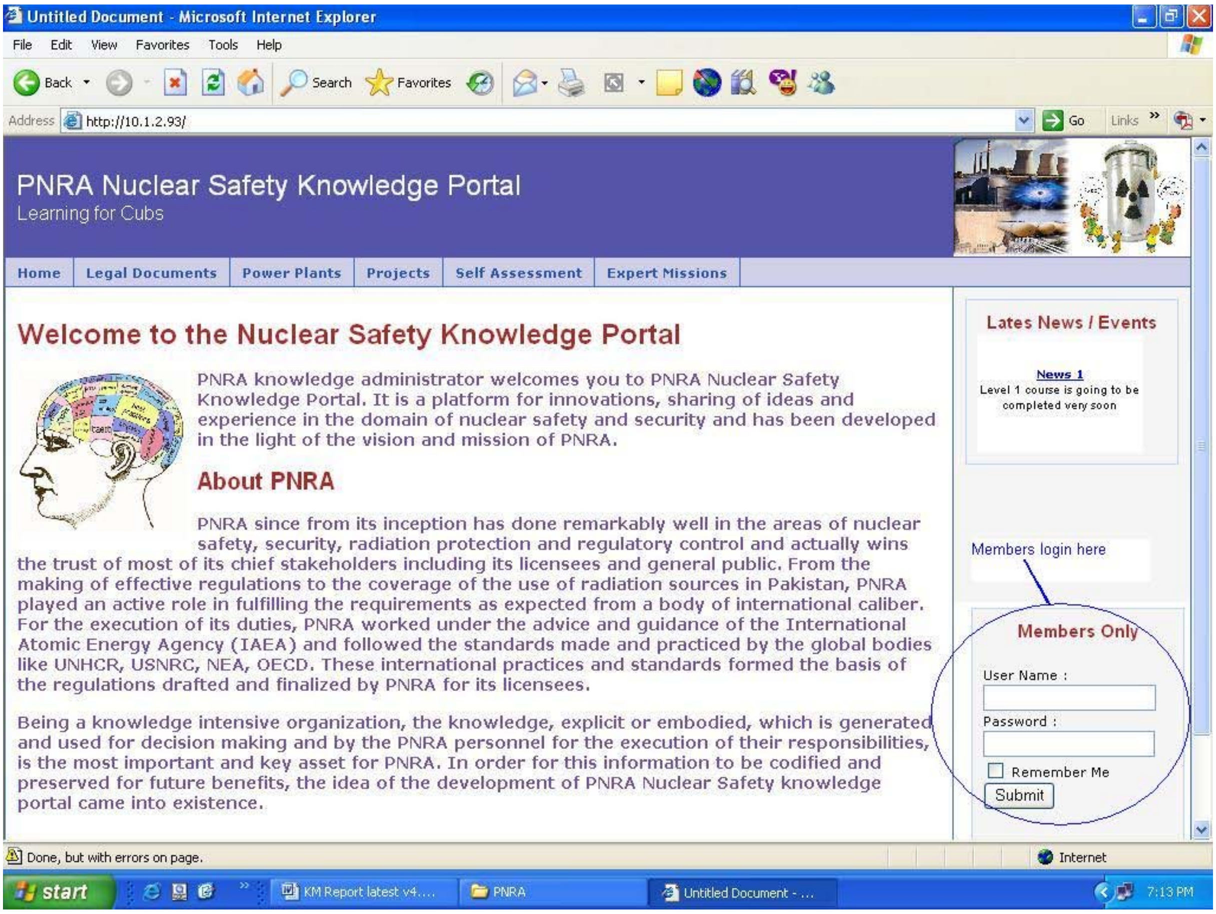

FIG. III.2. Portal home page — Members can login with an assigned user name and password.

III.5.6. Conclusion

With the help of experience gathered and achievements made, the PNRA has reached the following conclusions:

- Documented policies and procedures for KM should be formulated to include the proper allocation of funds and human resources;
- Research into more advanced methods of knowledge preservation (especially tacit knowledge) should be continued;
- Mutual coordination programmes of a similar kind should be continuously organized through the IAEA platform to help induce a positive KM culture in organizations of all Member States;
- Government and decision making authorities should be supervised in order to provide long term sustainability and expansion of KM programmes in strategic and knowledge intensive organizations;
- Priorities should be set regarding the criticality of knowledge to be preserved. Knowledge from experts nearing retirement and who are not willing to work as consultants should be extracted on a priority basis and preserved during their regular service.

III.6. USE OF OPEN SOURCE WEB DEVELOPMENT TOOLS IN IMPROVING THE NUCLEAR KNOWLEDGE PORTAL FOR THE PHILLIPINE NUCLEAR RESEARCH INSTITUTE, PHILIPPINES

III.6.1. Introduction

All organizations store, access and deliver knowledge in some manner or another. The Philippine Nuclear Research Institute (PNRI) is no different. As a nuclear research institute, it undertakes continuous research in the nuclear field, focusing on the safe and peaceful uses of nuclear techniques, materials, and processes to contribute to the Philippine government's efforts to increase agricultural and industrial productivity. As a nuclear regulatory body, it enforces regulations to ensure that the use of radioactive materials is carried out at maximum safety and security levels. It had successfully operated a research reactor, and was involved in regulating activities during construction of the first nuclear power plant in the country. These activities have produced abundant reusable nuclear knowledge that will aid in ensuring safety and usefulness of present and future activities.

The importance of preserving this knowledge has been recognized by the PNRI. It has joined the bandwagon of knowledge management enthusiasts aspiring to preserve and increase its nuclear knowledge capital. However, knowledge management is a complex undertaking. It involves the identification and capture of knowledge, the filtering and organization of this knowledge into domains, and the maintenance of a facility for sharing and using this knowledge. Therefore, thorough and careful preparation must be undertaken to identify the correct and reusable knowledge to be preserved and adapt the best possible methods to capture it; studies must be made on the best way to organize this knowledge into domains, and to implement the best, most cost effective, web based tool for storing and sharing this knowledge.

The PNRI participated in the IAEA's Coordinated Research Project Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation to improve its current nuclear knowledge portal through the use of open source web development tools.

III.6.2. Scope of the project

The project aims to develop a comprehensive, cost effective database repository and retrieval web site system of nuclear knowledge that will be shared with other organizations — commercial or research — working in the nuclear field.

It covers the following activities:

(1) Development of a practical methodology for the live capture of useful nuclear knowledge emanating from research projects and day-to-day operation at the institute;
(2) Development of a taxonomy for storing knowledge;
(3) Redesigning of the existing knowledge database system based on the storage, retrieval and access requirements of the taxonomy developed;
(4) Development of an external web portal that will allow for the sharing of these knowledge resources;
(5) Development of a reliable method or mechanism, supported by ICT tools, to capture and gather knowledge identified as reusable and relevant.

III.6.3. Results and discussion

KM is not about IT tools (such as portals) alone. As the word 'portal' suggests, it's a tool to support KM in an organization. KM encompasses a lot more than portals. The design and development of a knowledge portal needs to address which contents will be made available and how. Thus, this project included close coordination with the institute's KM technical team, which is also the committee handling implementation of the institute's Integrated Management System (IMS). The whole process went through the knowledge cycle of find/create, organize, share and use/reuse in the designing and implementation of the knowledge portal.

It was determined at the institute that knowledge is created and/or can be found in the following:

— Nuclear research activities;
— Regulatory and licensing activities;

— Conduct of nuclear services;
— Trainings/workshops/OJTs;
— Expert missions;
— Publications: PNJ, Nucleus, papers presented at national and international symposia;
— Project implementation.

And they can be organized in the following knowledge domains:

— Nuclear research;
— Nuclear services and facilities;
— Nuclear standards and regulations;
— Planning and internal audit;
— Finance and administration;
— IMS documents;
— International links and training;
— Integrated Management System documents.

The sharing of knowledge in PNRI happens through the following channels:

— Research technical reports/papers;
— Training/workshop/OJT reports and echo seminars;
— Expert mission reports;
— Project documents;
— Regulatory conferences;
— Peer reviews;
— Atomic research lecture series;
— IMS documents.

Implementation of IMS at the institute correlates with KM implementation. IMS documents are of prime importance because they outline how work is done, assessed and managed at the institute. This requires the documenting of unwritten procedures (such as those undertaken in laboratories, regulatory work, etc.) which allow, in a way, the capture of implicit and tacit knowledge. This provides records management, assessment of work performance and the monitoring and evaluation of projects/research.

To use and reuse knowledge at the institute and facilitate its sharing, access to documents and experts should be made available. This can be facilitated through the development of a knowledge portal which would contain a knowledge base, as well as access to experts and facilities for on-line collaboration and discussion.

Finally, the following taxonomy was developed to serve as a basis for design of the knowledge database, method of input and access to data/knowledge:

(1) Technical areas:
    — Nuclear fundamentals:
        • Nuclear physics;
        • Nuclear terminology;
    — Radioactive waste management;
    — Decommissioning;
    — Radiation applications:
        • Nuclear medicine;
        • Radiation therapy;
        • Industrial applications;
        • Food and agriculture;
        • Water resources.

(2) Activity areas:
- — IMS documents;
- — Nuclear regulations, licensing and safeguards:
  - RADPLAN;
  - PNPP-1 documents;
  - Standards and regulations;
  - Licensing;
  - Inspection;
  - Safeguards;
  - Radiation impact assessments;
  - RSSB;
  - Physical protection and security;
  - Transport of radioactive materials;
- — Research and development:
  - Physics;
  - Chemistry;
  - Biomedical;
  - Health physics;
  - Analytical measurements;
  - Isotope techniques;
  - Nuclear materials;
  - Agriculture;
- — Nuclear services:
  - Radiation waste management;
  - Irradiation services;
  - Radiation protection;
  - Public information;
  - Emergency preparedness;
  - Nuclear training;
- — Planning and internal audit:
  - Project profiles;
  - Project status monitoring;
  - Performance indicators;
  - Five-year plan;
  - Human resource development;
  - Internal audit;
- — General support:
  - Finance and administration;
  - Human resource;
  - Budget and accounting;
  - Procurement;
- — International collaborations and linkages:
  - Mission reports;
  - Training/workshop resource materials;
  - Travel reports;
  - Projects and fellows.

(3) Facility areas:
- — Radiation related facilities:
  - Irradiation facilities;
  - Radiation related laboratories;
- — Waste management facilities;
- — Nuclear training facilities;
- — Computer and network facilities;
- — Electronics and engineering facilities.

The knowledge portal is being developed using Open Source web tools, including MySQL for its database server and Apache for its web server. It is being developed internally and will be implemented in its entirety using the programming language PHP.

A study looking into good practices for video storage formats was undertaken. The study provided insights into the disadvantages and advantages of different video storage formats. File size was also taken into consideration. The study resulted in the adaptation of the '.avi' format from its raw 'vob' format to the storage format of video files in the knowledge repository. This decreases file size, making the format ideal for storage; it also allows for easy conversion to different formats for different purposes in the future.

All technical lectures and research status presentations are being captured on video. All video files have been stored in the KM portal server in a temporary folder waiting for final uploading to exact categories, based on taxonomy. No audio capture has been undertaken yet so far. The aim of this research project was to improve the existing knowledge base system of the institute, which is part and parcel of the PNRI intranet. The following has been completed in this area:

The knowledge base component of the local intranet has been duplicated to the KM portal server database to form the institute's knowledge portal PNRI Web Centre for Nuclear Knowledge Resources, which can be accessed at the following URL http://www.pnri.dost.gov.ph/km (Fig. III.3).

The knowledge resources database was designed and implemented on the basis of newly defined taxonomy.

The following components and features have been identified, partially implemented and are still developing:

(1) Knowledge base:

The knowledge base covers technical and activity areas and provides information on locally available nuclear related facilities and services. Here, the fundamentals of nuclear science are explained, and issues such as

FIG. III.3. Home page of the PNRI Web Centre for Nuclear Knowledge Resources.

radioactive waste management are tackled. The different functions of the Philippine Nuclear Research Institute (PNRI), are also described;

(2) Experts database:
This database features the local ‘Who’s Who’ in nuclear science and technology. Names, area(s) of expertise and relevant publications by scientists, trainers/academics, and specialists in the nuclear field can be found in this database;

(3) Local publication on-line review and evaluation:
On-line review of papers for publication is now facilitated by this electronic platform. Submissions to the local nuclear journal can be made via this link;

(4) e-Workspace:
This allows project collaborators and research investigators to have on-line discussions in order to exchange information, experiences and insights on project issues;

(5) Links to other nuclear knowledge portals and resources:
The links on this page lead to sites of various organizations which are authorities in the nuclear realm;

(6) FAQs.

III.6.4. Conclusion

PNRI has initiated and partially developed a knowledge portal using the most cost effective implementation.

III.7. SYSTEMATIC APPROACH FOR NUCLEAR KNOWLEDGE TRANSFER AND PRESERVATION IN ROMANIA

III.7.1. Scope

Starting with a thorough analysis of nuclear knowledge management (NKM) in other countries and based on a realistic study of the status of NKM processes and their efficiency in Romania, the purpose of this project was to improve knowledge transfer and preservation processes in Romanian nuclear (and support) organizations, especially at the INR.

III.7.2. Objectives

The general aim was to extract positive and negative ideas based on experience, and to formulate appropriate recommendations to be integrated into INR strategies and IAEA guidelines.

The project intended:

— To investigate the positive and negative aspects of nuclear knowledge transfer and preservation in our country, mainly at our institute, the Institute for Nuclear Research, Pitesti, Romania, over the last 15 years;
— To underline the tools and methods used to reach this goal, and to analyse the efficiency of these methods;
— To achieve a general comparison with the situation in other Eastern European countries.

The project was based on historical Romanian elements, desk research on NKM evolution in Eastern European countries and investigations into the INR research community.

Since explicit knowledge transfer and preservation in INR was implemented early through the practice of ISO 9001, the intention was to focus on the more delicate aspects of tacit knowledge transfer. The main research was based on interviews and questionnaires.

III.7.3. Approaches

The main activities in the first year work plan were:

— To apply the IAEA questionnaire to the current status of knowledge preservation in nuclear and supporting organizations at some Romanian nuclear institutions, and to analyse the obtained results;
— To develop a questionnaire focused on the status of knowledge transfer and preservation in INR (especially tacit knowledge), to apply it to INR experts and to analyse the obtained results.

(1) The IAEA questionnaire:
We applied the IAEA questionnaire to six nuclear and supporting organizations chosen from all fields of the nuclear domain, including energy production (Nuclear Power Plant Cernavoda), education (Polytechnic University of Bucharest — Energetic Faculty), governmental (Authority for Nuclear Activities Control Bucharest), fuel production (Nuclear Fuel Factory Pitesti), research (Institute for Nuclear Research Pitesti), and radioactive waste management (Radioactive Waste Agency Pitesti).
The persons questioned in each of these organizations were managers from Quality Management and Human Resources departments.

(2) The INR questionnaire:
In January 2007, a questionnaire based investigation on the actual status of INR knowledge transfer and preservation was started [18, 19].
The first step was questionnaire construction. It consists of two parts; there are 15 questions about specific knowledge management aspects of INR and five demographic questions.
The questionnaire was primarily directed at INR experts expected to retire in the next 5–10 years; 87 people were interviewed. They include physicists, engineers, researchers and technical staff from all INR departments. They each have over 20 years of expertise (with a maximum of 35 years of working experience). Those questioned were very interested because they consider the process of knowledge transfer and preservation to be very important both for the INR and for themselves. However, there is a divergence between organizational interests (effective and efficient transfer of knowledge to newcomers or existing personnel) and the interests of experienced people (who do not want to transfer the most important areas of their knowledge so they can continue their activities as consultants after retiring). The idea 'ballast is discharged' is very present in the mind of short term retiring experts. In this context, a main investigation objective was to answer the question, 'What is the motivation for an expert to transfer his/her expertise before retirement?' It should be noted that the majority see the face to face questionnaire as an opportunity to discuss their point of view concerning this problem, thus they participated with great interest.

(3) The INR method for knowledge loss risk assessment:
In order to obtain a more complete characterization of the actual state of risk assessment, the second year task was to analyse actual risk factors related to human resources in INR through desk research and questionnaire investigation. The following steps were taken to obtain the information required for this analysis:
— Desk research on methods used in relation to knowledge loss risk assessment;
— Development of an appropriate INR method to evaluate total risk factor;
— Application of a method and collection of the results in e-format.
According to specific literature [20], the total risk factor, F_{tot}, may be calculated as:

$$F_{tot} = A \times P$$

Where: A is the attrition risk factor;
P is the position risk factor.

Based on this classical method for assessing organizational knowledge loss risk, we developed an appropriate method that considers both INR specific conditions and the Romanian nuclear market [21], where the P factor is obtained through the multiplication of five parameters:

$$P = (P1 \times P2 \times P3 \times P4 \times P5)$$

Where: P1 is the importance/complexity of the knowledge/skills;
P2 is the availability on the market and inside the organization of appropriate receivers for knowledge transfer;
P3 is the attractiveness of proposed jobs for identified receivers (salary level, personal satisfaction, opportunities, future development etc.);
P4 is the risk of not achieving knowledge transfer;
P5 is the efficiency of tools and methods used for knowledge transfer.

The investigation was performed with the aid of some INR department heads. They received a questionnaire, a list of instructions regarding the description of each factor/parameter, and an explanation of the scale (from 1 to 5). Based on these, the department heads filled out the cells of an Excel file with factor/parameter values for each job position.

The values were automatically scaled by the application in order to keep total risk factors in the range of 1 to 25 (as is done in the classical method). The data are transformed into graphs using a common MS Excel tool.

Thus, for each position/individual in the organization, a value of between 1 and 25 was obtained, indicating total risk factor for that position/individual. The Ftot values allow us to arrange personnel/job positions into four classes of importance:

Ftotal = 20–25, critical risk of knowledge loss;
Ftotal = 16–19, major risk of knowledge loss;
Ftotal = 10–15, important risk of knowledge loss;
Ftotal = 1–9, common risk of knowledge loss.

III.7.4. Results

Herein we want to present some significant results of the above mentioned performed activities.

The highlights of some aspects of Romanian nuclear organizations which answered the IAEA questionnaire are listed below:

— No Romanian nuclear or support organization has a separate structure for knowledge preservation;
— The responsibility for knowledge transfer and preservation lies with the Quality Management or Integral Management and human resources departments;
— The methods and tools for transferring and preserving explicit knowledge are quite well known and applied. There are concerns related to the transfer of tacit knowledge.

The following relevant elements relate to the status of knowledge transfer and preservation in INR:

— The perception of the time interval required for an optimal KT process from the main body of expertise is as follows:

between 1 and 3 years — > 30%;
between 4 and 6 years — > 48%,
between 7 and 9 years — > 17%;
more than 9 years — > 3%;

— The perception of barriers working against knowledge sharing can be seen in Fig. III.4;
— The importance of factors affecting the motivation for knowledge sharing can be seen in Fig. III.5;
— The results of preliminary loss risk assessment are synthetically shown in Table III.3 (a risk matrix for knowledge loss).

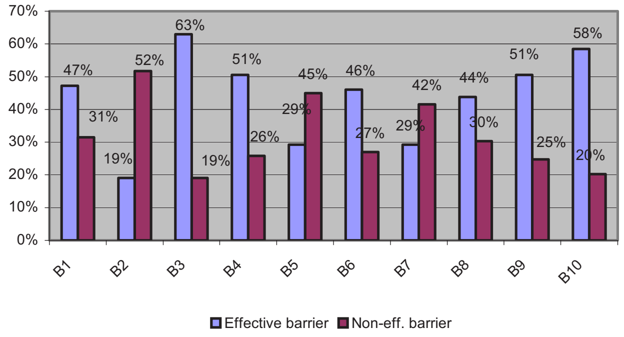

FIG. III.4. The perception of barriers working against knowledge sharing.

Notes:

B1 — lack of time
B2 — lack of trust
B3 — people grouping in functional departments/ buildings
B4 — poor means of knowledge capture
B5 — internal competition
B6 — top-down decision making
B7 — lack of awareness of how useful particular knowledge is to others
B8 — low interest among knowledge receivers
B9 — the syndrome ‘knowledge is power’
B10 — lack of discussion/social events/working in teams (individualism)

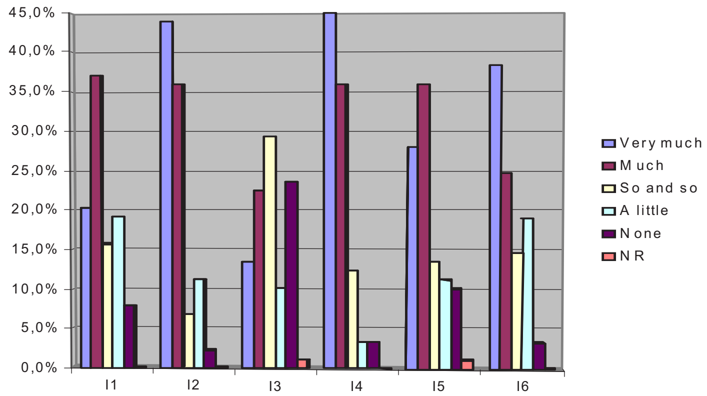

FIG. III.5. The importance of motivational factors in knowledge sharing.

Notes:

I1 — retirement awards depending on effective KT
I2 — increase of salary in the last years of service depending on KT transfer
I3 — clearance form completion only after a relevant exit interview
I4 — post-retirement collaboration contracts depending on the number and quality of prepared newcomers
I5 — support for future publications
I6 — free access to INR social/team building activities

TABLE III.3. RISK MATRIX FOR KNOWLEDGE LOSS

Risk class							
Critical risk 4 (20–25)		Major risk 3 (16–19)		Important risk 2 (10–15)		Common risk 1 (1–9)	
Number of jobs	Code + description	Number of jobs	Code + description	Number of jobs	Code + description	Number of jobs	Code + description
	A-14	2	C-7		A-4		A-1
	B-3		D-32		A-5		A-2
	B-7				A-33		A-3
8	C-22				B-12		A-6
	C-37				B-17		A-7
	C-43				B-24	125	…
	D-12			14	C-30		…
	D-14				C-36		
					D-6		
					D-9		
					D-11		
					D-16		
					D-30		
					D-39		

III.7.5. Conclusions

Based on the information accumulated and the results obtained via questionnaire investigations, some conclusions can be highlighted. It is important to mention that the work done has produced valuable results in terms of Romanian KM evolution and strategy.

Briefly, at the national level, the conclusions are:

— (C1) National policy in the nuclear field should include a separate strategy concerning knowledge management;
— (C2) Nuclear and support organizations need to be sustained by national decisions supporting the implementation and development of appropriate knowledge management strategies;
— (C3) Each nuclear and supporting organization must make its own efforts (human and financial) to elaborate and implement knowledge management strategies;
— (C4) In each organization, attention should be focused on finding appropriate methods and tools for knowledge transfer and preservation, especially of the tacit kind, due to the advanced age of personnel (almost 50% of the workforce are between 46 and 56 years).

Below is a short term strategy for INR regarding knowledge preservation;

— (C5) Undertake an annual assessment of knowledge loss risk to update the INR knowledge map;
— (C6) Hire new personnel (generally young) in order to compensate for important losses through retirement (about 25% of actual personnel) in the next 5–10 years;
— (C7) Select candidates directly from universities based on study contracts (supported by INR) between students and INR;
— (C8) Newcomers should be hired at least three years before staff members holding particular positions retire in order to obtain an optimal transfer of tacit knowledge;

— (C9) National funds should be obtained for KP to provide partial support for the preparation of young graduate newcomers undertaking nuclear research and nuclear industry activities; this should be based on the importance of the activity within the realm of scientific and industrial applications;
— (C10) Define a collaboration policy for retired researchers and INR.

III.8. METHODS AND TOOLS FOR NUCLEAR KNOWLEDGE GATHERING AND PRESERVATION, RUSSIAN FEDERATION

III.8.1. Introduction

The details of CRP project 13824/R0 (InterDCM, Moscow, the Russian Federation), tasks and results achieved during the first and the second years of the project are presented in the corresponding progress reports, submitted to the IAEA. The main objective of this brief report is to summarize the results of this particular (national/organizational) project for presentation in the final CRP report. Thus, this report does not cover all details of all project implementation findings, but reflects the main points.

III.8.2. Scope

The main tasks of the CRP were the following:

— To prioritize all Russian reactor types regarding KP importance, develop a taxonomy draft for knowledge needed for selected (based on prioritization) reactor life cycles (WWERs were initially selected) and to participate in common CRP activities in the first year;
— To refine a taxonomy draft, analyse and compare methods and tools for knowledge preservation and management, especially software tools available for internet portal creation, implementation and maintenance (this was refined during project implementation) in the next stage;
— Finally, based on the results of the first two priorities, to develop recommendations and concepts for the Internet portal which would be useful for the Russian utility.

III.8.3. Objectives

Main objectives:

— Based on priority, to select the most important NPP types for further knowledge preservation and consideration;
— To develop high taxonomy draft levels for selected NPP types;
— To develop recommendations and portal concepts based on knowledge portal surveys and analysis of portal creation methods.

III.8.4. Summary of main achievements after the first year

(1) Prioritization of reactor types in order of importance for knowledge preservation.
There are a few main nuclear power reactor types in the Russian Federation:
— WWERs (similar to PWRs);
— BN-600s (fast breeders);
— RMBKs (channel type graphite moderated reactors of the Chernobyl NPP type);
— EGPs (small graphite moderated, installed at the Bilibino NPP only).
Nuclear power plants with WWER reactors are the most popular and successful power reactors of Soviet Russian design. There are many such reactors in different countries around the world; the majority of them are in operation, and several are under construction. Two units at the Novovoronezh NPP are in the decommissioning stage (a full list is attached to the first progress report).

When new and ambitious plans for NPP construction in the Russian Federation are announced, one of the most important tasks is to assure an adequate knowledge level and sufficient number of qualified specialists to provide for the safe design, construction and operation of such new NPPs, which are mainly (about 90%) based on WWER reactors.

For this reason, plants with WWER reactors were ranked highest priority for consideration in the CRP project. Currently, WWER reactors represent quite a broad family of reactors, from reactors of the pilot design to serial reactors. For this reason, a more detailed prioritization was undertaken for the selected WWER family.

(2) Selection of NPP types for taxonomy draft development and approaching a utility for input:

Among the WWER family, serial reactors and reactors of the last generation were granted first priority, because they are the most important for the world market and further development.

After selecting the NPP type for first consideration, the Russian utility Rosenergoatom was approached to provide input for the taxonomy development of WWER reactors. A. Kolotov, head of the department responsible for WWER operation, was recommended as the proper expert for this purpose. A. Kolotov’s input was received, and further developed to be included in the WWER taxonomy draft (attached to the CRP progress report for year one).

(3) Draft of a taxonomy for the selected NPP type:

Before developing a detailed taxonomy of the knowledge needed for a WWER life cycle, the main aspects of this knowledge were considered and their goal functions described (answering the question why they are needed). The authors took the approach used earlier by the IAEA for fast breeders as a basis and further developed it for WWERs. The results of this (including the main aspects of the required knowledge and why it is needed for the WWER life cycle) are listed in Table III.4.

TABLE III.4. GOAL FUNCTIONS OF THE MAIN ASPECTS OF WWER TECHNOLOGY KNOWLEDGE

Main aspects of WWER technology knowledge	Goal functions
Neutron physics	— Ensuring a controlled chain fission reaction under both normal operation and emergency conditions — Provision of radiation protection for components and personnel — Provision of sub-criticality under required conditions — Neutron field control (three dimensional core control) including Xenon oscillation suppression
Thermohydraulics, thermal physics, hydrodynamics	— Provision of heat transfer and heat removal from the core into the secondary circuit — Provision of heat removal from the secondary circuit — Provision of coolant pressure control in the primary and secondary circuits including emergency steam pressure relief in the primary circuit and before the turbine [safety relieve valve (SRV) of pressurizer, turbine bypass valve to atmosphere (BRU-A), turbine bypass valve to condenser (BRU-K, SRV of steam generator)] — Provision of core residual heat removal through heat exchangers — Ensuring of emergency cooling in case of a loss-of-coolant accident (LOCA) — Provision of required operating conditions for systems and components

TABLE III.4. GOAL FUNCTIONS OF THE MAIN ASPECTS OF WWER TECHNOLOGY KNOWLEDGE (cont.)

Main aspects of WWER technology knowledge		Goal functions
Materials	Fuel	— Reliable generation of thermal energy in highly loaded core conditions — Ensuring fuel element tightness and geometry of assemblies during the entire life cycle of the fuel
	Coolant	— Provision of heat removal from fuel elements — Maintenance coolant during operation to meet required performance — Minimization of ill effects affecting fuel assemblies (corrosion and other chemical reactions)
	Gas environment: hydrogen, nitrogen, air	— Provision of equipment availability and safety (generator, hydroaccumulators in emergency core cooling systems (ECCS), pressurizer, pneumatic fittings, etc.)
	Constructional materials	— Reliability assurance of the reactor vessel and other NPP components and elements — Prevention of vessel embrittlement caused by neutron fluence
	Absorber	— Fulfillment of design functions (neutron flux flattening, shaping of an optimum neutron field)
	Other materials	— Reliability assurance of building structures and auxiliary systems
Safety issues		— Justification and provision of NPP safety operations under normal conditions, design basis and beyond design basis accidents — Justification, control and management of severe accidents — Design and operation of safety systems — Development of criteria and requirements to ensure reactor safety — Provision of chemicals; conditions in the primary and secondary circuits — Assessment of plant operational safety
Mathematical modelling of WWER systems, equipment and processes		— Adequate modelling of components and systems, as well as the processes in these systems for safety analysis, optimization of technological conditions and development of simulators for personnel training and for I&C control system testing
Technological information on systems, components, regulations and procedures		— Design, construction and operation of systems and components. — Development of operating procedures for personnel including emergency procedures. — Development of documents on technological maintenance.
Monitoring and control of plant systems and parameters		— Provision of monitoring and control of various NPP parameters and characteristics and keeping these in the required range — Automation of main functions of emergency and process protections and interlocks — Reduction of operator duty during monitoring and control of technological processes — HMI optimization — Assessment of plant systems operational performance
Personnel training and management		— Provision of effective and consistent personnel policy — Definition of requirements for personnel qualifications — Provision and maintenance of personnel knowledge and skills
Ecology		— Selections of sites for NPP construction, taking into account potential environmental impact and possible external environmental influences on the NPP (seismicity, flooding, etc.) — Minimization of radiation and other ill effects of the NPP on personnel, the population and the environment
Economics and social aspects		— Comparative economic analysis of NPP operations — Preservation of historically valuable data and archives — memoirs, photos and chronicles

III.8.5. Summary of main achievements after the second year

(1) The use of new IAEA approaches to enhance high level taxonomy:
The developed taxonomy draft for knowledge management of the WWER life cycle was later enhanced based on key NPP KP elements proposed by the IAEA for IAEA KM assisted missions. Examples of high level taxonomy taken into account are:
- Basic declarations and procedures of a plant (determination of control system and requirements to it; safety policy and procedures; administrative and technical procedures and instructions; operation instructions in abnormal and emergency conditions etc.);
- Documentation turnover system (technical drawings and guides; safety analysis; testing checks results). Configuration control (monitoring of plant conditions; monitoring of modifications and changes);
- Training and qualification (training appliances and compliance of simulators, laboratories and workshops with production potentials; databases on training, tests and examination results; mentorship and tutorship, etc.);
- Lessons elicited from operational experience (the analysis of internal and external events; reports on the accidents; benchmarking, etc.). Tracking corrective actions (the relevance of existing drawbacks, their gradual elimination and the status of correction; registration of correcting actions made before, etc.);
- Human resource control (planning the working resource of an organization, including plans for hiring and plans regarding succession of key positions; plans for individual development etc.).

(2) Survey to identify the proper tools for taxonomy implementation in the KP process:
A survey of NPP portals and software tools available for portal development, implementation and maintenance was prepared, reported and included into the paper for publishing (see final report). The main advantages of portal implementation were shown to be:
- A portal allows the organization to have of a set of processes for documentation turnover, in particular for the coordination of documents;
- It supports a single and constantly updated database of corporative information formed in accordance with the organizational structure;
- Internal information resources become integrated according to a ‘single window’ principle;
- Time losses and expenses involved in searching through separate information systems decrease, and productivity increases;
- The simplification of interaction within a group allows employees to fulfill their tasks more efficiently. According to expert estimations, the time spent by employees for communications decreases 2–2.5 times;
- The portal improves management and monitoring qualities of organization activity and makes decision making more effective.

(3) Proposal KP concept for the Rosatom state corporation:
Based on the survey and conducted comparison of IT technologies for NPP KP, a reasonable concept for a perspective WWER NPP portal. The concept was reported to the scientific and technical council of the Rosatom state corporation; see conclusion.

III.8.6. Conclusion

Atomic industry enterprises, including NPPs, neglecting KM processes risk losing important technological knowledge and, correspondingly, face reduced effectiveness. Knowledge is a key resource for most organizations in the contemporary world, therefore effective KM requires an understanding of and focus on a corporate knowledge concept instead of the traditional concept of individual concentrated knowledge. The IAEA recommended approach to gain a competitive advantage and keeping safety levels high is one example of the realization of such an approach. The acceptance of such an approach by atomic industry enterprises, in particular by NPPs, including active management of knowledge as a strategic resource, increases chances of long term competitiveness, reliability, safety and effectiveness. The main recommendations made to Rosatom, reflecting the results of the CRP are:

- Actions should be taken to preserve and control knowledge in the Rosatom state corporation, starting with the organizations which are the most prepared to implement contemporary information technologies;

- The development and implementation of an information portal, and further development and use of taxonomy is recommended as an effective means of knowledge preservation;
- Monitoring and regular partnership examinations of KM effectiveness should be introduced at Rosatom's enterprises. Through this, advanced experience and good practice in the field of KM can be addressed. IAEA guidelines should be used to determine the criteria for knowledge preservation assessments in nuclear organizations.

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ABBREVIATIONS

AECL	Atomic Energy of Canada Limited
AVI	audio video interleave
BPR	business process reengineering
CADD	computer-aided drafting and design
CANDU	Canada deuterium uranium
CBT	computer based training
CLIR	cross language information retrieval
CMC	content management system
CMMS	CANDU materials management system
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owner’s Group
CRP	coordinated research project (IAEA)
CSV	comma separated values
DB1–DBn	database 1–database n
DMS	document management system
DoMa	document management database
EAS	enterprise application software
EC	European Commission
EPR	European Pressurized Reactor
EPRI	Electric Power Research Institute
ERP	enterprise resource planning
FMS	feedback monitoring system
GIF	Generation IV International Forum
HDS	historical data system
HR	human resource
HTML	hypertext markup language
ICT	information and communication technology
IMS	information management system
INR	Institute of Nuclear Research
IP	Internet protocol
IRC	industrial research chair
IS	information system
ISO	International Organization for Standardization
IT	information technology
JPEG	joint photographic experts group
JRC	Joint Research Centre
KM	knowledge management
KP	knowledge preservation
KPI	key performance indicator
MPEG	Moving Picture Experts Group

NAM	nuclear asset management
NGO	non-governmental organization
NPP	nuclear power plant
NRC	Nuclear Regulatory Commission (USA)
NSERC	natural Sciences and Engineering Research Committee
O&M	operating and maintenance
ODIN	on-line data information network
OMS	organizational memory system
OPEX	CANDU Owners Group Operating Experience
ORACLE	Oracle database
OS	operating system
PSD	photoshop document
PHWR	pressurized heavy water reactor
QM	quality management
R&D	research and development
RDBMS	relational database management system
RRC	Russian Research Centre
RTF	Rich text format
SAT	systematic approach to training
SCM	source code management
SMART	systematic, measurable, achievable, relative, and time bound
SWOT	strengths, weakness, opportunities, and threats
TIFF	Tagged Image File Format
UNENE	University Network of Excellence in Nuclear Engineering
VCS	version control system
VOB	video object
XML	Extensible Markup Language

Annex I

IAEA SURVEY QUESTIONNAIRE ON CURRENT STATUS OF KNOWLEDGE PRESERVATION IN NUCLEAR AND SUPPORTING ORGANIZATIONS

<table>
<tr><td colspan="2">Responded by</td><td>Date:</td></tr>
<tr><td rowspan="3">Name of Country:</td><td colspan="2">Organization name:</td></tr>
<tr><td colspan="2">Type of organization:</td></tr>
<tr><td colspan="2">Size of organization (approximate number of employees):</td></tr>
<tr><td colspan="3">Contact information:</td></tr>
<tr><td colspan="3">Name:</td></tr>
<tr><td colspan="3">Address:</td></tr>
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(Please include your country and area code)</td><td>Fax No.: +
(Please include your country and area code)</td></tr>
<tr><td colspan="3">E-mail address:</td></tr>
</table>

1. POLICY AND STRATEGIES

1.1. Enumerate/describe the knowledge preservation (KP) principles that are being taken into consideration in your organization:

1.2. What policy/strategies have been developed to support KP?

☐ improving human performance;
☐ succession planning;
☐ developing methods and tools for KP;
☐ making KP a part of the organizational culture;
☐ investment in information system technology;
☐ formal (mandatory) KP procedures;
☐ informal (voluntary) KP practices;
☐ other.
Please describe briefly:

1.3. What ‘approaches’ are you applying to achieve the KP objectives?

☐ providing appropriate human resources;
☐ providing appropriate financial resources;
☐ getting all levels of management involved;
☐ establishing systems for encouraging individual contribution;
☐ defining clear criteria and standards;
☐ providing training for all processes;
☐ formal maintenance programme of KP systems;
☐ formalized KP procedures and processes;
☐ organization-wide KP systems;
☐ other.
Please describe briefly:

1.4. Do you have a nominated person/group responsible for knowledge preservation?

☐ Yes ☐ No

Please describe briefly:

2. MANAGEMENT FACTORS

2.1. Knowledge mapping

2.1.1. What are the sources of nuclear knowledge? How do you identify them for your organization?

2.1.2. Who are the specific users (current and future) of nuclear knowledge? How do you identify them?

2.1.3. How do you manage the knowledge map and how frequently is it updated?

2.2. Regulations and requirements

2.2.1. Is KP part of your Quality Management System?

☐ Yes ☐ No

Please describe briefly:

2.2.2. What QA standards, regulations and/or requirements do you apply?

☐ IAEA;
☐ ISO;
☐ ANSI/ANS;
☐ other

Please describe briefly:

2.2.3. What type of knowledge organization structure do you apply?

☐ centralized;
☐ decentralized;
☐ other

Please describe briefly:

2.2.4. What regulations do you follow for KP?

2.2.5. What is the procedure for the selection/adoption of new regulations?

2.3. Workflow

2.3.1. Does implementation of KP technologies and tools impact workflow considerations and Vice versa?

☐ Yes ☐ No

2.3.2. Provide examples of how KP tools are incorporated into the workflow?

2.4. Knowledge Systems Integrity

2.4.1. Have you a system administrator for KP?

☐ Yes ☐ No

2.4.2. Do you have specific procedures for:

☐ system security
☐ authentication
☐ access rights

Please describe briefly:

2.5. Human Resources

2.5.1. Does succession planning include a knowledge loss risk assessment?

☐ Yes ☐ No

Please describe briefly:

2.5.2. Are there key positions within your organization that are monitored with respect to KP?

☐ Yes ☐ No

Please describe briefly:

2.5.3. Have you established succession plans for these key positions?

☐ Yes ☐ No

Please describe briefly:

3. METHODS AND TOOLS FOR KNOWLEDGE LIFE CYCLE

3.1. Knowledge identification

3.1.1. How do you identify which knowledge should be captured, processed, maintained and preserved?

3.1.2. Do you apply graded approach for evaluation of knowledge significance?

☐ Yes ☐ No

Please describe briefly:

3.2. Capture

3.2.1. What methods and tools does your organization use to capture 'tacit knowledge'?

☐ employee interview;
☐ questionnaire;
☐ knowledge mapping;
☐ photo and video;
☐ other.

Please describe briefly:

3.2.2. What methods and tools does your organization use to capture 'explicit knowledge'?

☐ hard copies;
☐ digitization;
☐ databases;
☐ photo;
☐ video;
☐ models and simulations;
☐ editable source files;
☐ 3D models;
☐ decision support systems as a tool;
☐ other.

Please describe briefly:

3.2.3. What e-formats do you use to capture information? Please list (i.e. ASCII, MS Word, XML, PDF, scanned PSD, Rich Text Format, Comment Separated Variable (CSV), etc.):

Content searchable:

Content non-searchable:

3.2.4. Do you rate the validity of captured knowledge?

☐ Yes ☐ No

Please describe briefly:

3.3. Data processing

3.3.1. What techniques does your organization use for data processing?

☐ data analysis;
☐ data structuring;
☐ digitization;
☐ compressing;
☐ creation of metadata;
☐ statistical processing;
☐ visualization;
☐ format conversion;
☐ verification of correctness
☐ other.

Please describe briefly:

3.3.2. Do you use commercial software for data processing?

☐ Yes ☐ No

Please describe briefly:

3.4. Storage

3.4.1. What methods and tools do you use for knowledge storage?

- ☐ archiving of hard copies (%);
- ☐ archiving of digital information on:
  - ☐ hard discs (%);
  - ☐ optical (CD; DVD, etc.) (%);
  - ☐ streamers (magnetic tapes) (%);
- ☐ film library (%);
- ☐ other (%).

Please describe briefly:

3.4.2. What e-formats do you use for information storage? Please list (i.e. ASCII, MS Word, XML, PDF, scanned PSD, Rich Text Format, Comment Separated Variable (CSV), etc.):

Content searchable:

Content non-searchable:

3.4.3. What metadata is stored with any knowledge that is preserved? For example: author, date of production, release number, subject keywords (i.e. system, organization, reactor type, design etc.).

Please describe briefly:

3.4.4. Do you use thesauri, taxonomies, ontology or any other organizational structures?

☐ Yes ☐ No

Please describe briefly:

3.4.5. Do you use any computer aided metadata creation tools?

☐ Yes ☐ No

Please describe briefly:

3.4.6. What software/system tools are used to manage archives?

☐ commercial document management systems;
☐ Intranet technology;
☐ custom in-house DBMS system;
☐ other.

Please describe briefly:

3.4.7. Do you have any plans to upgrade storage format?

☐ Yes ☐ No

Please describe briefly:

3.5. Retrieval/access

3.5.1. Do you have any access control to stored knowledge?

☐ Yes ☐ No

Please describe briefly:

3.5.2. Do you have integrated information system which provides interoperability of different types of knowledge (text, data, drawings, videos, 3-D models, etc.)?

☐ Yes ☐ No

Please describe briefly:

3.5.3. Does your organization use data retrieval software?

☐ Yes ☐ No

Please describe briefly:

3.5.4. What procedures for knowledge retrieval software does your organization use?

Please describe briefly:

3.6. Knowledge Exchange

3.6.1. Do you exchange stored knowledge with external organizations?

☐ Yes ☐ No

3.6.2. What are the terms that govern knowledge exchange?

☐ free exchange;
☐ commercial;
☐ bilateral agreements;
☐ other.

Please describe briefly:

3.6.3. What e-formats do you use for knowledge exchange? Please list (i.e. ASCII, MS Word, XML, PDF, Scanned PSD, Rich Text Format, Comma Separated Variable (CSV), etc.):

3.6.4. What media do you use for explicit knowledge exchange?

☐ mail;
☐ e-mail;
☐ Internet/intranet;
☐ e-learning;
☐ simulation;
☐ other.

Please describe briefly:

3.6.5. What media do you use for tacit knowledge transfer?

☐ interviews/questionnaire;
☐ conference/meeting;
☐ mentoring/training;
☐ communities of practice;
☐ simulation;
☐ other.

Please describe briefly:

3.7. Multilingualism

3.7.1. What languages do you use for knowledge preservation?

3.7.2. Do you use computer aided translation?

☐ Yes ☐ No

Please describe briefly:

3.7.3. Do you have special procedures for validation of translated information?

3.7.4. Do you apply special means (i.e., thesauri) to assure multilingual use of information?

☐ Yes ☐ No

Please describe briefly:

3.8. Version control, updating and redundancy of knowledge

3.8.1. Do you have special procedures for version control, updating and redundancy of knowledge?

☐ Yes ☐ No

Please describe briefly:

3.8.2. What tools and methods does your organization use for version control, updating and redundancy of knowledge?

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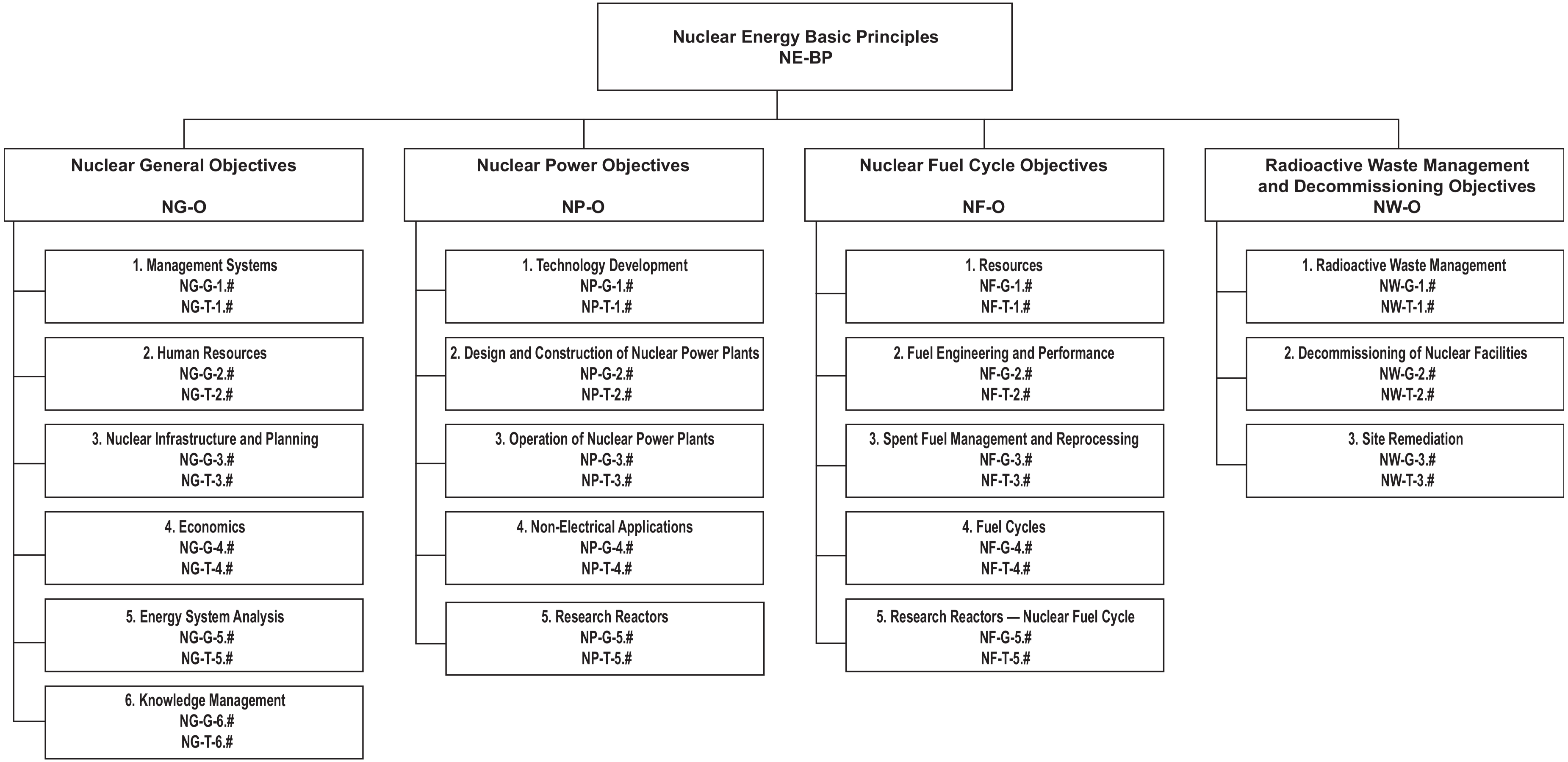

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