Managing Nuclear Knowledge: Strategies and Human Resource Development

Summary of an international conference

7–10 September 2004, Saclay

EUSIDIC FORATOM IAEA JAIF AEN NEA WORLD NUCLEAR UNIVERSITY

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MANAGING NUCLEAR KNOWLEDGE:
STRATEGIES AND HUMAN RESOURCE
DEVELOPMENT

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MANAGING NUCLEAR KNOWLEDGE: STRATEGIES AND HUMAN RESOURCE DEVELOPMENT

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IN COOPERATION WITH THE EUROPEAN COMMISSION,
OECD NUCLEAR ENERGY AGENCY,
EUROPEAN ATOMIC FORUM,
JAPAN ATOMIC INDUSTRIAL FORUM,
WORLD COUNCIL OF NUCLEAR WORKERS,
WORLD NUCLEAR UNIVERSITY AND
EUROPEAN ASSOCIATION OF INFORMATION SERVICES,
HOSTED BY THE GOVERNMENT OF FRANCE THROUGH THE
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EDITORIAL NOTE

FOREWORD

The nuclear industry is knowledge based, similar to other highly technical industries, and relies heavily on the accumulation of knowledge. Recent trends such as workforce ageing and declining student enrolment numbers, and the risk of losing accumulated knowledge and experience, have drawn attention to the need for better management of nuclear knowledge.

In 2002 the IAEA General Conference adopted a resolution on nuclear knowledge, which was reiterated in 2003; the resolution emphasized the importance of nuclear knowledge and information management and urged both the IAEA and Member States to strengthen their activities and efforts in this regard. Consequently, the International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development, which was held on 7–10 September 2004 in Saclay, was organized by the IAEA and the Government of France through the Commissariat à l'énergie atomique in cooperation with the European Commission, OECD Nuclear Energy Agency, European Atomic Forum, Japan Atomic Industrial Forum, World Council of Nuclear Workers, World Nuclear University and European Association of Information Services. The conference was attended by 250 experts, scientists and officials from 54 Member States and nine international organizations, giving the conference a very broad representation of the nuclear sector.

The objective of the conference was to reach a clear and common understanding of the issues related to nuclear knowledge management for sustaining knowledge and expertise in nuclear science and technology and to define a strategic framework for developing IAEA cross-cutting knowledge management activities. The conference provided a forum for professionals and decision makers in the nuclear sector, comprising industry, government and academia, as well as professionals in the knowledge management and information technology sectors.

Based on the results of the conference, the key insights, lessons learned and recommended future actions in managing nuclear knowledge and information, human resources for the nuclear sector and networking education and training are presented in this report.

Appreciation is expressed to all the participants who contributed to this publication. Particular thanks are due to V. Mahadeva Rao Koorapaty for his assistance in the compilation of this report. The IAEA officers responsible for this report were Y. Yanev and A. Kosilov of the INIS and Nuclear Knowledge Management Section, Department of Nuclear Energy.

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1. INTRODUCTION

1.1. NUCLEAR POWER PROSPECTS

Nuclear power has become a major source of electricity supply in some countries, but there has been no growth in the global share of electricity produced by nuclear power for more than a decade. The number of countries having nuclear power plants has also been level for a long time. However, in recent years there has been a growing recognition of the importance of factors such as energy supply security and environmental impacts, including climate change, in which nuclear power has advantages over other electricity generation options. New nuclear power plants are being constructed in Asia, and plans for a significant expansion of nuclear power programmes are taking shape in the two largest developing countries, China and India. Thus the long term prospects for global nuclear power growth appear to be brighter, although, in the short term, the industry focus is continuing to be on power upgrades, plant performance improvements, ageing management and life extension through refurbishment. Important developments are being pursued on new designs of nuclear power plants based on evolutionary concepts such as the EPR/VVER-1500 and revolutionary concepts such as accelerator driven systems or fission–fusion hybrids. Some countries are pursuing fast reactor programmes. Research and development (R&D) efforts are being continued in the area of waste management, including partitioning and transmutation, and in establishing repositories for long term waste storage. Development of innovative technologies for nuclear fuel cycles and nuclear power, coupled with the continued safe operation of the current fleet of reactors, is essential for addressing public and political concerns and enabling nuclear power to make a substantial contribution to world energy supplies in the 21st century and beyond.

1.2. NEED FOR NUCLEAR KNOWLEDGE MANAGEMENT

Like any highly technical endeavour, the use of nuclear technology relies on the accumulation of knowledge. The nuclear energy sector is characterized by long time scales and technical excellence. The early nuclear plants were designed to operate for 30 years, but their service life is now expected to be

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Note: The views and recommendations expressed here are those of the conference and the participants, and do not necessarily represent those of the IAEA.

50–60 years. Decommissioning and decontamination of nuclear plants will be spread over several decades, resulting in a life cycle, from cradle to grave, in excess of 100 years, which gives rise to two problems for the nuclear industry:

(a) Retention of existing skills and competences for a period of over 50 years, particularly in countries in which no new nuclear power plants are being planned;
(b) Development of new skills and competences in the areas of decommissioning and radioactive waste management when the nuclear disciplines have become unappealing to young people in many industrialized countries.

Many experts around the world are retiring, taking with them a great deal of knowledge and corporate memory. The people retiring are those who can answer questions easily and have tacit knowledge that was not extracted from them previously. Loss of employees who hold knowledge that is critical either to operations or safety poses an internal threat to the safety and operation of nuclear power plants. The primary challenge of preserving knowledge is to find ways in which tacit knowledge might be captured or at least be transferred to successors.

These problems are exacerbated by the deregulation of energy markets around the world. The nuclear industry is now required to reduce its costs dramatically in order to compete with generators with different technology life cycle profiles. In many countries, government funding has been dramatically reduced or has disappeared altogether, while the profit margins of generators have been severely squeezed. The result has been lower electricity prices but also the loss of expertise as a result of downsizing to reduce salary costs, a loss of research facilities to reduce operating costs and a decline in support to universities to reduce overheads. The above factors have led to a reduction in technical innovation and a potential loss of technical competences, drawing the attention of all concerned parties to the need for effective strategies and policies for nuclear knowledge management.

The Director General of the IAEA, Mohamed ElBaradei, in his statement to the 47th regular session of the IAEA General Conference in 2003, said:

> "Whether or not nuclear power witnesses an expansion in the coming decades, it is essential that we preserve nuclear scientific and technical competence for the safe operation of existing facilities and applications. Effective management of nuclear knowledge should include succession planning for the nuclear work force, the maintenance of the 'nuclear

safety case' for operational reactors, and retention of the nuclear knowledge accumulated over the past six decades."

1.3. WORKING DEFINITION OF KNOWLEDGE

The term 'knowledge management' was coined in the mid-1990s. At present, more than 80% of the world's leading nuclear industries, institutions and international organizations are pursuing knowledge management strategies. Definitions of knowledge differ widely.

Peter Senge, former professor at the Massachusetts Institute of Technology and currently the Chairperson of the Society for Organizational Learning, defines knowledge as the "capacity for effective action". Senge's definition of knowledge integrates the concept of action into the concept of knowledge. From this point of view, being knowledgeable means having the capacity to achieve the desired results. Such a capacity is acquired through an extensive process of integrating technical expertise, methodological knowledge and social competence.

Knowledge can be broadly categorized as explicit and tacit. Explicit knowledge includes technical information in the form of scientific research, engineering analysis, design documentation, operational data, maintenance records, regulatory reviews and other documents and data that can be transferred easily to interested parties. However, documents never comprise the experts' complete knowledge, and a novice reading those instructions might not end up with the same results as the expert. The tacit knowledge of the experts, including scientists, engineers and technicians, is acquired over a long period and may never be fully articulated.

The IAEA defines 'knowledge management' as an integrated, systematic approach to identifying, managing and sharing an organization's knowledge, and enabling persons to create new knowledge collectively in order to help achieve the objectives of that organization.

1.4. INTERNATIONAL CONFERENCE ON NUCLEAR KNOWLEDGE MANAGEMENT: STRATEGIES, INFORMATION MANAGEMENT AND HUMAN RESOURCE DEVELOPMENT

The risk of losing nuclear knowledge accumulated in the past brings a need for fresh initiatives in capacity building and knowledge transfer. However, because different countries are at different stages of the nuclear technology life cycle, these losses are not common to all countries, either in their nature or their extent; a competence that may have declined or been lost in one country may be strong in another. Hence international collaboration is an important solution to the problems that the nuclear sector faces.

The International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development was organized by the IAEA and the Government of France through the Commissariat à l'énergie atomique (CEA) in cooperation with the European Commission (EC), OECD Nuclear Energy Agency (OECD/NEA), European Atomic Forum (FORATOM), Japan Atomic Industrial Forum (JAIF), World Council of Nuclear Workers (WONUC), World Nuclear University (WNU) and European Association of Information Services (EUSIDIC). The conference was held at Saclay on 7–10 September 2004 and was chaired by B. Bigot, High Commissioner for Nuclear Energy, France.

The conference provided a forum for professionals and decision makers in the nuclear sector, comprising industry, government and academia, as well as professionals in the knowledge management and information technology (IT) sectors. The goals of the conference were:

(a) To exchange information and share experience on nuclear knowledge management, including on strategies, information management and human resource development;
(b) To identify lessons learned and to embark on the development of new initiatives and concepts for nuclear knowledge management in IAEA Member States.

Keynote addresses delivered by leading experts in the field, industrial leaders and governmental officials covered important aspects of nuclear knowledge management. The sessions were devoted to: managing and preserving nuclear knowledge; managing nuclear information; human resources for the nuclear sector; and networking education and training. The conference had two panels: The Young Generation in the Nuclear Sector and Innovation and Nuclear Knowledge. At the end of the conference, R.B. Grover, the Conference Rapporteur, presented a summary of the conference.

The conference was attended by 250 experts, scientists and officials from 54 Member States and nine international organizations, giving the conference a very broad representation of the nuclear sector.

1.5. SCOPE

Based on the results of the conference, this report presents the key insights, lessons learned and recommended future actions in the areas of managing and preserving nuclear knowledge and information, managing human resources for the nuclear sector, networking education and training, and nuclear knowledge management policies and strategies in Member States.

The conference programme, list of participants and unedited papers are on the CD-ROM attached to this report.

2. MANAGING AND PRESERVING NUCLEAR KNOWLEDGE

2.1. EXPLICIT AND TACIT KNOWLEDGE

Knowledge or expertise associated with any technological project is generally made up of two main components, explicit and tacit, which need to be managed differently as strategic resources. Explicit knowledge is contained in the documentation of technical information or in data, while tacit knowledge resides in the human resources as specialist skills.

Explicit knowledge is easier to manage through capturing all important information, in electronic form or hard copy, to create manuals, databases, project design documents, maintenance manuals, project variation orders and so on. Identification of documentation requirements and associated procedures for the creation, maintenance and updating of documents needs to be addressed, however, also as an upfront project requirement during the design phase, and should not be added on later as an afterthought.

Tacit knowledge primarily makes up the core competence within an organization and is more difficult to preserve and transfer to successors. Where the transfer of tacit knowledge has not been incorporated into organizational learning processes an organizational memory loss occurs when key people leave; this has often been the main reason for a project's failure. Organizational memory shapes an organization's culture, its management approach, its decision making process, its communication strategies and last, but not least, the definition of its operating boundaries, which are captured in its job descriptions. Tacit knowledge, by its very nature, is an elusive concept and cannot be captured easily by conventional means. The IAEA, established primarily as a knowledge based organization, has been capturing to a significant extent the tacit knowledge of pioneering nuclear experts in codes and guides for a long time, and a large body of knowledge has now been documented. Standards and codes are also being produced by national bureaus of standards of various countries as well as by professional societies, and these also help in knowledge preservation. The nuclear industry has to submit detailed documentation for clearance to national regulatory bodies, which has helped in documenting nuclear and radiation safety information in detail.

The real challenge facing knowledge management is the capture of this vital component of organizational continuity, particularly within rapidly changing organizations undergoing the turmoil of downsizing or re-engineering processes. New techniques and tools for knowledge preservation such as learning audits and the establishment of oral histories have now been added to the traditional technique of exit interviews.

Another problem in capturing tacit knowledge is that the person who has the knowledge often does not know that he or she has it, or does not realize that it is valuable. A cost effective way to solve this problem was reported in the experience of the World Bank in implementing its knowledge management practices. Debriefings of subject matter experts are carried out through audiotaped individual interviews. Subsequently the expert edits the transcripts and the contents are made available on the intranet and appropriately indexed. Hot links are also placed in the text whenever a report or document is mentioned, which creates a fully searchable document that incorporates context with official records. In this way, the transcript of an interview can be linked to thousands of pages of backup material. Most important is the inclusion of the interviewee’s telephone number, so that there can be follow-up questions.

Tools to facilitate the capture of tacit knowledge have been developed and are being continuously improved. The experience in building these tools and the lessons learned through their use were presented at the conference; the key insights include the following.

2.1.1. Planning for, implementing and evaluating knowledge management

Organizations should develop a knowledge management strategy, provide organizational structure for its implementation, allocate an adequate budget for the planned activities, provide incentives to the staff to implement and improve the process and, at the end of each activity, evaluate the performance compared with the expected results to enable feedback for continuous improvement of the process.

2.1.2. Fostering a knowledge sharing culture

In the knowledge based economy, knowledge sharing is not merely an alternative strategic option, it is required for organizational survival. Measures for the aggregation and sharing of knowledge should be initiated and a more open, knowledge sharing culture should be fostered within the organization. Capturing what is already known by someone else in the group and adding one's own knowledge is faster and more efficient than an individual reinventing a solution. The sharing of knowledge has particular relevance to the nuclear energy sector, where actions taken now may have consequences for the planet for tens of thousands of years.

Starting and implementing knowledge sharing in an organization must be done from inside the organization, not grafted from outside. Experience indicates that most successful knowledge sharing programmes are driven by insiders. The insiders must own the process, be involved in all aspects of it, make the changes happen and encourage others to make the changes. At the same time, the insiders must use the outside world to validate and push the agenda forward within the organization; for example, using external recognition and knowledge fairs and expos as ways of showing that what is happening internally is valid and adds value.

2.1.3. Establishing communities of practice

The phenomenon of communities of practice is known under different names, such as thematic groups, learning communities, learning networks, best practice teams and so on. It is essentially the formation of professional groups facilitating staff to come together voluntarily to share similar interests and learn from other's skills. Knowledge sharing on a significant scale is observed to take place only in organizations that have organized themselves into communities of practice. These communities need to be integrated into the company's strategy and its organizational structure. Communities, however, are a non-hierarchical phenomenon and management hierarchies have generally had considerable difficulty in learning how to nurture them. Modern organizations have been built on a rational and mechanistic approach to problem solving. However, experience shows that communities of practice only flourish when their members are passionately committed to a common purpose. This is a hard lesson to learn for companies and executives who have spent their lives trying to keep emotion out of the workplace.

2.1.4. Upgrading information management

Successful knowledge organizations have learned that building web sites and offering knowledge management IT tools neither create nor transfer knowledge by themselves. Employees stop visiting these web sites or using these IT tools if a community of practice is not bringing credibility and contributing content to these instruments. IT tools are made to facilitate knowledge sharing among users rather to constrain the emergence of a sharing culture by imposing complex technical requirements. An important insight is that building a 'learning organization' requires building communities within which that learning can take place. Without communities linked to structure, organizations do not learn very fast.

2.2. INNOVATION AND NUCLEAR KNOWLEDGE

Nuclear knowledge management is a critical input to the nuclear power industry, the associated nuclear fuel cycle activities and nuclear applications in medicine, industry and agriculture. It has an equally critical role to play in facilitating the development of innovative nuclear technologies.

Innovation is already taking place in nuclear technologies around the world. Examples include the development of the European pressurized water reactor, the advanced boiling water reactor and the Generation IV International Forum (GIF) activities. Tools such as robotics, 3-D simulation and laser scanning systems to reduce radiation exposure of staff have been developed to facilitate refurbishment of old plants. Above ground spent fuel storage facilities have been developed as an interim measure until a final decision on high level waste management is made. Tools have also been developed to assist nuclear utilities to improve capacity factors by converting plant data into useful information to facilitate the decision making process.

A major challenge is to ensure public acceptance, which is essential to the sustainability of the nuclear industry. The immediate issues to be dealt with relate to waste management and decommissioning of the first generation reactors. There is also a need to enthuse the young generation and attract them to join the nuclear industry in order to ensure an adequate supply of nuclear workers in the face of accelerated retirements of the current generation of workers.

In order to assess innovative ideas objectively, it is necessary to preserve specific knowledge on historical experience with the wide variety of reactor systems that have been designed and tested. Only a select few nuclear reactor types have survived to be commercially successful. There are many innovative concepts that are still awaiting practical development (thorium fuel, heavy metal coolants, liquid fuel reactors, etc.), but the list of concepts that have been abandoned is much larger (carbonic acid, organic and dissociating gas coolants, and nuclear superheating of steam, to name a few). Knowledge related to why some concepts were considered attractive at different stages in the 50 year history of nuclear power, and why they were dropped, is of great value to the future designers and innovators of nuclear systems. This knowledge has largely remained as tacit knowledge, which cannot be obtained from scientific articles and reviews. Capturing or transferring this knowledge to the future generations requires significant work involving highly qualified specialists with decades of experience in the field of nuclear science and technology.

2.3. NUCLEAR SAFETY AND NUCLEAR KNOWLEDGE

One of the most crucial roles of knowledge management lies in the field of nuclear safety, since lapses in safety due to loss of knowledge would have severe consequences for the industry. Implementing effective knowledge management systems in the field of nuclear safety is beneficial not only to the safety of plant personnel and the general public but also for improving the public perception of the nuclear industry as well as enhancing the commercial performance of plants. With fully trained, highly skilled and well equipped operational staff, nuclear safety can be maintained without much difficulty. Plants that are run safely also operate efficiently and reliably; production is maximized, which should ultimately have a positive effect on company balance sheets.

A wide variety of activities has been initiated by the IAEA relating to knowledge management and networking in the area of nuclear safety, and a holistic approach has been adopted to enhance the effectiveness of programme delivery. Innovative approaches are being utilized to capture, create and share safety knowledge and to assist Member States in their efforts to develop and maintain sustainable education and training programmes. A major nuclear safety challenge is to foster a global knowledge sharing culture to achieve the motto that ‘a safety improvement anywhere is an improvement of safety everywhere’. The measures being implemented include mapping and retrieving safety knowledge, development of process flows and facilitating the development of regional safety networks such as the Asian Nuclear Safety Network (ANSN).

2.4. INTERNATIONAL COLLABORATION

The decline in recent years of many nationally funded nuclear research programmes and the associated loss of facilities and expertise has encouraged countries to seek international collaboration. Although bilateral arrangements continue, multilateral programmes between many countries and research institutes are increasingly favoured to maximize the use of facilities and expertise as well as to share costs. Agencies such as the EC, IAEA and OECD/NEA play an important role in both promoting and coordinating this type of collaboration while ensuring that collaboration is open to as diverse a range of participants as possible. The OECD/NEA has adopted a strategy aimed at maintaining essential types of research facility through these collaborative arrangements.

While nuclear research centres can look back over a long history of international collaboration, the same is not true for universities. It is only recently that some regional collaborative networks have been created, in both Europe and Asia. The same principles apply to maintaining teaching expertise on nuclear related topics as to maintaining research capabilities, especially in those countries where such expertise may be in short supply. In this area more can be done at the national level to develop cooperation between universities; at the international level the recognized agencies have a key role in promoting and coordinating cooperation between countries.

Naturally, collaboration between industrial companies is limited by commercial interests. Some companies have merged and their internal activities are, as result, no longer restricted to national boundaries. However, overall, it is necessary to recognize that industrial collaboration will always be subject to limitations.

Collaboration, information exchange and exchange of personnel have always been an integral part of the development of nuclear power, inasmuch as political constraints have allowed. It is largely as a result of international collaboration that nuclear power has become a reliable energy source within a single generation, accounting for a significant proportion of the electricity produced in many countries today. That it may continue to do so in the future will depend even more on international collaboration, but as long as there are initiatives such as the OECD/NEA Halden project, the GIF and the IAEA project on innovative technologies, there will be grounds for quiet optimism.

3. MANAGING NUCLEAR INFORMATION

3.1. KEY INSIGHTS

The aim of nuclear information management is to get the best value from all the different types of information generated or used within an organization. The information could be from internal or external sources, structured or unstructured, published or not, useful over the short or long term, on paper or in electronic form and of significance that is purely local and administrative or enterprise-wide and strategic.

The practice of information management addresses all types and sources of information, allowing employees to more effectively exploit the information contained in the organization in order to meet the organization's needs and objectives. An effective information management system should eliminate inefficiencies, including the following: collection of unnecessary information; collection of the same basic data by more than one group of employees; important information not identified or collected; storage of information long after the need is over; duplicated storage of the same data; inaccessibility of useful information to potential users; and dissemination of information to those who do not need it.

By correcting these inefficiencies, organizations will not only reduce information handling costs, significant in itself, but will also add considerable value to all business activities: quality information would be made available to policy makers and planners, operational functions could be discharged more effectively, a higher quality of service could be provided to the customers, resulting in improved customer relationships, and so on.

The key insights that emerged from the presentations and discussions on managing nuclear information at the conference are grouped under four topics, described below.

3.1.1. Information requirements in nuclear organizations

Nuclear organizations are essentially knowledge based organizations. There is now a widespread recognition of the role and importance of high quality information in different nuclear organizations, and efforts are being made to identify what information is required for different objectives over different time frames; for example, the current energy policy of the German Government requires the gradual decommissioning of the country's nuclear power plants. E.ON, one of the major energy corporations in Germany, has developed a knowledge management concept targeting three objectives:

securing technical quality and safety standards during decommissioning projects; minimizing risks related to the duration and budget of decommissioning projects; and facilitating the expeditious training and optimal use of project staff. These objectives determine the nature and types of information that needs to be captured and managed.

Other examples of objectives that define information requirements include the following:

(a) The objective of the experimental fast reactor KNK-II in Germany is to capture and preserve the explicit and tacit knowledge in the facility for possible future use with fast reactors.
(b) In Japan the Radioactive Waste Management Funding and Research Center has drawn up its information requirements based on the objective of transferring to future generations information relevant to the safety of the high level waste repository.
(c) The primary objective of the nuclear knowledge portal in Brazil is to support the licensing and control of nuclear activities.

3.1.2. Organizing information

It is necessary to organize both internal information sources, especially the corporate database, and external information sources such as the Internet. The presented case studies examined how information systems can help nuclear organizations to manage their data in order to achieve the goals and requirements as well as the advantages possible from sharing information in strategic partnerships. Examples include:

(a) Web based networking within the framework of the Asian Network for Education in Nuclear Technology (ANENT) in the Republic of Korea.
(b) An intranet based knowledge management portal supporting document search and access, a discussion forum, news pages and other media in Germany.
(c) Development, in Japan, of the technology of laser engraving on to silicone carbide plate, which is the most durable artificial material in the world in terms of strength, corrosion resistance and wear due to abrasion. The objective is to enable preservation of documents without the need for sophisticated preservation environment controls and without the need for human intervention to initiate a duplication programme for over 1000 years.

(d) Launching of eDOC, an application that aims to provide a large catalogue of web based tools to create and manage communication and collaboration portals for communities of practice, in France.

3.1.3. Information systems management

The stages of growth of the various types of information systems were examined and a framework was introduced to assist the planning of strategic information systems. Key insights in this area include the following:

(a) All managers should be made aware of their responsibility to be proactive and informed about issues related to knowledge management strategy and the associated information systems.
(b) Knowledge management policies and activities should be rooted in the corporate culture of knowledge sharing.
(c) The importance of the organizational and cultural dimensions of knowledge management beyond the necessary technological infrastructure cannot be overemphasized.
(d) Information systems should provide a wide range of services for scientific publications and patents management, corporate or local knowledge bases and document repositories, project management and collaboration, rich media authoring, etc.

3.1.4. Analysing information

A proper analysis of the collected and stored data should be carried out so that they can add value subsequently to the decision making process. The presented papers gave some examples of the information analyses required by the different levels of management.

3.2. IAEA INFORMATION SYSTEMS

The International Nuclear Information System (INIS) has been recognized as a unique tool for nuclear knowledge management (including preservation and access) that provides continuous support to national programmes and activities in Member States. A medium term strategy for the development of INIS was discussed at the conference and a number of topical recommendations were developed.

To reflect the interconnected nature of INIS to its national centres, part of the discussion focused on collaboration between the IAEA Library and INIS centres and libraries in Member States to further develop the services of INIS.

In order to support innovation, INIS should make its tools and standards available for knowledge management and knowledge preservation. These tools include the Joint Thesaurus, maintained in collaboration with the Energy Technology Data Exchange (ETDE), and a forthcoming INIS classification, which could constitute the backbone of a nuclear knowledge portal. There was strong support for the concept of 'knowledge packages', with a recommendation that several such packages be developed to meet user requirements.

The main points emerging from the presentations and discussions in the special session on INIS are presented below.

3.2.1. User requirements of industry and research and academic institutions

INIS has mostly served the needs of researchers and academic users; it has served those of industry to a much lesser extent. Industry operates in a special environment in which knowledge and intellectual property protection is required. Collaboration to share the knowledge and information in the public domain would be possible. Although such collaboration could be initiated by the IAEA, this would set precedents. It should remain the responsibility of the INIS liaison officers to foster such relations, and the IAEA could establish a coordinated programme to identify and access this type of information.

Even if there is no commercial transaction, online access will only be possible if there is a link between the INIS metadata and the documents on the publishers' web sites. This will require the addition of online identifiers (and online resolution services). The digital object identifier (DOI) is one technology that can be applied retrospectively to metadata in the INIS database to provide such linking. INIS does not need to be an intermediary in such a case, and should investigate cooperating with organizations (such as CrossRef) that provide such services.

Strong support was given to the concept of 'knowledge packages', which would create new knowledge on the basis of information gathered from key individuals and specialist organizations in the field, including videos, commentaries on earlier works, state of the art reviews and information on work in progress. Each package could be presented to users as a separate knowledge base and a complement to the INIS database.

Non-conventional literature (NCL) constitutes approximately 25% of all input submitted to INIS. Direct online access to all NCL was a need expressed by all participants. It was understood that this will take many years, as INIS has to clarify online access rights and proceed with imaging of the microfiche part. It was also understood that not all NCL will ever be available because of intellectual property rights in various countries. However, there was a strong recommendation that all IAEA publications become available for free on the Internet.

INIS should archive documents found on the Internet if they are in the public domain. This includes ‘open access’ journals and articles put on the Internet by their authors (e.g. the Elsevier model). While developing such a model, which is Internet-centric, INIS also needs to take steps to ensure that those who cannot use high technology also have access to the material. This includes the maintenance of CD-ROM (or similar format) distribution and access. It was noted by participants that CD-ROM remained a preferred mode of access even where Internet access was available. Links between metadata and documents can also be made through the INIS CD-ROM product.

The CERN library offers its print and electronic collections through a combined web interface and maintains its database by semi-automated processes to upload bibliographic and full text records. It receives 60 000 documents of grey literature each year, which could be integrated within INIS. Partnerships with producers could bring such records with links to full text (e.g. Inspec, arXiv e-print archives). Suggestions were offered by which INIS could better match users’ expectations. These included implementing full text linking, increasing currency, expanding search and display functions and developing the richness of the data. Collaboration with the National Nuclear Data Center and the CrossRef DOI resolving service was also suggested in order to increase INIS visibility.

At the start, INIS was planned as a multilingual system to reflect that a number of national nuclear programmes had been established with their own national nuclear terminologies; this objective has never been fully realized. In order to manage nuclear information and knowledge at the international level, it is necessary to have appropriate multilingual linguistic tools that can handle not only translation but also the differences in knowledge formalization found in each language. The important role of the INIS Multilingual Thesaurus as a main linguistic tool for nuclear knowledge management was emphasized.

Deficiencies in coverage have been identified in key areas: conferences and meetings; legal material; standards; training documentation; material published by the European Community; journals covering nuclear technologies and their applications; and a number of non-core journals with a limited number of highly relevant articles. One solution already adopted by the INIS secretariat is to acquire the bibliographic records of journal articles directly from the publishers. Several initiatives were discussed, and it was recommended to extend such electronic acquisitions to other types of material.

There exists a number of valuable sources and services on the Internet. Integrating them into INIS according to a traditional model (by means of bibliographic input and collection of the documents in electronic form) may not always be cost effective, and the use of a distributed access model should be explored. A first task for INIS is to identify some of these resources — examples include preprint servers and the science.org web site, which also has links to US Patents Office information services — and to investigate methods to link and/or integrate them.

3.2.2. Central and regional developments/experiences

RRIAN, the Regional Nuclear Information Network, was established to develop a network of information centres in Latin America and the Caribbean. Its major aim is to improve the electronic access and use of nuclear literature. RRIAN also encourages participation in INIS by Latin American and Caribbean countries. The partners in this initiative are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Paraguay, Peru, Uruguay and Venezuela.

The INIS2 database host site (http://www.inis2.com) in the Republic of Korea acts as a mirror and provides enhanced regional access to the INIS database on the Internet.

The number of users and usage of INIS products in Members States have grown significantly in recent years. The INIS secretariat has launched initiatives to fulfil the needs of Member States to facilitate the dissemination of nuclear information and to reach potential users worldwide.

The users' requirements differ according to their location and level of development. IAEA regional technical cooperation projects should be proposed to network with African countries and to further develop RRIAN in Latin American countries.

INIS should foster a relationship with academia and integrate public domain training material from existing training web sites such as CANTEACH. INIS should also increase the penetration of the INIS database in universities worldwide and in the WNU.

3.2.3. INIS strategic development and the IAEA Library

Networking of nuclear libraries and/or information centres is an important part of the global effort to share information resources and expertise for the peaceful uses of nuclear energy and the development of nuclear sciences and technologies. It provides cost effective access, exchange and distribution of information resources and is a mechanism for cooperation and collaboration. The establishment of the IAEA Consortium of Nuclear Libraries and the development of the International Nuclear Electronic Library (INEL) were recommended. Collaborative reference and information services would provide consultancy and reference services to researchers through an international network of nuclear libraries. The IAEA Library and INIS could together play an active role in building such a platform — network, consortium, access tools and contents — that would form the foundation for a worldwide nuclear knowledge portal.

INIS was created nearly 35 years ago with the mission to provide its members with access to scientific and technical information. Although its methods of collection and distribution have evolved, the mission and objectives of INIS have remained constant: building a bibliographic database and collecting and distributing the full text of non-conventional (grey) literature. It is now agreed that the INIS model must evolve to meet the needs of a changed environment, both political and technical, as well as a different user base. The presentation outlined some of the initiatives from the INIS secretariat — changes to the data format and processing, acquisition of bibliographic records from publishers, adoption of a computer assisted indexing system, enhancement of the INIS database on the Internet and redefinition of the role of INIS at the IAEA — to evolve this traditional model to better serve the needs of Member States and users.

4. HUMAN RESOURCES FOR THE NUCLEAR SECTOR

4.1. AGEING OF THE WORKFORCE AND TRANSFER OF KNOWLEDGE

Maintaining competences in the nuclear industry and nuclear regulatory authorities will be one of the most critical challenges in the near future. There have been very few orders for new nuclear power plants in the western world in the past few decades. The ability of universities to attract top quality students to nuclear programmes, meet the future staffing requirements of the nuclear industry and conduct leading edge research in nuclear topics is becoming seriously compromised in the industrialized countries. National studies undertaken by several member countries of the OECD/NEA have shown that in spite of several initiatives undertaken by them, more engineers and scientists with nuclear knowledge are required than are graduating.

The continuing antipathy of students in many countries towards science, engineering and technology subjects has meant that the proportion of graduates in these areas has been falling in recent years. As a consequence, the competition for them is increasing and the signs are that the nuclear industry is losing out. Thus an additional concern to the nuclear industry is that even the approach of hiring non-nuclear technical graduates and training them in house is adversely impacted.

The major causes for this situation include the following: the decreasing number and dilution of nuclear programmes; consolidation of the nuclear industry; staff reduction and lack of fresh recruitment for over a decade; the decreasing number of students taking nuclear subjects; the lack of young faculty members to replace ageing and retiring faculty members; ageing research facilities that are being closed and not replaced; and the significant fraction of nuclear graduates not entering the nuclear industry.

Currently, the key themes in organizations include rapid response, a flexible employment structure and development of individualism. Consequently, employers are becoming increasingly dependent on the skills, flexibility and commitment of their employees. At the same time the trend is against a life long employment in a single company; for example, in the United States of America the average worker is estimated to change his or her employer every five years. This situation is not conducive to promoting company loyalty in employees and has an adverse impact on transfer of nuclear knowledge from retiring staff members to successors.

This problem is exacerbated by a situation in which nuclear organizations are losing knowledge workers not only to other nuclear organizations but increasingly to non-nuclear industries. Now that it cannot afford any further reduction in existing competences and needs to develop new ones in the areas of decommissioning and clean up, attracting young blood, retaining staff and attracting experts from other sectors in the face of competition from industries perceived as more attractive is proving problematic in many countries.

As a consequence, the average age of the nuclear workforce has been gradually rising for the past several years, a phenomenon commonly referred to as the ageing of the workforce. These workers, including scientists, engineers, technicians and other specialists, have worked in the nuclear industry since its inception and carry with them a vast amount of knowledge and experience that could be lost as they retire in large numbers over the next few years.

Capturing the tacit knowledge before the loss of key individuals as well as capturing the various knowledge repositories that they maintain for personal use is vital in order to reduce the need for performing this effort again. The second challenge is to find the successors to whom this knowledge could be transferred as well as developing the tools and techniques for an effective transfer of the tacit knowledge. Some of the experience in building these knowledge management tools as well as in capturing this information was presented at the conference.

There are some positive trends that indicate a revival of nuclear power growth, including: continuing new construction in Asia, a modest return to new construction in Europe, new plants being seriously discussed in North America and innovative designs being developed through the GIF. Plant life extensions and the improved operational and safety performance of plants overall are enhancing competitiveness and contributing to an improving image of the nuclear industry. However, the success of all of these efforts depends upon having sufficient well qualified personnel for their implementation.

Skills, knowledge and expertise residing with the human resources within an organization cannot be quantified and managed like traditional outputs. Knowledge is mainly people centred and thus requires management of people, with their differing aspirations, their need for independence and their need for job satisfaction gained from personal achievement. While technical skills remain the cornerstone of successful human performance in the nuclear industry, it has become increasingly clear that there needs to be a greater focus on maintaining and improving 'soft skills' such as communication, teamwork, leadership, performance assessment, coaching/mentoring and delegation of authority.

The use of a systematic approach to training has been found to be an effective method for developing training systems that address all competences needed for effective performance (i.e. integration of both technical competences and soft skills). However, skills and knowledge alone do not ensure excellence in human performance. Performance is considered to depend on a combination of knowledge, skills, attitudes, opportunities, efforts and motivations. Training clearly focuses on knowledge and skill, and partially builds or reinforces attitudes. The remaining three factors need to be addressed separately through an appropriate management of human resources.

Several solutions to these problems were presented and discussed during the conference. Key insights include those described in Sections 4.1.1–4.1.8.

4.1.1. Maintaining competence

Maintaining competence is a high priority issue. Continuous technical training, succession planning and effective implementation of a knowledge management strategy are of paramount importance in coping with the adverse impact of the increasing rate of retirement of nuclear workers.

4.1.2. Development of future nuclear workers

Use of enhanced university programmes and performance based training of nuclear power plant personnel are key elements in managing human resources in nuclear organizations.

4.1.3. Maintaining research and development capabilities

R&D is the backbone of an overall programme to maintain competence and advance nuclear technologies. Within companies, R&D is as important for training staff as for technical advancement. Where industry collaborates with universities and research institutes, it is an important source of recruits. In addition, such collaborations provide a reservoir of qualified and experienced personnel, which can service both the industry and the regulatory bodies on an ad hoc basis. Furthermore, R&D performed in universities revitalizes the education system by paving the way for new courses and encouraging academics to become positively engaged with industry.

4.1.4. Mobility of experts

To some extent the human resource situation can be ameliorated through the mobility of researchers and experts. This is often viewed as an important part of the education and training of the individual, on the one hand, and an effective way of coping with a temporary peak in workload or effecting knowledge transfer, on the other. However, in reality the mobility of researchers and experts may be rather limited. It appears that some research organizations are more prepared to accept researchers than to part with their own.

4.1.5. Networking of institutes of higher education

To promote nuclear education, 'e-learning' is a very convenient tool, which the IAEA has been encouraging. Another effective method is to promote networking of institutes of higher education. Several initiatives have been taken in this regard, including the European Nuclear Education Network (ENEN), ANENT and the WNU.

4.1.6. Improving industry–university collaboration

Industry and nuclear establishments in various countries are also experimenting with new methodologies for closer collaboration; for example, several industries are encouraging graduate internship programmes. India has been following a policy of ‘hire and train’ for the past five decades, and in recent years industry in Canada and the United Kingdom has adopted this policy. It is expected that these new initiatives will be able to attract the young generation to take up a career in nuclear engineering.

The measures implemented in Sweden include industry support to universities for professors’ chairs, to lecturers to further develop education material, grants to senior research students and post-doctoral fellows, and funding research in new techniques in important areas, such as waste management and non-proliferation, that are attractive to students. These measures are expected to give rise to a leverage effect by promoting the possibility that universities and institutions of technology could be seen as attractive partners in international research such as European Union (EU) projects.

In the USA, business leaders consider that networks of excellence between universities and industry are the best solution to both research and education needs. Experience indicates that while company researchers are good at addressing short term and urgent problems, universities are the best solution for long term problems or as a source of innovation and new ideas. Student and post-graduate programmes are a critical part of many firms’ staffing plans. More than two thirds of employers that emphasize college hiring use internships or cooperative education programmes to ‘test drive’ prospective employees and create a pool of quality candidates. Participants in post-graduate programmes (internships) have a relatively high rate of conversion to full time employees.

4.1.7. Integrated social network of communities of practice

In the context of the ageing of the workforce, a key component is the identification of not only the individuals about to retire but also the knowledge and the knowledge transfer capabilities that they will take with them when they do so. This loss not only impacts on decisions made about human resources supply side programmes such as education but also on programmes for building communities of practice to foster R&D across regions and countries. Within this context, an integrated social network analysis component provides the ability to map out the network of knowledge on any specific topic that could be integrated within a knowledge management system and/or a portal; for example, integrating this information with the Find-an-Expert Facility embedded in the INIS database would not only provide the names of the experts but also the communities of experts. In this regard the ACM portal, through its digital library, has already taken the first step.

4.1.8. International collaboration

In the context of loss of tacit knowledge due to workforce ageing it is important to point out the responsibility of each IAEA Member State according to the Convention on Nuclear Safety. Article 11.2 states:

> "Each Contracting Party shall take appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life."

As the majority of nuclear power plant operating organizations have taken positive steps to address the ageing workforce situation, including knowledge transfer to the next generation, the IAEA's activities on the management of human resources and knowledge transfer are continuing to receive strong support from Member States. The IAEA and the World Association of Nuclear Operators (WANO) are expected to take the lead in initiating activities that would facilitate retrieving the tacit knowledge available with senior plant operators and transferring it to their successors.

4.2. THE YOUNG GENERATION IN THE NUCLEAR SECTOR

The future of the nuclear industry is with the young generation. A dedicated panel discussion with representatives of young generation networks around the world — Argentina, France, Italy, South Africa and the USA — was held on the final day of the conference. From their different cultural, educational and professional backgrounds, the panellists reflected on the presentations made earlier in the week, providing their perspective on the knowledge management problem as the recipients of the nuclear legacy.

4.2.1. Effectiveness of initiatives for knowledge management

There is awareness in the nuclear industry of many aspects of the knowledge management problem. Current initiatives to combat the potential loss of crucial knowledge appear to focus on increased training and education collaborations with universities and research institutions, but very few innovative solutions are being considered. The educational programmes being initiated are not likely to attract the best talent from other more enticing fields of study and a significant investment is needed by the industry to develop and retain knowledgeable professionals through mentorship and professional development programmes. A methodology should be developed for measuring/grading the effectiveness of each initiative to attract new talent or to retain existing talent as a part of the knowledge management strategy.

Developing an effective and sustainable approach to knowledge management is of significant importance to the nuclear industry. It requires an objective assessment of the current strategies and initiatives and a significant amount of discussion in an open forum to develop new approaches to nuclear knowledge management.

4.2.2. Attracting new talent

Many in the nuclear industry assume that new plant builds will attract new talent. They, however, disregard the non-electricity applications of nuclear science and technology, which are experiencing significant growth or are perhaps 'sexier' options for young talent; for example, medical applications of nuclear technology are of significant importance to cancer diagnosis and treatment, and these applications are acceptable to the general public. Applications of nuclear technology to space power and propulsion — including radioisotopes and fission reactors — hold an appeal to young minds dreaming of space travel. Such applications, which are more socially acceptable, could be used as a 'hook' to engage young minds to further investigate the fields of nuclear science and technology, including nuclear power, waste management and decommissioning.

Young professional need not only a good salary, they also need:

(a) To be proud of their career choice;
(b) To have a well defined future;
(c) To have strong role models and leaders;
(d) To be able to dream about lofty goals;
(e) To feel that they are doing something important for humanity.

In the USA the nuclear fields carry significant prestige and command respect, but the broad range of applications of nuclear technology are not well known to members of the general public. As a result, many highly qualified individuals do not even consider nuclear science and technology as a career option. Others are simply influenced by negative media attention to nuclear technology.

The French Nuclear Energy Society proposes to establish a commission on 'integration of young professionals' and 'competences renewal' (nuclear knowledge management). One of the objectives of the commission would be to convince intermediate management that an investment in young professionals is a valuable long term investment for the entire nuclear community. The commission would be composed of high level managers in the nuclear field, primarily from nuclear related companies (AREVA, CEA, Electricité de France (EDF)) and subcontractors in France.

4.2.3. Transfer of knowledge

Knowledge transfer should not be visualized as a one way flow from the older to the younger generation. Young professionals also have the responsibility to seek out critical knowledge. Moreover, young professionals have many new things to offer; by being uninfluenced by years of experience, the door is left open for innovation. Sometimes ‘relearning’ something with a new perspective can offer an insight into a problem that was considered difficult in the past. As a young professional enters a new job situation, he or she must feel that the door is always open, that no question would be considered a waste of the valuable time of an experienced professional. The cultural basis of a successful knowledge management strategy consists of creating an atmosphere of trust and fairness, the ability to share both success and failures, and freedom of communication and understanding.

4.2.4. Need for strong leaders

Technology is made by people. Hence if technology is to make a difference in the lives of the general public the industry needs capable leaders who can make a difference. The median age of the global nuclear workforce is around 50 years. In 15 years half of the workforce (the most experienced) will retire. This appears to be a very short time, but Admiral Rickover required less than a half of this time to develop and deploy pressurized water reactor (PWR) technology. The motto of the nuclear industry should therefore be ‘Let’s build a glorious future for the nuclear industry and we will have the best of the young generation with us’.

4.2.5. Young generation networks

Young generation networks around the world bring together nuclear professionals in their own countries and regions to promote nuclear science and technology and enable knowledge transfer and preservation. The motivated individuals in these networks recognize the future benefit of an international network. The International Youth Nuclear Congress (IYNC), first organized in 2000, has so far held three successful congresses, in Slovakia (2000), Republic of Korea (2002) and Canada (2004), attracting delegates from more than 30 countries. The next congress will be held in Sweden/Finland in 2006. The IYNC offers an ideal forum for knowledge transfer to the young generation and networking among young nuclear professionals.

5. NETWORKING EDUCATION AND TRAINING

5.1. WORLD NUCLEAR UNIVERSITY

A number of international initiatives address the need for greater numbers of well qualified and educated nuclear industry recruits. The most recent of these is the WNU, launched in September 2003 by the World Nuclear Association (WNA). The founder supporters of the WNU are the IAEA, OECD/NEA, WANO and WNA; membership includes 26 organizations worldwide.

The mission of the WNU is to strengthen the international community of people and institutions so as to guide and further develop:

(a) The safe and increasing use of nuclear power as the one proven technology able to produce clean energy on a large global scale;
(b) The many valuable applications of nuclear science and technology that contribute to sustainable agriculture, medicine, nutrition, industrial development, management of fresh water resources and environmental protection.

The WNU is not a degree awarding institution but a composite of its participating institutions, each of which will continue to teach and award degrees. Its mission is proposed to be accomplished through a worldwide network that coordinates support and draws on the strengths of established institutions of nuclear learning to promote academic rigor and high professional ethics in all phases of nuclear activity, from fuel and isotope supply to decommissioning and waste management. Widely accepted global standards for academic and professional qualifications are proposed to be established.

A distinctive feature of the WNU is that there are no barriers to entry to its membership. It is a voluntary collaboration that offers individuals and institutions the opportunity to bring their strengths, creativity and vision to the task of enhancing nuclear science and strengthening the nuclear profession for an ever wider global role.

One of the main activities is to conduct an annual WNU summer institute, which will comprise six weeks of intensive training to develop and inspire future world leaders in nuclear technology. The first WNU summer institute is proposed to be held in July and August of 2005 at Idaho Falls.

The WNU coordinating centre operates from London, in collocation with the WNA, and focuses on conducting the WNU summer institute and coordinating the activities of the WNU's ten cooperative working groups, each of which comprises a worldwide group of experts in a particular nuclear or nuclear related discipline. One of these working groups is focused on knowledge management, with the goal of transforming the concept into an operational programme of action involving the world's leading nuclear companies and the WNU's institutions of nuclear learning.

5.2. ASIAN NETWORK FOR EDUCATION IN NUCLEAR TECHNOLOGY

Demand for energy and electricity has been increasing more rapidly in the developing countries of Asia than those in any other region of the world. Nuclear power is a strong option to meet the growing energy demand, since it produces no greenhouse gases and well run nuclear power plants are currently the least cost source of electricity in several countries.

Potential constraints on achieving the needed growth of nuclear programmes in the region include a shortage of a qualified and skilled workforce, the erosion of nuclear knowledge due to the decline in nuclear education programmes in universities, decreased enrolment of students and ageing faculty members. Also, the demand for human resources is not confined to the operation of nuclear power reactors but also for increasing the application of nuclear technology in agricultural production, health care and industrial processes.

The type and level of education and training programmes in Asia evolved based on the development paths followed for nuclear power and nuclear applications in each country, and as a result there is a significant diversity among them. Apart from universities and institutions of higher education, various types of education and training in nuclear engineering and technology are also provided by the national authorities responsible for nuclear technology development, research institutions, industry and professional associations. A network arrangement among nuclear institutions was recognized as a potential option to address the regional needs in this regard effectively and efficiently.

Following the first coordinating committee meeting organized by the IAEA in Kuala Lumpur, ANENT was established in February 2004 to promote, manage and preserve nuclear knowledge, to ensure the continued availability of talented and qualified human resources in the nuclear field in Asia and to enhance the quality of human resources for the sustainability of nuclear technology.

Universities, research centres, government agencies and other institutions involved in nuclear education and training in the region are accepted as participating members of ANENT, and international or regional networks are accepted as collaborating members. Currently there are 17 participating institutions from 11 countries (China, India, Indonesia, Malaysia, Mongolia, Pakistan, Republic of Korea, Sri Lanka, Thailand, the Philippines and Vietnam), and three networks (Asian School of Nuclear Medicine, ENEN and WNU) are collaborating members.

The mission of ANENT is to facilitate cooperation in education, research and training in nuclear technology through:

(a) Sharing of information and material in nuclear education and training;
(b) Exchange of students, teachers and researchers;
(c) Establishment of reference curricula and facilitating mutual recognition of degrees and transfer of credits;
(d) Facilitating communication between participating members and other regional and international networks.

The focus of ANENT in the short and medium term is on enlarging the number of participating institutions and full operation of the ANENT web portal for sharing of resources and developing curricula, with pilots in nuclear engineering and nuclear medicine/radiotherapy.

5.3. STATUS OF NUCLEAR EDUCATION AND TRAINING

An OECD/NEA report [1] quantified, for the first time, the status of nuclear education in member countries. It confirmed that in most of the OECD Member States nuclear education had declined to the point that expertise and competence in core nuclear technologies were becoming increasingly difficult to sustain. Several initiatives were identified to correct the situation, some of which are being implemented. The universities have improved the attractiveness of their educational programmes and started interacting early and often with potential students, with positive results. The industry is utilizing more rigorous training programmes and improving coordination with universities and research institutes to attract the younger generation.

Close cooperation between industry, universities and government has been recognized by most countries as a vital factor in improving nuclear education and training and in attracting young talent; for example, the close interaction between educational institutions and large nuclear facilities achieved by the Soviet system of science towns consisting of national research centres side by side with high technology organizations and educational institutions was recognized as the principal strength of the nuclear education system and was continued in the Russian Federation. The 1990s saw public demand for stopping nuclear power development as a consequence of the Chernobyl accident, minimization of financial support for all nuclear R&D, with the consequent loss of half the staff of the Kurchatov Institute, and the disappearance of some scientific institutions. However, due to the strength of industry–university cooperation, along with strong governmental support, the Russian nuclear complex survived the crisis decade. Currently, scholarships, grants, governmental support to scientific schools, etc., are attracting the younger generation back to the nuclear sector. The government has also adopted deferment of compulsory military service for several thousand young nuclear specialists in the past four years.

Networking of universities is an initiative taken by some countries, including Belgium, Canada, Japan, the Republic of Korea and the USA:

(a) The Belgian Nuclear Higher Education Network (BNEN) was created in 2001 by five Belgian universities and the Belgian Nuclear Research Centre (SCK•CEN) as a joint effort to maintain and further develop a high quality programme in nuclear engineering in Belgium. The course programme leads to the degree of Master of Science in Nuclear Engineering. All the subjects are taught by academics appointed by the partner universities, and the practical exercises and laboratory sessions are supervised by researchers from SCK•CEN. The final thesis offers an opportunity for internship in industry or in a research laboratory.

(b) In Canada an alliance of universities, nuclear power utilities and research and regulatory agencies known as the University Network of Excellence in Nuclear Engineering (UNENE) was established to ensure a sustainable supply of qualified nuclear engineers and scientists to meet the current and future needs of the Canadian nuclear industry. Under this programme, five major Canadian universities offer not only full time undergraduate and graduate degrees but also part time programmes delivered at nuclear sites, designed for students already employed. In addition, the industry started a new graduate hiring programme to balance the demography of nuclear workers and ensure continuity. The new graduates are rotated through a few different areas prior to taking up a specific position. Many summer students and 'co-op' students, who alternate between university and industry, are encouraged to choose a nuclear career by being hired and trained for specific positions.

(c) In Japan the JAIF proposed that a new network system be established for the education and training of nuclear personnel through cooperation between universities, research organizations and industry. In order to maintain continuous availability of basic knowledge on nuclear engineering and technologies under conditions in which students are not attracted to the nuclear field, these subjects were incorporated into other courses of study. Some of the Japanese universities providing systematic nuclear education programmes in their graduate schools have changed the names of their departments, so that the word 'nuclear' has been changed to broader words such as 'quantum', 'energy' or 'system'.

(d) In the Republic of Korea the Korean Atomic Energy Research Institute (KAERI) is making efforts to establish a Korean network of nuclear education and training and a cyber education system to facilitate a national level integration of nuclear education and training institutions and to systematically link them with ANENT.

(e) In the USA the Nuclear Engineering Department Heads Organization was formed in the early 1980s as a forum for discussion, coordination and collaboration on the issues facing academic programmes, emphasizing nuclear and radiological engineering. Several programmes and partnerships between universities and industry and government have been successfully established. Since 2000, students appear to be attracted to a nuclear career, due to a robust nuclear job market and one of the highest starting salaries in the engineering field.

Specialized institutions have been established in some countries to ensure a continuing supply of qualified and well trained engineers and technicians in the nuclear field:

(i) The Institut national des sciences et techniques nucléaires (INSTN) in Saclay, France, with a total staff strength of only 120, is a good example. It is a higher education establishment placed within the CEA. It has access to more than 1000 teachers, drawn from the best CEA specialists, university professors, researchers from public organizations and industry, and engineers from the electricity production company (EDF) and industrial companies involved in nuclear reactor fabrication and the fuel cycle (AREVA group). Thus it is ensured that the courses take into account the latest developments in the subject areas.

(ii) The Bhabha Atomic Research Centre Training School in India, established in 1957, is continuing to follow the approach of hiring graduate and post-graduate engineers and scientists from the universities every year and training them in nuclear engineering and the nuclear sciences. The teachers are obtained by networking with the R&D laboratories and industrial facilities under the Department of Atomic Energy (DAE) of India as well as the universities. The guarantee of employment at the end of the training period has significantly helped to maintain the ability to attract fresh graduates and post-graduates, even during the years of stagnation in nuclear power growth.

(iii) Following the decision of the Swedish Parliament to phase out nuclear power, the Swedish Centre for Nuclear Technology (SKC) was established in the early 1990s to ensure that the competence required for safety and non-proliferation work is maintained and developed within the Swedish Nuclear Power Inspectorate (SKI) as well as at the licensees' facilities and elsewhere in the country. The SKC, financed by the SKI, ABB–Atom (subsequently ABB–Westinghouse) and the Swedish utilities, provides PhD students with full grants in topics related to nuclear technology.

(iv) In Brazil the National Nuclear Energy Commission (CNEN) established the Energy and Nuclear Research Institute (IPEN) for the education and training of nuclear workers. The IPEN, in association with the University of Sao Paulo, conducts courses leading to master of science and PhD degrees in the areas of nuclear technology material, applications and nuclear power reactors.

Initiatives to improve the education and training of nuclear workers and efforts to attract the younger generation might be faced with a high risk of failure if the country's nuclear power programme is being phased out, as illustrated by the case of Lithuania. The Kaunas Technological University is specialized in providing nuclear education for bachelor's and master's courses. Several steps had been taken to attract the younger generation to nuclear courses, including organization of seminars, conferences and meetings with students graduating from secondary schools and publication of articles in popular journals. The university made agreements with the Ignalina nuclear power plant regarding additional scholarships and guarantees of employment for nuclear engineering students. However, the decision for an early shutdown of the Ignalina nuclear power plant nullified the results of these initiatives, as students do not wish to choose a course of specialized study that is perceived to have no future in the country.

With regard to the use of advances in IT, most nuclear power plant operating organizations are using IT to improve their systems for designing, developing and implementing training programmes, and for other human resource management functions. Some organizations have implemented or are now implementing integrated human resource management systems for all activities concerning planning, employment, organizing, assessment, training, development, protection of health and deployment of human resources in the organization. Use of IT tools for knowledge management is not yet common in most Member State nuclear power plant operating organizations. E-learning is used by some but not by the majority of operating organizations, and generally in limited ways (e.g. general employee refresher training). Some operating organizations have integrated computerized operation management systems, including work planning and control and document management functions. The outputs of these systems are readily available to all plant personnel through intranets.

6. NUCLEAR KNOWLEDGE MANAGEMENT POLICIES AND STRATEGIES IN MEMBER STATES

Several initiatives have been taken by Member States to manage and preserve knowledge. Industry and nuclear establishments in various countries are experimenting with new methodologies and have proven their long term competitiveness and sustainability through actively managing their core competences and knowledge as strategic resources. Much can be learned from their experience, as the fundamental elements of knowledge management remain essentially the same in different countries and organizations. Based on the papers presented at the conference by delegates from each of the participating Member States, the knowledge management policies and strategies in their countries are highlighted below.

6.1. COUNTRIES WITH OPERATING NUCLEAR POWER PLANTS

6.1.1. Argentina

The first nuclear power plant, Atucha I (313 MW(e)), a pressure vessel type heavy water reactor, designed and constructed on a turnkey basis by

Siemens–KWU of Germany, entered commercial operation in 1974. The second nuclear power plant, Embalse (600 MW(e), CANDU type), attained commercial operation in 1984. In 1981 the construction of Atucha II (745 MW(e), Atucha I type reactor) was started by the main contractor, Siemens. The project experienced considerable delays due to a variety of reasons, including financial, and currently 82% of the construction has been completed and the decision of the government to complete the project is awaited.

The original designer, Siemens, transferred its nuclear activities to Framatome–ANP. Fifty per cent of the professionals with knowledge on this type of reactor are over 50 years of age and will be retiring over the next 10 years. The number of university students in the nuclear field is very small. These are some of the important factors that motivated the National Atomic Energy Commission (CNEA) to develop and implement a knowledge management system.

Argentina needs to capture and preserve knowledge on this type of reactor, since it is unlikely to be built anywhere else in the world. Knowledge on all aspects of this type of reactor would be required for extending the service life of Atucha I and completing Atucha II, if approved by the government. It would also be required for the long term operation and maintenance of the two units and their eventual decommissioning.

The knowledge management strategy was based on identifying the critical knowledge to be preserved. The methodology used was to prepare a knowledge map that structures the knowledge of an area or domain and enables a comprehensive visualization of the domains of available knowledge in the company.

To evaluate the critical importance of the items of knowledge the following characteristics were used: rarity and inability to replace; strategic usefulness to the company; level of difficulty in identifying the source of knowledge; and level of complexity in using the knowledge. The knowledge map also facilitates the design and development of a knowledge portal.

Argentina is an active participant in RRIAN, which was established to develop a network of information centres in Latin America and the Caribbean. Its major aim is to improve the electronic access and use of nuclear literature and encourage the participation of Latin American and Caribbean countries in INIS.

6.1.2. Armenia

The Armenian nuclear power plant at Metsamor consists of two units of the WWER-440 type that entered commercial operation in 1976 and 1980, respectively. The Armenian nuclear power plant was the first in the former

Soviet Union to be built at a site with high seismicity. Nuclear knowledge in Armenia was at a high level of development in the 1970s, as several Armenian specialists and institutions participated intensively in all aspects of the siting, designing to suit the seismic conditions, construction and operation of the Armenian nuclear power plant units. After the 1988 earthquake, owing to public demand, the Armenian nuclear power plant units were shutdown in 1989, leading to dissipation of some of the knowledge and expertise.

Subsequent to the collapse of the Soviet Union, Armenia suffered from an energy crisis caused by the shortage of domestic energy resources, and in April 1993 the government decided to restart unit 2 of the plant. Efforts were made to recover the lost knowledge by training Armenian specialists at relevant science centres and nuclear power plant sites in the Russian Federation. Unit 2 was successfully put back into operation in November 1995.

At the Yerevan Polytechnic Institute, the Nuclear Power Plants and Installations Department that was closed down in 1989 was restarted in 1993. Currently, 12 to 15 nuclear power plant specialists graduate from the institute every year. In addition, there is a new branch called the Physics of Nuclear Reactors, which has an annual output of four or five graduates.

The former Science–Research Institute of Energy, with its Nuclear Energy Science–Research Department, established in 1973, became the leading organization in the Soviet Union, developing training systems for nuclear power plant operations personnel and the first digital full scope simulator for the WWER-1000 unit of the Novovoronezh nuclear power plant. The staff strength at its peak was about 450 persons, but the institute practically stopped work after the collapse of the Soviet Union. The institute was restarted in 1993 under the new name the Armatom Institute and is one of the main technical support organizations in Armenia for nuclear power. Similarly, the other technical support organizations, Atomservice and Atomseismoproject, were restarted in 1993.

Currently, proposals are being prepared for carrying out an inventory of the knowledge accumulated in Armenian institutions and for collecting the tacit knowledge residing with many retired specialists. The need for the development of a knowledge portal that could be accessed by all nuclear workers has been recognized.

6.1.3. Belgium

The Belgian Nuclear Research Centre SCK•CEN, founded in 1952, has always been a nuclear knowledge orientated organization. The need for a knowledge management system was highlighted after the government decided to phase out nuclear power plants.

The BNEN was created in 2001 by five Belgian universities and SCK•CEN to maintain and further develop the high quality programme in nuclear engineering in Belgium.

In 2002 SCK•CEN started development of a knowledge management approach to suit the specific needs of a nuclear research centre. The corporate knowledge management strategy was aligned with the organizational strategy: to encourage creativity and innovation for the survival and growth of the organization; to generate new knowledge; to ensure sustainable added value to the research work; and to stimulate scientific excellence. The existing knowledge networks were first identified and involved in pilot projects, as they would be enthusiastic proponents and could play the role of early adopters of knowledge management.

Existing systems to capture knowledge were selected for upgrading to be components of the knowledge management system. These include the quality assurance system, which requires writing down what is proposed to be done, and the information management system. To gain the trust of the knowledge workers, a library portal was set up to offer scientific information services to all users, with the integration of quality external scientific information sources with traditional library services. This library portal is gradually evolving towards a knowledge management portal.

Interactive communities of practice were set up through open source web based portals to facilitate elicitation of tacit knowledge while fostering collaboration through better internal communication channels. The current knowledge management and community portals at SCK•CEN include a library portal that evolved into a knowledge centre portal, a waste and disposal community portal and an instrumentation departmental portal used as an experiment management system for the gamma radiation facilities at the centre.

Currently, new paths to capture the documented and tacit knowledge of employees nearing retirement are being explored. The role of SCK•CEN in future projects funded under the sixth Euratom framework programme include building a knowledge centre for the Network of Excellence on Micro-optics with the same underling toolkit as that used in the internal knowledge management projects, coordination of the project for building the Network of Excellence on Actinides, implementation of a web based portal for knowledge management and project management and training as the overall project coordinator of the Integrated Project in the Near Field Key Processes for Nuclear Waste Disposal.

6.1.4. Brazil

Brazil developed a considerable amount of knowledge in the nuclear domain through a long term investment over several years in research as well as technology transfer. As this body of knowledge faces a risk of being lost, the need for introducing a knowledge management system emerged.

A methodology to identify, analyse and map the important knowledge within the organization was tested in a pilot project in the radiopharmacy centre of IPEN, the national nuclear research centre. Knowledge was identified through the study of processes and associated activities, followed by discussions with the knowledge workers. The approach of knowledge classification by domains was used to represent the knowledge assets pictorially. The criticality of each domain was assessed based on its relevance to the organizational objectives and its degree of vulnerability.

The Board of Radioprotection and Nuclear Safety is constructing a nuclear knowledge portal to preserve and manage the knowledge generated by professionals in the area of the licensing and control of nuclear facilities. The portal will be a repository of documents and information needed to support the main tasks in this area, such as engineering analysis, operational data, maintenance records, regulatory reviews and safety analysis report evaluations, thereby improving work, reducing search time and making collaborative work easier.

The State owned utility Eletronuclear established a special project called Determination of Technological Know-how of Electronuclear in January 2001 as a first step to preserve its essential technological know-how. The extent and location of the existing know-how was identified and the gaps in the essential know-how were evaluated. The results of this know-how survey were stored in an electronic databank, which facilitated the creation of several types of report. Proposals for short term and long term solutions to fill the gaps in the know-how were prepared. An indirect consequence was the creation of a nucleus of personnel competent in knowledge management, leading to the execution of other projects in knowledge management. Currently, knowledge management is being established as a permanent activity.

6.1.5. Canada

The Canadian nuclear industry and its regulatory agency, the Canadian Nuclear Safety Commission (CNSC), have recognized the importance of nuclear knowledge management and have already implemented a number of initiatives in order to maintain competence, capture and preserve existing knowledge, advance nuclear technology, develop future nuclear workers and maintain a critical R&D capability.

Over the past few years, plans have been developed at Atomic Energy of Canada Limited (AECL) and in other sectors of the industry to identify critical core competences and the schedule of future retirements and to prioritize the core competences to be tackled first. Development of future nuclear workers received a boost through the UNENE programme in Canada, which was launched in 2002. UNENE is an alliance of six Canadian universities, nuclear power utilities, AECL and the CNSC.

Capturing and preserving existing knowledge is taking place in Canada through a number of activities, notably the CANTEACH programme. Canadian utilities such as Ontario Power Generation, Bruce Power, New Brunswick Power and Hydro Quebec have been continuously updating their documentation on plant configuration and introducing new training programmes to enhance nuclear technology knowledge among staff.

Sustainability of R&D capabilities has also been addressed by the CANDU Owners Group through a review of R&D capability in Canada, and recommendations on necessary actions have been issued. Since then, AECL has undertaken a supplementary R&D programme in support of new features of the advanced CANDU reactor design.

6.1.6. China

The China Nuclear Information Centre (CNIC) is a comprehensive information research and publishing institution in the nuclear field and is the INIS representative for China. It has a central library and separate divisions for nuclear patents, information consultation, programme research, nuclear economic analyses, INIS coordination and translation. The translation division translates into Chinese all IAEA publications as well as the IAEA Bulletin.

The INIS division coordinates all the work related to INIS and facilitates its use by Chinese organizations. As data transfer from the IAEA over the Internet is slow, all the INIS data is migrated to the CNIC web site.

Chinese research organizations, universities, public libraries, nuclear plants and government authorities, as well as individual researchers, engineers, technicians, students and administrators, obtain information through the CNIC. Information from all these sources is also provided to the CNIC for publishing.

6.1.7. Finland

The forthcoming retirement of a large proportion of the staff who had worked in nuclear power plants from the beginning in Finland posed a significant challenge in transferring tacit knowledge to the successors. These senior employees have tacit knowledge related to the commissioning and initial operation of the power plants, a vast experience in all aspects of their operation and maintenance and effective domestic and international relations. This kind of tacit knowledge residing with employees had not earlier caused problems, as the turnover of workers has been low.

Helsinki University has completed a pre-study of the planned two year research project at the Finnish nuclear power plants regarding effective methods to transfer tacit knowledge. It was found that systematic methods for sharing this complex knowledge are still lacking. Six existing methods for sharing tacit knowledge are being utilized in the organizations, out of which three are connected to sharing tacit knowledge in a tacit form through socialization: mentoring, apprenticeship and occupational instruction. The remaining three methods are connected to externalization of tacit knowledge: writing memos, compiling situation reports and producing training material. The data gathered in this study indicate that tacit knowledge cannot be fully shared by verbalizing and disseminating it.

However, not all of the tacit knowledge embedded with these experts was considered worth transferring; in particular, some customs and practices were found more effective among the younger generation, and some prevailing practices were not desired to be maintained.

Another component of the tacit knowledge was related to the construction of new nuclear power plants. Documenting the tacit knowledge in an explicit form to the extent possible and ensuring the transfer of the remaining tacit knowledge to the successors is planned. Furthermore, challenges were also found in creating new training material and developing more multifaceted and interactive training, which would lead not only to transfer of explicit knowledge but also to effective transfer of tacit knowledge.

6.1.8. France

A strategic target was set at the Lisbon Summit in 2000 to turn the EU into an economic area whose performance and competitiveness are based on knowledge as a force to create jobs and cement social cohesion. It is France's ambition to play a leading role in the construction of Europe, an ambition that involves rising to the challenge of reconciling the need for openness and the distribution of knowledge with the need to maintain the competitive edge of partner enterprises, nations and Europe itself.

Knowledge management has been an important part of the CEA's quality charter for nearly a decade. Several successful knowledge management projects have resulted in the creation of 'knowledge basics'. R&D efforts at the CEA on methods and tools used in knowledge management have been further strengthened, as demonstrated by a number of partnership agreements signed with different enterprises.

The INSTN, whose primary mission is the transmission of knowledge and know-how from not only the CEA but also other French organizations such as EDF, AREVA and the Institut de radioprotection et de sûreté nucléaire, is playing a leading role in both initial and continuing vocational training and is encouraging people to choose nuclear related disciplines as well as helping in creating awareness of the importance of managing nuclear knowledge.

As part of the Euratom initiative in the fifth EU Framework Programme for Research and Technological Development (FPRD), France took part in the creation of the ENEN. This initial EC project on nuclear education and training in Europe started in January 2002 and terminated at the end of 2003. ENEN assembled European nuclear education and training institutions with the objective to develop a European master's degree in nuclear engineering (Euromaster). In addition to that objective, ENEN offered training courses in selected subjects that were held on a shared basis by several participating institutions, so that students would spend part of the course time at each participating institution (e.g. the Eugene Wigner courses), demonstrating the feasibility of joint nuclear education in Europe.

After the end of that ENEN project, a follow-up EC project was established under the name of the Nuclear European Platform of Training and University Organisations (NEPTUNO), as part of Framework Programme 6.

In parallel, participating institutions established a new organization in September 2003, the ENEN Association. The Euromaster degree has been agreed upon and introduced, including the curriculum, mutual recognition of the degree, awarding procedures and funding mechanisms.

The OECD/NEA has been focusing on identifying the resources required to maintain competence at the required level in the future. The measures taken by the OECD/NEA are designed to pool both the specialist skills and the available R&D infrastructure between the member countries as part of a drive to launch new international research projects on safety, along the lines of the Cabri initiative in France, which covers high burnup nuclear fuel.

6.1.9. Germany

The situation in Germany is as follows:

(a) No new reactors have been built since 1985;
(b) Personnel are now approaching retirement age;
(c) A nuclear power phase-out has been decided upon and measures have been taken to terminate operations prior to the scheduled end of plant life;
(d) Working in nuclear power has less prestige than in the past;
(e) Courses in the nuclear area are offered by only a few universities and research programmes have been reduced;
(f) The number of students graduating in nuclear related subjects dropped to almost zero in 2001.

However, irrespective of the phase-out policy, in the next decades it will be necessary to maintain competence in nuclear safety to meet the requirement of ensuring the safety of nuclear installations and waste disposal. Studies indicate that:

(i) Deficiencies in maintaining knowledge at state of the art levels and a subsequent degradation in education and training of operating personnel may endanger the safe operation of nuclear installations;
(ii) Knowledge deficits at authorities and expert organizations due to a lack of qualified successors would be an imminent threat to competent supervision of the safety of reactor plants.

An ‘alliance for competence’ has been established by the four major research organizations in Germany to track trends in employment and educational capacities, increase cooperation with universities and international initiatives, coordinate research programmes, promote qualified students and cooperate in furthering international safety standards. Pooling education and training in a supranational structure is the aim of the ENEN, which has initiated a virtual university to develop cooperative nuclear education in Europe. Eighteen universities from 17 countries are participating, offering courses ending with the award of the European Master of Science in Nuclear Engineering.

Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) is cooperating with the IAEA in a pioneer international project for a nuclear safety network to compile, analyse and share safety knowledge among Asian countries — the ANSN. A hub already established at GRS serves as a portal for the ANSN for access to German nuclear safety knowledge and experience. Experience emerging from this project will be most valuable for the further development and integration of safety networks in Germany. GRS is involved in the European Network of Excellence for a Sustainable Integration of European Research on Severe Accident Phenomenology (SARNET). Communication and collaboration with about 25 organizations and 200 participants is supported by advanced communication tools operated on its servers. The tools provide facilities to manage documents, discuss topics of common interest, organize the project's work packages, search and retrieve information on different topics, and more.

Germany is an active participant with several EU Member States in the Eurosafe initiative for promoting cooperation on safety issues. The Western European Nuclear Regulators' Association has been established as an association of the heads of nuclear regulatory authorities in western European countries to pursue the development of a common approach to nuclear safety and regulation and to provide an independent capability to examine nuclear safety and regulation in EU candidate countries.

6.1.10. India

The DAE in India, established 50 years ago, has pursued its activities with a focus on the development and transfer of knowledge towards the goal of self-reliance. Currently, India has an expanding nuclear power programme, with 14 reactors in operation, nine reactors under construction, including a 500 MW(e) prototype fast breeder reactor, radiation technology applications and a vast pool of well trained professionals and experts in all aspects of the fuel cycle and radiation technology applications.

India perceives knowledge management to comprise human resource development, scientific information resource management, technology transfer and technology assessment. Development of individuals was given an important place in the DAE from its inception, as it is considered to be the key element of knowledge management.

In order to attract bright young students graduating from universities, the principle of 'hire and train' has been adopted since the beginning and is being continued. The policy followed is that the first degree should be as broad as possible so as to provide enough employment opportunities for the young graduates. Specialization in nuclear areas should be acquired as a part of a second degree on the basis of an assured career path.

In recent years, a new scheme has been set up to include training in educational institutions, with a significant research component in areas of interest to the atomic energy programme. The research work leads to considerable enrichment of the training programme and also forms a valuable input to the programmes of the DAE.

Other dimensions of nuclear knowledge management in India include:

(a) Broad based funding of the university system and a consortium approach to collaborative research between scientists in the universities and DAE R&D centres.
(b) Buildup of skills and technologies in industry through collaborative technology development activities and setting up of captive technology centres in special areas.
(c) A framework agreement with the University Grants Commission (UGC) to set up the UGC–DAE Consortium for Scientific Research to involve the universities in DAE programmes.
(d) A proposal to set up a virtual university linking all the research centres and the grant in aid institutions to provide several well structured programmes for enhancing the educational qualifications of the employees and to attract young talent to join DAE institutions.

6.1.11. Japan

The fundamental law of atomic energy, which strictly restricts the application of atomic energy to peaceful uses, was established in Japan in 1955. Currently 29 boiling water reactors and 23 PWRs are in operation, five units are under construction and six units are planned to be built. Total capacity in operation is 45.7 GW(e) and the nuclear energy share is 30% of the total electricity generation in Japan. Several accidents have occurred in the nuclear facilities of electric power companies and the Japan Nuclear Cycle Development Institute during the past 10 years. In spite of these accidents, the important role of nuclear energy to sustain the lives of people in Japan is intact. Construction of nuclear power plants is likely to continue until 2010. Thereafter, replacements of nuclear power plants after 60 years of service are foreseen in the 2030s.

A lot of attention has been directed to the preservation of nuclear technology, competence and expertise until the period of replacement construction, in particular during the period between 2010 and 2030. Under the conditions of shrinking nuclear industries, the question of maintaining the present education system has also been receiving serious consideration in the universities. At present, nine universities provide nuclear education programmes in their graduate schools, although the departments of several universities have changed their names, in that the word ‘nuclear’ has been changed to broader words such as ‘quantum’, ‘energy’ or ‘system’.

Japan can fall back on the example of the traditional process of technology transfer from generation to generation in the Ise Jingu Shinto shrine , which traditionally moves and rebuilds its wooden sanctuaries every 20 years. This tradition has continued for over 1000 years, with a short interruption of 150 years in the wartime of the mediaeval ages. Ise Jingu officials explained that the period of 20 years was not chosen for the reason of technology transfer but comes from their philosophy of the holy place. This system of rebuilding every 20 years, however, has proved that technology, even if sophisticated, can be transferred from generation to generation for over 1000 years.

6.1.12. Republic of Korea

The importance of nuclear knowledge management for the preservation and transfer of knowledge to successors is widely recognized in the Korean nuclear community. International cooperation in facilitating the mobility of nuclear personnel to the countries where the need exists is considered an important measure to attract the young generation, develop the careers of nuclear personnel and upgrade the education and training capabilities in the country to an international level, thus increasing the mutual benefits. The needs for developing advanced nuclear technologies combined with other emerging technologies are also hoped to be addressed through international cooperation, and the expected framework of future cooperation for nuclear education and training might need to focus on the integration and sharing of available resources at the national, regional and inter-regional levels.

The global networking concept was conceived by KAERI, which includes ANENT as an important part. KAERI, on behalf of the Korean government, initiated discussions with the IAEA about the establishment of ANENT at the IAEA Scientific Forum on Knowledge Management held in September 2002. Subsequently, in July 2003 KAERI hosted an IAEA meeting to facilitate the establishment of ANENT. The institute actively supported the preparation of the ANENT framework, established a temporary web site and continued its active involvement in launching ANENT in February 2004 at the first ANENT coordination committee meeting.

The committee identified five group activities and their respective coordinators. KAERI became the coordinator for group activity 1, on the Web-based Exchange of Information and Material for Nuclear Education and Training, and established the ANENT web site, linking it with different sources. Information and material for nuclear education and training is being collected and loaded into the database. An important feature of the link function is an interconnection between the ANENT web site and INIS2.com, which is a host site of INIS for Asia. Also, substantial effort has been made, on the part of KAERI, for the establishment of a cyber training system on its own web site.

Web based networking is expected to promote communication and sharing of information and material, including multimedia and cyber material related to nuclear education and training, between ANENT members. It will also promote a joint creation of the required information and material. These will also facilitate greatly ANENT members in their self-learning as well as in their implementation of and participation in specific ANENT activities, for example regional and bilateral education and training programmes, including distance learning. Also, members in need of introducing new nuclear programmes or expanding their ongoing programmes will benefit from the establishment of the required human resource development infrastructure. Furthermore, young generations in Asia will be encouraged by the network, which is intended to facilitate a regional level mutual recognition of educational credits and thereby provide more meaningful opportunities for region-wide master and doctoral courses. Finally, the web based network for ANENT is expected to play an important role within the framework of a global network, cooperating with other networks like the WNU network. Thus this will lead to the establishment of internationally qualified curricula to deal with advanced nuclear technology combined with other emerging technologies, including bio-, nano-, information and space technologies.

6.1.13. Russian Federation

Since the very beginning of nuclear energy utilization in the former Soviet Union, the problem of the generation and accumulation of nuclear knowledge and providing the necessary human resources to apply this knowledge have received strong governmental support. Even in the face of severe difficulties, this policy has succeeded in meeting the needs of defence as well as the peaceful applications of nuclear energy. The lesson from this experience is that in a fast developing system, knowledge accumulation and transfer issues are solved almost automatically. The main elements of knowledge management that led to the past success are briefly described below.

A system of national research centres was created that went far beyond the needs of defence to achieve the widespread use of nuclear energy for peaceful purposes. These centres resulted in ‘science towns’ — relatively small towns with scientific R&D, testing of new techniques and training of high class specialists as the main activities. These towns gradually attracted other high technology organizations and educational institutions. Over 15 such towns devoted to nuclear aspects exist now in the Russian Federation. The nuclear technical university in Obninsk, which has 4000 students, provides specialists for the most important nuclear areas.

Nuclear schools were formed around eminent scientists working on major nuclear energy issues; these schools formed creative teams for the natural transfer of nuclear knowledge. The Federal Atomic Energy Agency provides organizational and material support to the Russian nuclear education system. Close connection between educational institutions and the country's largest nuclear centres was a principal element of the Soviet nuclear education system, which is continued in the Russian Federation today.

The public demanded cessation of nuclear power development after the Chernobyl accident, and governmental support to all nuclear R&D organizations was reduced to a minimum. In the 1990s the Kurchatov Institute lost half of its staff, and some scientific institutions simply disappeared. The collapse of the Soviet Union weakened ties with some research centres important for the whole nuclear complex, including the Kharkov Physics and Engineering Institute in Ukraine, the Belarus Nuclear Centre (which originated the family of fast reactors), the Kazakhstan Experimental Base, with a unique pulse reactor, and some others.

Due to the strength of the earlier knowledge management strategy and the policies of the former Soviet Union, the Russian nuclear complex survived the crisis decade. Over the past five years nuclear energy production has increased by a factor of about 1.5. Four new nuclear power units designed in the Russian Federation have been commissioned and five nuclear units of Russian design are under construction abroad. The current Russian political leaders have a clear recognition of the long term need to develop nuclear power. A high rate of technological innovations is taking place in the field of nuclear reactors and fuel cycles, based on the knowledge and experience accumulated during the first 50 years of nuclear development.

Scholarships, grants, governmental support to scientific schools, etc., are attracting the younger generation back to the nuclear sector. A new form of education has been introduced through the establishment of higher education institutions in the large scientific centres, which makes it possible for second or third year students to take part in important scientific research. Understanding the urgency of attracting the youth to science, the government has adopted deferment of compulsory military service for several thousand young nuclear specialists in the past four years.

On the social level, the Nuclear Society of Russia created the Young Generation Department, which managed to launch wide ranging promotional campaigns aimed at attracting young people to nuclear science and the industry and at increasing the prestige of the nuclear profession. It also successfully enhanced international cooperation. Preservation of the experience of the older generation of experts, who were directly taught by the nuclear pioneers, is being achieved through innovative methods, including conferences on the history of science, technology and plant design and commissioning, leading specialists to write books on the accumulated experience of their successes and failures.

6.1.14. United Kingdom

The capture and retention of knowledge is playing a vital part in the UK nuclear industry. The past focus of activities in the UK was primarily on operations: enrichment, fuel manufacture, electricity generation, reprocessing and waste management. More recently, the same level of priority as that for operations has been assigned to cleanup and decommissioning, including the many small sources used in agriculture, hospitals and other industries, the care and maintenance and decommissioning of those reactors that are coming to the end of their lives, and also the legacy facilities at sites such as Sellafield and Dounreay. Thus there is an opportunity for setting up processes and systems to capture the information, knowledge and skills that are gained during this exciting period for the industry, which will prove invaluable for use in future cleanup activities.

British Nuclear Fuels (BNFL) has invested in four university research alliances. These are:

(a) The radiochemistry research alliance at the University of Manchester;
(b) The particle technology research alliance at the University of Leeds;
(c) The waste immobilization research alliance at the University of Sheffield;
(d) The material performance research alliance at the University of Manchester Institute of Science and Technology.

The research alliance at Manchester has been up and running since June 1999 and has achieved the first PhD on plutonium for 20 years. Several students who have completed their studies at the university research alliances have gone on to other international research centres or were recruited by BNFL. Undergraduate courses in nuclear related areas are also supported. Appropriate parts of research programmes are placed with the alliances, providing real projects for the students as well as giving them an insight into work in the nuclear industry, thus encouraging them to follow a nuclear sector career.

6.1.15. United States of America

Great strides have been made in the field of knowledge management in the USA, and well established knowledge management strategies and implementation policies are being pursued by a wide variety of organizations, including those belonging to the nuclear industry.

The nuclear knowledge management experience of the International Criticality Safety Benchmark Evaluation Project (ICSBEP), an OECD/NEA project implemented by the Idaho National Engineering and Environmental Laboratory (INEEL), could be cited as a good example. The ICSBEP has preserved data and methodologies from thousands of integral experiments performed since the beginning of the nuclear industry in a form that will be of use to the criticality safety and nuclear data communities for decades.

Over 250 scientists from around the world have combined their efforts to produce the International Handbook of Evaluated Criticality Safety Benchmark Experiments [2]. The work of the ICSBEP has highlighted gaps in data, retrieved lost data, helped to identify deficiencies and errors in cross-section processing codes and neutronics codes, improved experimental planning, execution and reporting, preserved valuable criticality safety experimental data and widely distributed the handbook, which is currently being used in 58 countries.

6.2. OTHER COUNTRIES

6.2.1. Cuba

The Agency for Nuclear Energy and Advanced Technologies (AEN.T.A) recognized the need to establish a knowledge management system. The following steps have been taken so far in this regard.

The AEN.T.A has created an executive intranet site, which has seven dynamic applications on information management, dealing with the organization, corporate documentation, projects, human resources, economic results, international collaboration and the INIS database. The site is under continuous development.

A portal (http://www.aenta.cu) has been set up as part of the development of the web site for the AEN project. This site is the nuclear sectoral node belonging to the network of the Cuban National Energy System and is also linked from the Rednerg portal (http://www.energia.inf.cu).

In order to facilitate distance learning, a web based system called LaEscuela was developed. This site can be accessed by all institutions belonging to the AEN.T.A.

The Higher Institute of Technologies and Applied Science has carried out a case study on the partial implementation of a knowledge management system in the institute by mapping the existing knowledge and identifying the gaps with respect to the required knowledge and competences. The study identified areas in which special training was required. The personnel of the organization conducted a course utilizing tacit knowledge to improve the situation.

6.2.2. Indonesia

Indonesia is the largest archipelago in the world. It consists of more than 17 500 islands (6000 inhabited); five of these are major islands (Sumatra, Java, Kalimantan, Sulawesi and Irian Jaya). The total population is approximately 214 million, but more than half of Indonesia's people live on the island of Java. Nuclear power is the most sustainable alternative at present for replacing the fossil base load generation, especially in Java, and is needed not only to reach an optimum energy mix considering costs and the environment but also to relieve the pressure arising from increasing domestic demand for oil and gas.

The Indonesian strategy for developing the knowledge and capabilities for large scale utilization of nuclear energy focuses on strengthening national capacity building through human resources development, scientific facilities development and national participation in projects and technology transfer.

The National Nuclear Energy Agency (BATAN) is responsible for the nuclear R&D programme, establishing the necessary infrastructure and developing human resources. BATAN has made significant progress in building a nuclear science and technology complex in Serpong and developing highly competent personnel to support the national nuclear power programme. BATAN has three research reactors: the Triga mark II reactor (2000 kW), in operation since 1965 at Bandung, the Kartini reactor (100 kW), in operation since 1979 at Yogyakarta, and the multipurpose 30 MW research reactor at Serpong. Additional facilities at the Serpong nuclear research centre include a research reactor fuel element production facility, an experimental fuel element installation, a radioactive waste management facility, a radiometallurgy installation, a reactor safety testing facility, an informatics development facility, a nuclear instrumentation and design facility, and a hot laboratory.

The nuclear workforce problem has also arisen in Indonesia, as few students choose the nuclear engineering field, due to reduced job opportunities, and one nuclear engineering department at the undergraduate level has been closed due to a lack of students. In response to this situation

BATAN proposes the following solutions: establishing a school for nuclear engineering in Yogyakarta, promoting a fellowship programme to preserve and enhance nuclear knowledge and sending personnel abroad to obtain master's or doctoral degrees or for on the job training.

6.2.3. Islamic Republic of Iran

An interesting observation on the link between human factors and knowledge management was highlighted by the results of the investigation of an incident in the Tehran research reactor (TRR). The investigation report pointed out how knowledge of even routine practices could be eroded, with potentially disastrous consequences.

During a restart of the TRR in June 2001 the high absorber control rods were 70% out of core without achieving criticality, whereas criticality was achieved at 62% during the previous run. A scram occurred but was recorded in the log as due to low water flow. A stuck control fuel assembly (CFA) was replaced and the reactor restarted, this time achieving criticality with control rods 75% out of core. After 33 h of operation an abnormality was found, with a CFA hovering on the core top; the reactor was shut down and the problem was fixed, but instead of keeping it shut down for investigation, the reactor was operated again through the rest of the week.

The regulator ordered the reactor to be shut down, an ad hoc committee was assigned to conduct a peer review of the event and its findings were presented to the authorities. Investigations showed that human behaviour and knowledge degradation of personnel during routine operations played a major role in the initiation and propagation of malfunctions during this incident. Causes related to human factors were identified to include the following: the extra pay of operators during shift operation acted as an economic incentive to keep the reactor operating; there was a lack or possible curbing of curiosity and a questioning attitude by the operators due to the work environment, in which workers felt that questioning could cause them difficulty and that it would be better to be silent; the general practice of subordination of scientists and technical persons to administrators, as prevalent in most developing countries; inadequate systematic training; and a lack of access to the necessary technical documents, as there was a tendency on the part of the managers to keep most of the crucial information and documents closely guarded.

In the context of knowledge management and the factors causing loss of knowledge, an important lesson arising from this report is that managers could accelerate knowledge degradation of the workers under them, rendering the system 'self-destructive', and hence a periodic change at the managerial level would be desirable.

6.2.4. Kazakhstan

The problem of preserving the existing scientific and industrial knowledge and potential related to the nuclear field in Kazakhstan arose after the collapse of the Soviet Union. Despite the severe economic crisis at the time, the government took a decision in 1992 to establish the National Nuclear Center (NNC) at the former Semipalatinsk test site utilizing the associated research institutions and facilities. The main objective was to develop the research and technological infrastructure and the necessary human resources for nuclear energy utilization in the country. However, the immediate benefit was to prevent the emigration of research and engineering workers with nuclear knowledge and experience from the Soviet era and to motivate them to transfer their tacit knowledge to the younger generation in the country.

Thus the creation of the NNC facilitated the preservation of not only the unique scientific and technological facilities but also nuclear knowledge in the young sovereign State.

Another interesting initiative on the development of nuclear knowledge is the establishment of the Kazakhstan Tokamak for Material Testing (KTM), an experimental thermonuclear facility for material examination at energy levels close to those of the International Thermonuclear Experimental Reactor. The NNC and the Kurchatov Institute in the Russian Federation have been collaborating closely on KTM development and construction since 1998. The KTM is planned to go into operation in 2006.

6.2.5. Turkey

The Turkish Atomic Energy Authority (TAEK) is the centre for R&D for nuclear science and technology in Turkey. It has three research and training centres in Ankara and one in Istanbul.

The INIS section at the head office of the TAEK, founded in 2002, functions as the knowledge portal for the entire country. It is the focal point to meet the information needs of scientists and engineers of the TAEK and its research and training centres as well as other institutions, organizations and universities in the country. The duties of the INIS section of the TAEK are to conduct literature searches upon request, to supply literature from within the country and from other countries, to collect and select literature for submission as input to the INIS database and to collect scientific documents.

7. CONCLUSIONS AND RECOMMENDATIONS

The global initiatives and activities highlighting the importance of nuclear knowledge management issues launched or supported over the past few years by the IAEA in response to requests by its Member States were highly commended by the conference participants. It was reported that following the IAEA meeting on managing nuclear knowledge held in 2002 an impressive number of projects related to the preservation of knowledge and education and training had been triggered in Member States.

Future activities related to nuclear knowledge management that would be highly beneficial to Member States and need to be supported by international organizations such as the IAEA and the OECD/NEA were identified. The key conclusions and recommendations are briefly described below.

7.1. NUCLEAR KNOWLEDGE MANAGEMENT AND PRESERVATION

Several speakers highlighted the importance of ensuring that the nuclear community retains all the knowledge that has been painstakingly acquired over the past several decades by scientists and engineers working in laboratories and industry. Towards this end they suggested strengthening the information system of the IAEA and commissioning expert reviews. Efforts are also required on the part of Member States to attract the young generation to the nuclear field in preference to competing career options.

Some initiatives have already been taken by Member States and international organizations to manage and preserve knowledge. Examples include the IAEA fast reactor knowledge portal, the criticality safety benchmark of the OECD/NEA, compiling experience reports on decommissioning in Germany, development of markers for repositories by Japan, appointment of a knowledge manager for every project funded by the EU as per the decision at Lisbon and documentation of communities of practice by several organizations across the world.

The following issues emerged during the conference as the basic elements of a strategy for nuclear knowledge management:

(a) Maintaining competence. With the increasing rate of retirements of nuclear workers, knowledge resource management, succession planning and continuous technical training were considered to be of paramount importance.

(b) Capturing and preserving existing knowledge. This issue received significant attention in many Member States, and the development of knowledge management tools based on modern IT was considered an important activity to be pursued.

(c) Development of future nuclear workers. Enhanced university programmes and performance based training of nuclear power plant personnel were considered essential for the successful management of human resources in the nuclear sector.

(d) Maintaining R&D capabilities. It was recognized that any programme to maintain competence and make further advances in nuclear technology would require intensive collaboration between education and R&D.

(e) Collection and dissemination of scientific information and transfer of technology. The number and diversity of initiatives that individual countries can undertake on their own are rather limited. Retaining all the nuclear skills and competences required by the industry will require a greater degree of international collaboration than has occurred before, and the role of international nuclear agencies was considered crucial in coordinating activities on both research and skills related issues.

The recent GIF was cited as a good example of how countries and organizations could come together to collaborate on an issue with which they have a common interest. However, it was recognized that collaboration by industry beyond the early research stage could be limited by commercial interests.

In most countries, the responsibility for funding R&D was increasingly falling to industry, with its narrow focus on the short term requirement of skills and competences in critical areas such as safety and waste management. Strategic planning was considered necessary to accommodate longer term needs such as the development of innovative reactor systems, which could only be achieved in the absence of commercial pressures. A mix of industry and public funding was considered appropriate to support endeavours in this area, as benefits would accrue both to industry and the country.

International organizations were urged to initiate activities for the compilation of good practices and the development of methodology, guidance and tools on various aspects of nuclear knowledge management, nuclear information management and human resource management.

7.2. NUCLEAR KNOWLEDGE MANAGEMENT FOR NUCLEAR SAFETY

Participants emphasized the crucial role of knowledge management in the field of nuclear safety. Implementing effective knowledge management systems in the field of nuclear safety was beneficial not only to the safety of plant personnel and the general public but also in improving public perception of the nuclear industry and enhancing the commercial performance of the plants. A major nuclear safety challenge was to foster a global knowledge sharing culture to achieve the motto that 'a safety improvement anywhere is an improvement of safety everywhere'.

Attention was drawn to the necessity of significantly expanding international initiatives for sharing safety knowledge through networks, portals and the development of guidance documents and tools. Capturing of knowledge in safety codes and guides has been performed by the IAEA for a long time, and a large body of knowledge has now been documented. Standards and codes are also being developed by national bureau of standards of various countries as well as by professional societies, and these activities also help in knowledge preservation.

In recent years a wide variety of activities has been initiated by the IAEA relating to knowledge management and networking in the area of nuclear safety. Innovative approaches have been utilized to capture, create and share safety knowledge and to assist Member States in their efforts to develop and maintain sustainable education and training programmes. The measures being implemented include mapping and retrieving safety knowledge, development of process flows and facilitating the development of regional safety networks such as the ANSN.

The safety implications of the ageing workforce and the need to transfer tacit knowledge to the next generation have been widely recognized by many Member States. The participants suggested that as global organizations, the IAEA and WANO should take the lead in retrieving the tacit safety knowledge available with senior plant operators worldwide. In this regard, the IAEA's activities on human resources management and knowledge transfer were considered highly useful and effective in enhancing the results of initiatives by Member States.

7.3. NUCLEAR INFORMATION MANAGEMENT

The participants stressed the need to reduce information handling costs and at the same time provide quality information to policy makers and planners by correcting inefficiencies in the process of collection, organization and analysis of information. INIS was recognized as a unique nuclear knowledge management tool providing continuous support to national programmes and activities. INIS tools such as the Joint Thesaurus, maintained in collaboration with the ETDE, and a forthcoming INIS classification, could constitute the backbone of a nuclear knowledge portal.

A strong endorsement was given to the concept of ‘knowledge packages’, which would create new knowledge on the basis of information gathered from key individuals and specialist organizations in the field, including videos, commentaries on earlier works, state of the art reviews and information on work in progress. Each package could be presented to users as a separate knowledge base and a complement to the INIS database.

Networking of nuclear libraries and information centres was considered an important part of the global effort to share information resources and expertise, providing a cost effective mechanism to access, exchange and distribute information. The establishment of the IAEA Consortium of Nuclear Libraries and the development of the INEL would significantly facilitate the efforts of Member States related to nuclear knowledge and information management.

7.4. HUMAN RESOURCES FOR THE NUCLEAR SECTOR

The safe and efficient use of nuclear power requires a certain number of experts in nuclear specific areas. Depending on the stage and size of the nuclear power programme, the required number of experts in these essential disciplines may be small in some countries, and consequently the educational provision to supply them may disappear. Hence there is a need for government, academia, industry and research organizations to collaborate both nationally and internationally in order to secure sustainable groups of expertise.

The nuclear industry is facing fierce competition from other high technology industries to attract young talent. It was considered necessary to increase interaction with university science and engineering departments as well as with students about to make career choices and present the challenges and opportunities offered by the nuclear sector.

Large, high profile international R&D programmes were considered to have the potential to influence topics taught at university and to present a dynamic image of the industry to those making career choices. Examples cited were the current research programmes in the areas of partitioning and transmutation and the development of future power reactors (GIF), providing tangible evidence that nuclear technology continued to be considered a long term option in the participating countries.

Development of individuals was considered to be central to the process of nuclear knowledge management, and hence it was suggested that the involvement of experts and individuals from Member States in international activities related to nuclear knowledge management be encouraged.

7.5. EDUCATION AND TRAINING

Networking of educational institutions was considered a key strategy for capacity building and better use of available educational resources. There were good examples both in Europe (ENEN) and Asia (ANENT), where universities, facilitated by international organizations, were collaborating to establish common platforms for education at the master's level. Establishing and supporting similar education networks was considered essential for other world regions, for example Latin America and Africa. Founding of the WNU was a positive development in this regard.

It was considered necessary that governments, industry and academia work together to create a functional framework to support education and training through national and international collaboration.

International agencies were urged to facilitate transferability of education and skills between member countries, especially in critical nuclear specific disciplines. The strength of international organizations such as the EU, IAEA and OECD/NEA was their ability to create and secure frameworks in which member countries can work together and collaborate.

In some countries funding for nuclear research was being dealt with in isolation from funding for nuclear teaching within the same university. It was recognized that good teaching and good research go together and that a more integrated approach to funding was necessary. Organizations funding nuclear R&D should ensure that education and training aspects were an integral part of activities.

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Opening Session	B. Bigot	France
Session 1	B. Bigot	France
Session 2	C. Gobert	France
Session 3	J. van Halm	European Association of Information Services
Session 4	J. Gutteridge	United States of America
Session 5	C. Tuniz	Abdus Salam International Centre for Theoretical Physics
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The goals of the conference were to exchange information and share experience on nuclear knowledge management, comprising strategies, information management and human resource development, and to identify lessons learned and embark on the development of new initiatives and concepts for nuclear knowledge management in IAEA Member States. Keynote papers covered important aspects of nuclear knowledge management, while the sessions were devoted to managing and preserving nuclear knowledge, managing nuclear information, human resources for the nuclear sector and networking education and training.

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