KNOWLEDGE MANAGEMENT

Introduction

Like any highly technical endeavour, the use of nuclear technology relies heavily on the accumulation of knowledge. This includes technical information in the form of scientific research, engineering analysis, design documentation, operational data, maintenance records, regulatory reviews and other documents and data. It also includes knowledge embodied in people — e.g. scientists, engineers and technicians. Effective management of nuclear knowledge thus involves ensuring the continued availability of essential reservoirs of both technical information and qualified people. This is critical to ensuring safety and security, encouraging innovation, and ensuring the future availability of the benefits of nuclear technologies in the fields of human health, food and agriculture, water management, industrial applications and electricity generation.

In recent years, a number of trends have drawn attention to the need for better management of nuclear knowledge. The nuclear workforce is ageing as more nuclear workers approach retirement age without a compensating influx of appropriately qualified younger personnel to replace them. Fewer young people are studying nuclear science, nuclear engineering and related fields at university level, and a growing number of universities have given up their nuclear education programmes altogether. If the efficient transfer of nuclear knowledge from one generation to the next is constrained by an ageing workforce and fewer university programmes, that only increases the importance of maintaining accessible, clear and comprehensive technical information and documentation.

This document outlines the current dimensions of the "people problem" including both recent trends and projected personnel needs. It summarizes a number of initiatives that have been undertaken around the world in response. It then turns briefly to the challenge of ensuring the accessibility of comprehensive technical information and documentation, and concludes with a summary of current Agency activities.

Workforce Ageing

Recent Trends and Projections

Succession planning to ensure that as nuclear scientists, engineers and technicians retire, a younger generation of workers with appropriate educational backgrounds and career aspirations becomes available to take their place is an issue with potential safety, security and economic implications. Technical competence for the safe operation and regulatory oversight of existing nuclear installations — as well as for nuclear material safeguards, research and development, waste management and transport, and facility decommissioning — will be an essential feature for decades to come, regardless of whether or not nuclear energy expands.

Fig. 2.1 illustrates the trend in higher nuclear education in the USA over the past two decades, and shows substantial declines both in university reactors and undergraduate enrolment in nuclear engineering. The enrolment drop was particularly steep between 1993 and 2000. As discussed below, there is some reason to expect that the enrolment upturn in 2001 and 2002 will continue.

In 2000, the OECD Nuclear Energy Agency published a study entitled, "Nuclear education and training, cause for concern?", which found trends in other OECD countries similar to those in the USA. The NEA is currently planning to update the 2000 study.

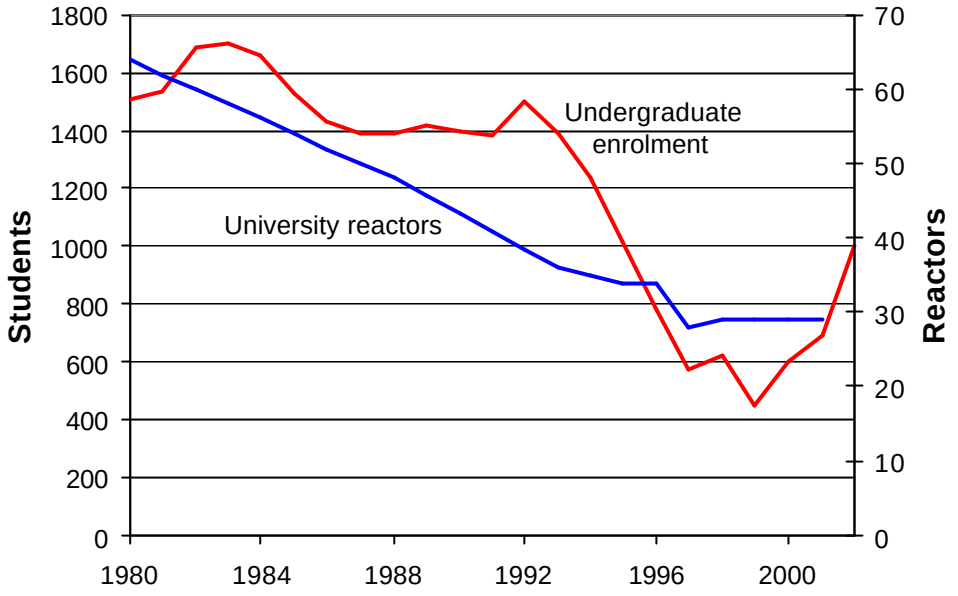

Fig. 2.1. US Trends in University Nuclear Engineering. Source: DOE Office of Nuclear Energy, Science and Technology.

Such declines in undergraduate enrolment mean that the supply of trained students emerging from universities is currently falling short of demand. Fig. 2.2 shows NEDHO[1] projections for the near term supply and demand of nuclear graduates in the USA. With respect to manpower needs across a broad range of disciplines — including trades personnel — an extensive study conducted by Navigant Consulting for the Nuclear Energy Institute (NEI) concluded that approximately 90 000 new nuclear professionals will be needed over the next ten years in the USA[2]. Fig. 2.3 shows that about half of these are in the government and government contractor segments.

Even in countries with policies to phase out nuclear power, the availability of qualified staff for the remaining lifetime of existing installations, for decommissioning, for regulatory purposes and for waste and spent fuel treatment and storage is essential. Fig. 2.4 shows the projected timeline for Germany's phase-out of nuclear power, indicating the extended lengths of time that expertise and a trained workforce will still be needed for reactor operation, decommissioning, interim storage of spent fuel and long-term disposal.

[1] NEDHO: Nuclear Engineering Department Heads Organization

[2] Alan Waltar, "Feeding the Nuclear Pipeline: Enabling a Global Nuclear Future," IAEA Scientific Forum, 17 September 2002, Vienna.

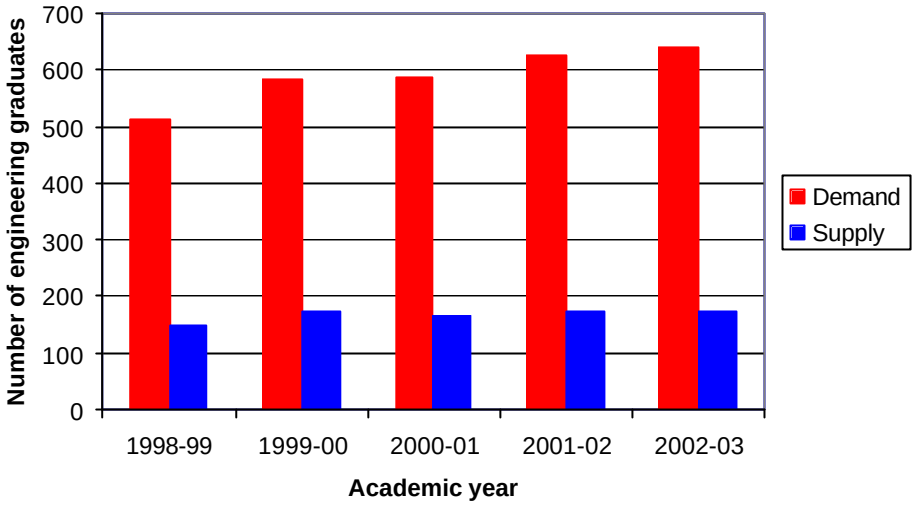

Fig. 2.2. US annual demand for nuclear engineering graduates. Source: DOE Office of Nuclear Energy, Science and Technology.

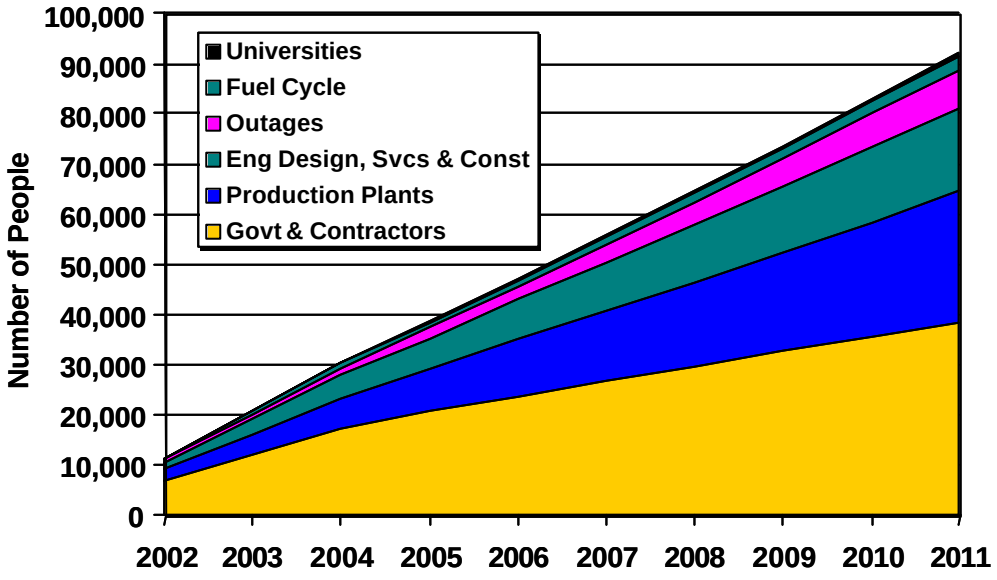

Fig. 2.3. Cumulative demand for new workers by segment in the USA. (Waltar, 2002)

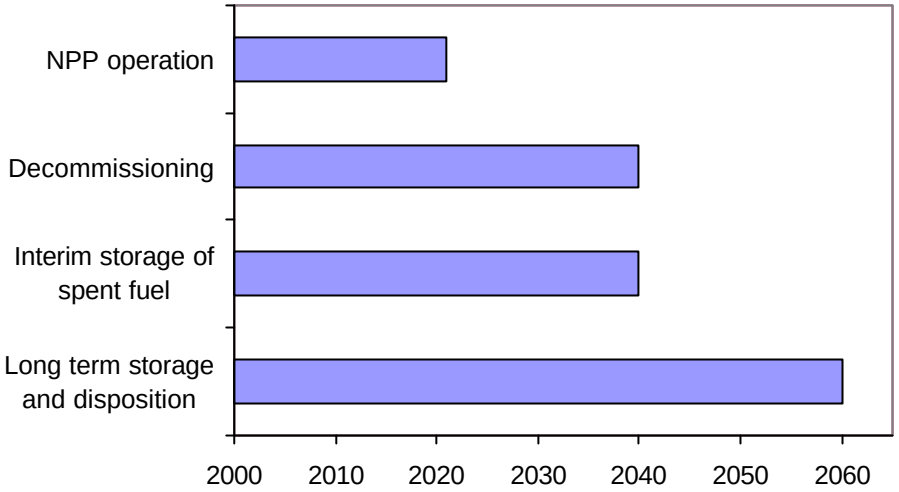

Fig. 2.4. Need for expertise and manpower from different activities in the German phase out of nuclear power.[3]

These timelines should be seen relative to the time required for developing competence in different sectors (Fig. 2.5). The German Network of Competence (described below) estimates that for Germany the time needed to generate expertise in different areas is: ten years to generate and establish the expertise necessary for higher university education in nuclear technology, eight years for research activities, five years for government regulatory authorities, and three years for industry expertise (Griffiths and Royen, 2000).

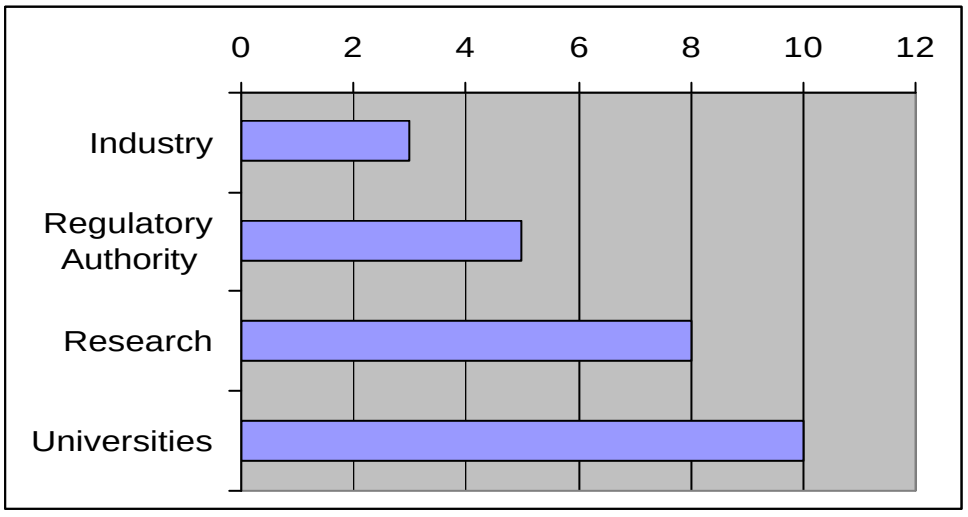

Fig. 2.5. Estimated lead times in years in Germany to develop nuclear expertise in different areas.[4]

[3] P. Fritz, "Know-How-Erhalt nach dem Ausstiegskonsens - Möglichkeiten und Grenzen", Research Centre Karlsruhe, Germany, VGB Kongress 2002; Berlin, 10. Oktober 2002

[4] S. Griffiths, J. Royen "Assuring future nuclear safety competence", NEA News 2000 – No. 18.1.

Current Initiatives

Programmes have begun or are planned in a number of countries to increase the number of young entrants to the nuclear workforce. The list below is not exhaustive. Indeed, one early objective of Agency activities in this field (described below) is to assemble and make broadly accessible more complete information on what initiatives exist or are planned, on what has worked and on what has been learned that can be built on in future programmes.

European Nuclear Engineering Network (ENEN)

In Europe, several initiatives address the issues of succession planning, education and training by networking institutions of higher education. At the national level these include the Belgian Nuclear Higher Education Network, the joint British Electricity Association (BEA) and British Nuclear Industry Forum (BNIF) Sector Skills Council for the Energy Sector in the UK, and the German Network of Competence in Nuclear Technology described below. A Europe-wide initiative is the European Nuclear Engineering Network (ENEN), which was launched in January 2002 as a collaborative project under the fifth framework programme of the European Community and will run until the end of 2003. The objective is to help safeguard nuclear knowledge and expertise through the preservation of higher education in nuclear engineering. The ENEN will review current and prospective reductions in Europe's teaching capacities, scientific equipment and research infrastructure, and develop a roadmap for making better use of reduced assets through co-operation among universities and research centres. Among other things, it will examine possibilities for harmonizing curricula and creating a new "Eurodiploma".

Canada

In August 2002 the University Network of Excellence in Nuclear Engineering (UNENE) was incorporated as a working partnership among universities and nuclear industries to create a highly qualified workforce for the Canadian nuclear sector and invigorate university based research. UNENE is developing a course-based Master's degree in nuclear engineering, that will be collectively offered by UNENE university partners to reorient graduates of traditional programmes and educate sponsored nuclear employees. It also seeks to ensure a steady supply of graduates with research based degrees (MSc, PhD.).

The key features of UNENE are the following. Each candidate for graduate studies in nuclear engineering is selected jointly by a university and an industry sponsor who provides scholarship funds. Each full-time student is offered work terms by the industry sponsor and, upon graduation, is offered full-time employment. Each UNENE university offers the necessary graduate courses, in a modular format, for a collaborative course-based MEng. Program in nuclear engineering.

Funding commitments are currently approximately $12 million, with a total target of $25 million for 2002–07. The intention is that industry investments will be matched by grants from various government programmes.

At the time of writing[5], research areas have been assigned to universities, the first group of students has been selected and admitted, and the first set of graduate courses has been identified.

Germany

In Germany a national Network of Competence was established in 2000 following a government initiative. Its objective is to ensure, even — or especially — with a national policy to phase out nuclear power in place, the availability of qualified manpower for the nuclear sector. It comprises both universities and research centres, such as the Research Centre Karlsruhe and Jülich and their neighbouring technical universities. One of the first tasks of the Network has been to assess future needs for qualified manpower. A detailed study confirmed that even under phase-out conditions, nuclear expertise in the utility and service branch as well as in licensing authority and R&D areas will continue to be needed for several decades (see Figures 2-4 and 2-5). A follow-up study on maintenance of nuclear knowledge is currently in preparation.

Russian Federation and Newly Independent States (NIS)

In May 2003, the Ministry of the Russian Federation for Atomic Energy (Minatom) convened a major meeting on the issues and challenges of maintaining and preserving nuclear knowledge in Russia. The meeting produced strong recommendations directed at participating nuclear research institutes, industrial enterprises and universities concerning urgent measures that need to be taken to sustain and further develop adequate nuclear expertise within Russia and to provide assistance to the NIS. The Central Research Institute of Management, Economics and Information of Russia (TSNII Atominform) will play an important role in future knowledge preservation activities.

United States of America

Following its 1997 report, in which the President's Council of Advisors on Science and Technology (PCAST) noted the precipitous decline in undergraduate enrolment in the nation's nuclear engineering programmes, PCAST helped created the Nuclear Energy Research Advisory Council (NERAC) in 1998. An important follow-up action was the establishment of the Nuclear Engineering Educational Research (NEER) programme to stimulate university research. It was pushed for a funding level of about $20M/year. NERAC's most recent focus has been to encourage the US Department of Energy (DOE) to support university research reactors to help halt the pattern of continuing closures. This initiative is known as INIE (Innovation in Nuclear Infrastructure and Education), for which NERAC has recommended funding at about $15 million per year. NERAC also recommended funding for graduate students at about $5 million per year.

In the fiscal year 2002 the Nuclear Energy Research Initiative (NERI), NEER, and INIE programmes were funded at levels of $23.4 million, $5 million, and $5.5 million. An international version of NERI, called INERI, was funded at $7.9 million.

The US nuclear industry is also working to expand the next generation of nuclear expertise. The Nuclear Energy Institute's Vision 2020 focuses on the need for qualified personnel to support a "nuclear renaissance" in the USA, and NEI has conducted workshops

[5] 25 November 2002

and focus groups to both frame the concerns and discuss corrective actions. NEI plans to establish partnerships with both the DOE and universities using web-based recruiting techniques and additional scholarship support. The Institute for Nuclear Power Operations (INPO) already manages a scholarship/fellowship programme that allocates approximately $1.0 million each year to students expressing an interest in launching a career in the nuclear power programme.

The American Nuclear Society (ANS) is also active. With DOE assistance ANS organized over fifty highly-rated workshops last year for secondary school teachers, which reached directly about 1000 teachers and, indirectly, some 90 000 students. The ANS also distributed 30 000 career posters and 50 000 career brochures through the extensive educational network that they have built up, and placed 13 000 Geiger counters in US high schools to help stimulate student interest.

The 2001–2002 upturn in undergraduate enrolments in Fig. 2.1 is an encouraging indication that these efforts are beginning to have an impact. Also encouraging is the recent announcement by two US universities that they will introduce new graduate and undergraduate nuclear engineering programmes. The new programmes at South Carolina State University and the University of South Carolina are the first new US programmes in more than 20 years.

Argentina

In Argentina, two knowledge management projects are being carried out at the National Atomic Energy Commission (CNEA). In the first project, knowledge management techniques are applied to all experimental reactors operated by CNEA, including those where CNEA participated in the construction. The planned result is a book documenting essential knowledge of experimental reactors. The aim of the second project, is to preserve knowledge of the technology of Atucha I type heavy water moderated reactors.

Asian Network for Higher Education in Nuclear Technology

In September 2002, the Scientific Forum held during the forty-sixth session of the Agency's General Conference discussed the establishment of a regional Asian network of institutions engaged in higher education in nuclear fields, based on a proposal by the Republic of Korea. The network is intended to broadly cover the Asian region, making it the second largest network (after ENEN) on education in nuclear technology. With support from the Agency, preparations for the network started in 2003 through an Internet-based discussion forum established and run by the Korean Atomic Energy Research Institute, Republic of Korea.

World Nuclear University

The World Nuclear Association (WNA) is promoting the establishment of a World Nuclear University as a network of existing universities. The Agency is supporting the initiative. WNA envisages the formal launch for the World Nuclear University in September 2003.

Nuclear Law

The International School of Nuclear Law (ISNL) was established two years ago by the University of Montpellier in co-operation with the NEA. It is co-sponsored by the International Law Association and the European Commission. The ISNL offers a high quality two-week summer course on all aspects of nuclear law. Participants are law students studying at the doctoral or masters level, and young legal professionals already active in the nuclear sector who wish to develop their knowledge. The programme provides an introductory course on nuclear law and covers the legal aspects of radiation safety, nuclear installation safety, radioactive waste management, transport of nuclear materials, physical protection (including the illicit trafficking of nuclear materials), non-proliferation and nuclear liability.

The Agency supports the ISNL by providing lecturers from the Office of Legal Affairs in the areas of safeguards, non-proliferation and nuclear safety, and by offering fellowships for candidates from developing countries. At the ISNL's second session in August 2002, 14 of a total of 57 participants were fellows supported by the Agency.

Retaining Knowledge and Data

There are two dimensions to ensuring the future accessibility of comprehensive technical information and documentation.

First is the potential loss of *institutional memory* as nuclear employees retire. Based on their work experience, they may possess essential but previously undocumented facts and insights ("skill of the craft") that could be lost. Preserving such knowledge has safety and security implications, particularly as facilities age or engineering modifications are undertaken. Although knowledge preservation can be considered largely a management issue for facility operators, the current challenges are sufficiently new, and the stakes sufficiently high, that there is a broader international interest in providing assistance or training to those who need it on recording and retaining undocumented information as employees retire.

Second is the importance of *retaining valuable data and other information* (e.g. documentation, scientific and engineering studies, research results and related data), with particular attention to be devoted to countries where the motivation or the resources to preserve this material is low.

Of several pilot projects that have recently been launched, two examples in which the Agency is involved concern fast reactors and gas cooled reactors. The IAEA initiative on "Fast Reactor Knowledge Preservation" seeks to establish a comprehensive, international inventory of fast reactor data and knowledge that would be sufficient to form the basis for fast reactor development 20 to 40 years from now. The objective is a knowledge base into which existing knowledge preservation systems will fit while allowing new efforts to preserve data and knowledge to complement the prior work. A secondary objective is quality assurance for the data and knowledge to be included. A major part of this effort is entraining the diminishing group of international experts in the review and interpretation of fast reactor information for the future.

In 2003, the project participants began to retrieve and preserve data from the German experimental fast reactor KNK II, which is currently being decommissioned. A first tranche of several dozen documents is being scanned and converted to electronic form. Bibliographical

records will be produced using the format and methods of the Agency's International Nuclear Information System (INIS), i.e. bibliographic descriptions and subject indexing using the INIS thesaurus.

This knowledge base is intended to provide access to assured quality information in the basic research, design, safety, fabrication, construction, operation, and decommissioning of fast reactors. "Access" here means a portal to the information. The free release of some of the information between nations may still require negotiation on a case-by-case basis.

In the case of gas cooled reactors, knowledge has been accumulating for over half a century. The archives of milestone projects such as DRAGON in the UK and AVR in Germany contain valuable information for supporting current high temperature gas cooled reactor (HTGR) projects and future technology developments. The IAEA has therefore begun building a knowledge base on HTGRs incorporating, for the moment, whatever technical information is publicly available from particularly these milestone projects.

International Co-operation and the Agency

The national projects described above and the two IAEA pilot projects above reflect the increasing attention being given worldwide to the problems of workforce ageing and data and knowledge retention. Another reflection of concern is the increasing interest of Agency Member States in expanding Agency activities specifically in this area. At the forty-sixth session of the General Conference they approved, with extensive co-sponsorship, a resolution calling on the Agency to increase the attention given to nuclear knowledge management activities, to increase awareness of these activities, to assist Member States in preserving nuclear education and training, to promote networking, and to identify ways to address the problems of workforce ageing and data and knowledge retention. While much of the Agency's programme over the years has included education, training, databases, and information services, there is now a more urgent interest in aggressively applying the Agency's resulting capabilities and expertise to the problems of workforce ageing and data and knowledge retention.

The General Conference resolution reflects the conclusions of a meeting that the Agency convened in June 2002 on managing nuclear knowledge with senior experts from academia, industry and government. There was unanimous consensus at that meeting that the IAEA has an obligation to lead activities toward preserving and enhancing nuclear knowledge by complementing, and as appropriate supplementing, activities by governments, industry, academia and international organizations. International co-operation is of vital importance, and the Agency was specifically requested to use its potential in assisting Member States to ensure the preservation of viable nuclear education and training, which is a necessary prerequisite for succession planning.

There was agreement on a list of proposed activities and actions for the Agency, with the following six top priority activities:

1. Integrate existing nuclear data and information bases (in the IAEA and in Member States) in the form of an easily accessible "Nuclear Knowledge Portal".

2. Promote networking of institutions for nuclear education and training in Member States in co-ordination with existing activities.

3. Develop Guidance Documents on the preservation of nuclear knowledge.

4. Implement targeted preservation of knowledge projects.

5. Design and implement outreach activities, which improve the general knowledge in society of the benefits of nuclear science and technology.

6. Facilitate the development of curricula for internationally accepted higher university degrees on “nuclear technology”, e.g. by networking universities.

In response to the General Conference resolution and the recommendations of the June meeting, the Agency’s proposed programme for 2004–2005 expands activities related to nuclear knowledge management and provides for clearer co-ordination. In Major Programme 1 (Nuclear Power, Fuel Cycle and Nuclear Science), priority will be placed on developing a comprehensive strategy for promoting education, training and research embracing all areas of interest to the Agency. A roadmap for establishing a nuclear educational network will also be developed. The Agency will facilitate the development of curricula for the basic disciplines of nuclear science, technology and nuclear law. Pilot knowledge preservation projects for specific areas of nuclear technology will continue. The participation of the International Centre for Theoretical Physics in Trieste in knowledge dissemination will be strengthened and developed. The role of the International Nuclear Information System and the Agency’s Library in nuclear knowledge management will be further enhanced and integrated, providing a nuclear knowledge portal for Member States and the Secretariat.

The contribution of Major Programme 2 (Nuclear Techniques for Development and Environmental Protection) includes the maintenance of important data sets, supporting education and training, and sustaining capacity in risk analysis for food safety, different aspects of nuclear medicine and isotope applications. A major effort will be made in the area of the education of health care professionals to ensure the safe and effective use of nuclear technology in cancer treatment in developing countries. Also important will be teaching and training modules to be developed in radiochemistry and nuclear analytical techniques.

Major Programme 3 (Nuclear Safety and Protection Against Radiation) will have projects for sustainable education and training in nuclear installation safety, radiation, transport and waste safety, as well as projects for maintaining expertise and knowledge in nuclear regulatory authorities. It will continue to maintain key databases to help preserve and disseminate important safety information to Member States. Nuclear safety networks will be established initially at the regional level and further developed into a global network. The intention is to create a flexible mechanism to compile, analyse and exchange nuclear safety knowledge.

Major Programme 4 (Nuclear Verification and Security of Material) will continue to work for increased global security. Towards this end, it will seek to strengthen knowledge management activities to maintain and develop appropriate information collection, processing and evaluation techniques, other essential infrastructure and wide-ranging professional expertise, both within the Secretariat and in Member States. Major efforts internally will be dedicated to state of the art techniques for effective information management and dissemination, notably through a re-engineering of the IAEA Safeguards Information System (ISIS), and to ensuring, on a continuing basis, that training curricula match perceived needs. The terrorist attacks of 11 September 2001 and the higher profile now being given to nuclear security issues are reflected in a consolidated Agency programme (recently moved to Major

Programme 3) on nuclear security covering all of its aspects. Training and outreach will no doubt continue to be key elements of the knowledge management process in this area.

Major Programme 6 (Management of Technical Co-operation for Development) will continue developing a network of national, regional and collaborating training centres to be the focus of proposed education, training and qualification initiatives in these fields.