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WORKING MATERIAL

NUCLEAR KNOWLEDGE PRESERVATION IN CIS-COUNTRIES: CURRENT STATUS AND RELEVANT SUGGESTIONS

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FOREWORD

The important role which the IAEA plays in assisting Member States in the managing and enhancement of nuclear knowledge and in facilitating international collaboration in this area has been recognized by the General Conference of the International Atomic Energy Agency in resolutions GC(46)/RES/11B, GC(47)/RES/10B, GC(48)/RES/13, GC(50)/RES/13 and GC(52)/RES/12.

A continued focus of IAEA activities in managing nuclear knowledge is to support Member States to analyze the needs for nuclear knowledge preservation, to estimate the current status of existing problems and to suggest common approaches towards them. Commonwealth of Independent States (CIS) has been a part of a larger nuclear knowledge community within the former USSR. Now these states have a lot in common in terms of nuclear energy industry and especially nuclear knowledge management. A peculiar feature of the present situation is that the significant amount of scientific texts and normative documents (standards, guides, methodologies, etc.) available only in Russian. In addition, most current nuclear professionals in atomic science and technology received their fundamental education in the Russian language.

Given this fact the CIS Commission for Peaceful Use of Nuclear Energy raised nuclear knowledge management (NKM) problem and requested its Secretariat to work with IAEA in order to estimate current status of the NKM problem in former USSR countries and to work out a certain common approach how to deal with it.

This report has been jointly developed by this Commission and IAEA. The IAEA officers responsible for this publication were I. Kitaev and S. Kruchinin of the Department of Nuclear Energy, V. Kupriyanov took part in the preparation of the document as a representative of the Commission.

The purpose of the publication is to provide information to organizations and experts working in the field of NKM on common approaches and possible solutions in preserving nuclear knowledge in the CIS countries and to develop recommendations on regional cooperation in the subject area.

EDITORAL NOTE

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1. INTRODUCTION

In recent years, the gap between the supply of fossil fuels and the growing demand for energy resources worldwide has been increasing. In the twentieth century, most energy was consumed by the western industrial countries. In fact, with only one billion people, these countries consume 80% of the world's energy — and this gap is expected to widen. Developing countries (China, India, Brazil and others), with three billion people, have begun to catch up with the West, in industrial terms, and need additional natural resources for their economic development, the rate of which will determine the world's economic profile in the twenty-first century.

Analysis of the world's energy balance in the recent years suggests an impending energy crisis. The gap between supply and demand in the oil market is likely to widen, resulting in further oil price growth, impacting the whole energy consumption chain and affecting economic development fundamentals. Assessments show that the oil market gap may lead to a 'chain reaction' throughout the whole energy market at any time, but certainly no later than 2015. Statistics show that neither price rises, nor additional efforts in exploring new resources will be sufficient to close the gap between supply and consumption. Technological solutions (primarily hydrogen fuel elements) proposed to improve the crucial oil market situation are unlikely to be developed, commissioned and operated commercially within this period. Neither can fusion technology for electricity production be expected to become commercially available within this period.

In this context, the role of nuclear energy in the global energy balance is again becoming increasingly important. By the end of 2006, 435 nuclear power reactors operating worldwide produced about 15% of the world energy output.

TABLE 1. ENERGY OUTPUT PRODUCED BY NUCLEAR POWER PLANTS ON FISRT JANUARY 2007

Country	National energy output
United States of America	20%
Japan	30%
Germany	32%
Republic of Korea	39%
Sweden	48%
France	78%

At present, the total global operating experience amounts to more than 12 000 reactor-years.

However, a characteristic feature of the present state of nuclear engineering development is that the speed at which new nuclear facilities are being commissioned is too low to maintain the share of nuclear energy in the world's electricity production output at the 15% level. Today's expansion of nuclear energy production, as well as near-term and long-term growth prospects, is concentrated in Asia. At present, of the 29 reactors under construction, 17 are in Asia (in China, Taiwan (China), the Republic of Korea, Japan and India).

The nuclear non-proliferation policy has an impact on global nuclear energy development. After the G8 summit at Sea Island in 2004 participating countries have been elaborating further measures which, on the one hand, would prevent exporting sensitive technologies to countries where there is a risk of proliferation or arming terrorists with nuclear materials and, on the other hand, would allow the benefits of peaceful nuclear technologies. At the summit, the parties agreed that such materials must be exported only according to the criteria corresponding to international non-proliferation norms and only to those countries which pursue the norms rigorously.

The specific features of the nuclear energy renaissance mentioned above have created new requirements for intellectual resources to support it.

During the past 20 years, most countries have suffered the loss of both middle aged scientists and young professionals from the nuclear field. Most currently active scientists are of retirement age and, with the lack of inflow of young professionals, the required transfer of knowledge and practical skills has not been maintained. As a result, some knowledge sectors in nuclear engineering and technology have become critical. In some cases it will be practically impossible to replace the staff and intellectual capability being lost and operating industrial plants have fewer highly qualified technicians, engineers and scientists available. A consequence of these factors is increasing difficulty in maintaining and improving the quality of systems and support for design-operating conditions of reactor technology. The Chair of the IAEA International Nuclear Safety Group General Conference in 2005 referred, in a letter, to witnessing the "…decay in the nuclear infrastructure". The recession in nuclear development over the past 20 years has resulted in fewer highly qualified experts and university educated nuclear graduates and a reduction of global financial resources for research in nuclear safety. Concentrated efforts on the restoration of nuclear infrastructure must become a high priority task; however, progress is very slow.

One solution to this problem would be to create a specific area of 'objective knowledge' in the form of an information systems complex addressing the fundamental sectors of nuclear science, technology and technological processes for producing materials and products. This complex could be created through the efforts of highly qualified, broad-minded professionals who have great insight in this field.

In a narrow sense it is the work on 'nuclear technology knowledge preservation' which will solve the problem. Here it is reasonable to broaden the content of such work from traditional scientific and research activities. First, such broadening is necessary since traditional mechanisms of creating scientific knowledge presuppose a 'competent' user. That is to say, it is implicitly supposed that the user of such knowledge is as good a professional as its creator. Such an assumption enables one to exclude context from the description of the knowledge and the user must be able to verify new knowledge by his/her self.

For knowledge preservation to be effective, the basic efforts should be concentrated on describing knowledge in a way that would make it understandable for an 'unqualified' user. Therefore, the context must be specified and demand for the context should be as low as possible (i.e. reduced to zero); verification being the responsibility of the person preserving the knowledge and not that of the user of this knowledge.

2. COOPERATION OF CIS MEMBER STATES IN USING NUCLEAR KNOWLEDGE FOR PEACEFUL PURPOSES

2.1. ENERGY COOPERATION ISSUES FOR CIS MEMBER STATES COMMISSION

The energy industry plays a key role in integrating the cooperation of CIS countries. The effective development of nuclear energy can make a significant contribution to the stable electricity supply of such CIS countries as Armenia, Russian Federation, and the Ukraine. For a number of other countries such as Georgia and Uzbekistan, non-energy applications of nuclear technologies are of greater importance. Kazakhstan, Kyrgyzstan, Tajikistan have to manage the consequences of former USSR nuclear industrial sites operating on their territories. Kazakhstan and Belarus are considering the possible use of nuclear energy in their economies. The urgency of coordinating efforts to solve these problems has been constantly stressed at meetings, and in resolutions, of the supreme regulating bodies of CIS Member States. The Agreement on the Basic Principles of Cooperation on the Peaceful Use of Atomic Energy from 26 June 1992 has become a fundamental intergovernmental document on the peaceful use of atomic energy, which is a great contribution to the developing cooperation of CIS countries.

For the agreement realisation an Advanced Plan for developing cooperation of CIS countries in peaceful use of atomic energy, improving the safety of nuclear facilities was developed and adopted by the national governmental leaders of ten CIS countries (excluding the Republic of Moldova and Turkmenistan).

To coordinate efforts to fulfil the measures of the advanced plan, the CIS Economic Council established a Commission of CIS Member States for the Peaceful Use of Atomic Energy (further referred to as Commission) in 1997.

The basic activities of the Commission were focused on coordinating cooperation in the following areas:

- Application of nuclear and radiation technologies in science and industry.
- Improvement of the legal and normative base for the use of nuclear technology.
- Provision for nuclear energy safety.
- Disposal of spent nuclear fuel and radioactive waste.
- Development of nuclear energy.
- Preparing staff for nuclear energy.
- Industry, science and engineering.
- Ecological issues and management of the consequences of radiation accidents and of the USSR’s nuclear complex sites operating on their territories.
- Public and environmental protection in the case of nuclear emergencies.

Plenipotentiary representatives of the Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Russian Federation, Tajikistan, Ukraine, and Uzbekistan participate in commission work.

Cooperation on atomic energy is developing on an international level — in terms of framework agreements, intergovernmental agreements, etc., and also in terms of direct bilateral and multilateral relations between enterprises and organizations of various nations.

Future trends in atomic energy development are the subject of extensive public debates in Russian Federation. A new organizational structure ‘Atomenergoprom’ has been just created. It includes responsibility for the complete production range from the mining of raw materials to energy generation as well as the utilization of spent fuel.

It is assumed that atomic energy development will be realized by introducing advanced and innovative projects including NPP projects based on the WWER–1000 design and its modifications. Innovative designs based on fast reactors (BN-800) will provide for transition to a qualitatively new level of nuclear technologies with improved safety and ecology, higher efficiency of fuel consumption and better disposal of spent nuclear fuel and radioactive waste.

In accordance with the development strategy an incremental increase of Russian NPP capacity of 2 GW/year is planed up to 2012. In addition, the construction of a small nuclear plant for electricity generation and heating based on the KLT-40S reactor facility is planned at Severodvinsk.

There are 15 operating power units in the Ukrainian nuclear energy system with a total capacity of more than 13 GW(e). Unit No.2 of Khmelnitskaya NPP was commissioned and introduced into the grid on 7 August 2004; in October 2004 another unit was put into operation — Unit No.4 of Rovenskaya NPP. In 2006, Ukrainian nuclear power plants generated 84.9 TWh, which was 47.5% of total country output.

Ukrainian atomic energy development plans include the construction of another 11 units.

There are no fuel production facilities in Ukraine; fuel being supplied by Russian and Kazakh enterprises. An agreement was signed between the Russian Federation Government, the Ministry of Ukraine and the Government of Kazakhstan in Astana city on 13 May 2003, rendering assistance in the development and operation of a closed joint stock company 'Ukrainian-Kazakhstan-Russian enterprise for nuclear fuel production'.

Armenia has restarted an existing, shut down, WWER-440 based NPP, and is discussing plans for construction of the second unit.

2.2. GOALS OF THE COMMISSION ACTIVITIES IN PRESERVING KNOWLEDGE ON NUCLEAR TECHNOLOGIES

The rapid global dynamics of nuclear energy growth will require solutions to the provision of safety and harmonizing the related normative and legal bases of various countries. To this end a conceptual approach to a system of international cooperation on and regulation of, ecological and technological safety is needed to provide risk-free and steady development. This would involve co-ordination of basic principles, foreseeing information and experience exchange, creating data-bases, harmonizing legislation and using best current technologies, up-to-date methods and regulating mechanisms.

Fundamental to the effective implementation of existing knowledge in this process (knowledge realization) is to switch from the traditional mechanisms of transferring experimental facts and scientific and technological evidence on nuclear problems to specialists (tacit knowledge transfer), to recording this knowledge directly in electronic form, which would divest this explicit knowledge from its professional carriers: i.e. a process of knowledge transfer through divesting, formalization and providing specialized access to the knowledge — in other words: transition to knowledge preservation and knowledge application management.

The IAEA General Conference (2002) specifically stressed that the nuclear knowledge preservation problem is of crucial importance for nuclear science and technology. The IAEA Conference on Knowledge Management in Nuclear Facilities (Vienna, 2007) marked the maturity of the IAEA programme on nuclear knowledge management (NKM), demonstrating a transition from problem definition to problem solution. In Russian Federation, in 2003, the problem of NKM was discussed at a topical meeting of the Ministry of Atomic Industry Science and Technical Council, and was considered at a conference of the Russian Nuclear Society. A draft agreement on cooperation in forming and exchanging information resources and creating and developing the information systems of CIS countries for the peaceful use of atomic energy was prepared, approved by Economic Council of CIS and recommended for signature by governmental Leaders.

One of the goals of the CIS Commission on using nuclear technological knowledge for peaceful purposes is the creation of a sharing environment for nuclear knowledge which is fixed in the Russian language and is necessary for nuclear technology development in CIS countries. In knowledge preservation, the basic process elements should be: specifying, concentrating, refining and verifying knowledge. It is evident that this work will be responsibility of particular specialists and that each country participating in the international activity of nuclear knowledge preservation has to make up their priority list based on their national interests. Here the IAEA could organize, inform and coordinate related activity in the countries participating in the project. In addition, the IAEA could identify common priorities, correlating them with fundamental future trends in the activity, e.g. knowledge for innovative reactor technologies and related fuel cycles for basic non-energy application of nuclear technologies.

Existing knowledge can be correlated with tasks through the proper retrospective analysis of the publications base of the INIS Atomindex. Categorization of this knowledge against the necessary areas will enable specialists on sites to concentrate on critical aspects. The IAEA has accumulated experience in this kind of work, e.g. in the 1970's WRENDA (Word Request for Neutron Data) which resulted in the creation of widely known photographic nuclear databases such as ENDF/B (USA), JENDL (Japan) and BROND (Russian Federation).

2.3. KNOWLEDGE MANAGEMENT TASKS

The second problem of knowledge management is that of the technological aspects of the transfer and application. Here the IAEA assumes that the development of a methodology is necessary to provide a common information environment for the global community for nuclear knowledge. At present it is necessary to define a common codification methodology for a topical area (to make up the 'knowledge map') to identify requirements for the tools to describe the basic ideas which are to be considered as 'elementary knowledge units, independent of national language' thereby enabling 'search' in electronic storage devices as well as facilitating international knowledge exchange.

The IAEA has accumulated such experience; the INIS/ETDE thesaurus can form the basis of a common system for describing knowledge. Knowledge verification is also needed which, when available, will provide the main function of knowledge management — its application in solving new problems.

Prior to creating information systems (databases) a process is needed to allow unifying approaches to knowledge preservation, including ensuring the appropriate information environment as well as its presentation or description. The essence of such a process can be reduced to the following operations:

- Properly defining an object to be considered as a storage unit (which creates the search reference in a storage system and determines the real effort required for its formation).
- Defining the linguistic means of indexing a stored object (which would uniquely characterize it among other objects and make best use of the available INIS thesaurus and multilingual terminology dictionary (Multilingual INIS/ETDE Thesaurus) when searching).
- Defining the conceptual space (describing the subject field through a specialized glossary) where knowledge objects must belong.
- Having studied the software requirements for access to information storage systems within the IAEA community, establishing the necessary format for the exchange of structures and descriptions among community members (at present XML is more suitable than anything else).
- In creating local information systems (without knowledge) it is worthwhile defining relations with existing international and national centres whose information will serve as a source for a knowledge system.

An initiative on developing uniform approaches, presentation forms and search complexes in databases may become very important for the IAEA.

2.4. CIS NORMS AND RULES IN NUCLEAR TECHNOLOGIES AS KNOWLEDGE OBJECT

A number of bilateral agreements are currently in force between CIS Member States. These are on scientific and technical cooperation, creating financial and industrial groups, joint ventures, producing and supplying nuclear fuel, etc. As stated above, a draft agreement which includes the issues of cooperation in forming and exchanging information resources and creating and developing information systems of CIS countries for the peaceful use of atomic energy has been approved by the Economic Council and recommended for signature by governmental Leaders.

Work on establishing interactions between the regulatory bodies of CIS countries is being pursued aggressively. In CIS countries the norms and rules of the former USSR and national normative documents are currently in effect in the field of nuclear energy. Documentary exchange is taking place between the bodies concerned in Armenia, Belarus, Russian Federation, Kazakhstan and Ukraine. However, this exchange is sporadic and has not been systemized or designed to create a consistent regulating base which could contribute to developing cooperation in the countries concerned.

A CIS professional group has been established to work on the problem of harmonizing normative documents for the peaceful use of atomic energy. The aim of the group is to determine countries' requirements for normative documents for the use and control of atomic energy and a methodological provision for elaborating the necessary normative acts, taking into account harmonization, regional features and existing legislation.

2.5. NUCLEAR ENERGY IN CIS COUNTRIES AS A 'CONSUMER' OF NUCLEAR TECHNOLOGY KNOWLEDGE

At present, there are three nations among CIS countries operating NPPs; Armenia, Russian Federation and Ukraine. Belarus and Kazakhstan are currently assessing possible NPP construction on their territories.

2.5.1. Armenia

The Armenian NPP (hereafter ANPP), consisting of two power units, total capacity 815 MW, was phased out in 1988. The second unit of 407.5 MW was restarted in 1995. In 2006, ANPP generated 2.4 TWh of electricity, which is 42% of total output of electric energy in the Armenia.

Currently cooperation is concentrated on engineering support and safety improvements in operating ANPP unit No. 2. In this respect, ANPP cooperates with Russian Federation and Ukrainian organizations.

One of the functions of cooperation on knowledge preservation is the transfer of knowledge related to the R&D of ANPP from Russia to Armenia, securing operating experience of the same type reactors in Russia and Armenia and exchanging methodological guides on nuclear energy practices.

2.5.2. Ukraine

In Ukraine there are a number of scientific schools with strong research traditions in nuclear technologies. In particular, the Kharkov Institute of Physics and Technology (KIPT) was a 'lead organization' from 1960 to 1980 in radiation materials studies among the USSR Ministry of SredMash's enterprises which accumulated significant knowledge assets in this field of nuclear research.

Currently a draft *Strategy of Development of Nuclear Power Complex of Ukraine until 2030* is being refined, having been reviewed by the Ukrainian government in the middle of 2007. The draft will be submitted for approval. The draft document contains 12 sections which cover all areas of activity of a nuclear power complex. According to the draft strategy, the existing and newly built nuclear power plants will produce up to 50% of the country's electricity. The effectiveness of generation and the stability of the entire system are to be ensured through the load-following operation of the reactors, synchronization with neighbouring foreign grids, the build-up of material inventories, diversification of product supplies and other measures.

The professional staffs of Russian-made operating reactors (WWER-1000 and RBMK-1000) need knowledge in the normative base and operation regulations, radiation ageing of materials and spent fuel storage technologies.

Ukrainian specialists pay significant attention to research associated with the elimination of the consequences of the accident on the Chernobyl NPP, including the migration of radio nuclides, their biological effects, and the excretion of radioactive isotopes from metabolic processes.

2.5.3. Belarus

Since 1993 the Belarus has been performing research on the feasibility of developing nuclear energy. All work is carried out in close cooperation with R&D organizations of the Russian Federation. A report on economic and technical issues *Energy-supply of Belarus and some of Russia's Regions through Various Energy Resources up to 2020* is planned to be developed within the joint programme framework.

The President of Belarus in his 2005 Decree approved two documents which determined the country's future energy policies. Construction of two 1000 MW NPP units is planned. In 2007 a new decree was issued to administratively support preparatory work to construct an NPP in Belarus. A preliminary assessment of construction sites for future NPPs should be completed by April–June 2008. The Government of the Belarus has decided to allocate US $23 million for 2007–2008 to carry out preparations for the construction of an NPP. The money will support design and engineering work, activities to select the site for construction of the NPP, the development of a justification for investment in construction of the plant and tender documentation.

The requirements for nuclear technology knowledge are determined by intensive activities in the following fields:

- Top priority norms and technical documents regulating the safe operation of nuclear energy sites in the Belarus are being developed.
- Studies are being performed on optimizing environmental monitoring systems for deploying NPPs in clean territories, and on sites partially contaminated with radio nuclides.
- Issues of approprieteness and feasibility of deploying NPPs on territories contaminated with Chernobyl radio nuclides are being explored.
- Studying transient regimes and possible accident processes in operating WWER reactors at various phases.
- Possibilities for the long-term controlled storage of radioactive waste, spent fuel and spent fuel reprocessing products in the Belarus, including storage sites deployed in NPP monitored areas are being studied.

Because the tasks to complete before starting NPP construction are known, of particular importance is the related knowledge on:

- Normative materials for the preparation of a *Declaration of Intent for the Design, Construction, Assembly and Commissioning of an NPP*; the development and adoption of a law on *Use of Atomic Energy* and development of missing normative documentation.
- Data on developing requirements for NPP design in order to define tenders for plant construction.
- Methodology for evaluating and substantiating investments required for construction, specification of possible resources and schemes of funding.
- Information to complete all activities to find a main and backup (redundant) site for plant construction.
- Ongoing activities to provide the authorities and the public with information related to energy policies and studies on the current status and trends of enegy sector development worldwide.

2.5.4. Kazakhstan

The fast reactor BN-350 (in Mangyshlak city) was shut down several years ago and the fuel discharged, since when there have been no operating nuclear power facilities in the Kazakhstan. According to an adopted national programme, nuclear physics facilities under construction are a heavy ion accelerator in Astana and a ‘Tokamak’ thermonuclear reactor, designed for material studies in RRC Kurchatov Institute.

In 2006 Kazakhstan and Russian Federation signed the basic instruments for establishing three Russian-Kazakh joint ventures (JV) for the peaceful use of atomic energy. The JV Atomic Stations has been established to develop and promote designs of power generation installations with small and intermediate power reactors in the markets of Russian Federation, Kazakhstan and other countries. The JV Zarechnoye has been established to develop the Yuzhnoye Zarechnoye uranium deposit and JV Akbastau — to develop the Budenovskoye uranium deposit in the Kazakhstan. The third enterprise is JV Uranium Enrichment Center.

The above projects need knowledge to support the following areas:

- Improving management efficiency through automatic control of the processes and transparency of organizational performance at all levels.
- Supporting the quality assuarance system in accordance with international standards.
- Supporting efficient accumulation, management and access of data and knowledge.
- Providing flexibility for staff policies due to the higher level of ‘formalization’ of the activities of each employee and the opportunity to store the whole range of his ‘pre-historic’ activities.
- Keeping records of all organizational activities (official internal investigations, analysis of the performance of departments, detecting ‘bottle-necks’ in processes, etc.).
- Optimizing business processes and automation of the operation and control.
- Eliminating or minimising organizational paper flow.
- Simplifying, where possible, the storage of paper documents due to the availability of an operating electronic archive.

2.5.5. Russian Federation

The Federal programme *Development of Nuclear Power and Industry Complex of the Russian Federation in 2007–2010 and for the mid-term until 2015* (FTP) has recently been approved. The FTP includes support to scientific developments, implementation of advanced technologies, and development of machine engineering and interfacing industries. The FTP's main objectives are to expedite the development of nuclear power and industry to support the country's geopolitical interests and energy security, through:

- Commissioning new, series-made, standard reactors at a rate of not less than 2 GW of installed electrical capacity per year;
- Promotion of products (works and services) of Russian nuclear complex entities in the world markets; and
- Transition to construction and operation of nuclear power plants abroad.

The programme is to be implemented within nine years in two stages: first stage during 2007–2010 and second stage 2011–2015. For 2007–2015 the programme funding is about US $60 billion, including US $27 billion of federal budget resources for capital investments. The federal budget resources are needed to improve the country's energy security, at state level, in conditions where the growth of electricity tariffs has to be suppressed. The programme plans include completion of construction of two units with WWER-1000 reactors (units Rostov-2 and Kalinin-4) to be commissioned in 2009 and 2011, respectively.

In addition, the programme foresees the construction of fourth unit at Beloyarsk NPP with BN-800 reactor, planned to be the lead unit in developing the closed nuclear fuel cycle technology; commissioning is planned for 2012. Starting in 2007–2008 three new series-made type WWER-1000 reactors will be under construction at Novovoronezh-2 and Leningrad-2, all to be commissioned in 2012–2013. Plans include construction of two new series-made type WWER reactors per year, starting in 2009, with a five year construction cycle. Thus, by the programme completion dates, ten new reactors with installed electrical capacity of not less than 9.8 GW will be commissioned at Russian nuclear power plant sites and another ten reactors will be at different stages of construction.

In 2007 the Russian President signed a decree on the reforming of the nuclear power and industry complex of Russian Federation. The decree-backed JSC Atomenergoprom will merge into one organization the entire technological chain of nuclear power from uranium mining through its processing, fuel fabrication, construction of nuclear power plants, electricity generation and plant decommissioning. The Federal Council of the Federal Assembly of Russian Federation adopted a law regarding *Establishing the State Corporation for Atomic Energy – Rosatom*. According to the document, the Federal Atomic Energy Agency (FAEA) will become the basis of the state corporation which will ensure unity of management of atomic energy uses and sustainable functioning of entities within the nuclear power plants, industry and nuclear weapons complexes. The corporation Rosatom will be given shares in JSC Atomenergoprom and property of federal state unitary enterprises which are on the books of the FAEA. Therefore, the new entity will unite enterprises of nuclear power and industry, nuclear weapons complexes, basic science institutes and organizations involved in ensuring nuclear and radiation safety.

Massive nuclear power development in Russian Federation will require good nuclear knowledge and human resource management. In Russia, the following activities in knowledge preservation have been organized recently:

- Participation in the IAEA *Knowledge Preservation for Fast Reactors project*.
- Developing technological tools for the description, storage and search of nuclear technology knowledge (developing specialized thesauruses and methodologies for classifying and dividing the knowledge according to subject headings).
- Describing data on the properties of substances and materials used in nuclear technologies.
- Developing collections of documents on norms and standards to provide for Russian Federation's transition onto the system of technical records instead of the previously

used system of obligotary National Standards (GOST USSR). Transition to this system currently affects each CIS country, since the USSR standards have been until now in effect in all CIS countries involved in nuclear power technologies.

2.5.6. Tajikistan

The Tajikistan is not an atomic energy user; nevertheless, research achievements in nuclear science and engineering are widely used in a number of areas, such as medicine and agriculture. Hence, the preparation of staff and preserving nuclear knowledge is a significant problem. In the USSR, specialists and other professional staff were prepared according to the plans of the centralized control system, both in specialized universities of the Soviet Union and Tajik State National University (TSNU) at the department of nuclear physics. At present, science in the Tajikistan is mature enough for the knowledge accumulated to be applied in the course of activities on preserving nuclear technology knowledge. Of particular interest is the knowledge to start R&D, and then operate systems designed to rehabilitate territories after decommissioning nuclear fuel mining sites deployed here, as well as related medical and biological activities.

2.5.7. Uzbekistan

At present there are no NPPs in the Uzbekistan and the major nuclear technological sites are a research reactor and nuclear fuel mining enterprises.

Since there are many organizations in Uzbekistan whose work is related to nuclear physics activity, the problem of nuclear knowledge preservation in science and technology is a top priority for the country. Examples include: the Institute of Nuclear Physics and other institutes coming under the umbrella of the Academy of Sciences (Physical and Technical Institute, Institute of Material Science and Institute of Nuclear Physics – 'The Physics–Sun', Department of Thermal Physics, Institute of Electronics, Institute of Space Instrument Manufacturing), universities, the Ministries of Health and Agriculture, the Ministry of Home Affairs and State Customs Committee, the National Security Service, such large industrial enterprises as Navoi Mining & Metallurgy Combinat (NMMC) and Almalyk Mining Metallurgical Complex, Chirchic Electrokhim-Prom Company and the Uzbek Plant of Refractory and Heat Resisting Metals (Chirchic city).

2.5.8. Kyrgyzstan

After the disintegration of the USSR, and the loss of the Soviet Ministry of Machine Manufacturing infrastructure, the Central Science and Research Laboratory (CSRL) emerged as the major provider of scientific and technical support for the underground uranium leaching process within the Kyrgyzstan as part of JSC Kara-Balta Mining and Processing plant (KGRK) (Kara-Balta city), despite there being no reprocessing facilities in the Kyrgyzstan.

CSRL managed not only to maintain the integrity of the information accumulated, but even expand the available information assets which (apart from the information on already commissioned uranium ore reprocessing technologies, hydrometallurgy and geo-technological mining methods as well as accompanying components of value) currently contain comprehensive data on both promising and, equally important, some discontinued directions of research.

The work performed in this field will result in:

- Creation of a computer-based bank of geological and geo-technological data covering the whole territory of the Kyrgyz Republic which will include information on natural resources for the uranium mining industry, ore mining and reprocessing technology, and more.

- Developing specialized computerized uranium maps which will include validated predictions and detailed recommendations for efficient geological exploration.
- Organizing information and publicity for Kyrgyz data on uranium resources and new ore reprocessing and enrichment technologies for promotion in the international market, in order to attract additional investments into geological and geotechnological studies.

2.5.9. Georgia and Azerbaijan

Georgia and Azerbaijan have demonstrated an interest in the use of nuclear technologies in industrial processes, medicine and ecology, despite not have any intentions to use nuclear energy.

2.6. INFORMATION AND TECHNOLOGY ENVIRONMENT FOR NUCLEAR TECHNOLOGICAL KNOWLEDGE

Those CIS countries operating NPPs; Armenia, Russian Federation and Ukraine are cooperating on improving safety, upgrading and prolonging the life of NPP units. Armenia is concentrating on engineering support for operation of the second Armenian NPP (ANPP) unit and improving the safety features of the unit. For this, ANPP is cooperating with the following Russian Federation organizations: Concern Rosenergoatom (Moscow), RDCI Atomenergoproekt (Nignij Novgorod), OKB Gydropress (Podolsk), OAO(JSC) VNIIAES (Moscow), RRC Kurchatov Institute (Moscow), and others. ANPP orders necessary instrumentation and spare parts from AO(SC) Electrosila (St. Petersburg), OAO(JSC) Komplekt-Atom-Izora (Kolpino), ZAO(CJSC) Atomenergo (St. Petersburg), OAO(JSC) Atommash Export (Volgodonsk), and some other Russian enterprises. Nuclear fuel is produced by the Electrostal Machine Plant in Electrostal city. It is worth mentioning that in the development of technical documents NII(SRI) Armatom is cooperating with Kola NPP.

In the Ukraine, ANPP is cooperating with OAO(JSC) Turbatom, (Kharkov), Dizelny zavod (Krivoy Rog), Promenergomash (Sumi) and the Kyivska Armatura Corporation (Kiev).

In the National High Technology Centre of Georgia, a *Directory on radiation safety* in English, Russian and Georgian languages has been published in cooperation with CNII(CSRI) Atominform (Russia). A Georgian-Russian-English dictionary/thesaurus of nuclear terminology is also being developed.

Russian enterprises have manufactured and supplied instrumentation for the safe operation of proton linear accelerators to the Sokhumi Institute of Physics and Technology, which produces short lived radio nuclides used in medical organizations in southern Russia.

The National High Technology Centre of Georgia and Russian enterprises are carrying out the following joint works:

- R&D designed to improve the neutronics of NPP absorbing elements based on boron carbide, for subsequent use at NPPs operating with thermal neutrons, thereby improving their nuclear and radiation safety.
- Development of an English-Russian-Georgian Directory on nuclear science, techniques and technology. Armenia has expressed a willingness to join in this project.

Azerbaijan and Russian Federation have resumed joint work on radiation investigations. The exchange of experience accumulated in licensing and inspecting the safe operation of all organizations using nuclear energy throughout their life cycle is taking place between the

Scientific and Technical Centre on Nuclear and Radiation Safety (Russian Federation) and the regulatory bodies of Armenia, Belarus, Kazakhstan and Ukraine.

2.6.1. Spent nuclear fuel and radioactive waste management

Ukrainian NPPs have been transporting spent fuel to Russian Federation reprocessing enterprises for many years. In 2006, spent fuel from Ukrainian NPPs was transported to the Russian Mining Chemical Combine (GKhK, Krasnoyarsk-26) and FGUP Mayak as planned.

Within the framework of *National Programme on eliminating the consequences of the Chernobyl Catastrophe*, regulations for decontamination and waste management activities have been developed by Russian and Belarus experts in close cooperation. These documents are currently being applied at the specialized enterprises of Goskomchernobyl of Belarus (Minsk).

2.6.2. Industrial and engineering areas

A Kazakh-Russian-Kyrgyz Company JV Zarechnoe was set up in 2001 to operate the Zarechnoye uranium deposit site in Kazakhstan. This is a uranium mining enterprise using the underground leaching (UL) process.

As part of the Ukrainian-Kazakh-Russian JV for nuclear fuel production the Kazakh Ulbinsk Metallurgical Plant is planning to start practical activities in developing cooperation in producing nuclear fuel for NPPs. The joint Belarusian-Russian enterprise Isotope Technologies has been operating since 1988. The enterprise deals with the production and supply of radioactive sources for industrial and medical uses as well as transportation, storage, charging/recharging and the repair of radioisotope instruments and facilities. In addition, the enterprise performs decommissioning work on gamma-setups of various types and provides transport services for radioactive commodities.

In May 2007 the Russian-Kazakh intergovernmental agreement to establish the International Centre for Uranium Enrichment (ICUE) was signed. It is considered as the first step in implementation of the Russian initiative to establish ICUE. Such centres would not only provide guaranteed access to uranium enrichment services for all their participants but also help to maintain an enriched uranium inventory sufficient to fabricate fuel for two charges of a 1000 MW reactor.

The ICUE will be monitored by the IAEA. Armenia and Ukraine have already confirmed their interest in participating in the ICUE.

2.6.3. Ecological issues

Existing storage sites for uranium production 'tails' and ionizing radiation sources, lacking ownership after the disintegration of the USSR, is a huge problem for many CIS countries. The situation is extremely complicated in Kyrgyzstan where there are 30 'tail' storage sites containing uranium production waste. Contamination from radioactive and toxic waste stored in Kyrgyzstan can also affect the ecological situation in the neighbouring countries of Central Asia — Kazakhstan, Tajikistan and Uzbekistan. Hence, work on scientific and engineering development of high-priority re-vegetation solutions is being undertaken jointly with VnipiProm Technology (Russia). Specialists from VnipiProm Technology and OAO(JSC) Atomredmetzoloto have evaluated the extent of high-priority exploration and design works in order to assess the investment required for re-vegetation of territories affected by uranium mining enterprises located in Tajikistan.

As a result of the sixth Commission meeting, professional teams are working on the rehabilitation of the territories affected by uranium production sites, as well as addressing the problem of inventory and utilization of ionizing radiation sources deployed on the territories of CIS countries.

2.7. PREPARING NUCLEAR POWER PERSONNEL

Universities in Russia, Ukraine and the International Sakharov Institute of Radioecology in Belarus are involved in preparing personnel for nuclear power engineering. The same institutions accept specialists from CIS countries for probation, postgraduate courses, courses in control and accounting nuclear materials and physical safeguards.

Novovoronezhskiy Training Centre (NVUTTs) is designed to prepare specialists for nuclear power plants.

The National Nuclear Centre of Republic of Kazakhstan, created with Russia's assistance, is successfully training specialists from the nuclear industry.

Currently the Member States of CIS Commission are discussing the technological aspects of participating in the activities of the World Nuclear University (WNU) and World Nuclear Association (WNA).

In order to provide information on the course of cooperation between the Member-States of Commission the Secretariat has established an internet site to enable the participants to update information remotely (http://sng.ainf.ru).

3. CONCEPT OF NUCLEAR KNOWLEDGE PRESERVATION IN RELATED PAPERS PUBLISHED IN RUSSIAN LANGUAGE

3.1. CHARACTERISTIC FEATURES OF KNOWLEDGE PRESERVATION PROBLEM IN CIS COUNTRIES

A major and promising direction of developing CIS countries cooperation is their interaction in the preservation and management of nuclear technology knowledge. A peculiar feature of the present situation is that a significant proportion of the normative documents (standards, guides, methodologies, etc.) in CIS countries only exist in the Russian language. In the 1990s a number of agreements were concluded according to which these normative documents would be in effect in the various countries until such time as appropriate documents would emerge in the legislation of each country. However, in some cases, e.g. when it is appropriate to maintain identical terminology, it is more rational to maintain the original language of the documents. Therefore multilingual dictionaries and thesauruses are being created to enable the use of national language when searching and describing documents stored in Russian. This is particularly true for methodological materials and textbooks.

Such materials can be neither originally prepared nor authentically translated, due to a lack of professional resources. Such a situation is not limited to CIS countries. Due to attrition of professionals from nuclear energy, many developing countries suffer similar problems with materials in both the English and French languages.

3.2. SUGGESTIONS FOR RESOLVING THE KNOWLEDGE PRESERVATION PROBLEM IN CIS COUNTRIES

In 2003 within the framework of the Commission a specialist team worked on nuclear technological knowledge preservation with the assistance of IAEA INIS experts.

Based on the knowledge preservation model the first and most important phase is the creation of the inventory of objects for knowledge preservation. In order to realize this phase, IAEA INIS/NKM Section offered a specific approach and an appropriate questionnaire to help CIS countries to consistently describe topics according to the data presented by the Commission members.

The team proposed the following activities:

- Develop a methodology for verifying knowledge which, when available, will support the main function of knowledge management — its potential use in solving new problems.
- Classify resources organizationally and methodologically.
- Use the multiingual INIS/ETDE thesaurus as for the basis of a unform system for describing knowledge.
- Assess CIS countries' requirements for knowledge in nuclear science and technology.

Based on the Commission members' proposals the priorities have been determined for each country. This data are presented in Table 2, where the knowledge requirements are based on a four point scale produced by the experts.

TABLE 2. THE PRIORITIZATION OF THE KNOWLEDGE REQUIRED FOR CIS COUNTRIES

Country	Nuclear science	Ecology of mining nuclear fuel	Planning and economics of power facilities	Operating NPP	Spent fuel management	Nuclear fuel reprocessing	Nuclear medicine and technologies	Preparing personnel for nuclear technologies	Nuclear ecology
Armenia	3	0	3	3	3	1	3	3	3
Azerbaijan	3	0	0	0	0	2	3	3	2
Belarus	3	0	3	0	0	0	3	3	3
Georgia	2	1	0	0	0	0	3	3	2
Kazakhstan	3	3	3	1	2	0	3	3	3
Kyrgyzstan	1	3	0	0	0	2	2	3	3
Russian Federation	3	3	3	3	3	3	3	3	3
Tajikistan	2	3	0	0	0	0	2	3	3
Ukraine	3	3	3	3	3	1	3	3	3
Uzbekistan	3	3	0	0	1	0	3	3	3

Notes: 0 – no requirement;
1 – knowledge of general character being adequate;
2 – special knowledge required for particular professional groups;
3 – professional knowledge required for specialists).

The Commission Member States are working to integrate knowledge in atomic science and techniques into one common system with regulated access to its resources.

The progress of scientific development has resulted in particular ways of organizing research and presenting findings; the scientific language and the means of presenting or describing new knowledge are so chosen that the results of research can be presented compactly and intelligibly for specialists working in the same 'cutting edge' of knowledge (it is worth noting availability of the so called 'tacit' knowledge and experts who are carriers of such knowledge). This approach is generally adopted regardless of the particular field of investigation. Since scientific research is seldom a consistent, purposeful accumulation of knowledge within the framework of some predetermined process, the results presented are often inconsistent. The models developed can prove inadequate and even contradictory data on properties being inaccurate. Nevertheless, the experience and qualification of a researcher allows him or her to move forward despite such features of scientific knowledge.

Activities on knowledge preservation are based on a fundamentally different premise, their objects not being based on the results of new studies but the knowledge already formulated by experts.

Currently a user of preserved knowledge is most likely to be a specialist lacking the whole range of evidence required to understand scientific texts (descriptions of research results) from the 'cutting edge' of science. This specialist is likely to have a different scientific background (in special cases, an applied researcher in the same field of knowledge), to be a scientific 'beginner' or an analyst, whose task is to design an (expert) information system enabling automatic use of the knowledge being preserved in subsequent applied studies.

A particular application of knowledge preservation may be to record the results of investigations which were cancelled for some reason but which, according to experts, might be required in future.

Knowledge preservation also differs from the traditional activity to popularize knowledge or to develop new academic courses for students (or guides and learning materials for upgrading courses). It is not explicitly oriented for student learning (i.e. it is not supposed to contain didactic material). As a rule knowledge preservation activities result in an independent (not associated with a researcher) complex of formalized descriptions of the findings of previous studies (this is usually a computerized information system). The basic value of such a complex is the simple and convenient access to the stored objects (i.e. supported by an effective search engine, possible easy application of knowledge to new investigations, etc.).

A methodology is needed for the creation of similar systems and the work of system analysts (experts) who provide system contents, as are specific tools for providing search and access to objects being stored (knowledge), including meta descriptions. So, for example, definition of set of base concepts, i.e. further indivisible 'blocks' of the knowledge which presence is necessary at a rubrication of a subject domain and codification of its objects is not trivial.

Current practice shows that this work should be based on specialized linguistic tools: classification rules, thesauruses and glossaries (e.g. INIS/ETDE thesaurus).

Thus, current knowledge preservation work may be defined as: the structural analysis of the topical area 'nuclear science and techniques' with its own technological tools: thesauruses, classification rules, glossaries of the field and computer based systems as well as a number of professionals/experts in nuclear science and technology, analysts and programmers with the expertise to create systems for knowledge retention.

All of these differentiate the activities involved from any other types of research activities.

3.3. DEVELOPING A METHODOLOGY AND COMMON APPROACHES TO THE PROBLEM OF KNOWLEDGE PRESERVATION

3.3.1. Sampling particular knowledge objects package

Due to very real commercial interests (national level, company, organization, enterprise and others) the process of knowledge preservation is to be reasonably performed at the corresponding structural/organizational level. The process may be implemented according to the following algorithm — sequential (consecutive) development of an inventory of knowledge in nuclear science and technology, initiated and performed by field enterprises and individuals (the knowledge carriers) which should result in first creating local, site-based, knowledge descriptions and then (as a final result of the inventory development) a national register of knowledge objects. The register in this case can be considered as unambiguously identified suggestions from the authors to refine the potential knowledge objects to be stored to a quality which will make them marketable.

Development of a centralized (accordingly managed organizations, companies, enterprises) national list of the field requirements for knowledge (i.e. creation of a 'requirements' specification for nuclear knowledge). This specification may be considered as the potential demand (request) for contents of the knowledge to be stored.

A similar activity is expected to be performed at international level as well, with the IAEA coordinating the work. For this, a specialized enquiry has been prepared which is under negotiation with the Commission Member States at present.

3.3.2. Principles for realizing separate projects

Specific features of knowledge preservation activities in nuclear science and technology are:

— A considerable element of commercial secrecy/sensitivity concerning technological projects developed by individual organizations.
— Existing restrictions in knowledge transfer due to nuclear technology non-proliferation requirements.
— High demands for the quality of knowledge being stored since it is applied in a sensitive field with rigid safety requirements.

A consequence of the first point above is that a significant amount of knowledge is registered in commercial reactor projects (e.g. PWR, WWER or CANDU) and the technological documents substantiating technical solutions and safety features of these facilities.

A still greater amount of knowledge has remained beyond industrial applications; this is particularly true of designs that have never been developed commercially, e.g. fast reactor based facilities.

In this context, the implementation of specific projects where it is necessary to register the knowledge within the framework of activities mentioned above, is most unlikely to be of a centralized nature, since the real priorities are based more on gaps in existing knowledge, rather than corporate activities. On the one hand, the extent of project readiness will have a major impact on potential implementation but, on the other hand, it will be affected by the degree of interest in the project from possible investors or customers. It is clear that the extent of project readiness will directly depend on the perfection of the tools, including the means of macro description of the knowledge.

It should be noted that the downsizing of local projects might result in various project elements existing in different languages (e.g. work on fast reactors was most dynamically undertaken in the Russian, French and Japanese languages and, to a smaller extent, in the English language). Therefore, the knowledge macro descriptions must not depend on the implementation language of creation.

The second and the third points above will place restrictions on the feasibility of project implementation.

The following steps may form the basis of particular knowledge preservation activities (a separate project):

- Collecting and verifying facts (possibly resulting in a database).
- Reducing all fact interpretations to one common point of view (resulting in a database).
- Evaluating facts and assessing their level of validity (resulting in a database).
- Collection methods (procedures) and descriptions of properties (resulting in programme texts, codes).
- Validation of methods (resulting in methods certified at a particular level of validity).
- Integrating methods and data, and validation (final result being the specification for a computer based system).
- Presenting material as a computer based information system for storing knowledge (the result here being a software product containing particular knowledge).

3.3.3. Tools for realizing knowledge preservation works (projects)

Developments in nuclear science, education, technology and industry have resulted in large amounts of various types of data. This data belongs to various agencies and organizations and may be grouped into the following sectors/classes:

- International intergovernmental organizations such as IAEA.
- Governmental and private information organizations.
- Higher educational organizations.
- Field institutions and laboratories dealing with applied studies and developments.
- The industrial sector, where the results of scientific research are adapted and implemented.
- Experts and expert groups who carry both explicit knowledge (subject to codification) and implicit (tacit) knowledge, which is sometimes of greater importance.

The amount of knowledge and data is so great that the problem of navigation within this ‘ocean’ of knowledge is becoming the top priority. This problem can be subdivided into the tasks of developing criteria for selecting relevant information, sifting that which is of no importance and certifying information and knowledge.

These long-known problems have been solved. Basic sources of certified (valid) data must be:

- Specialized international and national centres with systems for standard and referenced data on substances/materials properties and verified methods.
- International (e.g. NEA Data Bank) funds of algorithms and programs within and beyond the field.
- Higher educational institutions effectively selecting the most significant and reliable knowledge and transferring it to future generations.
- Expert groups, teams of authors and individual experts interacting with councils coordinating scientific direction.

It is of great importance to stress that all selected and certified knowledge must be converted into an electronic form and integrated into specific logical information systems, such as:

- Specialized expert systems (knowledge bases, including specialized software complexes).
- Factual databases.
- Systems for creating headings, catalogues and thesauruses in the Russian language.
- Tools for macro description.

These systems must include the means of accessing the stored objects (search engines).

A system of reliable expertise to estimate the validity of a final product in certifying the projects can be created according to the following hierarchical scheme:

- Author's quality assurance of the results in the form of a licence or author's agreement on their use.
- Implementation certificate.
- National certificate.
- International certificate (IAEA, NEA, IEA, etc.).

3.3.4. Requirements for knowledge storage environment

Regardless of how the local system (the object storing knowledge) architecture is arranged, it should represent the required results in a number of exchange formats, which would allow:

- Output from one system to input to a similar system.
- Generation of data files with a sequence of meanings sorted by generally accepted criteria.
- Generation of author's comments on output and stored data.
- Generation of information on the quality of data output.
- Reproduction of evidence certificates for the data forming the knowledge collections.

It is evident that effective knowledge preservation systems should be based on knowledge converted into an electronic format which will be possible only when the following requirements are met:

- Assurance of legitimacy of scientific and technical documents in electronic form (the legitimacy of previous scientific activities was assured by the use of a reputable publishing house, reviewing schemes, accessibility of publications, etc.).
- Availability of automated directory systems within industry or groups of enterprises which would provide regulated access to subject-oriented knowledge storage.
- Meeting requirements for knowledge indexing and codification tools.

3.3.5. Requirments for knowledge indexation and codification tools

Clearly any work to create knowledge collections must include the means to divide the topical area according to subject headings, for identifying objects to be stored, and search engines.

The need to divide a topical area according to subject headings is common to both bibliographic and factual systems. Currently the most advanced classification system used in nuclear science and technology is INIS/ETDE. Unfortunately, it is still incomplete but it can form the basis for the requirements for any new knowledge classification system. Here the main difficulty at present is to determine what constitutes an elementary object of knowledge, i.e. that which is unambiguously identified as an object to be stored and retrieved when necessary.

A system for indexing objects (INIS abstracts) for storage has almost been completed. This is the INIS/ETDE thesaurus. It's basic advantage and distinction from many comparable systems is its terminologically closed environment. This means that all of the thesaurus's terms, organized into a hierarchical system, refer only to the corresponding terms within the thesaurus.

Any stored object (an abstract, a table, etc.) can be indexed with a number of key words. Here the use of only INIS thesaurus vocabulary terms is of principal importance.

It is this very principle which enables the unambiguous identification of a stored object when searched. Moreover, it is this very principle which is violated by traditional Internet indexing systems.

3.3.6. Principles of knowledge objects inventory

To successfully create an inventory, one group of experts (specially organized as a working group) must determine and agree a number of general methodological characteristics that would be internationally acceptable:

- Develop, discuss and finalize (register), through specialized coordinating councils, the methodology and tools for providing a search engine for the stored knowledge.
- Define the object to be considered as a unit to be stored; this definition determining further possible formal descriptions for searching the references in the storage system and the real resources required to create this unit.
- Define and develop linguistic means of indexing a stored object which would uniquely characterize it among other objects and which would make it possible to search for it in a storage system, using the INIS thesaurus and multilingual terminology dictionaries as much as possible.
- Define the environment of concepts (i.e. describe the subject area through a specialized glossary) where knowledge objects stored as 'nuclear' must belong.
- Define common IAEA community requirements for software through which access to information storage systems is to be provided.
- Define an exchange format to enable the exchange of structures and knowledge descriptions among the community members (currently XML is most suitable for the purpose).

3.4. REQUIREMENTS FOR COUNTRIES — PROJECT PARTICIPANTS

Within the framework of the Commission the following measures would be logical to support further nuclear technology knowledge preservation activity:

- Agreeing a questionnaire, the answers to which would enable the Member States to determine potential national resources for each activity.
- Specifying relations with existing national and international establishments posessing databases whose data would contribute to a nuclear technology knowledge system.

The purpose of specifying these relations is to regulate the procedures in using:

- Certified data meanings on substance and material properties.
- Verified software tools, that is to develop formal procedures which would assure clients' confidence in the results presented by authors.

— Commercial and legal arrangements for using knowledge which is the subject of intellectual property.

National and international information systems under development must be compatible with all accumulated knowledge data arrays, have reliable data, demonstrate repeatability of previously obtained results and have the potential to include the information findings of recent investigations and developments in order to improve the technology of reactor materials and nuclear technology knowledge.

The use of knowledge must be regulated in accordance with the current principles of copyright.

3.5. CLASSIFICATION OF RESOURCES USED FOR KNOWLEDGE PRESERVATION

3.5.1. Organizational resources

(1) INIS national centres in CIS countries, IAEA INIS Section.
A common feature of cooperation with CIS countries within the framework of knowledge preservation work is the significant amount of scientific texts available in Russian and their unified presentation methodology, characteristic of traditional Russian scientific schools.
In addition, most current nuclear professionals in atomic science and technology received their fundamental education in the Russian language. Therefore it would be useful for the knowledge description, registering and access tools to be in Russian, taking advantage of much of the resources in Russian National INIS Centre (CNII (CSRI) Atominform).

(2) National research centres.
Before the collapse of the USSR, each national republic had a scientific centre doing research in nuclear science and technology. Currently, some work is under way in new research organizations, however previously accumulated knowledge is available in the corresponding archives and information systems.

3.5.2. Methodological resources

The IAEA specialists, primarily those in INIS and NKM Section are largely ahead in their knowledge preservation work compared with those of CIS countries, especially where complete nuclear knowledge material available in electronic form is concerned.

At present nuclear knowledge inventory results are loosely formalized in CIS countries. Apart from a general acceptance of the need there has been no consistent approach to such work, to say nothing of understanding of the structure and contents.

Obviously, the first step in such work is to develop a consistent description of tasks, resources and the potential of various participants within a unified methodological approach.

3.5.3. Recommendations on applying experience accumulated in bilateral interactions in the CIS community

The state of knowledge preservation work in CIS Member States varies dramatically. The linguistic tools for the description of nuclear technology knowledge applied in such INIS participants as Georgia and Kyrgyzstan are an example of this situation. While Georgia has been using a Georgian-Russian-English terminology dictionary for nuclear safety and ecology for several years, Kyrgyzstan is only just starting to plan such work.

Therefore involving CIS countries in IAEA nuclear knowledge preservation work is expected to synchronize the whole progress due to the application of common methodologies and exchange of experience, accumulated within a joint working plan.

3.6. INFORMATION SUPPORT OF PROGRAMME FOR CIS COUNTRIES COOPERATION FOR THE PEACEFUL USE OF NUCLEAR ENERGY

Existing IAEA facilities (methodological materials, INIS and NKM section's electronic databases, access engines, etc.) used to provide support and access for the commission's nuclear knowledge preservation work will allow greater realization of the potential of national scientific resources in advanced nuclear technology knowledge.

One of the ways to facilitate real knowledge application is to practically apply the knowledge that has been already accumulated. There are a number of materials in the Russian National INIS Centre, which can be made available to the community including, in particular:

- International wall table of isotope properties;
- Nuclide properties reference book;
- Basic Russian-English thesaurus vocabulary;
- Russian-English INIS header;
- INIS Atomindex search engine guidance in Russian;
- Georgian-English-Russian dictionary in nuclear safety and ecology.

There are plans to create an access medium and search engine for digitized microfiches of scientific papers (NCL), which are difficult to access. However, the status of these information tools has not been specified. These materials have been neither tested nor verified. It is assumed the IAEA will organize appropriate expertise and coordinate the production of full value knowledge objects from the existing software information tools in national centres. This would render a corresponding international status to such products and consequently improve potential users' confidence in them.

On the basis of information received from CIS countries on the status of their nuclear knowledge preservation problems, the following proposals are made for further developments within the framework of the Commission activities and jointly with the IAEA.

3.7. PROPOSALS FOR THE KNOWLEDGE PRESERVATION PROGRAMME

Taking the above into account, the following is proposed in the field of knowledge preservation:

- Cooperation in creating validated sets of standard and reference technological data on atomic science and technology based on those available from the systems of industrial centres.
- Creating validated sets of factual databases containing reliable values which would characterize the physical-chemical and nuclear properties of structural materials/substances used in nuclear technologies.
- Shared application of this data will reduce Commission Member States' costs for the verification and validation of data required for licensing and enhancing the safety of facilities. Using validated data is essential to reduce investment risk in realizing various nuclear energy projects in participating countries. Additionally, availability of such data will enable participation in an an exchange fund to be used when interacting with international research centers (e.g. OECD).

- Cooperation in the preparation and distribution of scientific and technological information abstracts on R&D results in the Russian language where the Russian INIS thesaurus is used as a basic tool for describing knowledge. Research currently undertaken in CIS countries is relatively unknown in other countries for various reasons. Reports on R&D previously undertaken, and archived, are not available to colleagues.

Creating an information system in abstracts (in terms of IAEA INIS technology) will enable scientific information exchange mechanisms in CIS countries to operate again; in addition, it will form a real basis for commercializing scientific results.

It is logical to present the results of describing data as databases of information in abstracts on optical media equipped with advanced navigation search engines. Distribution of such databases to appropriate organizations will improve the efficiency of implementing scientific developments.

3.8. POSSIBLE DIRECTIONS OF CIS COUNTRIES COOPERATION

Based on the results of the joint analyses performed by the Commission and the IAEA it is possible to outline the direction of further activities in the field of nuclear knowledge preservation and to formulate the top priority problems which the country-participants can address:

- Organizing on-line access to IAEA databases and INIS services.
- Creating an international system of classification, codification, unification (standardization) and certification of information resources.
- Developing and approving an agreement on international data certification.
- Creating databases with standard and reference information on the properties of substances and materials and organizing on-line access to them.
- Creating and supporting the operation of an international electronic library of scientific papers on nuclear technologies. Developing and approving an agreement on an international electronic library.
- Joint efforts in preparing specialists in the field of nuclear science and technology.

4. CONCLUSION

Despite the numerous problems mentioned above, knowledge preservation work can be arranged as a sequence of activities, the final objective being distinctly defined. The objective is to provide a potential user with a feasible access to information (data, procedure description, definitions of entities and relations between them) in response to a storage system enquiry. It should be particularly stressed that conventional search systems used in Internet media are not helpful in this particular case since the objects searched very often are not texts (tables of digits, graphs and the like). The enquiry must be in a form accessible for the user, e.g. motion through some hierarchy, from general to particular or some set of key words chosen from a directory-thesaurus, specially determined for this case. Clearly, the header and thesaurus are the core tools rendering meaning to sets of words, symbols of formulas or tabulated digits stored in a system.

The IAEA nuclear information system INIS has been developing tools for describing topical areas for 35 years — dictionaries, nuclear thesaurus, headers, etc. At present the INIS databases provide the most comprehensive macro descriptions of the topical area. The INIS/ETDE thesaurus contains more than 35 000 terms inscribed (entered) into a hierarchical relations system. It is obvious that the development of tools for preserving nuclear knowledge should take maximum advantage of the knowledge concentrated in the IAEA thesaurus.

The INIS multilingual thesaurus (dictionary) will solve one of the CIS's major technological problems — having to make INIS database enquiries in English. Applying a unified indexing system in the thesaurus will allow English language database enquiries to be made in Russian and, later, directly in national languages.

However, the thesaurus was developed primarily for bibliographic descriptions so the first priority is to develop and include tools for the identification other than text-based stored knowledge objects.

The second priority is to make identification systems more specific. The whole thesaurus is very large as it often has redundancy regarding requirements for the description of a particular object. Therefore, tools are needed to generate subsets of the thesaurus (specialized thesauruses) on recommended topics. It is evident that the first subset of this kind should be a specialized thesaurus on fast reactors.

Modification of the thesaurus must include work on interpreting terms as its present contents are designed for scientists who already possess the professional knowledge necessary for interpreting the meaning of each term.

Work on the linguistic instruments for preserving knowledge must be performed simultaneously in all national languages in which nuclear scientific and technological knowledge is available. The most obvious way to accomplish this work would be within INIS national centres, with the IAEA INIS section coordinating the activities.

In our opinion the task-oriented process of creating instruments for knowledge management in national languages must be mandatory for corresponding IAEA participating countries, as is currently the case with abstracting difficult-to-access papers for INIS databases.

Apart from the technological and linguistic issues reflecting participants' top priority requirements for creating the instrumentation needed for knowledge preservation, the solutions necessary for starting those works which do not need such instrumentation are also significant.

Within the framework of joint activities, one of the most critical knowledge preservation challenges is to create a map of nuclear technology knowledge specific to the former USSR countries. It is distinct from any other knowledge system, first because this knowledge was determined by the whole range of interrelated scientific schools in the USSR (in contrast to the schools of the USA and France) and second, due to the availability of particular materials developed historically by the course of research. Specifically, for a long time the Kharkov Physics-Technical Institute was the base for materials studies associated with development of new materials for nuclear energy. After the break-up of the USSR all Commission Member States continued to develop nuclear technologies in their own way and today the state of these activities is quite diverse. Nevertheless, since fundamental knowledge is based on common data, it is important for each country-participant to have all the documents, especially normative ones, substantiating the present state-of-the-art.

In creating the nuclear technology knowledge map it is necessary to jointly determine if the current document base is sufficient for future needs and, if necessary, how it will be augmented. This problem has been partially resolved by creating 'country files' in a common site http://www.sng.ainf.ru, however the information provided for this is rather fragmented and coordinated efforts are needed to develop the site. Such coordination is certain to be accomplished in terms of a Coordinated Research Project (CRP) prepared in the Commission on the topics of knowledge preservation.

An agreement on cooperation in creating and exchanging information resources and creating and developing the information systems of CIS countries in the peaceful use of atomic energy, will also have a significant impact on integrating knowledge. Negotiations on such an agreement are currently underway. This agreement will determine the normative base for further efforts.

When jointly preparing professional staff for nuclear science and technology it is important to consider that there are two fundamentally different contingents of trainees. The first group consists of junior scientists and engineers. The second consists of mature, experienced personnel who need retraining. For the first group, using such resources as the World Nuclear University, international courses, etc., based on the English language and international experience could prove useful. For the second group — specialized learning materials are needed in national languages, based on available operating experience. This knowledge can originate only from the national environment and must evidently be specially preserved and prepared 'on-site'.

The *Nuclear technology knowledge map* will enable the Commission Member States to create profiles of training specialists for those particular fields of knowledge which are critical for a country and where there is a lack of professional staff.

APPENDIX I. INFORMATION ON KNOWLEDGE RETENTION STATUS IN THE FIELD OF NUCLEAR SCIENCE AND TECHNOLOGY IN THE REPUBLIC OF ARMENIA

June 2005 — Armenia approves strategy of energy development. All activities in the field of energy technology are aligned with the strategy.

Currently in Armenia there is an operating NPP, the safety of which must be assured throughout the life of the plant. Eventually, the NPP will be shut down and decommissioned. Well-trained personnel are needed to support these activities. Therefore, the main task is to preserve nuclear knowledge at the current level in Armenia and to prepare new specialists in the field of nuclear knowledge as well as specialists able to maintain this knowledge.

In addition, considering the future development of energy in the Republic, experts need to be developed with a broad profile in the field of nuclear energy.

In Armenia the development of nuclear science and technology began in the 1960s. In the mid 1970s the first unit of the Armenian NPP was commissioned. At the same time several organizations and enterprises were established in the former USSR to provide engineering support for NPP operation. Since then many achievements in nuclear technology have been accumulated and registered in the Republic. After the break-up of the USSR and shut down of the Armenian NPP the country has suffered the loss of nuclear science and nuclear technology development. This has created the problem of how to preserve the information and knowledge accumulated throughout the Soviet years.

Considering all the above-mentioned and taking into account the great similarity of the problems in the former Soviet republics, NKM efforts in CIS countries' should be centralized and coordinated as far as practicable. In particular all existing knowledge in the field of nuclear science and technology should be identified and inventoried. Then these materials should be classified and ranked in order of importance for inclusion into international databases.

APPENDIX II. INFORMATION ON KNOWLEDGE RETENTION ISSUES IN THE FIELD OF NUCLEAR SCIENCE AND TECHNOLOGY IN THE REPUBLIC OF BELARUS

II.1. NUCLEAR KNOWLEDGE PRESERVATION PROBLEM AND POSSIBLE ACTIONS PROPOSED IN TERMS OF THE FUTURE DEVELOPMENT OF NUCLEAR ENERGY IN BELARUS

After the break-up of the USSR and becoming independent the energy supply problems experienced by CIS Members States are the most urgent of many problems.

Joint efforts to supply energy are among the key components of integration. In this respect, nuclear energy, which accounts for more than 33% of total European energy supply at present, could play an important role. Nuclear energy not only saves valuable fossil resources, allowing primarily oil and gas to be used more efficiently later, and enables a reduction in greenhouse gas releases, but is also a factor in improving the economic efficiency of the energy system, supporting stable economic and social development and enabling the development of alternative energy sources to maintain capacity.

As a result of the collapse of the common economic complex which integrated all the former Soviet republics, Belarus found itself in a more difficult position since it had a strong energy consuming industry and agriculture, which were not supported by an appropriate national energy generating infrastructure. National fuel resources (oil, gas, coal, etc.) make up only 15.1% of the country’s demand. The volume of gas imported from Russia is extremely high and accounts for 93% of gas used in energy production sector. More than 60% of energy generating facilities has exhausted their technical resources (spare parts, equipment, etc). Based on predicted socio-economic development in the Republic and increased demand for electricity, by 2020 the country will need to commission or upgrade about 6 TW of installed capacity. A review of various scenarios to close the energy capacity gap proved that introducing an NPP into the energy supply system would be economically feasible.

Thus, the expediency of nuclear energy development in the Belarus is determined by the following:

- Inadequate natural fuel resources.
- Required diversification of energy options and reduction of imported natural gas and crude oil.
- Potential long term reserves of nuclear fuel and independence from imported natural gas.
- Possible reduction in electricity production costs.
- Potential electrical energy export to improve foreign currency inflow into the Republic’s economy.

Since 1993 the Belarus has been investigating the feasibility of nuclear energy development. The first step was to develop a conceptual approach and draft programme for nuclear energy development in the Republic.

On behalf of the President and the Government of the Republic of Belarus, the work list for the development of nuclear energy in the Republic includes:

- Analysing the economic feasibility of introducing an NPP into the Republic’s energy grid.
- Studying the possibility of deploying an NPP and storing various types of radioactive waste within the Republic.
- Investigating the accummulated experience, problems and trends in developing nuclear energy worldwide and selecting an advanced design of NPP for construction in the Belarus.

- Examining the public attitude to options for overcoming the energy crisis and the outlook for nuclear energy development in the Republic.
- Implementing R&D and organizational work for the safe development of nuclear energy, radioactive waste management, NPP decommissioning and related challenges.

To accomplish these tasks, 17 industrial and academic institutions and a number of ministries and departments dealing with R&D have been engaged.

Studying various scenarios for energy system development has demonstrated that the optimum minimum cost option includes the introduction of an NPP into the national energy grid, i.e. development of nuclear energy in the Republic is economically feasible.

Research conducted on the possibilities of deploying an NPP and RW storages have yielded positive results. Potential NPP siting studies have identified three locations where six sites have been contoured. The sites meet not only international but also more rigid Russian requirements, stated in the normative documents for NPP deployment. A preferred and a redundant site have been determined for each location. The research results have also identified sites in the Republic suitable for reliable and controlled RW storage.

An interesting aspect of the investigations performed is that one option for NPP site is on land partially contaminated with radio nuclides.

There are international NPP designs which include advanced safety features to exclude the risk of LOCAs and radioactivity releases into environment. The best engineered, most reliable and safest reactor types, based on accumulated operating experience, have proved to be water-water reactor based NPPs of the PWR, BWR and WWER types. Taking into consideration the existing normative and legal bases, similar technological development, high level of safety, reliability and efficiency, the most promising designs for possible deployment in the Belarus, are the new generation Russian NPP projects of improved safety of WWER-640 and WWER-1000 reactor types.

To establish the public's attitude to possibility of developing nuclear energy within the Republic, three sociological studies were carried out in 1995–1998, in which the public, experts (specialists of high professional and scietific competence) and media employees were questioned sequentially.

The results showed that, during the period of these studies, the public's attitude to the possibility of developing nuclear energy in the Republic did not significantly change. One third were totally against; the remainder being prepared to support nuclear energy development provided a number of conditions associated with assuring public safety and routine NPP operation are met. Experts were mostly in favor (86% – pro), and media employees were opposed to the possible construction of an NPP.

As part of the *National Research and Technological 'Energetic' Programme*, between 1997 and 2005 two assignments were completed and a third is in progress, to provide a scientific and technological base for developing safe nuclear energy, which includes:

- Developing a draft concept for radioactive waste management.
- Analysing the possibility of constructing an underground NPP in the Republic.
- Starting work on normative documents to regulate the safe development of nuclear engineering, adapted to the local conditions and legislation of the Republic of Belarus.
- Studies on the effect of NPP siting on the public and the environment for both routine operations and within and beyond design accidents; as well as environmental influence on NPP operation.
- The basic factors required for comparative analysis and selection of optimum locations and sites for possible NPP deployment have been determined.

The following activities are under way:

- On-going development of the highest priority normative and technical documents for regulation of the safe operation of nuclear power facilities in the Republic.
- Research to optimize systems for monitoring environmental conditions when an NPP is deployed on land which is clean or partially contaminated with radio nuclides.
- Investigation of the potential and appropriateness of NPP deployment on land contaminated with Chernobyl radio nuclides.
- Research on transient and accident processes in WWER reactors during various phases of operation.

Studies are being conducted on the possible long term monitored storage in the Republic, of radioactive waste and spent fuel or spent fuel reprocessing by-products, including storage in NPP monitored areas.

Tasks to be completed before starting NPP construction are:

- Ongoing study of accumulated experience in nuclear engineering worldwide.
- Preparation of a *Declaration of Intent to Design, Construct and Commission an NPP*.
- Develop requirements for a plant construction tender and NPP design.
- Assess investment needed for construction, identify and confirm possible sources (of investment), and determine possibilities for funding and financial schemes.
- Complete the work package to select preferred and redundant NPP sites.
- Develop and adopt an *Act on Nuclear Energy Use*, identifying missing normative documents.
- Continue to provide information to support the authorities and inform the public on questions associated with energy policies and studies on the current state and trends in energy development worldwide.

The results of these studies (on the technical and economic justification of developing nuclear engineering in the Republic) will enable the Government of the Republic of Belarus to make a scientifically validated decision on NPP construction and reduce the preparatory work needed.

Work has been facilitated by the fact that nuclear science and technology has been in development in Belarus since the early 1960s within the all-union (USSR) programme:

- 1962 – thermal reactor IRT-2000 was commissioned.
- 1965 – Institute of nuclear energy within Belarus Academy of Sciences was established to undertake R&D on the development of a mobile NPP, gas cooled reactor fast reactor, etc.
- 1983 – construction of Minsk atomic power station intended for manufacture of electric energy and heat of 2000 MW capacity was started, Belarus NPP of 6000 MW construction planned.

It should be noted that the above mentioned nuclear engineering studies in Belarus were carried out in close cooperation with R&D institutions and design offices of the Russian Federation, as well as technical and information support from the IAEA and other international nuclear centers.

In 2005 the President of the Republic of Belarus approved two documents which determine national policy in the field for the future. In 2007 a new decree was issued to administratively support preparatory work to construct an NPP in Belarus. A preliminary assessment of construction sites for a future NPP should be completed by April–June 2008. The Government of the Republic of Belarus has decided to allocate US $23 million for 2007–2008 to prepare for the construction of an NPP.

II.2. DESCRIPTION OF NUCLEAR RESEARCH AND TECHNOLOGICAL FACILITIES OPERATING IN BELARUS

II.2.1. 'Hyacinth' critical assembly

At the request of President A. Lukashenko, when visiting the National Academy Science (NAS) and Joint Institute of Energy and Nuclear Research 'Sosny' in 1998, critical assembly of this institute has been reconstructed. The aim of the reconstruction is to create the multi-purpose critical facility 'Hyacinth', to enable the modeling of a wide range of water-uranium, uranium-hydride zirconium critical assemblies as well as un-moderated UO_2 fuel elements arrays with 10%, 21%, 36%, 45% and 90% ^{235}U enrichment, moderator blocks of hydride zirconium and blanket blocks of hydride zirconium, beryllium and stainless steel.

The 'Hyacinth' critical assembly has been designed to perform benchmark experiments on criticality to create a reliable experimental database to verify calculating codes for the physical characteristics of small sized reactors, used for various purposes in low power energy systems. In addition 'Hyacinth' is to be used in investigating a number of other physical characteristics of critical assemblies (fission density distribution over core volume, efficiency of control rod absorption, spectral indices, neutron spectra, reactor kinetics parameters, etc.), in developing new methodologies for the measurement of the physical characteristics of reactor systems.

The critical facility is also intended for use as a methodological and experimental learning facility to prepare Belarusian specialists in nuclear physics, reactor physics and the use of ionizing radiation.

II.2.2. 'YALINA' sub-critical facility

To meet President A. Lukashenko's demands regarding accelerator based investigations in the field of nuclear and neutron physics, long-lived fission products and actinides transmutation technologies in energy production 'YALINA', a unique neutron generator controlled sub-critical facility has been created with a thermal neutron spectrum. The facility is used for experimental studies on the physical characteristics and kinetics of future, external source controlled nuclear power reactors (with a thermal neutron spectrum), transmutation technologies for long-lived nuclear wastes, etc.

The experimental programme at this facility is undertaken in close cooperation with European nuclear centers in Spain, France, Germany, Italy, and Switzerland. Interest in the facility has been expressed by China, India, Japan, USA, Turkey and other countries.

II.2.3. 'YALINA-B' cascade sub-critical reactor system

Commissioning of the cascade sub-critical reactor system 'YALINA-B' will support further developments in the field of advanced nuclear technologies (nuclear physics, kinetics of next generation fast reactors, transmutation of radio-toxic isotopes from nuclear fuel cycle enterprises, etc.) required by President A. Lukashenko during a visit to 'Sosny' Joint Institute of Power and Nuclear Research in June 2002. Construction of 'YALINA-B' will be a significant step in creating an experimental complex of nuclear facilities designed for:

- fundamental studies in nuclear and neutron physics;
- solving important national economy problems related to the radiation testing of electronics components;
- developing technologies for creating radiation-resistant microelectronics products;
- neutron-activation analysis of geological samples (needed for mineral products exploration);

- solving problems in ecology, agriculture and oncological disease treatment;
- determining the composition of explosives and drugs;
- identifying nuclear materials, etc.

II.2.4. Shut-down and decommissioning of nuclear enterprises and facilities

(1) ‘Rosa’ critical facility for modeling and investigating uranium-hydride thermal nuclear reactor core grid.

Based on studies on nuclear reactor physics in Belarus in the 1960s the need to model and investigate thermal nuclear reactor uranium-water assemblies emerged, in addition to the experimental verification of calculation codes and nuclear data being generated. To accomplish these a critical facility ‘Rosa’ was commissioned in the Nuclear Energy Institute of Belarusian NAS in 1965.

The ‘Rosa’ facility enabled the creation of geometrically regular clean cores (cylinder, parallel-piped, and prism) free of excitation from experimental channels, regulating and absorbing rods, etc. The fuel from ‘Rosa’ since has been discharged and shipped to the ‘YAVAR’ storage facility, some of the equipment has been shipped to ‘YALINA’ and the facility is being prepared for dismantling.

(2) ‘Crystal’ critical assembly.

The ‘Crystal’ critical assembly was created to study the reactor physics of the ‘Pamir’ mobile atomic station. Fuel from the facility has now been discharged and shipped to the ‘YAVAR’ storage facility and the facility has been mothballed.

(3) IRT-4000 research thermal reactor.

The IRT-4000 research thermal reactor (2000 kW thermal power) was commissioned in 1962. The reactor construction was needed within the framework of an all-union (USSR) programme on nuclear science development in the Belarus. The reactor was rebuilt in 1971 to increase power to 4000 kW and was used to investigate thermal reactor physics, nuclear and radiation physics, neutron-activation analysis, radiation chemistry and nuclear biology. The advanced experimental base of the research reactor with its fully qualified personnel team made it possible, from the very beginning, to effectively assess the radiation consequences of the Chernobyl accident on the territory of the Belarus. The reactor was shut down in 1987 and decommissioning commenced in 1991. The irradiated fuel was shipped to a wet spent nuclear fuel storage facility and reactor decommissioning was completed in 1997.

II.2.5. Alternative (non-energy) uses of nuclear knowledge (nuclear medicine, agriculture and others)

(1) Ionizing radiation used in the national economy.

A number of technologies applying ionizing radiation are widely used in the economy of the Belarus, e.g. sterilization of medical products, processed electron beam medicine, preparation of various raw materials for drugs for organizations reporting to the Ministry of Health and homemade polymer products for various technical and medical applications.

Radiation technologies were also developed for the processing of food products such as spices, herbs, their mixtures, gelatin, lactose, chicken-meat, egg solids, etc.

Fundamental and applied studies, undertaken in cooperation between domestic and international organizations, at purpose-built experimental facilities (multi-purpose gamma-rig UGU-420 and electron accelerator UELV-10-10) provide further opportunities for the development of new technologies with direct commercial industrial process applications. The first of these are:

- Modification of polymer materials and products.
- Electron beam processing of various food products.
- Radiation sterilization of medical materials and products.
- Development of production technologies for medical substances, jointly with medical, biochemical and pharmaceutical organizations.
- Radiation testing of electronics and microelectronics devices.

(2) Production of radio-pharmaceutical isotope ^{99m}Tc.

A unique zero-discharge process for the production of the radiopharmaceutical isotope ^{99m}Tc has been developed. Having been clinically tested, the resultant preparation has proved to be very efficient. An automated pilot facility designed to produce radiopharmaceutical isotope ^{99m}Tc based on zirconium-molybdenum-gel technology has been patented in the Republic of Belarus and Russian Federation. Radioactive materials and product manufacturing activities have been licensed (production of isotope ^{99m}Tc).

(3) Production of radioactive sources for technological and medical uses.

In 1998, NAN Belarusian Institute of Energy Problems and the Russian Federal Research Center (Research Institute for Nuclear Reactors) established a joint Belarusian-Russian venture Isotopic Technologies. The company deals with the production and supply of radioactive sources for technological and medical uses in addition to the transportation, storage, charging, recharging and repair of radioisotope devices and facilities. All the activities listed are licensed in the Republic of Belarus. The company also provides services in decommissioning gamma-rigs of various types and the transportation of radioactive cargos.

Retention and further development of the processes based on ionizing radiation will enable widespread commercial use in the Belarus including such applications as modification of polymer materials and products, electron beam radiation of a wide range of food products, radiation sterilization of medical materials and products, medicine production technologies, radiation testing of electronics and micro-electronics products and the production of radio isotope sources. All of the facilities (and the new knowledge created in them) could be used for the preparation of new staff and the conduct of joint international research in the field of nuclear technologies.

II.3. ASSESSING THE NEED FOR CIS COUNTRIES TO MAINTAIN THE CURRENT OPERATING INFRASTRUCTURE AND APPROPRIATE LEVEL OF ACCUMULATED KNOWLEDGE AND EXPERIENCE IN THE NUCLEAR FIELD

In the 1960–1980s various educational establishments in the Belarus (Belarusian State University, Radio-Technical Institute, Polytechnic Institute, etc.) systematically prepared a wide range of junior nuclear power engineering specialists. Dozens of university graduates went on to study MSc and PhD postgraduate courses. After the break-up of the Soviet Union these activities ceased, the corresponding university chairs having been cancelled. Currently some higher educational organizations (Belarusian State University, International Sakharov Institute of Radioecology) have separate specialized lecture courses on physics and nuclear engineering technology problems and nuclear and radiation safety, with professionals from the ‘Sosny’ research institute functioning as scientific advisors on students’ course papers and diploma projects.

The following organizations and institutes of Belarus could participate in solving existing nuclear knowledge retention problems:

- Higher Academic Institutions of the Republic: Belarusian State University, International Sakharov Institute of Radioecology, Belarusian National Technical University (BNTU), Belarusian State University for Informatics and Radioelectronics, Belarusian State Technological University (BSTU) and others.
- Research institutes of Belarusian National Academy of Sciences.
- Ministry of Power Engineering of the Belarus and R&D institutions reporting to BelTEI, BelNIPI Energoprom, Energoproekt.

Is there an approach (methodology) in Belarus for solving the nuclear knowledge preservation problem taking into account the experience of the IAEA and other countries?

Currently there is no methodology for solving the nuclear knowledge preservation problem. For this work to be organized the following scheme can be proposed:

- Preservation of available knowledge and highly-qualified experienced personnel.
- Maintainance and further development of high-tech nuclear experimental complexes.
- Systematic preparation of younger specialists in the Republic's institutions, using highly qualified scientists and practical specialists as scientific advisors on students' course papers and diploma projects.
- Attracting younger specialists to research institutions and industrial enterprises dealing with nuclear technologies.
- Praparing highly qualified personnel through doctorate and postdoctorate courses.
- Participating in international projects associated with nuclear knowledge preservation.

II.4. POSSIBLE IAEA CONTRIBUTION TO RESOLVING CURRENT PROBLEMS; BELARUSIAN PROPOSALS FOR DEVELOPING INTERACTIONS WITH THE IAEA

Belarusian nuclear organizations have experience of interacting with the IAEA in solving various problems. During 1995–1997, the *Energy and nuclear energy planning for the Republic of Belarus using ENPEP codes package* project was accomplished within the BYE/0/003 framework of scientific and technical cooperation with the IAEA. During 1996–2000 the project *Compiling databases and optimizing Belarus energy sources for electricity generation* was completed. In 1999–2000 project BYE/2/002 *Quality assurance of radio-pharmaceutical preparation* ^{99m}Tc was undertaken.

Undertaking scientific and technical projects in cooperation with IAEA has contributed to improving the institutions' infrastructure and retaining personnel (jobs and salaries, additional financing).

IAEA courses on various topics are an effective means of upgrading the qualification of the employees in the field of nuclear technology. International scientific and technical conferences, symposia, workshops and seminars under the aegis of the IAEA contribute to international cooperation, information exchange (therefore nuclear knowledge preservation) and improvement of scientific activities. It is logical to maintain and develop these forms of cooperation with the IAEA.

APPENDIX III. STATUS OF ACTIVITIES IN KNOWLEDGE PRESERVATION IN THE GEORGIA

In the past the Institute of Physics of the Georgia Academy of Sciences routinely operated an IRT-type nuclear reactor as part of the then experimental research plans for R&D work, the results of which were used in many fields of science and technology. A key area was low-temperature radiation physics of solids. It is worth mentioning that the temperature achieved in the reactor core channels was as low as ~8 K. At that time the Institute of Physics was a lead institution on sub-ambient material studies within the Academy of Sciences of the former Soviet Union, presided over by the director and academic E. L. Andronikashvili.

Currently work in the field of nuclear science and technology has stagnated. However, some particular resources survive in many organizations. For these resources to be used they must be retained and properly financed. As in many other countries, the personnel in these organizations are aging, resulting in a loss of knowledge and, in some cases, whole exciting philosophies.

The inventory here is complicated and perhaps even impossible to complete. Nevertheless, a list of some activities currently performed in this country is given below.

(1) Intensive R&D is being undertaken to create ^{10}B isotope-based neutron absorbing materials primarily for isotope ^{10}B enriched boron carbide ($^{10}B_4C$). In addition, $^{10}B_4C$ products are being supplied for use in fast reactor BN-600. Work on fast breeder reactors is planned. Some work is underway to create an R-type thermo-element, based on $^{11}B_{6,5}C$, for a thermo-electrical converter of nuclear energy into electricity. There are excellent grounds to believe that this thermo-element will be widely used. Boron-10 isotope based passive systems are being developed to improve NPP nuclear and radiation safety.

(2) At the Institute of Physics of the Georgian Academy of Sciences activities are under way to restore the site of the IRT-type reactor. The institute is participating in creating radioactive waste storage (radioactive sources, etc).

(3) Tbilisi State University possesses a methodology for detecting low-level radioactive radiation and low-level mixtures.

(4) There are developments within organizations of the Georgian Academy of Sciences for creating pH-meter type devices and others designed for NPPs.

(5) At the Institute of High Energy Physics within the Tbilisi State University there are plans to create systems for various phases of the nuclear fuel cycle which would be based on Chernyshov rays and various light-conducting fibers to improve nuclear and radioactive safety.

(6) At Georgian higher educational institutions there are lecture courses on nuclear and atomic physics and, to a smaller extent, on nuclear facilities.

Thus, it is possible to find competent organizations and specialists in Georgia capable of solving nuclear science and technology problems at an advanced level. Nevertheless, specific tasks and funding would be required to employ them. Therefore it would be logical for Commission to make up a list of problems (tasks) which really need to be solved and are likely to be funded, with NPP proprietors (Ministry of Energy) financing the works.

The following are suggestions for the working group:

(1) Issue a directory on nuclear physics, technology and engineering in the English, Russian and Georgian languages. It has been agreed that the directory is to be published in cooperation with CNII Atominform from the Russian side and Georgian National High Technology Center (NHTC) from the Georgian side. Work on the directory is under way; however, appropriate funding is required to complete the work.

Azerbaijan and Armenian parties have expressed a wish to participate in developing the directory. Georgia (NCVT) has practical experience in this field. In 2000 a reference book on radiation protection was published in the same three languages — Russian, English and Georgian, in cooperation with CNII Atominform.

(2) Discussions on an encyclopedia on atomic energy would to be logical. Georgia could take an active part, especially in writing articles on stable isotopes, energy conversion, the radiation physics of solids, etc.

A main editorial board could be created to discuss the question, probably out of the commission members (representatives). The editorial board would discuss basic sections, problems, financial resources (IAEA), languages, etc.

It is worth mentioning that the *Concise Atomic Energy Encyclopedia* was published in the former Soviet Union in the past (1958), which was a great success.

(3) In CIS countries school classes and showrooms could be organized to display breakthroughs in atomic science and technology applied to various fields of human activity. In Georgia there are specialists who can deliver appropriate lectures. The commission is to apply to the IAEA for funding for the showrooms and lecture courses. Such arrangements will contribute not only to introducing the recent achievements of atomic science and technology in various fields of human activity, but also to improving the situation with illegal nuclear materials and the transport of radioactive sources, thereby reducing the risk of terrorist attacks. Commission must make a statement on this question at a meeting of the CIS Executive Committee.

APPENDIX IV. CREATING COMPUTER KNOWLEDGE BASE 'NAK KAZATOMPROM'

In addition to the human, financial and material assets necessary for effective operation at NAK(NCC) Kazatomprom Ltd. (further referred to as the 'Company') another strategic resource, which is information, is being considered, developed and successfully used. Due to the increasingly more complicated management of any/all current resources, information is becoming the most important resource for the Company's effective management and operation. Most large companies worldwide create automated systems for managing documents (including the creation, storage, access, use and destruction of documents) in order to efficiently use both incoming and available data to achieve their goals.

An organization either has document management or it does not. Managers in organizations find ways of resolving organizational document management problems according to the nature of the problems in each company. Most often companies introduce a reasonable filing arrangement on the server in order to be able to find necessary documents. In addition, they use electronic mail for sending documents to be discussed and for controlling execution. In general, such is the document management system of NAK(NCC) Kazatomprom. However, these measures are incomplete and will only be effective up to a point. Further, as the Company grows, it creates more and more complicated tasks, and such means of storing and retrieving information, supporting interactions and supervising performance, become inadequate. Here there are two possibilities; one is to introduce a rigidly limited paper document management system, which today would be like a return to the Stone Age; the other is to implement an electronic system. Usually the second way is favored, the main question being which system to choose.

To solve the problem it was imperative to build a unified information system, the 'Company knowledge base', taking advantage of recent computer technologies. This knowledge base will integrate, accumulate and store the whole experience accumulated by the Company throughout the period of its existence.

In addition to accomplishing the above-mentioned practical tasks, the system may function as a learning facility, enabling newly recruited staff of the Company to upgrade their qualifications, acquire new skills and improve their existing ones through access to text-books, learning materials, information on previously held events and work performed, advanced developments in various fields of science, technology, economics and law, all stored in the system.

Typically, large global companies and corporations introduce knowledge bases in order to solve problems, for example:

- Improving management performance due to automatic control of execution and organizational transparency at all levels.
- Supporting the quality assurance system (QAS) at a level corresponding to international standards.
- Supporting efficient capture and control of, and access to, information.
- Improving the effectiveness of staff due to improved formalization of each eployee's activity and the ability to store his/her work history.
- Recording company activities as a whole (internal office investigations, departments activities analysis, identifying 'bottle necks', etc.).
- Optimizing and automating business processes and their control, thereby minimising or excluding the company's paper document turnover.
- Excluding or simplyfying document storage due to the availability of electronic archiving.

A KPMG Consulting survey of 423 companies in the USA and Europe showed that 81% of companies questioned either have knowledge bases or are considering having them. Of the 81%, 38% already operate specialized knowledge bases, 30% are preparing programmes to create such bases, and 13% are starting work on them.

Any system for document management may include elements of the following categories. However, most of the systems will be particularly orientated within a specific field related to a target product. The categories are as follows:

(1) Information systems with storage and search engines (electronic archives (EA)). EA is a special form of document management designed for efficient information search and storage.

(2) Systems with a workflow (WF) capability. These systems are designed to support the passage of some objects over preset routes (so called ‘hard routing’). At each phase an object may change therefore the common term ‘work’ is used instead of ‘object’. Systems of this type are referred to as workflow — i.e. the flow of work. These systems can be used to organize specific work, all steps of which have been preset and can be described beforehand.

(3) Systems aligned to supporting organizational management and knowledge storage. These are ‘hybrid’ systems combining the two elements above, the basic concept being either a document itself or a job to be performed. To manage an organization both ‘hard and free routings’ are required. These systems are used dynamically in governmental agencies and the offices of large companies which have a distinctive hierarchy, where there are set rules and procedures for document routing, which is where NAK(NNC) Kazatomprom belongs.

The economic efficiency of electronic knowledge bases and document management systems is of prime concern to any corporation or company. Before discussing various factors for improving the efficiency of such systems, it is first necessary to decide how to define this efficiency. In accordance with the generally accepted definition, efficiency must be considered as a ratio of the performance output achieved to its cost.

$$\text{Efficiency} = \text{Output}/\text{Cost}$$

From this it is clear that it is possible to improve the Company’s efficiency in at least two ways: either decreasing costs or increasing output. Valid electronic document management systems enable both. Having implemented such systems an organization will have the potential to spend less and earn more.

Factors which reduce costs are as follows:

- Factor 1: Reducing the cost of paper documents.
- Factor 2: Reducing the non-productive time of employees.
- Factor 3: Speeding up information flows.
- Factor 4: Improving corporate culture.

In order to evaluate the possible economic benefit of implementing a knowledge base and electronic document management systems it is necessary to know how much time is spent by company employees on non-productive, routine operations on documents. An accurate assessment can be achieved by detailed studies and measurements of the existing document flow characteristics.

In accordance with assessments made by western consulting companies the share of such routine business operations can range from 20% to 30% of the whole working time. “Anyone who tried at least once to discuss a document in bureaucratic offices knows that it may take 60–70% of his working time” (an Internet quote).

Employees are known to spend 30–40% of their working time on searching necessary information and another 15% on communications to get the required data. Data and knowledge management assures continuous access to the required knowledge and employees do not waste their time on 're-inventing the wheel'.

According to data published after related studies were performed in US government offices, implementing such information systems increased the amount of work performed by 37% and the time required for this decreased by 24%.

Calculations show that in 1998 the Chief knowledge officer of BP saved the company US $260 million. According to studies carried out by KPMG Cosulting company in 2000, implementation of knowledge management programs resulted in increased efficiency in decision making of 71% and in 64% of cases, the quality of services supplied was improved.

As a rule, the introduction of knowledge management systems results in higher efficacy of operating time use, decreased costs and other advantages.

In order to start a pilot project at the Institute of High Technologies Kazatomprom 'Knowledge base' system was created and put into commercial operation within a short space of time. Currently documents, sources of knowledge, produced in the Company are fed into the knowledge base.

System architecture and a storage structure, comprising various subsystems, have been created.

Attributes have been created for documents accumulated on each topic developed with Microsoft Word, Microsoft Excel, Microsoft PowerPoint, AutoCAD and other applications. Before allocating documents in the storage system, a card was completed for each one, the cards now numbering several thousand.

In order to speed up document search, three categories were developed — by field and by key words.

At present Company is continuously inputting electronic documents in real time, from various sources, as well as viewing the design of document standard forms for their subsequent input. On completion of the card the document is directed for a discussion if necessary, appropriate document routes have been developed according to the knowledge base structure.

The technical and economic benefit to Company from the implementation of this project first became apparent by all employees being provided with the information they needed in a faster and more efficient way which will, in turn, bring about a higher productivity of work done. In addition, specialists can study various materials needed to fulfill their job obligations 'on-the-fly', finding out about recent breakthroughs in various fields of science and technology to continuously upgrade their qualifications and experience.

Apart from contributing to the production process, the system functions as a learning facility and enables recently enrolled employees to upgrade their qualifications and skills through access to learning materials, text-books, information on earlier events and work done and recent developments in many fields of science, technology, economics and law.

The strategic use of the information technology proposed in Company will result in the following:

- Giving employees fast and simple access to information at any time, at any place and with any facility. Analytical techniques and instruments are available for specialists to perform joint work, to interrogate the data base, assess data via their desk-top computers (using mobile systems in the future) and finally, utilising a generic tool for all facility types and integrating calendar, e-mail, problem synchronizer and control clock.
- Supplying scientific, engineering, consulting, R&D and other services to meet Company needs, responding to queries quickly and efficiently. In future, access to the knowledge bases will be possible with all possible types of tool. Company perfomance will be

increased through employee cooperation, integrating the information resource management of separate departments, keeping track of information and through analytical systems.

— Widespread adoption of Web-technologies, e.g. intranet and implementation of an infrastructure for message exchange, contributing to further development of communication systems and data sharing. The above will create a knowledge workplace where information is stored and systematized within the framework of all NAK(NNC) Kazatomprom enterprises and where the optimization of all business processes will facilitate the joint working of employees.

The knowledge management methodology proposed will provide an integrated approach to the creation, acquisition, integrated storage, accessing and effective use of the Company's information resources. These resources will combine the explicit knowledge accumulated over years, i.e. structured databases, text documents and tacit knowledge.

NAK(NNC) Kazatomprom is participating in the IAEA-TC coordinated project KAZ0003 *Nuclear Knowledge Management and Preservation in Kazakhstan* started in 2007. Its main objective is to preserve knowledge in critical areas, enhance capacity and further develop expertise and knowledge in nuclear science and technology in Kazakhstan.

APPENDIX V. KNOWLEDGE RETENTION STATUS AND KNOWLEDGE MANAGEMENT IN THE FIELD OF NUCLEAR SCIENCE AND TECHNOLOGY IN THE REPUBLIC OF KYRGYZSTAN

The former USSR Sredmash system's source of raw materials and basic enterprises became a part of NAK(NNC) Kazatomprom after the disintegration of the USSR, as it was located in the territory of the Kazakhstan. Similarly, the Central Science and Research Laboratory (CSRL) in Kara-Balta city, which supported underground uranium leaching activities, became part of the JSC Kara-Balta Mining and processing Plant (KGRK).

At the same time, research and engineering data on borehole uranium leaching technologies (1991–1992) undertaken in Kazakh enterprises is but a small part of developments accomplished in KGRK during its fifty years activity.

CSRL is maintaining and further developing resources which, in addition to existing reprocessing, hydrometallurgy and geo-technology procedures for uranium ore and the mining of valuable co-products, also contains comprehensive information on both advanced and some discontinued (which is no less important) directions of research.

Establishing and expanding the above mentioned enterprises has resulted in keen interest in, and tremendous growth of, research activities. However, retirement of aging experienced personnel, most of them leaving for Russian Federation, has led to a situation when there is no one to guard against repeating previous mistakes. Reasonable commercial use of CSRL technical library resources will help to avoid many problems associated with duplication of studies on those problems of underground leaching that were resolved several decades ago.

Regarding the above, in 2002 the Regional Educational and Methodical Center Geotechnology was enlisted to support significant work on reprocessing and digitizing scientific and engineering information resources of KGRK and CSRL, which it is intended to qualitatively upgrade.

Because Kazakhstan was the source of raw materials for KGRK, the Government of Kyrgyz Republic is undertaking appropriate efforts to create its own uranium supply.

In order to significantly increase the efficiency of geological exploration and attract direct investments in uranium mining technology the immediate generalization and reinterpretation of a huge amount of geological data on radioactive raw materials, accumulated over many decades in the Kyrgyz State Agency on Geology, is needed.

Accelerating this process will only be possible by implementing IT technologies in the processing of experimental results from all types of investigation (geological, geo-physical, geo-chemical) and converting information available in paper documents into electronic form.

The intended results of the completed work are:

- Creation of computer geological, geo-technological databases covering the whole territory of the Kyrgyz Republic including data on mineral raw materials, sources for the uranium mining industry, mining and ore processing technology, etc.
- Electronic versions of specialized computer uranium maps with validated forecasts and specific recommendations for efficient geological exploration work.
- Organization of information for advertisment purposes to provide maximum publicity of available data on Kyrgyz uranium resources and new ore reprocessing and enrichment technologies, in order to attract additional investments into geological and geo-technological investigations.

On the whole, the work performed in Kyrgyz Republic on nuclear technology and scientific knowledge management and preservation is consistent with the recommendations of international financial institutions (EBRD, World Bank, etc.) and meets the requirements of international companies for geological information in realizing Kyrgyz's geological and mining potential.

APPENDIX VI. KNOWLEDGE RETENTION STATUS IN THE FIELD OF NUCLEAR SCIENCE AND TECHNOLOGY IN THE RUSSIAN FEDERATION

According to IAEA data in 2006 nuclear energy share in the national energy balance was 16%, this being provided by ten Russian NPPs belonging to concern (Federal state unitary enterprise) Rosenergoatom which integrates all nuclear power plants, both operating and under construction.

There are a huge number of atomic enterprises in Russia. There are more than 170 organizations and enterprises in the field, under various forms of ownership. Under market conditions one of the top priorities is to find a niche in the market, which would assure further development. Therefore, since 1991 many research programmes have been cancelled. Unfortunately, the results of many years' research and implementation in design offices and research institutions are, as a rule, stored in the form of poorly ordered information arrays. They contain many thousands of reports, techniques, dissertations, descriptions of inventions, etc. A significant part of the resources being stored has become obsolete. The lack of subject or authors' catalogues, or the unified classification of open and closed sources, seriously impedes their application and, to a great extent, lessens the value of accumulated knowledge and those research results which have not yet lost their value. A ten year period of getting to the market has resulted in the attrition of qualified personnel capable of assessing and systematizing the accumulated materials. At the close of the century, this problem became very obvious.

In the field, there is a solid base for knowledge preservation. Eighteen data centers established at industrial enterprises deal with collecting, systematizing and automating databases. At present, an incomplete list, assumed as a basis for solving the knowledge preservation problem, is available at the State Nuclear Power Corporation GK(SC) Rosatom information center — CNII Atominform. The list is as follows:

- A national center of nuclear data with its own thesaurus and system.
- Industrial standard and reference data service.
- Computer modelling system for the nuclear fuel cycle at various enterprises (in any case they are available and used).
- Computer modelling system for nuclear reactor construction.
- Federal system for nuclear materials management and accounting as a certain database.
- CAD and CALS-technology in various forms (intensive activities have begun to develop these).
- Central source (fund) of insurance documentation.
- Automated information system to store the norms base for all industrial standards.
- Industrial information technologies and library center.

Due to the nuclear weapons tests prohibition, a new problem has arisen which is how to accumulate and maintain data resulting from hundreds of full scale nuclear weapons tests and dozens of physical experiments. Unfortunately, this data is not always documented. All-Russian Research Institute of Technical Physics VNIITF is undertaking this work under the leadership of one of the most prominent scientists of the field, Academician B. V. Litvinov. He has prepared a complete set of experimental data accumulated over about 50 years.

In 1998 All-Russian Scientific Research Institute for Inorganic Materials VNIINM started developing an information system on materials created in the institute in the field of atomic technology. The top priority was those information arrays on materials whose creation could only be proved by a very small number of leading professionals still working at the institute. This included data on steels, aluminum alloys, uranium, and hydride materials. The basic principle of classifying these materials was to align and structure information query logic to design processes, choice of materials, information supporting operating enterprises, substantiation of task-oriented investigations and technological developments. Within the information units created for separate materials there is basic data on the materials and related industrial technologies. In each section of an information unit, there is a list of original information sources containing detailed information needed for any in-depth studies on a particular subject.

The design, operation, safety assurance, and decommissioning of nuclear power facilities (NPF) have always been associated with knowledge of the thermal physics behavior of the materials used and the skill of calculating thermal physics processes.

In the Institute for Physic and Power Engineering named after A. I. Leipunsky, there is a major operating industrial thermal physics data center.

In recent years an advanced *Electronic directory on properties of substances used in thermal physics* in the form of an electronic book was proposed. This work was performed within the framework of a high school and fundamental science integration programme.

During the peak of nuclear activities in Russian Federation there were more than 100 critical facilities; now only a few dozen remain. Here they are:

- For WWER-type reactors — cold reactor bench in RRC Kurchyatov Institute and two benches in other organizations.
- For RBMK-type reactors — RBMK bench.
- Several facilities for studying innovation projects and fast reactors.

The lack of an accessible and understandable list of open and classified sources seriously impedes the utilisation of R&D results and greatly reduces the value of the results obtained and the knowledge accumulated.

It is therefore difficult to assess the real validity of R&D, so it is crucially important to preserve information and make it accessible. The future development of nuclear energy requires the systematization and preservation of knowledge on the problems of high temperature nuclear reactors, fast nuclear reactors and the use of plutonium as a fuel and thorium as a starting material for thermal neutron based nuclear energy with a high breeding ratio.

Knowledge on material studies is highly significant, especially the results obtained in a great amount of research on nuclear rockets, since these activities have practically ceased.

The following assets are available in the system of Federal Agency of Ecological, Technological and Nuclear Supervision and the Scientific and Technical Centre on Nuclear and Radiation Safety**:**

- A set of norms and regulating documents (rules and norms in nuclear engineering) as well as information on the development of the set.
- A bank of validation materials for software codes.
- An information base to substantiate the safety of nuclear technologies, prepared for licensing these technologies.
- An expert database substantiating the safety of new nuclear technologies in preliminary safety assessments.

Despite the fact that supporting and preserving these assets needs financing, they are of great practical value in operating present and developing future, nuclear technologies.

Currently concern Rosenergoatom is creating a complex programme of nuclear technology knowledge management. The main task of the programme is to concentrate nuclear technology evidence and documents to create ‘knowledge packages’ to support consistent decisions and requirements for the next generation of energy facilities.

In the programme great attention is also being paid to organizing knowledge on advanced reactor types (new technological platform) to be used in INPRO and GIF in which Russian Federation intends to play a part.

The federal programme *Development of Nuclear Power and Industry Complex of the Russian Federation in 2007–2010 and for mid-term until 2015* (FTP) has recently been approved. The FTP includes support for scientific developments, implementation of high technologies and the development of machine engineering and interfacing industries.

The FTP's main objectives are:

- To expedite the development of nuclear power and associated industry to support the geopolitical interests and energy security of the country through commissioning new series-made standard reactors at a rate of not less than 2 GW of installed electrical capacity per year;
- Promotion of Russian Nuclear Facility Centres' products (work and services) in world markets; and
- Transition to construction and operation of nuclear power plants abroad.

Massive nuclear power development in Russian Federation will require good nuclear knowledge and human resource management.

APPENDIX VII. INFORMATION ON KNOWLEDGE RETENTION STATUS IN THE FIELD OF NUCLEAR SCIENCE AND TECHNOLOGY IN THE REPUBLIC OF TAJIKISTAN

Republic of Tajikistan is not a nuclear country; neither is it a user of nuclear energy. However, achievements in nuclear science and technology are widely used in a number of areas such as medicine, agriculture, scientific investigations and others. Thus, preparing personnel and preserving nuclear knowledge is a significant issue. In soviet times, there was a centralized plan for preparing specialists and personnel both in the central universities of the Soviet Union and in the department of nuclear physics at Tajik State National University (TSNU).

The Department of Nuclear Physics at TSNU was established in 1961. Moscow physicists, well known for studies in the physics of cosmic rays, worked as part time professors at TSNU and, at the same time, did research. Until 1975 the basic research theme of the department was the physics of cosmic rays. In the 1970s and early 1980s the department's researchers also worked on the physics of activation analysis and radiation physics. Subsequently, the direction of research and personnel training has changed periodically, for two reasons:

- Firstly, the requirement of the national economy for narrow specialists (in nuclear spectroscopy, cosmic ray physics, nuclear physics methods of element analysis, geophysics, radiology, etc.); and
- Secondly, the change of scientific leaders and new department heads.

Throughout its existence the department has prepared many specialists in various fields of nuclear physics in close cooperation with the Joint Institute of Nuclear Research (JINR) and many other scientific centres of the Soviet Union.

The break-up of the USSR and it's effect on scientific relations between different research centers on the one hand, and insufficient funding and a lack of appropriate national infrastructure until 2000 on the other, led to a considerable deterioration in training specialists in the field of nuclear physics.

Since 2002 TSNU Department of Nuclear Physics has been changing its approach to educating and training from preparing fundamental scientists to applied professionals in such areas as: medical physics, dosimeters and radiation protection physics, and the country keenly needs these specialists.

The programmes of classical universities which, apart from humanitarian disciplines, include one to three year studies of fundamental physics and higher mathematics begin the preparation of these specialists (physicists). Then, starting with the sixth semester, the students are assigned to particular departments where, for period of two with half year, they take optional courses, write course papers and carry out diploma projects. During the time of the Soviet Union such specialists were prepared in central national academies, most of them being non-native people. After the break-up of the Soviet Union most of the specialists left the Tajikistan.

In preparing specialists regional and interregional projects of the IAEA and other international agencies are used.

During 2003 cancer specialists, radiotherapists, radiologists, monitoring specialists and others, undertook as many as 30 person/training courses, probations, and scientific visits within the framework of IAEA projects.

Having completed these training courses, many professionals serve as instructors for their associates on-site. The first steps have been taken in educating specialists in nuclear physics applied to radiation protection and medical physics. However, taking into account the fact that there are highly qualified professionals available as instructors (associate professors and full professors) originating from the former Soviet physics schools as well as IAEA support in this direction, there is every reason to believe that in the very near future a sufficient number of specialists will be prepared to meet the various requirements of the national economy.

Despite some problems in the Republic, physicists do fundamental research within the framework of various international projects as well as projects supported by the President's fund, through joint agreements with JINR and Moscow State University.

There are also intergovernmental, inter-academies and universities agreements and contracts in the field of research, education and personnel training.

An INIS centre has been established within the Nuclear and Radiation Safety Agency of the Tajik Republic Academy of Sciences, supported by the IAEA.

All of these are solid bases for knowledge preservation work in Tajikistan, particularly in the fields of fundamental nuclear physics, atomic science and technology.

APPENDIX VIII. INFORMATION ON KNOWLEDGE RETENTION ISSUES IN THE FIELD OF NUCLEAR SCIENCE AND TECHNOLOGY IN THE REPUBLIC OF UZBEKISTAN

VIII.1. RECOGNITION OF CURRENT NUCLEAR KNOWLEDGE PRESERVATION PROBLEMS AND POSSIBLE ACTIONS NEEDED

Retention and effective knowledge management has become a top priority problem worldwide. There are many organizations in Uzbekistan involved in nuclear physics work such as the Institute of Nuclear Physics (INP) and other institutions within the system of the Academy of Sciences (Physical and Technical Institute, Institute of Material Science and Institute of Nuclear Physics – 'The Physics–Sun', Department of Thermal Physics, Institute of Electronics, Institute of Space Instrument Manufacturing) universities, Ministries of Health and Agriculture, Ministry of Home Affairs, State Customs Committee, the National Security Service as well as large industrial enterprises such as Navoi Mining & Metallurgy Combinat and Almalyk Metallurgical Complex, Chirchik Electrochim-Prom Company and Uzbek Plant of Refractory and Heat Resisting Metals. Recognising that in all of them there is attrition of personnel, resulting in knowledge loss, and the problems of knowledge preservation and preparation of personnel are believed to be among the top priorities in the field of nuclear science and technology.

Although present national energy requirements are fully met by available gas, coal and hydropower reserves within the Republic, this does not exclude the possibility that some future conditions might require that the complete nuclear fuel cycle must be developed.

Therefore, it is reasonable to develop and support the current national nuclear fuel cycle technology; however deficient and imperfect in may be, since uranium mining and production is of national and international value. Uzbekistan is seventh in the list of national uranium deposits and fourth in uranium mining, the Navoi Mining & Metallurgy Combinat representing a complete uranium production cycle.

Current nuclear facilities and sites are not intended to be decommissioned in the foreseeable future.

In Uzbekistan nuclear knowledge is widely applied to non-energy activities, based on investigations carried out at INP of the Academy of Sciences where a 10 MW VVR-SM nuclear reactor, two cyclotrons (U-150-II and U-110), and a powerful gamma-radiator are in operation. The INP has a radio-analytical center and related laboratories performing studies in the field of nuclear physics and nuclear reactions, radiation physics and material studies, activation analysis, radiochemistry and the production and application of radioisotopes. At INP two enterprises Radiopreparat and Tezlatgich produce radioactive isotopes and there is a pilot plant manufacturing radio isotopic instruments. Most radioisotopes produced are exported to both the former Soviet republics and distant foreign countries.

In addition, research is performed at: the Scientific-Research Institute of Applied Physics of National University of Uzbekistan (NUU) named after M. Ulugbeck equipped with betatron SB-50; Samarkand State University equipped with microtone MT-22S; laboratories investigating problems of nuclear physics and analytical laser spectroscopy and a number of other scientific and academic institutions. Nuclear physics methodologies are widely used in agriculture, medicine, environmental protection, industry and many other fields in the Republic.

In Tashkent there are three medical centers dealing with nuclear medicine:

- The Republican Specialized Surgery Center where nuclear medicine procedures are used to assess various dysfunctions before complicated surgery on the heart, lungs and other organs, including the transplantation of such organs.

- The National Research Center of Oncology (NRCO) where nuclear medicine investigations are used for assessing the stage of malignant tumour intoxication. Here radioactive isotopes and an electron accelerator are used.
- The Institute of Endocrinology where nuclear medicine investigations are a prerequisite for treating endocrinous deseases using open radioactive sources.

The Navoi Mining & Metallurgy Combinat has accumulated a great amount of knowledge on mining and the production of uranium, whilst the State geological company Kyzyltepageologia possesses a great amount of knowledge on the exploration of uranium deposits.

The R&D results of various Uzbek companies and organizations involved in nuclear physics work were published in numerous papers and monographs, abstracts of which are available in INIS and other information systems.

VIII.2. ANALYSIS OF CURRENT INFRASTRUCTURE REQUIRED FOR THE RETENTION AND SUPPORT OF THE APPROPRIATE LEVEL OF EXPERIENCE AND KNOWLEDGE

In future, the provision of personnel will be achieved through education; in the department of nuclear physics of NUU by the present MSc programmes *Radio-preparations and nuclear technologies*, the *Nucleus and elementary particles physics programme* in Samarkand State University and in the INP of Uzbekistan Academy of Sciences where there are two scientific councils authorized to award ‘Candidate of science’ and ‘Doctor of science’ degrees in nuclear physics, nuclear physics applications and solid physics.

The Navoi State Mining and Metallurgical University educates and trains specialists in uranium exploration and mining and in other ores required for materials processing.

Thus, the complete continuity of personnel in nuclear physics and other nuclear related directions has been assured.

The following organizations can assist in solving nuclear knowledge retention problems:

- INP as a lead institution with many years of experience in collecting and applying INIS system resources as National INIS Center of Uzbekistan as well as experience in issuing nuclear topical materials. The institute also has a science and technological library comprising publications on nuclear knowledge, including those that are difficult to access, i.e. reports and dissertations.
- NUU, where at the department of nuclear physics and nuclear technologies nuclear researchers are trained.
- Science-Research Institute of Applied Physics of NUU.
- Samarkand State University with its laboratory of nuclear physics.
- The Navoi Mining & Metallurgy Combinat functioning as an organization creating and accumulating knowledge in the mining and production of uranium.

While performing research on the creation of electronic books, the INP at the National Academy of Sciences has developed and registered software (at the National Patent Office) which can convert nuclear knowledge contained in various materials into an electronic form and then make it accessible at the institute’s electronic library which is also available at the institute’s website http://www.inp.uz.

Therefore, it is reasonable to establish an office at the INP of the Uzbekistan National Academy of Sciences which would implement the centralized accumulation and storage of nuclear knowledge and which would output to the Internet through a fiber optic line.

In order to create the center, the institute is to be equipped with a computing complex with Redundant Array of Independent Disks or other similar data storage type.

VIII.3. POSSIBLE IAEA PARTICIPATION IN SOLVING MENTIONED ABOVE PROBLEMS

Possible IAEA participation could be in the form of technical and financial contributions to solving the following problems:

- Establishment of a knowledge inventory in organizations of great economic value for the Republic, institutions connected with nuclear medicine, etc.
- Development and implementation of a document management system in order to accomplish the inventory. The system will enable the management, classification, indexing, filing and storage of accumulated knowledge contained in different working documents (descriptions of developed methodologies, procedures and instructions, guides, etc.).
- Organization of joint work within a regional project. The INP resources used for the regional project could also be useful for preparing personnel.
  To this end, the following are proposed:
- Creating regional courses for training nuclear reactor operators, specialists in nuclear and radiation safety, nuclear radiation spectrometry and regulatory bases. Such courses could prepare personnel for Uzbekistan and its neighboring countries.
- Organizing, with IAEA assistance, a programme to prepare personnel in the field of nuclear science and technology. Within the framework of this programme, teachers for regional learning courses and young students at leading universities of Russian Federation and Europe could be educated in nuclear subjects.
- Creating a page on nuclear knowledge on the Website using information resources from National INIS Center of Uzbekistan.

A nuclear physics data system is to be developed, available through the Website, which would supply a wide range of services including full text of hard-to-access INIS documents and the whole range of publications issued in Uzbekistan for nuclear physics related institutions.

This portal would function as a nuclear knowledge management core system:

- Using INIS Web-services for collecting, appropriate processing and storing information.
- Creating a database of information thus collected (in accordance with general rules) within the framework of the joint regional project.
- Making use of the INIS Web-portal for nuclear university students to have free access to stored information when studying lecture courses, and other necessary learning materials according to the needs of the users.

APPENDIX IX. INFORMATION ON KNOWLEDGE RETENTION ISSUES IN THE FIELD OF NUCLEAR SCIENCE AND TECHNOLOGY IN THE UKRAINE

IX.1. CURRENT PROBLEMS IN NUCLEAR KNOWLEDGE RETENTION AND POSSIBLE MEASURES TO BE TAKEN BY UKRAINE

(1) Taking into consideration the outlook for nuclear energy development, in 2005 the Ukrainian Government established Sevastopol National University for Nuclear Energy and Industry (SNUNEI) based on the leading academy of Mintopenergo.
The fundamental responsibilities of the university are to:
- Prepare egineers (specialists) over the whole range of major topics to assure the safe operation of nuclear power plants (NPP).
- Prepare engineers (specialists) for nuclear fuel cycle and radioactive waste management enterprises.
- Prepare engineers (specialists) in physical safeguards and nuclear materials accounting and control.

(2) The Mintopenergo of Ukraine has approved the *Programme on Developing SNUNEI for 2006–2012* which assures comprehensive development of the field university.

(3) Maintain and upgrade SNUNEI education system including a university nuclear reactor where third year students begin ‘hands-on’ practice in nuclear reactor physics processes and radioactive waste management. The nuclear reactor is used as a learning facility in such major programmes as *Nuclear Power Plants*, *Automation of Technological Processes*, *Chemical Technologies of Rare Elements and Related Materials*, *Radioecology* and *Chemical Processes of the Nuclear Fuel Cycle*.

(4) In order to maintain the present level of nuclear knowledge on safe nuclear facility operation, SNUNEI is commissioning of the US complex analytical training facility on management of the block of the NPP with WWER reactor. In addition the university possesses local simulators for the reactor, turbine and electric shops. Moreover, the university laboratories are provided with authentic NPP equipment and instrumentation.

(5) A national system is being established for preparing specialists for nuclear fuel cycle enterprises as well as a uranium and actinides laboratory, a zirconium and hafnium laboratory and a laboratory for the study of rare elements technologies with extraction and ion-exchanging processes. These will enable the preparation of specialists who were previously educated and trained only in Russian Federation universities.

(6) The Ministry of Fuel and Energy Ukraine created an Institute of Professionalism for the managers and specialists of field enterprises. The basic task of the institution is to prepare highly qualified senior and middle managers and to upgrade the professional qualifications of nuclear-energy complex employees. In addition to this, SNUNEI has initiated the preparation of professional energy managers for NPPs within the ‘Energy engineering management’ curriculum.

(7) In order to meet Ukrainian demands for specialists in life-extension and the decommissioning of nuclear facilities, SNUNEI has established the specialization ‘NPP resource control and facilities’ maintenance’, meanwhile National Nuclear Energy Generating Company of Ukraine Energoatom has created a retraining programme for NPP personnel in controlling the resources of NPP facilities.

IX.2. ANALYSIS OF THE NEED TO MAINTAIN CURRENT INFRASTRUCTURE AND APPROPRIATE LEVEL OF EXPERTISE AND KNOWLEDGE ACCUMULATED IN NUCLEAR FIELD

(1) In the Ukraine academic and material resources will ensure the preparation of new personnel for nuclear energy based on the outlook for future development. A new list of baccalaureate and other qualification programmes has been developed which are designed to prepare, in addition to bachelors in nuclear engineering, specialists in applied atomic physics, ecological safety, information and measuring systems, instruments and systems for non-destructive diagnostics, computer-based chemical engineering, etc.

(2) SNUNEI is a leading university in solving the problems of assuring an appropriate quality of nuclear knowledge. In addition, National Technical University of Ukraine (NTUU) and Odessa National Polytechnic University are involved in the preparation of power engineers for atomic complexes. Specialists in nuclear physics are educated in National Taras Shevchenko University of Kiev.

(3) The Ukraine has developed an approach and methodology to solve the problem of nuclear knowledge preservation. The basis of the approach is the methodology developed in the USSR Department of Defence for submarine engineers' nuclear knowledge preservation. SNUNEI, possessing unique academic and material resources in cooperation with the Ukrainian Ministry of Education and Mintopenergo, has started developing a *Quality Assurance System for Preparation and Licensing Knowledge Acquired by University Graduates — Specialists Prepared for Atomic Industrial Complexes*.

IX.3. POSSIBLE IAEA CONTRIBUTION TO RESOLUTION OF THE EXISTING PROBLEMS, CIS PROPOSALS ON DEVELOPING INTERRELATIONS WITH THE IAEA

SNUNEI has participated in a number of joint projects with the IAEA (UKR0008-87291S, C6 UKR/06004P). However, the university is interested in further developing relationships with the IAEA.

Therefore, in order to improve the quality of professional training courses in the safety culture of operating NPPs, the university would appreciate additional IAEA funding for purchasing the following:

— Software-hardware complexes for operating and monitoring NPP nuclear facilities (reactor power control regulator, automatic capacity regulator, neutron flux automatic control, group measurement and control system, etc.).
— Simulator complexes and virtual models of NPP facilities developed by the Belgian company BARKO.

The university is interested in prolonged IAEA projects in physical safeguards, accounting and control of nuclear materials along the following lines:

— Purchasing and assembling a Rubejh-type complex for providing security of information against unauthorized access.
— Instruments to complete the equipping of a laboratory for nuclear materials physical safeguards, accounting and control (e.g. EGISTM defender type explosives detection equipment, radioactive waste SKG-02 heading recorder, SHS-02A neutron counter, 'Yantar', 'Porog, 'RKS-02', 'Kordon' type radiation monitors, MKS-AO3 type radiometers, detecting elements, turniket-type access and clearance systems).

BYBLIOGRAPHY

INTERNATIONAL ATOMIC ENERGY AGENCY

Meeting Report, Meeting of Senior Officials on Managing Nuclear Knowledge, 17–19 June 2002, IAEA, Vienna (2002).

Strengthening of the Agency's Activities Related to Nuclear Science, Technology and Applications, Resolutions GC(46)/RES/11B(2002), GC(47)/RES/10B(2003), GC(48)/RES/13C(2004), GC(50)/RES/13C(2006), GC(52)/RES/12C(2008), Sections on Nuclear Knowledge, IAEA, Vienna.

Summary of an International Conference on Managing Nuclear Knowledge: Strategies and Human Resource Development, held in Saclay, 7–10 September 2004, IAEA Proceedings Series STI/PUB/1235, IAEA, Vienna (2006).

Managing Nuclear Knowledge, Proceedings of a workshop held in Trieste, 22–26 August 2005, IAEA Proceedings Series STI/PUB/1266, IAEA, Vienna (2006).

Risk Management of Knowledge Loss in Nuclear Industry Organizations, IAEA Publication STI/PUB/1248, IAEA, Vienna (2006).

Knowledge Management for Nuclear Industry Operating Organizations, IAEA-TECDOC-1510, IAEA, Vienna (2006).

ABBREVIATIONS

ANPP	Armenian nuclear power plant
AO(SC)	Stockholder Company
BP	British Petroleum
BROND	Evaluated Nuclear Data Library in ENDF-6 Format
BWR	boiling water reactor
CAD	Computer-aided design
CALS	Computer-Aided Acquisition & Logistics Support
CANDU	Canada deuterium-uranium reactor
CIS	Commonwealth Independent States
CNII(CSRI)	Central Scientific Research Institute
CRP	Coordinated Research Project
CSRL	Central Science and Research Laboratory
EA	electronic archives
EBRD	The European Bank for Reconstruction and Development
ENDF	Evaluated Nuclear Data File
ENPEP	Energy and Power Evaluation Program
ETDE	Energy Technology Data Exchange
FAAE	Federal Atomic Energy Agency
FGUP	Federal State Unitary Enterprise
FTP	Federal Programme
GIF	Generation IV International Forum
GK(SC)	State Corporation
GUP	State Unitary Enterprise
IAEA	International Atomic Energy Agency
ICUE	International Centre for Uranium Enrichment
IEA	International Energy Agency
INIS	International Nuclear Information System
INP	Institute of Nuclear Physics
INPRO	International Project on Innovative Nuclear Reactors and Fuel Cycles
IRT	Research Thermal Reactor
JENDL	Japanese Evaluated Nuclear Data Library
JV	joint ventures
KGRK	Kara-Balta Mining and Processing plant
LOCA	loss of coolant accident
NAK(NNC)	National Nuclear Company
NAS	National Academy of Science
NCL	non-conventional literature
NCVT	
NEA	Nuclear Energy Agency
NII(SRI)	Science Research Institute
NKM	nuclear knowledge management

NPF	nuclear power facility
NPP	nuclear power plant
NRCO	National Research Center of Oncology
NUU	National University of Uzbekistan
OAO(JSC)	Joint Stock Company
OECD	Organization for Economic Co-operation and Development
OKB	Experimental Design Bureau
PWR	pressurized water reactor
QAS	Quality assurance system
R&D	research and development
RAID	redundant array of independent disks
RBMK	high-power channel-type reactor
RDCI	Research, design, and construction institute
RRC	Russian Research Centre
RW	radioactive waste
SNUNEI	Sevastopol National University for Nuclear Energy and Industry
TSNU	Tajik State National University
TSNU	Tajik State National University
VNIIAES	Russian Research Institute for Nuclear Power Plant Operation
WF	workflow
WNA	World Nuclear Association
WNU	World Nuclear University
WRENDA	Word Request for Neutron Data
WWER	water cooled water moderated power reactor
XML	Extensible Markup Language

CONTRIBUTORS TO DRAFTING AND REVIEW

Kadyrova, M.	Institute of Nuclear Physics, Republic of Uzbekistan
Karumidze, G.	Atomic Commission of Georgia Academy of Sciences, Georgia
Kitaev, I.	International Atomic Energy Agency
Kosilov, A.	International Atomic Energy Agency
Kruchinin, S.	International Atomic Energy Agency
Kupriyanov, V.	FGUP CNII ATOMINFORM, Russian Federation
Kuvshynov, V.	National Academy of Sciences of Belarus, Republic of Belarus
Mukusheva, A.	Strategic Research Agency Ltd., Republic of Kazakhstan
Petrosyan, V.	Armenian Scientific Research Institute for Operating Nuclear Power Plants 'ARMATOM', Republic of Armenia
Salomov, D.	Nuclear and Radiation Safety Agency, Republic of Tajikistan
Savchenko, G.	Kyrgyz-Kazakh Methodological and Training Center 'Geo-technology', Kyrgyz Republic
Smirnov, S.	Sevastopol National University for Nuclear Energy and Industry, Ukraine
Stulova, E.	FGUP 'CNII ATOMINFORM', Russian Federation
Yanev, Y.	International Atomic Energy Agency

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