Programme D. NUCLEAR SCIENCE

Rationale: The multifaceted aspects of atomic energy in nuclear power production and applications of radioisotopes and ionizing radiation in every sphere of science and technology are contributing significantly towards sustainable development and improving the quality of life. Many Member States also have significant nuclear power programmes, while non-power applications of nuclear sciences continue to grow and contribute to sustainable development.

Research reactors are essential facilities for nuclear science and technology. They are the main source of radioisotopes, and are extensively used for materials development and characterization. The last decade has also seen a rapid growth in accelerator science and technology, including the production of reliable accelerators for protons, heavy ions and electrons, and for their routine application in industry, research and medicine. High energy proton accelerators are used as sources of spallation neutrons for advanced materials research and have the potential for transmutation.

An important factor in the progress of nuclear science has been the development of nuclear instrumentation for reactor control and for all kinds of radiation measurements. Continuous evolution in the capabilities of nuclear instruments has facilitated progress in many areas, and properly functioning instrumentation is vital for all applications. Nuclear fusion has the potential to become an abundant, environmentally clean source of energy. About 50 Member States (including 30 developing countries) have programmes in plasma physics and fusion research. Since experimental facilities for high temperature plasmas are expensive to build and operate, international co-operation facilitated by the Agency is particularly important.

The entire spectrum of nuclear sciences and applications is deeply rooted in atomic and nuclear physics data. As a consequence of co-operative efforts, nuclear data generation, evaluation and dissemination have become integrated activities worldwide. The Agency is the main source of up-to-date information in this area for many Member States.

The Agency has the responsibility to promote research, development and practical applications of atomic energy for peaceful purposes. The growth of nuclear science and its applications is sustained by continuous R&D input from research institutes within the Member States, particularly the nuclear research centres. Continuous involvement of the Agency in co-ordination of this worldwide effort was recommended in a meeting on 'Nuclear Research Centres in the 21st Century'. Furthermore, the developing Member States seek technical assistance from the Agency in order to enhance their nuclear science based programmes. The continued involvement of the Agency is required to foster new developments. The programme on nuclear science is formulated by taking into account the comments of Member States and of external multinational advisory groups such as the evaluation committees, the Standing Advisory Group on Nuclear Energy (SAGNE), the International Data Committee (INDC), and the International Fusion Research Council (IFRC).

Objective: To increase Member State capabilities in the development and application of nuclear science as a tool for their economic development.

Outcomes
— Increased international co-operation in nuclear sciences. — Increased competence of national institutions, better use of resources, facilities, nuclear data and Agency databases.
Performance Indicators
— Number of Agency's products/documents provided to and used by Member States for their nuclear science activities. — Number of nuclear science institutions participating in/benefiting from the Agency's programme.

Specific criteria for prioritization:

— Fuel cycle aspects of research reactors and decommissioning.
— Effective utilization of nuclear instruments, research reactors, particle accelerators and fusion (plasma) devices.
— Nuclear data services.

Subprogramme D.1. Atomic and Nuclear Data

Rationale: All nuclear technologies depend on atomic and nuclear data to provide accurate descriptions of the underlying processes employed for both energy and non-energy applications. Such quantitative understanding of the formation and decay processes guarantees appropriate safety margins, for example, in the operation of nuclear plants and medical applications of radioisotopes. The necessary data include reaction cross-sections for many projectile–target combinations, energy based properties of the resulting reaction products, specifications of the atomic and nuclear levels, and the quantification of an extensive range of radioactive decay characteristics. While these data are reasonably well defined for some applications (e.g. uranium-based nuclear power plant), much remains to be done in support of other nuclear fuel cycles, proposed methods of transmutation, fusion reactor designs and nuclear medicine.

The Agency contributes significantly by taking the lead role in co-ordinating various international networks and undertaking in house studies that assist greatly in the establishment and maintenance of an extensive range of data libraries dedicated to experimental and evaluated atomic, molecular and nuclear data. Convenient and cost free access is provided by the IAEA Nuclear Data Centre to these shared international databases of compiled and evaluated data. The Agency also exploits on-going advances within information technology to speed up and improve the communications and scientific services of the Centre to all Member States.

Beneficiaries within Member States consist of fission and fusion reactor plant designers and operators, reprocessing facility operators, fuel transport design, radwaste storage facilities, and non-energy nuclear applications (e.g. materials analysis, materials research, environmental monitoring and nuclear medicine).

Objective: To increase the capabilities and expertise of Member States to ensure safe and economic adoption of all forms of nuclear technologies by providing access to reliable atomic and nuclear data for energy and non-energy applications.

Outcomes
— Access to and use of good quality atomic and nuclear databases by Member States for both energy and non-energy applications. — Increased quality in computerized data services (more extensive and speedier capabilities) provided to Member States.
Performance Indicators
— Increase in data services provided by the Agency, as measured by the number of data downloads by customers and that of data sets delivered on CD-ROM to the customers. — Growth in size and quality of the shared international atomic and nuclear databases.

Programme changes and trends: No general change in direction is proposed — essential services require continued development and maintenance in order to meet the demands of all nuclear data users in the foreseeable future. The user friendly IT system encourages customers to access and extract the most up-to-date high quality atomic, molecular and nuclear data. The IAEA Nuclear Data Centre will continue to extend these capabilities through IT development, along with the maintenance of hardcopy and CD-ROM services to all Member States (as also specified previously for 2002–2003).

Data development work continues to be shaped and supported by the external standing committees (INDC and Atomic and Molecular Data (A+M) Subcommittee of IFRC). This reshaping has most recently focused on the need to develop additional atomic and molecular databases associated with materials–plasma interactions and concomitant radiation damage. Debate on advanced fuel cycles and reactor designs has continued, and proposals have been made to ensure the availability of the desired nuclear data of a suitable quality as these discussions progress, necessitating the formulation of a new project category. While theoretical models will continue to be developed to assist in the preparation of key data files, work on the formulation of databases for X/gamma ray standards and fission yields will be phased out, and replaced with new initiatives dedicated towards advanced fuel systems and the assembly of a reference database for neutron activation analysis. All of these continuing and new initiatives are in response to recent debate in the INDC and A+M Subcommittee of IFRC, along with expressions of interest from scientists in Member States.

Resource changes and trends: The proposed resources for Subprogramme D.1 for 2004–2005 remain unchanged compared with 2003.

Financial resources (2003 prices)

D.1	2003	2004	2005
Reg. budg.	2 378 000	2 378 000	2 379 000

Recurrent Project D.1.01: Data services, data networks and user support

Main outputs: The project will result in: seventeen updated data libraries, including photonuclear, charged particle cross-section and Evaluated Nuclear Data Files (ENDF/B-VI), Computer Index of Neutron Data (CINDA), Computer Index of Atomic and Molecular Collision Data (CIAMDA) bibliographic publications and database, and Experimental Format (EXFOR) datafiles; trained personnel (mainly from developing Member States) in the use of databases that include reaction data for nuclear reactors (operational physics, design and safety aspects), medical applications of nuclear data, modelling of fusion plasmas, and evaluation of nuclear structure and decay data.

Unfunded activities/means of implementation: Rapidly developing non-alpha systems and guidance for regional data centres.

Ranking: 1 ex aequo

Project D.1.02: Nuclear data standards and evaluation methods

Main outputs: The project will result in: evaluated cross-sections for light isotopes and their uncertainties for adoption as reaction standards; and input parameters for nuclear reaction modeling codes.

Duration: 2002–2008

Ranking: 15 ex aequo (priority 3)

Project D.1.03: Nuclear data for radiotherapy using radioisotopes or external radiation sources

Main outputs: The following products will be available: up-to-date web page containing data on therapeutic radioisotopes; and improved data libraries for electron/photon transport processes in radiation biology.

Duration: 2002–2007

Ranking: 11 ex aequo (priority 2)

Project D.1.04: Atomic and molecular data for fusion experiments

Main outputs: The project will result in: the publication of Atomic and Plasma–material Interaction Data for Fusion; International Bulletin on Atomic and Molecular Data for Fusion; data on the interaction of plasma with wall materials, erosion of tiles and deposition of energy; and final reports of two CRPs (atomic and molecular data for fusion plasma diagnostics, and tritium inventory in nuclear fusion machines).

Duration: 2002–2007

Ranking: 1 ex aequo

Project D.1.05: Data for the Th–U fuel cycle

Main outputs: Final report of a CRP on nuclear data for Th–U fuel cycle, evaluated data files for Th–U fuel cycle materials, and web page of nuclear data for safeguards will be available.

Duration: 2002–2008

Ranking: 1 ex aequo

Project D.1.06: Nuclear data for reactor dosimetry

Main outputs: The project will provide databases applicable to prompt gamma ray activation analysis (PGAA), reference database for neutron activation analysis studies, and recommended dosimetry files for use by Member States.

Duration: 2002–2007

Ranking: 11 ex aequo (priority 2)

Project D.1.07: Nuclear data libraries for advanced nuclear facilities

Main outputs: An applications based library of recommended decay data for actinides, and Integrated Evaluation Development – data for advanced systems will be made available.

Unfunded activities/means of implementation: Development and support of a reference library for neutron transport calculations for advanced systems are partially unfunded.

Duration: 2004–2009

Ranking: 1 ex aequo

Subprogramme D.2: Research Reactors

Rationale: For over fifty years research reactors have been a cornerstone of nuclear science and technology. Their contribution to the development of nuclear power, basic sciences, materials development, radioisotope production for medicine and industry, and education and training of scientists and engineers is well documented. Research reactor issues are of great interest and importance to 58 countries that have one or more research reactors, 40 of which are developing countries. For nuclear research and technology development to continue to prosper, research reactors must be safely and reliably operated, adequately utilized, refurbished when necessary, provided with adequate non-proliferating fuel cycle services and safely decommissioned at the end of life. Moreover, since about 60% of the operating research reactors in the world are over 30 years old, ageing core materials and the technology of ageing management are priority issues in the majority of Member States with research reactors.

The Agency has established its competence in the area of research reactors with a long history of assistance to Member States in improving their utilization, by taking the lead in the development of norms and codes of good practice for all aspects of the nuclear fuel cycle and in the planning and implementation of decommissioning. This subprogramme is formulated to cover this broad range of issues and to promote the continued development of scientific research and technological development using research reactors. Member States look towards the Agency for co-ordination of the worldwide effort in this area and for help in solving specific problems.

To reflect the maturity of activities around research reactors and their average age, the focus of the subprogramme is gradually changing from the traditional support of fundamental research and training to helping facilities with strategic planning to increase utilization in more commercial areas such as isotope production and materials modification, in refurbishment and replacement of ageing equipment, in the management of increasing spent fuel inventories and in planning decommissioning.

Objective: To increase the capabilities of interested Member States to safely and reliably carry out scientific research and technology development at research reactors, conduct ageing management and decommissioning, refurbishing and modernization, planning of new facilities when needed, and reducing proliferation risks by core conversion.

Outcomes
— Increased use of Agency's guidance by Member States to address issues in research reactor utilization and related fuel cycle. — Increased use by Member States of Agency provided information to manage ageing research reactor facilities and to plan and implement decommissioning.

Performance Indicators
— Number of facilities planning utilization strategies and number of new applications implemented. — Number of facilities with improved spent fuel storage conditions. — Number of reactors converting from HEU to LEU fuel. — Number of facilities carrying out ageing management programmes or formulating and implementing decommissioning plans.

Programme changes and trends: In the biennium 2002–2003, a number of activities on research reactors, in different areas of the programme, were integrated to define this new subprogramme which represents the first holistic approach to the important issues associated with research reactors. To focus on different facets of research reactors the subprogramme has four projects. The project on effective utilization has concentrated on improving strategic planning and developing beam line applications. In 2002–2003, a project was introduced to track research reactor technology and to improve the capabilities of Member States for planning new and innovative research reactors. Following the evaluation of activities on research reactors and low energy accelerators, one project focuses specifically on the qualification of new, high density, low enriched uranium (LEU) fuels and the back-end of the fuel cycle, while another focuses on the technological and engineering aspects of ageing management and decommissioning. In all of the projects, engineering and technological development for safety is included.

As the return of US origin research reactor fuel from countries around the world is now running routinely, support for the programme has been phased out except for the routine updating of the guidelines for shipment as national and international rules and regulations are changed.

Resource changes and trends: The proposed resources for Subprogramme D.2 amount to $865 300 in 2004, reflecting an increase in the budget of $46 300, or 5.7% compared with 2003. There is a further increase of $13 000 for 2005 compared with 2004. The increased resources reflect an overall strengthening of all projects under this subprogramme, namely the utilization, modernization, fuel cycle and decommissioning of research reactors.

Financial resources (2003 prices)

D.2	2003	2004	2005
Reg. budg.	819 000	865 300	878 300

Project D.2.01: Effective utilization of research reactors

Main outputs: This project will provide training for the preparation of strategic plans, deployment of additional research reactor applications and marketing of research reactor services. CRPs on neutron radiography and prompt gamma activation analysis are ongoing and should permit additional services on research reactors. A new CRP on neutron beam techniques for residual stress measurement will be initiated. Results of the CRPs will be published as TECDOCs. The project will also provide an updated reactor database, accessible via the Internet, giving the status of research reactors worldwide. The publication of *Research Reactors of the World (RDS-3)* will provide a compact summary of that information. The research reactor list server and calendar will also be updated.

Unfunded activities/means of implementation: Development of a research reactor assessment methodology and of technical transfer packages for specific research reactor applications; and a CRP on research reactor core conversion to uranium–molybdenum alloy fuel.

Duration: 2002–2005

Ranking: 1 ex aequo

Project D.2.02: Supporting research reactor modernization and promoting information exchange on innovative technology development

Main outputs: The result of this project will be the publication of a TECDOC on the design of new and planned multipurpose research reactors.

Unfunded activities/means of implementation: Organization of annual regional workshops on research reactor modernization and refurbishment.

Duration: 2002–2006

Ranking: 1 ex aequo

Project D.2.03: Addressing research reactor fuel cycle aspects

Main outputs: The project will result in: report on summary statistics of research reactor spent fuel inventories and their problems; publications on research results of CRP on corrosion of research reactor aluminium clad fuel in water; and updated guidebooks on conversion of research reactors from HEU to LEU and on shipment of research reactor fuel to its country of origin.

Unfunded activities/means of implementation: Preparation of "Code of Good Practice" for the management and storage of research reactor spent fuel.

Duration: 2002–2006

Ranking: 1 ex aequo

Project D.2.04: Facilitating transfer of know-how on decommissioning of research reactors and irradiated core materials

Main outputs: The transfer of know-how on decommissioning of research reactors and irradiated core materials will be done through the use of the following documents: a TECDOC on the results of the CRP on ageing of materials in spent fuel storage facilities; and a technical report on the decommissioning of research reactors.

Unfunded activities/means of implementation: Preparation of a TECDOC on the decommissioning of research reactors and small nuclear facilities using limited resources. In addition, preparation of a TECDOC on the use of samples from the cores of research reactors being decommissioned or refurbished to increase understanding of the radiation degradation of materials is partially unfunded.

Duration: 2002–2006

Ranking: 1 ex aequo

Subprogramme D.3. Utilization of Accelerators and Instrumentation

Rationale: Many Member States have acquired accelerators and nuclear instrumentation to meet their developmental needs and to build an infrastructure for sustainable exploitation of nuclear energy. Thousands of low energy accelerators are used in Member States in industrial applications. High energy accelerators are used in applications such as synchrotron light sources, spallation neutron sources, medical therapy and material structure studies. Member States seek Agency assistance to achieve reliable operation, to develop new applications, and to implement quality assurance and there are many requests for technical co-operation in this area. The accelerator utilization programme strategy is aligned with the latest evaluations. Training in the proper use and operation of nuclear instruments and in instrumentation maintenance are indispensable prerequisites for sustaining nuclear applications. The Agency therefore develops teaching kits and conducts training in nuclear instrumentation maintenance and repair. A recent evaluation report of nuclear instrumentation recommends that the Agency support education and training on instrument maintenance and repair continuously. There is a continuous demand from the developing Member States for Agency support in this area.

Objective: To strengthen nuclear science research, development and education through enhanced utilization of accelerators and nuclear instrumentation.

Outcomes
— Increased capability of Member States to utilize existing facilities, instrumentation and methodologies.
— Enhanced use of accelerators and instrumentation in applications.
Performance Indicators
— Number of institutions benefiting from accelerator related programmes.
— Number of persons trained in nuclear instrument maintenance.
— Number of publications, software and training aids provided to Member States.

Programme changes and trends: The accelerator project will promote emerging applications through CRPs on the use of focused ion beams and of accelerator mass spectrometry for trace element analysis. Information exchange will be facilitated by the low energy accelerator database developed during the last cycle. A symposium on accelerator applications will be organized. Within the nuclear instrumentation maintenance project, training modules for distance learning are under development taking into account the latest innovations in information and telecommunication technology. A new CRP on the development of quality assurance procedures for maintenance and repair of nuclear instruments will be initiated. New instruments for specialized applications such as environmental monitoring will be developed. The nuclear instrument improvement project will continue, with the development of new detectors, electronics and software for room temperature XRF spectrometers, so as to expand the range of applications.

Resource changes and trends: The proposed resources for Subprogramme D.3 amount to $2 406 800 in 2004, reflecting an increase in the budget of $55 800 or 2.4% compared with 2003. This increase will contribute to the refurbishment of some parts of the Seibersdorf laboratories.

Financial resources (2003 prices)

D.3	2003	2004	2005
Reg. budg.	2 351 000	2 406 800	2 413 800

Project D.3.01: Effective utilization of particle accelerators

Main outputs: The project will result in: an upgraded database of low energy accelerators; a report on intercomparison of software, methods and algorithms for analysis of X ray and gamma ray spectra obtained from room temperature detectors; a report on image analysis software for neutron radiography; reports of CRPs on materials modification of insulators, dating and ultra-trace element analysis, and focused ion beam applications such as implantation and lithography; and reviews of developments in

accelerator technology and applications, such as use of ion beams in archeometry (preservation of cultural heritage) and the production of three dimensional microstruture.

Unfunded activities/means of implementation: International co-operation in the use of high energy accelerators for research, therapy and applications.

Duration: 2002–2005

Ranking: 11 ex aequo (priority 2)

Project D.3.02: Nuclear instrumentation maintenance

Main outputs: The project will result in: repaired instruments; trained technical staff for maintenance of nuclear instruments under QC procedures; ICT based training tools for Member States to train their technical staff; and technical documents related to repair and maintenance including QC.

Unfunded activities/means of implementation: Monitoring, assessment and review of training programmes and courses.

Duration: 2002–2005

Ranking: 1 ex aequo

Project D.3.03: Improvements in nuclear spectrometry applications

Main outputs: The project will produce: final reports of CRPs on alpha particle spectrometry and in situ applications of XRF techniques; reports of a CRP on radiation detectors; updated nuclear spectrometry software; XRF Newsletter and list server; worldwide databases for XRF laboratories and for standard reference materials for X ray spectrometry; reports on intercomparisons of software and methods for analysis of X/gamma ray spectra from room temperature detectors; image analysis software for neutron radiography and software for analysis of TR-XRF X ray spectra; worldwide proficiency test for results from XRF laboratories; reviews of nuclear methods for detection and imaging of contraband materials; and an updated training programme on XRF analysis.

Unfunded activities/means of implementation: Review of modern signal processing systems for nuclear spectrometry.

Duration: 2002–2005

Ranking: 15 ex aequo (priority 3)

Subprogramme D.4. Nuclear Fusion Research

Rationale: Nuclear fusion has the promise of becoming an abundant source of energy with good environmental compatibility. Excellent progress has been made in controlled nuclear fusion research based on both magnetic and inertial approaches for plasma confinement. Some machines are now producing 10–15 MW of fusion power during pulses. The science and technology of tokamaks, the leading magnetic confinement method, has advanced to a level that the construction of a 500 MW International Thermonuclear Experimental Reactor (ITER) is under negotiation and prototype components for ITER's main systems have been fabricated. Significant progress has also been made using other magnetic confinement approaches such as stellarators and spheromaks as well in inertial confinement.

Programmes to harness the potential of nuclear fusion for power production are being pursued in many countries. Progress so far has clearly established the feasibility of controlled thermonuclear fusion on the basis of the underlying physics, but there are remaining scientific, technological and economic issues that need to be addressed before fusion power can become a viable energy option. The Agency plays a catalytic role in fusion area by promoting information exchange and providing research co-ordination. The interest of Member States is reflected by the strong participation in Agency sponsored meetings using national resources. The Agency fusion programme receives guidance from the International Fusion Research Council (IFRC), which includes representation from developed and developing Member States having fusion research programmes. Activities have been aligned with the latest evaluations of the programme.

Objective: To enhance international co-operation for the development of nuclear fusion as a viable source of nuclear energy.

Outcomes
— Progress in plasma physics and fusion research. — Technology development catalysed by the construction of fusion devices.
Performance Indicators
— Increase in the number of publications in the field of nuclear fusion research. — Number of cost free participants in Agency sponsored meetings on fusion.

Programme changes and trends: The fusion activities are conducted in accordance with the Long Term Guidance Report of the IFRC. Public information and research co-operation between large laboratories in developed Member States and small laboratories in developing Member States are emphasized. In response to expressions of interest from scientists in Member States, CRPs on dense magnetized plasma and control, data acquisition and remote participation for fusion research are on-going. The Agency activities are co-ordinated with those of the International Energy Agency of the OECD.

Resource changes and trends: The proposed resources for Subprogramme D.4 amount to $539 900 in 2004, reflecting an increase in the budget of $12 900, or 2.4%, compared with 2003. This increase

has been necessary to properly conduct the proposed technical committee meetings as recommended by the IFRC. There is a decrease of $21 000 for 2005 compared with 2004 in the area of supporting plasma physics and fusion research.

Financial resources (2003 prices)

D.4	2003	2004	2005
Reg. budg.	527 000	539 900	518 900

Project D.4.01: Supporting plasma physics and fusion research

Main outputs: The main outputs will be: a final CRP report on elements of inertial fusion power plant design; CRP reports on dense magnetized plasma, and on control, data acquisition and remote participation in fusion research; the published proceedings of the 21st Fusion Energy Conference (2004); and summary reports and proceedings of technical meetings.

Duration: 2002–2007

Ranking: 1 ex aequo

Project D.4.02: International Thermonuclear Experimental Reactor (ITER)

Main outputs: Reports of negotiations by ITER parties and agreements signed by parties, as well as the *ITER Newsletter* and ITER related reports and documents, will be produced.

Duration: 2004–2005

Ranking: 11 ex aequo (priority 2)

Subprogramme D.5. Support to ICTP

Rationale: The overall mission of the Abdus Salam International Centre for Theoretical Physics (ICTP) at Trieste, Italy, was defined in the 1969 IAEA–UNESCO Agreement, approved by the Board of Governors, concerning the Centre's joint operation, which was to foster, through training and research, the progress of all branches of theoretical physics, with emphasis on responding to the needs of science in developing countries. The programme of ICTP has since expanded to include the use of theoretical physics in many applied fields. Recent years have seen enhanced scientific collaboration between ICTP and the Agency with increase in joint activities at the Centre in the areas of its expertise. The role of ICTP needs to be fully strengthened in order to effectively implement the identified common programmes with the Agency in information exchange, research and scientific studies, and training.

Objective: To enhance the scientific capability of developing countries through training and exchange of knowledge between scientists from the developing and the developed countries in the nuclear field as well as fields related to the applications of nuclear technology.

Outcome
— Scientists from the developing and developed Member States making use of knowledge obtained through their participation in the scientific programmes of ICTP.
Performance Indicator
— Number of scientists benefiting from ICTP programmes in fields related to the Agency programmes and using the information in their home institutions.

Programme changes and trends: The number of IAEA–ICTP joint activities and co-sponsored activities will increase, with emphasis in the fields of nuclear data, reactor physics and nuclear power plant operation, models for isotope hydrology studies, dispersion of radionuclides in the environment, and seismic risk analysis for nuclear power plants.

Resource changes and trends: Resources remain constant in both years compared to 2003.

Financial resources (2003 prices)

D.5	2003	2004	2005
Reg. budg.	2 084 000	2 084 000	2 084 000

Recurrent project D.5.01: Support to ICTP

Main outputs: The joint Agency–ICTP activities will result in: trained scientists in the nuclear and related fields, particularly of nuclear data, reactor physics and nuclear power plant operation simulation. Models for isotope hydrology studies, climate change and the dispersion of radionuclides in the environment will be developed. Results of seismic risk analysis will be used in nuclear power plant design and siting.

Ranking: 15 ex aequo (priority 3)