

IAEA Coordinated Research Project (CRP) on “Analytical and Experimental Benchmark Analyses of Accelerator Driven Systems (ADS)”

A. Background Situation Analysis

Sustainability goals are a major challenge to be met when developing innovative nuclear technology as a long-term option for the world's energy mix. The sustainability challenge has two aspects: resources and radioactive waste. Looking at the resources aspect, one has to acknowledge that nuclear power production cannot be sustainable if only 0.7% of the fissile resources in natural uranium are used. Ultimately, this means that the fertile reserves (uranium-238, which makes the remaining 99.3% of the natural uranium, and thorium) will have to be tapped. Utilization of breeding to secure the long-term fuel supply for electricity generation with nuclear power has been the main aim of fast reactor development, and remains the ultimate goal. In the context of the proposed CRP, however, in addition to the more long-term “breeder mission” of fast reactors, plutonium recycle (utilization) in fast reactors, as well as transmutation/incineration of minor actinides (MA) and long-lived fission products (LLFP) (second aspect of the sustainability goal) in various types of fission reactors, accelerator driven systems (ADS) and molten salt reactors is under investigation in several IAEA Member States. The advantages of some of these concepts (e.g., ADS) that are put forward are intrinsic low waste production, high transmutation capability, enhanced safety characteristics, and better long-term resources utilization (e.g., with thorium fuels). Important R&D programs are being undertaken by various institutions in many IAEA Member States to substantiate these claims and advance the basic knowledge in this innovative area of nuclear energy development. For these groups, there is the clearly perceived need for coordinating their efforts and also for getting access to information from nationally and internationally coordinated activities. Whatever the medium term perspective, the flexibility needed to meet the above mentioned sustainability requirement with regard to natural resources and long-lived radioactive waste management asks for a continuous development of the fast neutron spectrum reactor technology. As a matter of fact, flexibility with regard to breeding or incineration/transmutation is attained only in reactors based on fast neutron cores due to their favourable neutron balance. Moreover, fast spectrum systems are the only ones that provide a high degree of flexibility with regard to isotopic separation (i.e., reprocessing), in theory going as far (at least for sub-critical concepts) as to envisage systems that would both incinerate plutonium, and transmute MA and LLFP without isotopic separation. All these R&D activities, covering the spectrum from evolutionary/advanced fast reactors to hybrid systems (e.g., ADS), have to rely on, firstly, the capability to develop and validate reprocessing technologies for the advanced fuels envisaged (taking into account all criteria and requirements, e.g., non proliferation, and simplification of the fuel cycle), and, secondly, on the availability of a fast neutron spectrum irradiation facility for fuel and material testing.

The situation analysis is showing the following picture with regard to the ongoing Partitioning and Transmutation (P&T) R&D efforts in IAEA Member States:

In Europe, most R&D activities in the area of P&T are performed within the EURATOM framework [the 5th (FP5, 1998-2002), and the current 6th framework programme (FP6,

2002-2006)]. In FP5 [1], there are 13 projects distributed among three “R&D clusters” on transmutation, and one on partitioning. The latter includes the projects PYROREP, PARTNEW, and CALIXPART, all addressing issues that lie outside the scope of this paper. The transmutation clusters are FUETRA, BASTRA, and TESTRA.

The three FUETRA projects are FUTURE, CONFIRM, and THORIUM CYCLE. The first one, FUTURE includes R&D activities (thermo-chemical characterization, performance studies, fabrication processes) aiming at the development of TRU oxide homogeneous fuel for transmutation (there are three fuel variants under investigation: Pu-Am oxide, Th-Pu-Am oxide, and Pu-Am-Zr oxide). The CONFIRM project focuses on inert (uranium-free) nitride fuel (characterization, fabrication, modelling, performance, including irradiation experiments). The fuel under consideration are U-Pu, Pu-Zr, and Am-Zr nitrides. The latter is produced at ITU Karlsruhe, on the basis of the carbo-thermic fabrication process. The irradiation experiments are foreseen at the R2 reactor (Studsvik, Sweden). The THORIUM CYCLE project investigates the feasibility of the thorium cycle for light water reactors (PWRs) and for ADS. Apart from reactor physics calculations, the project includes also two irradiation experiments, one at the HFR in Petten, the Netherlands (U-oxide, Th-oxide, U-Pu oxide, and Th-Pu oxide targets are irradiated and will be characterized in PIEs), and one at the German 340 MWe PWR Obrigheim (Th-Pu oxide target).

The BASTRA cluster includes three projects: MUSE, HINDAS, and n-TOF_ND_ADS. The zero power series of experiments MUSE is performed at CEA’s MASURCA facility. MASURCA consists of a U-Pu mixed oxide fuelled assembly with sodium simulated coolant, surrounded by a stainless steel plus sodium reflector and a stainless steel shielding (reactor grade plutonium, 25% Pu enrichment). MASURCA can be set-up in critical and sub-critical configurations. The objective of the MUSE experiments is to validate the reactor physics methodology for sub-critical core analyses. As an example, the currently running MUSE-4 experiments, couples the deuteron accelerator, GENEPI, placed outside MASURCA, with a (fusion process) D-T or D-D target, placed in the centre of MASURCA. GENEPI is able to produce short ($0.7 \mu\text{s}$) neutron pulses with as much as 1.2×10^{10} n/s at 4 kHz pulse repetition. A lead region, which adjust the neutron energy spectrum of the target in such a way, as to simulate a realistic spallation target, surrounds the source in front of the vacuum pipe that guides the GENEPI deuteron beam into the centre of MASURCA. The other two projects in the BASTRA cluster are in the area of nuclear data for P&T and ADS. HINDAS addresses nuclear data in the intermediate and high-energy range (20 MeV-2 GeV) needed for the simulation of the spallation target in ADS physics calculations. Nuclear reaction cross section measurements for uranium, lead, and iron are performed using proton, neutron and heavy ion beams (the latter as inverse kinematics experiments) in various European laboratories. Apart from the experimental work, HINDAS also covers theoretical R&D (nuclear model simulations, data evaluation, library generation). The last BASTRA cluster project, n-TOF_ND_ADS, is based at CERN’s new “neutron-time-of-flight (n-TOF)” facility in Geneva, which has the highest instantaneously intense neutron source for this kind of facilities: the 20 GeV/c proton beam pulses from the CERN-PS (7×10^{12} protons per pulse, 5-7 ns pulse duration) are sent to a $80 \times 80 \times 40$ cm lead target with a repetition frequency of 0.1 to 1 Hz. This allows to deliver, as a collimated neutron beam of 4 cm diameter, 6×10^5 neutrons per pulse to the sample, which is located 186 m away from the lead target. The n-TOF_ND_ADS project includes the measurement and evaluation of capture and fission cross sections for MA and LLFP, capture and (n,2n) cross sections for lead, bismuth, thorium, and zirconium, as well as a certain number of total cross sections.

The TESTRA cluster covers technological studies for transmutation which are sub-divided into four projects: ASCHLIM, MEGAPIE-TEST, TECLA, and SPIRE. The ASCHLIM project deals with heavy liquid metal thermal hydraulics. Computational fluid dynamics (CFD) international benchmark exercises, covering all major issues of heavy liquid metal thermal hydraulics that are relevant to ADS (e.g., bubbly flow, turbulence, free surface effects) constitute the main activity of this project. The MEGAPIE-TEST project covers the experimental and analytical R&D work performed for the 1 MW lead-bismuth eutectic (LBE) spallation target that will be irradiated in the SINQ facility of the Paul Scherrer Institute PSI (Switzerland). The project enjoys wide international participation: in addition to the European partners SCK•CEN (Belgium), CEA (France), FZK (Germany), (ENEA) Italy, and PSI (Switzerland), the project is supported also by Japan (JAERI), the Republic of Korea (KAERI), and the USA (DOE). The project is an important milestone (full-scale thermal hydraulics, and the first beam-on experiment) in the development of LBE targets for ADS. Experimental support for MEGAPIE is provided through basic LBE investigations in the KALLA (Germany) and CIRCE (Italy) facilities. The TECLA project studies the physical and chemical properties of lead alloys in view of their use in ADS as coolant and spallation target material. The principal R&D thrust lies in the area of corrosion by lead alloys and the development of corrosion protection technologies. SPIRE is investigating the effects of neutron and proton irradiation on steel structures. Experiments including ion beam irradiations and irradiations in a neutron field (HFR Petten, BR2 Mol, and BOR-60 Dimitrovgrad) are performed to investigate the physical and mechanical properties of various structural steels. The project provides experimental and analytical validation for the ADS spallation target design.

In addition to the three transmutation R&D clusters discussed above, FP5 is also providing the framework for preliminary design studies of an experimental ADS (project PDS-XADS). This project is evaluating – for all ADS systems (accelerator, spallation target, and sub-critical reactor) – the major technological choices for an experimental ADS, and identifying the open issues for which additional R&D is necessary. Both the cyclotron and the linear accelerator are being evaluated. For the spallation LBE target, both the concept with a window separating the LBE from the vacuum tube that delivers the proton beam, and the window-less options are considered. As for the coolant of the sub-critical core, the gas and the LBE options are investigated. In FP5, the coordination between R&D work performed within the four P&T clusters, on the one hand, and the activities of the PDS-XADS project, on the other, is ensured by an international collaboration network called ADOPT.

P&T activities are likely to continue within the frame of FP6. The evaluation of proposals is currently ongoing. Partitioning R&D activities are pooled into one integrated project (IP) called IP EURPOART. In the transmutation area, an IP EUROTRANS proposal has been submitted by ENEA, CEA, FZK, and SCK•CEN. According to this proposal, the objectives of IP EUROTRANS would be to demonstrate experimentally ADS operation and dynamic characteristics, and to deliver a design concept for an European ADS demonstrator, including proving its overall technical feasibility and performing an economic assessment.

Outside the European Union, P&T activities are also pursued in China, India, Japan, the Republic of Korea, Russia and some other countries of the Commonwealth of Independent States (mostly within the framework of the International Science and Technology Centre ISTC, details given farther down), and in the USA. The rationale for these activities varies from country to country, and so do the transmutation strategies envisaged. However, no matter whether energy production or long-lived waste transmutation is considered to be the main driving force, and independent from the particular short, medium, and long-term

strategies, there are many common generic R&D activities that are pursued by most groups, and for which international collaboration is sought.

In China, a two-phase program is in place, aiming at, in the first phase (1998-2002), system optimisation, reactor physics and technology studies, accelerator physics and technology studies, and nuclear and material R&D. The second phase (2000-2007) is devoted to the ADS concept verification study. As regards Fusion/Fission Hybrid System, in the near-term the emphasis will be put on the experiments performed at the two large testing facilities, HL-1M and HT-7. In parallel, scope and objectives for both the medium-term and long-term development of Fusion/Fission Hybrid System will be determined, and the respective R&D programs developed. China is envisaging ADS also as critical systems for energy production, breeding, and transmutation, specifically a medium sized, sodium-cooled fast breeder concept (AD-FBR), and a pressurized heavy water cooled and moderated concept (AD-PHWR). Considerable flexibility with regard to the three objectives (energy production, breeding, transmutation) is claimed for the AD-FBR: decreased plutonium inventory, improved breeding capability, and, forfeiting only 15% of the energy production, the possibility to transmute the spent fuel from two 1 GWe PWRs. For the AD-PHWR, both the uranium-plutonium and the thorium-uranium cycle were considered, and the results indicate that the latter, attaining high burnups and a breeding ratio slightly over 1, shows better performance than the former.

In India, a detailed study by a Coordination Committee of BARC of various aspects of ADS lead to the definition of a few short-term work modules that have their own applications and spin-offs. Currently, ongoing activities are related to (a) experimental plan of a sub-critical core driven by 14-MeV neutrons from $T(d,n)^4\text{He}$ reaction for reactor physics studies, (b) development of a high-intensity 10-MeV proton linear accelerator as front-end of accelerator for ADS, (c) setting up molten lead-bismuth eutectic experimental loop, and (d) developing a fabrication and characterizing facility for bulk niobium super-conducting RF cavities.

In Japan, a 800 MWth sub-critical lead-bismuth eutectic cooled core concept is proposed. This ADS could transmute 250 kg of MA per year, corresponding to the minor actinide amount produced per year in about ten 1 GWe LWRs. Considerable R&D work is under way and planned at JAERI in the fields of sub-critical core design, spallation target technology, accelerator development, and minor actinide fuel development. In particular, with the objective of studying and evaluating the physics and engineering feasibility aspects of the ADS, JAERI has proposed the construction of the Transmutation Experimental Facility (TEF) within the framework of the High Intensity Proton Accelerator Project

In the Republic of Korea, KAERI has been working on the HYPER (HYbrid Power Extraction Reactor) concept since 1997. The HYPER conceptual design will be completed by 2006. KAERI's ADS R&D consists of 3 stages: a basic concept of HYPER was established in the first stage (1997-2000), the basic technology related to HYPER is being investigated in the second stage (2001-2003), and the conceptual design will be completed in the third stage (2004-2006). Presently, KAERI is focusing on heavy liquid metal (lead-bismuth eutectic), and on fuel studies. As already mentioned, KAERI joined the MEGAPIE, and is constructing a lead-bismuth corrosion loop. For the fuel studies, KAERI is discussing a possible collaboration with ANL-West, and also investigating fission product irradiation tests using its own research reactor HANARO.

In Russia, there is considerable R&D effort dedicated to the development of the ADS technology. These studies are strongly coupled with advanced fuel cycle studies that aim at waste minimization and at a strong overall simplification of the nuclear fuel cycle (e.g.,

molten salt). Recent ADS R&D highlights in Russia include (a) the delivery of the spallation target MK-1 to the University of Nevada, Las Vegas, where it is currently undergoing thermal hydraulics testing. This target, for which all isothermal off-beam tests have been completed, was designed and constructed in Russia during the year 2001, originally foreseen for irradiation in the 800 kW proton beam of the LANL accelerator; (b) analysis of a proposal to establish an international ADS demonstration project at the SSC RF IPPE site in Obninsk (the Nuclear Waste Burner (NWB) project: the construction of the NWB could be completed in 7 to 8 years, and preliminary results show that a burning rate of ~10-20 kg MA per year can be achieved in a sub-critical core having 200 to 400 kg MA inventory); (c) the definition of RF Minatom's program of work for the sub-critical cascade molten salt reactor concept in a closed nuclear fuel cycle (RSC KI and VNIITF); and (d) activities within the framework of the ISTC Sub-critical Assembly Dubna (SAD) project (JINR).

As mentioned, several ISTC projects address ADS related R&D topics in the areas of nuclear data, fuel development, reprocessing, and accelerator technology. Coordination with the R&D work performed in Europe, Asia, and the USA is ensured through the ISTC Contact Expert Group (CEG) for ADS. The following list illustrates the broad scope of the ADS R&D activities performed within the ISTC framework:

ISTC #B70: Experimental and Theoretical Research on Transmutation of Long-lived Fission Products and Minor Actinides in a Sub-critical Assembly Driven by a Neutron Generator (YALINA, Minsk, Belarus). The YALINA facility consists of the 14 MeV neutron generator and the zero power sub-critical assembly. The neutron generator consists of a high-current deuteron accelerator and a high-performance water-cooled rotating D-T or D-D target placed outside the sub critical assembly. The generator has been operated since 1997 in both pulsed and continuous mode. Its maximum intensity is $(1.5-2.0) \times 10^{12}$, and $(2.0-3.0) \times 10^{10}$ n/s for 13.0-15.0, and 2.0-3.0 MeV neutrons, respectively. When operating in pulse mode, pulse duration of the neutron beam is in the range 5-100 ms, with pulse repetition frequency 1-1 000 Hz. The core of the sub-critical assembly is a rectangular parallelepiped (40×40×57 cm). It is assembled from polyethylene blocks with channels to place the fuel rods. The core is arranged as a square lattice with 2.0 cm pitch. A neutron producing lead target (8×8×60 cm), placed in the centre of the sub-critical assembly, receives and multiplies the neutrons produced by the D-T or D-D fusion process outside the assembly. The experiments performed in YALINA address the following topics: measurements of transmutation rates of fission products and MA; investigation of spatial kinetics of sub-critical systems driven by external neutron sources; validation of various experimental techniques, e.g., for monitoring the sub-criticality level, for measuring neutron spectra, etc; investigation of dynamics characteristics of sub-critical systems driven by external neutron sources operating in pulse-mode.

ISTC # 1486 and 1606: Pyrochemical fluoride reprocessing of spent molten salt fuel (continuation of the MSR Russian program).

ISTC #839: Experimental and theoretical studies of the residual product nuclide yields in thin targets irradiated by 100-2600 MeV protons: more than 60 experiments with thin targets are performed. The targets are: ^{56}Fe , ^{58}Ni , ^{59}Co , ^{63}Cu , ^{65}Cu , ^{93}Nb , ^{99}Tc , ^{182}W , ^{183}W , ^{184}W , ^{186}W , $^{\text{nat}}\text{W}$, $^{\text{nat}}\text{Hg}$, ^{206}Pb , ^{207}Pb , ^{208}Pb , $^{\text{nat}}\text{Pb}$, ^{209}Pb , ^{232}Th , and $^{\text{nat}}\text{U}$. The energies of the protons are in the range 0.1-2.6 GeV. About 5,000 values of the residual nuclide production cross sections are determined and uploaded to the EXFOR database. Activity and dose rates of the irradiated samples as a function of the cooling time are also determined.

ISTC # 2002: Experimental and theoretical studies of the yields of residual product nuclei produced in thin Pb and Bi targets irradiated by 40-260 MeV protons: 55 experiments are being conducted with ^{206}Pb , ^{207}Pb , ^{208}Pb , $^{\text{nat}}\text{Pb}$, and ^{209}Bi , within a minutely fractionated proton energy range, namely, at 0.04, 0.07, 0.10, 0.15, 0.25, 0.4, 0.6, 0.8, 1.2, 1.4, 1.6, and 2.6 GeV. Additional measurements are performed for ^{208}Pb (1.0 GeV), ^{197}Au (0.8 GeV), and ^{238}U (1.0 GeV) and will be compared with inverse kinematics data measured at GSI, Germany. Approximately 5,000 values of the residual nuclide production cross sections are expected to be determined.

ISTC #1145: Nuclear physics investigations in support of weapons plutonium conversion studies, and long-lived radioactive waste transmutation studies: integral experiments permitting the validation of transport codes (e.g., LAHET) and high-energy data bases (e.g., MENDL), as well as the determination of high-energy threshold excitation functions to be used for unfolding the neutron spectra inside ADS. The experiments include also the measurements of the reactions rates inside NaF-ZrF₄ micro-models of ADS targets. Furthermore, the project includes neutron cross section measurements in the energy range <20 MeV (capture ^{238}U , ^{237}Np , ^{232}Th ; fission ^{235}U , ^{237}Np , ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu , $^{242\text{m}}\text{Am}$, ^{243}Cm , ^{245}Cm , ^{247}Cm).

ISTC #2578: Detailed review of the ISTC projects related to nuclear data relevant for ADS.

ISTC #2267: Sub-critical Assembly Dubna (SAD). This project consists in constructing a low-power (15-20 kW) integral system on the basis of JINR's (Dubna) 660 MeV proton accelerator and a sub-critical core fuelled with uranium-plutonium mixed oxide. The sub-criticality level foreseen is $k_{\text{eff}} \approx 0.95$. The proton beam power will be in the range of 0.75-1 kW. SAD will provide an important experimental tool to study all aspects of sub-critical reactor physics. The first SAD conceptual design is completed, and construction of the SAD facility is expected to last 3-4 years.

In the US, the Advanced Accelerator Applications (AAA) program has evolved into the Advanced Fuel Cycle Initiative (AFCI), broadening the scope into a program for development of fuel cycles for enhanced nuclear fuel and waste management, including transmutation. The program emphasizes activities in the areas of reactor and accelerator based transmutation, advanced fuels and separations development, and long-term waste toxicity reduction. The main program goals are reduction of waste volumes and inventories of civilian plutonium, recovery of the energy value remaining in spent nuclear fuel, reduction of the radio-toxicity of waste for disposal, reduction of short and long term heat loads in the repository, elimination of the technical need for a second repository, and support of advanced fuel development. There has been an increased attention to near term activities in fuel cycle, which are driven by the stated capacity limits and schedules of the proposed waste repository at Yucca Mountain. This increased attention to near-term fuel cycle developments has led to the definition of a multi-stage approach in the AFCI. The activities in the first stage aim at using existing or near-term reactors to accomplish reduction of high level waste volumes, optimisation of economics and performance of planned repository, reduction of technical need for second repository, reduction of long-term plutonium inventories, and enabling the proliferation-resistant recovery of energy contained in spent fuel. The activities under the second stage aim at using fast spectrum reactor technology to accomplish reduction of toxicity of waste for disposal, reduction of long-term heat generation rate of waste for disposal, providing a sustainable fuel source for nuclear energy, and supporting future operation of innovative systems developed within the Generation IV International Forum. The third stage will investigate innovative systems dedicated to MA incineration and LLFP transmutation (e.g.,

ADS). The main activities under AFCI include systems analysis, separations, fuels development, and transmutation engineering. Results of systems analysis indicate that radio-toxicity reduction is the hardest objective to achieve: existing reactors, although effective at stabilizing and (under the assumption of enhanced MOX utilization) even reducing plutonium inventories, are not very effective at reducing the radio-toxicity of the spent fuel. Current activities in system analysis aim at defining a complete transmutation architecture for AFCI, based on the development of transmutation criteria and assessment of options. The treatment of the Experimental Breeder Reactor II (EBR-II) spent fuel has been integrated into the AFCI program. Although work has started in developing separations processes for Generation IV fuels (second stage of AFCI), separations activities currently focus on the first stage and on the EBR-II spent fuel treatment. In the first AFCI stage, the separations activities are driven by the demonstration of separations technologies leading to the selection of a preferred technology in fiscal year 2007. A separations facility based on the selected technology might conceivably be deployed by 2015. Separations work includes demonstration and development of UREX and UREX+, PYROX (an adaptation of the electrometallurgical treatment process for oxide LWR spent fuel), and a hybrid process of UREX and pyroprocessing. Recent accomplishments include the hot demonstration of UREX at the Savannah River Site (SRS) and the laboratory-scale demonstration of the reduction of LWR oxide fuel for subsequent pyroprocess treatment. The successful operation of the pyroprocess technology facilities at Argonne National Laboratory (ANL) in Idaho is continuing with additional treatment of spent EBR-II fuel. Under the AFCI integration, however, the facilities maintain treatment goals for EBR-II fuel, but also play a more prominent role in supporting the technology development for advanced recycle technologies. Emphasis under the current AFCI separations plan is on technology development to increase process throughput, including demonstration of the oxide fuel reduction, transuranic recovery processes, high-throughput electro refiners, and demonstration of the hybrid UREX-Pyroprocess. The characterization of the waste forms is performed, obtaining very positive results in terms of nuclide release rates measured in immersion tests. The development of transmutation fuels for fast spectrum systems is also continuing: fabrication of samples of metal and nitride fuel is currently taking place, for irradiation in the Advanced Test Reactor (ATR) in Idaho. Samples include a variety of compositions of plutonium and MA. Non-fertile and low-fertile samples are being prepared for irradiation. Preparations are also ongoing for test irradiations at the Phénix reactor, in collaboration with CEA. Activities in transmutation engineering are also ongoing in several areas. In physics, work is being performed for the analysis of the MUSE-4 experiments, support of the European accelerator-sub-critical core coupling experiment TRADE, and analysis of PROFIL irradiation experiment. Further progress has been made in cross section data and additions to the AAA materials handbook. The collaboration with MEGAPIE in the areas of spallation target technology and physics and engineering support is continuing.

Summarizing, for nuclear energy to remain a long-term option in the world's energy mix, nuclear power technology development must meet sustainability goals with regard to fissile resources and waste management. The utilization of breeding to secure long-term fuel supply remains the ultimate goal of fast neutron spectrum systems. Plutonium recycle in fast reactors, as well as incineration/transmutation of MA and long-lived fission products in various hybrid reactor systems (e.g., ADS) also offer promising waste management options. Several R&D programs in various Member States are actively pursuing these options, along with the energy production and breeding mission of fast reactor systems.

B. Overall Objective

The CRP proposed here is assisting - in line with IAEA's statutory objective expressed in Article II – the IAEA Member States' activities in the area of advanced technology development for utilization and transmutation of actinides and long-lived fission products by providing an international umbrella for information exchange and collaborative R&D to pool resources and expertise.

The CRP will contribute to the generic R&D efforts in various fields common to innovative fast neutron system development, i.e., heavy liquid metal thermal hydraulics, dedicated transmutation fuels and associated core designs, theoretical nuclear reaction models, measurement and evaluation of nuclear data for transmutation, and development and validation of calculational methods and codes. Apart from analytical benchmark exercises, it will integrate some of the planned experimental demonstration projects of the coupling at power between a sub-critical core and an external neutron source (YALINA-Booster in Belarus, TRADE in the EU, and SAD at JINR, Dubna). Ultimately, the CRP's overall objective is to make contributions towards the realization of a transmutation demonstration facility.

C. Specific Research Objective

The specific objective of the CRP is to improve the present understanding of the coupling of an external neutron source (in particular a spallation source) with a multiplicative sub-critical core. As outcome, the CRP aims at advancing the efforts under way in the Member States towards the proof of practicality for ADS based transmutation by providing an information exchange and collaborative research framework needed to ensure that the tools to perform detailed ADS calculations, namely from the high energy proton beam down to thermal neutron energies, are available.

The CRP will address all major physics phenomena of the spallation source and its coupling to the sub-critical core. The participants will perform computational **and** experimental benchmark analyses using integrated calculation schemes and simulation methods.

D. Expected Outputs (Results)

The output from the CRP will be a final report (IAEA Technical Report) summarizing the considered analytical and experimental benchmark exercises, and concluding on the validation status of integrated calculation and simulation schemes for ADS. It will also identify remaining open issue and R&D needs, and indicate a possible role for the Agency in the future. The CRP results will also be published in peer-reviewed journals and presented at international conferences.

E. Action plan (Activities)

Member States with a strong involvement in the field of P&T will be invited to participate in the CRP. The following institutes in Member States and international organizations have informally indicated their interest in participating:

Argentina	Comisión Nacional de Energía Atómica, Centro Atómico Bariloche
Belarus	Joint Institute for Power and Nuclear Research Academy of Sciences
Belgium	SCK•CEN Mol
Brazil	Instituto de Pesquisas Energéticas e Nucleares – IPEN
China	China Institute of Atomic Energy, and China Academy of Sciences Institute of Plasma Physics
Czech Republic	Nuclear Research Institute Rez plc
France	Commissariat à l’Energie Atomique CEA
Germany	Forschungszentrum Karlsruhe FZK
Hungary	Budapest University of Technology and Economics Institute of Nuclear Technology, and KFKI Atomic Energy Research Institute
India	Bhabha Atomic Research Centre (BARC)
Indonesia	Bandung Institute of Technology
Italy	ENEA, and Politecnico Torino
Japan	JAERI, and JNC
Netherlands	Nuclear Research and Consultancy Group NRG
Rep. of Korea	KAERI
Russian Federation	State Scientific Centre Institute of Physics and Power Engineering (IPPE) Obninsk, and RRC - Kurchatov Institute, Moscow
Spain	CIEMAT, Madrid
Sweden	Royal Institute of Technology RIT, Stockholm
CERN, Geneva	
EC Joint Research Centre, JRC Petten, Netherlands	
Joint Institute for Nuclear Research JINR, Dubna, Russia	

The estimated duration of the CRP is 5 years. Following the establishment, during 2004, of an international team by putting in place research agreements and contracts, the following activities will be undertaken to achieve the outputs expected from the CRP:

- I. Convene, in 2005, the 1st (kick-off) research coordination meeting (RCM) to agree upon the topical areas to be covered by the CRP, identify lead organisations among the CRP participants for each of the topical areas, to produce an agreed upon definition of detailed tasks as well as work plans and deadlines, to identify responsibilities for competing tasks, and to establish an outline and responsibilities for completion of the final IAEA TECDOC that will report the results of the CRP.
- II. Convene the 2nd and 3rd RCMs, in 2007 and 2008, respectively, to review progress to technical work and TECDOC development, and identify needed improvements and/or modifications to the tasks and/or work plans, also considering the status of the experimental programmes that will be considered within the scope of the CRP.
- III. Convene the 4th RCM in 2009 to review the status of the technical work and perform an overall review of the CRP results, provide the final input to the TECDOC and finalize the draft of the TECDOC, identify open issues and R&D needs to resolve them, as well as the possible role of the Agency in doing this.