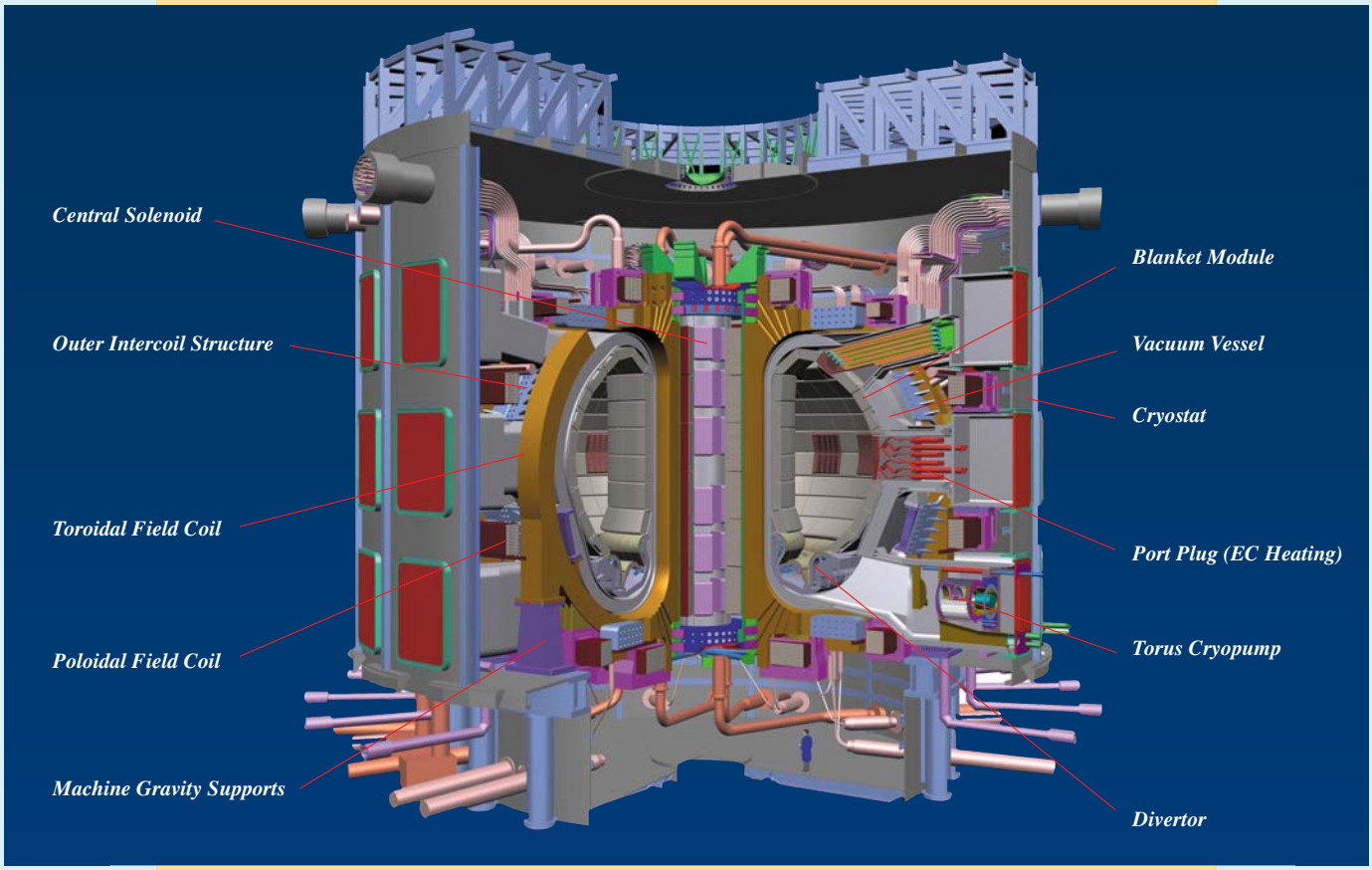
Eleventh Plan Proposals

Report of the Working Group
R&D Sector



International Thermonuclear Experimental Reactor (ITER)

सत्यमेव जयते

Government of India
Department of Atomic Energy
and
Atomic Energy Regulatory Board

September 2006

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Preface

The Department of Atomic Energy (DAE) is a broad based organization comprising research centres, industrial units, public sector undertakings and fully aided grant-in-aid institutions, all working together to develop and deploy applications of atomic energy to support national development process. Complete organizational chart of the Department is given in the Annex A and locations of various units are given in the map in the Annex B. Various DAE institutions together with other institutions in the country have been a very successful framework to take R&D in nuclear sciences and technologies to commercial deployment.

Considering the multiplicity of functions performed by the Department, its plan and non-plan outlays are formulated under three heads viz., Power sector, Industries & Minerals sector and Research & Development sector. The Power sector deals with the construction and operation of nuclear power plants. Industries & Minerals sector caters to the requirements of the nuclear fuel cycle and proposals of units such as Nuclear Fuel Complex, Heavy Water Board, Board of Radiation and Isotope Technology and activities of other units in the areas of reprocessing and waste management. The Research & Development sector outlay provides support to research and development for new power reactor concepts and related long-term research, radiation technology applications, development of advanced technologies and basic research in subject areas related to the above topics.

The Planning Commission has constituted a steering committee on S&T for the formulation of the XI Five Year Plan, which in turn has set up working groups to formulate plans of individual departments and one such working group is for the DAE (See Annex C). To help the working group to complete its task and to provide a forum for internal discussion, DAE in turn constituted an Internal Working Group (IWG) (See Annex D). The IWG met on 20th June and 8th July 2006. Considering the broad sweep of the subjects pursued by the Department,

it was considered to identify theme areas and create specialists' groups for each theme area to enable in-depth peer review. Twenty major theme areas were identified and Specialist Groups (SGs) formed for review of proposals from across the units. The SGs and the guidelines for review of projects are given as Annex to the constitution of IWG (Annex-D). The responsibilities of the IWG and SGs are not only formulation of XI Plan proposal but also include their periodic review throughout the plan period. These SGs met independently on several occasions and presented their report in the two IWG meetings.

In the year 2004, an exercise was conducted to examine what the Department has achieved in the past and to plan for the future. Wide ranging discussions were held on various topics, which were divided in categories like Energy vision, Societal vision, Technological vision, Directions for basic research and possible feedback into DAE programmes, and Human Resource Development. A summary of the exercise was published in the form of a report titled, "Our Collective Vision". This report formed the starting point for the formulation of the XI plan.

Proposal of Atomic Energy Regulatory Board (AERB), the independent regulatory body catering to the regulatory needs relating to use of atomic energy in the country is included separately in the document in Chapter 6.

The working group met on 27th July and 12th August 2006. This report is an outcome of all these deliberations. The outlay proposed for R&D Sector during the XI Five Year Plan period for DAE and AERB are detailed in this report.

Chapter 1

Executive Summary

The Department consists of research centers and grant-in-aid institutions and both the set of institutions carry out research and development. While the research centers focus more sharply on technology and product development, the grant-in-aid institutions concentrate more on basic research. Technologies and products developed are deployed either by the industrial units of the Department or transferred under well established technology transfer mechanisms. Research centres and Grant-in-aid institutions have provided high caliber technologists as well as scientists to the Department, but for which India's spectacular strides in the field of nuclear sciences and their applications would not have been possible. To further accelerate this process, the Department of Atomic Energy (DAE) has set up an Institute to be called 'Homi Bhabha National Institute, (HBNI)' having the status of a deemed university.

In the pursuit to fulfill the mandate of the Department, research and development activities of the Department are categorised into seven major programmes with specific deliverables for each of these major programmes. The major programmes are then further classified into sub-programmes identifying specific areas of work. These are given as Annex to the constitution of Internal Working Group (IWG) (see Annex-D).

Considering the broad sweep of the subjects pursued by the Department, twenty major theme areas were identified and Specialist Groups (SGs) formed for review of proposals from across the units. These SGs have reviewed the scientific content of the proposal, identified overlap, if any, of the proposals from different units, reformulation of proposals to minimize overlap while keeping any desired overlap and suggested filling of the gaps in the programmes etc. The SGs and the guidelines for review of projects are given as Annex to the constitution of IWG (Annex-D).

Every continuing scheme was examined for technical feasibility and economic viability including analysis on the principles of **Zero Based Budgeting.** All new proposals are examined at the level of Constituent Units, in respective SGs, IWG for R&D Sector, Department and finally at the level of Atomic Energy Commission. It is

proposed to subject all the continuing schemes to one more scrutiny to be conducted by groups specifically set up by the DAE.

Being a multi-disciplinary and multi-functional organisation it has pursued research in basic science, development of technologies and transferring them to the industrial domain. Research in these fields are continued to maintain the cutting edge. It has participated and contributed in international mega-science projects and its contribution is recognized by the international scientific community. Major achievements during the X Plan are given in the Chapter on Achievements of X Five Year Plan in the document. More than 92% of the plan allocation is likely to be utilized during the X Plan period. Shortfall in utilization will be mainly due to rescheduling some of the major programmes of the Department.

In line with the growth in economy and the vision for the XI Plan as brought out in the approach paper to the XI Five Year Plan by Planning Commission, DAE has also tuned itself to take quantum leap during this plan period. Major programmes that are planned during the XI Plan are given in the Chapter on DAE XI Five Year Plan Proposals. Some of the major areas in which the Department intends to focus are given in the subsequent paras.

Natural uranium fuelled Pressurised Heavy Water Reactors (PHWRs) and associated front and back end fuel cycle facilities are being set up in the first stage of nuclear power programmes. R&D support will continue to continually improve capacity utilization, environment & safety and economic competitiveness and also to upgrade technology based on latest developments in the entire PHWR fuel cycle. R&D work on development of 700 MWe PHWR will also be taken up. To increase installed capacity based on PHWRs beyond what is planned at present, it is necessary to step up uranium exploration. This plan will focus on uranium exploration, both in developing new techniques for exploration and in deploying known techniques extensively for quick results.

Second stage envisages setting up of Fast Breeder Reactors (FBRs) backed by reprocessing plants and plutonium-based fuel fabrication plants. In order to augment the indigenous nuclear power generation capacity, fast breeder reactors are necessary. They are also essential for establishing use of thorium on a large scale in the third stage of our power programme. Prototype FBR (PFBR) is the first indigenous reactor in the series of FBRs to be constructed. Since the nuclear power programme in the next few decades would have a large component of FBRs, it is essential to step up the investment in R&D on FBRs to develop materials, equipment

and processes on a comprehensive basis. It is necessary that advanced fuels are developed for use in fast breeder reactors as soon as possible and proposals to this effect are put up in this plan. R&D in FBR fuel reprocessing, study of fuel chemistry and other safety studies would also be carried out to be on a firm footing during the operation of PFBR and planning of subsequent FBRs.

- R&D for 700 MWe PHWR and life extension programme for existing PHWRs
- Intensifying exploration of Uranium
- Strengthening R&D on back end fuel cycle including long term radioactive storage strategies
- R&D for further development of fast breeder fuel cycle
- Thorium utilization programme - AHWR
- High temperature reactor for co-generation of electricity, hydrogen and desalinated water
- India joins ITER Project

While the current generation nuclear energy systems have been very successful in safely and economically producing power, it is necessary to continue R&D for the development of advanced nuclear reactor systems especially since India has very high reserves of thorium, while its known uranium reserves are quite modest. Work towards the development of the mainly thorium-fuelled Advanced Heavy Water Reactor (AHWR) was initiated in the IX and X Plan with considerable success and the same would continue. The AHWR is under review by Atomic Energy Regulatory Board (AERB). Another initiative taken is in development of Indian High Temperature Reactors (IHTRs). In the XI Plan it is envisaged to build a demonstration unit of a Compact High Temperature Reactor which would serve as a platform for development and demonstration of very high temperature heat removal capabilities and other challenges associated with the operation of high temperature components of newer materials. This demonstration facility is proposed to be built at Trombay campus of Bhabha Atomic Research Centre (BARC). Work on development of materials for high temperature reactors including fusion reactor would also be taken up. Work on generation and storage of hydrogen is also proposed during this plan.

As a part of working for energy security, one of the options is energy from fusion reactor. India has recently joined (International Thermonuclear Experimental Reactor) ITER as one of seven full partners, the others being China, European Union, Japan, Korea, Russia and USA. India will contribute equipment worth nearly 500 million US dollars to the experiment and will also participate in its subsequent

operation and experiments. ITER is a prestigious international project which will nearly complete the scientific and technological investigations required to build a prototype demonstration reactor DEMO, based on the magnetic confinement scheme of controlled thermonuclear fusion. India's contributions to ITER are largely based on the indigenous experience and the expertise available in Indian industry. Work on fusion and plasma science research would continue to strengthen domestic technologies. A short write up on ITER India is given in Annex E of this report.

- New Multipurpose research reactor
- Development of advanced technologies
- Expansion of programme aimed at application of radiation technologies to agriculture, food preservation and health care

Research reactors APSARA, CIRUS, DHRUVA and KAMINI provide the reactor based facilities for research in basic sciences like physics, chemistry and biology. In addition, they also provide services like production of radioisotopes, neutron radiography, neutron activation analyses, material irradiation testing, fuel testing, shielding studies etc. Existing research reactors would be refurbished. It is also planned to set up a Multi Purpose Research Reactor with high flux especially for continuing basic research in frontier areas of science and for applied research related to development and testing of nuclear fuels and other materials. A radioisotope processing facility is also proposed to be set up at Visakhapatnam.

Radioisotopes and radiation finds application in different fields such as medicine, industries, food processing, hydrology, agriculture, research etc. The XI Plan proposals related to these fields address the current needs in these areas and target societal benefits. To promote these technologies for societal benefits, interactions haven going on with various State/Central Ministries and other Organisations. Annex F gives a brief on the same.

Projects in the area of food preservation & hygeinisation, isotope hydrology & industrial tracers, production of radioisotopes & radio-labelled compounds and radiation processing of materials are planned. Desalination of sea water is one of the ways for augmenting the water supply and hence its development has been a thrust area in the DAE. Development of various types of membranes and setting up of few small size plants are proposed to be taken up during this plan period.

Development of laser technologies for engineering applications in nuclear and industrial fields will be pursued at Raja Ramanna Centre for Advanced Technology (RRCAT). Accelerator and Accelerator Driven Systems development which would be used in the third stage will also be pursued vigorously. Development of beam lines for Indus-2 and their utilisation would be taken up. Diagnostic beam lines for synchrotron radiation studies are also planned. Development of superconducting cavities and associated technologies for high energy accelerators would be taken up. A proton therapy unit is planned to be assembled and tested at Kolkata and then shifted to Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), Navi Mumbai for clinical application in treatment of cancer. Medical cyclotron is under construction and the same would be available during the XI Plan period. Development of Special materials is also planned. Development of nuclear instrumentation is one of the advanced technology areas which require special attention. Various type of instruments used in nuclear applications will be developed indigenously.

DAE has been developing indigenous supercomputers which are comparable to the best in the world. It is planned to develop internationality competitive state of the art high performance computing platforms. Computing capabilities in various R&D institutions are planned to be enhanced. A program on enhancement of DAE GRID and Anunet facility will be taken up to improve the communication and computing power of the DAE units.

- Strengthening domestic programmes by participation in international mega-science projects and initiation of international participation in domestic programmes
- Creation of international centre for Magnetic Resonance in collaboration with DST
- Development of human resource for scientific programmes
- Setting up of National Institute of Science Education and Research at Bhubaneshwar to undertake integrated 5-yr Masters course in core and emerging branches of science for students after the 10+2 stage
- Initiation of Prospective Research Fund
- Infrastructure development to support scientific activities

Successful participation of Indian scientists in project Large Hadron Collider (LHC) at CERN, Geneva has made Indian strengths visible to the world scientific community and Indian scientific community is being invited to participate in several large international mega projects. Any such participation has been on the basis of cost benefit analysis. Benefit could be in the form of acquisition of new technologies, our participation in frontline scientific research, Intellectual Property Rights on

technology under development, attracting young towards science and perhaps many other aspects. We would be participating in international projects like International Linear Collider (ILC), Facility for Antiproton and Ion Research (FAIR), X-ray Free Electron Laser (XFEL). Some of these projects will have participation of DAE units along with other scientific community of the country. It is also planned to have an Indian Neutrino Observatory (INO) in collaboration with various scientific community of the country. This would also be open for international participation.

Basic research activities would also be continued in the field of biology, biophysics and cancer research. Advanced Physical Sciences, Material science, Astronuclear Physics and Astroparticle Physics, Astronomy and Chemistry. Project on Energy conversion technologies has also been taken up for study of alternate energy conversion technologies.

Research Education linkage has been the backbone in development of scientific manpower for the country and within the Department. The programmes undertaken are some of the major scientific programmes of the country and hence would require participation of best scientific manpower. Also in terms of activities, we are the largest users of scientific facilities. Hence, it is necessary for us to play a proactive role in the academic activities. It would be very useful if education policy in the country is looked into for attracting young to participate in these programmes.

On our part, as we move from the first stage to the second stage of our power programme, we will need more trained scientific manpower in the field of fast reactors. In the XI Plan, a training school at Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam as an affiliate of the BARC Training School will be started. It will cater to the needs of the Fast Breeder Reactor programme of DAE. It is planned to have a separate training school for Atomic Minerals Directorate for Exploration & Research (AMD) in lines with other training schools in the Department. A DAE Administrative Training Institute is also planned to be set up for training (both induction and in service) on a regular and continuous basis, personnel in the support services like Administration, Accounts, Purchase, Stores, Security, etc.

A campus is proposed to be set up at Visakhapatnam for pursuing the activities of HBNI. Increasing intake of students by increasing number of DAE fellowships for pursuing Ph.D. under HBNI is planned. This will also require development of additional infrastructure in terms of building hostels. DAE-Mumbai University Centre for Excellence will be set up in Mumbai to conduct five years integrated B.Sc.-M.Sc. programme in Sciences. It is also proposed to increase the

outlay for the extra mural research presently being funded through Board for Research in Nuclear Sciences (BRNS) and National Board of Higher Mathematics (NBHM). A new initiative in terms of Prospective Research Fund is also proposed which will provide funds on competitive basis to the Departmental personnel for pursing research complementary to the major projects.

In the recent visit of Honorable Prime Minister of India Dr Manmohan Singh to Institute of Physics, Bhubaneshwar on 28th August 2006, PM announced setting up of National Institute of Science Education and Research (NISER) at Bhubaneshwar. He announced that NISER will be at par with the IISER being established in other places but will operate under the umbrella of DAE. It will undertake integrated 5-yr Masters courses in core and emerging branches of science to provide world-class educations to students after the 10+2 stage. It can also include an integrated M.Sc-Ph.D. after graduation level.

To meet the requirements of expanding programmes of the Department, investment in infrastructure is a must. Infrastructure at the existing units is proposed to be strengthened. New campuses are being set up at Visakhapatnam for BARC, at Rajarkhat, Kolkata for Variable Energy Cyclotron Centre (VECC)/ Saha Institute of Nuclear Physics (SINP), at Gandhinagar for Institute for Plasma Research (IPR) and Mumbai for Tata Institute of Fundamental Research (TIFR). A large investment is also planned within BARC for strengthening the infrastructure from security reasons, up-gradation of old buildings.

The estimated expenditure during the X Five Year Plan is Rs.3,200 crs. The new schemes proposed for DAE during the XI Plan costs Rs 11,973.45 crs with outlay for XI Plan being Rs 9,564.61 crs and a spill over component of Rs 2,408.84 crs in the XII Plan. Some of the DAE schemes of the X Plan would continue in the XI & XII Plan for which the outlay required would be Rs 1,432.92 crs and Rs 399 crs respectively. Thus the total outlay required during XI Plan for DAE schemes would be Rs 10,997.53 crs with a spill over component of Rs 2,807.84 crs in the XII Plan. The requirement for AERB is Rs 15 crs with outlay for XI Plan being Rs 13 crs and spill over component of Rs 2 crs in the XII Plan. Total requirement for DAE and AERB during XI Plan is Rs 11,010.53 crs. This is the minimum requirement for achieving the targets set by this Department in moving from developmental stage towards becoming world leader in areas of our work.

Chapter 2

Research and Development in Nuclear Science and Technology

2.0 Introduction

Department of Atomic Energy (DAE) has been pursuing research in high-tech areas and developing technology to meet the technological requirements of the country. In the DAE scientific enquiry and technology development are pursued in a manner that provides for synergy between science and technology development and establishes an organic linkage between the laboratory developing the technology and the industry receiving the technology. Fulfilment of both these requisites can be facilitated in a broad based organization having multiple functional units with seamless boundaries. The Department of Atomic Energy (DAE) is an organization incorporating research centres and closely linked industrial units and provides conditions for fulfilling both the above requisites. This has enabled the Department to plan and successfully execute a comprehensive programme in the area of nuclear science involving the chain of activities viz. research, development, demonstration and deployment of technologies. This approach has been a crucial factor in building a self-reliant capability in all aspects of the nuclear fuel cycle. Even in the present era when globalisation and liberalization have become the buzzwords, in the nuclear field we have to retain and strengthen our ability to carry forward with further domestic developments of advanced technologies, so that the country can remain immune from technology denial regimes. That apart, our programme has to be in tune with our nuclear resource profile. With modest uranium and vast thorium resources that we have, a situation unique to India, our programme has also to be on somewhat different lines as compared to other countries. There is thus a strong justification and necessity for us to push ahead with our own domestic development. While the technologies for Pressurised Heavy Water Reactors developed indigenously are now in commercial domain and we expect their rapid deployment through support under power sector, under R&D sector it is proposed to push the fast reactor and thorium technologies.

Research and development activities of the Department are categorised into seven major programmes with specific deliverables for each of these major programmes. The major programmes are then further classified into sub-

programmes identifying specific areas of work. This categorization was first done at the beginning of the X Plan and has been slightly modified to reflect the current realities. These are given as Annex to the constitution of Internal Working Group (IWG) (see Annex-D). In addition, the DAE has to cater to national strategic needs and would continue special programmes of strategic importance at select units.

2.1 Power Programme

An examination of data (IEA – 2005) indicates that India is the 5th largest producer of electricity in the world. However, while India is amongst the top 10 countries of the world for production of electricity by hydro, coal, oil and gas, it is nowhere near the top 10 with respect to nuclear power generation. For a large country like India, this is an anomaly in need of correction. Claude Mendil, Executive Director, IEA writes, “No single fuel or technology should be canonized, nor should any single fuel or technology be crucified” (Mendil – 2005). It is thus necessary to examine all issues related to nuclear energy and lay down a policy framework to make the necessary transition.

For the development of nuclear power, India is pursuing a three stage nuclear power programme which has been formulated to provide long term energy security to the country based on indigenous nuclear fuel resources. The programme envisages a closed fuel cycle involving reprocessing of the spent fuel to separate the fissile fuel for recycling.

The first stage comprising setting up of Pressurised Heavy Water Reactors (PHWRs) and associated fuel cycle facilities is already in the industrial domain. The technology for the manufacture of various components and equipment for PHWRs in India is now well established and has evolved through active collaboration between the DAE and the industry. Fourteen PHWRs are operating, and four more 220 MWe PHWRs are under construction. With the successful commissioning of two 540 MWe indigenously designed PHWRs at Tarapur has been a major landmark in the development of PHWR technology. This design is further scaled up to 700 MWe and construction of several of such units is planned. The gestation period in construction has now reached international standard. As DAE gains experience and master various aspects of the nuclear technology, performance of nuclear power plants is continuously improving. Average availability factor of nuclear power plants has steadily risen from 69% in 1995-96 to over 90% during the X Plan period.

The second stage envisages setting up of Fast Breeder Reactors (FBRs) backed by reprocessing plants and plutonium-based fuel fabrication plants. In order to expand the nuclear power capacity in our country, fast breeder reactors are necessary for our programme. A large power-generating base is also needed to establish use of thorium on a large scale in the third stage of our programme. A 40 MWt Fast Breeder Test Reactor (FBTR) has been operating at Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam since attaining first criticality on 18th October 1985. FBTR uses a unique and indigenously developed mixed uranium carbide-plutonium carbide fuel, which has functioned extremely well up to the current burn up of over 154.3 GW days/tonne without any fuel pin failure in the core. FBTR has provided valuable experience with liquid metal Fast Breeder Reactor Technology and the confidence to embark upon the design and technology development of a 500 MWe Prototype Fast Breeder Reactor (PFBR). PFBR is different from FBTR. After detailed design and technology development of the PFBR, construction of the first indigenous reactor was launched on 23rd October 2004. This marked the launch of second stage of our power programme.

The third stage will be based on the thorium-uranium-233 cycle. Uranium-233 is obtained by irradiation of thorium in PHWRs and FBRs. An Advanced Heavy Water Reactor (AHWR) is being developed at Bhabha Atomic Research Centre (BARC) to expedite transition to thorium based systems. The reactor physics design of AHWR is tuned to generate about 65% power in thorium, and to maintain negative void co-efficient of reactivity under all operating conditions. Due to its passive safety systems, there is no need to planning off-site emergency system. Its design life is for 100 years. Work towards the development of this reactor was initiated in the IX and X Plan periods. A lot of progress has been made since then. It is currently under pre-licensing appraisal of Atomic Energy Regulatory Board (AERB). The design has received international recognition. Detailed project report for this reactor is being made and it should be possible to launch the construction of this reactor in a few years. We have formulated an approach to the third stage of the power programme and this includes developing Accelerator Driven Systems (ADS) in addition to AHWR. Accelerator systems are becoming very important in the context of thorium use as well as for waste incineration. Design of AHWR being developed would be consistent with a possible thermal blanket of a future ADS.

To jump-start the nuclear power programme, two Boiling Water Reactors were set up at Tarapur near Mumbai in late sixties. These reactors are still in operation. In a similar manner, in parallel to the indigenous self-reliant three-stage programme, two 1000 MWe units of Light Water Reactors (LWRs) at Kudankulam is being step

up in collaboration with the Russian Federation. These reactors are expected to become operational by 2010. R&D activities are proposed to be further stepped up to assimilate this technology.

To ensure energy security of our country another initiative has been taken during the X Plan period. India has joined a major international initiative to develop fusion technology. It has joined International Thermonuclear Experimental Reactor (ITER) project as full partner. Others being China, European Union, Japan, Korea, Russia and USA. Participation in ITER project will lead to strengthening our domestic programme. This is an investment for the future both in terms of scientific and technological goals and will help in being at par with developed world in terms of energy security.

2.2 Radiation Technology and Advanced Technologies

Radiation has a variety of applications areas including health care, agriculture, food preservation, industry and research. Parallel to the nuclear power programme, radiation technology applications have made considerable progress in India. Radiation can be produced either from radioisotopes or from accelerators. Research reactors at Trombay regularly produce a variety of radioisotopes and meet a major part of their demand in the country. In addition to research reactors, power reactors have been equipped to produce cobalt-60. While indigenous capability to design and construct research reactors is well established, good progress has been made in the development of accelerators as well and many accelerators have been built. Development of indigenous lasers for a variety of applications has also been a very successful programme. For the past several years, based on radiation technology applications, we have made significant contributions in food and agriculture, health care and industry. The chapter dealing with the achievements of IX Plan provides the details.

2.3 Basic Research

In parallel to the above programmes, the units of DAE lay strong emphasis on basic research in nuclear sciences and allied areas. This covers frontier areas in physics like condensed matter physics, nuclear physics, theoretical physics, molecular and optical sciences, plasma physics, astrophysics, cosmic ray and high energy physics, accelerator and laser physics; in chemistry like radiation and photo-chemistry, laser chemistry, interfacial chemistry and chemical dynamics; in biology like molecular biology, cell biology, radiation biology, genetics, cancer research; in

agricultural sciences and food technology; and in mathematical and computer sciences. Basic research in DAE, while contributing to the knowledge pool in nuclear and related topics and thereby strengthening our technology development capability, is also intimately linked with development of cutting edge technologies so essential for pursuing basic research.

One should also participate in collaborative advanced basic research at the international level. Such participation, in addition to basic research per se, opens a window to the state-of-the-art technologies invariably used in the mega experimental facilities. Over the past several years, international community has been inviting India to participate in international projects. Participation of DAE in the building of the Large Hadron Collider (LHC), CERN, Geneva, and ITER Project are such examples. In the XI Plan also India is proposing to participate in international projects. The projects have been chosen on the basis of a careful cost benefit analysis. Benefit could be in the form of acquisition of new technologies, participation of Indian scientists in frontline research, Intellectual Property Rights on technology under development, attracting young towards science and many other similar aspects. Some of the mega science projects which involve multi-institutional multi-organisational participation are X-ray Free Electron Laser (XFEL), International Large Collider (ILC) and Facility for Antiproton and Ion Research (FAIR) at Germany. It is now planning to set up Indian Neutrino Observatory (INO) in the country. This will be a mega-science project with participation of many institutes of the Department, universities and Department of Science & Technology (DST). It is also open for international participation. Participation of high profile international community at our existing Giant Metrewave Radio Telescope (GMRT) project is an example of beginning of reverse flow of scientific community in Indian projects. INO would be another opportunity for such international participation.

2.4 Human Resource Development and Research Education Linkage

Human resource development has been given importance right from the day the nuclear programme was initiated in the country. Adequate training facilities have been set up within the department to provide specialized training in nuclear related areas. A Training School to impart one year orientation course in nuclear science and engineering has been functioning since the late fifties. World-class Graduate Studies programmes has been running at Tata Institute of Fundamental Research (TIFR) for several years which has enabled TIFR to get the status of a deemed university. Based on the success of such programmes and to meet the growing demands of trained scientific manpower, training schools as affiliates of BARC

Training School have been set up at Raja Ramanna Centre for Advanced Technology (RRCAT) and Nuclear Fuels Complex. Similar training school is proposed to be set up at Indira Gandhi Centre for Atomic Research (IGCAR). Atomic Minerals Directorate for Exploration & Research (AMD) has also proposed to set up a Training Centre. A DAE Administrative training centre is also planned to be set up for training the administrative staff of the Department. Many new schemes have been introduced in the recent years to further augment the training facilities.

DAE is a firm believer in synergistic interaction between the national laboratory system and the university system. A new element has been added by launching of Homi Bhabha National Institute (HBNI) as a Deemed to be University. The HBNI will function as a Graduate School and will further help in strengthening the linkages between R&D and technology development in the Department. A DAE-University Grants Commission (UGC) Consortium for Scientific Research has also been initiated to further enhance the linkage between DAE-University. In addition to having its own R&D programme, it funds research in universities and national laboratories on areas of relevance. This funding is channelised through Board of Research Nuclear Sciences (BRNS) and also directly by its units to pursue specific programmes. A new initiative is proposed during this plan to enhance creativity within the Department. It is proposed to create a Prospective Research Fund for funding basic research related to major projects being undertaken by the Department. This will be available to the Departmental personnel on competitive basis.

2.5 Concluding Remarks

India has now been recognised as a developed nation as far as nuclear power programme is concerned. Development of PHWR technology attaining a capacity utilisation of over 90%, mastery over operation and maintenance of these power reactors, successful closing of entire fuel cycle, successful operation of FBTR with record fuel burn-up and even free handling of liquid sodium are some of the testimonies for India to be ranked amongst the leaders in nuclear technology. Fact that these achievements have been made without external inputs speaks volumes of the indigenous developmental efforts. Owing to the availability of limited domestic uranium reserve and large thorium reserve, our three stage sequential nuclear power programme has made us make technological choices which are different from others. Hence, we have to drive on our own path. It is due to these technological choices and developmental work carried out in thorium technology, India is already recognised as world leader in these fields.

India is making efforts to focus more on R&D to accelerate economic growth, which is the essential condition for improving the living condition of the citizens. Departments like the DAE, which have developed expertise in wide ranging areas of science and have contributed to the development process in the country in various ways including increase in Gross Domestic Product (GDP), are well qualified to channelise the investments in R&D with a degree of assurance. Nuclear power plants set up by the Department are producing electricity at competitive rates, radiation technology applications to industry and agriculture are providing direct contribution to GDP, use of radiation in health care is providing relief to millions of citizens and research in basic sciences is laying foundation of growth for the future. After detailed discussion within the Department and with outside experts, DAE has arrived at a number of project proposals to be pursued during the XI Five Year Plan and they are outlined in this report. Working Group expects that steady and constant support by the Government to enable the DAE to pursue these proposals.

Chapter 3

DAE Achievements of X Five Year Plan

3.0 Introduction

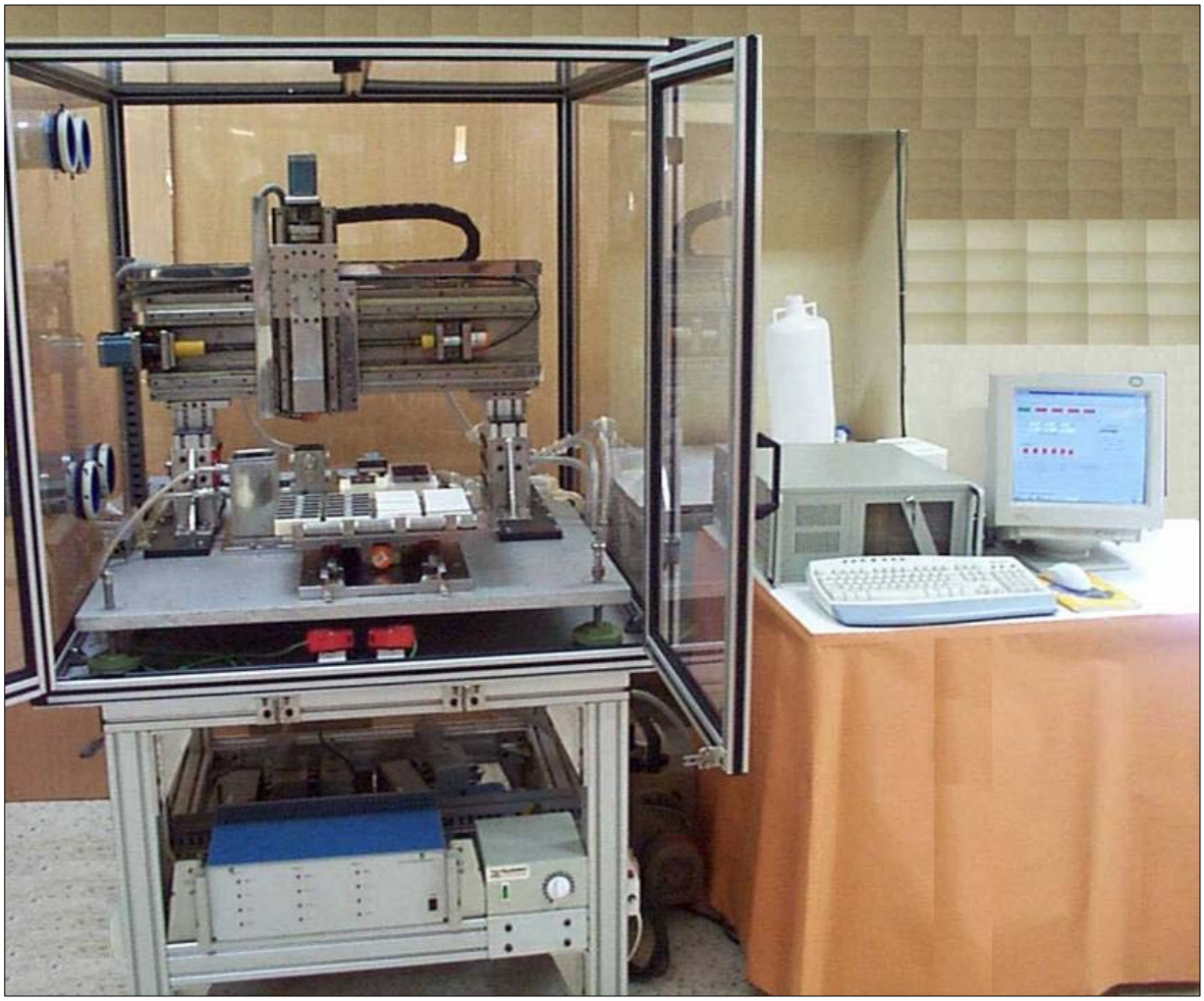
Department of Atomic Energy (DAE) has been pursuing its mandate of research in the use of atomic energy for power and non-power related uses. Being a multi-disciplinary and multi-functional organisation it has pursued research in basic science, development of technologies and transferring them to the industrial domain. Research in these fields are continued to maintain the cutting edge. It has participated and contributed in international mega-science projects and its contribution is recognized by the international scientific community. Programmes of R&D Sector are carried out in our R&D units and grant-in-aid institutions. During the X Plan, we categorized our work into seven major programmes and their related sub-programmes. This note broadly reviews major programme-wise progress made by the plan projects during the ongoing X Plan.

3.1 A brief description of major achievements

3.1.1 Major Programme 1: Nuclear Power Programme – Stage – 1

Mobile robot for remote survey and inspection developed at BARC

First stage of Nuclear Power Programme comprises setting up of Pressurised Heavy Water Reactors (PHWRs) and associated fuel cycle facilities. These are already in the industrial domain. The technology for the manufacture of various components and equipment for PHWRs in India is now well established and has evolved through active collaboration between the DAE and the industry. Fourteen PHWRs are operating, and four more 220 MWe PHWRs are under construction. With the successful commissioning of two 540 MWe indigenously designed PHWRs at Tarapur has been a major landmark in the development of PHWR technology. R&D support for improved capacity utilization, safety, control instrumentation and ageing management etc needs to be carried out in all these areas. Some of the major achievements in these areas are given in the subsequent paras.



Prototype DNA Microarrayer System at BARC

- At BARC, a 3-Axis Robotic system for making DNA Microarrays has been developed and commissioned. It is being used for research purposes in the area of molecular biology.
- This is an attempt to indigenously develop high-throughput systems required for research in the area of Genomics.
- It is the first of its kind developed in India. An advanced Microarrayer with higher precision and higher throughput is being assembled.

Advanced reactor design & technology development project envisaged technology development for remotisation and automation, fluid power technology for nuclear fuel cycle, radiation monitoring instruments for PHWRs, advanced technologies and techniques on Control & Instrumentation of nuclear power and research reactors, software reliability techniques, development of vibration monitoring and diagnostic techniques etc. Most of these objectives would be met

during the X Plan and the project will be completed as originally scheduled in March 2008. Some of the deliverables under this project included polyurethane booting for rugged duty manipulators, special purpose water hydraulic valves, in-core flux mapping system, DNA microarrayer etc. Work on development of PHWR-Fuels, Materials, safety & water chemistry studies has progressed well and will be continued in the XI Plan as originally scheduled. Of these technologies, a special ion-exchange process for selective removal of Gadolinium Nitrate in presence of Boron from its Moderator System and on-line system for vibration diagnostic for the steam turbine was developed and used at TAPP. The later technology has now been offered to NTPC for their 500MWe thermal power plants. A new technique based on ultrasonic sensor developed for generating axial creep data of PHWR pressure tubes was successfully used for the first time in TAPP-3. With the tools developed by BARC, pre-service inspection was carried out on 20 coolant channels prior to criticality. Quality assurance services were provided for fuel and core components of TAPP-3 manufactured at NFC. BARC has also developed a methodology for the evaluation of passive systems named Assessment of Passive System Reliability (APSARA). This would be useful in new reactors under development.

The installation of equipment and systems of the hot facility of P-4 Experimental facility is completed and is undergoing commissioning trials. The commissioning for high temperature operation will be completed shortly and handed over to operation group for experimentation. Manufacture of subassemblies for prototype reactivity control mechanisms for Light Water Reactors (LWR) made progress.

- Work on development of PHWR-Fuels, Materials, Safety & Water chemistry progressed as per schedule
- Installation of equipment and systems of hot facility of P-4 Experimental facility completed
- On-line system for vibration diagnostics of steam turbine developed
- Methodology for evaluation of passive systems named Assessment of Passive System Reliability(APSRA) developed
- New technique based on ultrasonic sensor developed for generating axial creep data for PHWR pressure tubes

AGRS/AM survey of 4980 line km, reconnaissance survey of 10350 sq. km, detailed survey 331 sq. km, geochemical survey of 3200 sq. km and drilling 35,565 m has been completed till the end of 4th year of this plan and is progressing well.

This has resulted in augmentation of U3O8 resources. A Technology demonstration pilot plant on batch scale for extraction of uranium from uranium ore using alkaline leaching process under elevated pressure and temperature and also other downstream facilities with matching capabilities were set up at Jaduguda. A process for recovery of uranium from low grade Tummallapalle ore using pressure alkali process has been successfully developed.

Technology development for production of identified metal extractants has progressed well. Technology for production of few of these metal extractants has been transferred to Heavy Water Board for setting up full scale plants. Suitable processes have also been developed using these solvents for bulk separation of trivalent actinides from high level waste (HLW). These processes have been tested and validated on a full scale In-active engineering partitioning loop leading to more than 99% recovery of lanthanides which were used to simulate trivalent actinides. An active demonstration plant for bulk separation of Actinides and Lanthanides at Solid Storage Survilance Facility (SSSF), Tarapur is under construction. Removal of Uranium from simulated HLW was demonstrated on full scale leading to recovery of uranium as a resource material. Based on these studies, adoption of this process & technology, an active plant for removal of uranium and associated plutonium is being set up in Waste Immobilisation Plants of Tarapur (SSSF) & Trombay.

- Arial, reconnaissance, detailed and geochemical survey targets being met leading to augmentation of U_3O_8 resources
- Technology for production of identified metal extractants developed and transferred to Heavy Water Board for setting up full scale plants
- IERMON set up at 37 stations across the country. Intended to expand to 500 stations for getting on-line radiation data
- Mobile radiological survey laboratory developed and deployed

BARC has established a countrywide environmental radiation monitoring network called Indian Environmental Radiation Monitoring Network (IERMON) with 37 monitoring stations across the country with central station located at the Environmental Assessment Division of BARC. These stations get hourly data from all stations; the same is assimilated and sent to the Emergency Control Room of the DAE. The central station is also linked to the Emergency Response Centre at Modular Laboratories, BARC. The IERMON network provides on-line information about radiation levels at various stations which facilitates environmental impact assessment of nuclear emergencies. It also helps provide knowledge-based environmental awareness to public through participation of Universities and other

educational institutions. Mobile radiological survey laboratory is also developed and deployed on need based basis at various locations.

3.1.2 Major Programme 2: Nuclear Power Programme – Stage – 2

In FBTR, the Mark-I fuel [U-Pu mixed carbide fuel with 70% Pu] has reached a burn-up of 154.3 GWd/t without any fuel pin failure in the core. A detailed Post Irradiation Examination [PIE] was conducted on 100 GWd/t of FBTR fuel sub assembly. The PIE data obtained include density measurement of wrapper, mechanical property evaluation of Fuel Sub-Assembly [FSA] wrapper at high temperature and fission gas analysis of fuel pins. The burn-up was measured by mass spectrometric technique. These results, combined with a comprehensive modelling of the fuel, formed the basis for enhancing the mixed carbide fuel burn-up beyond 150 GWd/t.

Desk-top Articulated Robot with 6 degrees-of-freedom developed at IGCAR for studying fuel pellet handling, remote repairs and decontamination

CORAL facility was hot commissioned successfully for reprocessing of irradiated mixed carbide fuel. Fuel discharged from FBTR at 25, 50 and 100 GWd/t burn-up was successfully reprocessed at CORAL. It is to be noted that CORAL is the first facility in the world to have reprocessed high Pu content carbide fuel at high burn-up. The experience from CORAL operation has provided significant inputs to the design of equipment and flow sheet for Demonstration Fast Reactor Fuel Reprocessing Plant (DFRP).

In the field of Materials technology, Indigenous development of activated flux for autogenous TIG welding has been successfully carried out towards characterisation of mechanical properties. An eigen value based approach has been developed for enhanced detection and imaging of shallow defects in ferromagnetic materials such as carbon steel and modified 9Cr-1Mo steel. Hot forging techniques for a new temperature sensitive new sensor material [$Ni_{50}Fe_{37}Co_{13}$] for diverse safety rod drive mechanism was achieved followed by successful sensor fabrication. Ti-5Ta-1.8Nb alloy has been developed for the dissolver and evaporation tanks of fast breeder reactor fuel reprocessing plants. Towards characterisation of mechanical

properties, Alloy D9 pressurised capsules for irradiation creep testing of PFBR fuel cladding and wrapper tubes were developed and weld integrity was demonstrated. Indigenisation of modified 9Cr-1Mo welding electrodes with better than commercially available electrodes in international market was completed.

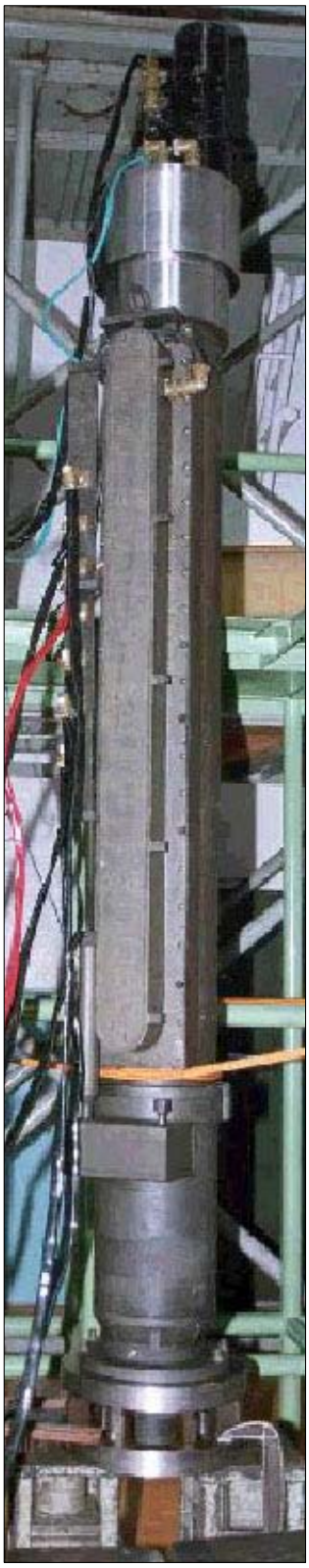
Sodium resistant concrete has been developed to protect the structural concrete, a sacrificial layer, which is less aggressive with liquid sodium.

As a part of Reactor Engineering studies, towards developing robust steam generator for FBRs, a Steam Generator Test Facility [SGTF] has been commissioned. Commissioning of ¼ scale model (SAMRAT) of reactor assembly and carrying out experiments for determining flow distribution amongst IHX, velocity distribution in hot pool, gas entrainment with & without baffles, free level fluctuation, flow induced vibration of control plug, weir instability of main vessel cooling baffle, thermal stratification etc., were completed successfully, qualifying PFBR design. Control and Safety Rod drive mechanism for PFBR was qualified based on sodium testing. Hydraulic tests on fuel and blanket subassembly were completed to validate PFBR design.

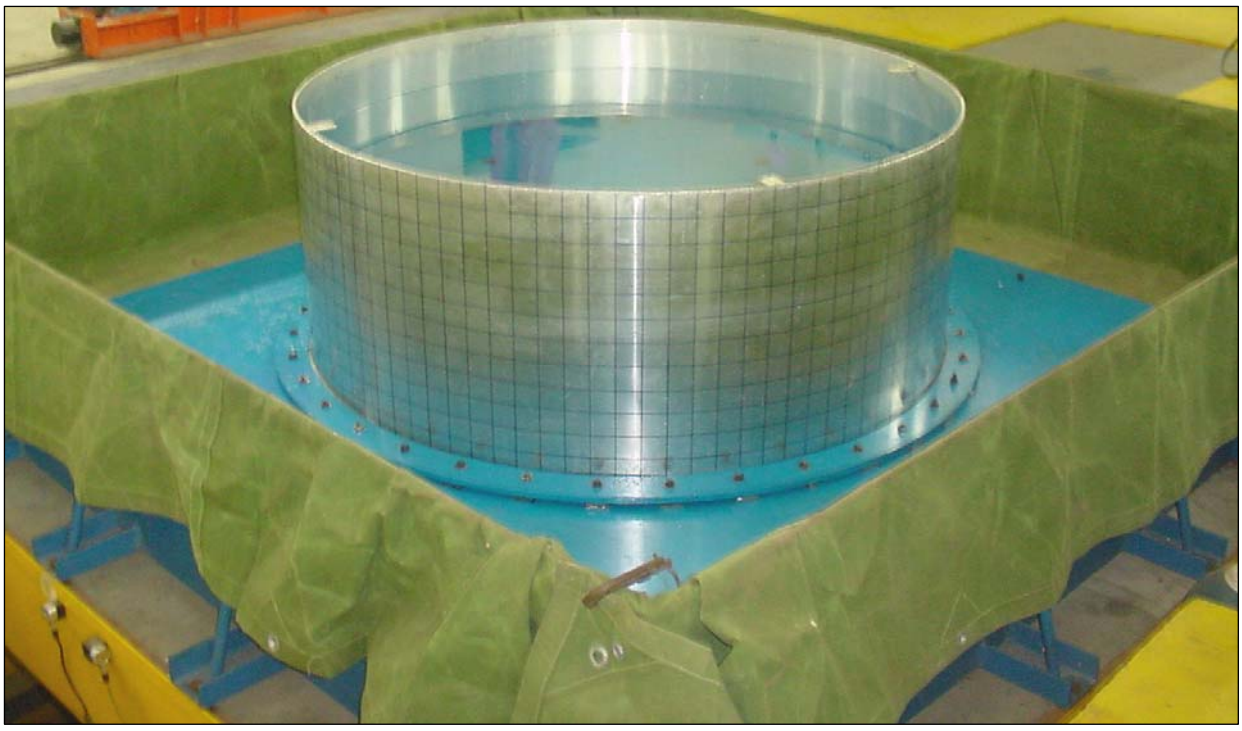
- Mark-I fuel reached burn-up of 154.3 GWd/t without any fuel pin failure in the core
- Post Irradiation Examination conducted on 100 GWd/t of FBTR fuel sub assembly
- CORAL, first facility in the world to reprocess high Pu content carbide fuel at high burn-up successfully commissioned. Fuel of 25, 50 and 100 GWd/t burn-up from FBTR successfully reprocessed
- Indigenous development of activated flux for autogenous TIG welding successfully carried out towards characterization of mechanical properties
- Sodium resistant concrete developed to protect structural concrete
- Steam Generator Test Facility commissioned
- Commissioning of ¼ scale model (SAMRAT) of reactor assembly and successful completion of experiments on it

Some of the other major activities completed during X Plan, towards R&D support during construction of PFBR were creep tests on end plug weld configurations for the fuel pins, thermal cycling tests on the grid plate model, qualification of indigenously developed in-bore welding of steam generator tubes, qualification of bend tubes made of modified 9Cr-1Mo for steam generator by fatigue testing, leak before break justification of steam generator shell nozzle junction and flow distributor plates inside the spherical header at the primary pump sodium outlet.

Inflatable seal testing facility for FBTR and PFBR seals



Testing of Control and Safety Rod Drive Mechanism (CSRDM) in Sodium for Prototype Fast Breeder Reactor



Experiments using 10t Seismic Shake Table. The Shake Table has been installed and commissioned. It will be used for Seismic qualification of Reactor components (Scale Models). A few experiments have been conducted.

Top view of 1/4th Reactor Assembly Model. The set up has been erected. Various Thermal Hydraulics Experiments will be carried out using the above facility.

Some of the experiments carried out for design validation were ratcheting design of main vessel, inner & outer walls of reactor vault under seismic forces, experiments on biological shield cooling system focusing on the contact resistance at the interface between the cooling tube & concrete and validation of seismic design of main vessel including sloshing based on shake table tests with 1/10th scaled down model to simulate the dynamic characteristics.

As a part of NDT studies of reactor components, micro-focal radiography for tube to tube sheet weld joints of steam generators, remote field eddy current technique for in-service inspection of steam generator tubes, infrared thermal imaging for thermal ratcheting studies of the 316LN stainless steel cylindrical structures have been developed and successfully analysed. A prototype eddy current based position-sensing device was also developed to record the free fall time of Diverse Safety Rod in PFBR. Impact echo and ultrasonic examination of sodium fire exposed concrete blocks were conducted for the first time for determination of the sacrificial layer.

- Experiments carried out for design validation of PFBR
- Major NDT Studies of reactor components carried out
- Production of Boric acid enriched in ^{10}B upto 65% achieved and technology transferred to Heavy Water Board for setting up a large scale plant
- R&D programmes for back end of FBR fuel cycle taken up

Towards development of NDT methods for inspection of reactor components, ultrasonic procedures were developed for the inspection of main vessel, safety vessel, sodium circuit weld joints and in-service inspection of shell weld of core support structure in the main vessel of PFBR. Eddy current testing for inspection of steam generator tubes was also carried out. A prototype In-service Inspection (ISI) robotic device was developed in collaboration with Bhabha Atomic Research Centre (BARC) for ISI of Main vessel and safety vessel of PFBR. A highly stable ferro fluid based leak-free sealant, using ferromagnetic nano-particles, has been developed for dynamic sealing applications.

Production of Boric acid enriched in ^{10}B upto 65% was achieved and process flow sheet transferred to Heavy Water Board for setting up a large plant for PFBR. Enriched elemental boron [65% ^{10}B] of nuclear grade purity was made from enriched boric acid for the first time in the country.

Electrochemical hydrogen meters for use in sodium systems and compact version of cover gas hydrogen meter were developed and incorporated in SGTF, Sodium Water Reaction Test facility and FBTR have performed satisfactorily. The cover gas hydrogen meter showed the capability to measure 30ppm levels of hydrogen in the cover gas. Design, development and testing of cross wire type leak detector for detecting the rupture of rupture disc after a sodium water reaction and eddy current flow meter for PFBR primary sodium pump have been completed. Diverse safety logic systems were developed for PFBR. A 32-bit advanced Real Time Computer was designed and installed at FBTR to supervise FBTR core. Automated miniature facilities were developed for rapid electro-analytical and thermo-analytical measurements in basic research and in rapid chemical assay with small volumes.

A robust safe and economic fuel cycle for fast reactors has to be realised in order to achieve rapid growth of fast reactors in the country. With this objective, IGCAR has undertaken R & D programmes in a variety of crucial areas related to fuel cycle such as development of novel processes and equipment, materials development and testing for catering to back end fuel cycle, extraction of valuable fission products from waste, etc.

A lab scale facility for developing remote fabrication of oxide fuel through sol-gel process is in the commissioning stage. During the XI Plan period, test fuel pins will be fabricated and irradiated in FBTR, with the ultimate objective of minor actinide burning in fast reactors. The operational inputs from CORAL have been incorporated in the design of DFRP. Design of chopper for DFRP was fine tuned based on the operational feedback from CORAL facility. Titanium dissolvers for FBTR & PFBR and Centrifugal extractor were designed. Prototype Fluidic Pumps were developed for the first time in the country. Fibre optic based spectroscopy system for online analysis was demonstrated in CORAL.

- Prototype Fluidic Pumps developed for the first time in the country
- Lab scale facility for developing remote fabrication of oxide fuel through sol-gel process is under commissioning
- Comprehensive programme on development of metallic fuels for FBRs launched
- Atmospheric dispersion models to predict radiological impact with on-line access commissioned
- Lab scale Supercritical Fluid Extraction Facility set up for recovery of actinides from waste materials. Recovery of U, Pu and Am from tissue paper waste has been demonstrated

As part of a programme to develop ceramic hosts for waste immobilisation, Synroc monoliths of near-theoretical density, incorporating simulated HLW compositions expected from FBTR fuel reprocessing were fabricated, employing hot isostatic pressing and hot uniaxial pressing. The quantitative supercritical extraction of uranium from tissue waste was established for the first time. A radioactive supercritical CO_2 facility for extraction of actinides from waste was set-up and commissioned; the extraction of Am and Pu from tissue matrix was demonstrated for the first time.

Fast Breeder Reactors based on Metallic fuel will form the mainstay of the Nuclear power programme in the coming decades. With this in mind, a comprehensive programme on metallic fuel development has been launched during the X Plan. A facility for fabricating U-Zr alloy test fuel pins with sodium bonding is being set up and will be commissioned in 2007. Thermochemical properties of metallic fuels are being studied. To develop Pyrochemical reprocessing technology for oxide as well as metallic fuels, lab scale studies on electrorefining of uranium oxide have been completed and the electrorefining of uraniumoxide in a novel MgCl2 based electrolyte has been successfully demonstrated. Decontamination from selected fission products has been studied and a model for electrotransport of U and Pu has been developed for the first time. In the XI plan, these studies will be continued with a view to demonstrate the electrorefining process for uranium on an engineering scale. The facility for these experiments is in an advanced stage of completion.

Atmospheric dispersion models to predict the radiological impact with on-line access was commissioned in a cluster and access of weather data through intranet was demonstrated. Experimental studies were carried out in full-scale model, in water, to study and improve the design for postulated Beyond Design Basis Events. An Aerosol Test Facility was designed, fabricated and tested for characterization of aerosols during core disruptive accident in FBR. The models can be extensively implemented for non-radiological applications like industrial gas leaks.

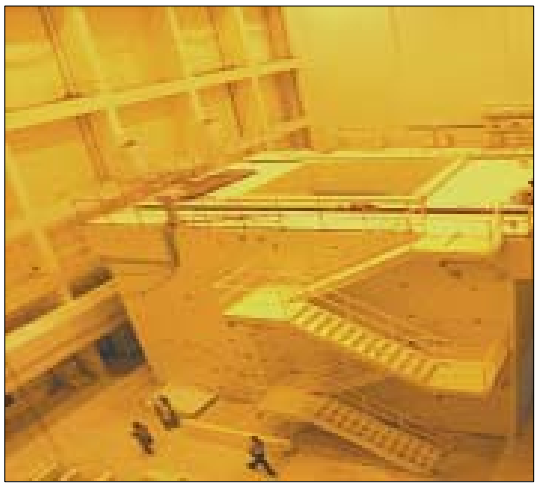
3.1.3 Major Programme 3: Nuclear Power Programme – Stage – 3 and Beyond

Technology Development for Fuelling Systems & Control System for Refueling the project is progressing well and is expected to get completed by March 2010 as per original schedule. One major deliverable under the project is AHWR Fuelling Machine (prototype) which is expected to be completed by March-2008.

This machine will be tested in the new facility to be set up at Tarapur (NPCIL R&D Centre). Detailed engineering of nuclear island and conventional systems of AHWR, design validation and technologies development has progressed well and is expected to get completed by June 2010 as per original schedule.

Development Programmes for Advanced Nuclear Reactors were undertaken with the objective of technology development for innovative Water Cooled Reactor Systems, Engineering Research and Development for High Temperature Reactor Systems and Augmentation of analytical and experimental capabilities for Reactor Physics Studies and all these have progressed well and the project is expected to get completed by March 2009 as per original schedule. Installation of passive valve test facility, development and demonstration of conductivity probe, procurement of high speed CCD camera and development of indirectly heated fuel rod simulator, procurement, fabrication and installation of the liquid metal loop have been completed.

- Development of fuelling systems & control systems for refueling machine made good progress. AHWR fuelling machine (prototype) to be completed by March 08
- Development programmes for advanced nuclear reactors undertaken
- New process based on coated agglomerate particles for Th-U^{233} MOX fuels developed



Reactor Block of Advanced Heavy Water Reactor (AHWR)

High voltage platform for the Accelerator Driven Sub-critical System (ADS) ion source at VECC

Under the Thorium Fuel Cycle Technology Development and U233 Clean Up project a new process based on coated agglomerate particles (CAP) for (Th-U233) MOX fuels has been developed, which results in less dust and reduced man rem exposure.

Under the project Materials for NPP-stage 3, Pilot plant for production of pure beryllia and process development for fabrication of beryllia shapes was setup. Precursors for preparation of chemically inert and non-graphitizing carbons have been identified. Technology for coating of buffer pyrolytic carbon and silicon carbide was demonstrated on 500 micron-size surrogate zirconia spheres. Test pieces of carbon-carbon composite for HTR were provided. The project has progressed well.

- Pilot plant for production of pure beryllia and process development for fabrication of beryllia shapes were set up
- Laboratory development on vitreous matrices for HLW from AHWR/FBR carried out
- Hot cell facilities for processing of Th fuel for immediate requirement of U^{233} for AHWR programme are being set up at Trombay
- Design and development work for ADS system being undertaken
- India joins ITER as full partner

Laboratory development on vitreous matrices for HLW with aluminium fluoride and thorium were carried out addressing the waste to be generated from AHWR/FBR reprocessing. Hot-cell facilities for processing of Thorium fuel for immediate requirement of U-233 for AHWR programme are being set up at Trombay.

Significant amount of design and development work in connection with a 30 mA advanced ion source floating at 100 keV platform was carried out as part of ADS programme. Several intricate systems and components have been fabricated. Development of a unique, low-energy beam transport line for highly intense proton beams is going on.

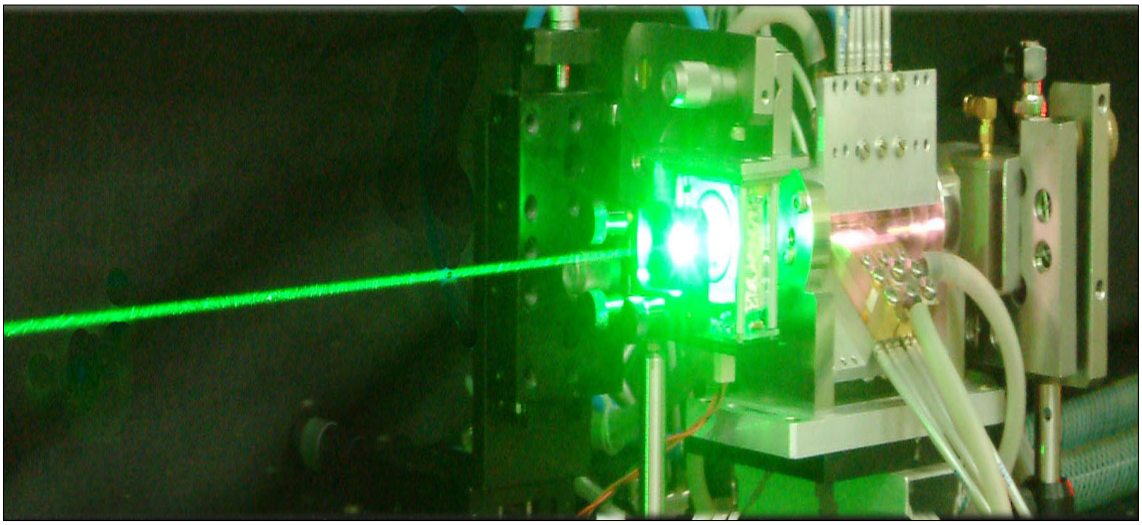
To ensure energy security of our country another initiative has been taken during the X Plan period. India has joined a major international initiative to develop fusion technology. It has joined International Thermonuclear Experimental Reactor (ITER) project as full partner. Others being China, European Union, Japan, Korea, Russia and USA. Participation in ITER project will lead to strengthening our domestic programme. This is an investment for the future both in terms of scientific and technological goals and will help in being at par with developed world in terms of energy security.

3.1.4 Major Programme 4: Advanced Technologies and Radiation Technologies and their Applications

A] Advanced Technologies and their Applications

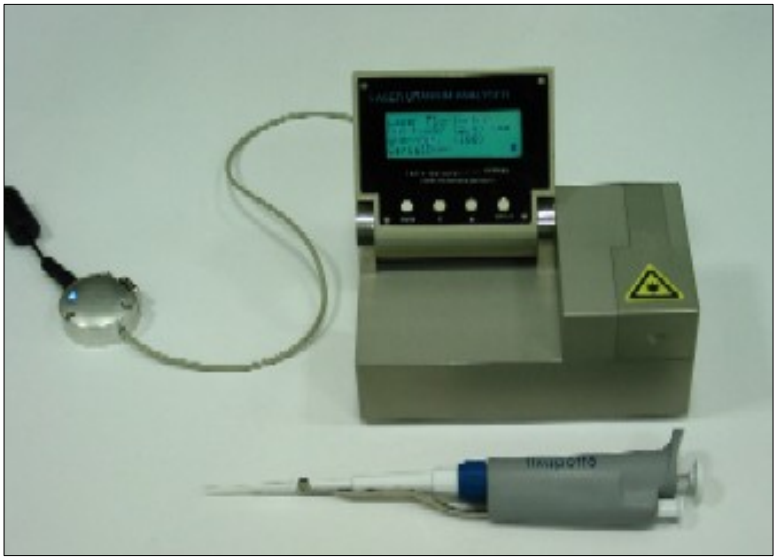
Refurbishing CIRUS Research Reactor was completed during the X Plan. This involved systematic ageing assessment of various components and systems of CIRUS reactor. The project involved long reactor shutdown involving core unloading. Various reactor systems were systematically decommissioned and thoroughly inspected. Some major components of the reactor, which had degraded due to ageing and were beyond economic repairs, were replaced / refurbished. Several safety upgrades were also carried out during the process of the refurbishment. After the successful completion of refurbishment work all the reactor systems were re-commissioned. A seawater desalination unit for demonstration of Low Temperature Vacuum Evaporation Process utilising low grade reactor waste heat, was also integrated with CIRUS. The plant is operational and producing 30 Te/day of desalinated water to meet the entire process requirements of CIRUS.

- Refurbishing of CIRUS reactor completed
- Fundamental studies in physics, chemistry, biology etc and application of laser in medical, industrial, material processing, defence etc undertaken
- A set up using Nd:YAG laser (of up to 250 W average power) developed and deployed for in-situ cutting operation of en-masse coolant channel replacement at Narora power plant
- Facility for autogenous laser welding of automobile transmission gear assemblies using indigenously developed high power CO_2 laser set up at RRCAT
- RRCAT has set up a Metal Organic Vapor Phase Epitaxy (MOVPE) facility to grow multilayer structures for developing laser diodes.

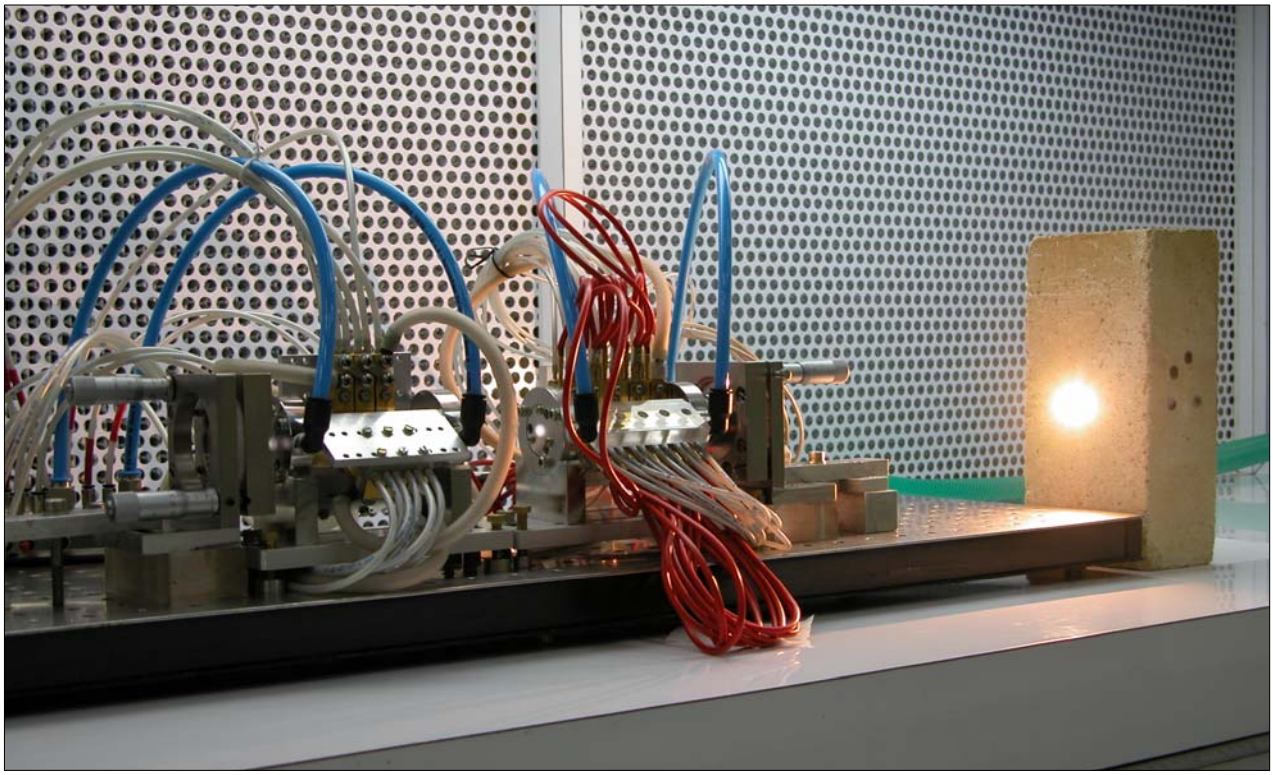


65 W intra - cavity frequency doubled green laser developed at RRCAT

Laser based Land Leveler. Technology transferred to M/s OSAW Udyog, Ambala by RRCAT

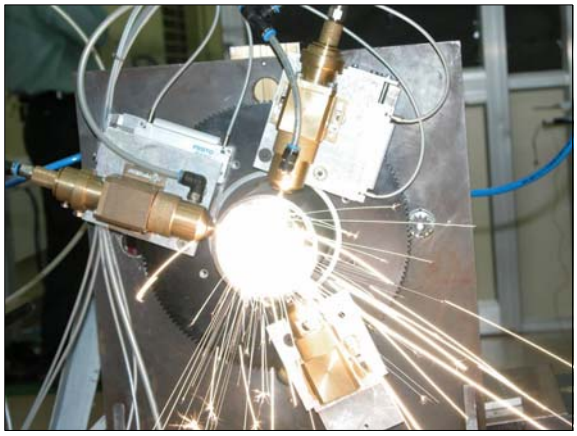


Laser Uranium Analyser. Twenty such units will be supplied to various units of DAE for uranium mining, radio chemistry, effluent monitoring and health physics applications. Two have been recently supplied to BARC, Mumbai and HWP, Talcher

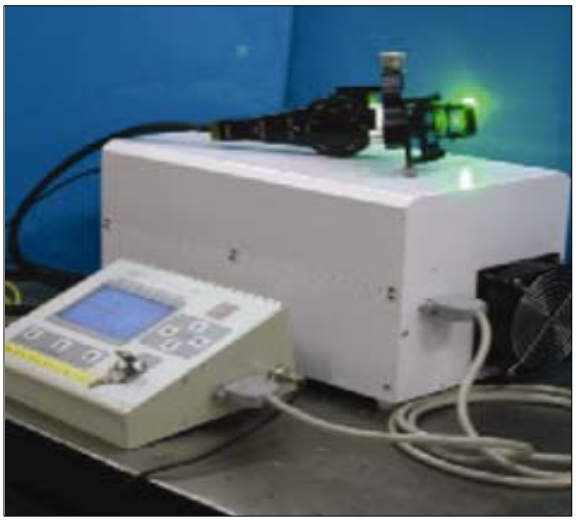


350 W diode-pumped high power CW IR laser developed at RRCAT. This laser will be used for various applications in R&D, industry and medicine.

25 Watts CuBr Laser developed at RRCAT



Laser system developed at RRCAT



India's first green laser photo-coagulator for treatment of diabetic retinopathy of the eye, developed at RRCAT

In the area of laser, their applications extend over a wide range. From fundamental studies in physics, chemistry, biology etc. to various applications covering medical, industrial, material processing, and defense etc to building extremely accurate atomic clocks for improved GPS technology to even producing nuclear transmutation with ultra powerful lasers. DAE labs have been pursuing programs in nearly all these areas. A set up which uses Nd:YAG laser (of up to 250W average power) was recently developed at RRCAT & deployed for in-situ cutting operation during the campaign for en-masse coolant channel replacement in Narora PHWR. Such a system can also help to further cut parts removed from the reactor for compact storage. A high power diode pumped Nd:YAG laser of 350 W and an intracavity frequency-doubled diode pumped green solid state laser offering 30 W in CW mode and 75 W average power in pulsed mode was built by RRCAT as an alternative to copper vapour laser for pumping dye lasers. To promote industrial use of lasers, RRCAT has recently created a facility for autogenous laser welding of automobile transmission gear assemblies using indigenously developed high power CO_2 lasers. In the area of applications of copper vapour lasers (CVL), coherent UV radiation at 255 nm, 271 nm & 289 nm have been generated and used for high-speed fabrication of fiber Bragg gratings.

RRCAT has also built laser-based systems for quality assurance of uranium oxide fuel pellets being produced by Nuclear Fuels Complex. RRCAT has also set up a Metal Organic Vapor Phase Epitaxy (MOVPE) facility to grow multilayer structures for developing laser diodes. Using GaAs/AlGaAs, InGaAs/GaAs, GaAsP/AlGaAs quantum well laser structures, the first batch of prototype diode lasers have been already developed at RRCAT in the wavelength range of 740-1000nm. The maximum peak power delivered by the prototype laser diode is 4.2 W at 810 nm in pulse mode. Packaging of such diodes and enhancing the power levels still further is being pursued. Apart from the above studies RRCAT & BARC are jointly working on ways to address some of the problems associated with thorium fuel cycle and also on some other aspects of nuclear fuels. RRCAT & IGCAR are working on laser based schemes to evaluate reactor components. For various R&D studies related to laser produced plasmas, RRCAT recently set up a 50 fs, 10 TW Ti:sapphire laser system producing a focused intensity on target ~10^{17}-10^{18} W/cm^2 range which can accelerate charged particles, create flash x-ray source & produce shock waves generating pressure up to tens of Mbars.

Indigenously developed Cryogenic (Helium) Refrigeration System at BARC

In the He Liquefier He-refrigeration and Fuel Cell Development project, several critical cryogenic components for helium liquefiers have been developed indigenously. The first two models of the high-speed turbo expander on a single shaft, cryogenic valves have been fabricated and tested. The plate and fin exchangers, the cold box, as well as the conversion of screw compressor for air to helium service will be completed. The systems will be assembled in the fifth year of the X Plan and installed for regular operation in the CFB building during the XI Plan period. Substantial progress has been made in the development of the processes for ceramic materials synthesis and thin film processes for tube geometry for the solid oxide fuel cell components.

- Several critical cryogenic components for helium liquefiers have been developed indigenously
- Substantial progress has been made in the development of the processes for ceramic materials synthesis and thin film processes for tube geometry for the solid oxide fuel cell components.
- Eight types of ASICs, such as, singleplex, CODA, MICON, BLR, etc, and eleven types of Hybrid microcircuits were developed for DAE applications
- A host of high technology detector for HR Gamma Chambers, Boron and Tritium chambers, Beam Loss Monitor, SPND and He detectors have been made
- Technologies of the intelligent gauging instruments and advanced mass spectrometer have been demonstrated

The project Electronics and Instrumentation Control Systems will complete all the objectives in design and implementation of ASICs, Advanced Servo Systems, NDE acoustic emission technology, and in the studies of super conducting motors and fault current limiters. Eight types of ASICs, such as, singleplex, CODA, MICON, BLR, etc, and eleven types of Hybrid microcircuits were developed for DAE applications. An advanced wide bands resonant AE sensor with 8 channels AEA has been developed. This will be further improved to 16-channel system. Single phase and three-phase fault current limiters have been made. RF Resonator Controllers and related instrumentation have been developed and commissioned at TIFR-LINAC and Nuclear Sciences Centre, and Australian National Universities. A host of high technology detector for HR Gamma Chambers, Boron and Tritium chambers, Beam Loss Monitor, SPND and He detectors have been made and the Fission and Boron counters for the PFBR programme will be completed in the fifth year of the X Plan. Similarly, under nuclear and medical instrumentation, many indigenous instruments have been developed and deployed in DAE. The technologies of the intelligent gauging instruments and advanced mass spectrometer have been demonstrated. These technologies will be further developed for industrial application in the XI Plan

period. Developments of Neutron Sensors, Sodium leak detectors, H_2S Sensors for reactor applications are other highlights of this project.

- Development of Beam Technologies for Nuclear and Non Nuclear Applications taken up.
- A 10 MeV RF Linac at Kharghar, Navi Mumbai has been installed and made operational at low power
- 3 MeV DC accelerator with RF oscillator to be commissioned in the 5th year of this plan

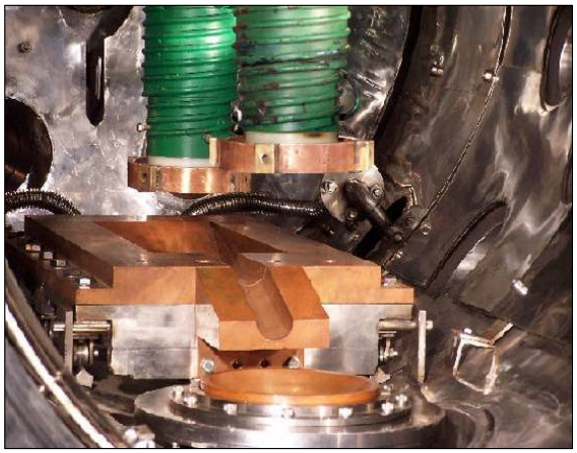
A highly sophisticated inductively coupled plasma ion source with high-brightness performance has been developed for production of nano-beams aimed at fabricating MEMS and NEMS.

Indigenously developed Radio Frequency cavity for 10 MeV RF LINAC

Development of Beam Technology for Nuclear and Non Nuclear Applications was taken up. A 10 MeV RF Linac at Kharghar, Navi Mumbai has been installed and made operational at low power. The 3 MeV DC accelerator with RF oscillator will be commissioned in the 5th year of the plan. The 20 kW plasma reactor and the 300 kW plasma melter have been installed. The electron beam evaporator, the internals and the laser system have been installed and are being tested. Significant progress has been made on the laser induced fluorescence studies on the U-Th mixtures of the process stream and in the LIF studies in the photo-ionization chamber. The objectives of this project will be completed by March 2008.

Electron Beam Centre set up by BARC at Kharghar, Navi Mumbai

KALI 5000 Accelerator System installed at BARC

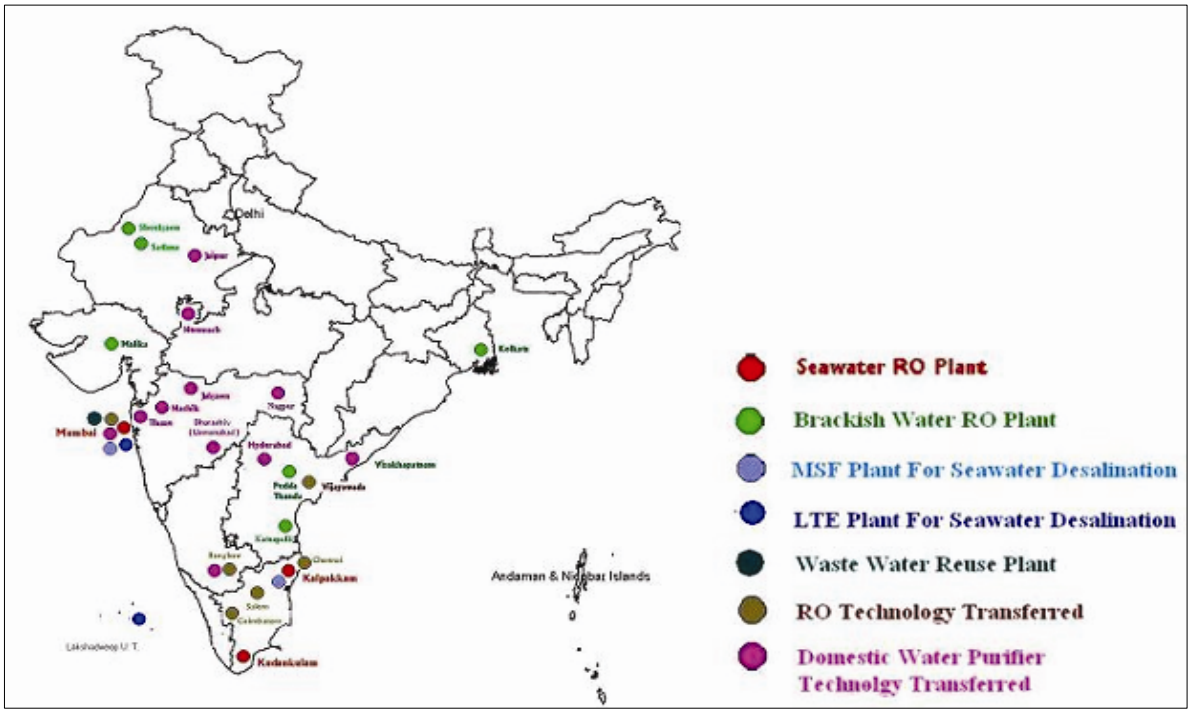


450 kW Two-Torch Plasma Melter System set up by BARC

Laser Welding of Automobile Components developed at RRCAT

B] Radiation Technologies and their Applications

As a part of the national programme to improve the quality of life in our society, Department of Atomic Energy (DAE) has been engaged in research and development (R&D) activities on desalination since last several years. Technologies developed includes sea water Reverse Osmosis (RO) plant in coastal areas, brackish water RO plant in villages for producing safe drinking water, Multistage Flash (MSF) evaporator plant for seawater desalination using low grade steam, Low Temperature Evaporation (LTE) plant using waste heat for seawater desalination, waste water recycle and reuse plants for the effluent, RO technology and domestic water purifier technology transferred to various parties in different parts of the country. DAE has put up several big and small plants in different parts of the country and is providing guidance and consultancy to several agencies in this regard. A



Map showing locations of various desalination plants set up by BARC

1800 cubic metre Reverse Osmosis based desalination plant at Kalpakkam

1800 m3/day RO based plant is under operation at Kalpakkam. Two plants have been installed in Nagapattinum district and one at Sadras, Kalpakkam in Tamil Nadu. Plants have been transferred to local authorities for operation & maintenance (O&M) and supplying drinking water to local population.

- Seawater desalination unit for demonstration of low temperature vacuum evaporation process utilizing low grade reactor waste heat integrated with CIRUS. Plant producing 30 Te/day desalinated water
- An 1800 m^3/day RO based desalination plant is under operation at Kalpakkam. Two smaller plants installed in Tamil Nadu and O&M transferred to local authorities

In the field of Nuclear Agriculture, with an active collaboration of the agricultural universities and the Indian Council of Agricultural Research, 26 elite Trombay varieties have been developed at Bhabha Atomic Research Centre (BARC). These varieties, released and gazette notified for commercial cultivation include 13 oil seed crops (10 Groundnut, 2 mustard and 1 Soybean), 11 pulse (4 Blackgram, 5 Greengram and 2 Pigeonpea) and one each of rice and jute. During the X Plan, 2 varieties of Groundnut (TPG-41 and TG-37A) have been released and notified by Ministry of Agriculture (MoA) for commercial cultivation. It has also notified one variety of soybean (TAMS-38) and one variety of greengram (TMB-37). About six varieties of oilseeds and pulses have been released by various Agriculture Universities and are awaiting notification by Ministry of Agriculture. Major achievements in biotechnology include development of somatic embryogenesis in banana cultivars, multiple shoot cultures from the medicinal plant *Ophiorrhiza*, sequencing of eight hundred cDNA clones from *Trichoderma viren*s, establishment of infrastructure for insect cell line facilities, development of protocols for obtaining multiple shoots in pineapple, transgenic expression of antimicrobrial peptide (magainin) and hepatitis B surface antigen (for edible vaccine) in banana, development of a biosorbent and demonstration its use in the removal of Co-60 from HIRUP pool water and denitrification of nuclear waste. The department has also been working on transferring technologies from laboratories to land through interaction with Indian Council for Agricultural Research (ICAR), State Agriculture Universities, Seed Corporations, Krishi Vigyan Kendras, and participation in Kissan Melas, Exhibitions, and awareness programmes. A laser-based land leveling system was built by RRCAT at the behest of Ministry of Agriculture and this technology has been transferred to M/s OSAW Udyog of Ambala Cantt for mass production of such systems.

CROP VARIETIES DEVELOPED BY BARC USING MUTATION BREEDING

	Crop	No.	Characteristics
	GROUNDNUT	10	High yielding, improved quality
	PIGEON PEA	2	High yielding, disease resistant, early maturing improved quality
	BLACK GRAM	4	High yielding, disease resistant
	MUNG BEAN	5	High yielding, disease resistant
	RICE	1	High yielding, improved quality
	MUSTARD	2	High yielding, improved quality
	JUTE	1	High yielding, fibre yielding
	SOYABEAN	1	High yielding

Soybean

A woman farmer in Sattupally village, West Godavari district of Andhra Pradesh, proudly exhibiting the harvested groundnut TG-26 from her field

Trombay varieties Released & Notified by Ministry of Agriculture, Government of India for commercial cultivation (2004-05)					
	Crop	**Year of Release**	**Maturity (M) Yield (Y) & Yield Increase (YI)**	**Released for**	**Remarks**
	Greengram TMB-37	2005	M: 63 Y: 1100 YI: 20	Eastern UP, Bihar,Jharkhand, Assam and West Bengal	Tolerant to yellow mosaic virus
	Soybean TAMS-38	2005	M: 95 Y: 2318 YI: 20	Maharashtra	Early maturing, resistant to bacterial pustule, Myrothecium leaf spot
	Groundnut TPG-41	2004	M: 120 Y: Summer 2407 YI: 26	All India	Large seed (65g 100 seeds), Fresh seed dormancy, On farm trials 4551 kg/ha, 49% increase
	Groundnut TG-37A	2004	M: 110 Y: Kharif 1993 YI: 26-38	Rainy Season Rajasthan, Punjab, Haryana, Gujarat, UP Rabi/Summer W. Bengal, Orissa, Assam/N.E.	Wider adaptability, seed dormancy

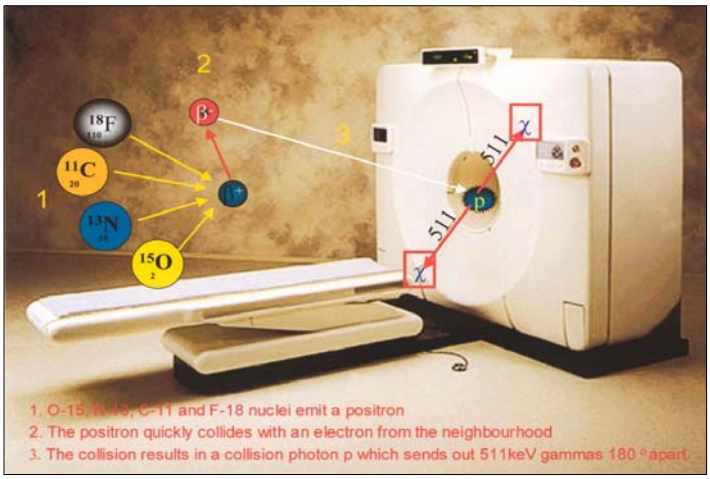
Trombay varieties Released (2006) (Awaiting Notification)				
	Crop	**Name**	**Identified by**	**Released for**
	Soybean	TAMS-98-21	PDKV, Akola	Vidarbha
	Mustard	TPM-1	MPKV, Rahuri	W. Maharashtra
	Sunflower	TAS-82	PDKV, Akola	Vidarbha
	Groundnut	TLG-45 TG-38B	MKV, Parbhani ICAR	Marathwada W. Bengal, Orissa, Assam/NE
	Greengram	TM-96-2	ANGRAU, AP	AP

- Two varieties of Groundnut and one variety each of Soybean and Mung released and notified by Min. of Agriculture. Six varieties of oilseeds and pulses released by various Agriculture Universities are awaiting notification by Min. of Agriculture. So far 26 elite Trombay varieties released and notified for commercial cultivation
- Major developments undertaken in the field of biotechnology
- Food irradiators are now in public domain. MoU signed with 14 private parties out of which 4 plants are operational and the remaining are under various stages of construction
- Laser based land leveling system built for application in agricultural fields and technology transferred to M/s Osaw Udyog of Ambala Cantt

Radiation Processing Plant for Spices at Navi Mumbai

A lot of work has been done in the field of food irradiation also. Successful running of irradiators at Navi Mumbai and Nasik has enthused many private entrepreneurs to participate in deployment of this technology all over the country. MoUs have been signed with private parties for setting up 14 commercial facilities out of which four plants are already in operation.

Installation of the first medical cyclotron and a Positron Emission Tomo-graphy (PET) facility at Radiation Medicine Centre (RMC), Mumbai for the diagnosis and treatment of several diseases including cancer, epilepsy, inflamm-atory, neurological and cardio vascular diseases was completed. On an average 8 to 10 patients are being investigated daily on the PET scanner. Cyclotron generated F-18 is used for the synthesis of F-18 fluorodeoxyglucose, a radiophramaceutical for PET imaging, which is being regularly supplied to RMC, Tata Memorial Hospital (TMH) and other nearby PET centres. A dedicated Bioimaging Unit with the country's first PET-CT machine was commissioned at the Tata Memorial Centre (TMC) in 2004. Integrating



PET Scanner at Tata Memorial Centre

the information on metabolically active cancer cells from PET with its anatomical counterpart of CT images in a single study is very useful in cancer management. To compliment the PET-CT and image tumors that do not concentrate available PET Radiopharmaceuticals, a SPECT-CT Scanner was commissioned in 2006.

Tiny rice sized radioactive seeds based on I-125 have been developed for brachytherapy applications and have been used in clinical trials for treatment of ocular cancers. Thus far 10 patients have been treated at Sankara Netralaya, Chennai, with promising results.

- First medical cyclotron in India and a Positron Emission Tomography (PET) facility installed at RMC Mumbai, for diagnosis of several diseases including cancer, epilepsy, inflammatory, neurological and cardio vascular diseases
- Tiny rice size radioactive seeds based on I-125 developed for brachytherapy applications and used in clinical trials for treatment of ocular cancers
- Medical facilities at BARC Hospital augmented
- ACTREC, the R&D centre of TMC was successfully commissioned in a new 60 acre campus in Kharghar, Navi Mumbai

Hydroxy apatite particles of 2-10 micron size were radiolabeled with Ho-166. This molecule was taken up for clinical trials and was proved to be a useful radiopharmaceutical for use in radiation synoviorthesis in knees of patients with joint disorders such as rheumatoid arthritis.

Detailed planning and infrastructure development for a 30 MeV, 500 mA proton cyclotron has been carried out at Kolkata. This cyclotron will be used for production of SPECT and PET radioisotopes for medical diagnostics applications. The SPECT isotopes are presently available in the country only through imports.

Facilities at the BARC hospital were upgraded by the acquisition of a new X-ray machine, two 2D-echo equipment for cardiology, urosurgical and urodynamics equipment an operative arthroscope and also by the replacement of obsolete equipment in radiology, cardiology and ENT departments. A voice disorder clinic has been initiated. A new hospital information management system (HIMS) is being installed under an MoU with Amrita Vishwa Vidyapeetham, Coimbatore. First phase of interconnecting all hospital units and dispensaries in Anushakthi Nagar has been completed. Medical facilities at DAE hospital in Kalpakkam have also been enhanced with the addition of a surgical ward with 15 beds and an ECG room.

During the X Plan period, the Advanced Centre for Treatment Research and Education in Cancer (ACTREC), the R&D centre of TMC was successfully commissioned in a new 60 acre campus in Kharghar, Navi Mumbai. This started with the relocation of the Cancer Reseach Institute, conducting basic research from Mumbai campus, to this new Kharghar campus in 2002 and commissioning of the Clinical Research Centre in 2005. Along with sophisticated equipment and infrastructure for basic cancer research, a state-of-the-art 50 bedded clinical research centre has also been set up. A Radiotherapy Facility with Linear Accelerator, Indigenous Telecobalt (Bhabhatron), Simulator, TPS, networking, brachytherapy unit, Dosimetry Labs etc. is commissioned and is being used exclusively for cancer patients in clinical trials. Bhabhatron, the indigenous telecobalt machine developed at BARC was successfully commissioned at ACTREC where it has undergone rigorous dosimetric and clinical evaluation and further technical improvements have been made to make it comparable in performance to the more expensive imported machines. All the diagnostic and therapeutic facilities at ACTREC which includes wards, day care, ICU, operation theatres, transfusion medicine, radiology, molecular pathology are now fully functional and being used exclusively for patients participating in clinical trials.

- Bhabhatron, the indigenous telecobalt machine developed at BARC successfully commissioned at ACTREC. Technology transferred to a private entrepreneur
- Construction of a new eleven storied Tata Clinic with state-of-the-art radiotherapy and other therapeutic facilities started
- At TMH, facilities for film-less operations, including the necessary infrastructure for the capture, archival and distribution of radiological images, have been established
- A telemedicine network connecting all the Regional Cancer Centres with TMC has been commissioned. So far 19 cancer hospitals including seven in the North East and two from abroad have been connected with Tata Memorial Hospital

Advanced Centre for Treatment, Research and Education in Cancer (ACTREC)

Tata Memorial Centre Rural Outreach Programme (TMCROP) in action

Bhabhatron, a Cobalt-60 Teletherapy Machine, developed at BARC. The machine has been commissioned at the Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), Navi Mumbai. Right : A patient undergoing teletherapy with Bhabhatron machine

Medical Instruments developed at BARC

Anu Photo Rheograph

The tiny ^{137}Cs Brachytherapy seed used in treatment of cancers of uterus/cervix

SpO2 Monitor

NIBP Monitor

Gamma camera used in testing the novel radiopharmaceuticals by imaging animals

At the TMH, a new eleven storied Tata Clinic is being constructed with state-of-the-art radiotherapy and other therapeutic facilities. This would not only improve patient care but also enhance capabilities for pursuing medical research and human resource development in oncology. At TMH, facilities for film-less operations, including the necessary infrastructure for the capture, archival and distribution of radiological images, have been established. A tele-medicine and computerization facility has been commissioned for standardization and uniformity in the delivery of cancer care across various cancer centres in the country, better and quicker access to quality cancer care for patients in remote under-served areas and for the updating of cancer care physicians and coordination of cancer research programmes. Development of a first of its kind Bone Marrow Donor Registry of potential voluntary marrow donors in the country to facilitate searches for matched donors has been started. As a part of a comprehensive programme for prevention and early detection of cancer, a rural population based cancer registry is being established at Dervan, Chiplun, Maharashtra. Surveys, screening, diagnosing and treatment of oral, breast and cervical cancers in the rural districts of Ratnagiri and Sindhudurg of Maharashtra are being conducted in collaboration with Walawalkar Hospital.

In IGCAR, the feasibility study on application of thermal imaging for detecting early breast cancers has been initiated. Results obtained from a preliminary clinical study showed good correlation of thermography with the established imaging modalities such as mammography, ultrasonogram and fine needle aspiration cytology.

- In IGCAR, the feasibility study on application of thermal imaging for detecting early breast cancers has been initiated. Early results are promising. Clinical trials are underway
- India's first green laser photo-coagulator for treatment of diabetic retinopathy of the eye, developed and delivered to M/s Aurolab for clinical trials
- Extensive studies on the use of laser induced fluorescence technique for cancer diagnosis carried out

RRCAT also developed India's first green laser photo-coagulator for treatment of diabetic retinopathy (DR) and delivered the first prototype unit in September 2005 to M/s Aurolab (an adjunct of Aravind Eye Hospital, Madurai) for clinical trials. The autofluorescence spectroscopic diagnosis system developed at RRCAT was used for in-situ detection of the cancer of oral cavity at Government Cancer Hospital, Indore. This study showed the diagnostic efficacy (sensitivity and specificity of > 90 % towards cancer) of this cost effective technique. New optical approaches were

developed for (a) depth resolved measurements on tissue fluorescence, (b) for measurement of glucose in tissue and (c) for size and hemoglobin concentration of red blood cells.

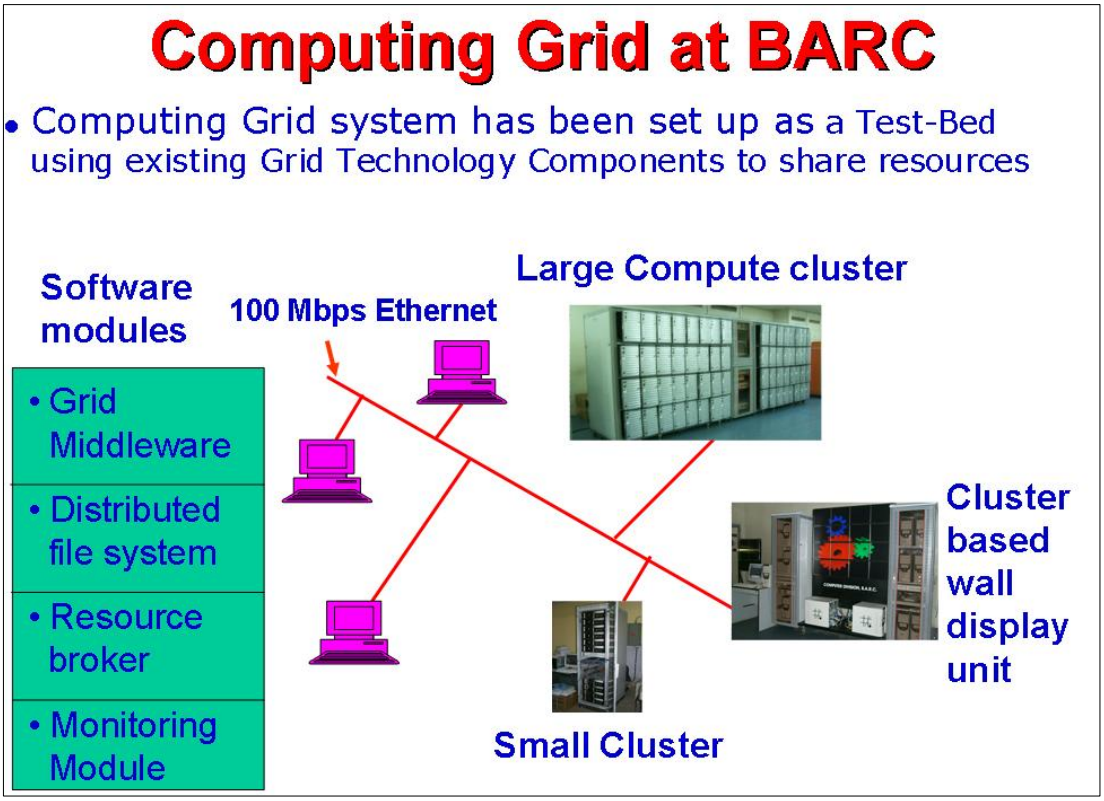
3.1.5 Major Programme 5: Basic Research

Honorable Prime Minister of India, Dr. Manmohan Singh, inaugurated a new Supercomputing facility at BARC on 15th November, 2005. ANUPAM-AMEYA parallel processing system is the largest configuration in the country. Development, testing, fine tuning and commissioning of 512 node Xeon based Anupam-Ameya super computer gave a speed of 1.7 teraflop for High Performance Linpack benchmark. The system is being used for in-house applications and has given tremendous boost to development of high end scientific and engineering applications in BARC. Scalable graphics system with 20M Pixels resolution has been fabricated and tested. A High Performance Computing (HPC) facility including the Cray XD1 with 10 chassis each comprising of 12 AMD Optern 2.2 GHz processors totaling 96 such processors was set up at SINP.

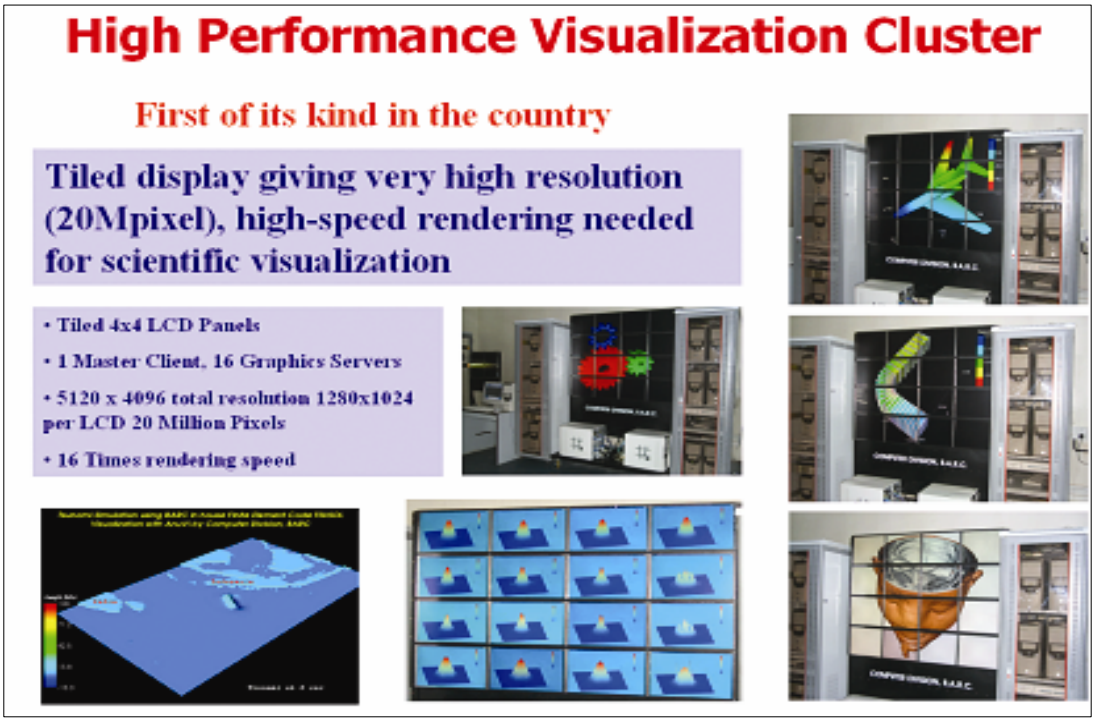
External View of New Super Computing Facility

BARC's supercomputing facility : Tera Flop Class 512 Node Anupam-Ameya Supercomputer

- Development, testing, fine tuning and commissioning of 512 node Xeon based Anupam-Ameya super computer has been completed giving a speed of 1.7 teraflop.
- High Performing Computing facility including the Cray XD1 set up at SINP



Computing Grid at BARC



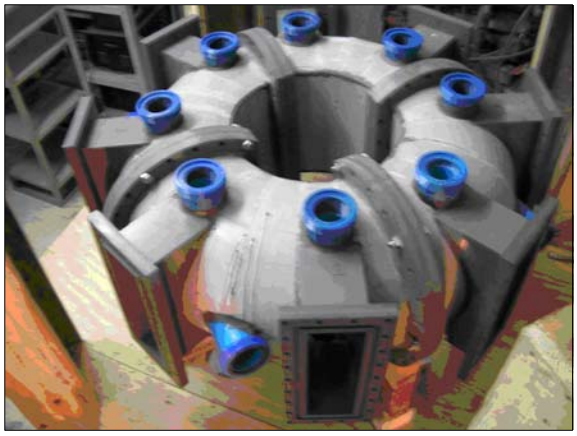
High Performance Visualization Cluster at Trombay

A National facility for High Field NMR studies with 500, 600 and 800 Mhz spectrometers has been commissioned and is utilized by several institutions in the country. Research at the Facility has continued to remain at the cutting edge with many original contributions coming from various researchers across the country. The Facility has continued to provide an excellent link between industrial R & D and academic research.

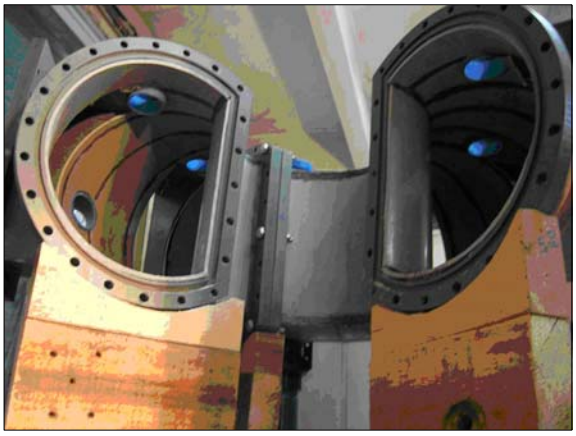
Feasibility study on setting up of the India-based Neutrino Observatory (INO), a large multi kiloton magnetized iron detector with RPC's as the detector elements was taken up during the X Plan. R&D on detectors (glass RPC) has been carried out, the site has been chosen in the Nilgiris in Tamil Nadu, and simulation packages are being set up.

- A National facility for High Field NMR studies with 500, 600 and 800 Mhz spectrometers has been commissioned and is being utilized by several institutions in the country
- The Indian National Gamma Array (INGA) was successfully set up and utilized by scientific community from BARC, TIFR, SINP, VECC and IUAC and universities
- GMRT has achieved significant international success
  Indian Lattice Gauge Theory Initiative was undertaken at TIFR, VECC, SINP, IMSc, HRI and IOP has made good progress

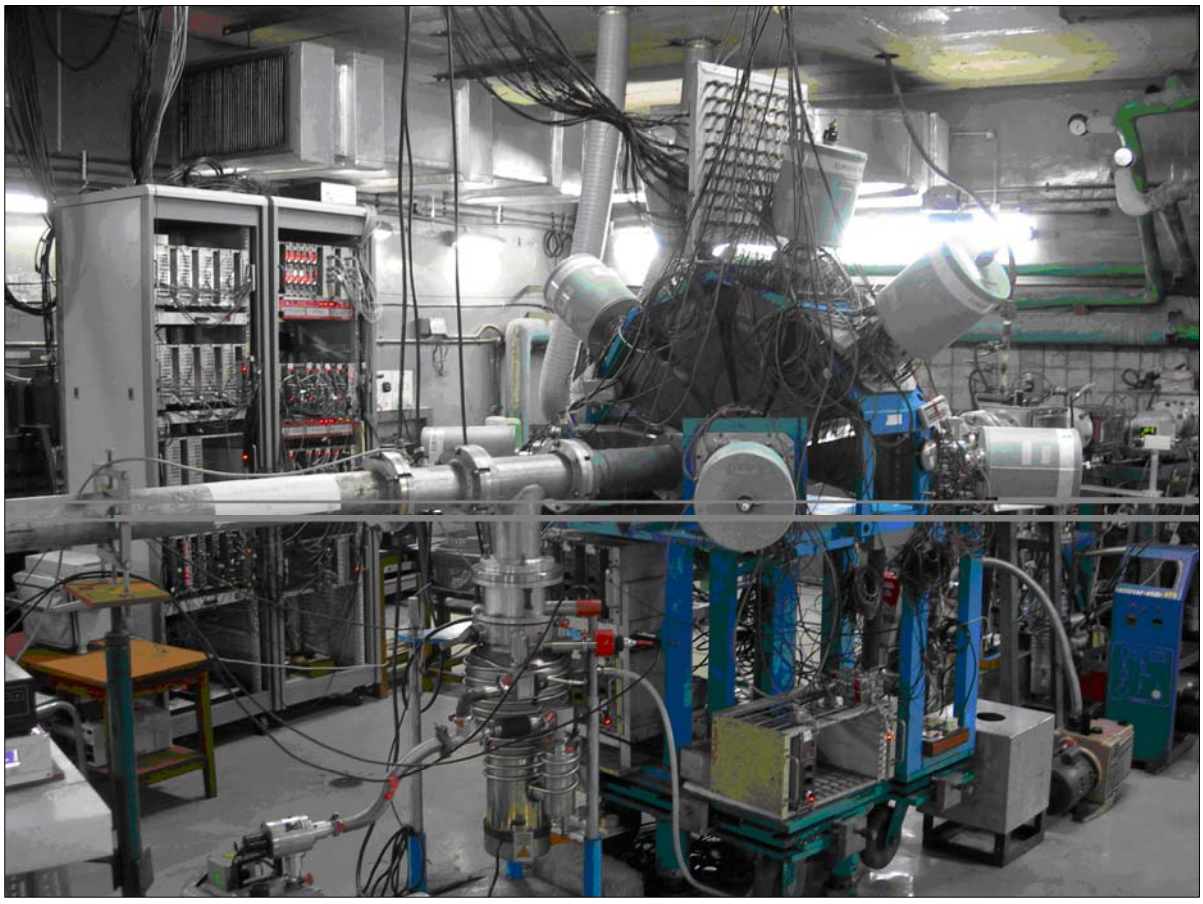
In the field of Nuclear Physics, The Indian National Gamma Array (INGA) was successfully set up and utilized by the community of scientists from BARC, TIFR, SINP, VECC and IUAC and universities. Detailed spectroscopic studies, band structure lifetime measurements, high spin states, shape evolution of nuclei and other studies were carried out. During the X Plan the main emphasis has been on the design and development of large detector arrays for gamma rays, neutrons and charged particles to be used for nuclear structure and reaction studies using low and medium energy heavy ion beams. Work related to this has been in progress with some projects completed and others under completion in the DAE institutions (BARC, TIFR, SINP, and VECC).



The constructed model of the Saha Institute Stellartor (SISA) model



Linear magnetized plasma device developed at SINP



Indian National Gamma Array (INGA) at VECC, Kolkata. This array has been planned by the nuclear physics community of the country

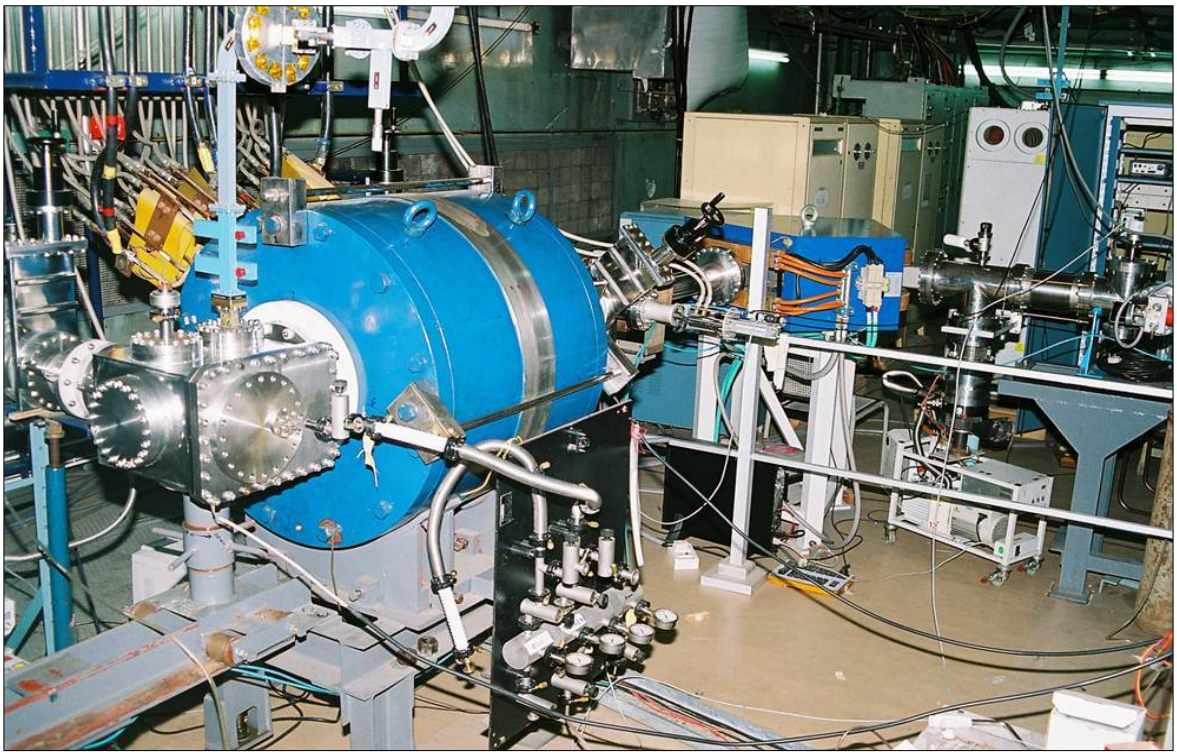
In the field of Astrophysics, currently ongoing programs are GRAPES (TIFR) at Ooty and MACE, which will consist of a Cherenkov array at the Himalayan Gamma Ray Observatory (HiGRO of BARC-TIFR-IIA) near Hanle. The main objectives of these programs are the determination of the source of high energy cosmic ray particles, their composition, their acceleration and propagation

mechanisms – top down / bottom up –and search for dark matter (Standard Model and beyond the Standard Model). GRAPES has been running for many years.

Of the three payloads for Astrosat mission of ISRO two are being piloted by teams from TIFR. Picture shows the soft X-ray telescope mirror assembly for the X-ray payload.

In the field of Astronomy, GMRT has achieved significant international success. TIFR has participated in the ASTROSAT project. Indian Lattice Gauge Theory Initiative was taken up in the X Plan at TIFR, VECC, SINP, IMSc, HRI and IOP. Good progress has been made in this project, in particular at TIFR using a CRAY supercomputer for solving problems in quark gluon plasma physics. This work has achieved international recognition and is referred to by the experimentalists to plan their future experiments. For the XI plan an enhancement of the number crunching power is proposed and considering their excellent track record, it would seem most worthwhile. The prototypes of the LAXPC and the X ray mirror for the ASTROSAT project have been developed. Two of the 7 telescopes of HAGAR experiment were installed at Hanle. Extensive tests were conducted on these telescopes. The design, drawing and manufacturing process have been completed for the remaining 5 telescopes by IIA, Bangalore, our collaborator.

Superconducting Cyclotron at VECC

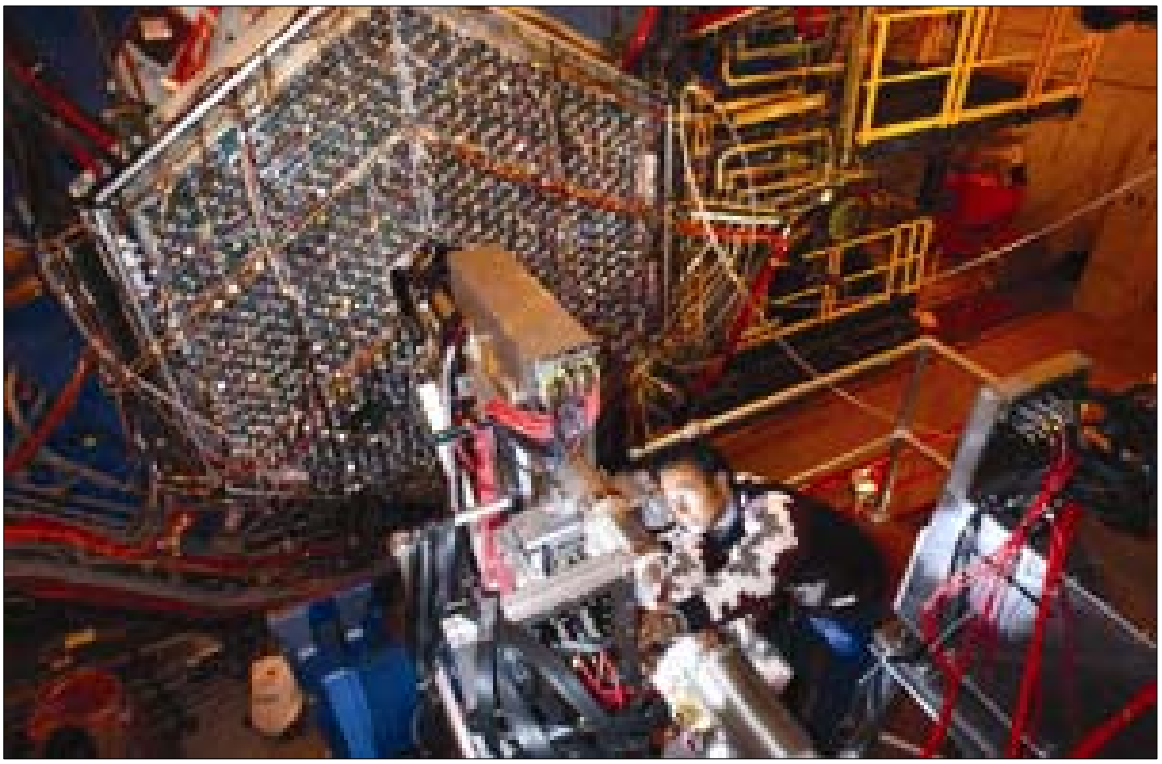


Radioactive Ion Beam Facility at VECC

In the IX & X Plans DAE labs have set up facilities like Superconducting Cyclotron at VECC, Kolkata, Synchrotron Radiation Source Indus-2 at RRCAT, Indore, Superconducting linac booster (as a joint BARC-TIFR effort) and several smaller accelerators for a variety of applications. For the superconducting cyclotron all major systems were completed and superconducting magnet, weighing about 100 tones and being single largest component of the machine, was commissioned and operated satisfactorily for over one year for test purposes. Assembly of complete cyclotron will be completed during X Plan and commissioning will be done soon thereafter. The superconducting cyclotron will be the largest nuclear physics facility of the country.

- Superconducting Cyclotron set up at VECC, Kolkata. Largest superconducting magnet has been built in the country for this Superconducting cyclotron
- Synchrotron Radiation Source Indus-2 set up at RRCAT, Indore. First synchrotron light out of Indus-2 was recorded on December 2, 2005 and the facility was dedicated to the Nation by Prime Minister on December 17, 2005.
- Superconducting Linac booster (joint BARC-TIFR effort) and several small accelerators for a variety of applications set up
- Notable progress made in low energy, ISOL-based Radioactive Ion Beam facility at VECC
- Contributed high quality components for the world's biggest particle accelerator, Large Hadron Collider
- Delivered Photon Multiplicity Detector for Relativistic Heavy Ion Collider at Brookhaven National Laboratory
- First beam line in the new beam hall of FOTIA has been installed and commissioned

In addition, notable progress has been made in the low energy, ISOL-based Radioactive Ion Beam (RIB) facility utilizing VEC as the primary beam source being set up at VECC and in laser based strategic programs at BARC and RRCAT. AT RIB commissioning of sophisticated low beta RFQ accelerator and online ECR source has been the major achievement of this project. All systems of RIB employ complex accelerator physics and technology. Besides these domestic programs, DAE's international involvement, like contributing high quality components for the world's biggest particle accelerator, the Large Hadron Collider (LHC) ahead of schedule, building detectors around LHC, and delivering photon multiplicity detector (PMD) for the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory have won high praise. All these required hundreds of man-years & large multi-disciplinary teams. In addition, DAE labs have taken up new major accelerator programs, which include High Intensity Proton Accelerator (HIPA), and novel accelerator technologies program started by CERN, which indicate that we can optimistically take up larger R&D activities in the areas of Accelerators & Lasers in the coming future.



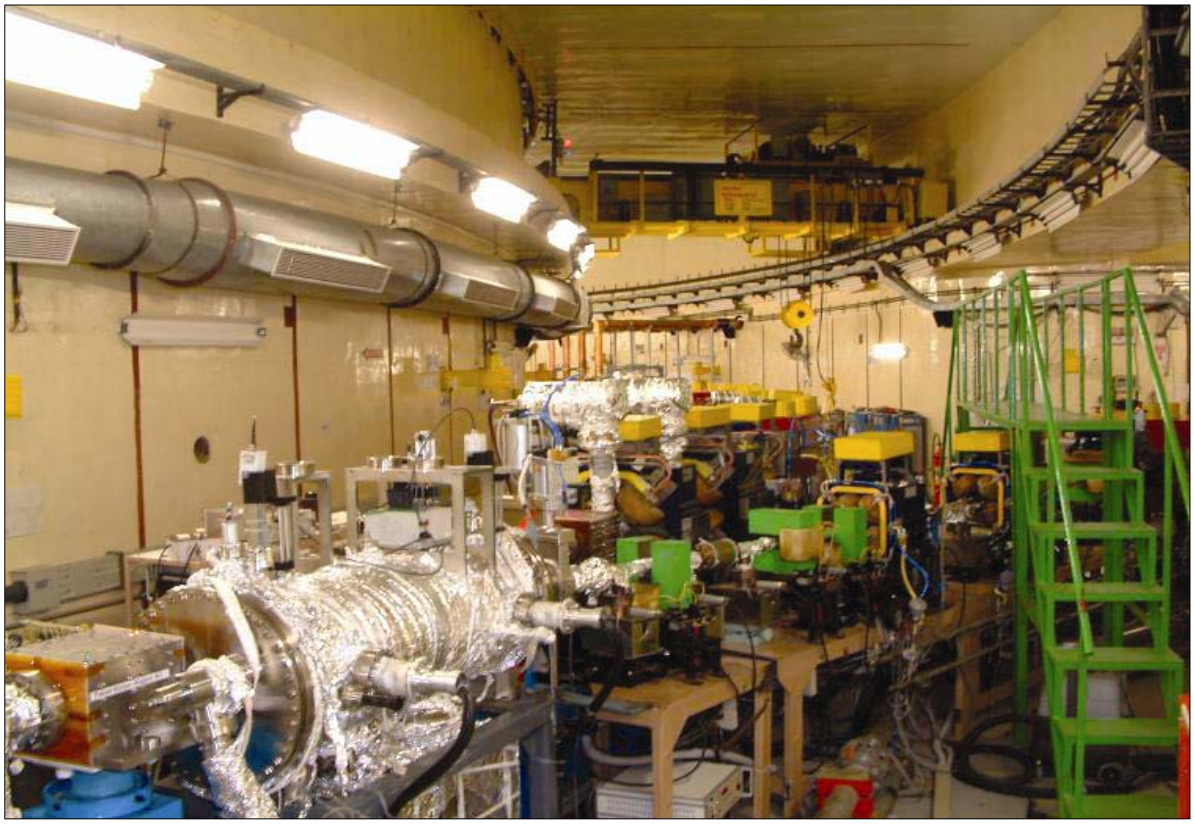
STAR Photo Multiplicity Detector developed by VECC and setup at Brooke-Haven National Laboratory, USA

International CMS Collaboration Programme - TIFR.
HO module installed at CERN

CERN Jacks provided by Raja Ramanna Centre for Advanced Technology

One of the 616 superconducting MCDO magnets supplied to CERN by RRCAT

Indus-2, the 2.5 GeV Synchrotron Radiation Source (SRS) is now going through final commissioning phase, and would be ready for exploitation in the coming months. First synchrotron light out of Indus-2 was recorded on December 2, 2005 and the facility was dedicated to the Nation by Prime Minister on December 17, 2005. The Superconducting linac booster in Mumbai has already delivered beams for experiments. The largest superconducting magnet which has been built in the country, for the Superconducting cyclotron at Kolkata was a major achievement of VECC in 2005. As for DAE's contributions to LHC, these have been greatly valued by the CERN and India was accorded the status of an "Observer State", which has been extended to only a few other countries, such as, USA, Japan, Russian Federation etc. The success of Indian participation in LHC has also led to international community inviting India to join other mega facilities, such as, ILC (International Linear Collider), X-FEL (X-ray Free Electron Laser) taken up by DESY, Hamburg and FAIR (Facility for Antiproton & Ion Research) taken up by GSI, Darmstadt in Germany. Equipments and components about 7080 Nos. of Precision Magnet Positioning System jacks, 5500 Nos. of Quench Heater Power Supplies (QHPS) and 1435 Nos. of Local Protection unit (LPU) have been supplied by DAE and have been accepted at CERN. DAE teams have completed the integration of the QHPS and LPUs in the racks at CERN.



Indus-2 Synchrotron Radiation Source

Indus-2 High Resolution X-ray diffraction beamline

In the last decade or so, world over big particle accelerators have been initiated for various applications that range from nuclear waste transmutation to heavy ion therapy for cancer treatment. In India DAE has initiated efforts, at BARC, RRCAT and VECC which are aimed at developing segments of high intensity proton accelerator. Eventually our target is to build spallation neutron sources besides an Advanced RIB facility at VECC. All these activities will be pursued vigorously in the XI Plan. The first beam line in the new beam hall of FOTIA has been installed and commissioned. All construction activities in the new LINAC beam hall at TIFR have been completed. The particle beams from the superconducting LINAC will be available for experiments at this beam hall in a few months.

- SST-1 fabricated and assembled. Commissioning test under progress
- Components of Neutron Beam Injector System fabricated. Assembly on test stand and commissioning to be completed in the X Plan
- Advanced New Systems for SST-1 Auxilliary Heating has progressed well
- A number of advanced diagnostics have been developed
- ADITYA diagnostics have been upgraded and RF system installed

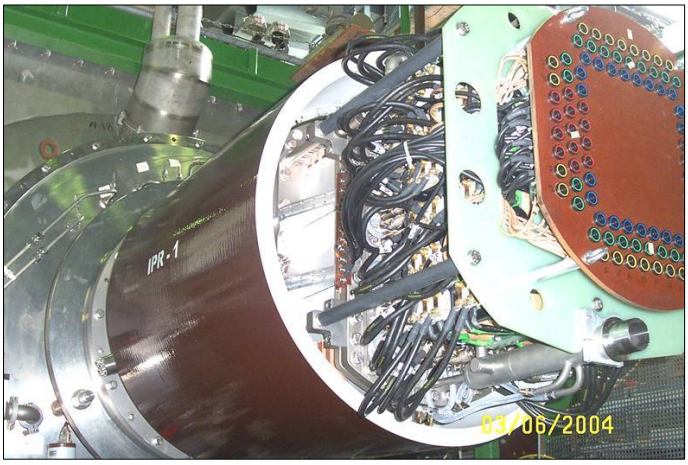
In the field of Fusion and Plasma Science, one of the major achievements is the recognition of India's capabilities in fusion science and its acceptance to join as full partner in the international ITER project.

At IPR, Gandhinagar, Steady State Tokamak-1 (SST-1) project, which was continued from IX Plan, was completed in 3rd year of X Plan. The deliverables have been completed and the machine is undergoing commissioning tests at present. Projects on Studies of high density plasmas produced by lasers and Advanced New Systems for SST-1 Auxilliary Heating Systems have progressed well. Neutron Beam

Injector system assembly on test stand is in progress and tests is scheduled to start by end of year 2006. 200 kW 91.2 MHz RF source has been assembled and tested. 3.7 GHz klystrons are under procurement.

Steady State Tokamak (SST-1) at IPR Ahmedabad

Progress of Advanced New Systems for SST-1 Modern Diagnostics and FW Systems has been satisfactory. A number of advanced diagnostics have been developed. The fabrication of FW components has been completed. Data Acquisition modules have been developed and installed. All the deliverables will be completed by end of 5th year of X Plan. Project on Fundamental Plasma Science has progressed well. A number of interesting experiments have been carried out. Plasma turbulence studies have been carried out numerically and large vector supercomputing facility has been established. ADITYA diagnostics have been upgraded and RF system installed. PECVD and PSII techniques for material processing have been developed. All the deliverables will be completed during the X Plan period.



Advanced New System for SST-1 Auxiliary Heating System

In the field of Material Science, project on development of Nanomaterials and Nanotechnology was taken up. Gas sensor for measuring ppm levels of hydrogen and MEMS based silicon ultrasonic transducer for inspection of FBR components were developed. Monolithic and multilayer coatings of oxides and nitrides were produced and evaluated for mechanical and wear properties. Basic research in material science was carried out using 1.7 MV Tandetron accelerator which was commissioned in 2002. This facility has been used extensively to obtain information on void swelling behavior of Alloy D9 used for clad tubes and wrappers in PFBR core. SQUID (Superconducting Quantum Interference Device) based sensors were developed. Research programme on computational materials science started using

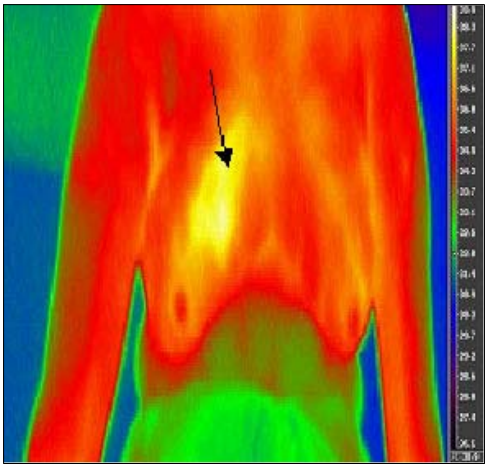
64 node parallel computer. At TIFR work has been carried out on semiconductor nano-composites, nano-crystalline superconductors, laser-solid interactions in nanomaterials and stability of carbon clusters.

- Development of nanomaterials and nanotechnology have been taken up
- Gas sensors for measuring ppm levels of hydrogen developed
- MEMS based silicon ultrasonic transducer for inspection of FBR components developed
- Basic research in material science carried out using 1.7 MV Tandetron accelerator commissioned during this plan
- SQUID based sensors developed
- Facility for growth of device quality single crystals established and crystals developed
- At IOP, several nanostructure semiconductors were synthesized
- Work on bio-molecule capping of nanostructures and activities on nanobiointerface initiated

While developing laser materials, facilities for growth of device-quality single crystals were established. New seed isolation technique developed. Growth of single crystals, ceramics, basic research and development of fusion targets achieved. PZT, BST, relaxor ferroelectric, transparent PLZT, carbon foam monoliths synthesized. Ferroelectric ceramics were used for displacement transducer.

At IOP for their Cluster activity project, several nanostructure semiconductors were synthesized by electro-deposition process. Fabrication of HgTe-DNA and CdSe-DNA systems were carried out. Work on bio-molecule capping of nanostructures and activities on nano-biointerface was initiated. Ion beam modified surfaces, nanostructures on Si and InP are investigated using SPM. Valence band electronic structures of clusters assembled thin films by ARUPS facility was also investigated.

TIFR has done some excellent work on Epitaxial Growth, semiconductor materials, Quantum wells and Quantum wires. A number of publications have resulted. A new (Metal-Organic Vapour Phase Epitaxy) MOVPE system for GaN based materials is established. This is very timely since Nitrides offer a lot of potential for devices. At BARC, high purity Antimony was prepared by vacuum distillation



Thermography for Medical Applications

and zone refining of commercial grade metal and a methodology to prepare 7 mm dia. antimony rods of desired density and uniform thickness was developed. A convenient method for preparation and purification Trimethyl gallium (Me_3Ga) free from hydrocarbon and alkoxide impurities has also been developed. Trimethyl gallium is widely used as precursor in MOVPE for depositing gallium based semiconductors like GaAs, GaN etc.

- New MOVPE system for GaN based material established at TIFR
- High purity antimony prepared and methodology to prepare 7mm dia rods of desired density and uniform thickness developed at BARC
- SQUID magnetometer with 10-7 emu sensitivity commissioned using the indigenously developed SQUID sensor.

Basic studies in materials science at IGCAR have resulted in many significant results such as superconducting properties in carbon doped MgB2, enhanced photoluminescence from Ag nanoclusters embedded in silver-exchanged glass substrate, atomic force measurement studies on conductivity landscape in highly oriented pyrolytic graphite, studies on the origin of negative thermal expansion in Zr-tungstate, studies on phonon modes in colloidal crystals investigated by dynamic light scattering and computer simulations, positron beam studies on defects at interfaces, and studies on material behavior at high pressures and temperatures. These results have been publishes in high impact journals and have got good citations indices.

With the development of polyacrylamide hydrogels with bisacrylamide cross-linking by photopolymerization and covalently bonding the cation selective crown ether to the hydrogel, it has become possible to extract specific ion like Sr from a solution of Sr salt and nitric acid. Incorporating an acrylic acid grafted polystyrene particle self assembled into a bcc structure as motif into hydrogels, an intelligent optical diffraction method device to measure minute changes in the gel volume has been established. This could find applications in radioactive leaching, and part of this development has been patented. Development of SQUID system for non-destructive evaluation and its application for the studies on weldment samples subjected to fatigue cycling. Another notable achievement has been the commissioning of a SQUID magnetometer with 10-7 emu sensitivity using the indigenously developed SQUID sensor.

The multifaceted basic biological research programme of DAE has made significant contributions in radiation, stress and cancer biology along with related

fields such as cell cycle regulation, signaling pathways, apoptosis, DNA repair, mutagenesis, immune function, development and differentiation as demonstrated by important publications. Leads emerging from the fundamental biological research programme are also being pursued within different DAE research laboratories in a more focused disease specific approach to understand their biological underpinnings or to develop potential diagnostic and therapeutic strategies for important human diseases such as cancer, malaria, HIV and some challenging genetic, neurological or mental diseases. These studies were undertaken using modern methods of molecular biology including global expression profiling, relevant animal models, structural biology, bio-informatics etc.

- High throughput technologies are being established at different DAE institutes for basic biological research
- Assessment of genetic and health effects of continuous high level natural radiation in Kerala continues. No deleterious affects have been noticed thus far
- DNA based analysis has been carried out on more than 250 families and health audit survey has been completed in 25000 houses in the Monazite belt of Kerala
- Drug-resistant mutants of HIV-1 protease enzyme have been produced in large quantities at BARC for crystallization trials

High throughput (HTP) technologies are being established at different DAE institutes during the X Plan for basic biological research. Using these HTP approaches, a beginning was made at BARC by undertaking proteomic studies to understand the mechanism of high radioresistance in the bacterium *Deinococcus radiodurans*. Possibility of transferring the potential of this organism to other organisms has opened the vistas for constructing genetically engineered organisms for bioremediation. Research on intriguing phenomena such as bystander effects, genomic instability, adaptive response and clastogenic factors induced by radiation have been undertaken and the contribution of reactive oxygen species in radiation-induced damage has been demonstrated in several animal and bacterial model systems. Search for a suitable radioprotector for human use continues. Several plant based compounds have been screened.

Considerable insight has been obtained on the effects of low-dose radiation in immune system. Screening of more than 100,000 new born has been achieved midway through the X Plan for assessment of genetic effects of continuous high level natural radiation in Kerala. No deleterious affects have been noticed thus far. DNA based analysis has been carried out on more than 250 families and health audit

survey has been completed in 25000 houses in the Monazite belt of Kerala. Effects of high LET radiation proton beam on DNA damage have been assessed in mouse lymphocytes. Electroporation technique in combination with radiation was evaluated to increase the efficacy of cell killing in malignant cells. Indigenous development of a DNA microarrayer was completed.

Drug-resistant mutants of HIV-1 protease enzyme have been produced in large quantities at BARC for crystallization trials. Crystals have been grown of substrate complexes with HIV-1 protease. At SINP the project on physico-chemical basis of biological function was taken up with an objective to understand how the laws of interaction of the physical and chemical world give rise to such diverse and yet specific functional behaviour of biological systems. The systems studied include aromatic dyes and organic/inorganic quenchers in solution, enzymes and drug-DNA complexes, radiosensitizers and their biological targets, etc. Crystal structures of medically important enzymes and inhibitor proteins have been determined. Several proteins involved in leukemia, thalassemia and Huntington's disease have been cloned and their structures and interactions with other proteins investigated. Immune escape in haemotopoetic malignancies was studied with MHC enhanciosome New laboratory space of 5000 sq feet has been created and large number of instruments have been purchased and commissioned.

In the basic cancer research wing at ACTREC, commissioned in 2002, necessary infrastructure and equipment for basic research in cancer including Genomics, Proteomics, Cancer Genetics, Gene Therapy, Pharmacogenomics and Pharmakokinetics has been established. Data analysis from the proteomic and genomic studies is being supported by relevant bioinformatics through online access to worldwide protein and genome sequence data-bases, hardware and software for acquisition and analysis of the information. A state-of-the-art animal house has been established with different strains of mice, rats, Nude and Scid mice required for basic cancer research and the drug discovery and development program is fully functional.

- Several proteins involved in leukemia, thalassemia and Huntington's disease have been cloned and their structures and interactions with other proteins investigated at SINP
- An optical imaging facility has been established with a laser scanning confocal microscope and two epifluorescence microscopes at TIFR
- At TIFR investigations were undertaken in a variety of areas and interesting results obtained in respect of cellular signaling, development of nervous system, motor-cargo interaction and proteins of malarial parasite

At the Division of Biological Sciences, TIFR (Mumbai) investigations were undertaken in a variety of areas involving diverse biological issues, such as cellular signaling dynamics, neuronal synaptic changes, patterning/development of nervous systems in Drosophila and vertebrate models, biology of immune protections against malaria parasite, as well as mechanistic analyses of genome dynamics/repairs at molecular, cellular and whole organism levels and new insights were unveiled resulting in several high impact publications. An optical imaging facility has been established with a laser scanning confocal microscope and two epifluorescence microscopes. A TEM facility is likely to be established soon. Molecular analyses showed that a non-glycolytic function of P. *falciparum* enolase confers partial protection against malaria when selective inactivation of parasite enolase was achieved. A cDNA expression library of the human malarial parasite *Plasmodium falciparum* identified several expression clones, antibodies against which are present only in the malaria immune persons and not in malaria patients. One of these proteins, a ribosomal phosphoprotein, P0, present on the surface of the parasites was shown to play an important novel role during the parasite invasion of the red blood cells. Antibodies raised specifically against this P0 protein could protect mice against challenge with lethal murine malarial parasite. In the area of genome repairs/dynamics, insights were gained about specificity of mismatch recognition, followed by transduction of this information to the downstream events involving strand specific nicking. In homologous recombination human Rad52 was shown to facilitate three-stranded pairing that is subsequently exchanged by the action of hRad51 protein. Chromosomal break repair proteins (Translin/Trax) in human were found to be functionally very distinct from those of Drosophila. *Chlamydomonas reinhardtii*, a unicellular green plant was developed as a model system to study the connectivity between cell-signalling and genome repair.

At NCBS, TIFR, Bangalore, methods have been developed for detecting structural similarity of distantly related proteins, which will prove very useful in the light of the vast quantities of sequence information becoming available now that whole genomes are being sequenced rapidly. Mechanism by which a particular class of chaperone proteins helps the adoption of specific three-dimensional structure by other proteins synthesised in the cell has been elucidated. Pathway of cell death in plants and animals share critical mitochondrial components was demonstrated. Role of signaling proteins in human cancer progression was identified. Likewise the mechanism by which ROS and NO regulate T cells in immune memory and the physico-chemical mechanisms for building lipid-based membrane complexes for endocytosis were explored.

- At NCBS, TIFR, Bangalore, methods have been developed for detecting structural similarity of distantly related proteins
- That the pathways of cell death in plants and animals share critical mitochondrial components was demonstrated
- Mechanism of stress induced changes in neuronal architecture and behavior deciphered
- Optical coherence tomography (OCT) set up developed and used for various experiments

The understanding of how sense organs connect during development, in a functional manner, to the brain has greatly increased. Mechanism of stress induced changes in neuronal architecture and behavior was deciphered. New methods to quantitate olfactory responses in Drosophila larvae were established. New programs were initiated on human embryonic stem cells and on deciphering axonal transport.

At the Department of Chemical Sciences and the National Facility for High Field NMR at TIFR, solution structure, dynamics, folding, misfolding and their relationships to protein function and disease have been investigated on a number of systems, which include, HIV-1 protease, Small Ubiquitin Modifier (SUMO), Domains of dynamin, calcium binding proteins, cytochrome p450, dynein light chain protein, and malarial parasite protein P2.

Optical coherence tomography (OCT) set up was developed and used for imaging of animal eyes and non-invasive monitoring of chemical carcinogen induced morphological alterations in hamster cheek pouch with axial resolution of ~ 10 μm and lateral resolution of ~ 17 μm. Photo sensitizers based on chlorophyll-a derivatives were synthesized in house, characterized in detail, and used for photodynamic treatment of chemically induced tumor of oral cavity in hamsters. Photodynamic inactivation of an antibiotic resistant strain of *Pseudomonas aeruginosa* by the use of endogenously synthesized porphyrins was achieved. New laser micromanipulation techniques were developed and two patents were filed for the same. This set up has been used for several studies which include the first demonstration of three-dimensional orientation of intracellular objects, guidance of neuronal growth cones with asymmetric transverse gradient force laser tweezers, laser assisted injection of genetic material or drugs in cells, and malaria diagnosis with laser tweezers.

3.1.6 Major Programme 6: Research Education Linkage

Different units of DAE continued their HRD programmes. A new element that has been added to those programmes is the launching of Homi Bhabha National Institute (HBNI) as a Deemed to be University. The HBNI will help strengthen the linkages between R&D and technology in the department. The efforts to generate excellent manpower for research in basic sciences have been boosted by recognition of Tata Institute of Fundamental Research (TIFR) as a Deemed to be University. From this year, TIFR is starting five years integrated M.Sc-Ph.D. programme. The Centre of Advanced Research and Education (CARE), set up at SINP under X Plan is helping nurture talented students in basic sciences. The nurture programmes of National Board for Higher Mathematics (NBHM) is continuing to attract talented young minds to mathematics. The DAE-University linkages have been further strengthened by DAE-UGC inter-university consortium. Board of Research in Nuclear Sciences (BRNS) supported a number of new initiatives in universities.

- HBNI as a deemed to be University launched
- TIFR recognized as deemed to be University
- HBNI and TIFR to strengthen linkages between R&D and technology and generate scientific manpower
- TIFR is starting 5 yrs integrated M.Sc-PhD programme this year
- Centre of Advanced Research and Education (CARE) set up at SINP
- BRNS and NBHM continues to sponsor research in the field of nuclear science and Mathematics respectively
- HBCSE started National Initiative for Undergraduate Science
- Olympiad programmes of HBCSE have yielded impressive performance in international Olympiads

A new building will be ready by the end of the X Plan for the BARC Training School at Mumbai. Land for the new campus at Visakhapatnam has been acquired. Basic work on development of land is in progress.

Homi Bbhabha Ccentre for Science Education (HBCSE) started National Initiative for Undergraduate Science (NIUS) wherein some B.Sc. students from all over the country are invited to HBCSE for summer and winter camps. Under this scheme, besides some classroom teaching, they carry projects under the guidance of scientists from BARC, TIFR and IIT-Bombay. The Olympiad programmes of HBCSE have been strengthened as is evident by increasingly impressive performance in international Olympiads.

3.1.7 Major Programme 7: Infrastructure & Housing

Development of infrastructure facilities to meet the requirements of the various projects viz. Augmentation Facilities for Plutonium based Fuels (PRAFPUL) I and II, Purnima-4 (P4) facility, Critical Facility, New Hot Cell facility, Super Computing Facility, Revamping of Uranium Metal Plant, Radioactive Solid waste Management Services (RSMS) expansion facilities, Power Reactor Thoria Reprocessing Facility (PRTRF), Advanced Telerobotic Facility at Division for Remote Handling & Robotics, Nuclear Recycle Group (NRG) projects, Integrated Fuel Fabrication Facility, Common Facilities Building, Non Destructive Technology building, New Upgradation of Metal Reduction Technology & Effluent Handling building at BARC, Trombay was taken up. Facilities for New Technology at BARC, Kalyan, High Block – Revamping of Power Reactor Fuel Reprocessing Plant, NRG projects at Tarapur, Infrastructure & housing at Nuclear Research Laboratory, Mount Abu, National Centre for Free Radical Research (NCFFRR) lab at Pune, Seismology stations at Kasan, Gauribidanur, Electron Beam Centre at Khargar were also taken up. Land was purchased at Rajarhat for VECC/SINP new campus and preliminary infrastructure development at Visakhapatnam for BARC new campus was taken up.

- Infrastructure facilities have been constructed for various projects undertaken during the X Plan
- Land for new campus for BARC and VECC/SINP procured and preliminary development initiated
- New houses constructed for various units of the Department
- Renovation of existing buildings undertaken for life extention
- Infrastructure in housing colonies upgraded

Residential quarters were constructed for AMD at their central, south and western regional centres. Housing colony at BARC, school building and shopping complex at Anushaktinagar were constructed. Housing colony for IGCAR, IMSc, TMC, HRI were also augmented. Some of the residential quarters taken up during the IX Plan at Anushakthinagar were completed in this plan. Renovation of Heritage OYC building was taken up and is progressing well. Infrastructure at the existing units was strengthened. This involved renovation of many existing buildings, hostels, auditorium, office building, repair and new construction of roads, water pipelines, electrical work modernization, up-gradation of fire emergency services etc. Some of these upgrades were taken up to strengthening of security around DAE installations.

Chapter 4

DAE XI Five Year Plan Proposals

4.0 Introduction

In the year 2004, an exercise was conducted to examine what the Department has achieved in the past and to plan for the future. For this exercise, several satellite meetings were organized and they culminated in a plenary vision meeting held during 17-19 May, 2004 held at Bhabha Atomic Research Centre. Wide ranging discussions were held on various topics, which were divided in the following categories.

- Energy vision,
- Societal vision,
- Technological vision,
- Directions for basic research and possible feedback into DAE programmes, and
- Human Resource Development.

A summary of the exercise was published in the form of a report titled, “Our Collective Vision”. It was expected that this report will guide the formulation of XI Plan and even subsequent plans. This exercise formed the starting point for the formulation of the XI Five Year Plan.

The Department consists of research centres and grant-in-aid institutions and both the set of institutions carry out research and development. While the research centres focus more sharply on technology and product development, the grant-in-aid institutions concentrate more on basic research. Technologies and products developed are deployed either by the industrial units of the Department or transferred under well established technology transfer mechanisms. Organization chart of the Department is given in Annex A.

4.1 Formulation Process

A Steering committee on Science and Technology has been constituted by the Planning Commission for the formulation of the XI Plan proposals for all the Scientific Departments in the Country. The Steering committee, in turn, has constituted a Working Group (WG) for the Department of Atomic Energy for R & D

Sector (Annex-B). This Working Group includes members from within and outside the Department. At the Departmental level, an Internal Working Group (IWG) has been formed to provide inputs to the Working Group (Annex-D).

In pursuit to fulfill the mandate of the Department, research and development activities of the Department are categorised into seven major programmes with specific deliverables for each of these major programmes. The major programmes are then further classified into sub-programmes identifying specific areas of work. This categorization was first done at the beginning of the X Plan and has been slightly modified to reflect the current realities. These are given as Annex to the constitution of IWG (Annex-D).

Considering the broad sweep of the subjects pursued by the Department, it was considered to identify theme areas and create specialists' groups for each theme area to enable in-depth peer review. Twenty major theme areas were identified and Specialist Groups (SGs) formed for review of proposals from across the units. These SGs have reviewed the scientific content of the proposal, identified overlap, if any, of the proposals from different units, reformulation of proposals to minimize overlap while keeping any desired overlap and suggested filling of the gaps in the programmes etc. The SGs and the guidelines for review of projects are given as Annex to the constitution of IWG (Annex-D). The responsibilities of the IWG and SGs are not only formulation of XI Plan proposal but also include their periodic review throughout the plan period. The SGs have presented their reports in the two meetings of the IWG. The report of the IWG was put up to the WG for discussion. The present report is an outcome of all these deliberations.

4.2 Methodology followed for project review / appraisal within the unit

Apart from the process of review at the Departmental level, a rigorous review process is followed by each unit at the unit level. As an illustration, the process followed by BARC is described here. To understand the process, it is necessary to know the structure of BARC. BARC is divided into several groups and each group consists of divisions and sections. Scientific programmes of each group are discussed at the level of Group Board and the scientific programmes of BARC as a whole are discussed at the level of Trombay Scientific Committee (TSC).

Based on the mandate of various Sections/ Divisions and the document, "Our Collective Vision", project proposals were formulated at the Sectional/ Divisional level after detailed internal discussion. These were then discussed at the Group

Board meetings. In the meetings of the Group Board called to discuss plan proposals, Director BARC himself participated. He consolidated all proposals, identified gap areas and made a presentation to the TSC. Thereafter, the proposals were fine tuned and gaps were taken care of by formulating additional proposals. Thereafter the proposals were submitted to SGs for peer review and further fine tuning.

4.3 A brief description of the Major Programmes

4.3.1 Major Programme 1: Nuclear Power Programme – Stage – 1

Natural uranium fuelled Pressurised Heavy Water Reactors (PHWRs) and associated front and back end fuel cycle facilities are being set up in the first stage of nuclear power programme. These reactors are being designed, constructed and operated by Nuclear Power Corporation of India Limited. While this programme is now in the industrial domain, R&D support has to be continued to ensure to continually improve capacity utilization, safety and economic competitiveness and also to upgrade technology based on latest development particularly in control and instrumentation and material science. Ageing management is another important aspect and the technological areas directed towards ageing management are – enhancement of channel inspection technologies, in-service inspection, decommissioning, chemical and biological studies relating to coolant circuits, non-destructive examination, testing and characterization of irradiated materials and corrosion of nuclear structural materials.

- Augmented R&D support to existing and next generation (700 MWe) PHWR programme for improved capacity utilization, safety, control instrumentation, ageing management, corrosion, materials etc.
- Intensification of Uranium exploration efforts including development of indigenous capability for locating concealed deposits having no surface manifestation
- Development of indigenous technologies related to fuel development for light water reactors
- Comprehensive and sustained R&D for back-end programmes of fuel reprocessing and waste management in the areas such as development of solvents, new separation methods, equipment and materials, remote handling & robotics and safety
- Several safety related research programmes in the areas of thermal hydraulics, life extension, accident behavior analysis using simulation and experimental setups
- Setting up more rigorous and comprehensive environmental monitoring systems around nuclear facilities

To increase installed capacity based on PHWRs beyond what is planned at present, it is necessary to step up uranium exploration. This would require development of indigenous capability for locating concealed deposits having no surface manifestation, enhancing the analytical capabilities of exploration as well as processing laboratories and development of process technology for the exploitation of all proven deposits including large and isolated rich small deposits. Besides these, there is a need to recover uranium from secondary sources particularly from phosphate rocks or from phosphoric acid which is imported in huge quantities in the country. Projects have been formulated to augment uranium resource within the country.

The success of the nuclear energy programme to a great extent depends on the maturity attained in the area of nuclear fuel cycle, and planning of adequate fuel cycle capacities. Reprocessing, waste management and waste disposal form vital components of the nuclear fuel cycle. The substantial increase planned in nuclear power generation has to be matched by commensurate increase in back end programmes, which demands a comprehensive and sustained R & D. These R & D programmes involve a variety of disciplines including physics, chemistry and engineering and encompass a variety of areas such as process development, materials development, equipment development, instrumentation development, remote handling, robotics and safety. Proposals have been formulated to meet the increased requirement of back end services including development of solvents for extraction, advanced technologies for extracting and treating waste, repository studies etc. The major proposals include improvement in the existing facility for back-end technology development at Trombay and setting up of new R&D facilities at Visakhapatnam.

Proposals for strengthening the nuclear safety related to fuel cycle facilities and nuclear reactor power programmes have been formulated. The areas covered are environmental and radiation safety, thermal hydraulic safety, structural safety and generation of data to improve the design of core components and fuel sheath by studying degradation mechanism of zircoalloy material properties under normal and accidental conditions. Projects involving environmental and radiation safety studies will enhance our capability to calculate low dose and associated risk appropriately. Validation of computer codes in the area of dispersion analysis, effluent dilution and migration of radionuclide in soil will be carried out. Projects involving thermal hydraulic safety studies will improve our understanding of some phenomena and issues in the area of severe accidents. Data generated would help in validating

computer codes. Hydrogen re-combiner will be developed and tested so that it can be installed in operating / new nuclear power plants. Structural safety studies will provide inputs to the design of advanced safe nuclear power plants. Tests conducted would provide safety margin under accident loading. Projects on enhancing the life of components and structures will also be taken up. Seismic study and tests on shake table would provide input for carrying out optimization of seismic design of structures, components and piping system.

4.3.2 Major Programme 2: Nuclear Power Programme – Stage – 2

The second stage envisages setting up of Fast Breeder Reactors (FBRs) backed by reprocessing plants and plutonium-based fuel fabrication plants. In order to augment the indigenous nuclear power generation capacity, fast breeder reactors are necessary. They are also essential for establishing use of thorium on a large scale in the third stage of our power programme. Prototype FBR (PFBR) is the first indigenous reactor in the series of FBRs to be constructed. Since the nuclear power programme in the next few decades would have a large component of FBRs, it is essential to step up the investment in R & D on FBRs to develop materials, equipment and processes on a comprehensive basis. Project proposals for development of fabrication routes for mixed oxide as well as metallic fuels for fast reactors are being taken up during this plan. Mixed oxide fuels fabricated through sol-gel route will be irradiated in FBTR as part of the programme to develop this alternate fuel fabrication route that promises many advantages over the conventional powder pellet route. To ensure expeditious development of metallic fuels, R&D on thermo-chemical and thermo-physical properties of metallic fuels and fuel-clad chemical interaction are proposed to be undertaken. It is proposed to initiate fabrication of test fuel pins with metal alloys and irradiation in FBTR with the twin objectives of fuel cycle development as well as expanding the core of FBTR. A life extension program for FBTR for another 20 calendar years is planned to be taken up. Studies on sodium chemistry will be continued with the aim of developing radioactive removal traps, sodium removal from components using water-vacuum process and miniature versions of sensors for fast reactor technology.

R&D activities encompassing hydraulic studies for the reactor pool and steam generator, heat removal capability of safety grade decay heat removal circuit, in-sodium studies relating to e.m. pumps and flow meters, integrated cold trap sodium purification system, reactor safety instrumentation, sodium instrumentation, material development and characterisation, and reactor engineering studies towards core catcher, development of sodium resistant refractory lined concrete and sodium

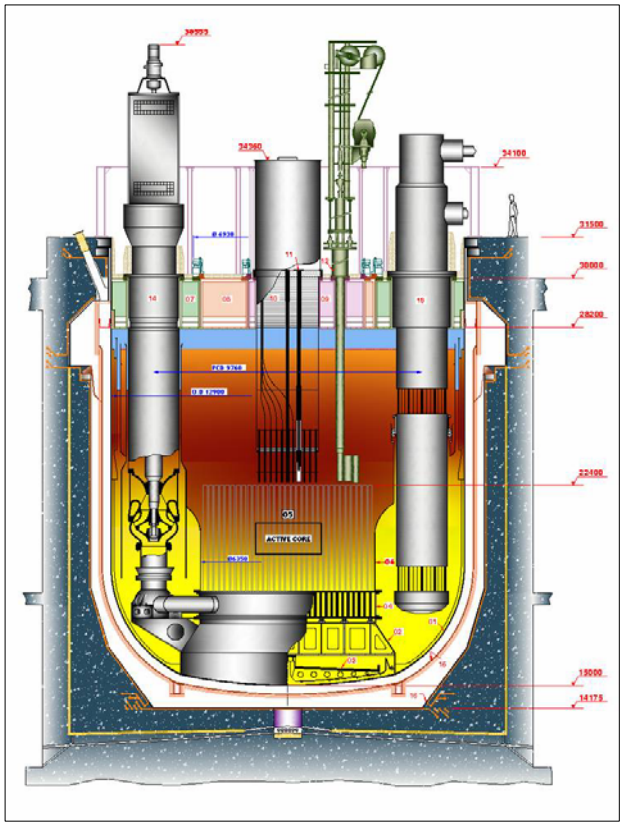
aerosol removal system have been planned to optimise the design concepts and to provide inputs for the design of future FBRs. Structural mechanics experiments will be continued to validate innovative design features of future FBRs in the field of high temperature, fatigue, buckling and seismic design. Special shake table to study seismic aspects of thin vessels is planned.

- Intensification of R & D efforts to develop materials, equipment and processes on a comprehensive basis for FBRs
- Enhanced efforts towards development of process for fabrication of mixed oxide and metallic fuel for FBRs
- Demonstration of fabrication technology of helium bonded metallic fuel elements for fast reactors
- Generation of characterisation data for metallic fuels for fast reactors
- Initiation of fabrication of test fuel pins with metal alloys and irradiation in FBTR with the twin objectives of fuel cycle development as well as expanding the core of FBTR
- Life extension programme of FBTR by another 20 calendar years
- Studies on Sodium chemistry and related equipment development to continue
- R&D activities towards understanding reactor engineering aspects of FBR systems to continue
- Structural mechanics experiments will be continued to validate innovative design features of future FBRs in the field of high temperature, fatigue, buckling and seismic design
- Pre-service, in-service and post irradiation examination technology to be developed
- Repair and inspection service including quality assurance programme to be developed
- R&D on development of safe and economical reprocessing technology using mixed oxide fuel as well as envisaged use of metallic fuels to be intensified

Technologies for pre-service inspection, in-service inspection, post irradiation examination, irradiation experiments and remote handling for FBRs and fuel cycle facilities using advanced robotic techniques will be developed.

The emphasis on the induction of fast reactors for nuclear energy production implies R & D on areas that will address the challenges that arise due to the high Pu content of the fuels and the high levels of radioactivity associated with the irradiated fuel on account of the high burn-up reached. While the experience with the reprocessing of mixed carbide fuel from FBTR forms a strong base for further development of the back end of the fast reactor fuel cycle, a number of R&D issues need to be addressed to make fast reactor fuel reprocessing more robust and economical. The use of metallic fuels envisaged in future fast reactors adds further

to the spectrum of challenges since these fuels will be reprocessed through the pyro-chemical routes (which involves a lot of new technologies such as electro-refining in



Schematic of Fast Breeder Reactor

Artist's view of 500 MWe Prototype Fast Breeder Reactor (PFBR), construction of which was launched on October 23, 2004.

molten salts at high temperatures) as compared to the thermal reactor fuels and the mixed oxide fuels of FBRs, which are reprocessed by the well established Purex route. The R & D programmes envisaged in the XI Plan period seek to address these challenges in a comprehensive manner. Both flow sheet development and equipment development will be taken up so as to make the reprocessing technology more safe and economical. Use of novel separation technologies such as supercritical fluid extraction and microwave denitration will be explored. Centrifugal extractors and maintenance free metering pumps are examples of equipment whose development would support not only the back end of fuel cycle but also the front end.

At IGCAR, we would enhance research in materials science that aims to explore and exploit functional materials under combinations of extreme of pressure, temperature and magnetic fields. Studies on soft condensed matter and nanomaterial systems, to function as ultra sensitive sensors, will be explored. The indigenously developed SQUID sensors and associated systems will be exploited towards applications in NDT, MEG and geophysical prospecting. It is proposed to strengthen studies on ion beam simulation of radiation damage with the addition of a 400 keV ion accelerator that will facilitate dual beam irradiation with Ni and He. These studies will be complimented with large scale computer simulations and multi scale materials modelling.

4.3.3 Major Programme 3: Nuclear Power Programme – Stage – 3 and Beyond

While the current generation nuclear energy systems have been very successful in safely and economically producing power, it is necessary to continue R&D for the development of advanced nuclear reactor systems due to the following main reasons.

a) India has very high reserves of thorium, while its known uranium reserves are quite modest. Therefore, for India it is essential to develop reactors of new design, making optimum use of thorium on a commercial scale. India is already in the forefront of countries, which are working in the area of thorium utilization.

b) Considering the sheer size of the programme, as will evolve in the future due to increase in energy and electricity requirements, the nuclear energy systems need to be evolved having advanced systems to enhance their economics, safety, environmental friendliness and sustainability of resources. Work in these directions is in progress in several other advanced countries of the world. These new reactor designs, in particular, would aim to achieve higher goals for safety, to

the extent needed for avoiding a need for intervention in public domain, on account of any event occurring inside the plant.

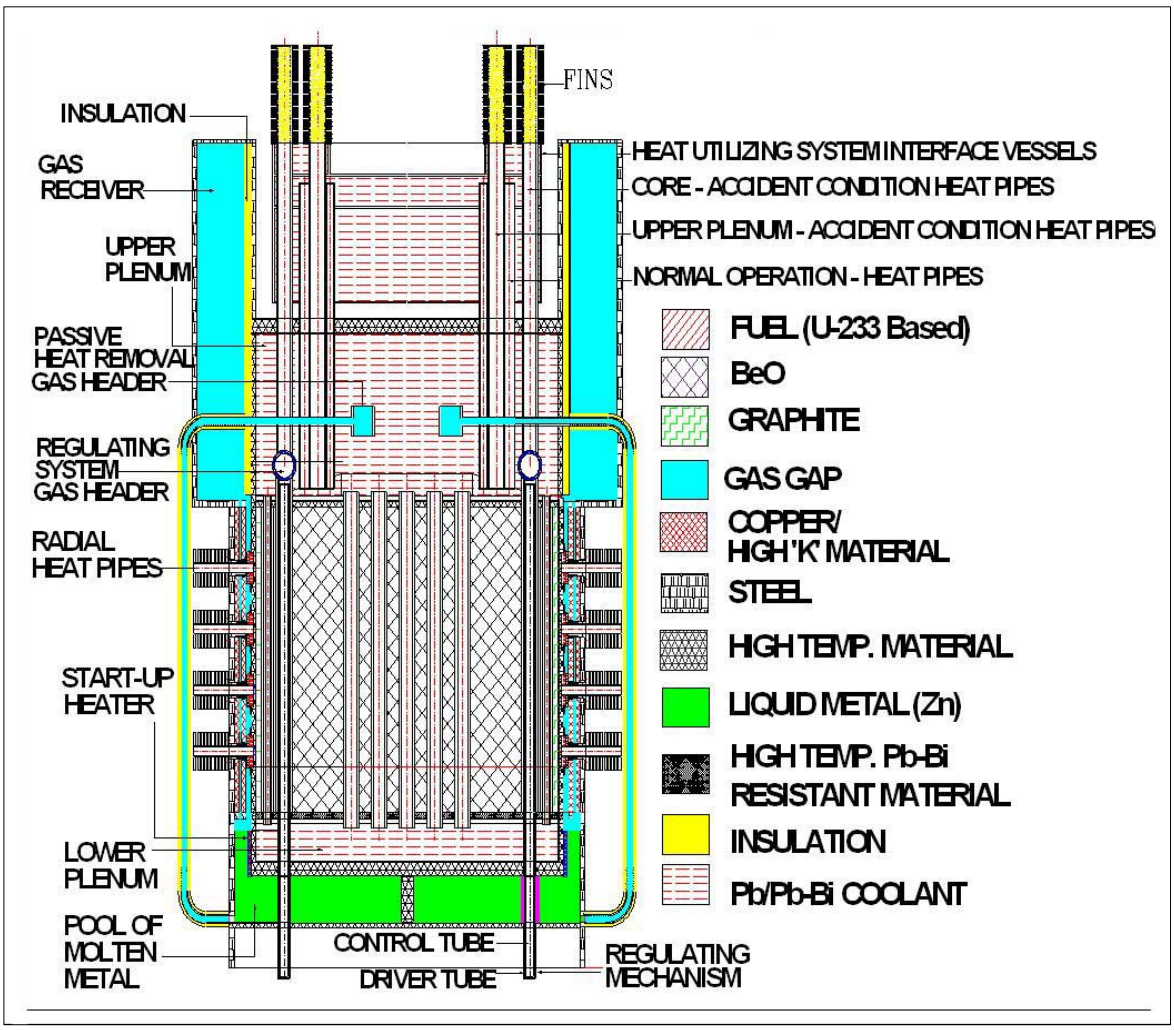
c) So far all countries have concentrated on fission based reactors. Based on recent developments, the world fusion community has come to conclusion that time is ripe to launch a major initiative to develop fusion systems and several nations together have decided to launch a project to develop fusion system and India has also joined this international initiative.

Considering the large time frame involved in the development, validation and regulatory approval for 'first-of-a-kind' technological features of a nuclear reactor, it is essential to initiate the work for R&D pertaining to advanced nuclear reactors well ahead, so that the results are available in time for large scale commercial deployment of advanced, mainly thorium fuelled reactors.

Work towards the development of the mainly thorium-fuelled Advanced Heavy Water Reactor was initiated and continued in the IX and X Plan periods leading to a significant development in all the relevant technologies as needed for launching this programme in the near future. Additional activities relating to full scale engineering validation of major innovative features of this reactor, and assessment of the associated design margins, are being planned to be carried out in the XI Plan period. This objective is being met by setting up of major, large size experimental facilities at Tarapur, supplemented by the programmes at Trombay to facilitate continued development of advanced technologies for next generation reactor systems. In parallel, the detailing of the design of AHWR, mainly for the non-nuclear systems and conventional structures, is being continued with the help of consultants.

- To pursue full scale engineering validation of major innovative features of AHWR reactor and assessment of the associated design margins
- Setting up of major large size experimental facilities at Tarapur, supplemented by the programmes at Trombay to facilitate continued development of advanced technologies for next generation reactor systems
- Detailing of the design of AHWR, mainly for the non-nuclear systems and conventional structures will be continued
- Develop facilities to demonstrate Thorium material technologies
- To build a demonstration unit of a Compact High Temperature Reactor which would serve as a platform for development and demonstration of very high temperature heat removal capabilities and other challenges associated with the operation of high temperature components

Another initiative, recently taken, pertains to generation of high temperature process heat using advanced nuclear reactors (Indian High Temperature Reactors – IHTRs). This process heat could be used for a variety of purposes including hydrogen generation and for serving as a compact nuclear power pack for remote areas. The technologies inherent for such reactors are highly challenging on account



Schematic of Compact High Temperature Reactor (CHTR)

of a need for special materials, which could withstand such high temperature and new technologies, for ensuring core heat removal passively under all conditions including normal operation, shut down and accident conditions commensurate with the requirements stipulated for advanced nuclear reactors. In the XI Plan, it is envisaged to build a demonstration unit of a Compact High Temperature Reactor which would serve as a platform for development and demonstration of very high temperature heat removal capabilities and other challenges associated with the operation of high temperature components of newer materials or hitherto unused

materials for nuclear reactors. This demonstration facility is proposed to be built at the Trombay campus of BARC.

Due to availability of limited space and other infrastructure for setting up new major facilities at BARC, Trombay, major portion of future activities pertaining to the high temperature reactor development is proposed to be carried out at the new campus of BARC in Visakhapatnam. Similarly, while the initial work for the development and characterization of new materials for high temperature materials, as necessary for the setting up of CHTR, will be carried out at Trombay, all major materials development activities for IHTRs will be taken up at the Visakhapatnam campus.

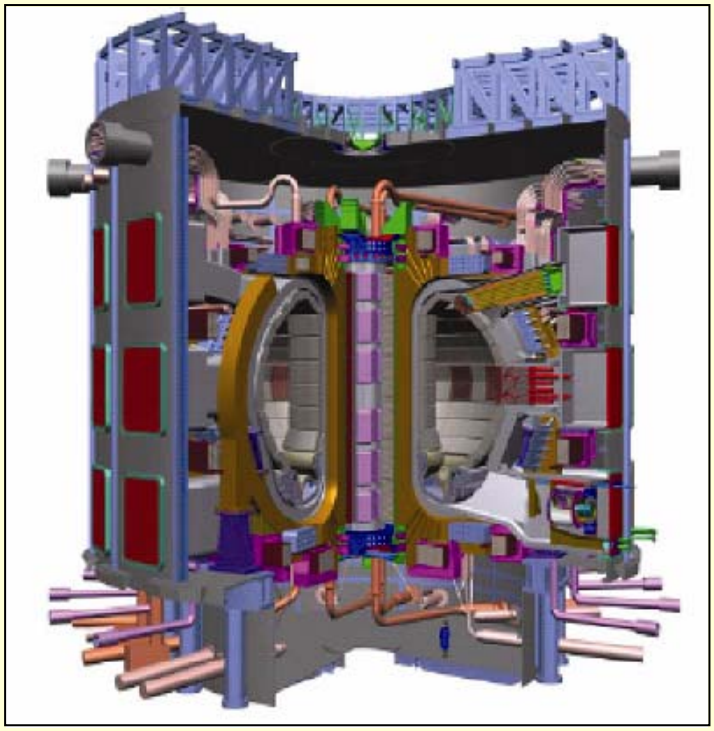
- Setting up plant for special materials for High temperature reactors at Visakhapatnam
- Development of processes for generation and storage of hydrogen. Towards this a demonstration plant for hydrogen production by electrolysis route based on high surface area electrode developed in BARC is to be set up at BARC, Trombay.
- Participation in ITER project as full partner. Towards domestic infrastructure development and fabrication of components and diagnostic systems to be supplied to the project will be taken up with industry partners

For the first time we are introducing a specific project on hydrogen energy. Hydrogen is an attractive energy carrier and is expected to play a major role in energy systems for many economic sectors in the next few decades. In the medium term, its most promising application appears to be in the transport sector where it can be a substitute for hydrocarbon fuel. This substitution becomes necessary because of high cost of hydrocarbons and/or environmental reasons. The advantage of hydrogen energy systems will depend upon the process of production of hydrogen. Hydrogen will be an environment friendly and sustainable energy carrier only if its production is sustainable i.e. it does not consume non-renewable natural resources and also does not degrade environment. Several processes like water splitting processes using energy from nuclear or solar systems, thermo-chemical processes etc. are being planned to be taken up. Thermo-chemical Iodine-Sulphur process is estimated to be the most promising and energy efficient. It is proposed to develop this process to demonstrate its feasibility. A separate building for closed loop systems is proposed at the new BARC campus at Visakhapatnam.

The high temperature required for thermo-chemical process can be obtained from various sources including nuclear and solar. Studies on conversion of solar

energy to get high temperature of the order of 900-1000^{o}C is also proposed. A demonstration plant for hydrogen production by electrolysis route based on high surface area electrode developed in BARC is also proposed to be set up at BARC, Trombay. Detailed design has already been worked out. This will demonstrate the feasibility of hydrogen production based on electrolysis using indigenously developed membrane. Basic studies about interaction between hydrogen and other materials are also proposed to be carried out. All the proposed projects except the one for setting up demonstration plant are the new programmes and hence would be executed in research mode. The understanding and the development of Iodine-Sulphur process based thermo-chemical process for hydrogen production and a demonstration plant for hydrogen production using indigenously developed membrane are the main outcome of this project.

As a part of working for energy security, one of the options is energy from fusion reactor. India has recently joined (International Thermonuclear Experimental Reactor) ITER as one of seven full partners, the others being China, European Union, Japan, Korea, Russia and USA. India will contribute equipment worth nearly 500 million US dollars to the experiment and will also participate in its subsequent operation and experiments. ITER is a prestigious international project which will nearly complete the scientific and technological investigations required to build a prototype demonstration reactor DEMO, based on the magnetic confinement



ITER (International Thermonuclear Experimental Reactor)

scheme of controlled thermonuclear fusion. India's contributions to ITER are largely based on the indigenous experience and the expertise available in Indian industry. India will be fabricating the 28 m dia, 26 m tall SS cryostat , which forms the outer vacuum envelope for ITER. It will also take up the design and fabrication of eight 2.5 MW ion cyclotron heating sources, complete with power systems and controls. It will also take up the fabrication of a diagnostic neutral beam system which will give crucial information about the physics of burning plasmas in ITER. India will also be responsible for a number of other diagnostic subsystems. Finally, India will contribute to cryo-distribution and water cooling subsystems. All this equipment will have to be built with ITER quality standards and in a time frame (approximately ten years) determined by the International Team at the host site in Cadarache, France. In the long run, participation in ITER project will lead to strengthening our domestic programme. This is an investment for the future both in terms of scientific and technological goals and will help in being at par with developed world in terms of energy security. Annex E gives a brief write up on ITER Project.

4.3.4 Major Programme 4: Advanced Technologies and Radiation Technologies and their Applications

A] Advanced Technologies and their Applications

Research reactors APSARA, CIRUS, DHRUVA and KAMINI provide the reactor based facilities for research in basic sciences like physics, chemistry and biology. In addition, they also provide services like production of radioisotopes, neutron radiography, neutron activation analyses, material irradiation testing, fuel testing, shielding studies etc. Timely replacement of aged equipment, upgradation of the systems/equipment, refurbishment of systems is essential for the safe operation and continued high availability of these reactors. It is also essential to maintain the facilities that provide inputs to these reactors in efficient state of operation so that necessary inputs are available in desired quantity and quality as and when required. It is planned to upgrade APSARA reactor by changing the HEU core to a LEU core to ensure continued availability of the reactor and to enhance the reactor power up to 2 MW. Seismic retrofitting of APSARA building is also planned to be carried out to increase the life of the building. Process water/ sea water Heat exchangers for DHRUVA are also planned to be replaced. Instrumentation & Control system of DHRUVA are also proposed to be replaced with state of the art system for improved availability and long-term performance.

Fabrication facilities at Atomic Fuels Division are planned to be upgraded to meet the fuel requirements of DHRUVA. This involves installation of new machineries and equipments. The project will result in economy, better quality and higher productivity. An experimental physics lab having online flux mapping system, counting set-ups, fuel scanner & wire scanner and Image processing system at Critical facility will be set up. This will provide necessary database for thorium based reactors. To develop and establish fabrication processes & characterization for proposed APSARA Fuel on a sustainable basis, a project involving installation of furnaces for fuel alloy preparation, roll bonding of fuel plates, setting up of radiography facility, bond testing facility, metrology and surface inspection facility and fuel element manufacturing including swaging and packaging facility is proposed to be set up. The project will establish the facilities for production of fuels needed for the modified APSARA reactor and eventually establish the processes for the development of high performance fuels to be used for other research reactors such as Multi Purpose Research reactor (MPRR).

- A high flux Multipurpose Research Reactor is planned at Visakhapatnam with possibility of coupling external neutron supply to enhance facilities for basic research, material irradiations & production of radioisotopes of high specific activity
- Upgradation of APSARA reactor to ensure continued availability of reactor and enhancing the reactor power up to 2 MW planned
- Upgradation and replacement of systems/equipment for other research reactors is also to be taken up for improved availability and long term performance
- Efforts for indigenous development of manufacturing technologies and medical / scientific instruments
- Isotope processing facility is planned along with MPRR at Visakhapatnam

It is envisaged to modernise safety critical instrumentation of KAMINI Reactor by replacement of the neutron detectors and neutronic channels of KAMINI reactor by state-of-the-art systems to enhance the performance of the reactor and improve its' operational safety.

High flux research reactors play a crucial role in providing unique facilities for basic research in frontier areas of science and for applied research related to development and testing of nuclear fuels and other materials. These reactors also cater to the needs for radioisotopes for application in the fields of medicine, agriculture and industry. Keeping in view the projected requirements of reactor based facilities for basic and applied research as also the projected demand for radio isotopes in the country, construction of a new MPRR and an Isotope Processing

Laboratory is proposed at the new BARC Campus at Visakhapatnam. This project involves construction of a 30 MW pool type research reactor with a maximum thermal neutron flux of 6.5 X 10^{14} n/cm2/sec. Possibility of coupling the proposed research reactor with an accelerator beam in future is also being explored with a view to demonstrate the technology of accelerator driven sub-critical systems.

A radioisotope processing facility is proposed to be set up at Visakhapatnam. The project would involve construction of an isotope-processing laboratory with five hot cells, clean room facility with sterile area, radio-pharmaceuticals lab, target preparation & sealing facility along with a carrier tunnel between reactor building and isotope processing laboratory. The project will greatly enhance the isotope production capability especially of high specific activity isotopes as also therapeutic isotopes not being produced presently in the existing reactors. It is also proposed to develop cold-neutron source at MPRR for conducting experiments to investigate microscopic structures at atomic length scales up to 1000 nm in bulk and magnetic multilayered samples, and low-energy dynamics in large molecular systems.

Development of high power lasers for engineering applications in nuclear and industrial fields will be pursued at RRCAT. Semiconductor lasers of high power capacity will be developed which is crucial for making future solid state lasers to be more compact and efficient. High power solid state lasers and laser systems on turn-key basis will be set up for applications in various cutting operations in nuclear reactors. Methodologies of laser material processing including laser refurbishing of engineering components, laser rapid manufacturing and hybrid laser processing will be established.

- Development of high power lasers for engineering applications in nuclear and industrial fields will be pursued at RRCAT
- Methodologies of laser material processing including laser refurbishing of engineering components, laser rapid manufacturing and hybrid laser processing will be established
- Technology developed at VECC during the X Plan is proposed to be utilized to construct a superconducting magnet energy storage system for a variety of applications
- A 10 MeV, 5 miliamperes proton cyclotron is proposed to be built, indigenously, as part of the ADS programme at Kolkata
- Technologies for development of ADSS to be taken up
- Fifth beam line, heavy density liquid metal target system at medical cyclotron, Kolkata will be set up

SINP proposes to take up a project on trace scale analysis. They intend to set up sophisticated trace analysis laboratory which will deal with detection, speciation and dynamics of trace elements especially with the radioactive isotopes interface scale.

High temperature superconductors will be used for the magnet coil. The technology developed at VECC during the X Plan is proposed to be utilized also to construct a superconducting magnet energy storage system for a variety of applications. Moreover, VECC also proposes to develop superconducting RF cavities for intense proton accelerators. A 10 MeV, 5 miliamperes proton cyclotron is proposed to be built, indigenously, as part of the ADS programme at Kolkata. Development of a nano-beam ion implanter facility is also planned to be done.

Deliverables from the Accelerators and Accelerator Driven Sub-critical systems (ADSS) development will involve setting up of infrastructure and development facility for RF structures / systems for ADSS, Development of UHF solid-state power amplifier, high stability high voltage power supplies and test facilities. Upgraded FOTIA / Pelletron Accelerators & Facilities will also be taken up. Fifth beam line, heavy density liquid metal target system at medical cyclotron, Kolkata will be set up.

The up-gradation of injector & Indus-2 will lead to better beam quality & higher beam current in booster synchrotron & Indus-2 Synchrotron Radiation Source (SRS). Also the filling time of Indus-2 will reduce considerably and improve the flux level of SR of Indus-2. Enhancement of utilization of Indus-1 & Indus-2 is planned. Indus-2 utilization programme involves setting up of experimental facilities for beam line users. Synchrotron radiation has medical & industrial applications (Angiography, lithography) and hence will directly lead to benefits the society. Facilities like 50 MeV Injector Linac Upgrade Booster, TL1, TL2 & TL3; Insertion Devices for Indus-2 will be created and augmentation of Indus-2 subsystems will be taken up.

Diagnostic beam lines for SR studies and improvement are also planned. Development of Superconducting Technology for Accelerators will involve making Superconducting cavities for which Niobium Sputtering Facility, High Power RF Test Bench, Clean room for cavity assembly, SCRF Cavity Polishing, High Pressure Rinsing Facility, and Vacuum Annealing Furnace will be set up.

- Upgradation of injector and Indus-2 will lead to better beam quality and higher beam current in booster synchrotron & Indus-2 Synchrotron Radiation Source
- Enhancement of utilization of Indus-1 and Indus-2 planned
- Diagnostic beam lines for SR studies and improvement planned
- Setting up of High Current Proton Injector Linac for Spallation Neutron Source planned
- R&D towards major accelerator based scientific facilities, such as X-ray Free Electron Laser (XFEL) in Europe (spearheaded by DESY lab in Germany) and International Linear Collider (ILC) through transnational participation are currently being pursued vigorously through collaboration between countries across the globe. Participation in these programmes to develop in-house expertise to build critical subsystems for future accelerators

Objective of setting up High Current Proton Injector Linac for Spallation Neutron Source is to develop pulsed H^- accelerator upto 4.5 MeV, to develop & characterize prototype DTL & SFDTL structures for medium energy beam acceleration and to develop infrastructure facilities for proton linac. Development of prototype establishes technology, methods & procedures to be followed in series production and builds confidence to take up large projects like Spallation Neutron Source (SNS). SNS has applications in condensed matter research, material science etc. SNS is a potential tool in the development of new materials, compounds, pharmaceuticals, Hi Tc super conductors. Also, it can be used to generate nuclear data for various targets and structural materials for ADS applications. SNS can also be extended to study and demonstrate low power ADS.

R&D towards major accelerator based scientific facilities, such as X-ray Free Electron Laser (XFEL) in Europe (spearheaded by DESY lab in Germany) and International Linear Collider (ILC) through transnational participation are currently being pursued vigorously through collaboration between countries across the globe. The technology that is involved in these accelerators is at the cutting edge, which will play a major role in the development of several front ranking enterprises in the future. This would greatly help in developing in-house expertise to build critical sub systems for future accelerators. Our participation would also help in developing a strong base for experimental activities around mega scientific facilities.

Narrow line width tuneable dye laser will be developed and these indigenous lasers will be available for laser isotope separation of elements of interest to DAE and medical science. The high voltage pulse power supply developed for Copper Vapour Laser (CVL) will be useful in various gas discharge applications like pollution control. Indigenous technology of making excimer laser and copper vapour lasers using solid state switches and magnetic pulse compression will be available.

Laser-based instrumentation and optical systems will be developed for application in nuclear industry for non-destructive testing and non-contact measurements in radioactive environment. Prototype fabrication facilities will be set up for various sensors based on micro-electro-opto-mechanical systems (MOEMS). Optical coating systems and multilayer sputtering facility will be set up for producing specialized optical coatings for use in lasers and metallic coatings for accelerator components.

B] Radiation Technologies and their Applications

Continuing on the leads from the X Plan, it is proposed to develop various desalination technologies and manufacturing processes for various types of membranes, set up a MED - RO based plant at BARC Trombay and also a RO based plant at Visakhapatnam to augment water supply at these places. A few small size plants are also proposed to be set up in various parts of the country to popularize desalination technologies which are expected to have multiplier effect.

Radioisotopes and radiation find application in different fields such as medicine, industries, food processing, hydrology, agriculture, research etc. The XI plan proposals address the current needs in these areas and target societal benefits such as food preservation & hygienization, isotope hydrology & industrial tracers, production of radioisotopes & radiolabelled compounds and radiation processing of materials.

- To develop various desalination technologies and manufacturing processes for various types of membranes, set up a MED - RO based plant at BARC Trombay and also a RO based plant at Visakhapatnam to augment water supply at these places
- Projects in the areas of food preservation & hygienisation, nuclear agriculture, isotope hydrology & industrial tracers, production of radioisotopes & radiolabelled compounds and radiation processing of materials are planned

Research in the field of nuclear agriculture and biotechnology will continue. Work on mutation breeding for biotic and abiotic stresses and quality improvement in oil seeds and pulses and seed multiplication of BARC varieties will be carried out. At Visakhapatnam, seed multiplication, plant metabolic engineering, molecular farming and crop improvement by TILLING (Targeting Induced Local Lesions in Genomes) will be taken up. Development of mutants/genotypes with higher productivity,

resistance to specific diseases, tolerance to abiotic stresses and improved quality for enriching germplasm is envisaged.

Several proposals using radiation, nuclear and other advanced technologies would be addressing important issues in health care, especially cancer. The Tata Memorial Centre (TMH & ACTREC) would expand the existing programmes and initiate new programmes of prevention, clinical management and basic, translational and clinical research in cancer. As the apex cancer referral centre in the country it would continue to provide state-of-the-art and cost-effective cancer care and optimal facilities to a large number of patients from all over the country. A new 11 storey clinical facility (Tata Clinic) would be completed along with augmentation and replacement of several radiotherapy, radiology, nuclear medicine, surgical, telemedicine, teleradiology and hospital information equipment at TMC. International accreditation of various clinical facilities would be obtained. Integrated R&D is proposed at TMC in collaboration with other DAE units and national laboratories for indigenous equipment and technologies that are more cost effective or novel and are

14 storied Hospital (Tata Clinic) with state of the art radiotherapy and therapeutic facilities is being set up.

This clinic will house

1) Outpatient evaluation and treatment facilities to meet the increasing demand of patient care,

2) Surgical, Medical and Radiation Oncology facilities to reduce the waiting time for patients,

3) Inpatient facilities with additional beds to improve throughput of services,

4) Seminar/Lecture/Faculty rooms for academic activities and

5) 4 stroied Atrium which would create a large waiting space and provided the much needed amblience.

- Tata Memorial Centre (TMH & ACTREC) would expand the existing programmes and initiate new programmes of prevention, clinical management and basic, translational and clinical research in cancer
- A new 11 storey clinical facility (Tata Clinic) would be completed along with augmentation and replacement of several radiotherapy, radiology, nuclear medicine, surgical, telemedicine, teleradiology and hospital information equipment at TMC
- R&D in collaboration with DAE units and national laboratories for development of indigenous equipments and cost effective technology for cancer diagnosis, treatment, rehabilitation and research
- Further development work on telecobalt machine '*Bhabhatron*' to be undertaken for its accessories and treatment planning to make it versatile and cost effective
- Developement of Cancer Care facility at Shillong and Ranchi

Due to the high cost of imported equipment, the country has only 350 teletherapy machines for cancer radiotherapy as against the requirement of 1000 such machines. To fulfill this national objective, '*Bhabhatron*' was developed as an indigenous telecobalt machine at BARC and is now being used very satisfactorily for treatment of cancer patients at ACTREC. Further R&D work is proposed for its accessories and a radiotherapy planning system in order to make it more versatile and further cost-effective for India and with better export potential. To ensure patient safety a rigorous nation-wide quality assurance programme with training of more medical physicists, dosimetrists and radiation safety officers is proposed and a dedicated dual-energy electron accelerator will be acquired for this purpose.

The availability of PET system as a diagnostic modality and the production of conventional and new radiopharmaceuticals for PET will be enhanced at RMC.

Major part of the Medical Cyclotron Project at Kolkata will be implemented within the first year of the XI Plan. A unique 30 MeV, 500 microamperes beam current cyclotron will be available for medical isotope production as well as research and development experiments to the wide spectrum of Indian users. A 250 MeV superconducting cyclotron for proton beam is also proposed to be constructed at VECC for subsequent installation and use at ACTREC for cancer therapy, radiobiology, physics and related research. Proton beam therapy has unique radiobiological and physical advantages over the most advanced photon based radiotherapy technique and this will be first of its kind in the country.

- 30 MeV Medical Cyclotron will be available for medical isotope production as well as R&D experiments to a wide spectrum of Indian users
- A 250 MeV superconducting cyclotron for proton beam will be constructed at VECC and installed at ACTREC for cancer therapy, radiobiological and related research. This will be the first of its kind in the country
- Biocompatible materials for orthopedic and other implants to be developed to bring down their cost and make them widely available
- Facilities at BARC hospital, Anupuram dispensary (IGCAR) will be augmented

Leads on Biocompatible materials such as shape memory alloys of Cobalt-Chromium-Nickel-Tungsten for developing orthopedic implants, porous bone implant, orthodontic and endodontic implants etc., will be pursued at BARC to bring down their cost and make them widely available.

Considering the increasing number and age of CHSS beneficiaries and rising cost of referrals to tertiary hospitals, at the BARC hospital multi-specialty facilities will be augmented, new medical equipment procured and home-care programme will be initiated. R&D activities in cytogenetics and molecular diagnosis will be initiated. A new dispensary with pathology and dental facilities is proposed for Navi Mumbai. Considering the proposed increase in the number of flats from the present 675 to 2000 at Anupuram and its distance from the IGCAR hospital at Kalpakkam, a 15-bed ward, radiology, physiotherapy, dental and labor room facilities at Anupuram is proposed with further strengthening of surgical, pediatric and hospital information facilities at IGCAR hospital.

4.3.5 Major Programme 5: Basic Research

DAE has been pursuing its activities under Basic Research with major target of development of indigenous nuclear power programme. Most of the developments have been in line with existing development elsewhere in the world. Now we are at par in most of areas of science and to retain our position we have to be at the cutting edge. We must further strengthen Basic Research while we work on DAE related areas of Basic Research. We are taking part in the new areas of Basic Research and are working on development of our human resource for the same. We need to move from the mature state where we are into areas of original thinking and technology development based on new science that is coming up. This is a paradigm shift. We are already recognized as leader in closing the fast breeder cycle and work in the areas of thorium fuel cycle. Synergy between major R&D institutions within the department is leading to alignment of activities towards

achieving the mandate of the Department. Basic Research activities are also taking into account the perspective of energy security in the long run.

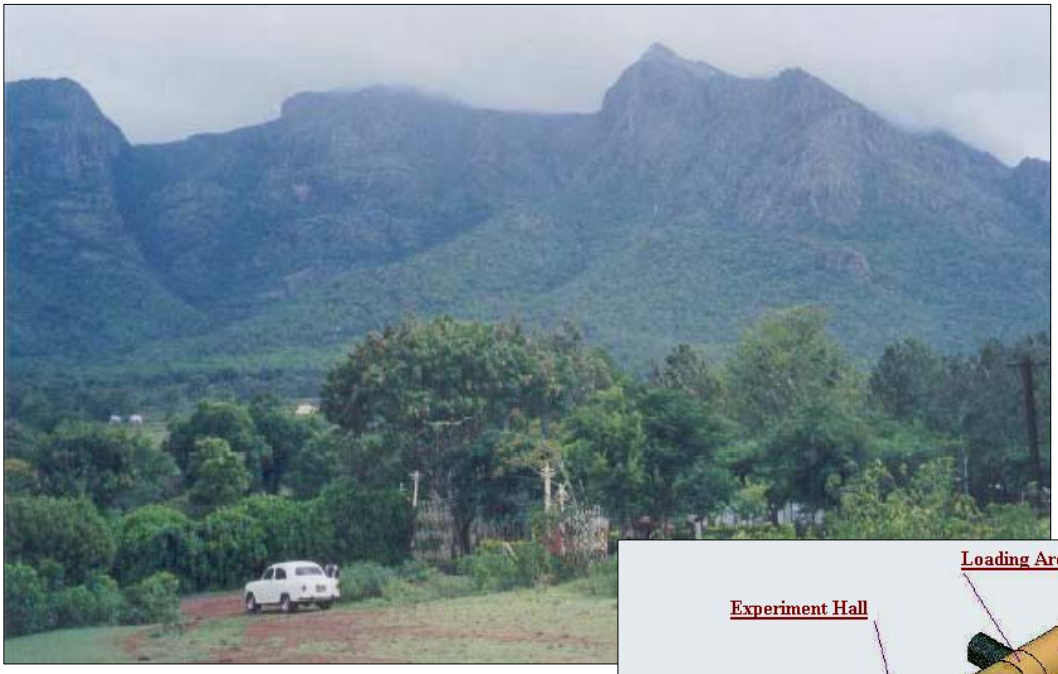
DAE has been developing indigenous supercomputers which are comparable to the best in the world. It is planned to develop internationality competitive state of the art high performance computing platforms, building advanced integrated high capacity network and telecom systems, develop and deploy distributed information systems, R & D in Information security, surveillance and access control systems, new computing paradigms, computational mechanics laboratory at Hall-7 and Upgrade parallel computing system (32 nodes) at HPPD during this plan period.

- Development of internationally competitive state of the art high performance computing platforms by BARC
- R & D in Information security, surveillance and access control systems, new computing paradigms to be taken up
- IT set up at various units of the Department to be upgraded to meet the present day requirements

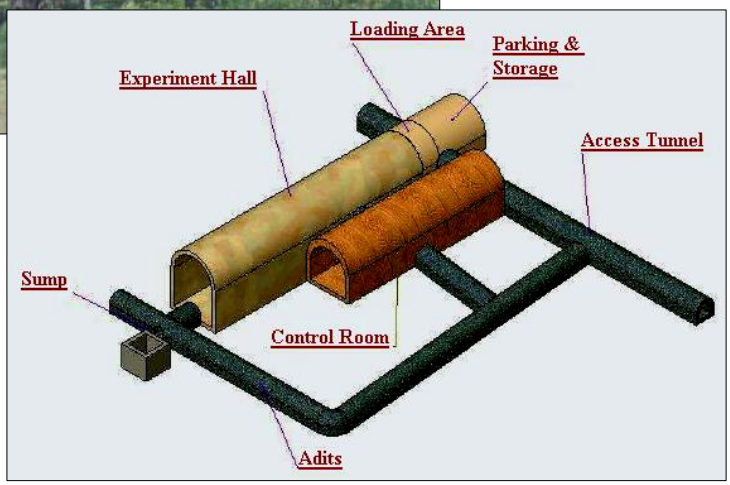
Augmentation of existing IT setup in RRCAT to meet future requirements. This is required for developing various accelerator sub-systems and other programs of RRCAT. The IT facility will be very useful in carrying out simulation studies, storage of design data / results of complex scientific problems. At IGCAR, it is planned to set up centre for advanced visualization and computational intelligence which will provide the state of the art computing facility with compute intensive Clusters, Servers, Workstations and advanced CAD/CAE application software & scientific libraries/tools for the various R&D activities of IGCAR and upgrade the existing computing facility to meet the growing computational requirements of the users. Similar upgradation will be carried out at VECC. Distributed data acquisition on embedded technology and R&D on the state-of-the-art computing techniques, grid computing, image processing is proposed to be carried out at VECC. New computer facility would be created at Rajarhat campus. IMSc, TIFR, SINP and IOP, who are working on the advanced mathematics and computational networks, will continue to upgrade their facilities to meet the challenges in the field.

The India-Based Neutrino Observatory (INO) is the main program in the field of particle physics in the country. The main objectives of this program are study of neutrino oscillation properties in many aspects, starting with atmospheric neutrino study. It is envisaged as a large multi kiloton magnetized iron detector with RPC's as the detector elements. During the X Plan a feasibility study has been in progress. R&D on detectors (glass RPC) has been carried out, the site has been chosen in the

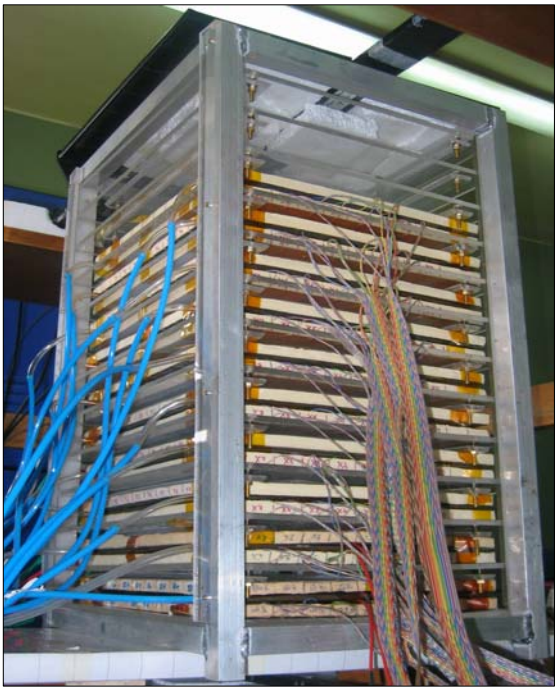
India-Based Neutrino Observatory (INO)



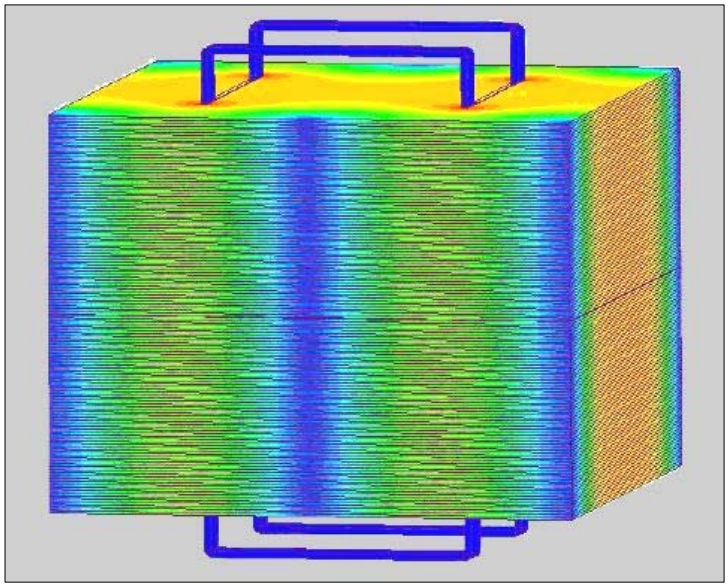
Panoramic view of the mountain peak of PUSHEP. The laboratory cavern will be located directly under this peak.



An artist illustration of the Laboratory Cavern Complex



Stack of 10 Resistive Plate Chambers (RPC) as active detector element for Muon tracking



One module of Iron CALorimeter (ICAL) magnet with coil inserted

Nilgiris in Tamil Nadu, and simulation packages are being set up. During the XI plant it is planned to continue R&D for another 2 years to firmly establish feasibility in all aspects; then to start on a modular construction schedule together with development of the large underground laboratory. This will be a multi-institutional programme with possibility of international participation. INO will be our preparation for participation in international underground experiment.

In the nuclear physics field in the country, currently ongoing programs at various units of the Department including up-gradation of Pelletrons, construction of the Superconducting Cyclotron at VECC etc, shall continue. With such up-gradation, many exciting new studies will be made. In general one may say that one will be carrying out detailed studies of nuclei under extreme conditions. For continuing the work in future, it is planned to set up a National Radioactive Ion Beam Facility (RIB) at VECC, Kolkata. This is a domestic development and needs to be supported. It is also proposed to set up an accelerator for Nuclear Astrophysics studies, FRENA – Facility for Research in Experimental Nuclear Astrophysics, at the new campus of SINP.

In the last decade or so, world over big particle accelerators have been initiated for various applications that range from nuclear waste transmutation to heavy ion therapy for cancer treatment. In India DAE has initiated efforts, at BARC, RRCAT and VECC which are aimed at developing segments of high intensity proton accelerator. Eventually our target is to build spallation neutron sources besides an Advanced RIB facility at VECC. All these activities will be pursued vigorously in the XI Plan.

- A multi-institutional, multi-organisational Indian Neutrino Observatory to be set up. It will be open for international participation
- Using Accelerators like Pelletron, Superconducting cyclotron etc detailed studies of nuclei under extreme conditions will be undertaken
- To set up National Radioactive Ion Beam Facility at VECC, Kolkata
- Facility for Research in Experimental Nuclear Astrophysics (FRENA) will be set up at the new campus of SINP at Rajarhat, Kolkata
- A Centre for Astroparticle physics to be set up at new campus of SINP

A Center for Astroparticle Physics is proposed to be set up at the new SINP/VECC campus at Rajarhat, Kolkata. The broad topics of research would include, search for high energy gamma rays from Gamma Ray Bursts (using HAGAR/MACE), study of high energy neutrinos, R&D for INO detectors, search for

dark matter particles, theoretical research in interface areas of high energy, astrophysics & cosmology, including dark matter and dark energy.

In the field of Advanced Physical Sciences, proposal have been put up for continuing pioneering work in the field of theoretical physics, including inter-institutional projects like the Indian Lattice Gauge Theory Initiative, Astronomy & Astrophysics, Non-accelerator high-energy physics, Nuclear Physics, Atomic, Molecular & Optical sciences, Condensed matter physics. In the Inter-institutional programmes, a new facility at Hanlé involving setting up of telescope is proposed. For studies of ultra-intense relativistic laser-plasma interaction, the existing high power lasers will be upgraded to 100 TW level. These will have important applications in realizing schemes of setting up compact electron accelerators and table-top generation of coherent X-ray radiation and highly charged energetic ions.

It is proposed to create an international centre for Magnetic Resonance in collaboration with DST as equal partners. This will be located at the new TIFR campus. Existing national facility for high field NMR located at TIFR (which is currently supported by DAE, DST, DBT and CSIR) would then be shifted to this international centre.

A new project on Energy Conversion is proposed during this plan. In recent years, there had been significant efforts to harness the alternate sources and carriers of energy and its efficient utilization. This proposal deals with the studies related to energy conversion materials and a variety of activities in Chemical Sciences which are relevant to the Department such as the development of suitable materials for thermopiles, hydrogen generation from water using sulpher-iodine route, catalysts for environmental applications such as abatement of volatile organic compounds, hydrogen mitigation under LOCA condition, ultra-purification of metals and organometallic precursors for semi-conducting materials, mixed oxides for intermediate temperature solid oxide fuel cells and some of the frontline research areas such as synthesis and characterization of nano-structured materials, structural and thermal expansion studies of nano-oxides, photochemical processes at the interface, hydrogen generation via photo-catalytic and ultrasonic processes and its storage, computational studies of Metal clusters and surfaces and other advance

- Improvement in the sensitivity of the TACTIC gamma ray telescope at Mt. Abu and the Low Energy Neutron pile at Gulmarg and setting up of an advanced neutron beam research facility are planned by BARC
- Development of energy conversion technologies to harness alternate sources and carriers of energy and its efficient utilization planned
- R&D work in materials will be carried out at RRCAT to indigenously grow large size non-linear optical crystals, ceramics and thin films for use in lasers, photonics and other devices

functional materials for energy related research. The development and understanding of above materials shall be useful in direct conversion of heat to electricity, enhancing safety of nuclear reactors and production and storage.

At RRCAT, R&D work in materials will be carried out to indigenously grow large size non-linear optical crystals, ceramics and thin films for use in lasers, photonics and other devices. Studies will be performed for growth of nano-structured semiconductors, high–k dielectric films, magnetic, superconducting and ferroelectric materials, for applications in magnetic cooling, development of superconducting RF cavities, actuators & sensors.

Projects on development of new methods of chemical characterization to understand photochemical processes of relevance to fuel reprocessing, Chemical and biophysical approaches for understanding natural processes, Chemical Science viz Chemical Dynamics, Materials Chemistry and Synthetic Chemistry are also proposed to be taken up during the XI Plan.

As a sequel to India joining ITER, projects on Prototype Magnets for Fusion Grade Tokamaks, Prototype Vacuum vessel and Cryopump and Prototype Divertor Casettes aiming at development of prototypes of systems for fusion grade tokamaks on which detailed design information is accessible from ITER but India is not directly involved in the manufacturing. The project will help in acquiring critical technical know how for our own demonstration reactor DEMO development program. The project on Fusion Blanket Technology development aims at R&D on materials and fabrication technologies as well as on tritium handling that is required for the construction of the two ITER Blanket Modules that India as a full partner of ITER, has agreed to submit for testing. This will help in developing tritium breeding blanket technologies for our future fusion reactors. Liquid Breeder Blanket Modules for ITER is a project for the specific development of a liquid breeder blanket module for ITER either using lead-lithium eutectic with ferritic steel as the structural material or a module based on the liquid Lithium with Vanadium alloys as the basic structural material. Solid Breeder Blanket Modules for ITER is for the specific development of helium cooled ceramic solid breeder concept for a Test Blanket Module of ITER. Lithium titanate and lithium silicate pebbles are considered as the breeding material, beryllium as the neutron multiplier material and martensitic steels as the structural material. Negative ion based neutal beams with energies in excess of 1 MeV are considered necessary for heating and current drive in fusion reactor plasmas. This requires the development of large area, high current density, negative ion sources and that of very high voltage steady state power supplies. The project Neutral Beam

Development for Fusion Grade Tokamaks aims at development of first phase prototypes for the ion source and the power supplies in the XI Plan period. The project on Fundamental Plasma Science proposes to carry out a number of basic experiments and upgradation on ADITYA. It is proposed to develop plasmas wakefield accelerators and stationary plasma thrusters. Integrated modeling of tokamak discharges also form important component of the project. SINP proposed to take up project on Deep space plasma propulsion experiments is interesting and relevant to the space programme. It is aimed at starting experiments designed to understand the physics behind the deep space plasma propulsion.

- India's participation in ITER project is to prepare for Indian demonstration fusion reactor DEMO and develop prototypes for future Fusion reactor grade Tokamaks using accessible ITER designs and thereby generate indigenous know how/ technologies required for such machines
- Enhanced R&D efforts on development of nanotechnology under "Micro-Nano Initiative" of DAE at various units of Department

Materials Science and Technology are essential components of the DAE's overall programme. Very rapid developments are occurring in the materials field in all aspects: synthesis, novel properties and ways of measuring them, applications and technology. This is especially true with the enormous effort worldwide in the Nano-scale materials. This is also bringing closer the community of physicists, chemists, material scientists, biologists and engineers. In this respect proposals under the "Micro-Nano Initiative" of DAE have been put up by TIFR, BARC, SINP, IGCAR, CAT and IOP. Nanofabrication Laboratory at TIFR as general purpose DAE facility is planned. Centre for Nanoscale Science and surface physics at SINP is also proposed to be set up. Advanced Electron Microscopy at TIFR and improvement in the TEM facility at IOP are also planned. Physics – Bio interface programme of IOP with linkages to biologists at University/DAE institutions is also proposed during this plan.

India's contribution in the international projects has been highly acclaimed. It is proposed to continue to participate in international projects to be at par with the happening in the international scene. Some of the international collaborations proposed are as given below. All these international participation are multi-institutional and multi-organisational with participation from DST and universities. The proposals include DAEs share of the project cost.

In Particle Physics field, currently ongoing experiments, DZERO, BELLE, PHENIX, STAR will be tapered off by 2009-10. During the XI Plan, successful installation/integration of all detectors in CMS and ALICE will be taken up. LHC machine will start operation in 2007. This will explore a new energy/intensity regime which would enable a definitive search for the Higgs particle, the last missing link in the standard model of particle physics and thought to be responsible for the generation of mass. It would also test predictions of beyond-standard-model scenarios like Super-Symmetry etc, and also probe the nature of QCD again with definitive search for signatures of the quark gluon plasma state of matter. A very rich physics program is anticipated. International Linear Collider (ILC) program for R&D support between 2007-10 and participation from 2010-2025. India has been contacted for participation in the ILC project by various governmental agencies (US, Japanese, ACFA) and participation in the R&D towards the detector and accelerator projects are envisaged. The accelerator side R&D also includes XFEL and high intensity proton source interests for us. At TIFR a project has been included in the XI Plan which would be in the international ILC R&D framework. An India-ILC Forum is being formed to oversee the future participation of India in ILC.

- Ongoing international experiments like DZERO, BELLE, PHENIX, STAR to get completed in the XI Plan
- Participation in new international projects like ILC, XFEL and FAIR for strengthening domestic programme

In the field of Nuclear Physics, participation in the Facility for Antiproton and Ion Research (FAIR) is planned**.** FAIR will be a multidisciplinary facility which will address problems in a number of physics topics that include nuclear physics, astrophysics, particle physics, plasma physics, condensed matter physics, atomic physics etc. GSI is piloting it as an international facility and is in contact with DST, Govt. of India. We can join accelerator or specific physics programs. During the DAE-DST Vision Meeting held in April 2006 a team has been identified to consult the Indian nuclear physics community and come out with a document proposing a scenario for Indian participation in FAIR within 6 months or so. Some proposals are planned to be taken up during the XI plan. DST is expected to take a lead role in this project.

The DAE core research programme on biological effects of radiation and other genotoxic stress on microbes, animal and plant systems, human health and cancer would be expanded. Important leads from the fundamental research in areas such as cell cycle regulation, signaling pathways, apoptosis, DNA repair,

mutagenesis, immune function, development and differentiation will be pursued using high throughput techniques to answer important biological questions and to translate some of them into improving human healthcare in diseases like cancer, malaria, HIV and certain genetic and neurological diseases. Such a directed basic research will include search for mechanisms of radiosensitivity and radioresistance, tools for appropriate drug design, and screening of novel sources of bioactive materials for radioprotection.

Identification and characterization of genes/proteins important in radioresistance and DNA repair will be carried out in *Deinococcus radiodurans,* cyanobacterium *Anabaena* and rice. Gene expression will be examined in Rice cultivars in response to salinity stress. The development of miniaturized bio-analytical systems for separation of biological macromolecules will be initiated. Self assembled nanomaterials and microbial system will be explored for recovery of uranium from sea water and bioremediation.

- DAE core research programme on biological effects of radiation and other genotoxic stresses on microbes, animal and plant systems, human health and cancer would be expanded
- Identification and characterization of genes/proteins important in radioresistance and DNA repair will be carried out
- Development of miniaturized bio-analytical systems for separation of biological macromolecules will be initiated
- Studies on biological and health effects in the human population exposed to continuous high-level natural radiation will be continued to understand the nature of molecular DNA lesions and genes involved in congenital malformation
- Radiation exposed individuals will be monitored to generate information on their immune status and other markers

Development of novel redox-active anti-cancer and anti-ulcer herbal and synthetic drugs and receptor specific radiopharmaceutical ligands will be attempted. To device better radio-protection strategies, structural modifications and physico-chemical characterization will be carried out on important phytochemicals and herbal formulations.

Studies on biological and health effects in the human population exposed to continuous high-level natural radiation will be continued to understand the nature of molecular DNA lesions including cluster damages and to study radio-adaptation. Gene expression profiles of population groups from different dose levels and the genetic basis of malformation and selected diseases will be investigated and correlated with *de novo* mutation. At IGCAR cell-cycle related gene expression will

be monitored in occupationally exposed individuals and premature chromosome condensation will be evaluated as a bio-dosimetry parameter.

Mechanisms of non-targeted radiation effects in the low dose region e.g., bystander effect, genetic instability and clastogenic factors will be further investigated. Occupational radiation workers will be monitored to generate information on their immune status and other markers. Research on decorporation of heavy metal radio-nuclides will be continued to reduce toxicity during occupational / accidental exposure.

Every biological process, be it transport of intracellular cargo by the motor proteins, response of brain to different agents or understanding the development of nervous and other systems and cell death, has its own inherent mechanistic challenges. Over the years TIFR ([Dept. of Biological Science] & National Centre for Biological Studies [NCBS]), BARC and SINP have demonstrated their capabilities in addressing such problems.

Three dimensional structures of several proteins involved in human diseases, parasite invasion or transport of cargo inside the cells will be investigated at BARC, SINP and TIFR. High-resolution structures will be generated and used for drug design and to understand disease pathogenesis. This requires multi-disciplinary expertise including crystallography and spectroscopy, computational structure predictions and model building, gene cloning, sequencing, expression and quantification.

- Mechanistic aspects of intracellular transport, protein folding, cell death and development of nervous and other systems their regulation to be further investigated at TIFR, NCBS, BARC and SINP
- Basic and molecular epidemiological research is proposed for understanding the pathogenesis of malaria and the sex dependent control of host responses along with identification of novel drug targets and vaccine candidates
- In the area of cellular organization and signaling, studies will be carried out on the development of human cervical cancers, regulation of cell death by immune system, protein based regulation of DNA functions and molecular mechanism of endocytosis

At DBS, TIFR existing facilities for imaging, microscopy, tissue culture, electro-physiology, molecular biology, radioactivity laboratory and animal house will be upgraded. Basic research will be pursued towards unraveling the developmental and neurobiological regulations in model organisms. Basic and molecular

epidemiological research is proposed for understanding the pathogenesis of malaria and the sex dependent control of host responses along with identification of novel drug targets and vaccine candidates. Motor-cargo interaction *in vivo* will be studied in *Drosophila* neuron. The relative activity of molecular motors and motor complexes will be monitored using laser based single molecule detection methods. Identification and visualization of molecular interactions that mediate cell shape, cell motility, cell sheet movements and epithelial plasticity will be approached by studying, in time and space, the trans-membrane adhesion molecules that mediate the development of form and function in multi-cellular organisms. Protein based regulation of DNA functions will be further investigated in the context of homologous pairing and recombination, post replication repair and chromosomal translocation in *Drosophila* and yeast. Putative cell-to-cell communication that ensues between normal and apoptotic cells will be studied in the single celled plant *Chlamydomonas reinhardtii*.

At National Centre for Biological Sciences, TIFR, Bangalore up-gradation of several common facilities for DNA sequencing, specialized cell culture, spectroscopy, imaging and computational facilities will be undertaken. A world-class supercomputing infrastructure will also be established. The mechanisms whereby macromolecules attain their functional architecture will be investigated. In the area of cellular organization and signaling, studies will be carried out on the development of human cervical cancers, regulation of cell death by immune system molecular mechanism of endocytosis and regulation of mitochondrial remodeling. Defective genes (alleles) that result in psychiatric diseases will be identified in human population. The presence of multi-allellic traits in human population will be exploited to understand their origin.

At the National Facility for High Field NMR, and the Department of Chemical Sciences, TIFR, new facilities for solid state NMR of proteins will be added to facilitate investigation of many new variants of HIV-1 protease, malarial proteins, metal binding proteins, proteins related to neurodegenerative diseases etc. In-cell NMR of the malarial parasite and spermatozoa will be studied.

- New facilities for solid state NMR of proteins will be added at the National Facility for High Field NMR for investigation of many new variants of HIV-1 protease, malarial proteins, metal binding proteins, proteins related to neurodegenerative diseases etc
- At ACTREC, existing and new leads on potential cancer biomarkers will be validated and these will be developed as diagnostic agents and therapeutic targets through basic, preclinical and clinical studies
- At RRCAT, Indore, studies on the use of lasers for biomedical imaging, diagnosis, manipulation and processing of biological samples will be continued

At ACTREC, existing and new leads on potential cancer biomarkers will be validated and developed as diagnostic agents and therapeutic targets through basic, preclinical and clinical studies. Facilities for basic biological research, transgenic/knock out /Nude/SCID mice, advanced animal imaging and anti cancer drug screening will be refined and expanded. Basic cancer research in focus areas such Glycobiology, Stem cell biology, Bioinformatics, Pharmacogenetics, Molecular mechanisms of translocations, Physical Biochemistry/Structural Biology, Virology, Chemoprevention, Epidemiology and animal models etc. will be initiated and/or strengthened. To harness the full potential of stem cells, studies to understand the mechanisms regulating the differentiation of stem cells into different cell types would be initiated at the BARC, TIFR and ACTREC which may lead to clinical studies.

At RRCAT, Indore, studies on the use of lasers for biomedical imaging, diagnosis, manipulation and processing of biological samples will be continued. Polarization sensitive and Fourier domain Optical Coherence Tomography will be developed for dermatological & dental applications. Studies will also be initiated on the use of near field effects on light scattering, polymeric and coated metal nanoparticles, photodynamic therapy and laser micromanipulation techniques for various biomedical applications. The use of electron beam for processing of polymers and synthesis of biocompatible nanogels and hydrogels will also be investigated.

4.3.6 Major Programme 6: Research Education Linkage

Research Education linkage has been the backbone in development of scientific manpower for the country and within the Department. As we move from the first stage to the second stage of our power programme, we will need more trained scientific manpower in the field of fast reactors. In the XI plan, a training school at IGCAR, Kalpakkam as an affiliate of the BARC Training School will be

started. It will cater to the needs of the Fast Breeder Reactor programme of DAE. It is planned to have a separate training school for AMD in lines with other training schools in the Department. This will help organize various training programmes for updating the technical skills and enthuse multi-disciplinary approach to all levels of employees. The new employees of AMD would be trained at this training school before they take up their assignments.

- Training School as an affiliate of BARC Training School to be started at IGCAR for trained manpower required for second stage of our NPP
- Training School for AMD in lines with other training schools in the Department
- DAE Administrative Training Institute for personnel in support services

A DAE Administrative Training Institute is also planned to be set up for training (both induction and in service) on a regular and continuous basis, personnel in the support services like Administration, Accounts, Purchase, Stores, Security, etc. The institute will also conduct programmes for Scientific/Technical personnel on project management, works/purchase procedures, Financial Management, etc. as also tailor made programmes for PSUs/Aided Institutions under DAE.

A major initiative taken in the X Plan is in setting up of Homi Bhabha National Institute (HBNI) as deemed university. A campus is proposed to be set up at Visakhapatnam for pursuing the activities of HBNI. Increasing intake of students by increasing number of DAE fellowships for pursuing Ph.D. under HBNI is planned. This will also require development of additional infrastructure in terms of building hostels. DAE-Mumbai University Centre for Excellence will be set up in Mumbai to conduct five years integrated B.Sc.-M.Sc. programme in Sciences. It is also proposed to increase the outlay for the extra mural research presently being funded through Board for Research in Nuclear Sciences (BRNS) and National Board of Higher Mathematics (NBHM). To further expand the activities of Homi Bhabha Centre for Science Education (HBCSE), new laboratories for educational purposes will be set up. These will be oriented especially to the needs of the Olympiad programmes. The programmes at the Centre of Advanced Research and Education (CARE), set up at SINP under X Plan will be strengthened further.

- HBNI to help increase intake of PhD students and development of scientific manpower for the Department
- DAE-Mumbai University Centre for Excellence will be set up in Mumbai to conduct five years integrated B.Sc.-M.Sc. programme in Sciences

In the recent visit of Honorable Prime Minister of India Dr Manmohan Singh to Institute of Physics, Bhubaneshwar on 28th August 2006, PM announced setting up of National Institute of Science Education and Research (NISER) at Bhubaneshwar. He announced that NISER will be at par with the IISER being established in other places but will operate under the umbrella of DAE. It will undertake integrated 5-yr Masters courses in core and emerging branches of science to provide world-class educations to students after the 10+2 stage. It can also include an integrated M.Sc-Ph.D. after graduation level.

Excerpt from Prime Ministers Speech at IOP, Bhubaneshwar on 28th August 2006.

"……I am particularly delighted that my first visit to this State is associated with the announcement of the establishment of the National Institute of Science Education and Research……"

"……NISER will be at par with the IISER being established in other places but will operate under the umbrella of DAE. It will undertake integrated 5-year Masters courses in core and emerging branches of science to provide world-class education to students after the 10+2 stage. It can also include an integrated M.Sc.-Ph.D. after graduation level……."

"….While working within the DAE family and awarding degrees under the Homi Bhabha National Institute (HBNI), which is already a Deemed University for post-graduate studies, NISER will be an institute at par with the best in the country in terms of facilities and faculty. It will have a research to teaching load as practiced in the best universities in the world. This will ensure world class education and also attract the best researchers. It will have world-class experimental facilities in all the current and emerging branches of science including physics, chemistry, modern biology and environmental sciences. We will provide enough resources to DAE to convert this into reality within a very short time frame….."

"…I am confident that the National Institute of Science Education and Research will become a Mecca for science just as TIFR and IISc are today. ……"

Improvement of Scientific Information Resources in all units including up-gradation of conventional and digital libraries is aimed during the XI pan. Also for Improving infrastructure for holding national and international symposia at various DAE units, a convention centre at HRI, Allahabad and another at BARC, Mumbai are planned. Modernization of Administrative set-up including setting up of an integrated information system for DAE and its constituent units enabling seamless flow of information across HRD, finance, accounting, procurement, health care,

infrastructure development and all administrative functions is also planned during this period.

- BRNS and NBHM to continue funding research in nuclear field and Mathematics
- To further expand the activities of HBCSE, new laboratories for educational purposes will be set up especially for training students for Olympiad programmes
- Prospective Research Fund introduced

A new initiative has been undertaken for doing basic research in complimentary areas of the existing projects and to enrich the scientific knowledge of the Departmental personnel in the form of Prospective Research Funding. Details of this initiative are given in subsequent paras.

4.3.7 Major Programme 7: Infrastructure & Housing

To meet the requirements of expanding programmes of the Department, investment in infrastructure is a must. Infrastructure at the existing units is proposed to be strengthened. This will involve renovation of many existing buildings, new quarters, hostels, auditorium, convention centre, development of roads, water pipelines, electrical work modernization, up-gradation of fire emergency services, new research laboratories at BARC, residential quarters for CISF security personnel, crèche facility at Anushaktinagar etc. Some of these upgrades are essential due to strengthening of security in and around DAE installations. Expansion of NCBS campus at Bangalore, new medical enclave at IGCAR etc is also proposed. A new campus is being developed at Rajarhat in Kolkata for VECC/SINP and at Visakhapatnam for BARC. An additional campus for IPR and TIFR is also planned at Gandhinagar and Mumbai respectively. In the new campus, there are several projects planned. Each of these project costs includes cost of infrastructure development required for the project at this new campus. A Training School building is proposed to be constructed for IGCAR, Kalpakkam, AMD at Hyderabad, and DAE Administrative institute at Mumbai. It is also proposal for setting up building at Anushaktinagar for outstation organization of DAE. Setting up of NISER at IOP will also be taken up. New office building and laboratories are also proposed to be constructed.

- New campus planned for BARC at Visakhapatnam, IPR at Gandhinagar, TIFR at Mumbai and VECC/SINP at Rajarhat, Kolkata
- Expansion of NCBS campus at Bangalore to be taken up
- Campus for HBNI at Visakhapatnam

- Training School building to be constructed for IGCAR at Kalpakkam, AMD at Hyderabad and DAE Administrative Institute at Mumbai
- Construction of convention centre at Mumbai and auditorium for HRI at Allahabad planned
- Hostels and family accommodation for large participation of research scholars in Departmental programmes at all our major R&D centers
- Strengthening of infrastructure development for security reasons
- Upgradation and maintenance of existing infrastructure
- Construction of new housing colony at various units including quarters for CISF personnel

During this plan, it is proposed to have a large participation of research scholars in the Departmental programmes at all our major R&D Centers. Development of additional infrastructure for this floating research scientists such as hostel accommodations, quarters for married research scholars etc need to be created and the same are proposed.

4.4 Prospective Research

It is proposed to introduce a new element in the XI Plan and it is creation of a 'Prospective Research Fund (PRF)'. It will be operated on lines similar to BRNS. Project proposals will be invited from units within the Department. This would primarily bring in some flexibility for pursuing basic research. While most of the plan projects of the Department are mission oriented and contribute to the overall goals of the Department, the proposals through this fund would facilitate research on new ideas that could arise during the plan period. The fund would also enable the Department to fill critical gap that might arise during the course of XI plan.

The project proposals will be invited from within the constituent units and autonomous bodies under this department covering mainly the following areas which will be considered for funding under this scheme.

- Basic Research complimentary to the major projects proposed to be taken up during XI plan

- Filling up critical gap areas that might arise during the course of XI plan period

- Enrichment of scientific knowledge and stimulating futuristic research

The proposals could be mainly from small research groups/individuals needing funding for curiosity driven research in areas of relevance. The proposals received will be examined by specialist groups constituted by DAE on the same pattern as advisory committees of BRNS that examine proposals under BRNS funding. The funding under this scheme will be on competitive basis and it is possible that the research complimentary to major projects might get done in a unit different from where the major project is being done. The projects under this scheme will be reviewed periodically by the same specialist group which recommended it for funding in the first place. The existing administrative mechanism of BRNS will be followed for funding the projects under this scheme.

4.5 Listing of proposals

Major programme wise listing of all proposals under consideration is given as Annex to this chapter.

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
MAJOR PROGRAMME - 1: NUCLEAR POWER PROGRAMME - STAGE - 1					
	PRESSURISED HEAVY WATER REACTOR				
	Continuing Schemes				
10-R&D-BAR-1.01-0100	Advanced Reactors-Design & Technology Development	40.05	33.05	7.00	0.00
10-R&D-BAR-1.01-0200	PHWR-Fuels, Material Development, Safety & Water Chemistry studies	40.97	30.97	10.00	0.00
	TOTAL CS - PHWR	**81.02**	**64.02**	**17.00**	**0.00**
	New Schemes				
11-R&D-BAR-1.01-0100	R&D for Heavy Water Reactors	45.50	0.00	45.50	0.00
	TOTAL NS - PHWR	**45.50**	**0.00**	**45.50**	**0.00**
	TOTAL CS + NS - PHWR	**126.52**	**64.02**	**62.50**	**0.00**
	LIGHT WATER REACTOR				
	Continuing Scheme				
10-R&D-BAR-1.02-0100	Light Water Reactor Development	10.70	7.30	3.40	0.00
	TOTAL CS - LWR	**10.70**	**7.30**	**3.40**	**0.00**
	New Scheme				
11-R&D-BAR-1.02-0100	R&D for Improved Rotor Performance	89.00	0.00	69.00	20.00
	TOTAL NS - LWR	**89.00**	**0.00**	**69.00**	**20.00**
	TOTAL CS + NS - LWR	**99.70**	**7.30**	**72.40**	**20.00**
	FRONT END FUEL CYCLE				
	Continuing Schemes				
10-R&D-AMD-1.03-0100	Augmentation of Uranium Resources	78.78	61.72	17.06	0.00
10-R&D-AMD-1.03-0200	Technology Demonstration & Infrastructure Development	11.29	5.86	5.43	0.00
10-R&D-BAR-1.03-0100	Uranium extraction process development	12.00	8.80	3.20	0.00
	TOTAL CS - FRONT END FUEL CYCLE	**102.07**	**76.38**	**25.69**	**0.00**
	New Schemes				
11-R&D-AMD-1.03-0100	Augmentation of airborne and ground geophysical capabilities	77.00	0.00	77.00	0.00
11-R&D-AMD-1.03-0200	Augmentation of Laboratory Facilities	30.00	0.00	30.00	0.00
11-R&D-AMD-1.03-0300	Infrastructure Facilities for Field Related Activities	6.00	0.00	6.00	0.00
11-R&D-AMD-1.03-0400	Uranium Investigations in Proterozoic Basins	34.00	0.00	34.00	0.00
11-R&D-AMD-1.03-0500	Uranium Investigations in Iron Oxide Breccia, QPC, Sandstone & Calcrete type of Deposits	30.00	0.00	25.00	5.00
11-R&D-BAR-1.03-0100	R&D support in Front End Fuel Cycle	78.35	0.00	78.35	0.00
	TOTAL NS - FRONT END FUEL CYCLE	**255.35**	**0.00**	**250.35**	**5.00**
	TOTAL CS + NS - FRONT END FUEL CYCLE	**357.42**	**76.38**	**276.04**	**5.00**
	BACK END FUEL CYCLE				
	Continuing Scheme				
10-R&D-BAR-1.04-0100	Back End Fuel Cycle Development Studies	49.66	17.16	32.50	0.00
	TOTAL CS - BACK END FUEL CYCLE	**49.66**	**17.16**	**32.50**	**0.00**
	New Schemes				
11-R&D-BAR-1.04-0100	R&D in Back-End processes	94.50	0.00	84.50	10.00
11-R&D-BAR-1.04-0200	Fuel Cycle Research Centre	100.00	0.00	100.00	0.00
	TOTAL NS - BACK END FUEL CYCLE	**194.50**	**0.00**	**184.50**	**10.00**
	TOTAL CS + NS - BACK END FUEL CYCLE	**244.16**	**17.16**	**217.00**	**10.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	HEALTH, SAFETY & ENVIRONMENT				
	Continuing Schemes				
10-R&D-BAR-1.05-0100	Health Safety and Environment programmes	36.06	31.26	4.80	0.00
10-R&D-BAR-1.05-0200	Radiation Emergency Response System	9.25	7.25	2.00	0.00
	TOTAL CS - HS & E	**45.31**	**38.51**	**6.80**	**0.00**
	New Schemes				
11-R&D-BAR-1.05-0100	Safety Related Research	88.20	0.00	88.20	0.00
11-R&D-BAR-1.05-0200	Environmental Studies	35.50	0.00	35.50	0.00
11-R&D-DAE-1.05-0100	DAE Emergency Response Centre	5.00	0.00	5.00	0.00
	TOTAL NS - HS & E	**128.70**	**0.00**	**128.70**	**0.00**
	TOTAL CS + NS - HS & E	**174.01**	**38.51**	**135.50**	**0.00**
	TOTAL - MP-1: NPP - STAGE - 1	**1,001.80**	**203.36**	**763.44**	**35.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
MAJOR PROGRAMME - 2: NUCLEAR POWER PROGRAMME - STAGE - 2					
	FAST REACTORS				
	Continuing Scheme				
10-R&D-IGC-2.01-0405	PFBR Full Scope Replica Training Simulator	12.10	10.00	2.10	0.00
10-R&D-IGC-2.01-0500	Research and Development for FBRs	20.55	11.74	8.81	0.00
	TOTAL CS - FAST REACTORS	**32.65**	**21.74**	**10.91**	**0.00**
	New Schemes				
11-R&D-IGC-2.01-0100	Providing infrastructure for SNM storage and fuel assembly in FBTR complex	10.19	0.00	10.19	0.00
11-R&D-IGC-2.01-0200	Life Extension of FBTR	16.13	0.00	16.13	0.00
11-R&D-IGC-2.01-0300	Augmentation of Central Workshop facilities	5.48	0.00	5.48	0.00
11-R&D-IGC-2.01-0400	Engineering Development & testing for FBR	53.54	0.00	49.26	4.28
11-R&D-IGC-2.01-0500	KAMINI & PFBR experiments & collaboration	1.40	0.00	1.40	0.00
11-R&D-IGC-2.01-0600	Continuing Structural Mechanics Experiments with state-of-art instrumentation	37.65	0.00	37.65	0.00
11-R&D-IGC-2.01-0700	Civil Engg. Design of FBR	5.15	0.00	5.15	0.00
11-R&D-IGC-2.01-0800	State-of-Art Modern Design Office	10.07	0.00	5.07	5.00
	TOTAL NS - FAST REACTORS	**139.61**	**0.00**	**130.33**	**9.28**
	TOTAL CS + NS - FAST REACTORS	**172.26**	**21.74**	**141.24**	**9.28**
	MATERIALS				
	New Schemes				
11-R&D-BAR-2.02-0100	Fuels for Fast Reactors	32.00	0.00	32.00	0.00
11-R&D-IGC-2.02-0100	Materials Development and Characterisation	60.46	0.00	54.46	6.00
	TOTAL - NS - MATERIALS	**92.46**	**0.00**	**86.46**	**6.00**
	TOTAL CS + NS - MATERIALS	**92.46**	**0.00**	**86.46**	**6.00**
	FBR-FRONT END FUEL CYCLE				
	New Schemes				
11-R&D-IGC-2.03-0100	Fuel Fabrication	13.63	0.00	13.63	0.00
11-R&D-IGC-2.03-0200	Design and development of I&C systems for FBR.	13.28	0.00	11.28	2.00
11-R&D-IGC-2.03-0300	Fast Reactor Fuel Chemistry	17.14	0.00	15.18	1.96
11-R&D-IGC-2.03-0400	Sodium Chemistry	7.53	0.00	7.53	0.00
	TOTAL NS - FBR - FRONT END FUEL CYCLE	**51.58**	**0.00**	**47.62**	**3.96**
	TOTAL CS + NS - FBR - FRONT END FUEL CYCLE	**51.58**	**0.00**	**47.62**	**3.96**
	FBR - BACK END FUEL CYCLE				
	New Schemes				
11-R&D-IGC-2.04-0100	Back End Fuel Cycle	13.01	0.00	9.83	3.18
11-R&D-IGC-2.04-0200	R&D in FBR fuel reprocessing	43.59	0.00	39.89	3.70
11-R&D-IGC-2.04-0300	Measurement tools for the assay of fissile materials	11.92	0.00	11.92	0.00
11-R&D-IGC-2.04-0400	Development of process for separation of strontium, cesium, lanthanides and actinides from simulated wastes	6.26	0.00	6.26	0.00
	TOTAL NS - FBR - BACK END FUEL CYCLE	**74.78**	**0.00**	**67.90**	**6.88**
	TOTAL CS + NS - FBR - BACK END FUEL CYCLE	**74.78**	**0.00**	**67.90**	**6.88**
	REPAIR AND INSPECTION TECHNOLOGIES				
	New Scheme				
11-R&D-IGC-2.05-0100	Development of technologies for inspection, irradiation experiments and remote handling for FBRs and fuel cycle facilities.	33.85	0.00	30.35	3.50
11-R&D-IGC-2.05-0200	Advanced Inspection, QA and QM of fast reactor components	11.02	0.00	11.02	0.00
	TOTAL NS - REPAIR AND INSPECTION TECHNOLOGIES	**44.87**	**0.00**	**41.37**	**3.50**
	TOTAL CS + NS - REPAIR AND INSPECTION TECHNOLOGIES	**44.87**	**0.00**	**41.37**	**3.50**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	FBR - HEALTH, SAFETY & ENVIRONMENT				
	New Scheme				
11-R&D-IGC-2.06-0100	Radiological Safety Studies	16.72	0.00	14.97	1.75
11-R&D-IGC-2.06-0200	Engineering Safety	7.21	0.00	7.21	0.00
11-R&D-IGC-2.06-0300	Environmental & Industrial Safety	3.62	0.00	3.62	0.00
	TOTAL NS - FBR-HEALTH, SAFETY & ENVIRONMENT	**27.55**	**0.00**	**25.80**	**1.75**
	TOTAL CS + NS - FBR-HEALTH, SAFETY & ENVIRONMENT	**27.55**	**0.00**	**25.80**	**1.75**
	TOTAL - MP-2: NPP - STAGE - 2	**463.50**	**21.74**	**410.39**	**31.37**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
MAJOR PROGRAMME - 3: NUCLEAR POWER PROGRAMME - STAGE - 3 AND BEYOND					
	ADVANCED HEAVY WATER REACTOR				
	Continuing Schemes				
10-R&D-BAR-3.01-0100	Technology Development for Fueling Systems & Control systems for Refueling	16.80	6.80	10.00	0.00
10-R&D-BAR-3.01-0200	AHWR Design Validation, Testing, Inspection & Repair Technologies	46.35	22.35	24.00	0.00
	TOTAL CS - AHWR	**63.15**	**29.15**	**34.00**	**0.00**
	New Scheme				
11-R&D-BAR-3.01-0100	Advanced Nuclear Reactor Development	85.00	0.00	71.50	13.50
	TOTAL NS - AHWR	**85.00**	**0.00**	**71.50**	**13.50**
	TOTAL CS + NS - AHWR	**148.15**	**29.15**	**105.50**	**13.50**
	THORIUM FUEL CYCLE				
	Continuing Scheme				
10-R&D-BAR-3.02-0100	Thorium Fuel cycle Technology development and U233 clean Up	73.38	29.38	44.00	0.00
	TOTAL CS - THORIUM FUEL CYCLE	**73.38**	**29.38**	**44.00**	**0.00**
	New Scheme				
11-R&D-BAR-3.02-0100	Thorium Technologies	47.00	0.00	40.00	7.00
	TOTAL NS - THORIUM FUEL CYCLE	**47.00**	**0.00**	**40.00**	**7.00**
	TOTAL CS + NS - THORIUM FUEL CYCLE	**120.38**	**29.38**	**84.00**	**7.00**
	OTHER THORIUM REACTOR SYSTEMS				
	Continuing Scheme				
10-R&D-BAR-3.03-0100	Development Programmes for Advanced Nuclear Reactors	7.90	5.20	2.70	0.00
	TOTAL CS - OTHER THORIUM REACTOR SYSTEMS	**7.90**	**5.20**	**2.70**	**0.00**
	New Scheme				
11-R&D-BAR-3.03-0100	High Temperature Reactor Development Programme at Vizag	93.00	0.00	67.50	25.50
	TOTAL NS - OTHER THORIUM REACTOR SYSTEMS	**93.00**	**0.00**	**67.50**	**25.50**
	TOTAL CS + NS - OTHER THORIUM REACTOR SYSTEMS	**100.90**	**5.20**	**70.20**	**25.50**
	ACCELERATOR DRIVEN SUBCRITICAL SYSTEMS				
	Continuing Schemes				
10-R&D-BAR-3.04-0100	Physics studies and Technology Development	38.94	10.44	28.50	0.00
10-R&D-CAT-3.04-0100	High Current Proton Linac and Synchrotron for Spallation Neutron Source	28.49	12.09	16.40	0.00
10-R&D-VEC-3.04-0100	Development of High Current Cyclotron for ADSS PH I	5.41	3.41	2.00	0.00
	TOTAL CS - ADSS	**72.84**	**25.94**	**46.90**	**0.00**
	New Scheme				
11-R&D-VEC-3.04-0100	Development of High Current Cyclotron for ADSS	37.00	0.00	25.00	12.00
	TOTAL NS - ADSS	**37.00**	**0.00**	**25.00**	**12.00**
	TOTAL CS + NS - ADSS	**109.84**	**25.94**	**71.90**	**12.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	MATERIALS				
	Continuing Scheme				
10-R&D-BAR-3.05-0100	Materials for NPP-Stage-III	**12.70**	**6.70**	**6.00**	**0.00**
	TOTAL CS - MATERIALS	**12.70**	**6.70**	**6.00**	**0.00**
	New Schemes				
11-R&D-BAR-3.05-0100	High Temperature Materials	42.50	0.00	36.50	6.00
11-R&D-BAR-3.05-0200	Special Materials for High Temperature Reactors at Vizag	95.00	0.00	20.00	75.00
11-R&D-BAR-3.05-0300	Fusion Reactor Material Development	19.00	0.00	19.00	0.00
	TOTAL NS - MATERIALS	**156.50**	**0.00**	**75.50**	**81.00**
	TOTAL CS + NS - MATERIALS	**169.20**	**6.70**	**81.50**	**81.00**
	HYDROGEN ENERGY				
	New Scheme				
11-R&D-BAR-3.06-0100	Hydrogen Energy	47.00	0.00	30.00	17.00
	TOTAL NS - HYDROGEN ENERGY	**47.00**	**0.00**	**30.00**	**17.00**
	TOTAL CS + NS - HYDROGEN ENERGY	**47.00**	**0.00**	**30.00**	**17.00**
	FUSION REACTOR				
	New Scheme				
11-R&D-IPR-3.07-0100	ITER-India	2,500.00	0.00	1,489.62	1,010.38
	TOTAL NS - FUSION REACTOR	**2,500.00**	**0.00**	**1,489.62**	**1,010.38**
	TOTAL CS + NS - FUSION REACTOR	**2,500.00**	**0.00**	**1,489.62**	**1,010.38**
	TOTAL - MP-3: NPP - STAGE - 3	**3,195.47**	**96.37**	**1,932.72**	**1,166.38**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
MAJOR PROGRAMME - 4: ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS					
	RESEARCH REACTORS				
	New Scheme				
11-R&D-BAR-4.01-0100	Research Reactors	48.50	0.00	48.50	0.00
11-R&D-BAR-4.01-0200	Multi Purpose Research Reactor and Isotope Processing Laboratory at Vizag	320.00	0.00	122.00	198.00
11-R&D-IGC-4.01-0100	Modernisation of Safety Critical Instrumentation of KAMINI Reactor	2.50	0.00	2.50	0.00
	TOTAL NS - RESEARCH REACTORS	**371.00**	**0.00**	**173.00**	**198.00**
	TOTAL CS + NS - RESEARCH REACTORS	**371.00**	**0.00**	**173.00**	**198.00**
	ISOTOPE PROCESSING				
	Continuing Scheme				
10-R&D-BAR-4.02-0100	Isotope Processing	1.85	1.25	0.60	0.00
	TOTAL CS - ISOTOPE PROCESSING	**1.85**	**1.25**	**0.60**	**0.00**
	New Schemes				
11-R&D-BAR-4.02-0100	Isotopes & Radiation Technologies	65.25	0.00	25.25	40.00
11-R&D-SIN-4.02-0100	Trace Analysis: Detection, Dynamics and Speciation (TADDS)	5.01	0.00	5.01	0.00
	TOTAL NS - ISOTOPE PROCESSING	**70.26**	**0.00**	**30.26**	**40.00**
	TOTAL CS + NS - ISOTOPE PROCESSING	**72.11**	**1.25**	**30.86**	**40.00**
	AGRICULTURE				
	Continuing Scheme				
10-R&D-BAR-4.03-0100	Research on Agricultural products	8.50	7.40	1.10	0.00
	TOTAL CS - AGRICULTURE	**8.50**	**7.40**	**1.10**	**0.00**
	New Scheme				
11-R&D-BAR-4.03-0100	Nuclear Agriculture	75.00	0.00	25.00	50.00
	TOTAL NS - AGRICULTURE	**75.00**	**0.00**	**25.00**	**50.00**
	TOTAL CS + NS - AGRICULTURE	**83.50**	**7.40**	**26.10**	**50.00**
	FOOD PROCESSING				
	New Scheme				
11-R&D-BAR-4.04-0100	R&D in Radiation Technology for Food Preservation and Hygeinization	8.25	0.00	8.25	0.00
	Total NS - Food Processing	**8.25**	**0.00**	**8.25**	**0.00**
	Total CS + NS - Food Processing	**8.25**	**0.00**	**8.25**	**0.00**
	HEALTH				
	Continuing Scheme				
10-R&D-BAR-4.05-0100	Radiation Medicine, Radiation Effects and Health Care	19.24	13.64	5.60	0.00
10-R&D-TMC-4.05-0100	Up gradation of facility	43.00	0.00	43.00	0.00
10-R&D-TMC-4.05-0200	Cancer Registry	5.00	0.00	5.00	0.00
10-R&D-VEC-4.05-0100	Nuclear diagnostics	5.80	3.80	2.00	0.00
10-R&D-VEC-4.05-0200	Setting up 30 MeV medical cyclotron	73.10	15.56	57.54	0.00
	TOTAL CS - HEALTH	**146.14**	**33.00**	**113.14**	**0.00**
	New Schemes				
11-R&D-BAR-4.05-0100	Augmentation of Healthcare Services	74.00	0.00	74.00	0.00
11-R&D-IGC-4.05-0100	Up gradation of medical facilities at Anupuram/Kalpakkam (*)	12.75	0.00	10.75	2.00
11-R&D-TMC-4.05-0100	Automation and Tele Services	17.50	0.00	17.50	0.00
11-R&D-TMC-4.05-0200	Service and Outreach Programme	67.00	0.00	67.00	0.00
11-R&D-TMC-4.05-0300	Infrastructure Development	21.50	0.00	21.50	0.00
11-R&D-TMC-4.05-0400	Development of Cancer Care Facility at Shillong and Ranchi	50.00	0.00	50.00	0.00
11-R&D-VEC-4.05-0100	Nuclear Diagnostics and Medical use of PET	15.00	0.00	15.00	0.00
	TOTAL NS - HEALTH	**257.75**	**0.00**	**255.75**	**2.00**
	TOTAL CS + NS - HEALTH	**403.89**	**33.00**	**368.89**	**2.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	WATER				
	New Scheme				
11-R&D-BAR-4.06-0100	Desalination & Water Purification Technologies	77.00	0.00	44.00	33.00
	TOTAL NS - WATER	**77.00**	**0.00**	**44.00**	**33.00**
	TOTAL CS + NS - WATER	**77.00**	**0.00**	**44.00**	**33.00**
	INDUSTRIAL APPLICATIONS				
	Continuing Scheme				
10-R&D-CAT-4.07-0100	Accelerator and LASER development for industrial applications	17.80	10.81	6.99	0.00
	TOTAL CS - MFG. TECH. AND INDUS. APPLNS.	**17.80**	**10.81**	**6.99**	**0.00**
	TOTAL CS + NS - MFG. TECH. AND INDUS. APPLNS.	**17.80**	**10.81**	**6.99**	**0.00**
	ACCELERATORS				
	Continuing Scheme				
10-R&D-CAT-4.08-0100	Development of Linear Accelerator based Far-Infra-red Free Electron Laser	5.20	4.58	0.62	0.00
	TOTAL CS - ACCELERATORS	**5.20**	**4.58**	**0.62**	**0.00**
	New Schemes				
11-R&D-BAR-4.08-0100	Accelerator & ADS Technologies	94.25	0.00	71.25	23.00
11-R&D-CAT-4.08-0100	Improvement in Indus Accelerators	57.45	0.00	57.45	0.00
11-R&D-CAT-4.08-0200	Indus-2 Beam Line Development Programme	44.50	0.00	44.50	0.00
11-R&D-CAT-4.08-0300	Development of Superconducting Cavities and Associated Technologies for High Energy Accelerators	91.88	0.00	73.38	18.50
11-R&D-CAT-4.08-0400	High Current Proton Injector Linac for SNS	83.35	0.00	75.70	7.65
11-R&D-CAT-4.08-0500	Proton Synchrotron Sub- System	41.20	0.00	41.20	0.00
11-R&D-CAT-4.08-0600	Infrastructure for Evaluation & Qualification of Advanced Accelerator Subsystems	43.35	0.00	43.35	0.00
11-R&D-CAT-4.08-0700	Participation in Advanced International Accelerator programme like, X-ray Free Electron Laser (XFEL) & International Linear Collider (ILC)	40.00	0.00	30.00	10.00
11-R&D-IOP-4.08-0100	Development of an ECR Ion Source (ECRIS) based High Current Low-to-Medium-Energy Ion Beam Facility	5.50	0.00	5.50	0.00
11-R&D-TFR-4.08-0100	Inter-Institutional Research Programme-III	30.00	0.00	30.00	0.00
11-R&D-TFR-4.08-0200	Atomic & Optical Science	11.00	0.00	11.00	0.00
11-R&D-VEC-4.08-0100	Design, analysis and development of high-β multicell superconducting RF linac cavity	15.00	0.00	15.00	0.00
11-R&D-VEC-4.08-0200	Development of 250 MeV High temperature Superconducting Cyclotron for Proton therapy	85.00	0.00	70.00	15.00
11-R&D-VEC-4.08-0300	Development of nano-ion beam implanter and related technology	30.00	0.00	30.00	0.00
	TOTAL NS - ACCELERATORS	**672.48**	**0.00**	**598.33**	**74.15**
	TOTAL CS +NS - ACCELERATORS	**677.68**	**4.58**	**598.95**	**74.15**
	LASERS				
	New Schemes				
11-R&D-CAT-4.09-0100	Development of narrow line width tunable laser system and applications	25.63	0.00	25.63	0.00
11-R&D-CAT-4.09-0200	Instrumentation and Optics related to Lasers	22.52	0.00	22.52	0.00
	TOTAL NS - LASERS	**48.15**	**0.00**	**48.15**	**0.00**
	TOTAL CS + NS - LASERS	**48.15**	**0.00**	**48.15**	**0.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	SPECIAL MATERIALS				
	Continuing Schemes				
10-R&D-BAR-4.10-0100	High Performance Rotor Development & Infrastructure	240.09	173.09	67.00	0.00
10-R&D-BAR-4.10-0200	Strategic Materials Development	27.23	18.23	9.00	0.00
10-R&D-BAR-4.10-0300	Manufacturing and processing technology development	39.00	28.65	10.35	0.00
	TOTAL CS - SPECIAL MATERIALS	**306.32**	**219.97**	**86.35**	**0.00**
	New Scheme				
11-R&D-BAR-4.10-0100	Special Materials Development	450.00	0.00	400.00	50.00
	TOTAL NS - SPECIAL MATERIALS	**450.00**	**0.00**	**400.00**	**50.00**
	TOTAL CS +NS - SPECIAL MATERIALS	**756.32**	**219.97**	**486.35**	**50.00**
	ADVANCED TECHNOLOGIES				
	Continuing Schemes				
10-R&D-BAR-4.11-0100	Liquid He/ He Refrigeration System & Fuel Cell Development	32.50	21.50	11.00	0.00
10-R&D-BAR-4.11-0200	Electronics and Instrumentation control systems	42.78	32.78	10.00	0.00
10-R&D-BAR-4.11-0300	Centre for Micro Electronics and MEMS	10.00	5.00	5.00	0.00
10-R&D-BAR-4.11-0400	Micro-Nano Technology programme and related areas	34.02	14.02	20.00	0.00
10-R&D-BAR-4.11-0500	Development of coating facility for long hard x-ray mirrors	3.00	1.00	2.00	0.00
10-R&D-BAR-4.11-0600	Development of Beam Technology for Nuclear and Non-Nuclear Applications	25.87	19.97	5.90	0.00
10-R&D-CAT-4.11-0100	Development of High Power Microwave & RF Tubes and Cryogenics Technologies	31.21	19.93	11.28	0.00
	TOTAL CS - ADVANCED TECHNOLOGIES	**179.38**	**114.20**	**65.18**	**0.00**
	New Schemes				
11-R&D-BAR-4.11-0100	Nuclear Instrumentation & Radiation Detectors	86.50	0.00	72.50	14.00
11-R&D-BAR-4.11-0200	Advanced Electromagnetic Technologies	94.00	0.00	80.20	13.80
11-R&D-BAR-4.11-0300	Manufacturing Technologies	83.70	0.00	83.70	0.00
11-R&D-BAR-4.11-0400	Scientific & Medical Equipment Development	93.50	0.00	93.50	0.00
11-R&D-CAT-4.11-0100	High Power Lasers for Engineering Applications	48.60	0.00	48.60	0.00
11-R&D-IGC-4.11-0100	Development of SQUID sensors, and associated electronics and cryogenic instrumentation for applications in NDT, MEG and geological prospecting.	4.25	0.00	4.25	0.00
11-R&D-IGC-4.11-0200	Development of hardware and computer based system for fast reactor instrumentation and control.	25.00	0.00	23.00	2.00
11-R&D-SIN-4.11-0100	CMOS X-ray Imager for Medical Imaging and Related Image Processing Techniques (MOXIM)	4.00	0.00	4.00	0.00
11-R&D-SIN-4.11-0200	Diamond nanotechnology for bio applications	4.00	0.00	4.00	0.00
11-R&D-VEC-4.11-0100	Non- Cryogenic Helium Purification and Seismic Related Gas Assaying	5.76	0.00	5.76	0.00
11-R&D-VEC-4.11-0200	Superconducting magnet energy storage system technology development	30.00	0.00	30.00	0.00
	TOTAL NS - ADVANCED TECHNOLOGIES	**479.31**	**0.00**	**449.51**	**29.80**
	TOTAL CS+ NS - ADVANCED TECHNOLOGIES	**658.69**	**114.20**	**514.69**	**29.80**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	SPECIAL PROGRAMMES				
	Continuing Schemes				
10-R&D-BAR-4.12-0100	Special programs	29.68	25.68	4.00	0.00
10-R&D-BAR-4.12-0200	Experimental High Pressure Physics Laboratory (EHPPL)	72.38	40.38	32.00	0.00
10-R&D-BAR-4.12-0300	Physical Protection System for BARC Facilities at Tarapur & Kalpakkam	20.00	15.00	5.00	0.00
10-R&D-BAR-4.12-0400	Additional BARC Campus	1110.49	175.49	536.00	399.00
	TOTAL CS - SPECIAL PROGRAMMES	**1,232.55**	**256.55**	**577.00**	**399.00**
	New Scheme				
11-R&D-IGC-4.12-0100	Process control with pulsating sensors	1.16	0.00	1.16	0.00
	TOTAL NS - SPECIAL PROGRAMMES	**1.16**	**0.00**	**1.16**	**0.00**
	TOTAL CS + NS - SPECIAL PROGRAMMES	**1,233.71**	**256.55**	**578.16**	**399.00**
	TOTAL - MP-4: ADVANCED TECHNOLOGIES AND RADIATION TECHNOLOGIES AND THEIR APPLICATIONS	**4,408.09**	**647.75**	**2,884.39**	**875.95**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	MAJOR PROGRAMME - 5: BASIC RESEARCH				
	MATHEMATICS & COMPUTATIONAL SCIENCES				
	Continuing Schemes				
10-R&D-BAR-5.01-0100	Computational facilities and their up gradation	65.10	52.10	13.00	0.00
10-R&D-TFR-5.01-0100	Mathematics, Technology and Computer Science (Centre for Applicable Mathematics)	13.75	12.75	1.00	0.00
	TOTAL CS - MATHEMATICS & COMPUTATIONAL SCIENCES	**78.85**	**64.85**	**14.00**	**0.00**
	New Schemes				
11-R&D-BAR-5.01-0100	Enhancement of Computing Power and Connectivity	95.50	0.00	80.50	15.00
11-R&D-BAR-5.01-0200	Computing Facility at Vizag : Phase - 1	50.00	0.00	30.00	20.00
11-R&D-CAT-5.01-0100	Scientific Computing Infrastructure	23.00	0.00	23.00	0.00
11-R&D-HRI-5.01-0100	Special Years in Mathematics	1.61	0.00	1.61	0.00
11-R&D-IGC-5.01-0100	Centre for Advanced Visualization & Computational Intelligence.	30.20	0.00	27.20	3.00
11-R&D-IMS-5.01-0100	Fundamental Studies in Mathematics and Theoretical Computer Science	12.02	0.00	12.02	0.00
11-R&D-IOP-5.01-0100	Computing and network facilities	3.00	0.00	3.00	0.00
11-R&D-SIN-5.01-0100	Centre for Applied Mathematics & Computational Science - Phase II, SINP	9.00	0.00	9.00	0.00
11-R&D-TFR-5.01-0100	Mathematics	5.28	0.00	5.28	0.00
11-R&D-TFR-5.01-0200	Technology & Computer Science	2.25	0.00	2.25	0.00
11-R&D-VEC-5.01-0100	Advanced Computing and Automation	50.00	0.00	50.00	0.00
	TOTAL NS - MATHEMATICS & COMPUTATIONAL SCIENCES	**281.85**	**0.00**	**243.85**	**38.00**
	TOTAL CS + NS - MATHEMATICS & COMPUTATIONAL SCIENCES	**360.70**	**64.85**	**257.85**	**38.00**
	PHYSICS				
	Continuing Schemes				
10-R&D-BAR-5.02-0100	Basic & Applied Research in Physics and its application	38.80	25.80	13.00	0.00
10-R&D-BAR-5.02-0200	Sub-TeV Light Experiments (SUBTLE)	38.03	1.28	36.75	0.00
10-R&D-BAR-5.02-0300	CIRUS reactor utilisation programme for basic and applied research	4.00	1.50	2.50	0.00
10-R&D-IOP-5.02-0104	Development of Theoretical Physics Research Programme	1.40	0.40	1.00	0.00
10-R&D-TFR-5.02-0300	Research Facilities & Common Services (Ballon Facility, Hyderabad: Upgrade and Refurbishment BF Infrastructure)	37.47	34.97	2.50	0.00
10-R&D-TFR-5.02-0401	Inter-Institutional Research Programme (R&D for India based Neutrino Observatory Proposal)	10.17	6.27	3.90	0.00
10-R&D-TFR-5.02-0402	Information, Science & Technology Services & Infrastructure (Hostel & Other infrastructural Facilities)	38.61	24.61	14.00	0.00
10-R&D-VEC-5.02-0100	Superconducting Cyclotron Utilisation Project	48.77	15.47	33.30	0.00
10-R&D-VEC-5.02-0200	Radioactive Ion Beam Facility-Phase II	21.29	17.29	4.00	0.00
	TOTAL CS - PHYSICS	**238.54**	**127.59**	**110.95**	**0.00**
	New Schemes				
11-R&D-BAR-5.02-0100	National Facility of Neutron Beam & Astrophysical Research	15.00	0.00	15.00	0.00
11-R&D-BAR-5.02-0200	Research in Frontier Areas in Nuclear Physics	18.50	0.00	18.50	0.00
11-R&D-CAT-5.02-0100	Research in Frontier Areas of Physics with Lasers	39.30	0.00	39.30	0.00
11-R&D-HRI-5.02-0100	Scientific Computing and Networking	9.96	0.00	9.96	0.00
11-R&D-HRI-5.02-0200	High Performance Scientific Computing	10.58	0.00	10.58	0.00
11-R&D-HRI-5.02-0300	Scientific Human Resources Training	4.01	0.00	4.01	0.00
11-R&D-HRI-5.02-400	Regional Centre for Accelerator-Based Particle Physics (RECAPP)	3.69	0.00	3.69	0.00
11-R&D-IGC-5.02-0100	Basic research in materials science & condensed matter physics.	17.10	0.00	15.10	2.00
11-R&D-IMS-5.02-0100	Thrust Areas in Theoretical Physics at IMSc	3.33	0.00	3.33	0.00
11-R&D-IOP-5.02-0100	An advanced growth and characterisation laboratory for thin films and nanostructure materials	15.00	0.00	15.00	0.00

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
11-R&D-IOP-5.02-0200	Strengthening theoretical condensed matter research and setting up a complex system lab	3.50	0.00	3.50	0.00
11-R&D-IOP-5.02-0300	Up gradation of the 3 MV Pelletron Accelerator related facilities at IOP	2.00	0.00	2.00	0.00
11-R&D-IOP-5.02-0400	Particle Physics	1.00	0.00	1.00	0.00
11-R&D-SIN-5.02-0100	Physics of complex systems under extreme conditions	35.00	0.00	35.00	0.00
11-R&D-SIN-5.02-0200	International Collaboration for Experimental and Theoretical Condensed Matter Physics Divisions	2.00	0.00	2.00	0.00
11-R&D-SIN-5.02-0300	Centre for Astroparticle Physics	15.00	0.00	15.00	0.00
11-R&D-SIN-5.02-0400	A Facility for Research in Experimental Nuclear Astrophysics (FRENA)	35.00	0.00	35.00	0.00
11-R&D-SIN-5.02-0500	Multidisciplinary Research in Atomic and Nuclear Sciences	15.20	0.00	15.20	0.00
11-R&D-SIN-5.02-0600	Investigating Double Beta Decay, Dark Matter & GRB	1.00	0.00	1.00	0.00
11-R&D-SIN-5.02-0700	Development of an Adaptive and Parallel Solver for solving problems related to Nuclear Detectors	0.52	0.00	0.52	0.00
11-R&D-SIN-5.02-0800	Frontiers of Theoretical Physics	20.00	0.00	20.00	0.00
11-R&D-SIN-5.02-0900	Fast, Whole body Digital X-ray Scanning & Imaging.	7.00	0.00	7.00	0.00
11-R&D-SIN-5.02-1000	Indian Neutrino Observatory (INO)	670.00	0.00	320.00	350.00
11-R&D-TFR-5.02-0100	Theoretical Physics	4.50	0.00	4.50	0.00
11-R&D-TFR-5.02-0200	Theoretical Physics Special Programmes	1.10	0.00	1.10	0.00
11-R&D-TFR-5.02-0300	Astronomy & Astrophysics I	17.00	0.00	17.00	0.00
11-R&D-TFR-5.02-0400	Astronomy & Astrophysics II	5.00	0.00	5.00	0.00
11-R&D-TFR-5.02-0500	High Energy Physics I	1.00	0.00	1.00	0.00
11-R&D-TFR-5.02-0600	Condensed Matter Physics I (Inter Metallic, Correlated Electron Systems, Super Conductivity & Semi -conductors)	28.50	0.00	28.50	0.00
11-R&D-TFR-5.02-0700	Radio Astronomy I	13.50	0.00	13.50	0.00
11-R&D-TFR-5.02-0800	Radio Astronomy II, Research Initiative & Instrumentation & New Tech.	10.00	0.00	10.00	0.00
11-R&D-TFR-5.02-0900	Inter Institutional Research Programme I	10.00	0.00	10.00	0.00
11-R&D-TFR-5.02-1000	Inter Institutional Research Programme II	10.00	0.00	10.00	0.00
11-R&D-TFR-5.02-1100	Interdisciplinary Areas	24.80	0.00	24.80	0.00
11-R&D-TFR-5.02-1200	Research Facilities	83.00	0.00	54.00	29.00
11-R&D-TFR-5.02-1300	Engineering , Technical Services	25.00	0.00	25.00	0.00
11-R&D-TFR-5.02-1400	Common Services	48.00	0.00	48.00	0.00
11-R&D-VEC-5.02-0100	Radioactive Ion Beam Facility at VECC	75.00	0.00	75.00	0.00
11-R&D-VEC-5.02-0200	Advanced Detector facilities	12.50	0.00	12.50	0.00
11-R&D-VEC-5.02-0300	Development of micro0-pattern detectors for medical imaging and other applications	6.51	0.00	6.51	0.00
11-R&D-VEC-5.02-0400	R&D for INO	1.00	0.00	1.00	0.00
	TOTAL NS - PHYSICS	**1,320.09**	**0.00**	**939.09**	**381.00**
	TOTAL CS + NS - PHYSICS	**1,558.63**	**127.59**	**1,050.04**	**381.00**
	CHEMISTRY				
	Continuing Scheme				
10-R&D-BAR-5.03-0100	Advanced Research in Chemistry	37.70	24.00	13.70	0.00
	TOTAL CS - CHEMISTRY	**37.70**	**24.00**	**13.70**	**0.00**
	New Schemes				
11-R&D-BAR-5.03-0100	Energy Conversion	67.00	0.00	67.00	0.00
11-R&D-IGC-5.03-0100	Chemistry	3.38	0.00	3.38	0.00
11-R&D-SIN-5.03-0100	Chemical and biophysical approaches for understanding natural processes	10.00	0.00	10.00	0.00
11-R&D-TFR-5.03-0100	Chemical Science I (Inorganic & Material Chemistry & Chemical Dynamics)	13.00	0.00	13.00	0.00
11-R&D-TFR-5.03-0200	Chemical Science II (Bio Inorganic Chemistry &Molecular Biophysics)	8.00	0.00	8.00	0.00
	TOTAL NS - CHEMISTRY	**101.38**	**0.00**	**101.38**	**0.00**
	TOTAL CS + NS - CHEMISTRY	**139.08**	**24.00**	**115.08**	**0.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	BIOLOGY				
	Continuing Scheme				
10-R&D-BAR-5.04-0100	Advance Research in Molecular Biology and study of radiation effects on human health	34.80	24.80	10.00	0.00
	TOTAL CS - BIOLOGY	**34.80**	**24.80**	**10.00**	**0.00**
	New Schemes				
11-R&D-BAR-5.04-0100	Radiation Effects in Biological Systems	37.80	0.00	37.80	0.00
11-R&D-IGC-5.04-0100	Gene expression studies.	1.11	0.00	1.11	0.00
11-R&D-SIN-5.04-0100	Structural Proteomics & Genomics of Human Genetic Diseases	22.00	0.00	22.00	0.00
11-R&D-SIN-5.04-0200	Molecular Mechanism of Diseases and Drug Action	9.50	0.00	9.50	0.00
11-R&D-TFR-5.04-0100	Biological science I	18.00	0.00	18.00	0.00
11-R&D-TFR-5.04-0200	Biological science II	7.00	0.00	7.00	0.00
11-R&D-TFR-5.04-0300	NCBS I	24.00	0.00	24.00	0.00
11-R&D-TFR-5.04-0400	NCBS II	30.00	0.00	30.00	0.00
	TOTAL NS - BIOLOGY	**149.41**	**0.00**	**149.41**	**0.00**
	TOTAL CS + NS - BIOLOGY	**184.21**	**24.80**	**159.41**	**0.00**
	CANCER				
	New Schemes				
11-R&D-TMC-5.05-0100	Technology & Infrastructure Development	19.50	0.00	19.50	0.00
11-R&D-TMC-5.05-0200	Cancer and Public Health Research	36.50	0.00	36.50	0.00
	TOTAL NS - CANCER	**56.00**	**0.00**	**56.00**	**0.00**
	TOTAL CS + NS - CANCER	**56.00**	**0.00**	**56.00**	**0.00**
	SYNCHROTRONS & THEIR UTILISATION				
	Continuing Schemes				
10-R&D-BAR-5.06-0100	Development of Indus-2 Beamlines for various applications	38.85	23.85	15.00	0.00
10-R&D-CAT-5.06-0100	Development, Up gradation and Utilisation of Synchrotron Radiation Sources, Indus-1 & 2 Beam Lines and Three Insertion Devices for Indus-2	41.01	21.33	19.68	0.00
	TOTAL CS - SYNCHROTRONS & THEIR UTILISATION	**79.86**	**45.18**	**34.68**	**0.00**
	New Scheme				
11-R&D-BAR-5.06-0100	Advanced Spectroscopy & Utilization of Synchrotron Sources	25.00	0.00	25.00	0.00
	TOTAL NS - SYNCHROTRONS & THEIR UTILISATION	**25.00**	**0.00**	**25.00**	**0.00**
	TOTAL CS + NS - SYNCHROTRONS & THEIR UTILISATION	**104.86**	**45.18**	**59.68**	**0.00**
	CYCLOTRONS & THEIR UTILISATION				
	Continuing Scheme				
10-R&D-VEC-5.07-0100	Modernisation of VEC Technical System	**21.10**	**17.75**	**3.35**	**0.00**
	TOTAL CS - CYCLOTRONS & UTILISATION	**21.10**	**17.75**	**3.35**	**0.00**
	New Schemes				
11-R&D-VEC-5.07-0100	Augmentation of technical facilities	39.00	0.00	39.00	0.00
11-R&D-VEC-5.07-0200	Enhancement of infrastructure and systems for the superconducting cyclotron	36.20	0.00	36.20	0.00
	TOTAL NS - CYCLOTRONS & UTILISATION	**75.20**	**0.00**	**75.20**	**0.00**
	TOTAL CS + NS - CYCLOTRONS & UTILISATION	**96.30**	**17.75**	**78.55**	**0.00**
	FUSION & OTHER PLASMA TECHNOLOGIES				
	Continuing Scheme				
10-R&D-BAR-5.08-0100	Laser induced shock studies & Laser based neutron sources	11.93	3.93	8.00	0.00
	TOTAL CS - FUSION & OTHER PLASMA TECHNOLOGIES	**11.93**	**3.93**	**8.00**	**0.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	New Scheme				
11-R&D-IPR-5.08-0100	Fundamental Plasma Sciences	37.00	0.00	37.00	0.00
11-R&D-IPR-5.08-0200	Prototype Magnets for Fusion grade Tokomaks	40.00	0.00	40.00	0.00
11-R&D-IPR-5.08-0300	Prototype Vacuum Vessel & Cryopump for Fusion grade Tokomak	40.00	0.00	40.00	0.00
11-R&D-IPR-5.08-0400	Prototype Diverter Cassette development for Fusion grade Tokomak	40.00	0.00	40.00	0.00
11-R&D-IPR-5.08-0500	Research and Development of Fusion Blanket related technologies	45.00	0.00	45.00	0.00
11-R&D-IPR-5.08-0600	Development of Liquid Breeder Blanket Module for ITER: Phase I	40.00	0.00	40.00	0.00
11-R&D-IPR-5.08-0700	Development of Solid Breeder Blanket Module for ITER: Phase I	40.00	0.00	40.00	0.00
11-R&D-IPR-5.08-0800	Neutron Beam Injection (NBI) Technology development for Fusion Grade Tokomaks	45.00	0.00	45.00	0.00
11-R&D-IPR-5.08-0900	Auxiliary Technology Development for Fusion Research	40.00	0.00	40.00	0.00
11-R&D-SIN-5.08-0100	Saha Institute Spherical Stellarator Assembly	3.00	0.00	3.00	0.00
11-R&D-SIN-5.08-0200	Up gradation of linear plasma devices	1.00	0.00	1.00	0.00
11-R&D-SIN-5.08-0300	Deep space plasma propulsion Experiment	2.00	0.00	2.00	0.00
11-R&D-SIN-5.08-0400	Centre for Ultrahigh Magnetic Field Facility (Phase-I)	35.00	0.00	35.00	0.00
	TOTAL NS - FUSION & OTHER PLASMA TECHNOLOGIES	**408.00**	**0.00**	**408.00**	**0.00**
	TOTAL CS + NS - FUSION & OTHER PLASMA TECHNOLOGIES	**419.93**	**3.93**	**416.00**	**0.00**
	MATERIALS SCIENCE				
	New Schemes				
11-R&D-BAR-5.09-0100	Advanced Functional Materials	46.50	0.00	46.50	0.00
11-R&D-CAT-5.09-0100	Material Research and Development for Devices	25.00	0.00	25.00	0.00
11-R&D-IGC-5.09-0100	R&D on Nano Materials for Sensors and Coatings.	6.65	0.00	6.65	0.00
11-R&D-IGC-5.09-0200	Simulation of neutron damage using ion beams and computer simulations	9.55	0.00	8.55	1.00
11-R&D-IOP-5.09-0100	Nonstructural growth on Patterned Surfaces for fundamental and technological applications	5.40	0.00	5.40	0.00
11-R&D-IOP-5.09-0200	Patterning of Surfaces by Ion Beam Sputtering (IBS) and Investigating Biology on the Surfaces	5.00	0.00	5.00	0.00
11-R&D-SIN-5.09-0100	Development of Linear Ultrasonic Transducer Array for Medical Imaging and Related Image Processing Techniques (LINUT)	6.00	0.00	6.00	0.00
11-R&D-SIN-5.09-0200	Centre for Nanoscience and Surface Physics (CENSUP)	42.80	0.00	42.80	0.00
11-R&D-TFR-5.09-0100	Condensed Matter II (Nao Science & Technology)	48.00	0.00	48.00	0.00
11-R&D-VEC-5.09-0100	Studies of Radiation damage in Nuclear Structural Materials by Particle Irradiation using accelerator	14.00	0.00	14.00	0.00
11-R&D-VEC-5.09-0200	Synthesis of conducting polymer/ceramics nanocomposites for radiation shielding and their characterization	3.00	0.00	3.00	0.00
	TOTAL NS - MATERIALS SCIENCE	**211.90**	**0.00**	**210.90**	**1.00**
	TOTAL CS + NS - MATERIALS SCIENCE	**211.90**	**0.00**	**210.90**	**1.00**
	INTERDISCIPLINARY AREAS				
	New Scheme				
11-R&D-CAT-5.10-0100	Use of Lasers & charged particles beams for biomedical and societal applications.	10.00	0.00	10.00	0.00
	TOTAL NS - INTERDISCIPLINARY AREAS	**10.00**	**0.00**	**10.00**	**0.00**
	TOTAL CS + NS - INTERDISCIPLINARY AREAS	**10.00**	**0.00**	**10.00**	**0.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	INTERNATIONAL RESEARCH COLLABORATION				
	Continuing Schemes				
10-R&D-BAR-5.11-0100	Study of New Particles with the CMS Detector at the Large Hadron Collider (LHC)	1.72	1.22	0.50	0.00
10-R&D-CAT-5.11-0100	DAE-CERN Collaboration on Novel Accelerator Technologies and Joint Participation in Advanced Accelerator Programmes	17.50	2.00	15.50	0.00
10-R&D-IOP-5.11-0100	A Large Ion Collider Experiment (ALICE) Project	1.61	1.01	0.60	0.00
10-R&D-TFR-5.11-0101	Grid tier-2 Regional Computer Centre for TIFR - CMS groups (EHEP & HECR)	12.87	5.15	7.72	0.00
10-R&D-VEC-5.11-0100	ALICE GRID Tier-2 Centre	10.05	1.35	8.70	0.00
	TOTAL CS - INTERNATIONAL RESEARCH COLLABORATION	**43.75**	**10.73**	**33.02**	**0.00**
	New Schemes				
11-R&D-DAE-5.11-0100	International Collaboration in Mega Science Projects	2.00	0.00	2.00	0.00
11-R&D-IOP-5.11-0100	A proposal for ALICE utilization, Establishment of ALICE Tier-3 centre, Participation in CBM and Development of a prototype detector for medical imaging purposes.	10.00	0.00	5.00	5.00
11-R&D-SIN-5.11-0100	Development of High Resolution Gaseous Detector for FAIR Facility at GSI, Germany	1.00	0.00	1.00	0.00
11-R&D-SIN-5.11-0200	ALICE operation and utilization	20.60	0.00	10.40	10.20
11-R&D-SIN-5.11-0300	GRID Computing facility for the ALICE experiment	2.50	0.00	2.50	0.00
11-R&D-SIN-5.11-0400	Study of Exotic Nuclei and Development of High Energy Neutron TOF with good Efficiency and Position Resolution	3.65	0.00	3.65	0.00
11-R&D-TFR-5.11-0100	High Energy Physics II	7.50	0.00	7.50	0.00
11-R&D-TFR-5.11-0200	High Energy Physics III [International Collaborations]	20.00	0.00	20.00	0.00
11-R&D-TFR-5.11-0300	Nuclear Physics	7.50	0.00	7.50	0.00
11-R&D-TFR-5.11-0400	Participation in International Linear Collider (ILC) program and related Advanced Accelerator R&D (XFEL, HIPA)	7.00	0.00	7.00	0.00
11-R&D-VEC-5.11-0100	Development of High Resolution Gaseous Detector and Superconducting magnet based detector System for FAIR at GSI, Germany	45.00	0.00	35.00	10.00
11-R&D-VEC-5.11-0200	International Collaboration in Intermediate Energy Nuclear Physics	2.00	0.00	2.00	0.00
11-R&D-VEC-5.11-0300	ALICE operation and utilization	45.79	0.00	22.79	23.00
	TOTAL NS - INTERNATIONAL RESEARCH COLLABORATION	**174.54**	**0.00**	**126.34**	**48.20**
	TOTAL CS + NS - INTERNATIONAL RESEARCH COLLABORATION	**218.29**	**10.73**	**159.36**	**48.20**
	TOTAL - MP-5: BASIC RESEARCH	**3,359.90**	**318.83**	**2,572.88**	**468.20**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
MAJOR PROGRAMME -6: RESEARCH EDUCATION LINKAGES					
	HUMAN RESOURCES DEVELOPMENT				
	Continuing Schemes				
10-R&D-BAR-6.01-0100	Up gradation of Educational Training facilities	26.38	23.98	2.40	0.00
10-R&D-DEM-6.01-0100	Additional Space in training School - Phase-II for HBNI	13.57	9.57	4.00	0.00
10-R&D-DEM-6.01-0200	Convention Centre / Sr. Officers Guest House	40.00	0.00	40.00	0.00
	TOTAL CS - HUMAN RESOURCE DEVELOPMENT	**79.95**	**33.55**	**46.40**	**0.00**
	New Schemes				
11-R&D-AEE-6.01-0100	Enriching AEES Schools for all round Development in Primary and Secondary Education	115.00	0.00	115.00	0.00
11-R&D-BAR-6.01-0100	Scientific Information Resource Augmentation and Technology Transfer	70.50	0.00	70.50	0.00
11-R&D-DEM-6.01-0100	DAE Administrative Training Institute	32.00	0.00	32.00	0.00
11-R&D-GIA-6.01-0100	National Board for Higher Mathematics (NBHM) Programmes	75.00	0.00	75.00	0.00
11-R&D-GIA-6.01-0200	Exhibition	8.00	0.00	8.00	0.00
11-R&D-GIA-6.01-0300	Fellowship	30.00	0.00	30.00	0.00
11-R&D-GIA-6.01-0400	Symposiums	15.00	0.00	15.00	0.00
11-R&D-GIA-6.01-0500	Public Awareness and Neighborhood Welfare Programme	1.00	0.00	1.00	0.00
11-R&D-GIA-6.01-0600	External Relations Programmes	0.25	0.00	0.25	0.00
11-R&D-HRI-6.01-0100	Library Development Project	3.39	0.00	3.39	0.00
11-R&D-IGC-6.01-0100	IGCAR Training School	10.39	0.00	10.39	0.00
11-R&D-IGC-6.01-0200	Fast Reactor Training Centre	10.87	0.00	10.87	0.00
11-R&D-IGC-6.01-0300	Advanced Digital Library	10.24	0.00	10.24	0.00
11-R&D-IGC-6.01-0400	Comprehensive Projects, Materials, Finance and Human Resource Management through Automation and Integration of Software systems.	5.10	0.00	5.10	0.00
11-R&D-IOP-6.01-0100	Scientific Manpower Development at IOP	500.00	0.00	300.00	200.00
11-R&D-SIN-6.01-0100	Centre for Advanced Research and Education (CARE) : Phase II	10.00	0.00	10.00	0.00
11-R&D-SIN-6.01-0200	Library Digitisation and E-Resources	3.35	0.00	3.35	0.00
11-R&D-SIN-6.01-0300	Information Management System at SINP	10.00	0.00	10.00	0.00
	TOTAL NS - HUMAN RESOURCE DEVELOPMENT	**910.09**	**0.00**	**710.09**	**200.00**
	TOTAL CS + NS - HUMAN RESOURCE DEVELOPMENT	**990.04**	**33.55**	**756.49**	**200.00**
	SPONSORED RESEARCH				
	New Schemes				
11-R&D-GIA-6.02-0100	Board of Research in Nuclear Sciences	400.00	0.00	400.00	0.00
11-R&D-GIA-6.02-0200	Miscellaneous R&D Schemes	12.50	0.00	12.50	0.00
11-R&D-GIA-6.02-0300	Assistance to Radiation Medicine Centers & Cancer Hospitals	70.00	0.00	70.00	0.00
	TOTAL NS - SPONSORED RESEARCH	**482.50**	**0.00**	**482.50**	**0.00**
	TOTAL CS + NS - SPONSORED RESEARCH	**482.50**	**0.00**	**482.50**	**0.00**
	PROSPECTIVE RESEARCH				
	New Scheme				
11-R&D-GIA-6.03-0100	Prospective Research Funding	90.00	0.00	90.00	0.00
	TOTAL NS - PROSPECTIVE RESEARCH	**90.00**	**0.00**	**90.00**	**0.00**
	TOTAL CS + NS - PROSPECTIVE RESEARCH	**90.00**	**0.00**	**90.00**	**0.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
	HOMI BHABHA CENTRE FOR SCIENCE EDUCATION				
	Continuing Scheme				
10-R&D-TFR-6.04-0200	National Initiative on Undergraduate Science (NIUS) Continuing	14.61	4.61	10.00	0.00
	TOTAL CS - HBCSE	**14.61**	**4.61**	**10.00**	**0.00**
	New Scheme				
11-R&D-TFR-6.04-0100	Homi Bhabha Centre for Science Education (HBCSE)	11.50	0.00	11.50	0.00
	TOTAL NS - HBCSE	**11.50**	**0.00**	**11.50**	**0.00**
	TOTAL CS + NS - HBCSE	**26.11**	**4.61**	**21.50**	**0.00**
	INFORMATION TECHNOLOGY APPLICATIONS DEVELOPMENT				
	New Scheme				
11-R&D-DAE-6.05-0100	DAE Integrated Information Systems Applications Project	46.50	0.00	46.50	0.00
11-R&D-DAE-6.05-0200	Enhancement of ANUNET and DAE Grid	23.00	0.00	20.00	3.00
	TOTAL NS - IT APPLICATIONS DEVELOPMENT	**69.50**	**0.00**	**66.50**	**3.00**
	TOTAL CS + NS - IT APPLICATIONS DEVELOPMENT	**69.50**	**0.00**	**66.50**	**3.00**
	TOTAL - MP-6: RESEARCH EDUCATION LINKAGES	**1,658.15**	**38.16**	**1,416.99**	**203.00**
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
MAJOR PROGRAMME -7: INFRASTRUCTURE & HOUSING					
	INFRASTRUCTURE				
	Continuing Schemes				
10-R&D-BAR-7.01-0100	Development of Manufacturing Technology and Processes (CWS), Renovation of services of RLG	15.20	11.70	3.50	0.00
10-R&D-BAR-7.01-0200	Electrical & Mechanical Utilities	35.00	24.00	11.00	0.00
10-R&D-BAR-7.01-0300	Architectural & Civil Engg. Services	24.75	15.75	9.00	0.00
10-R&D-CAT-7.01-0100	Infrastructure Development - Phase IV	28.37	23.99	4.38	0.00
10-R&D-CAT-7.01-0200	Housing	5.74	5.49	0.25	0.00
10-R&D-DAE-7.01-0102	Anunet-II and Intra DAE Grid Network	4.68	3.97	0.71	0.00
10-R&D-DEM-7.01-0100	Renovation of OYO interiors, External Development & Security Access Control Security System	10.53	6.03	4.50	0.00
10-R&D-DEM-7.01-0304	Up gradation of Services & Water Supply System	9.00	4.50	4.50	0.00
10-R&D-IGC-7.01-0201	Construction of RCC Protection wall, Single lane bridge, extension to existing bridge, Re-surfacing of Asphalted concrete road, Water Treatment Plant, Tree Plantation, Tsunami Memorial and Electrical Works etc. Under Tsunami relief works (Phase-II) in DAE/Anupuram township at Kalpakkam	5.13	4.15	0.98	0.00
10-R&D-IGC-7.01-0202	Construction & re-construction of R.R. Masonry compound wall in Northern boundary and along coastal areas, Construction of STF barracks and kennel, Laying of WBM patrolling road and providing security lighting along coastal areas under Tsunami relief Works (Phase III) in DAE premises of IGCAR plant site at Kalpakkam	40.30	25.61	14.69	0.00
10-R&D-IGC-7.01-0400	Construction of various types of quarters (200 Nos) and Infrastructure in Anupuram	25.00	24.05	0.95	0.00
10-R&D-IMS-7.01-0100	Expansion of research scholars' hostel	6.50	1.50	5.00	0.00
10-R&D-TFR-7.01-0100	Housing	16.45	12.45	4.00	0.00
10-R&D-VEC-7.01-0100	Infrastructure Development of VECC PH-II	4.49	3.84	0.65	0.00
	TOTAL CS - INFRASTRUCTURE	**231.14**	**167.03**	**64.11**	**0.00**
	New Schemes				
11-R&D-AMD-7.01-0100	Creation of HRD Facilities	10.00	0.00	10.00	0.00
11-R&D-AMD-7.01-0200	Construction of Office Complex (Phase-II) at NER, Shillong and purchase of land and construction of Guest House at Guwahati	4.50	0.00	4.50	0.00
11-R&D-BAR-7.01-0100	Security & Emergency Infrastructure	88.00	0.00	88.00	0.00
11-R&D-BAR-7.01-0200	Up gradation of Existing Engineering Services	90.00	0.00	76.50	13.50
11-R&D-BAR-7.01-0300	Replacement of Facilities with Permanent Structure	94.00	0.00	94.00	0.00
11-R&D-CAT-7.01-0100	Infrastructure Development Phase -V	40.91	0.00	40.91	0.00
11-R&D-DEM-7.01-0100	Liasoning Office in Anushaktinagar for outside units of DAE	2.80	0.00	2.80	0.00
11-R&D-DEM-7.01-0200	Up gradation of Services like lift, electrical wiring for old building, community centre etc.	16.00	0.00	16.00	0.00
11-R&D-DEM-7.01-0300	Providing security road in Eastern Sector, widening road, providing security lighting in western sector	2.50	0.00	2.50	0.00
11-R&D-DEM-7.01-0400	Providing Creche facility for employees' children	2.56	0.00	2.56	0.00
11-R&D-DEM-7.01-0500	Infrastructure for shifting DIG, CISF Office from Hyderabad to Mumbai	4.70	0.00	4.70	0.00
11-R&D-DEM-7.01-0600	Purchase of readymade flats / land for dispensary in Kharghar	0.60	0.00	0.60	0.00
11-R&D-HRI-7.01-0100	Civil & Infrastructure Development	30.01	0.00	30.01	0.00
11-R&D-HRI-7.01-0200	Equipping & Furnishing of Conference Centre	0.98	0.00	0.98	0.00
11-R&D-IGC-7.01-0100	Augmentation of infrastructure facilities at Kalpakkam Township	31.40	0.00	28.24	3.16
11-R&D-IGC-7.01-0200	Providing infrastructure facilities at IGCAR Plant site.	17.75	0.00	15.94	1.81
11-R&D-IGC-7.01-0300	Augmentation of Electrical services for IGCAR	35.43	0.00	32.28	3.15
11-R&D-IGC-7.01-0400	Air conditioning and ventilation requirements of IGCAR	5.75	0.00	5.75	0.00
CS= Continuing Schemes	*NS= New Schemes*				

Major Programmewise list of Projects

(Rs in Crores)

Project Identification Code (PIC No.)	Project Title	Sanctioned/ Estimated Cost	Est. Exp. up to X Plan	XI Plan Outlay	Spillover to XII Plan
11-R&D-IMS-7.01-0100	Providing additional Office Space in the new office building	0.60	0.00	0.60	0.00
11-R&D-IMS-7.01-0200	Extension and modernization of Library	8.10	0.00	8.10	0.00
11-R&D-IOP-7.01-0100	Infrastructure at IOP	3.90	0.00	3.90	0.00
11-R&D-IPR-7.01-0100	New Campus for Fusion Reactor related activity	48.00	0.00	48.00	0.00
11-R&D-IPR-7.01-0200	Additional Buildings at IPR	22.00	0.00	22.00	0.00
11-R&D-SIN-7.01-0100	Infrastructural Development	55.35	0.00	55.35	0.00
11-R&D-TFR-7.01-0100	Infrastructural facility I	35.00	0.00	35.00	0.00
11-R&D-TFR-7.01-0200	Interdisciplinary Centre	20.00	0.00	20.00	0.00
11-R&D-TFR-7.01-0300	NCBS Phase II & III	47.00	0.00	47.00	0.00
11-R&D-TFR-7.01-0400	New Campus Development	50.00	0.00	50.00	0.00
11-R&D-VEC-7.01-0100	Infrastructure Developments (Saltlake and Rajarhat campus)	12.00	0.00	12.00	0.00
	TOTAL NS - INFRASTRUCTURE	**779.84**	**0.00**	**758.22**	**21.62**
	TOTAL CS + NS - INFRASTRUCTURE	**1,010.98**	**167.03**	**822.33**	**21.62**
	HOUSING				
	Continuing Scheme				
10-R&D-AMD-7.02-0100	Construction / Purchase of Residential Quarters at CR/SR/WR	8.41	4.58	3.83	0.00
	TOTAL CS - HOUSING	**8.41**	**4.58**	**3.83**	**0.00**
	New Schemes				
11-R&D-AMD-7.02-0100	Housing - Construction of Residential Quarters at Eastern Region, Central Region and at Hyderabad (for training school)	10.00	0.00	10.00	0.00
11-R&D-CAT-7.02-0100	Housing for RRCAT	4.50	0.00	4.50	0.00
11-R&D-DEM-7.02-0100	Residential Quarters for CISF	10.50	0.00	10.50	0.00
11-R&D-DEM-7.02-0200	Hostel for trainees of BARC & HBNI etc (1000 rooms)	37.50	0.00	37.50	0.00
11-R&D-HRI-7.02-0100	Housing	14.00	0.00	14.00	0.00
11-R&D-IGC-7.02-0100	Construction of Housing, Public buildings and other Infrastructure facilities at Anupuram Township.	62.99	0.00	56.67	6.32
11-R&D-IOP-7.02-0100	Additional Residential Quarters	2.10	0.00	2.10	0.00
11-R&D-IOP-7.02-0200	Extension of guest house	0.50	0.00	0.50	0.00
11-R&D-IPR-7.02-0100	Housing at New Campus	20.00	0.00	20.00	0.00
11-R&D-SIN-7.02-0100	Housing	3.00	0.00	3.00	0.00
11-R&D-TFR-7.02-0100	Housing	17.80	0.00	17.80	0.00
11-R&D-TMC-7.02-0100	Housing-TMC	14.00	0.00	14.00	0.00
	TOTAL NS - HOUSING	**196.89**	**0.00**	**190.57**	**6.32**
	TOTAL CS + NS - HOUSING	**205.30**	**4.58**	**194.40**	**6.32**
	TOTAL CS - MP-7: INFRASTRUCTURE & HOUSING	**239.55**	**171.61**	**67.94**	**0.00**
	TOTAL NS - MP-7: INFRASTRUCTURE & HOUSING	**976.72**	**0.00**	**948.78**	**27.94**
	TOTAL - MP-7: INFRASTRUCTURE & HOUSING	**1,216.27**	**171.61**	**1,016.72**	**27.94**
	TOTAL DAE R & D SECTOR	**15,303.19**	**1,497.82**	**10,997.53**	**2,807.84**

Chapter 5

Implementation Aspects of the DAE's XI Plan Proposals

5.1 General Guidelines

As part of X Plan, a large number of activities are being pursued in DAE and through an approach based on multi-disciplinary task force, many disciplines in a given activity have been successfully integrated. DAE units are moving towards realizing most of the goals set for the X plan and the department is now ready for a steep take-off. While formulating proposals for the XI plan, efforts have been made to take up projects within the mandate of the Department and also be a front runner in the cutting edge technologies of the world. The thrust is on development of domestic technologies and international participation is for the strengthening of home grown technologies. In this plan, to further streamline the efforts of the multiple-agencies of the Department, activities of the Department have been grouped into 20 themes and Specialist Groups (SGs) have been formed for each of these themes. These SGs reviewed proposals from across the units in terms of scientific content of the proposal, identified overlap, if any, reformulated proposals to minimize overlap while keeping any desired overlap and suggested filling of the gaps in the programmes etc. Every scheme has been examined for technical feasibility and economic viability including analysis on the principles of **Zero Based Budgeting.** When finally sanctioned, every scheme would have been examined at the level of Constituent Units, in respective SGs, IWG for R&D Sector, Department and finally at the level of Atomic Energy Commission. It is proposed to subject all the continuing schemes to one more scrutiny to be conducted by groups specifically set up by the DAE.

In addition to the guidelines provided by the Planning Commission, the following general points have been kept in perspective by the Department while formulating the plan proposals.

(a) The three stage power programme formulated by the Department has stood the test of time. This takes cognisance of India's nuclear fuel resources, particularly abundant availability of thorium. Thorium fuel is of interest mainly to India and its utilization is of crucial importance to the Department.

(b) DAE has built up a formidable base in the past and general expectation from the department to deliver 20,000 (MWe) by around 2020, to speed up further

development of fast reactor programme in the industrial domain and take up an efficient thorium utilization programme.

(c) Accelerator Driven System (ADS) technology, with focused efforts, may turn out to be an appropriate technology for the utilization of thorium in a reasonable time frame.

(d) For ensuring energy security for the country, India has joined the international ITER Project as full partner along with six other participants. Institute of Plasma Research, Gandhinagar has been identified as host agency for this project. Domestic R&D support to this programme is to be further enhanced.

(e) To continue to provide R&D support to the present power programme as well as the future programme, NPCIL has also set up its own R&D centre to look into short-term R&D needs of PHWRs.

(f) Make XI plan more oriented towards programme with objectives. Rather than spending efforts in building infrastructure/equipment/facilities, that may exist elsewhere, networking with all R&D and Academics institutions has been initiated in the X Plan. This will be taken up in big way during the XI Plan. This will help utilise the available facilities and expertise to achieve programme objectives. It will create inter-institutional synergy to strengthen capability and draw on national resources. Setting up of HBNI and DAE-UGC consortium for Scientific Research during the X Plan will catalyse multi-centric, multi-institutional programmes. For all such projects, we may think in terms of providing funds for the scheme instead of for the Institute.

(g) Extramural funding through BRNS and NBHM has been very successful. This has helped in utilisation of expertise available outside the Department and in development of scientific manpower for the country. To move further, a campus is proposed to be set up at Visakhapatnam for pursuing the activities of HBNI. Increasing intake of Ph.D. students by increasing number of DAE fellowships is planned. DAE-Mumbai University Centre for Excellence will be set up in Mumbai to conduct five years integrated B.Sc.-M.Sc. programme in Sciences. Mumbai University Institute of Chemical Technology (UICT)-DAE initiative for doctoral education and research programmes is also planned to be taken up.

(h) Prospective Research Fund is being created for Departmental personnel for research complementary to the major projects, filling up of critical gaps, which

might be identified during the XI Plan and enrichment of scientific knowledge and stimulating futuristic research. This would be available on competitive basis and would be operated on lines similar to BRNS.

(i) There may be instances where some specific work is done simultaneously at two or more places. This should be done more by design than by default. Concerned persons should sit together and discuss details of the proposed projects and divide the scope, responsibilities and budget. The proposals should then be redefined to bring out the totality of the programme in proper perspective. SGs will play an important role in bringing such groups together.

(j) Meticulous project planning, including all aspects should be carried out while preparing the Detailed Project Report (DPR). Provision for midcourse correction should be provided particularly to incorporate new ideas, new developments in science and technology and participation of newer groups. At the planning stage itself, we must plan for smooth transfer of technology to the end user.

(k) Estimates of the budget and time schedule should take into account realistic implementation rate consistent with the available infrastructural resources. For manpower, by and large, rely mainly on redeployment for new programmes.

(l) International collaborations may be planned so as to be a part of the Indian programme.

5.2 Monitoring and Follow-up

The SGs and the Internal Working Group (IWG) formed for the formulation of XI Plan proposal has been made to function not only for the formulation of XI Plan but are made responsible for review and monitoring of these projects throughout the XI Plan period. The SGs will hold periodic review to ensure that objectives of every project are realised in the time frame envisaged in the plan documents. The SGs will also examine the requirement of any midcourse corrections in the scientific contents of the programmes and attempt to integrate the activities of a given programme across various units of the DAE. Wherever possible, the groups will be interacting with other institutions and national laboratories in the country for the implementation of XI plan projects.

Chapter 6

AERB XI Five Year Plan Proposal

Significant expansion of the Indian Nuclear Power Programme and the related activities is envisaged during the XI Plan. Atomic Energy Regulatory Board (AERB) will have to meet the challenge to cater to the regulatory needs of this large expansion in activities. This will require significant increase in the resources of AERB in terms of manpower, infrastructure and facilities. The '**XI Plan AERB Expansion Project**', is formulated to achieve this required growth. The primary objective of this project is to augment infrastructure and expertise needed to cater to the envisaged substantial increase in the regulatory functions of AERB, to strengthen R&D support for regulatory activities and to establish southern and eastern regional centres of AERB for expeditious implementation of regulatory functions. The augmentation has become necessary in view of the following:

(1) DAE has already taken up substantial expansion of the Nuclear Power Programme by setting-up new power projects and commensurate augmentation of front-end facilities. Significant further expansion is slated to be taken up by DAE in the XI Plan.

(2) The types of nuclear power plants under construction and those planned are of varied designs such as VVERs at Kudankulam, PFBR at Kalpakkam, PWRs of western design at Jaitapur, 700 MWe PHWRs at Kakrapar and Rawatbhata and the AHWR. Safety review of these new reactors of diverse and innovative designs would require substantial enhancement of regulatory capabilities.

(3) It is likely that in the near future nuclear power generation in the country may be opened up to private sector participation, both Indian and foreign. With this, there will be substantial increase in AERB's workload, both in terms of carrying out preparatory work in the form of laying down rules and safety requirements to cater to this new dimension and for the detailed safety review of such new proposals.

(4) Recent developments in safety evaluation based on the experience gained over the years and emerging international practices call for the use of new tools and techniques for safety evaluation such as application of Probabilistic

Safety Assessment (PSA), use of Safety Indicators and Periodic Safety Review.

(5) For old facilities, ageing management, major safety upgrades and relicensing/ life extension need to be taken up which are manpower resource intensive activities.

(6) Large growth in the number and variety of facilities for application of radiation in the industrial and medical fields including significant expansion of these activities in the private domain, necessitating strengthening the design safety review, inspection and enforcement activities in this field.

(7) There is going to be a very substantial increase in the international co-operation activities of AERB. This is by way of expected enhancement of activities under the AERB-USNRC nuclear safety co-operation, and, in the wake of the recent developments of our joining the Convention on Nuclear Safety, the forum of regulators of countries having VVER type Nuclear Power Plants, the International Trafficking Data Base (ITDB) of IAEA and the renewal of the bilateral nuclear safety co-operation agreements with the French and Russian Regulatory bodies. Further, the scope of our on-going participation in IAEA's activities such as those related to the Incident Reporting System, International Nuclear Event Scale (INES) based reporting including its recent expansion to include incidents involving radiation sources and transport of radioactive materials, senior regulators forum of countries operating CANDU type of NPPs, participation in Co-ordinated Research Programmes and in the safety documents development work is also likely to expand further in the XI Plan period.

(8) The AERB's Safety Research Institute (SRI) established recently at Kalpakkam has a very small strength of scientific staff presently. In order to realise the full potential of SRI in support of regulatory work, augmentation of its staff and some of the facilities is absolutely necessary. The proposals in this regard have been developed based on detailed deliberations on the subject recently in the SRI Council.

(9) With the spread of nuclear and radiation facilities at several places across the country, it is now considered appropriate to establish some Regional Centres of AERB for speedy and more effective regulation. To begin with, it is envisaged to establish a Southern Regional Centre at SRI, Kalpakkam /

Chennai and an Eastern Regional Centre in the new premises of VECC at Rajarhat, Kolkata. Work on regional centre for the northern region will be taken up subsequently, possibly starting towards the end of the XI Plan with the major part of activities in the XII Plan.

(10) The AERB Annex building (to be named as NIYAMAK BHAVAN-B; existing building as NIYAMAK BHAVAN-A), presently under construction, will be ready for occupation before end of the year 2006 and will be utilised to accommodate the new staff inducted / being inducted under the X Plan. To accommodate the additional staff in the XI Plan, further office space would be needed. Recently it has been proposed that the CTCRS building adjacent to Niyamak Bhavan be made available to AERB during the XI Plan period by shifting CTCRS staff to any of the new buildings being constructed in the XI Plan in the BARC campus at Trombay. Training activities of Radiological Physics and Advisory Division of BARC that are presently being done in CTCRS building can be shifted to the existing or new BARC Training School Complex. Discussions with BARC authorities have been initiated in this regard.

(11) AERB's enforcement actions under Atomic Energy (Radiation Protection) Rules 2004 at times are challenged in the courts by various stakeholders. Also, at times AERB is cited as one of the respondents in certain public interest litigations necessitating submission of affidavits etc by AERB. The handling of such legal matters by scientific staff is indeed a difficult job since it involves different kind of expertise. In view of above, it is felt essential to have a small legal cell in AERB for appropriately handling the court cases/public interest litigations.

The project has been proposed to undertake the above activities. The cost of this project is estimated as Rs 15 crs with an outlay of Rs 13 crs in the XI Plan and a spill over component of Rs 2 crs in the XII Plan as given in table 6.1. The project has been developed based on discussions in the AERB executive committee and the SRI Council and has been endorsed by the Board of AERB.

Table 6.1
AERB: XI Plan (R&D Sector)

Project Identification Code (PIC No.)	Project Title	Sanctioned / Estimated Cost	XI Plan Outlay	Spill over to XII Plan
	New Scheme			
11-R&D-AER-7.01-0100	AERB Expansion Project	15.00	13.00	2.00
	TOTAL NS - AERB	15.00	13.00	2.00
	TOTAL CS + NS - AERB	15.00	13.00	2.00

Chapter 7

Financial Summary

7.1 Financial Outlay of XI Plan Proposals

The estimated expenditure during the X Five Year Plan is Rs.3,200 crs. Figure 1 gives the year wise performance during the X Plan period. The new schemes proposed for DAE during the XI Plan costs Rs 11,973.45 crs with outlay for XI Plan being Rs 9,564.61 crs and a spill over component of Rs 2,408.84 crs in the XII Plan. Some of the DAE schemes of the X Plan would continue in the XI & XII Plan for which the outlay required would be Rs 1,432.92 crs and Rs 399 crs respectively. Thus the total outlay required during XI Plan for DAE schemes would be Rs 10,997.53 crs with a spill over component of Rs 2,807.84 crs in the XII Plan. The requirement for Atomic Energy Regulatory Board (AERB) is Rs 15 crs with outlay for XI Plan being Rs 13 crs and spill over component of Rs 2 crs in the XII Plan. Total requirement for DAE and AERB during XI Plan is Rs 11,010.53 crs. This is the minimum requirement for achieving the targets set by this Department in moving from developmental stage towards becoming world leader in areas of our work.

Major Programmewise distribution of outlays and Unit-wise distribution of proposed outlay are given in the table 7.1 and 7.2 respectively. Unit-wise distribution list also includes the funding through Grant-in-aid mechanism. Figure 2 gives per percentage share of Major Programmes in XI Plan while Figure 3 gives Subject wise distribution of XI Plan proposals.

Table 7.1
DAE: XI Plan (R&D Sector)
Major Programmewise Outlay

(Rs in Crores)

MP No.	Title	XI Plan			Spill over to XII Plan
		CS	NS	Total	
1	Nuclear Power Programme Stage-1	85.39	678.05	763.44	35.00
2	Nuclear Power Programme Stage-2	10.91	399.48	410.39	31.37
3	Nuclear Power Programme Stage-3 and Beyond	133.60	1799.12*	1932.72*	1166.38*
4A	Advanced Technologies and their Applications	729.15	1670.15	2399.30	750.95
4B	Radiation Technologies and their Applications	121.83	363.26	485.09	125.00
5	Basic Research	227.70	2345.18	2572.88	468.20
6	Research Education Linkage	56.40	1360.59	1416.99	203.00
7A	Infrastructure	64.11	771.22**	835.33**	23.62**
7B	Housing	3.83	190.57	194.40	6.32
Total DAE + AERB		**1432.92**	**9577.61**	**11010.53**	**2809.84**

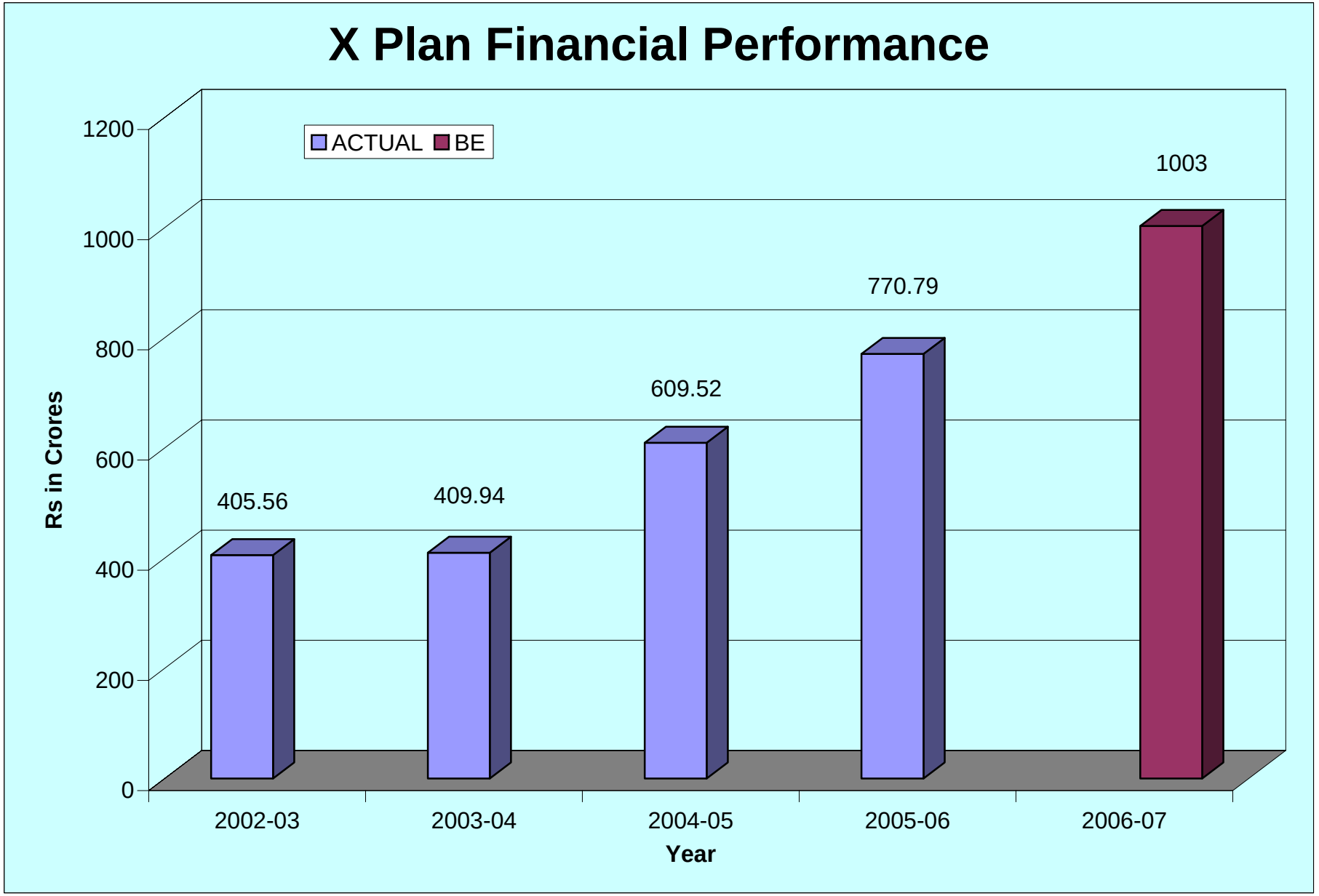
* Includes ITER India

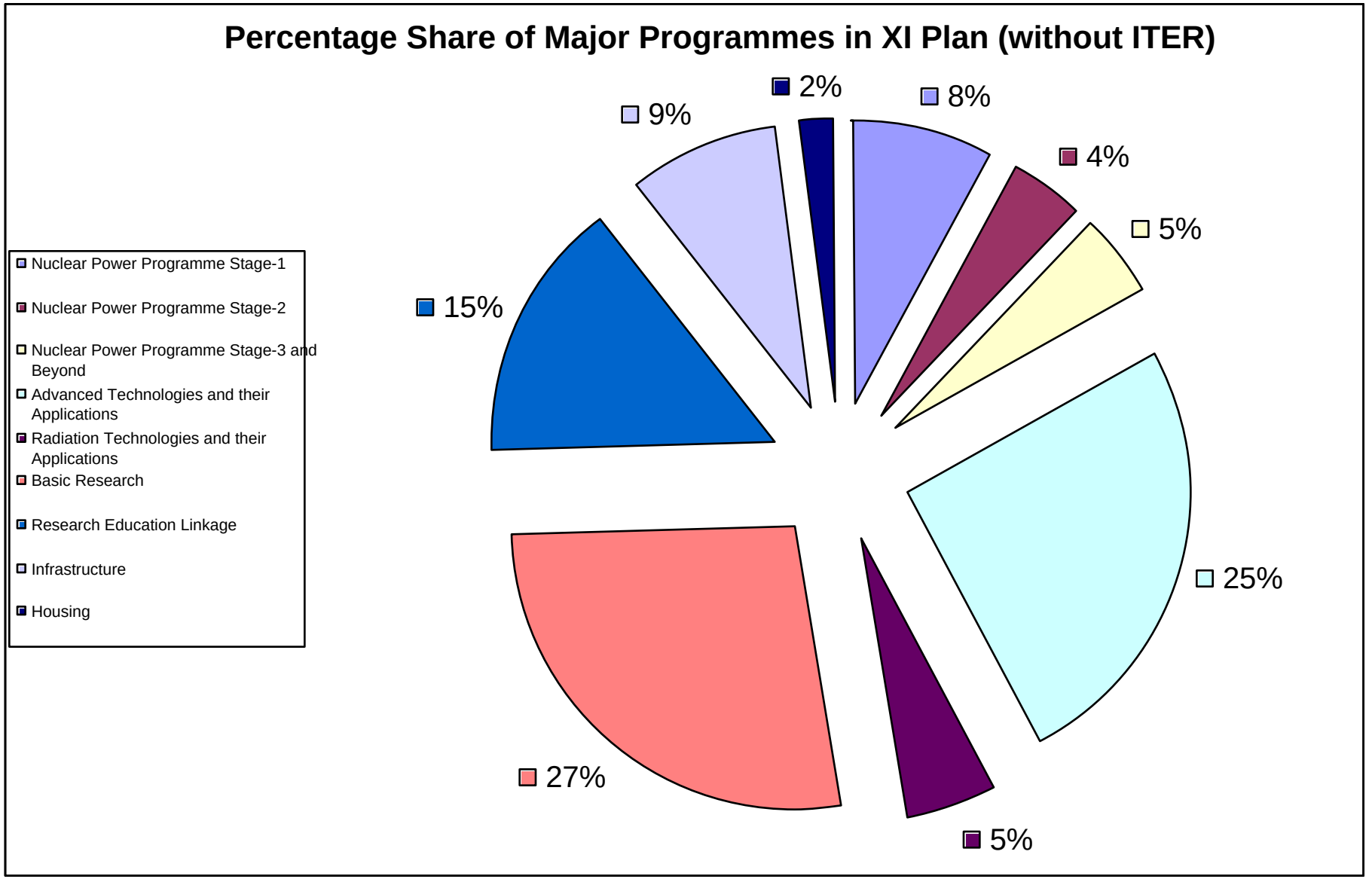
** Includes AERB Project Proposal

Table 7.2
DAE: XI Plan (R&D Sector)
Unit-wise Outlay
(Including Grant-in-aid*)

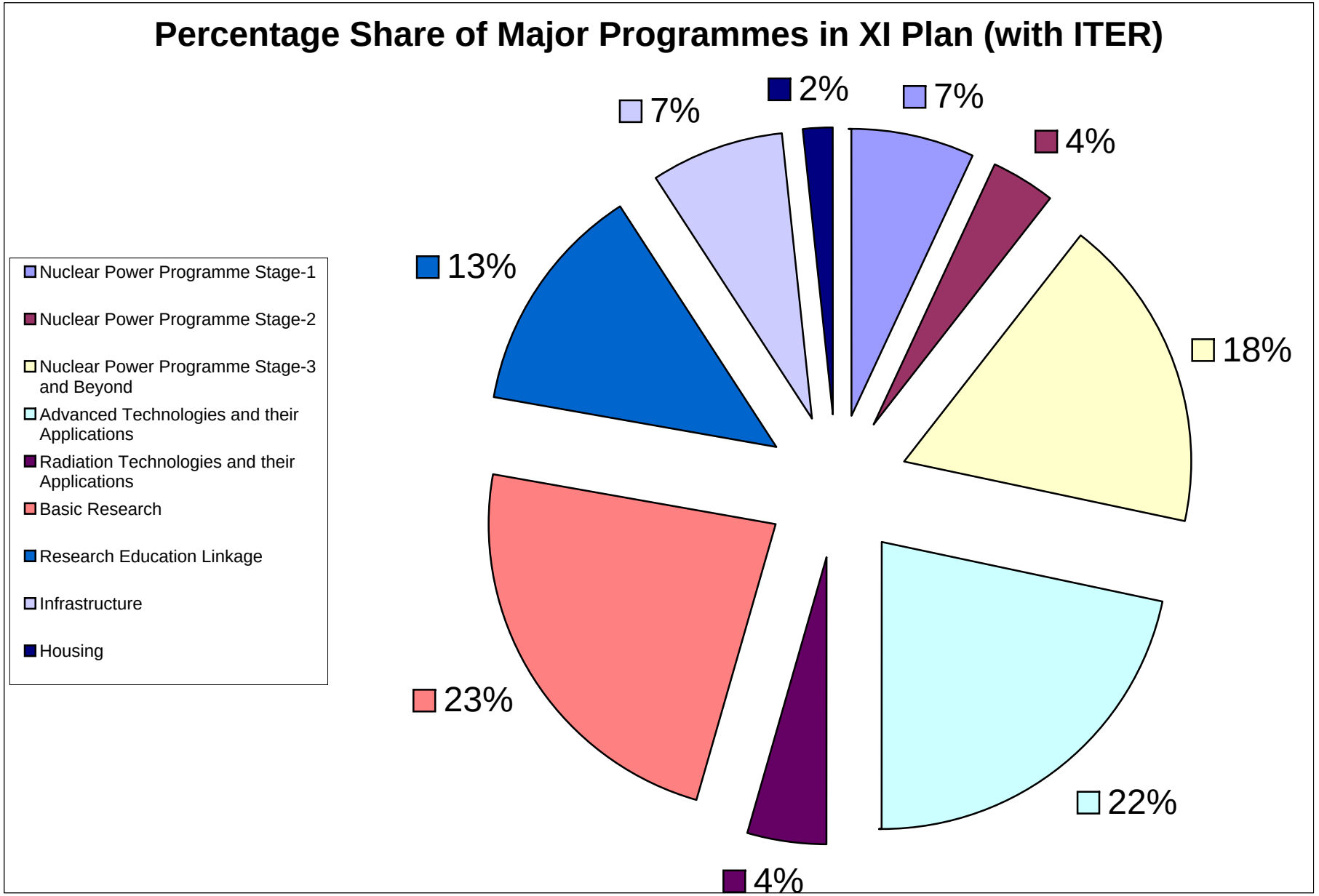
(Rs. in Crores)

Sl. No.	Unit	Proposed Outlay			
		XI Plan			Spill over XII Plan
		CS	NS	Total	
1.	AEES	0.00	115.00	115.00	0.00
2.	AMD	26.32	196.50	222.82	5.00
3.	BARC	1041.00	2615.00	3656.00	1043.30
4.	RRCAT	75.10	605.04	680.15	36.15
5.	DAE	0.71	73.50	74.21	3.00
6.	DCS&EM	53.00	109.16	162.16	0.00
7.	*Grant-in-Aid	0.00	701.75	701.75	0.00
8.	HRI	0.00	78.21	78.21	0.00
9.	IGCAR	27.53	646.61	674.14	55.81
10.	IMSc	5.00	24.04	29.04	0.00
11.	IOP	1.60	351.90	353.50	205.00
12.	IPR ITER India	0.00 0.00	457.00 1489.62	457.00 1489.62	0.00 1010.38
13.	SINP	0.00	703.28	703.28	360.20
14.	TIFR	43.12	672.23	715.35	29.00
15.	TMC	48.00	226.00	274.00	0.00
16.	VECC	111.54	499.76	611.30	60.00
Total DAE		**1432.92**	**9564.61**	**10997.53**	**2807.84**
AERB		0.00	13.00	13.00	2.00
Total DAE + AERB		**1432.92**	**9577.61**	**11010.53**	**2809.84**


X Plan Financial Performance
ACTUAL
BE
Rs in Crores
1200
1000
800
600
400
200
0
405.56
409.94
609.52
770.79
1003
2002-03
2003-04
2004-05
2005-06
2006-07
Year


Percentage Share of Major Programmes in XI Plan (without ITER)
Nuclear Power Programme Stage-1
Nuclear Power Programme Stage-2
Nuclear Power Programme Stage-3 and Beyond
Advanced Technologies and their Applications
Radiation Technologies and their Applications
Basic Research
Research Education Linkage
Infrastructure
Housing
2%
8%
4%
5%
25%
5%
27%
15%
9%

Percentage Share of Major Programmes in XI Plan (with ITER)



Subject wise Distribution of XI Plan Proposals

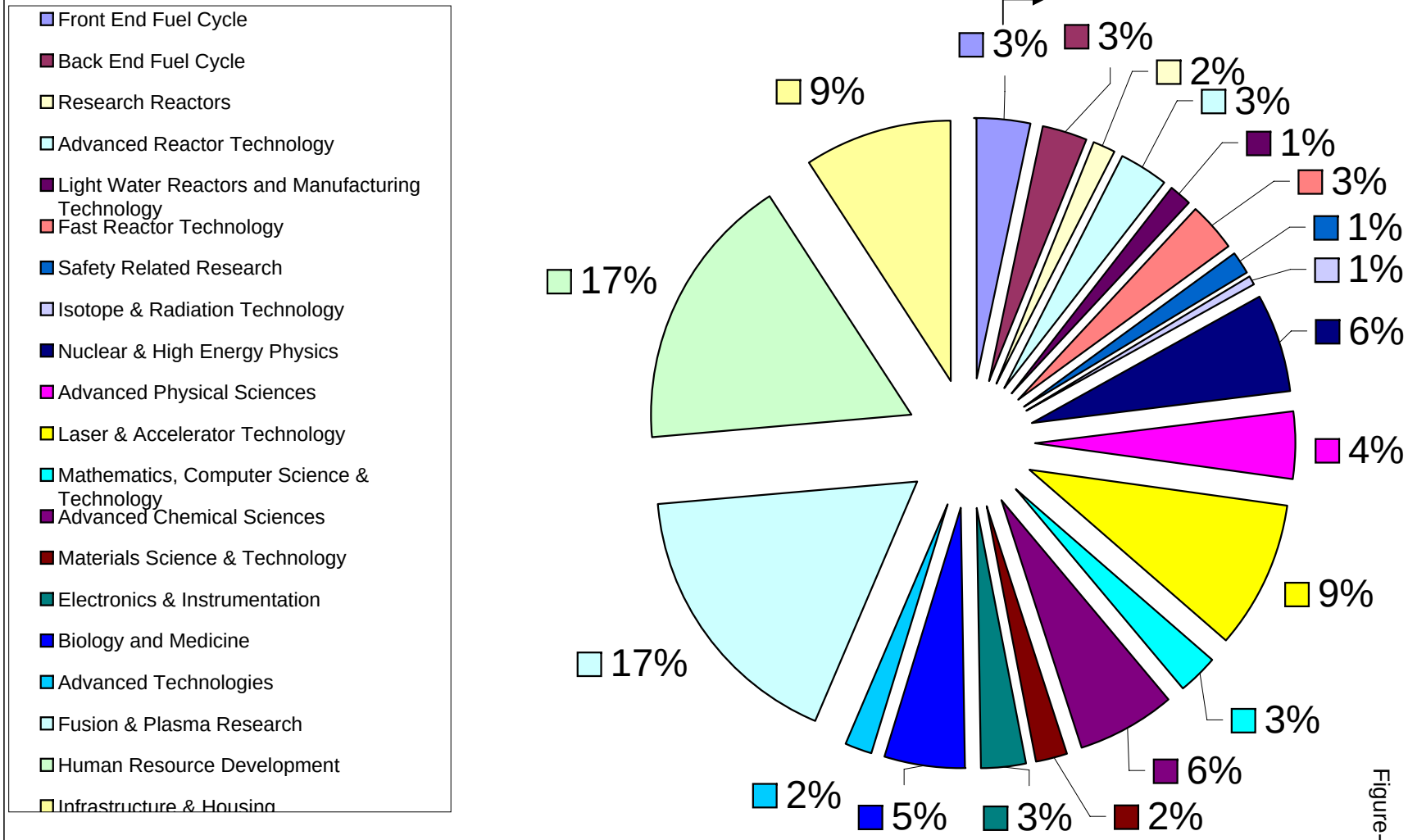
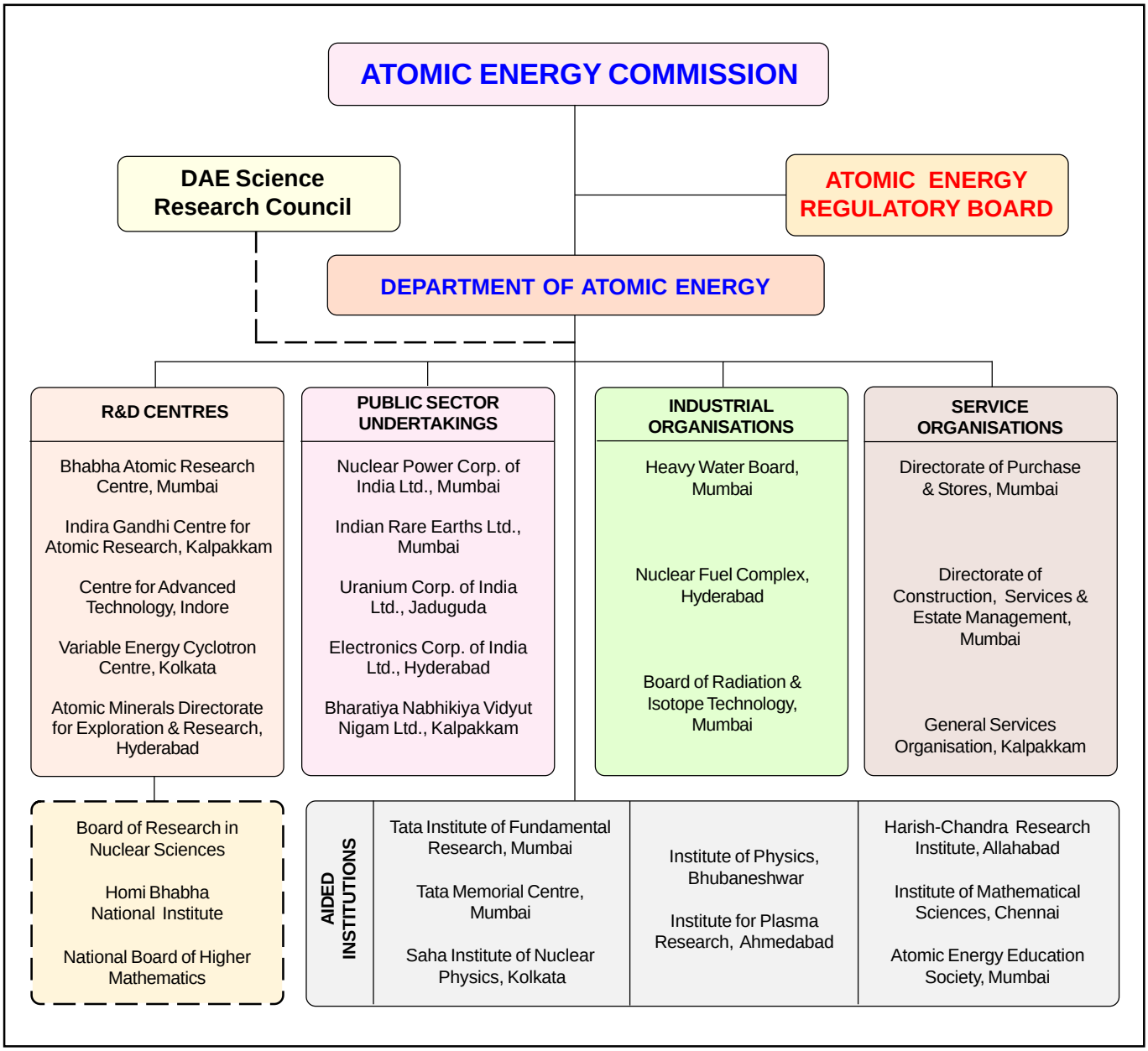


Figure-2

ANNEXES

DEPARTMENT OF ATOMIC ENRGY



Atomic Energy Establishments in India

Annex-C

No. Prn.SA/ADV/SC/2006
Government of India
Office of the Principal Scientific Adviser to the Government of India

311, Vigyan Bhawan Annexe,
Maulana Azad Road,
New Delhi 110011
Dated: 8th May, 2006

OFFICE MEMORANDUM

Subject : Constitution of Working Group under the Steering Committee on Science on Technology for the Formulation of Eleventh Five Year Plan (2007-2012).

Planning Commission has constituted a Steering Committee on Science and Technology for the Formulation of Eleventh Five Year Plan (2007-2012). To assist the Steering Committee and to finalize its recommendations, a Working Group is being constituted for Department of Atomic Energy (R&D Sector). The composition and terms of reference of the Working Group would be as follows :

I. Composition

Sr. No.	Name, Designation and Organization	
1.	Dr. Anil Kakodkar,Secretary, Department of Atomic Energy, Anushakti Bhawan, C.S.M. Marg, Mumbai – 400 001.	Chairman
2.	Dr. Srikumar Banerjee, Director, Bhabha Atomic Research Centre, Trombay,Mumbai – 400 085.	Member
3.	Mr. S.K. Sharma, Chairman, Atomic Energy Regulatory Board, Niyamak Bhavan Anushaktinagar, Mumbai - 400 094.	Member
4.	Chairman, Board of Research in Nuclear Sciences Department of Atomic Energy, Anushakti Bhawan, C.S.M. Marg, Mumbai – 400 001.	Member
5.	Director, UGC-DAE Consortium for Scientific Research	Member
6.	Prof. P. Balaram, Director, Indian Institute of Science, Bangalore – 560 012	Member
7.	Dr. R.B. Grover, Director, SPG, Department of Atomic Energy, Anushakti Bhawan, C.S.M. Marg, Mumbai – 400 001.	Member
8.	Prof. Ashok Mishra, Director, Indian Institute of Technology, Bombay, Powai,Mumbai – 400 076	Member
9.	Prof. J.B. Joshi, Director, University Institute of Chemical Technology, Bombay, University of Mumbai, Matunga, Mumbai – 400 019	Member

10.	Dr. Baldev Raj, Director, Indira Gandhi Centre for Atomic Research (IGCAR), Kalapakkam – 603102, Tamil Nadu	Member
11.	Shri K.A. Dinshaw, Director, Tata Memorial Centre Dr. E Borges Road, Parel, Mumbai - 400 012	Member
12.	Prof. Sabyasachi Bhattacharya, Director, Tata Institute of Fundamental Research,Homi Bhabha Road, Mumbai 400 005	Member
13.	Director, CAT	Member
14.	Director, VECC	Member
15.	Dr. C.V. Ananda Bose, Joint Secretary (R&D), Department of Atomic Energy,Anushakti Bhawan, C.S.M. Marg, Mumbai – 400 001.	Member
16.	Representative DST	Member
17.	Representative M/o Information & Technology	Member
18.	Representative ICMR	Member
19.	Representative CSIR	Member
20.	Representative UGC	Member
21.	Shri Arun Srivastava, SPG, Department of Atomic Energy, Anushakti Bhawan, C.S.M. Marg, Mumbai – 400 001.	Member Secretary

II. Terms of Reference

1. To review and assess the progress made by the various constituent units and grant-in-aid institutes of DAE during the Tenth Five Year Plan identifying the achievements, weaknesses/ shortfalls and gap areas.

2. To suggest plans and programmes of the various constituent units and grant-in-aid institutes of DAE based on the policy, approach, thrust and priorities for the Eleventh Five Year Plan taking into consideration convergence of various ongoing schemes including weeding out of the schemes which are no longer relevant and completion of ongoing schemes on a priority basis and also to suggest an optimum outlay for the R&D Sector, comprising, the ongoing commitment and new programmes proposed to be undertaken, keeping in view the overall resource position in the country.

3. The Chairman may co-opt members for specific task.

4. The expenditure on TA/DA in connection with meetings of this group would be met by the concerned department.

5. The report of the Group would be submitted by 15th July, 2006.

(S. Chatterjee)
Adviser

Copy forwarded to:

1. Chairman, all members and Member Secretary of the Working Group.

2. Dr. V.L. Chopra, Member (S&T and Agriculture), Planning Commission, Yojna Bhawan, New Delhi

3. Dr. P.K. Biswas, Advisor (S&T), Planning Commission, Room No. 213, Yojana Bhawan, Sansad Marg, New Delhi

(S. Chatterjee)
Adviser

ANNEX - C

No. Prn.SA/ADV/SC/2006
Government of India
Office of the Principal Scientific Adviser to the Government of India

311, Vigyan Bhawan Annexe,
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16.	Representative DST	Member
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18.	Representative ICMR	Member
19.	Representative CSIR	Member
20.	Representative UGC	Member
21.	Shri Arun Srivastava, SPG, Department of Atomic Energy, Anushakti Bhawan, C.S.M. Marg, Mumbai – 400 001.	Member Secretary

II. <u>Terms of Reference</u>

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(S. Chatterjee)
Adviser

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3. Dr. P.K. Biswas, Advisor (S&T), Planning Commission, Room No. 213, Yojana Bhawan, Sansad Marg, New Delhi

(S. Chatterjee)
Adviser

Annex-D

Government of India
Department of Atomic Energy
Strategic Planning Group

Anushakti Bhavan
CSM Marg
Mumbai 400001

No. DAE/DSPG/B-14.1/2006/85 May 01, 2006

Subject : Constitution of Internal Working Group for Department of Atomic Energy (R&D Sector).

.....

The Planning Commission is likely to set up a Working Group for formulating the XI Five Year Plan proposals of this Department in the R&D Sector for the period 2007-2012. To facilitate the finalisation of the Plan proposals by the Main Working Group, it has been decided to set up an Internal Working Group (IWG) in the Department. The composition of the Internal Working Group will be as under:

1. Dr.S. Banerjee, Director, Bhabha Atomic Research Centre - Chairman
2. Dr.Bikash Sinha, Director, Variable Energy Cyclotron Centre - Member
   Director, Saha Institute of Nuclear Physics
3. Dr.Baldev Raj, Director, Indira Gandhi Centre for Atomic Research - Member
4. Dr.V.C.Sahni, Director, Raja Ramanna Centre for Advanced Technology - Member
5. Prof.P.K.Kaw, Director, Institute for Plasma Research - Member
6. Prof. S.Bhattacharya, Director, Tata Institute of Fundamental Research - Member
7. Prof.R.Balasubramanian, Director, Institute for Mathematical Sciences - Member
8. Shri G.P.Srivastava, Chairman & Managing Director, ECIL - Member
9. Shri V.K.Mehra, Director, Reactor Projects Group, BARC - Member
10. Dr. R.B. Grover, Director, Strategic Planning Group, DAE - Member
11. Shri H.S.Kamath, Director, Nuclear Fuels Group, BARC - Member
12. Shri H.S.Kushwaha, Director, Health, Safety & Environment, BARC - Member
13. Shri R.K.Sinha, Director, Reactor Design & Development Group,BARC - Member
14. Dr.V.Venugopal, Director, Radiochemistry & Isotope Group, BARC - Member
15. Dr.K.B.Sainis, Director, Bio-Medical Group, BARC - Member
16. Dr.C.V.Ananda Bose, Joint Secretary (R&D), DAE - Member
17. Shri Arun Srivastava, Strategic Planning Group, DAE - Member Secretary

The terms of reference of the Internal Working Group (IWG) are given in the Annexe-1. The IWG will get inputs from the Specialist Groups (SGs) working on various themes. The themes and the SGs are given in Annexe-2, while the guidelines for review of X Plan projects and submission of XI Plan project proposals in R&D sector are given in Annexe-3. SGs will continue to work throughout the XI Plan so as to monitor the progress of ongoing and new projects.

It is proposed to introduce a new element in the XI plan and it is creation of a 'Prospective Research Fund (PRF)'. It will be operated on lines similar to BRNS. Project proposals will be invited from units within the Department. The proposals covering the following areas will be considered for funding.

- Research complimentary to the major projects proposed to be taken up during XI plan.
- Filling up of critical gaps, which might be identified during XI Plan.
- Enrichment of scientific knowledge and stimulating futuristic research.

While proposing major projects, complimentary research areas and funds needed for such research may be indicated in the outline of the proposals submitted for XI plan. Funds for the remaining have to be estimated and ideas are welcome. All such requirements will be consolidated and funds will be requested under the head, PRF. Individual needing funding for curiosity driven research on areas of relevance may send their proposals to DAE and these will be examined by SGs on the same pattern as advisory committees of BRNS examine proposals for funding from BRNS. Funding will be on a competitive basis and it is possible that research complimentary to a major project might get done in a unit different from where the major project is being done.

The Internal Working Group may start preparatory work immediately and coordinate its activities with the main Working Group when set up in such a way that the main Working Group will be able to submit the proposals to the Planning Commission within the stipulated time.

This issues with the approval of Secretary, DAE.

Sd/-
(R.B Grover)
Director, Strategic Planning Group

Chairman & Members of the IWG

Heads of Constituent Units & Aided Institutions

Annex 1

Internal Working Group on R&D Sector

Terms of Reference

1. To review various schemes/projects undertaken by the Department of Atomic Energy during the X Plan period in the R&D Sector and to suggest specific projects for the next Plan period along with the Plan outlay required, keeping in view the mandate of the Department.

2. To review the XI Plan proposals submitted by different DAE units (R&D centres, Industrial Units and Autonomous Institutions) and vetted by Specialist Groups identified for different R&D themes.

3. To identify the technologies developed by DAE which have potential for commercial exploitation and suggest the manner in which these potential capabilities can be utillised for societal developments in cooperation with other agencies including Central and State Governments, cooperative bodies and NGOs.

4. To indicate year-wise phasing of R&D activities and the budgetary allocation and other inputs required in the XI Plan period 2007-2012.

5. To periodically review and monitor the progress made in XI Plan R&D projects.

6. To submit the report of the review of XI Plan R&D Projects to the Department on a six-monthly basis.

Annex-2

R&D themes and Specialist Groups for reviewing X Plan projects and outlines of XI Plan project proposals.*

Theme No.	Theme	Sub-Programmes Nos. (Ref. Annex-6)	Specialists Group
1.	Front End Fuel Cycle	1.03, 3.02., 3.05	Dr.A.K.Suri, AD(P), Mat.Group, BARC-**Convenor** Shri R.M.Sinha, Director, AMD Shri R.N.Jayaraj, CE, NFC Shri P.Swaminathan, Dir.EIG, IGCAR Shri D.Acharya, Dir.(Tech), UCIL
2.	Back End Fuel Cycle	1.04, 1.06, 2.04	Dr.P.R.Vasudeva Rao, Dir, CG, IGCAR-**Convenor** Shri R.Natarajan, AD, RpG, IGCAR Shri P.K.Wattal, OS, NRG, BARC Shri P.K.Dey, Head, FRD, BARC
3.	Research Reactors	4.01	Shri V.K.Raina, AD, RG, BARC-**Convenor** Dr.R.Srivenkatesan, Hd., RPDS, BARC Shri P.K.Nema, SO/H, NPD, BARC Shri G.Srinivasan, Tech.Supdt., FBTR, IGCAR
4.	Advanced Reactor Technology	1.01, 3.01, 3.03, 3.04, 3.05	Shri R.K.Sinha, Director, RDDG, BARC-**Convenor** Shri K.B.Dixit, ED (Engg), NPCIL Shri Manjit Singh, AD, A&MG, BARC Shri K.K.Rajan, Head, Sodium Facilities Dvn., IGCAR
5.	Light Water Reactors and Manufacturing Technology	1.02, 4.11, 7.01	Shri V.K.Mehra, Director, RPG, BARC-**Convenor** Dr.A.K.Ray, Director, BTDG, BARC Shri R.L.Suthar, Head, CDM, BARC Shri U. Mahapatra, SO/H, CnID, BARC
6.	Fast Reactor Technology	2.01, 2.02, 2.03, 2.05, 2.06	Shri S.C.Chetal, Director, REG, IGCAR-**Convenor** Shri Prabhat Kumar, Proj.Dir., Bhavini Shri R.Prabhakar, Dir (Tech), Bhavini Shri Arun Kumar, SO/H, RMD, BARC
7.	Safety Related Research	1.05, 2.06	Shri H.S.Kushwaha, Dir., HS&EG, BARC-**Convenor** Dr.D.N.Sharma, Head, RSSD, BARC Shri K.C.Sahoo, ex-Head, PIED, BARC Shri M.Rajan, Director Safety Group, IGCAR
8.	Isotope & Radiation Technology	4.02, 4.03, 4.04	Dr.V.Venugopal, Dir., RC&IG, BARC-**Convenor** Dr.A.K.Kohli, CE, BRIT Dr.(Smt) M.Venkatesh, Hd., RPhD, BARC Dr.A.K.Sharma, Head, FTD, BARC
9.	Nuclear & High Energy Physics	5.02, 5.11	Prof. Atul Gurtu, TIFR- **Convenor** Dr.S.Kailas, AD(N), PG, BARC Dr.D.K.Srivastava, Hd.Phy.Gp., VECC Dr.R.K.Choudhury, SO/H, PG, BARC Prof. Rohini Godbole, IISc.
10.	Advanced Physical Sciences	5.02	Prof. Deepak Mathur, TIFR- **Convenor** Dr.J.V.Yakhmi, AD, Phy.Grp., BARC Dr.C.S..Sundar, Head, Mat.Science Dvn., IGCAR Prof. Amitava Raychandhuri, Dir. HRI Dr. P.D. Gupta, RRCAT

Theme No.	Theme	Sub-Programmes Nos. (Ref. Annex-6)	Specialists Group
			Prof. Avinash Khare, IOP
11.	Laser & Accelerator Technology	3.04, 4.05, 4.07, 4.08, 4.09, 4.11, 5.02, 5.06, 5.07, 5.10	Dr.V.C.Sahni, Director, RRCAT- **Convenor** Dr.R.K.Bhandari, AD, VECC Dr.J.K. Mittal, RRCAT Dr.Pitamber Singh, SO/H, NPD, BARC Shri A.S. Kotiah, PM, Indus-II, RRCAT
12.	Mathematics, Computer Science & Technology	2.01, 5.01, 6.05, 7.01	Prof. R.Balasubramanian, Dir., IMS- **Convenor** Shri P.S.Dhekne, AD, E&IG, BARC Dr. Sunanda Banerjee, TIFR Shri S.A.V.Satyamurty, Head Networking Section, IGCAR
13.	Advanced Chemical Sciences	3.06, 4.06, 4.10, 5.03	Shri D.S.Shukla, Dir., ChE&TG, BARC- **Convenor** Dr. T.Mukherjee, Dir., CG, BARC Dr. T.Gnanasekharan, Head, Liquid Metal & Structural Chem.Dvn., IGCAR Dr. S.K. Kulshrestha, AD, CG, BARC
14.	Materials Science & Technology	5.09	Prof. B.M.Arora, TIFR- **Convenor** Dr. Milon Sanyal, SINP Dr. K.Bhanushankar Rao, Head, Mat.& Metallurgy Dvn., IGCAR Dr.G.K.Dey, SO/H, MSD, BARC
15.	Electronics & Instrumentation	4.11, 4.12, 6.01	Shri G.P.Srivastava, CMD, ECIL- **Convenor** Shri B.B.Biswas, Head, RCnD Shri S.I.Sambasivan, Head, Electronics & Instrumentation Dvn., IGCAR Shri P.R. Hannurkar, RRCAT Shri V.K. Handu, Head, VIPD
16.	Biology and Medicine	4.05, 5.04, 5.05	Dr. K.B.Sainis, Director, BMG, BARC- **Convenor** Dr. Rajiv Sarin, Director, ACTREC Dr. N. Nair, Head, RMC Dr.S.K.Apte, AD, BMG, BARC
17.	Advanced Technologies	4.11	Dr. L.M.Gantayet, Head, L&PTD, BARC- **Convenor** Shri S. Bhattacharya, Head, CnID, BARC Dr.A.K.Nath, SO/H, RRCAT Shri Trilok Singh, Head, CT Div., BARC
18.	Fusion & Plasma Research	3.07, 5.08, 5.11	Prof. P.K.Kaw, Director, IPR- **Convenor** Prof. Abhijit Sen, IPR Prof. Y.C. Saxena, IPR Dr. A.K. Das, BARC
19.	HRD	4.12, 6.01 to 6.05	Dr. R.R.Puri, Head, HRDD, BARC- **Convenor** Dr.M.Saibaba, Head, Strategic Planning& Human Resource Dev.Section, IGCAR Shri Umesh Chandra, NPCIL Prof Duttagupta, SINP
20.	Infrastructure & Housing	7.01, 7.02	Shri S.Ramanujam, AD, ESG, BARC- **Convenor** Shri Y.C.Manjunatha, Dir., ESG, IGCAR Shri K.S.Wagh, Director, DCSEM

***Note: This is an updated list.**

Annex-3

Guidelines for review of X Plan projects and submission of XI Plan projects proposals in R&D sector by Specialist Groups.

(a) X Plan projects in the R&D sector will be grouped into several theme areas and for each theme area a small group of specialists have been identified (as listed in Annex-2). Specialist groups will review the progress made in all the X Plan projects falling under respective theme areas. Existing Major programmes and sub-programmes falling under each theme areas have also been identified in Annex-2. Specialist groups may propose additional sub-programmes.

(b) Outlines of XI Plan projects will be invited by JS (R&D) from different DAE units (R&D centers, Industrial Units and Autonomous Institutions) in the format enclosed and forwarded to the theme groups. These outline proposals, as cleared by the respective unit Heads, will be reviewed by the same Specialist group as per the theme area of the project. Format for submission of project outline is given in Annex-4.

(c) Project outlines should include objectives, work methodologies, specific deliverables related to departmental programmes, major facilities to be created, benefits to the society from the project, cost estimates, requirement of manpower and other inputs such as space/building, infrastructure, etc., and time schedules.

(d) Specialist groups, will review the project outlines, examine the importance of the project with respect to Department's mandate, offer their comments and suggestions and recommend acceptance of the proposed project outlines.

(e) Projects in which deliverables are clear and adequate pre-project activities have been completed will be supported in the mission mode. All such projects might require some complimentary basic research. While proposing such a project, complimentary research to be done and funds needed for the purpose may be separately indicated.

(f) As indicated in the letter, curiosity driven research projects related to major projects, projects aimed at critical gap areas and projects aimed at formulation

of future projects in different R&D themes can be proposed by individuals or groups and will be examined by the respective Specialist groups for funding on a competitive basis. Selected projects will be recommended to BRNS for funding from the head PRF.

(g) Once the projects are sanctioned, Specialist Groups will meet once in six months to review the financial and physical progress and make recommendations to the DAE.

Note: Major programmes and sub-programmes as identified at the beginning of X - Plan are given in Annex-6. One additional sub-programme has been added (7.02 – Housing). Specialist Groups and IWG are free to propose additional sub-programmes and merge existing sub-programmes. Small projects in a given sub-programme may be merged in an umbrella project as this facilitates project approval and monitoring.

Annex-4

XI PLAN – R&D SECTOR
PROJECT OUTLINE

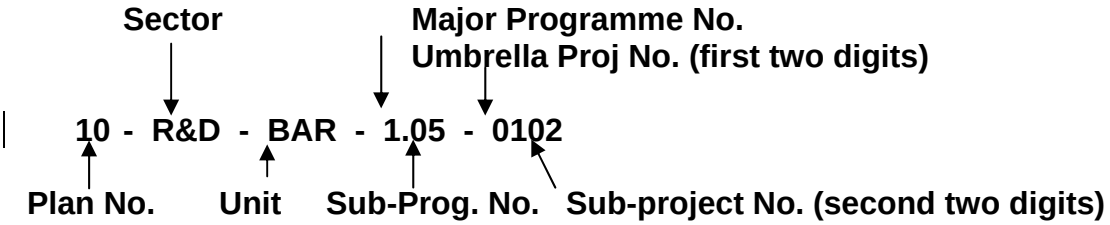
1.*	Theme Name	
2*	Project Number **(See Annex-5)**	
3.	Title of the Project	
4.	Objectives (Scientific / Social)	
5.**	Outcome / Deliverables related to departmental programmes	
6.**	Benefits to the society from the Project	
7.	Major Facilities to be created	
8.	Location of the Project	
9.	Work Methodologies	
10.	Start / Completion Date	
11.	Cost of the Project (Rs in Lakhs)	
12.	Yearly Outlay during XI Plan (Rs in Lakhs) [spillover to be given separately]	
13.	Manpower requirements	
14.	Infrastructure requirements	
15.	Remarks	
16.	Contact Person	

*** Theme name as per Annex 2. Project numbering as per Annex 5.**
**** Information to be provided in brief.**

Annex – 5

Project Identification Code

NUMBERING SYSTEM



ABBREVIATIONS FOR UNITS

AEE	Atomic Energy Education Society
AER	Atomic Energy Regulatory Board
AMD	Atomic Minerals Directorate for Exploration and Research
BAR	Bhabha Atomic Research Centre
CAT	Raja Ramanna Centre for Advanced Technology
DAE	Department of Atomic Energy
DEM	Directorate of Construction, Services & Estate Management
GIA	Grant in Aid
HRI	Harish-Chandra Research Institute
IGC	Indira Gandhi Centre for Atomic Research
IMS	Institute of Mathematical Sciences
IOP	Institute of Physics
IPR	Institute of Plasma Research
SIN	Saha Institute of Nuclear Physics
TFR	Tata Institute of Fundamental Research
TMC	Tata Memorial Centre
VEC	Variable Energy Cyclotron Centre

Annex-6

Major Programmes and Sub-Programmes**

MP-1 Nuclear Power Programme – Stage -1

1.01 PHWR (Pressurised Heavy Water Reactor)
1.02 LWR (Light Water Reactor)
1.03 Front End Fuel Cycle – Exploration, Mining & Ore Processing, Fuel Fabrication, Heavy Water Production
1.04 Back End Fuel Cycle- Reprocessing
1.05 Health, Safety & Environment
1.06 Waste Management

MP-2 Nuclear Power Programme – Stage -2

2.01 Fast Reactors
2.02 Materials
2.03 FBR-Front End Fuel Cycle (including Fuel Selection, Chemistry, Fabrication, Sodium and its related activities, Boron etc)
2.04 FBR-Back End Fuel Cycle
2.05 Repair and Inspection Technologies
2.06 FBR-Health, Safety & Environment

MP-3 Nuclear Power Programme – Stage -3 and beyond

3.01 AHWR (Advanced Heavy Water Reactor)
3.02 Thorium Fuel Cycle
3.03 Other Thorium Reactor Systems
3.04 Accelerator Driven Sub-critical System
3.05 Materials
3.06 Hydrogen Energy
3.07 Fusion Reactor

MP-4 Advanced Technologies and Radiation Technologies and their Applications

4A Advanced Technologies and their Applications

4.01 Research Reactors
4.08 Accelerators
4.09 Lasers
4.10 Special Materials

4.11 Advanced Technologies
4.12 Special Programmes

4B Radiation Technologies and their Applications

4.02 Isotope Processing
4.03 Agriculture
4.04 Food Processing
4.05 Health
4.06 Water
4.07 Industrial Applications

MP-5 Basic Research

5.01 Mathematics and Computational Sciences
5.02 Physics
5.03 Chemistry
5.04 Biology
5.05 Cancer
5.06 Synchrotrons & their Utilisation
5.07 Cyclotrons & their Untilisation
5.08 Fusion & Other Plasma Technologies
5.09 Materials Science
5.10 Interdisciplinary Areas
5.11 International Research Collaboration

MP-6 Research Education Linkages

6.01 Human Resource Development
6.02 Sponsored Research
6.03 Prospective Research Fund
6.04 HBCSE
6.05 Information Technology Applications Development

MP-7 Infrastructure & Housing

7.01 Infrastructure
7.02 Housing

****Note: This is an updated list**

Annex E

The ITER INDIA Project

ITER, which is the Latin for “the way”, is also an acronym for the International Thermonuclear Experimental Reactor. It is a prestigious international project which will nearly complete the scientific and technological investigations required to build a prototype demonstration reactor DEMO, based on the magnetic confinement scheme of controlled thermonuclear fusion. India has recently joined ITER as one of seven full partners, the others being China, European Union, Japan, Korea, Russia and USA. India will contribute equipment worth nearly 500 million US dollars to the experiment and will also participate in its subsequent operation and experiments. The equipment will largely be made by Indian industries in India,

India’s energy needs are enormous. With a rapidly growing economy and the rising expectations of its citizens to enjoy a decent standard of living ,the energy requirements of India are simply staggering. We have one fifth of the world’s population but our per capita electricity consumption is still only a quarter of the average of the world, 1/13th of that of Western Europe and 1/30th of that of the United states. Today we are consuming about 130 GW of power, 95 % of which comes from thermal or hydro sources. This number is likely to go up to a 1000 GW by the middle of this century. If this power continues to be produced by the mix we have today, the consequences for our environment are ominous. Therefore, we have to change the energy mix and go to a more aggressive pursuit of nuclear energy and renewable sources. We have an ambitious and indigenous nuclear energy programme within the country. Right now about 3 % of our electricity generation is based on nuclear power. This power generation is based on reactors using the pressurized heavy water concept, a technology we have mastered. We are now in the process of building the first 500 MW prototype fast breeder reactor at Kalpakkam, Tamilnadu. This is a follow up on the successful experiments with the 40 MW Fast Breeder Test Reactor. We would like to bring the share of nuclear power to about 10 per cent by the year 2020. Nuclear fusion is viewed as an advanced successor technology to nuclear fission, and is likely to play a commercially important role sometime in the second half of this century.

Nuclear fusion is the process which has kept the stars burning brilliantly for billions of years. On the earth its devastating power has been seen through the hydrogen bombs. The most convenient fusion reaction is that of heavy isotopes of hydrogen, which are either readily available or may be readily bred from available material in earth's crust and the oceans :

$$_1D^2 + {}_1T^3 = {}_2He^4 + {}_0n^1 + 17.6 \text{ MeV}$$

For the past fifty years or more, controlled thermonuclear fusion experiments have been investigating how to confine a low density fusion grade plasma of deuterium and tritium at temperatures approaching hundred million degrees by magnetic fields, so that slow and controlled release of fusion energy may become possible. This search has led to a successful magnetic bottle concept, viz. the tokamak concept, in which the magnetic confinement geometry is produced by a combination of fields produced by external coils and fields produced by plasma currents. The plasma is heated by the plasma currents and by injection of radio frequency waves and energetic neutral particle beams into the plasma. Once the fusion reaction is ignited, the fusion plasma can be kept hot by the stopping of energetic helium nuclei in the plasma. The electrically neutral neutrons carry their energy out of the plasma where it is collected in a blanket, used to generate steam and utilized for electricity generation by the use of standard steam turbine cycles. Large experiments with millions of amperes of plasma current and tens of Megawatts of injected power (like JET in Europe and JT-60U in Japan) have produced fusion reactor grade plasmas with breakeven conditions. Empirical scaling laws have been established which indicate that an experiment of the size of ITER will produce an energy amplification by a factor of 10 and will thus be able to generate about 500 Mwatts of fusion power. This is why it is important to do an experiment of the size of ITER before designs for prototype commercial fusion reactors can be finalized.

India has had a fusion research programme of its own since the early eighties. Two tokamaks have been indigenously built at the Institute for Plasma Research (IPR) near Ahmedabad and a small tokamak has been imported from Toshiba, Japan at the Saha Institute for Nuclear Physics , Kolkata (SINP). The SINP tokamak has been used for an intense study of low q tokamak discharges. ADITYA, the first indigenously built Indian tokamak, has ben extensively used for the study of plasma turbulence in the edge and scrape-off layer regions. This novel work led to the discovery of intermittency in tokamak turbulence, which is related to the presence of coherent structures in the

turbulence and leads to bursty transport effects. The second IPR tokamak, SST1, is a steady state superconducting tokamak and is currently undergoing commissioning tests. It will have Megawatts of ion cyclotron and neutral beam based auxiliary heating. These two tokamaks and associated auxiliary equipment have been built by Indian industries with designs and integration responsibilities taken up by IPR. Many sophisticated diagnostic tools have also been developed at IPR and SINP.

India's contributions to ITER are largely based on the indigenous experience and the expertise available in Indian industry. India will be fabricating the 28 m dia , 26 m tall SS cryostat , which forms the outer vacuum envelope for ITER. It will also take up the design and fabrication of eight 2.5 Mwatt ion cyclotron heating sources, complete with power systems and controls. It will also take up the fabrication of a diagnostic neutral beam system which will give crucial information about the physics of burning plasmas in ITER. India will also be responsible for a number of other diagnostic subsystems. Finally, India will contribute to cryo-distribution and water cooling subsystems. All this equipment will have to be built with ITER quality standards and in a time frame (approximately ten years) determined by the International Team at the host site in Cadarache , France. This is the challenge.

The opportunity that participation in ITER offers us is also enormous. This is the first time we will be full partners in a prestigious international experiment. We will have to come to international standards of quality, safety, time schedule maintenance etc immediately. Our scientists and engineers will get direct hands on experience in design, fabrication, operation etc of the latest fusion technologies. We will get access to a number of fusion technologies on the scale relevant to fusion reactors for the first time. If we backup the ITER INDIA effort with an aggressive well focused national programme, it will allow us to leapfrog by at least a couple of decades.

Annex-F

Interaction with State/Central Ministries and Other Organisations

The constituent units and grant-in-aid institutions of the Department of Atomic Energy have been working in their mandated fields. While pursuing the mandate, several spin-off technologies have been developed. The Department has been transferring these technologies to the interested agencies in the government, public and private sectors. To provide benefit of the expertise available in the Department to other organizations in the country, wherever necessary, collaborative hi-tech programs are also pursued. We also provide consultancy and expert services in hi-tech areas to other organizations. Examples are: design and development of generator overheating monitoring system for identification of hot spots, capacitor banks for energy storage for applications in electromagnetic forming etc., hospital information management system, thyristor based chopper-controlled system for the Indian Railways, instrumented pipeline inspection gauge (PIG) for inspection of cross country oil pipelines for the Indian Oil Corporation, servo controls and drive systems for the Departments of Space and Defence, shape memory alloy components for LCA, plasma spray coating services, electron beam welding services and laser processing services, virtual reality packages, parallel computers, particle size classifiers**,** bio-pesticide, eco-friendly strategies for crop improvement, bio-reactors for propagation of cell culture for medicinal plants, tissue culture based protocol for cultivars of banana**,** technology for production of boron carbide and high purity boron powder etc.

Some important technologies that can improve the standard of living of the society are being pursued in cooperation with other ministries; examples follow.

Desalination

BARC has developed desalination technologies based on multi-stage flash (MSF) evaporation, reverse osmosis (RO) and low temperature evaporation. BARC has set up a 1800 cubic meter per day reverse osmosis (RO) plant at Kalpakkam. A 4500 cubic meter per day multi-stage flash distillation plant is under construction. A RO plant is currently meeting the fresh water requirements of Kudankulam project of NPCIL. DAE has set up several smaller desalination plants in the rural areas of Rajasthan, Andhra Pradesh and Gujarat producing 30,000 litres/day drinking water from brackish water for providing safe drinking water to villagers. The technology has been licensed to about seven industries and several such plants have been supplied by them for location in remote areas. BARC has also developed desalination plants for rural areas, ship-borne aplication, and for other uses. To a barge mounted autonomous reverse osmosis plant for catering to coastal water scarcity region is also under development. For installing desalination plant at Lakshdweep, Daman and Diu, Ministry of Home Affairs has constituted an Expert Group to carryout the comparative evaluation of different available technologies for setting up desalination plants at Kavaratti and nine other islands of Lakshadweep. BARC is a member of the Expert Group. It is in the process of preparing Detailed Project Report for the same.

DAE has developed an ultra-filtration membrane based device for on-line purification of domestic water to take care of biological and other contaminants like suspended solids, organics, colour, odour etc. The technology for online domestic water purifier based on ultrafiltration polysulfone membrane for producing bacteria free safe drinking water has been transferred to more than twelve parties for commercialization. Many of them are already in the market.

Agriculture

A group in BARC is working in the area of Bio-sciences. To ensure that results of research are actually deployed in the field, DAE and Ministry of Agriculture have set up an interface which has been very effective.

A] **Oilseeds and Pulses**

Using nuclear techniques 24 elite Trombay varieties have been developed at Bhabha Atomic Research Centre (BARC). These varieties, released and gazette notified for commercial cultivation include 13 oil seed crops (10 Groundnut, 2 mustard and 1 Soybean) and 11 pulse (4 Blackgram, 5 Greengram and 2 Pigeonpea)[1]. These are transferred from laboratory to land through interaction with Indian Council for Agricultural Research (ICAR), State Agriculture Universities, Seed Corporations, Krishi Vigyan Kendras, and participation in Kissan Melas, Exhibitions, and awareness programmes.

B] **Radiation Processing of Food and Agro products**

Radiation processing is a simple technique for enhancing shelf life, improving hygienic quality and satisfying quarantine requirements without worries related to chemical residues.

The Government of India has approved radiation processing of certain food items both for export and domestic consumption. For radiation processing of spices and other products, a Spice Plant with an initial throughput of 20 tonnes/day, set up by BRIT at Navi Mumbai, has been operating since January, 2000. A commercial demonstration plant KRUSHAK for the treatment of potatoes and onions and other products requiring low doses, has also been operational at Lasalgaon, District Nashik, Maharashtra. Private and cooperative sectors are being encouraged to set up similar plants. So far four plants owned by private entrepreneurs have become operational. Another ten are under various stages of construction. Ministry of Food Processing Industries is encouraging and supporting this technology. Large scale deployment of this technology has the potential for catalyzing higher production through price stability, access to wider markets including exports as well as greater value addition.

C] **Others**

A laser-based land leveling system was built by Raja Ramanna Centre for Advanced Technology, Indore at the behest of Ministry of Agriculture and this technology has been transferred to M/s OSAW Udyog of Ambala Cantt for mass production of such systems.

[1] In addition, BARC has also developed 1 variety of jute and one of rice.

Urban and Rural Waste Recycle

The waste water sludge generated by a city sewage plant is typically very odorous and contains a high level of pathogens which limit the reuse of this waste which is otherwise a rich source of nutrients. The pathogens present in the sewage sludge can be effectively removed from the sewage sludge by exposing it to high-energy radiation from Cobalt-60. BARC, in collaboration with Vadodara Municipal Corporation, has established a Sludge Hygienisation Research Irradiator (SHRI) at Vadodara to demonstrate this upcoming technology. The radiation treatment of sewage sludge offers an efficient, simple and reliable method to produce pathogen free sludge, thus allowing safe recycle of a polluting waste which can be further upgraded to produce a value added bio-fertilizer.

BARC's NISARGRUNA plant offers "Zero garbage, Zero effluent" method for biodegradable waste disposal in urban as well as in rural areas. Seven such plants have been installed. NISARGRUNA plant can process almost any biodegradable waste including kitchen waste, paper, grass, gobar, dry leaves agricultural residue etc. There is a good potential for energy generation in this biphasic biomethanation plant. NISARGRUNA thus presents a unique opportunity to convert urban and rural biodegradable agricultural residue into valuable manure and energy in the form of methane while eliminating pollution as a result of decay. Mumbai Municipal Corporation has supported construction of such plants as a part of its solid waste management.

Ministry of Non-Conventional Energy Sources as well as Ministry of Agriculture have also shown interest and is actively supporting installing NISARGRUNA type plants all over the country.

Health

Countrywide Service in Cancer through Telemedicine

In India with its vast distances and remote areas, access to available health care is a major issue for large number of economically challenged population. This is even more relevant to cancer patients, especially because 60-70% patients first visit a hospital only with advanced disease. The use of telemedicine and technology would bridge this gap allowing quick access to expert advice and appropriate medical attention. This would greatly mitigate the financial and physical burden of the patients, exponentially expand care reach to remote corners of the country and promote educational and training opportunities to all cadres of medical professionals. Cancer Desk of Ministry of Health and Family Welfare have assigned this project to Tata Memorial Centre, a grant-in-aid institution under the DAE. Department of Space is actively assisting establishment of linkage through satellite connectivity. Pilot project has been launched. So far 19 nodes have been connected with TMC including seven in North-East region and two cancer hospitals abroad. All Regional cancer centers in the country would be net-worked by the end of the X Plan.

Bhabhatron, the indigenous telecobalt machine developed at BARC was successfully commissioned at ACTREC where it has undergone rigorous dosimetric and clinical evaluation and further technical improvements have been made to make it comparable in performance to the more expensive imported machines. Currently there are about 350 teletherapy units in the country i.e. 0.3 per million populations as

compared to WHO recommended norm of 1 unit per million populations for the developing countries. The teletherapy equipment (Telecobalt or Linear Accelerator) is quite expensive, often costing several crores for each machine and have traditionally been imported from Europe and North America. The present market cost of the imported equipment is a very major deterrent towards fulfilling the huge shortfall of 700 teletherapy units required for effective cancer treatment in India. DAE is interacting with Ministry of Health & Family Welfare for promotion of this machine under the National Cancer Central Programme.

DAI Kit, is a low cost radiation sterilized midwifery kit for delivery developed by BRIT for use in rural areas for preventing infection of mothers and minimizing the infant mortality rate. Over one million such kits have been distributed through WHO funded rural health programmes.

Hydrogel for treatment of burn injuries have been developed and this technology has been transferred to two parties including Reddy's lab.

Plasma Pyrolyser: Technology for treatment of hospital waste has been developed by Institute for Plasma Research and has already been transferred to private enterprise. This technology effectively treats hospital waste with near negligible residue.

Other Technologies

RRCAT developed India's first green laser photo-coagulator for treatment of diabetic retinopathy (DR) and delivered the first prototype unit in September 2005 to M/s Aurolab (an adjunct of Aravind Eye Hospital, Madurai) for clinical trials.

The autofluorescence spectroscopic diagnosis system developed at RRCAT was used for in-situ detection of the cancer of oral cavity at Government Cancer Hospital, Indore. This study showed the diagnostic efficacy (sensitivity and specificity of > 90 % towards cancer) of this cost effective technique.

Scientific Productivity

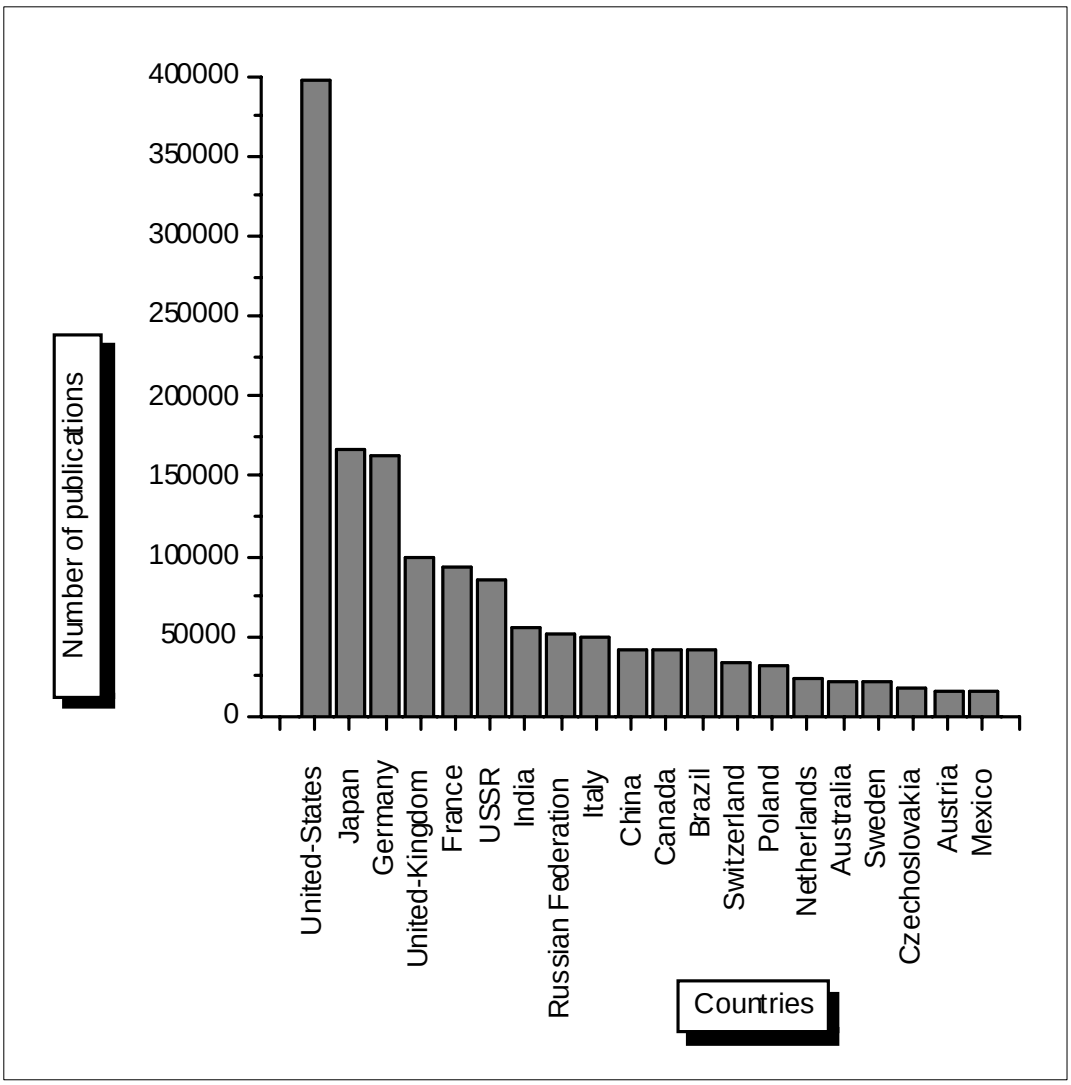
Apart from carrying out project oriented R&D activities, DAE laboratories are publishing many important basic research papers in international journals having high impact factors. A quantitative analysis of the growth and development of Science and Technology research in India in terms of publication output has been done[1] using Science Citation Index which is regularly published by Institution of Scientific Information, Philadelphia. Science Citation Index gives a compilation of bibliographic and citation details of articles from more than 4000 reputed journals published in the field of science and technology globally. Out of more than few thousand institutions producing R&D publications in India, top most productive institutions have been listed. It is found that 8 DAE institutions are in the first 52 in the list with BARC ranking at second most productive institution. Other DAE institutions, with ranks in bracket, listed are TIFR, Mumbai (4), SINP, Kolkatta (20), IGCAR, Kalpakkam (25), IPO, Bhubaneshwar (45), IMSc, Chennai (49), RRCAT, Indore(50) and TMH, Mumbai (52).

Another review[2] was carried out for all Physical Review journals including Physical Review Letters which are considered to be most highly rated in basic physics. There have been about 3200 papers published from India in those journals since 2000. DAE laboratories have published half of it and this number is double of the total publications in these journals during this plan by IISc and all IITs put together.

In the field of Nuclear Science, in a recently published paper titled "Scientometric dimensions of nuclear science and technology research in India: A study based on INIS (1970-2002) database" by Kademani et. al, Malaysian Journal of Library & Information Science, Vol.11, no.1, July 2006: 23-48, analysed quantitatively the growth and development of Nuclear Science and technology research in India in terms of publication output as reflected in International Nuclear Information System (INIS) database. During 1970-2002 a total of 55,313 papers were published by the Indian Nuclear Scientists in various domains: Physics (23,033), Chemistry (16,368), Life and Environmental Sciences (7,203), Engineering and Technology (6,960), Other aspects of Nuclear and Non Nuclear Energy (981) and Isotopes and Radiation Application (768). In India, major work in nuclear

[1] Personal communication, Dr Vijai Kumar, Head SIRD, BARC, 11-09-06.
[2] Perconal communication, Prof Milan K Sanyal, Head, Surface Physics Division, SINP dt. 24-08-06

science is carried out by DAE and hence we may say that the majority share in these publications is from DAE. Top 20 highly productive countries in Nuclear Science and Technology as per INIS (1970-2002) database are indicated in the Figure below. India is ranked 7th.



Top twenty highly productive countries in Nuclear Science and Technology as per INIS (1970-2002)

Abbreviations

ACTREC	Advanced Centre for Treatment, Research and Education in Cancer
ADS	Accelerator Driven Systems
ADSS	Accelerator Driven Sub-critical System
AERB	Atomic Energy Regulatory Board
AHWR	Advanced Heavy Water Reactor
ALICE	A Large Ion Collider Experiment
AMD	Atomic Minerals Directorate for Exploration & Research
ASIC	Application Specific Integrated Circuit
BARC	Bhabha Atomic Research Centre
BRNS	Board for Research in Nuclear Sciences
BST	Barium Strontium Titanate
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CARE	Centre of Advanced Research and Education
CCD	Charge Coupled Device
CERN	European Organisation for Nuclear Research (English name)
CMS	Compact Muon Solenoid experiment
CORAL	Compact Reprocessing Facility for Advanced Fuels in Lead cells
CT	Computed Tomography
CVL	Copper Vapour Laser
DAE	Department of Atomic Energy
DCS&EM	Directorate of Construction, Services & Estate Management
DFRP	Demonstration Fast Reactor Fuel Reprocessing Plant
DNA	Deoxyribonucleic acid
DR	Diabetic Retinopathy
DST	Department of Science & Technology
DZERO	D Zero
FAIR	Facility for Antiproton and Ion Research
FBR	Fast Breeder Reactor
FBTR	Fast Breeder Test Reactor
FOTIA	Folded Tandem Ion Accelerator
FRENA	Facility for Research in Experimental Nuclear Astrophysics
GMRT	Giant Metrewave Radio Telescope
GRAPES	Gamma Ray Astronomy at PeV Energies
HAGAR	High Altitude Gamma Ray experiment
HBCSE	Homi Bhabha Centre for Science Education
HBNI	Homi Bhabha National Institute
HEU	Highly Enriched Uranium
HIMS	Hospital Information Management System
HIPA	High Intensity Proton Accelerator
HLW	High Level Waste
HPC	High Performance Computing
HRI	Harish-Chandra Research Institute
HTP	High Throughput
ICAR	Indian Council for Agricultural Research
ICU	Intensive Care Unit

IEA	International Energy Agency
IERMON	Indian Environmental Radiation Monitoring Network
IGCAR	Indira Gandhi Centre for Atomic Research
IHTR	Indian High Temperature Reactor
IHX	Intermediate Heat Exchanger
IIA	Indian Institute of Astrophysics
IISER	Indian Institute of Science Education and Research
ILC	International Linear Collider
IMSc	Institute of Mathematical Sciences
INGA	Indian National Gamma Array
INIS	International Nuclear Information System
INO	India-based Neutrino Observatory
IOP	Institute of Physics
IPR	Institute for Plasma Research
ISI	In-service Inspection
ISRO	Indian Space Research Organisation
IT	Information Technology
ITER	International Thermonuclear Experimental Reactor
IUAC	Inter University Accelerator Centre
IWG	Internal Working Group
LAXPC	Large Area X-ray Proportional Counter
LET radiation	Linear Energy Transfer radiation
LEU	Low Enriched Uranium
LHC	Large Hadron Collider
LOCA	Loss of Coolant Accident
LPU	Local Protection Unit
LTE	Low Temperature Evaporation
LWR	Light Water Reactor
MACE	Major Atmospheric Cerenkov Experiments
MEMS	Micro-Electro-Mechanical Systems
MEOMS	Micro-Electro-Opto-Mechanical Systems
MoU	Memorandum of Understanding
MOVPE	Metal Organic Vapor Phase Epitaxy
MPRR	Multi Purpose Research Reactor
MSF	Multi Stage Flash
NBHM	National Board for Higher Mathematics
NCFFRR	National Centre for Free Radical Research
NCRA	National Centre for Radio Astrophysics
NDT	Non Destructive Testing
NEMS	Nano-Electro-Mechanical Systems
NISER	National Institute of Science Education and Research
NIUS	National Initiative for Undergraduate Science
NMR	Nuclear Magnetic Resonance
NPCIL	Nuclear Power Corporation of India Limited
NPP	Nuclear Power Programme
NRG	Nuclear Recycle Group
O&M	Operation & Maintenance
OCT	Optical Coherence Tomography
PET	Positron Emission Tomography
PFBR	Prototype Fast Breeder Reactor
PHWR	Pressurised Heavy Water Reactor

PLZT	Lead Lanthanum Zirconate Titanate
PMD	Photon Multiplicity Detector
PRTRF	Power Reactor Thoria Reprocessing Facility
PZT	Lead Zirconate Titanate
QHPS	Quench Heater Power Supplies
RF	Radio Frequency
RFQ	Radio Frequency Quadrapole
RHIC	Relativistic Heavy Ion Collider
RIB	Radioactive Ion Beam
RMC	Radiation Medicine Centre
RO	Reverse Osmosis
RPC	Resistive Plate Chamber
RSMS	Radioactive Solid waste Management Services
S&T	Science & Technology
SG	Specialist Group
SGTF	Steam Generator Test Facility
SINP	Saha Institute of Nuclear Physics
SNS	Spallation Neutron Source
SPECT	Single Photon Emission Computed Tomography
SQUID	Superconducting Quantum Interference Device
SR	Synchrotron Radiation
SRS	Synchrotron Radiation Source
SSSF	Solid Storage Surveillance Facility
SST-1	Steady State Tokamak-1
SUMO	Small Ubiquitin Modifier
TIFR	Tata Institute of Fundamental Research
TIG	Tungsten Inert Gas
TILLING	Targeting Induced Local Lesions in Genomes
TMC	Tata Memorial Centre
TMH	Tata Memorial Hospital
TSC	Trombay Scientific Committee
TW	Terra Watt
UV	Ultra Violet
VECC	Variable Energy Cyclotron Centre
WG	Working Group
XFEL	X-ray Free Electron Laser