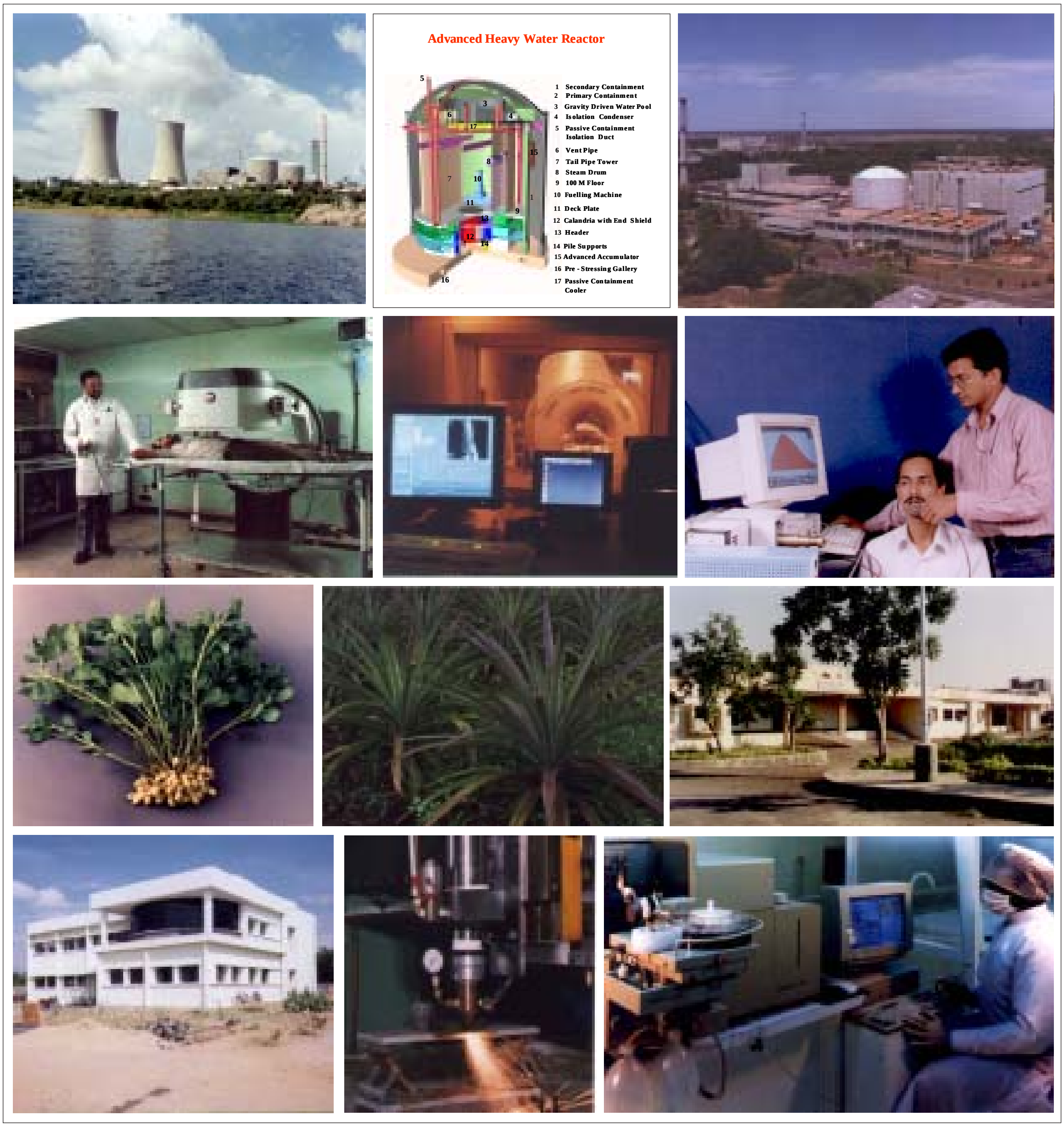
Long Term Vision of the Department of Atomic Energy



सत्यमेव जयते

Government of India

Department of Atomic Energy

Long Term Vision of the Department of Atomic Energy

THE PRESENT

Success of any agency pursuing hi-tech areas demands that 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. Fulfillment 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 (see plate-1 for organization chart of DAE) 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 sciences 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. In the nuclear field we have to retain and strengthen our ability to carry forward with further domestic developments of advanced technologies, so as to remain immune from technology denial regimes and tailor our programme to be in tune with our nuclear resource profile.

Nuclear Power Programme

Increased availability of electricity is a necessary requirement for the development of the country. This has to be done in a manner that provides long-term energy security, is sustainable and is based on diverse fuel sources and technologies. That implies that we have to examine all fuel resources in the country and tap them keeping short, medium and long term scenarios in perspective. Hydro potential and renewables must be exploited to the maximum possible extent and in as short a time-frame as possible. These together with coal would meet short and medium-term requirements, but to meet long-term requirements, it is necessary to exploit nuclear resources. 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. Three stage nuclear power programme formulated by the Department takes cognizance of the nuclear resource profile.

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. Twelve PHWRs are operating, and two more 220 MWe PHWRs and two PHWRs of 540 MWe rating[1] are under construction. Construction of more such units is being planned. As DAE gains experience and masters various aspects of the nuclear technology, performance of nuclear power

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[1] *These units were intended to be 500 MWe units, but based on subsequent studies have been uprated to 540 MWe. Studies are in progress to further uprate the unit capacity.*

plants is continuously improving. Average capacity factor of nuclear power plants has steadily risen from 60% in 1995-96 to 82.5% in the year 2000-01.

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 the country, fast breeder reactors are necessary. A large power-generating base is also needed to establish use of thorium on a large scale in the third stage of the programme. A 40 MWt Fast Breeder Test Reactor (FBTR) has been operating at Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam. FBTR has provided valuable experience with liquid metal Fast Breeder Reactor Technology and the confidence to embark upon construction of a 500 MWe Prototype Fast Breeder Reactor (PFBR). Detailed design, R&D and technology development of the PFBR is in advanced stage. Construction work on this is expected to start in a few months. This will also be located at Kalpakkam near Chennai.

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 75% power in thorium, and to maintain negative void co-efficient of reactivity under all operating conditions. A detailed project report for AHWR is being made and it is proposed to launch its construction during the X plan.

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, we are planning to set up light water reactors. The deal with the Russian Federation for setting up two 1000 MWe units at Kudankulam is a step in this direction. Pre-project activities for setting up these units are in progress and we expect to start the construction of these units towards the end of the year 2001.

Radiation technologies applications programme and other advanced technologies

This programme, because of its high societal relevance is as important as the nuclear power programme. It has many components, the main being the technologies for the production of radiation and the technologies for their application. Radiation can be produced either from radioisotopes or from accelerators. Therefore, for the production of radiation, one has to develop research reactors and accelerators. Another technology, being pursued by the DAE is lasers and their applications. The DAE has developed and is continuing to develop research reactors, accelerators and lasers and other advanced technologies.

Application areas of radiation technologies include health care, agriculture, food preservation, industry, water resources and research. Parallel to the nuclear power programme, radiation technologies applications have made considerable progress in India. 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, some of the 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 industrial accelerators as well by units of DAE viz., Centre for Advanced Technology (CAT), Indore and BARC, Mumbai.

Development of indigenous lasers for a variety of applications has also been a very successful programme by CAT. In the recent years, based on radiation technologies applications, we have made significant contributions in food and agriculture, health care and industry.

In the process of developing nuclear technologies, the Department has acquired expertise in a variety of advanced areas and these technologies have enriched the hi-tech base in the country in several ways. Certain technologies have been transferred to other private and government agencies as spin-offs; examples include development of process flow sheets for special materials, medical instruments like impedence plethysmograph, laser communicator etc. In certain cases expertise generated has helped in cross-over of technologies to the other sectors of the economy, examples include development of instrumented pipe inspection gauge for monitoring the health of cross-country oil pipelines, use by Electronics Corporation of India Ltd. (ECIL) of its expertise for defence, steel, railways and other sectors. Vendor development for the supply of equipment and components has also resulted in technology cross-over.

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, astro-physics, 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 the development of cutting edge technologies so essential for pursuing basic research. Setting up of accelerators for basic research and expertise so acquired has given us the expert base to think of launching the Accelerator Driven Sub-Critical System (ADS) programme. Strong synergy between basic research and technology development with drive towards nurturing excellence in both areas has been an important distinguishing feature of DAE laboratories. Excellence in research being judged on the basis of contribution to scientific knowledge comparable to the best at the international level and excellence in technology development on the basis of benefit received by target recipient, on both these counts, the DAE units have shown excellent performance.

Human Resource Development and Research Education Linkage

Research education linkage has a large multiplier effect in terms of human resource development and diffusion of knowledge. Such diffusion takes place through migration of trained personnel within a sector of economy or from one sector to another sector. Such linkages and in-house human resource development have 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. The Graduate School at TIFR is rated as one of the best in the

world and attracts the best talent in the country. Many new schemes have been introduced in the recent years to further augment the training facilities. Board of Research in Nuclear Sciences (BRNS), the agency of DAE for funding research in the universities and national laboratories, is as old as the atomic energy programme.

THE TARGETS

- The DAE plans to have an installed nuclear generation capacity of 20,000 MWe in the country by the year 2020. This will consist of a mix of Pressurised Heavy Water Reactors, Fast Breeder Reactors and Advanced Light Water Reactors.

- PHWR technology has already reached a stage of maturity. Further efforts will be concentrated to reduce plant gestation period, reduce capital cost and improve designs as well as O&M practices to achieve highest possible capacity factors.

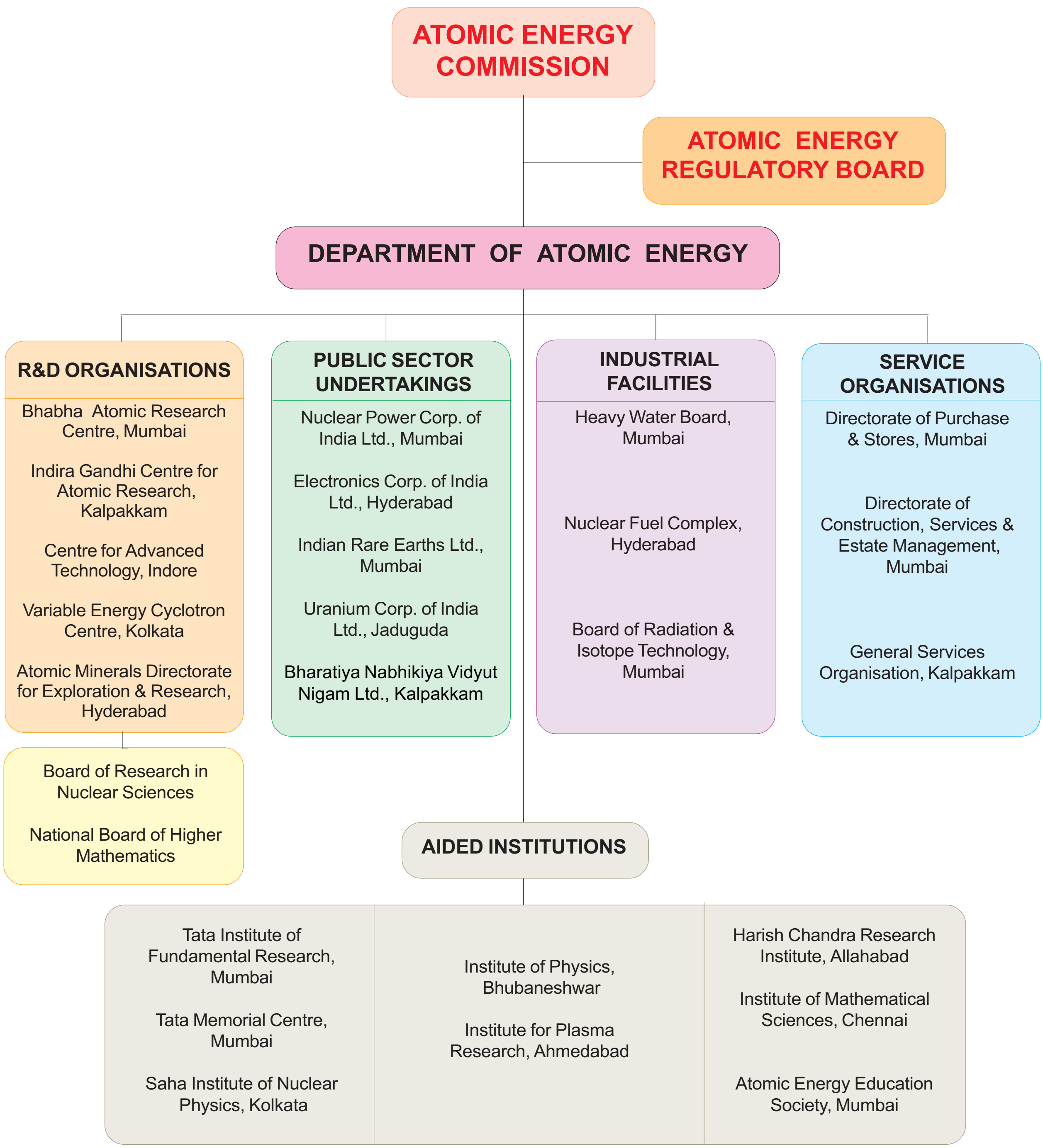
- It will be our endeavour that by the year 2020, FBR technology also reaches a stage of maturity. It would involve research, development, demonstration and deployment of fast reactor technology as well as associated fuel recycle technologies. Specific aims of R&D would be to come up with plants having long design life, higher thermal efficiency, very high burn-up fuel, short doubling time, low gestation period and low capital cost.

- Third stage of the nuclear power programme envisages utilization of thorium on large scale. During the next 20 years, we would like to lay a firm foundation for the use of thorium by developing appropriating technologies. Specific goals would include to launch the first AHWR, develop all components, equipment and sub-systems for the Accelerator Driven Systems and commission a spallation neutron source.

- A matching augmentation in the fuel cycle facilities to support the power programmes is envisaged. This includes setting up of heavy water plants, opening new uranium mines after exploration of uranium sources, setting up of new and augmenting the capacity of existing fuel fabrication plants, setting up of adequate spent fuel reprocessing and waste management facilities. R&D efforts are being pursued to develop and deploy energy efficient and near zero discharge process flow sheets for all the chemical operations involved in the fuel cycle activities.

- Radiation technologies have been developed by the DAE and have been deployed in a manner that they are contributing to increase in the GDP of the country or are leading to improvement in the quality of life by providing better health care services in the areas of nuclear medicine and cancer treatment. These contributions will be further increased by deploying existing technologies on a larger scale and by developing new technologies. Particular emphasis will be laid on development of indigenous accelerators for industrial applications, medical treatment and food preservation. Lasers and their application on a large scale in health care and material processing will receive equal emphasis.

THE ORGANISATION *



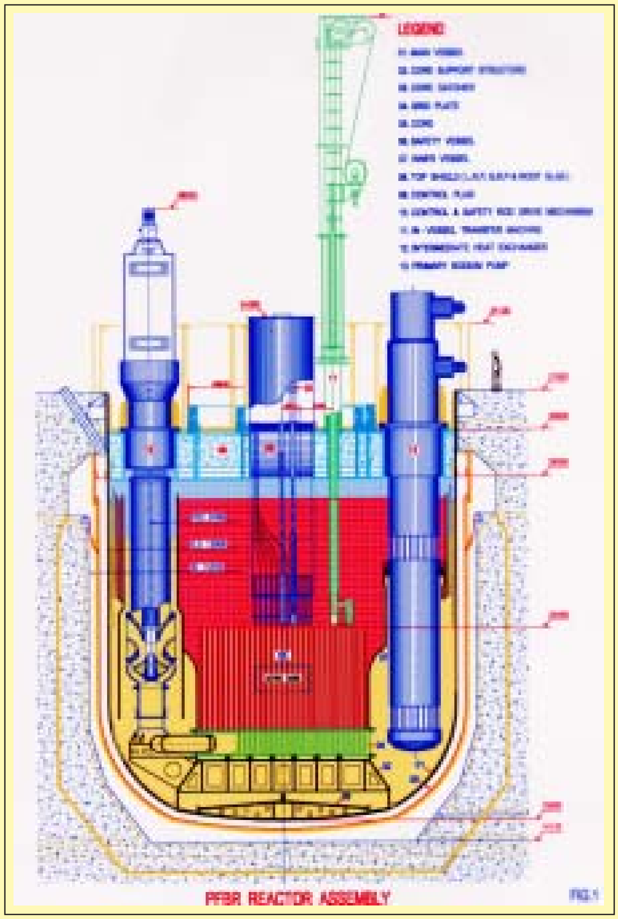
* *Latest updated data*

Nuclear Power Programme
Pressurised Heavy Water Reactors

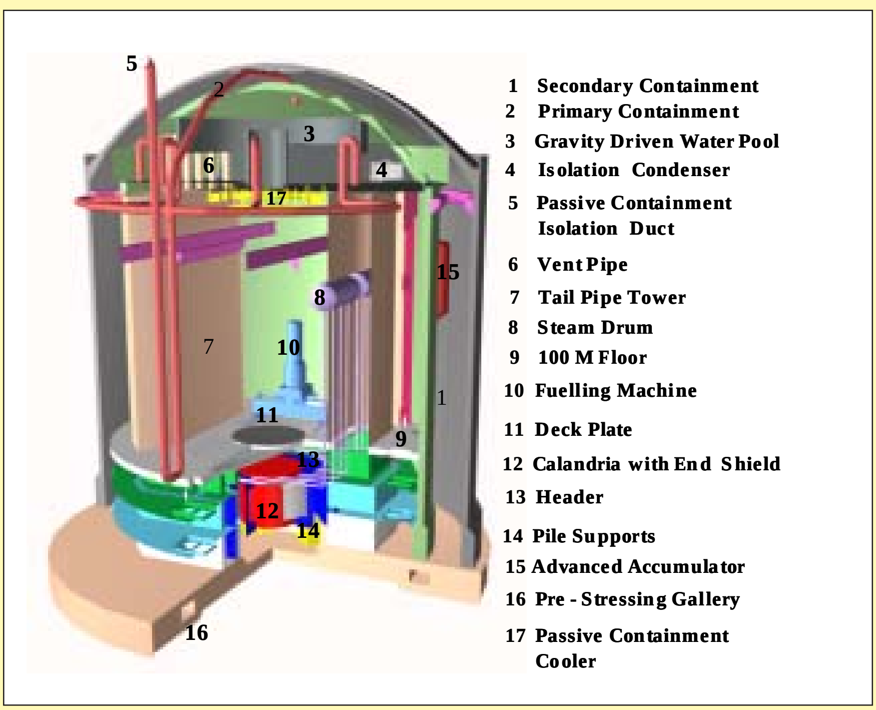
Rajasthan Atomic Power Station 3&4.

Kaiga Atomic Power Station 1&2.

Nuclear Power Programme
Fast Breeder and Thorium Based Reactors

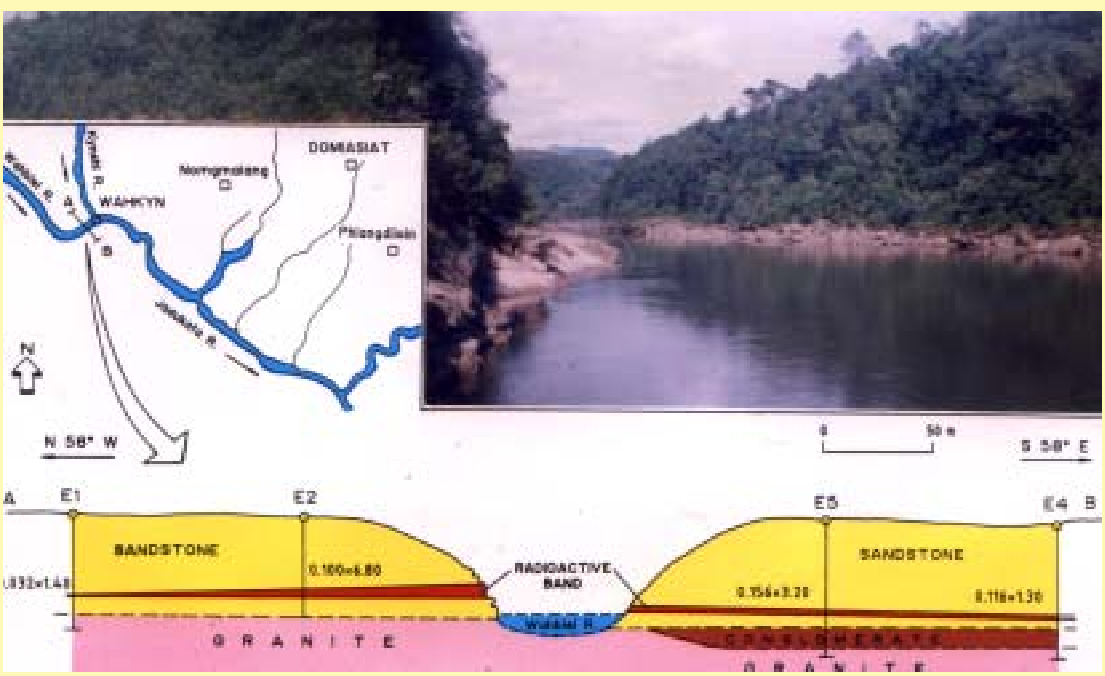


Schematics of Prototype Fast Breeder Reactor and (below) Advanced Heavy Water Reactor, being developed at Indira Gandhi Centre for Atomic Research (IGCAR) and Bhabha Atomic Research Centre (BARC) respectively.



Nuclear Fuel Cycle
Mineral Exploration & Mining

Heavy mineral rich Inayam Teri Sand Deposit, Kanyakumari district, Tamil Nadu. The deposit has been discovered by the Atomic Minerals Directorate for Exploration & Research (AMD).



Wahblei river section exposing radioactive horizons along the bank with correlation section of uranium mineralisation at Wahkyn, West Khasi Hills district, Meghalaya. The discovery was made by AMD.

Nuclear Fuel Cycle
Heavy Water Production & Fuel Fabrication

Heavy Water Plant at Manuguru, Andhra Pradesh. For production of heavy water, the plant uses hydrogen sulphide-water exchange process developed at BARC.

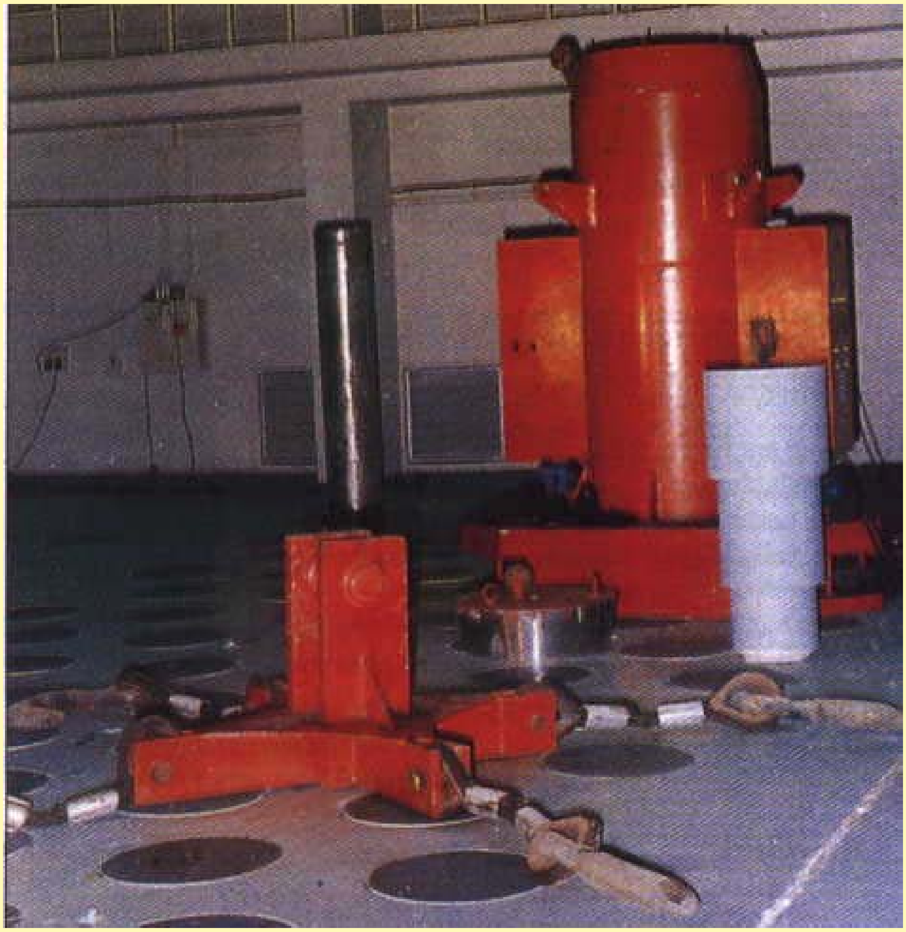
New Uranium Fuel Assembly Plant at Nuclear Fuel Complex, Hyderabad.

Nuclear Fuel Recycling

Kalpakkam Reprocessing Plant (KARP) at Kalpakkam, Tamil Nadu. Based on state-of-the-art technology, this plant has been built by BARC with indigenous expertise. The hybrid maintenance concept introduced in KARP considerably reduces the occupational exposure of plant personnel.

Inside view of Lead Mini Cell at IGCAR, Kalpakkam. The plant will reprocess fuel from Fast Breeder Test Reactor (FBTR).

Nuclear Fuel Cycle:Waste Management

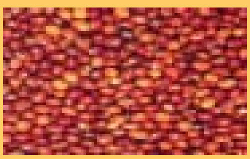
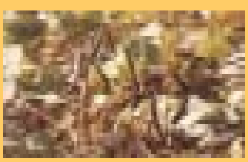
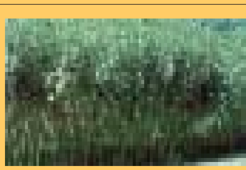


Solid Storage and Surveillance Facility of BARC at Tarapur. The storage vault of the facility has been designed and constructed indigenously for interim storage and surveillance of the vitrified waste product overpacks.

Waste Immobilisation Plant (WIP) set up at Tarapur by BARC. Waste Immobilisation Plants are also being constructed at Trombay and Kalpakkam.
India is one of the few countries in the world who possess the expertise of immobilisation of waste in glass matrix.

Nuclear Agriculture: Mutation Breeding of crop seeds

CROP VARIETIES DEVELOPED AT BARC USING MUTATION BREEDING

	CROP	NO.	CHARACTERISTICS
	GROUNDNUT	9*	**High yielding, improved quality**
	PIGEON PEA	2	**High yielding, disease resistant, early matur-ing Improved quality**
	BLACKGRAM	4	**High yielding, disease resistant**
	MUNG BEAN	4	**High yielding, disease resistant**
	RICE	1	**High yielding, improved quality**
	MUSTARD	2	**High yielding, improved quality**
	JUTE	1	**High yielding, fibre yielding**

* *Latest updated data*

Nuclear Agriculture: Radiation Processing of Food Items

The 20 tonnes/day Spice Plant set up by the Board of Radiation and Isotope Technology, at Vashi, Navi Mumbai. The plant, in operation since January, 2000, is a big boon to spice exporters.

KRUSHAK (Krushi Utpadan Sanrakshan Kendra) Lasalgaon, district Nashik, Maharashtra.

Nuclear Desalination

6300 cubic metre/day combined multi-stage flash-reverse osmosis (MSF-RO) technology based, Nuclear Desalination Demonstration Plant at Kalpakkam, Tamil Nadu.
The plant will provide potable water to people around Kalpakkam town, and demineralised water to Madras Atomic Power Station, Kalpakkam.

Reverse Osmosis (RO) based Desalination Plant set up by BARC at Sheelgan village, Barmer distt., Rajasthan. The plant provides potable water to the villagers.

Nuclear Medicine : Radiation Imaging

At Radiation Medicine Centre: Gamma Camera in action for diagnosis.

Technetium-99m Generator.

Thyroid scanning.

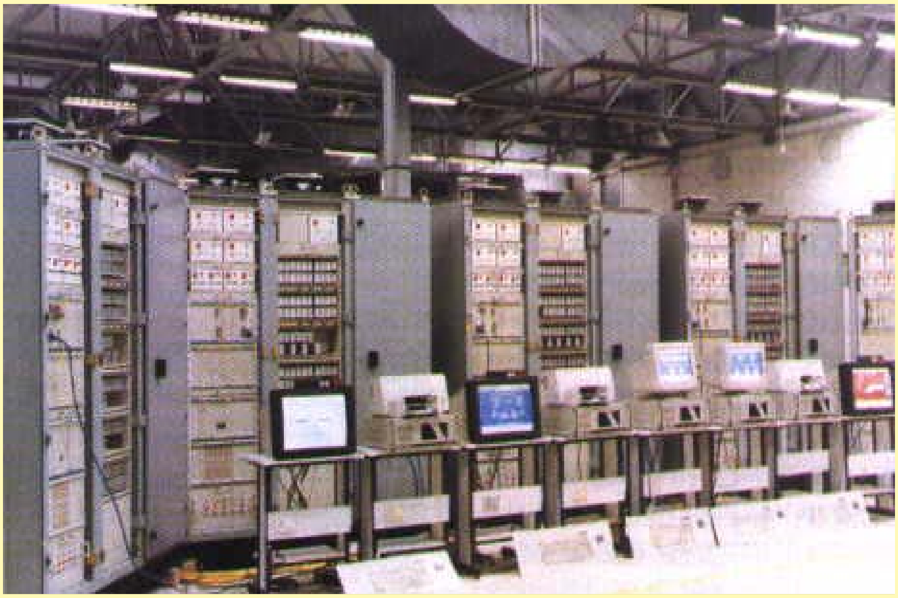
Nuclear Medicine
Radio-diagnosis & Treatment of Cancer

One of the state-of-the-art facilities at Tata Memorial Centre (TMC), Mumbai : Linear Accelerator Clinac-2100c for cancer treatment.

Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), at Owe Village, Navi Mumbai.

Electronics & Instrumentation

*Anupam-Xenon/128 supercomputer. (The computing speed of this supercomputer is observed to be higher than 340 giga floating-point operations per second (giga flops) on high performance unpack benchmark programme and is about three times faster than the 64-node supercomputer developed in July 2002)**



SCADA hardware developed by BARC for Rajasthan Atomic Power Station 3&4.

** Latest updated data*

Radiation Technology : Lasers

Dye-Laser Pumped Copper Vapour Laser. Both these lasers have been developed and fabricated inhouse at the Centre for Advanced Technology, Indore.

Carbon dioxide surgical laser. The laser is undergoing trials at various hospitals.

Laser equipment developed at CAT, for treatment of oral cancer.

Radiation Technology Products & Services

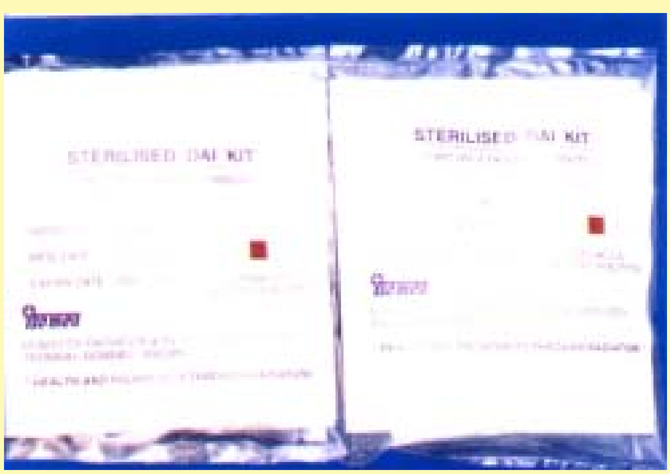
Gamma Chamber

ROLI Camera introduced by BRIT

Blood Irradiator

Radiation sterilised medical products

Dai Kits : Radiation sterilised kits and delivery packs, for use in rural areas for preventing infection of mothers and helping to minimize infant mortality rate, have been distributed through rural health programmes funded by WHO.



Radiation Technology : Electron Beam

500 keV Industrial Accelerator of BARC, at Vashi, Navi Mumbai, for various material processing applications.

Radiation Technology : Lasers

1

2

3

4

1&2 : Industrial carbon laser and laser for cutting of mild steel plate. Both the lasers have been developed at CAT, Indore.

3.Two-way communication equipment based on laser beam, has been developed at Trombay. The equipment generates telephone quality communication.

4.Laser Density measurement station for precise measurement of dimensions and densities of sintered UO_2 pellets. The station has been developed at CAT.

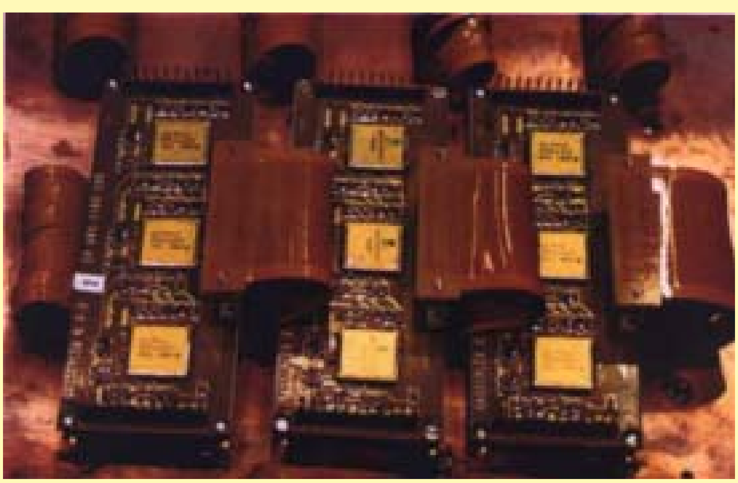
Accelerators

Developed at CAT, Indore : Synchrotron Radiation Source: INDUS 1 and (below) one of its beamlines meant for Photo-electron Spectroscopy research.

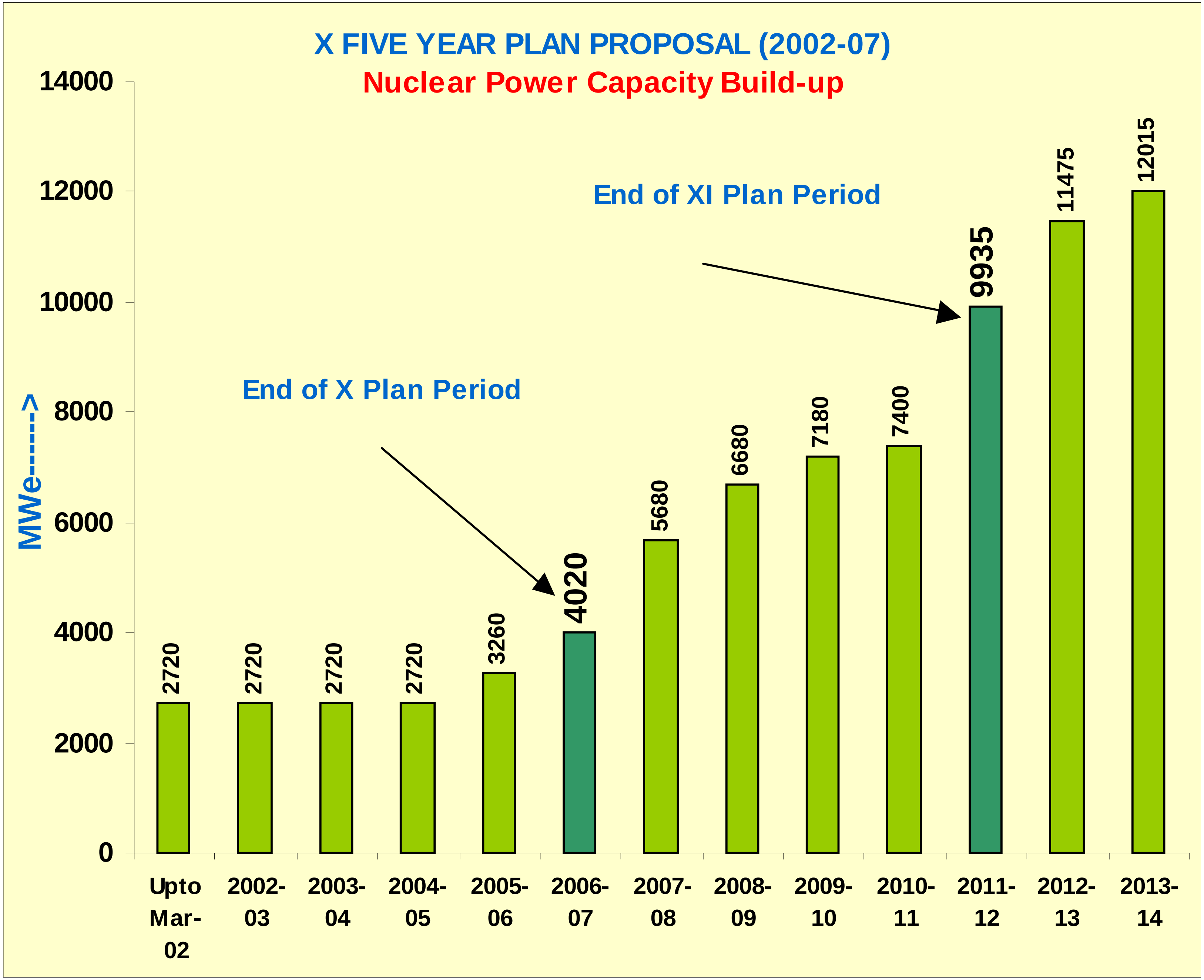
Basic Research

Machining of the central return path ring of main magnet frame for the superconducting cyclotron project at VECC

Superconducting coil winding facility developed for the superconducting cyclotron project at VECC



MANAS on cathode pad chambers (CPC) prototype developed at SINP


X FIVE YEAR PLAN PROPOSAL (2002-07)
Nuclear Power Capacity Build-up
MWe------>
14000
12000
10000
8000
6000
4000
2000
0
End of X Plan Period
End of XI Plan Period
2720
2720
2720
2720
3260
4020
5680
6680
7180
7400
9935
11475
12015
Upto Mar-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14

- Pursuit of basic research in a synergistic manner, which is the main strength of the Department, will be continued in areas related to the mission mode programmes of the Department.

- Research-education linkage has been always nurtured by the DAE and in the years to come, the DAE plans to expand the existing mechanisms and initiate new programmes. A major initiative to be taken up in the X plan includes setting up a new campus for Bhabha Atomic Research Centre (BARC) with a co-located academic framework of university status.

- Development and deployment of advanced technologies in all related areas such as advanced materials, electronics devices, supercomputing, automation, medical technologies etc.. Attempt will be to deploy every possible method of technology management for strengthening the hi-tech base of the country.

- Development of new technologies of strategic importance and deployment of technologies already developed as per national perspective will be continued with due regard to safety and economics.

ACTION PLAN

The programme planned by the Department is quite challenging and we are working to meet the challenges. Apart from technological and market forces related challenges, these challenges also originate from international politics, short-term outlook of local media, politics originating from the neighbourhood of nuclear facilities, public perception about nuclear technology in general and waste management in particular and misplaced proliferation concerns of certain interest groups.

As indicated earlier, we are going in for import of light water technology as an external additionality in order to accelerate the nuclear power programme. This, however, requires overcoming certain constraints imposed by international politics. Any reasonable world order can only expect countries to fulfill their international safeguards commitments and no more than that. The Nuclear Suppliers Group (NSG) guidelines, however, make demands beyond the genuine proliferation concerns and are obviously coercive in intent and are slowing down the expansion of nuclear power capacity in the world. To explain our position to vendor countries, we have prepared and widely distributed through Ministry of External Affairs (MEA) a booklet titled, “Nuclear Power for National Development : An Indian Perspective”.

We have also noticed a certain pattern in the observations of ‘leaders’ of population living around nuclear facilities and certain section of the local media. Issues like demand for jobs, requirement of infrastructural facilities like water, schools and roads are projected as nuclear issues and highlighted at environmental hearings. Health effects arising out of malnutrition, water impurities and other natural local causative factors are attributed to radiation. Overcoming such hurdles requires concerted efforts to educate the public and to generate a baseline data of disease patterns in the neighbourhood of nuclear facilities. This is an area which we have to address in the coming years. We also have to conduct social audit to explain the benefits derived by communities from the nuclear facilities.

There is a general need to launch public awareness programmes to explain all aspects of nuclear technology, particularly to allay fears related to nuclear radiation, waste management and safety issues.

All these challenges need to be addressed by the DAE in cooperation with other agencies.

Expansion of Ongoing Programme

To plan the ongoing programme of increasing nuclear installed capacity in the country, a committee was set up by the DAE which has recommended planning of the activities of the DAE to attain a total nuclear installed capacity of about 20,000 MWe by the year 2020. This plan has been further fine-tuned by the Internal Working Group (Power) set up by DAE for the formulation of the X five year plan. The Group has recommended increasing the installed capacity to 9,935 MWe by the end of the XI plan (see plate-20 for details).

The mix of the proposed capacity addition up to the year 2,020 includes several 220 MWe PHWRs, 540 MWe PHWRs, 1000 MWe LWRs and 500 MWe FBRs. In addition to the above, a 235 MWe AHWR will be set up as a technology demonstration project for utilisation of thorium for electricity generation. The activities on the associated nuclear fuel cycle facilities forming the front and the back ends of the cycle viz., fuel, heavy water, spent fuel reprocessing, waste management and recycle fuel fabrication will to be taken up to match the requirements of the power programme.

For isotope production, there is a need to set up a new research reactor and it is proposed to start construction of the reactor during the X plan and complete it before the end of the XI plan.

In parallel to the setting up of nuclear power plants, R&D will be continued on the following.

- Development of in-service inspection techniques, repair technologies to carry all jobs remotely, upgradation of control and instrumentation systems to take advantage of advances in information technologies, aging management and life extension of all operating nuclear power stations. For the PHWRs to be constructed, latest advances in material science and information technology will be exploited. All management procedures will be optimized to reduce the gestation period of the plants under construction Front end and back end activities will also be continuously audited to effect energy conservation in all operations, aim at zero discharge and wherever possible, recycle materials and chemicals used in processing.

- PFBR and AHWR will be set up and designs for future similar units will be evolved by studying the prototype units. Main parameters to be optimized are safety, ease of operation and maintenance and economic competitiveness.

- We will continue to upgrade the existing mega facilities for basic research and build new facilities. At CAT, Indore, beam line construction on the synchrotron radiation source Indus-1 will be completed; Indus-2 and associated beam lines will be completed. Superconducting cyclotron under construction at Variable Energy Cyclotron Centre (VECC), Kolkata will be completed.

- Ongoing work on development of Electron Beam Accelerators and their applications at CAT and BARC will be pursued and wherever practical, technologies will be transferred to interested agencies. Similarly all programmes for the development of lasers and laser based applications will be pursued and technologies will be transferred.

- Health care equipment like cobalt-60 based teletherapy machine will be developed and technology transferred for mass manufacture.

New Approach to Deployment of Technologies

The DAE also proposes to initiate projects around all its installations for the deployment of technologies such as farming, using mutant seeds developed by BARC, setting up of laboratory facilities for the production of saplings by tissue culture techniques for distribution to farmers, and any other technology which could provide an improved means for livelihood to the people. For this purpose, land around a nuclear installation will be utilized with the involvement of farmers in the neighbourhood with the DAE scientists providing the necessary expertise to improve their standard of living and at the same time having a multiplier effect (in terms of spread of expertise) on the surrounding neighbourhood. Investment by the DAE will be limited to the setting up of minimum initial infrastructure and some seed money.

In the area of food processing, the DAE proposes to facilitate multiplication of food processing units using radiation technologies in conjuction with complimentary food processing technologies. DAE will act as a facilitator and technology provider in a flexible manner depending on the needs. We have already signed MoUs with private entrepreneurs to enable them to set up radiation processing plants with full technical assistance by the DAE. One entrepreneur has made good progress and hopes to commission the plant towards the end of 2002. We are also in touch with Ministry of Food Processing Industries for setting up more such plants. Interest has also been evinced by the Governments of Orissa and Andhra Pradesh and seafood exporters for setting up plants for radiation processing of seafood. So far we have developed and released 22 varieties of mutant seeds for cultivation and we hope to release many more varieties (of groundnut and pulses) in near future. In the area of tissue culture technique also, we have now standardized the protocol for pineapple in addition to 12 cultivars of banana. During the X plan and beyond, technologies already developed will be taken to the field and new technologies will be taken up in the laboratories.

New Developments

New developments will be in the area of fast reactors, thorium utilization envisaged in the third stage of the programme and new technologies as they emerge from basic research done in the units of DAE or elsewhere in the country and abroad.

New developments in case of FBRs will aim at reducing the capital cost, O&M costs and fuelling cost, while improving safety. Specific thrust areas to achieve these objectives are the following.

- Long design life about 60 years. This would also reduce the cost of decommissioning.

- Improving the thermal efficiency by 4 to 5 % points by using higher steam temperature. This would require better materials and enhancement in structural analysis capability.

- Reducing the dimensions of some of the components by better engineering e.g., reactor assembly diameter, length of control and safety rod drive mechanisms.

- Reduction in the number of steam generators.

- Integrated sodium purification circuit for primary and secondary circuits. This would improve safety and reduce construction time.

- Optimising the plant layout.

- Development of high burn up fuel (from 100 GWd/t to 300 GWd/t) to reduce fuel cycle costs, fuel handling costs, radwaste etc. This would require development of better materials for the hexcan of fuel assembly.

- Fast reactor fuel reprocessing technology development and fuel refabrication technology development

- Development of short doubling time fuel to increase the rate of capacity growth of fast breeder reactors. This would require development of large diameter fuel pins and quick reprocessing.

Maximum attention will have to be paid to developing technologies for exploiting thorium reserves and this would require development of accelerator driven systems and associated technologies such as large accelerator, spallation sources and appropriate reactor systems. To give a concrete shape to all steps to be taken for the systems to be developed for the third stage, we have prepared the following documents.

- Shaping the third stage of the nuclear power programme.

- Roadmap for development of accelerator driven sub-critical systems.

Applications of radiation for societal development will also be pursued vigorously in the years to come. In particular, accelerators technology will be deployed to the maximum possible extent. To prepare a complete outline of all our activities in the area of societal development, we have prepared a document titled, “Radiation - Sources, Technologies and Applications for Societal Development”.

Basic Research and Research -- Education Linkage

In the X plan and beyond, the Department will continue to pursue basic research in mathematics and computer science, physics, chemistry, biology, cancer, synchrotrons and their utilization, cyclotrons and their utilization, fusion and plasma science, material science, interdis-

ciplinary areas and international collaboration in areas of relevance to the Department. The disciplines pursued by the units of the DAE have been selected for their relevance to the mission mode programmes of the Department. One may recall that the entire programme of the Department was 'conceived and born' at the Tata Institute of Fundamental Research (TIFR). Technology institutions like Society for Applied Microwave Electronics Engineering and Research (SAMEER) have been set up based on the research done at TIFR. We will continue to look for opportunities to create and nurture Technology Institutions based on basic research done in DAE units.

Research-education linkage has been always nurtured by the DAE and in the years to come, the DAE plans to expand the existing mechanisms and initiate new programmes. It is proposed to increase the outlay of the Board of Research in Nuclear Sciences (BRNS), and the increased outlay will be used for setting up more centres in universities in such a way that UGC's Advanced Centre Programme is strengthened in the areas of the interest to DAE. Attempts will be made to set up focused programmes at select departments in universities and institutes having potential in specific areas. All existing programmes in the area of Human Resource Development (HRD) will be continued and new ones aimed at specialized areas as and when they emerge will be added. The scope of the MoU with Inter-University Consortium for DAE Facilities (IUC-DAEF) will be widened and infrastructure will be added to the existing centres and if possible, new centres will be set up. New arrangements with universities aimed at increasing the student strength in the research centres, will be initiated. Activities of Homi Bhabha Centre for Science Education (HBCSE) have been expanded to include functions like training students for international Olympiads in mathematics, physics, chemistry and biology, and all this will be continued.

DAE units will continue to 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. Participation of DAE in building of the Large Hadron Collider (LHC), CERN, Geneva is one such example. Collaboration with CERN will continue for next two decades and even beyond

New Infrastructure for Research

A major initiative to be taken up in the X plan includes setting up a new campus for Bhabha Atomic Research Centre (BARC) with a co-located academic framework of university status. The campus will have a research reactor, isotope processing laboratories, and other infrastructure to take up research and development work related to the third stage of the nuclear power programme. Senior scientists of the research centre will have an adjunct position in the university with reciprocal arrangements for the faculty from the university to use and participate in programmes at the campus. The concept of having adjunct positions and co-location with a university will spur linkage with the education system. A group of senior scientists is already working on site selection and for devising the programme profile for the new campus. The new campus is planned to be fully functional by the end of the XI plan.