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# NUCLEAR India

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## *The Beginning ........ August 3, 1954*

*Old Yacht Club Building -- the birth place of Department of Atomic Energy*

*The logo of DAE selected for its golden jubilee (August 2003 to August 2004) celebrations . The reactor dome with greenery in the foreground depicts nuclear power as a clean and environment friendly source; five human figures on the dome are symbolic of growth and prosperity of the nation and enhancement in quality of life of the people accrued from the research & development work being pursued in the Department.*

# *Five decades of DAE*

*August 3 this year marks the beginning of the Golden Jubilee year of DAE. On this date, in 1954, the Department was setup with the mandate to harness nuclear energy for electricity generation, develop radiation technologies, and advanced technologies such as lasers, accelerators and others, for varied applications and promotion of research and development in the country.*

*Today, the DAE umbrella covers a whole range of institutions and expertise.*

*The five decades of DAE have seen trend setting efforts in developing technologies in a difficult area despite the restrictive technology control regimes, and in applying them for development, prosperity and security of India. Today the nation can be justifiably proud of its self-reliant capability in translating R&D in nuclear power technologies to world class excellence.*

*In 1954, a 3-stage nuclear power programme was adopted by DAE. The first stage of the programme comprises setting up of pressurised heavy water reactors (PHWRs) and associated fuel cycle facilities; its second stage envisages development of fast breeder reactors using Uranium and Plutonium obtained from the depleted uranium fuel of the first stage, and the third stage aims at the development of reactors based on Uranium-233 fuel obtained from irradiated Thorium.*

*The first stage of the nuclear power programme is already in the commercial domain. Comprehensive capability in the design, construction and operation of PHWR has been achieved. The design of the 220 MWe reactor has been standardized and scaled upto 540 MWe capacity. Development 700 MWe PHWR is a new initiative.*

*In about four years from now, DAE will reach an installed capacity of 6800 MWe — around 4500 MWe with pressurised heavy water reactors, and another 2320 MWe with light water reactors.*

*In 1964, India had become the fifth country in the world to start reprocessing of spent nuclear fuel. Based largely on indigenous materials and capabilities, the waste management programme in the country is progressing well and India is now one the few countries having the technology of vitrification of nuclear waste.*

*Over a period of time, the technology for the manufacture of various components and equipment for PHWR is now well established in India, and has evolved through active collaboration between DAE and the industry.*

*The Department is set to launch the second stage of the nuclear power programme. It has already achieved 18 years of successful operation of the 40 MWt Fast Breeder Test Reactor (FBTR) at Kalpakkam, Tamil Nadu. This reactor has been the test bed for the development of future fast breeder reactors. The carbide core, which has been used in a fast reactor for the first time in the world, has given excellent results. FBTR has provided valuable experience with liquid metal fast breeder reactor technology that has given the confidence to set up a 500 MWe Prototype Fast Breeder Reactor (PFBR). PFBR design is ready and construction of the reactor will begin soon.*

*In the field of Thorium utilization, India is a world pioneer now. Kamini reactor at Kalpakkam, that uses Uranium-233 fuel produced from irradiated Thorium, has been operating since 1995. To expedite transition to thorium based systems, an Advanced Heavy Water Reactor is being developed at BARC. For further utilization of Thorium, a road-map has been prepared to develop accelerator driven sub-critical systems. A compact high temperature reactor is also being developed. In the field of fusion power, the Steady State Superconducting Tokamak (SST-1) being built in Gandhinagar, Gujarat, is approaching completion.*

*Steps are now aimed at further improving the safety and availability of operating stations, and reducing the gestation period of plants under construction.*

*DAE has formulated a programme that envisages setting up of about 20,000 MWe installed nuclear power capacity by the year 2020.*

*Over the years, DAE has built up a strong infrastructure and developed expertise and gained wide range of experience in the field products and sevices realting to radiation technology. Starting from the production of radioisotopes, soon after the commissioning of the Apsara reactor at Trombay in 1956, today, India is one of the large producers of radioisotopes in the world. A variety of radioisotopes are produced for use in medicine, industry, agriculture and research. Radioisotope products are supplied to institutions in India and also abroad.*

*Application of radiation technology of mutation of seeds has resulted in the development of 23 varieties of mutant seeds of pulses, groundnuts, rice, mustard and jute at Trombay. These seeds are being used by the Indian farmers.*

*The research and development of over three decades has unequivocally established the benefits of the radia* tion processing in preservation of farm produce and processed agro products. A spice hygienisation plant at Vashi, Navi Mumbai and a low dose radiation processing plant for sprout inhibition in onions and other edibles at Lasalgaon, Nashik (Maharashtra) are running on commercial scale. Private entrepreneurs are also being encouraged to set up such plants in other parts of the country.

Radiation technology is also being employed for diagnostic, therapy and for sterilization of medical products, and for many applications in industry.

Since seventies, BARC has been engaged in R&D activities relating to desalination. The centre has developed these technologies and deployed them successfully. Successful operation of the RO module of the Nuclear Desalination Demonstration Plant at Kalpakkam, has been a recent achievement.

In the fields of advanced technologies, DAE's programme is focused on research and development relating to accelerators and lasers for varied applications. For research and development in this area, CAT was set up at Indore, Madhya Pradesh in 1984.

As far back as 1977, Variable Energy Cyclotron set up by DAE at Kolkata, became operational. It was then an epoch making development in academic circles. Later, a number of accelerators for variety of purposes were set up in the country. The range covers from Linear Accelerators (LINACs) to advanced Synchrotrons. Superconducting Cyclotron and Radioactive Ion Beam Facility are being set up at Kolkata. BARC has developed several applications of Electron Beam and is setting up an Electron Beam Centre at Kharghar, New Mumbai. Recently, CAT has developed electron beam accelerator for preservation of agro-products.

DAE has also successfully developed a number of other state-of-the-art technologies. These are supercomputer systems, advanced remote handling and robotic devices and servo-manipulators for advanced applications.

The Department has defined a roadmap for further Technology developments such as fuel cycle with shorter doubling time, advanced heavy water reactor and its fuel cycle, compact high temperature reactor, accelerator driven systems for shorter doubling time with thorium fuel cycle as well as for incineration of long lived radioactive waste, hydrogen-related technology, etc.

Right from its inception, safety and conservation of environment have been a part and parcel of the Indian Nuclear Programme. DAE has gained over 200 reactor-years of operating experience with a good record of safety of the operating personnel, public and the environment. Safety measures in all the activities of DAE are in conformity with the norms stipulated by an independent regulatory body, the Atomic Energy Regulatory Board (AERB).

The DAE research centres and the grant-in-aid autonomous research institutes of DAE, are centres of excellence in basic reseach that ranges from mathematics to computers, physics to astronomy and biology to cancers.

Several recent initiatives such as the DAE Graduate Fellowship Scheme, Centres for research programmes of DAE interest initiated in academic institutions and national laboratories, Science Research Council awards for innovative research, broad basing of Inter-University Consortium - DAE Facilities (IUC-DAEF) mandate, efforts to strengthen academic linkage between programmes at DAE -R&D centres and autonomous research institutions etc., have been launched.

DAE's another salient achievement over a period of five decades is the nurturing of the excellent Human Resource in the field of nuclear science and technology. This has resulted in developing excellent scientists and engineers, who have been contributing to the programme of the nation.

In every aspect of nuclear technology expertise has been developed. Presently a major expansion of its nuclear power programme is undergoing — both in terms of commercial deployment of the present day technologies as well as bringing in newer technologies. Necessary industrial and R&D infrastructure is in place to facilitate this process.

Homi Bhabha had given us a vision of developing indigenous and self-reliant capability in nuclear science and technologies and deploying their applications for the benefit of our people. It is a matter of great satisfaction that DAE has made significant all round progress on the path to realize Bhabha's vision, despite hurdles.

In nuclear science and technology, India is now a self-reliant nation. As a consequence, India has earned a place for itself amongst the countries most advanced in the nuclear technology.

(Anil Kakodkar)
Chairman, AEC & Secretary, DAE

# SALIENT MILESTONES OF ATOMIC ENERGY IN INDIA

March. 12, 1944 : Dr. Homi Jehangir Bhabha writes to Sir Dorabji Tata Trust for starting Nuclear Research in India.

June 1, 1945: Tata Institute of Fundamental Research (TIFR) was set up at Mumbai as a result of initiative taken by Dr. Homi Bhabha.

December 19, 1945 :Tata Institute of Fundamental Research (TIFR) Mumbai is inaugurated.

April 15, 1948 : Atomic Energy Act is passed

August 10, 1948 : Atomic Energy Commission is constituted.

July 29,1949 : Rare Minerals Survey Unit brought under Atomic Energy Commission and named as 'Raw Materials Division' (RMD), with Headquarters at New Delhi. In 1958, this unit becomes Atomic Minerals Division (AMD), and later shifts to Hyderabad in 1974. It is renamed as Atomic Minerals Directorate for Exploration and Research (AMD) on July 29, 1998.

August 18, 1950 : Indian Rare Earths Limited (IRE), owned by the Government of India and Government of Travancore, Cochine, is set up for recovering minerals, processing of rare earths compounds and Thorium - Uranium concentrates. In 1963, IRE becomes a full-fledged government undertaking under DAE

April 1951: Uranium Deposit at Jaduguda is discovered by AMD. Drilling operations commence in December 1951.

December 24, 1952 : Rare Earths Plant of IRE at Alwaye, Kerala, is dedicated to the nation and production of Rare Earths & Thorium - Uranium concentrate commences.

August 03, 1954 :Department of Atomic Energy is created.

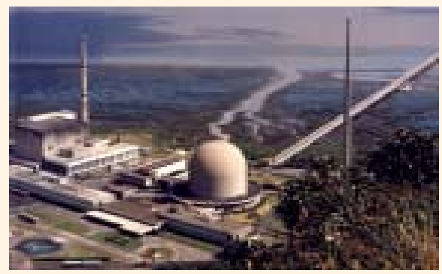
1955: Saha Institute of Nuclear Physics, Kolkata, becomes the grant-in-aid institute of DAE.

August 01, 1955 : Thorium Plant at Trombay goes into production. ( Plant is now closed).

1956 : AMD discovers uranium mineralisation at Umra, Rajasthan.

August 04, 1956 :APSARA - first research reactor in Asia, attains criticality at Trombay, Mumbai.

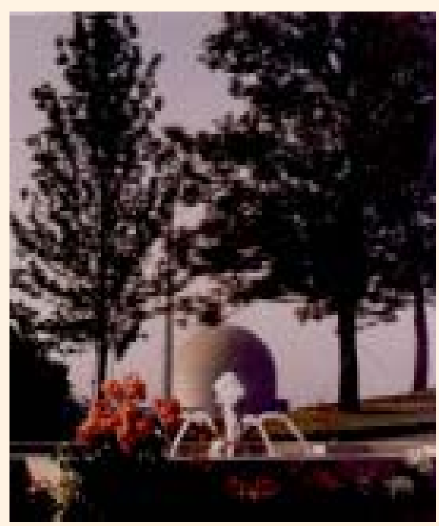
January 20, 1957 : Atomic Energy Establishment, Trombay (AEET) is inaugurated. It is named as Bhabha Atomic Research Centre (BARC) on January 22, 1967.



August 19, 1957 : AEET Training School starts functioning at Trombay.

January 30, 1959 :Uranium Metal Plant at Trombay produces Uranium.

February 19, 1960 : First lot of 10 Fuel Elements for CIRUS reactor, is fabricated at Trombay



# SALIENT MILESTONES OF ATOMIC ENERGY IN INDIA

July 10, 1960 : CIRUS – the 40 MWt research reactor, attains criticality. The plant has been refurhised recently.

January 14, 1961 : Research Reactor ZERLINA attains criticality. (Decommissioned in 1983).

1962 : Administrative control of Tata Memorial Centre comprising Tata Memorial Hospital and Cancer Research Institute, was transferred to DAE.

1965: IRE takes over operation of Mineral Processing Unit at Manavalakurichi in Tamil Nadu and at Chavara in Kerala.

January 22, 1965 : Plutonium Plant is inaugurated at Trombay.

April 11, 1967 : Electronics Corporation of India Limited (ECIL) is set up at Hyderabad for producing electronic systems, instruments and components.

June 1, 1967 : Power Projects Engineering Division (PPED), Mumbai is formed. The Division is subsequently converted to Nuclear Power Board on August 17, 1984.

October 4, 1967: Uranium Corporation of India Limited (UCIL) is established with head quarters at Jaduguda in Jharkhand (then Bihar).

May 1968: Uranium Mill at Jaduguda, with a capacity of 1,000 TPD, commences commercial production of Magnesium diuranate (yellow cake). Jaduguda Mine Shaft is commissioned in November 1968.

December 31, 1968 : Nuclear Fuel Complex is set up at Hyderabad, Andhra Pradesh.

March 12,1969 : Reactor Research Centre starts at Kalpakkam, Tamil Nadu. The Centre, established in 1971, is named as Indira Gandhi Centre for Atomic Research (IGCAR) on December 18, 1985.

May 01, 1969 : Heavy Water Projects is constituted at Mumbai. This later becomes Heavy Water Board.

October 02, 1969 : Tarapur Atomic Power Station commences commercial operation.

1970 : AMD hands over Uranium Deposits at Narwapahar to UCIL.

September 06, 1970 : Uranium-233 is separated from irradiated Thorium.

February 18, 1971 : Plutonium fuel for Research Reactor PURN-IMA-I is fabricated at Trombay.

1972 : AMD hands over beach sand heavy mineral deposits of Chhatrapur, Orissa and Neendakara-Kayankulam, Kerala to IRE.

February 3, 1972 : DAE Safety Review Committee is formed.

May 18, 1972 : Research Reactor PURNIMA-I attains criticality.

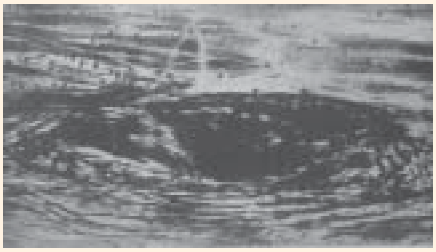
November 30, 1972 : Unit-1 of Rajasthan Atomic Power Station at

# SALIENT MILESTONES OF ATOMIC ENERGY IN INDIA

Rawatbhatta, Rajasthan, begins commercial operation. Unit II goes commercial on November 1, 1980.

1974: By-product Recovery Plant of UCIL at Jaduguda is commissioned.

May 18, 1974 : Peaceful underground Nuclear Experiment is conducted at Pokhran, Rajasthan.



March 1975 : Commercial production of Uranium Mineral Concentrates from copper plant tailings at Surda, Hindustan Copper Limited commences.

September 1975 : Surda Uranium Recovery Plant of UCIL is commissioned.

June 16, 1977 : Variable Energy Cyclotron becomes operational at Kolkata.

1979 : AMD hands over Bhatin and Turamdih (East) uranium deposits (now in Jharkhand State) to UCIL.

Nov 18, 1979 : Plutonium-Uranium Mixed Oxide (MoX) fuel is fabricated at Trombay, Mumbai.

November 19, 1982 : BARC's Power Reactor Fuel Reprocessing Plant at Tarapur is commissioned.

February 1983 : Rakha Uranium Recovery Plant of UCIL is commissioned.

November 15, 1983 : Atomic Energy Regulatory Board (AERB) in Mumbai is constituted.

1984 : Sandstone-type uranium deposit at Domiasiat, Meghalaya is discovered.

January 27, 1984 : Madras Atomic Power Station - Unit I at Kalpakkam starts commercial operation. Unit II goes commercial on March 21, 1986.

February 19, 1984 : Centre for Advanced Technology (CAT) at Indore (Madhya Pradesh) is inaugurated.

March 08, 1984 : Plutonium - Uranium mixed Carbide Fuel for Fast Breeder Test Reactor (FBTR) is fabricated at Trombay.

May 10, 1984 : Research Reactor PURNIMA-II, a Uranium-233 fuelled homogenous reactor, attains criticality at Trombay.

1985 : AMD hands over the Bodal uranium deposit to UCIL.

March 05, 1985 : Waste Immob-ilisation Plant (WIP) at Tarapur is commissioned.

March 25, 1985 : DAE takes up Institute of Physics, Bhubaneswar, Orissa, as a grant-in-aid institute. The Institute was earlier established in 1974 by the Government of Orissa as an all-india institute of research and advanced studies.

August 08, 1985 : Research Reactor DHRUVA (100 MWt) attains criticality. It attains full power on January 17, 1988.

# SALIENT MILESTONES OF ATOMIC ENERGY IN INDIA

October 18, 1985 : FBTR at IGCAR attains criticality.

1986: Institute of Mathematical Sciences, Chennai, Tamil Nadu, becomes the fully aided institute of DAE. The Institute was earlier founded in 1962, as a national institution for higher learning for promotion of fundamental research in frontier disciplines of mathematical sciences.
- Dredge Mining, Mineral Separation and Synthetic Rutile Plant at OSCOM, Chhatrapur, Orissa is commissioned by IRE.
- HERO Project at Alwaye, Kerala, is commissioned. Production is started at OSCOM.

October 1986 : Bhatin Mine is commissioned by UCIL and ore is transported to Jaduguda mill for processing.

December 1986 : Mosaboni Uranium Recovery Plant of UCIL is commissioned.

1987 : AMD hands over Turamdih (West) uranium deposits to UCIL, and beach sand deposits in Tamil Nadu to IRE.

September 17, 1987 : Nuclear Power Corporation of India Limited (NPCIL) is formed by converting the erstwhile Nuclear Power Board.

1988 : AMD hands over Kuttum-angalam and Vettumadia sand deposits, Tamil Nadu to IRE.

December 30, 1988 : 14 MV Pelle-tron Accelerator is inaugurated in Mumbai. The accelerator is a joint endeavour of BARC & TIFR.

1989 : AMD Training School is inaugurated.
- Board of Radiation and Isotope Technology (BRIT) is constituted.

January 3, 1989 : Regional Radiation Medicine Centre (RRMC) at Kolkata is inaugurated.

March 12, 1989 : Unit I of Narora Atomic Power Station, Uttar Pradesh attains criticality. Its Unit II attains criticality on October 24, 1991.

1990 : Dolostone-hosted uranium mineralisation in the western margin of Cuddapah basin is discovered.
- Mineral Research Development Centre (MRDC) of IRE is launched at Kollam. HERO Plant is commissioned at Alwaye. Dredge & Wet Concentrator Plant at Chavara, Kerala, is commissioned.

November 09, 1990 : Research Reactor PURNIMA-III, a Uranium-233 fuelled reactor, attains criticality.

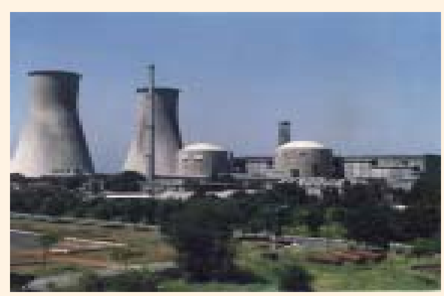
1991: AMD discovers uranium mineralisation at Lambapur, Nalgonda district, Andhra Pradesh and produces upgraded xenotime concentrate at 'Pre-concentrate Upgradation Plant' at Kunkuri.

May 16, 1991: First Electron Cyclotron Resonance (ECR) heavy ion source of the country becomes operational at the Variable Energy Cyclotron Centre, Kolkata.

1992: Mehta Institute of Mathematics and Mathematical Physics, Allahabad, Uttar Pradesh, (now Harish Chandra Institute of Mathematics and Mathematical Physics), comes under the DAE umbrella, as a grant-in-aid institute.

1992 : First remotely operated radiography camera is launched.
- Significant heavy mineral concentration along the East Coast, Andhra Pradesh, is identified.
- New Thorium Plant at OSCOM, Chhattrapur, Orissa is commissioned by IRE.

September 03, 1992 : Kakrapar Atomic Power Station - Unit I attains criticality. Unit II attains criticality on January 08, 1995



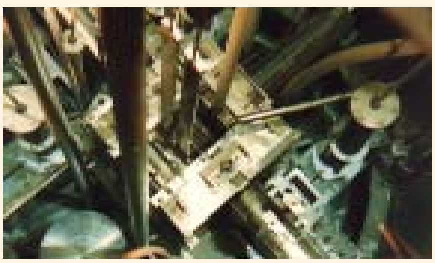
1993 : BARC supplies one millionth radioisotope consignment.

1995 : Research Irradiator Gamma Chamber 5000 is launched by BRIT.

# SALIENT MILESTONES OF ATOMIC ENERGY IN INDIA

January 1995 : Narwapahar mine of UCIL is inaugurated.

1996 : 30kWt Kamini Reactor attains criticality. The reactor is taken to full power in September, 1997.



March 27, 1996 : Kalpakkam Reprocessing Plant (KARP) is cold commissioned. KARP is dedicated to the nation on September 15,1998.

October 1, 1996: Institute for Plasma Research, Ahemdabad, Gujarat, becomes an autonomous institute of DAE.

October 20, 1996 : Kalpakkam Mini Reactor (KAMINI), with Uranium-233 fuel, attains criticality at IGCAR, Tamilnadu.

1997 : AMD discovers uranium min-eralisation in brecciated limestone at Gogi, Gulbarga district, Karnataka in the Bhima basin.
- Microzir Plant of IRE is commissioned in Chavra, Kerala.

March. 31, 1997 : Unit-1 of Rajasthan Atomic Power Station, Rawatbhatta is recommissioned.

December 1997: Jaduguda Mill is expanded to treat 2,090 tonnes ore per day.
- PRYNCE (95% Neodymium Oxide) Plant is commissioned at Rare Earths Division of IRE.

May 11 & 13, 1998 : Five underground nuclear tests are conducted at Pokhran Range, Rajasthan.

May 27, 1998 : Unit-2 Rajasthan Atomic Power Station is recommissioned after enmasse replacement of coolant channels.

August 10, 1998 : The 500 keV industrial electron accelerator developed indigenously by BARC is commissioned for its first phase of operation.
- Ammonium diuranate production commences at Rare Earths Division of IRE, at Alwaye, Kerala.

April 22, 1999 : 450 MeV Synchrotron Radiation Source Indus-1 achieves electron beam current of 113 milli-ampere superceding the design value of 100 milli-ampere.

July 1999 : Solid Storage and Surveillance Facility (S3F) is commissioned at Tarapur.

September 24, 1999 : Unit-2 of Kaiga Atomic Power Station, Karnataka attains criticality. It is synchronised to the grid on December 02, 1999, and becomes commercial on March 16, 2000.

December 24, 1999 : Unit-3 of Rajasthan Atomic Power Station attains criticality. It is synchronised to the grid on March 10, 2000, and becomes commercial on June 2, 2000.

January 1, 2000 : BRIT's Radiation Processing Plant at Vashi, Navi Mumbai is commissioned.


2000 : Boron Enrichment Plant is commissioned at IGCAR, Kalpakkam.

March, 2000 & May 2000 : First concrete pour of Unit-3 and Unit-4

# SALIENT MILESTONES OF ATOMIC ENERGY IN INDIA

of Tarapur Atomic Power Project-3 & 4.

April 21, 2000 : Folded Tandem Ion Accelerator (FOTIA) at Trombay delivers first beam on target.

September 26, 2000 : Unit-1 of Kaiga Atomic Power station attains criticality. It synchronises to the grid on October 12, 2000.

November 03, 2000 : Unit-4 of Rajasthan Atomic Power station attains criticality. It creates history by synchronising with the grid within a period of 14 days on November 17, 2000. The unit becomes commercial on December 23, 2000.

November 16, 2000 : Unit-1 of Kaiga Atomic Power Station becomes commercial.

2001 : FBTR fuel reaches burn up of 100,000 MWd/T.

March 18, 2001: Units 3 & 4 of Rajasthan Atomic Power Station are dedicated to the nation.

February 12, 2002 : India signs the biggest contract with the Russian Federation for the Nuclear Power Station at Kudankulam, Tamil Nadu.

March 30 & May 10, 2002 : First pours of concrete respectively of Unit-3 and Unit-4 of Kaiga Atomic Power Project-3 & 4.

March 31, 2002 : First pour of concrete of Units 1&2 of Kudankulam Atomic Power Project, Tamil Nadu.

September 18, 2002 : First pour of concrete of Unit-5 of Rajasthan Atomic Power Project 5 & 6

October 31, 2002 : Waste Immobilisation Plant and Uranium-Thorium Separation Plant at (both at Trombay), and the Radiation Processing Plant Krushak at Lasalgaon, district Nasik, Maharashtra, are dedicated to the Nation.

November 2002 : UCIL's Turamdih Mine, Jharkhand is inaugurated and Technology Demonstration Pilot Plant becomes operational at Jaduguda.

2003 : 1.7 MeV Tandetron Accelerator and the demo facility and Lead Mini Cell (LMC), for reprocessing of FBTR carbide fuel on lab scale, are commissioned at IGCAR.

**"…….Looking from the perspective of a large and growing economy like India, with its small hydrocarbon reserves and depleting coal reserves, development of nuclear energy based on a closed cycle approach enabling fuller use of uranium and thorium is the only way to meet development aspirations of over a billion people. ……"***

Mr. President,

I congratulate you, on behalf of my Government and on my own behalf, on your election as President of the 47th General Conference. I am sure that, under your able leadership and with the support of your Team and the Secretariat of the Agency, this General Conference will be able to accomplish the tasks before it.

I would like to compliment the Director General Dr. Mohamed ElBaradei on his continued successful stewardship of the Agency. He faced some of the biggest challenges this year, but was able to carry out his mandate effectively and impartially.

Mr. President, at the outset, I would like to repeat what I had said in the recently held international symposium on Innovative Reactors and Fuel Cycle here in Vienna.

According to the World Development Report 2003 of World Bank, world's population crossed 6 billion mark in the year 1999. Most current estimates suggest that around 2 billion people will be added over the next 30 years with another billion in the following 20 years. Virtually all increase will be in the developing countries with the bulk in urban areas. The core challenge for development would thus be to ensure availability of productive work opportunities and access to basic amenities for these people. At present, however, there are wide disparities. The average income in the richest 20 countries is now 37 times that in the poorest 20 and this ratio has doubled in the past 40 years. Availability of energy within the reach of everyone could significantly correct this situation. Energy is the engine for empowerment and growth. It multiplies work done through human labor and increases productivity. Availability of energy thus leads to enhanced livelihood and access to better amenities. With the sustainability issues staring at us, this realization is possible only if the energy supply becomes abundant and within the reach of all. Only the power of atom can make it happen.

*Dr. Anil Kakodkar, Chairman, AEC addressing the General Conference of the IAEA*

As we commemorate the "Atoms for Peace" initiative launched fifty years ago and take stock of the achievements, which are indeed very impressive both in terms of share of nuclear electricity in the total electricity production as well as in terms of other non-electricity applications, the barriers to growth of this important technology for the benefit of the larger part of humanity are yet to be addressed. This is better done before it is too late as otherwise the threat to global climate as well as the inequality tensions could assume unmanageable dimensions. Clear signatures of these threats are already visible.

Combating the dangers of malevolent use of nuclear and radioactive material by unscrupulous and terrorist elements has emerged as a new threat. We are glad to see that this issue is receiving due attention in the Agency. We recently conducted in collaboration with the IAEA an international training course on Security for Nuclear Installations. The course was well received and the feedback is encouraging. This course could serve as a 'model course' and we could conduct more such courses on a regular basis.

We welcome the G-8 statement on the safety and security of radioactive sources. India actively participated in the search operations to locate orphaned sources in Georgia. Our expert team joined IAEA and provided state-of-the-art Arial Gamma Spectrophotometer Survey system and other survey meters. India has actively participated in discussions on evolving the IAEA Code of Conduct on the Safety and Security of Radioactive Sources. Let me inform this august gathering that we have in place adequate legislative and regulatory infrastructure to achieve the objectives of this Code of Conduct.

Our atomic energy programme,

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** Statement by Dr. Anil Kakodkar, Chairman, Atomic Energy Commission and Leader of the Indian Delegation, at the 47th General Conference, IAEA, Vienna, 17th September 2003.*

which is in its 50th year, has come a long way on its march to serve Indian people. Today we are on a fast track growth backed up by a strong R&D, industrial and safety infrastructure. In around four years from now, we would reach an installed generating capacity of around 4500 MWe with Pressurised Heavy Water Reactors, the main stay of the first stage of our indigenous nuclear power programme, and another 2320 MWe with Light Water Reactors making a total of around 6800 MWe as against the present capacity of 2720 MWe. A few days back Government of India has approved construction of a 500 MWe Prototype Fast Breeder Reactor (PFBR). This indigenously developed technology can enhance the installed power generation capacity to well above 300,000 MWe even with our modest Uranium resources. Pre-project activities for PFBR project have already commenced with some of them already completed.

Nuclear electricity generation of 19,358 million units (MUs) was realized during the year 2002-03 with Nuclear Power Corporation of India Limited (NPCIL) achieving annual overall capacity factor of 90%, which is among the best in the world. The Kakrapar Atomic Power Station – 1 was judged the best performing unit amongst PHWR category during the rolling 12 months period from October 1, 2001 to September 1, 2002. For the calendar year 2002, the three NPCIL PHWR units were amongst the five best PHWR units in the world.

The WANO peer reviews for Kaiga Generating Station and Rajasthan Atomic Power Station Unit – 3&4 were completed during January 2002 and January 2003 respectively. All the operating nuclear power stations are now ISO 14001 certified.

En-masse coolant channel replacement and upgradation of unit-2 of Madras Atomic Power Station was completed in a record time of about one and a half years. Scale up of the PHWR design to 700 MWe by permitting partial boiling in the channels of 540 MWe unit design is also progressing on schedule.

Fast Breeder Test Reactor [FBTR] is in operation at IGCAR since 1985 with indigenous Uranium-Plutonium Carbide fuel and has achieved a burn up of 103,000 MWd/t with excellent performance, without any fuel failure. The irradiation of Uranium-Plutonium mixed oxide fuel of PFBR composition (30 % $PuO_2$ and 70 % $UO_2$) using U-233, as additional fissile supplement to achieve the required linear heat rating has commenced in FBTR in July 2003. In order to close the FBTR fuel cycle, a facility for reprocessing the carbide fuel has been commissioned and the reprocessing campaign has commenced.

The second Waste Immobilisation Plant (WIP) for the vitrification of the high level waste was commissioned. The Uranium Thorium Separation Facility for separation of uranium 233 from irradiated thorium fuel on a plant scale has become operational.

Growth of nuclear energy in the developing countries particularly in fast growing economies with large population should be a matter of global interest in view of its potential to protect the earth from irreversible climate changes. Wherever there are no genuine concerns, barriers to deployment of nuclear energy technologies need to be examined and brought down through a pragmatic approach. We must move towards a more peaceful and prosperous world on the basis of plenty of energy available within the reach of all. Mindless controls without addressing the core issue of meeting development aspiration of the needy does not help the situation. Rather it makes matters worse.

The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) of the IAEA for the development of the next generation of nuclear reactor and fuel cycle technologies is important in this context. It has the potential of providing a technological solution to address the barriers to deployment of nuclear power worldwide. Development of Advanced Heavy Water Reactor (AHWR) in India, which would more than meet the INPRO objectives in terms of sustainability, economy, safety and proliferation resistance, is progressing according to plans. In addition, this reactor system would enable us to get started with large scale energy production using Thorium.

We are conscious of our responsibilities arising from the possession of advanced technologies in the nuclear field. We have a commitment and an interest in contributing as a partner against proliferation. Even as we move forward towards developing and using proliferation resistant nuclear technologies we must shed the baggage inherited from the past – which still restrict the flow of equipment and technologies related to the peaceful uses of nuclear energy.

Looking from the perspective of a large and growing economy like India, with its small hydrocarbon reserves and depleting coal reserves, development of nuclear energy based on a closed cycle approach enabling fuller use of uranium and thorium is the only way to meet development aspirations of over a billion people. Based on a recent study, India needs to reach around 5000 kWh/capita of annual electricity availability to assure a quality of life consistent with modern norms. This would be possible only if the share of nuclear power is at least 25%. We are therefore pursuing a comprehensive R&D programme to explore newer technologies to widen the scope of nuclear energy use. Programmes are already under way to develop FBR fuel cycle with shorter doubling time, clean up of Uranium-233, Accelerator driven systems for better doubling time with

Thorium fuel cycle and for waste transmutations, and a Compact High Temperature Reactor. Together these developments would help faster deployment of nuclear energy, further simplification of radioactive waste issue and expand role of nuclear energy as a primary energy source.

At our Institute for Plasma Research, SST 1, one of the world's first super conducting steady state tokamaks with elongated diverter plasmas and 1000-second operation capability is undergoing erection and commissioning. We are watching the recent developments in the progress of ITER and would be keen on opportunities of participation in this international effort.

The thickly populated coastal region of the southern state of Kerala, with its vast deposits of Monazite sands (a rich source of Thorium) and high natural background radiation has provided us an unique opportunity to study effects of low level radiation on human beings. Dose rates in this region range from 1.0 mGy/year to as high as about 40mGy/year which envelope the range of occupational exposures. The studies so far indicate clearly that high level natural radiation has had no discernible impact on the health of the population. The research conducted in this area has the potential to provide valuable insights to our understanding of the mechanisms of response of biological systems to low level radiation.

Various Institutions in India are participating in the STAR experiment at the Relativistic Heavy Ion Collider in the Brookhaven National Laboratory of United States. Photon Multiplicity detectors for the experiments have been fabricated and assembled. India's participation in the Large Hadron Collider (LHC) and its experiments CMS and ALICE under construction at the European Organisation for Nuclear Research (CERN), Geneva, has been expanding to mutual benefit. Several state of the art technology items have been supplied from India.

The Giant Metrewave Radio Telescope (GMRT) is now a full fledged international observational facility for radio astronomy below 1.4 $GH_z$. A number of national and international users have started observing a variety of astronomical objects from our galaxy as well as from other far off galaxies using this facility. Gamma ray astronomy facility at Mt. Abu is also operational.

The Technical Cooperation (TC) programme of the agency has been playing a valuable role in developmental activities using nuclear techniques. We have a comprehensive domestic programme on applications in agriculture, health, water resources and industry. We have been and would continue to be active in sharing our experience with other countries. Our Honourable Minister of State for Water Resources Mrs. Bijoya Chakrovarty and Chairman, Task Force on Interlinking of Rivers, Mr. Suresh Prabhu participated in the agency programmes here in Vienna. Last year we trained 33 IAEA fellows in India and hosted 8 IAEA & RCA events and sent 50 experts on different IAEA assignments. We would continue our strong support to IAEA activities. The Agreement reached this year to establish a link between the growth in the regular budget and the quantum of Technical Cooperation Fund (TCF), we hope, will further enhance the resources available for Technical Cooperation. We have been consistently pledging and paying our contribution to Technical Cooperation Fund (TCF) in full. We do so this year too.

The Agency's programme on 'managing and preserving the knowledge' is timely and relevant to the nuclear industry. In India we are in a fortunate position with respect to our very capable human resource available in large numbers. We could therefore effectively contribute to global efforts in this area. The recent coming into existence of the World Nuclear University is a very positive development, in which we intend to participate effectively. We also participated actively in the establishment of Regional Asian Network for Higher Education in Nuclear Technology. It may be also worthwhile at this stage to mention that Indian scientists have perhaps made the largest contributions to scientific publications on Pressurised Heavy Water Reactors.

Last year, we witnessed the intense consultations in the IAEA Board to arrive at consensus for the Programme & Budget for the years 2004-05. The spirit of compromise and comraderie typical of IAEA resulted in the final compromise position. The opportunity provided by the decision to move away from the Zero Real Growth concept enabled us to rectify certain imbalances and to remove some procedural complexities which had crept in over the years. The trust that Member States have in the Agency's capability to deliver programmes that would benefit humanity was again abundantly clear. The Director General's initiative of the one house concept must be fully realised and not remain as a mere slogan. This can be done effectively with 'technology' as the key driver comprehensively addressing and linking various programmes of the Agency. We stand ready to participate in the various studies proposed by the Board to further streamline procedures and to effect economies.

Mr. President, before I conclude, I wish to remind the GC that the improvements in quality of human life have primarily come about as a result of developments in science and technology. Some new problems may have arisen in the process, but even their resolution took place through further application of science and tech

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# CHALLENGES BEFORE AMD

AMD's present exploration strategy is to concentrate geological survey and exploration for the classical unconformity-types and the Lambapur-types in the middle proterozoic basins of India.

> Vision and dream of AMD is to make India not only self-sufficient but a surplus country with regard to uranium resources, by proving high grade and large tonnage uranium deposits. The task is not easy, but can be achieved with sustained efforts and application of exploration strategies.

The analysis of data accrued at Lambapur has established the pronounced control of both unconformity and basement fractures on this mineralisation. These controls were successfully projected and proved in the adjoining Peddagattu outlier (of 25 sq.km.), which on completion of exploration has become an economically viable uranium deposit. The projection of these geological features for the entire Srisailam sub-basin (of more than 3000 sq. kms.), with similar geological set-up, leads to infer a very huge uranium resource for this basin.

The significance of the Middle Proterozoic basins is well understood with regard to uranium deposits as in Srisailam sub-basin of Cuddapah basin, Andhra Pradesh, India.

There are 14 (fourteen) large and small middle proterozoic basins in India. They are: (i) Cuddapah Basin; (ii) Bhima Basin; (iii) Kaladgi Basin; (iv) Pakhal Basin; (v) Ampani Basin; (vi) Indravati Basin; (vii) Khariar Basin; (viii) Abujhmar Basin; (ix) Chhattisgarh Basin;

## New Director of AMD

Shri R M Sinha has taken over as the new Director of the Atomic Minerals Directorate for Exploration and Research (AMD), Hyderabad.

Having obtained M.Sc. Applied Geology from the Indian School of Mines, Shri Sinha joined AMD in October 1966 and carried out survey and exploration for uranium in diverse geological environments of the country.

During his 36 years of service, the most significant exploration and evaluation with which Shri Sinha was associated, include:

- the vein-type uranium deposits of Turamdih Group associated with the Singhbhum Shear Zone in Jharkhand and Bodal deposit associated with the Dongargarh System in Chhattisgarh;
- the Quartz-Pebble Conglomerate-type uranium deposits at Walkunji and Arbail associated with the Dharwar Supergroup rocks of the Western Ghat Belt, Karnataka;
- the first Sandstone-type uranium deposit associated with the Cretaceous Mahadek Formation at Domiasiat, Meghalaya; and
- the first uranium depost, akin to Unconformity-type, associated with basement granite along the unconformity with the overlying Srisailam Formation in the Cuddapah Basin in the Lambapur-Peddagattu areas of Andhra Pradesh.

Shri Sinha contributed significantly to the assessment of economic viability of a number of uranium deposits. He was a trainer for the Regional IAEA training programmes on uranium prospecting, exploration and ore-reserve estimation in 1974 and 1991.

Shri Sinha has guided the exploration programmes for Rare Metals as well as Beach Sand minerals and supervised geophysical surveys, in addition to uranium exploration of Southern, South Central, Central and Western Regions of AMD.

In recognition of the significant discovery and proving the first unconformity-type uranium deposit at Lambapur-Peddagattu area in Cuddapah Basin, Andhra Pradesh, the National Mineral Award for the year 1996 in the field: "Mineral Discovery of Economic or Strategic Importance" was conferred upon him alongwith others, by the Ministry of Steel and Mines, Government of India.

Shri Sinha has participated in a number of national and international conferences.

(x) Khairagarh Basin; (xi) Vindhyan Basin; (xii) Delhi Basin; (xiii) Kunjar Basin; and (xiv) Shillong Basin. Most of these basins, have become very favourable targets to host unconformity-type deposits (both Lambapur and classical-types).

Out of the 14 middle proterozoic basins in India, the ones that have the potential to host high grade classical unconformity-type deposits, are :

Cuddapah Basin, Andhra Pradesh; Shillong Basin, Meghalaya; Kunjar Basin, Orissa; Vindhyan-Gwalior, Vindhyan-Bijawar and Vindhyan-Mahakaushal basins, Madhya Pradesh; and Delhi-Aravalli Basin, Rajasthan. All these basins are under some stages of survey and exploration.

Very limited work has been carried in search of Iron Oxide Breccia Complex" Type deposits in India, but it is expected that similar geological set-up exists in a number of rift zones, e.g. Son-Narmada, Godavari and Mahanadi rifts. Also, the mantle plume along the $90^o$ E ridge holds potential for such deposits, especially in the Meghalaya Plateau.

Such a deposit at Olympic Dam, Australia has a very large tonnage of 1.2 million tonnes uranium and was deciphered by geophysical surveys, with association of both magnetic and gravity highs over an area of 7 km x 4 km and occurring at a depth of 300 to 1000 m. Such a depth range constraints the geophysical inputs available in India.

To conclude, India is endowed with a large number of Middle Proterozoic basins, which can host high grade unconformity-type uranium deposits. The low grade (0.10% $U_3O_8$) deposit, identified at Lambapur, also belongs to this category, but is of lower grade owing to its host rock. In the Middle Proterozoic basins of India, the search for Lambapur-type deposits can easily be accomplished with AMD's present

capabilities and resources. But for proving high grade deposits, the capabilities with regard to geophysical equipment and interpretations and deviation-controlled drilling have to be upgraded.

The X Plan of AMD has been drawn with a two-fold objective to execute exploration in a number of middle proterozoic basins to prove a number of uranium deposits of Lambapur type and to upgrade AMD's capability of geophysical exploration and deviation-controlled drilling, by procuring the appropriate equipments. The fulfillment of the second objective will enable it to achieve the ultimate goal of establishing high grade (more than 0.5% U ) deposits in India.

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nology. Looking back to the 1950s and 1960s, it was then feared that developing countries with large population like India, would not be able to feed their growing populations. Thanks to the green revolution in agriculture, the doomsday scenarios of famine and starvation did not materialize in these countries. In the development of nuclear power technology like wise, there is a need to embark on a new technological revolution and address residual issues facing us, in the developing and the developed world alike.

Looking at the present scenario the nuclear technology finds itself in, we need a proactive two pronged strategy which safeguards the developmental aspirations that can inevitably be met by nuclear technology and at the same time prevents its malevolent use. This is an important challenge as ignoring either dimension could lead to disastrous consequences. With science and technology based collective wisdom at its command, I feel that this United Nations Organisation is in a unique position to find new paths that could significantly contribute to world peace and prosperity. We all need to work together in this important task. We owe it to humanity.

Thank you Mr. President.

# ANUPAM SUPER-COMPUTER

Supercomputers are extensively used for solving very large computational problems in scientific research, engineering, industry, defence and business for variety of applications like molecular dynamics, modeling & simulation, Computational Fluid dynamics, Finite element analysis, Monte-Carlo simulation, Simulation of collision of galaxies, crash studies of vehicles in automobile, aerospace, nuclear-weapon, seismic studies, oil exploration, geology etc.

*ANUPAM Super-Computer*

Since 1991 BARC is involved in developing series of parallel computing architectures to meet high performance computing needs of in-house researchers. There is no single way to connect a bunch of processors in parallel fashion. BARC developers recognized that a processor-independent design only can keep pace with changing technology and adopted a flexible design approach to parallel processing architecture and concentrated more on development of system software, tools and parallel-ization of application software.

In 2002 BARC developed 64-node ANUPAM parallel machine, which has attained 43 Gflops sustained performance, which is about 2 to 3 times that of older 84-node ANUPAM. The new ANUPAM system uses Pentium IV microprocessors operating at 1.7 GHz interconnected through 100 Mbps fast Ethernet network and has 256Mb memory per node. This system is about 30-40 times faster than any parallel Supercomputer indigenously developed by other institutions in the country. The latest ANUPAM_PIV computer consisting of 64 nodes has attained 43 Gflops of sustained performance using fast Ethernet, for Industry standard benchmarks. This has been now enhanced to 72 Gflops by incorporating ultra high speed 2D/3D PCI based Scalable Coherent Interface (SCI) connectivity a very low latency (about 8 microsecond), ultra high bandwidth (up to 667 Mbytes) network.

In June 2003, BARC achieved very significant milestone in the field of supercomputers by developing a 128-processor ANUPAM supercom-puter. The computing speed of this supercomputer is observed to be higher than 340 Giga Floating Point Operations Per Second (GFLOPS) on High Performance Linpack benchmark program. This computer is about six times faster than the 64-node supercomputer developed earlier, in July 2002. The present supercomputer is more than 10,000 times faster than the first 4-node super computer developed at BARC in December 1991.

The ANUPAM Systems have not only made available supercomputing power at a fraction of supercomputer cost to the DAE scientists, but these systems are also being used in several outside labs including Department of Space (VSSC), Defense (ADA), many IIT'S and several universities. Since December 1999 ANUPAM-ALPHA system has been operational at NCMRWF, New Delhi and it has replaced old Cray-XMP at NCMRWF, New Delhi running operational weather codes much faster and costing less than one tenth that of Cray supercomputer. There was only one CRAY X-MP supercom-puter in India, which was used at the National Center for Medium Range Weather Forecasting (NCMRWF), New Delhi. So far BARC has commissioned 37 ANUPAM systems based on i860, Alpha and Pentium at BARC and other leading institutes in the country including ADA, Banglore, VSSC, Trivendram, NCMRWF (weather), NewDelhi, IIT's and many universities.

Also number of additional parallel software tools such as Automatic installer, Parallel I/O file system, Integrated virtual console environment, Grid enable software, Parallel batch scheduler etc have been developed to enrich parallel environment to help users in using ANUPAM system much more effectively. These efforts and investment in HPC have resulted in the generation of valuable expertise and capability in using these systems, awareness, large trained manpower and skills which very few countries have.

So far BARC has developed 16 different models of the ANUPAM series of parallel supercomputers using a variety of processors as compute nodes and various technologies for interconnection networks. ANUPAM supercomputers have highly user-friendly software environments and provides very high reliability of operation required for continuous operations of such supercomputers on 24*7 hours basis, for solving very large problems. These systems being based on commercially available off-the-shelf components are highly cost effective and easy to manufacture.

## Collaboration between Department of Atomic Energy and the European Organisation for Nuclear Research. CERN

The European Organisation for Nuclear Research i.e. CERN was established soon after the second world war by the countries of Western Europe to promote research in particle physics. In 1996, CERN embarked upon its most ambitious project namely to construct the Large Hadron Collider (LHC). When completed, this accelerator will accelerate two proton beams moving along a circular path in opposite directions to energies of TeV (Terra Electron Volts) (1 TeV = 1 million million electron volts), and make them collide. This collision will generate many new particles. To study these particles, scientists are also developing special detectors requiring large and sophisticated instrumentation. Indian scientists are also participating in the construction of two such detectors named ALICE and CMS. Using such detectors, particle physicists will be looking for the elusive Higgs Boson, a particle predicted by theory but not yet experimentally observed. Similarly, the LHC can also accelerate heavy ions such as lead ions and make them collide. In such a collision the protons and neutrons in the lead ions will disintegrate into quarks and gluons, of which protons and neutrons are made.

Construction of the LHC is scientifically and in terms of engineering, the most challenging scientific project ever undertaken by mankind. The LHC is a circular accelerator of 27 kms circumference which will be built in a tunnel about 100 metres below the ground.

*Dr. Anil Kakodkar, Chairman, Atomic Energy Commission of India handing over the 1000th magnet for CERN project, to Dr. Lyndon Evans, Director, Ecuropean Organisation Nuclear Research (CERN), Geneva. Seen in picture is Dr. D.D. Bhavalkar, Director, CAT, Indore (extreme left) and Dr. Philippe Lebrun, CERN, Geneva (second from extreme right) and Dr. Philip John Bryant, CERN, Geneva (extreme right).*

In March 1996 the DAE and CERN signed a protocol for India's participation in the LHC. According to this protocol, India would contribute US $25 million, which is 1% of the cost of the project, by developing and supplying high tech components for LHC, by developing software for LHC and by providing skilled manpower supported for special tasks at CERN. With the signing of this protocol, India thus joined Canada, Japan, Russia and USA to participate in the construction of LHC as a non-member state. Earlier this year, India became an Observer in the CERN Governing Council. The only other Observer States are Israel, Japan, Turkey, USA, the European Commission and UNESCO.

The Centre for Advanced Technology at Indore is coordinating DAE's efforts in this direction. Through a series of technical discussions with experts from both sides, DAE has identified a number of high tech components for the LHC. These include more than 2000 superconducting magnets, 6800 precision magnet positioning system jacks, nearly 6000 quench protection electronics and quench protection system power supplies, engineering design and studies of specific systems of LHC, trained manpower support for magnet measurement, development and control software for the LHC machine etc.

The super conducting corrector magnets were designed and developed at CAT but they are being manufactured at Kirloskar Electric Company Ltd., Bangalore and Crompton Greaves Ltd., Bhopal. The Indian industries thus are directly contributing high tech components to an international scientific project.

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