Chapter 7

Scientific and Technological Developments

INDIA has a long and distinguished tradition in science and technology from the ancient times to great achievements during this century; the latter half prior to independence has been related largely to pure research. At the time of independence, our scientific and technological infrastructure was neither strong nor organised as compared to the developed world. This had resulted in our being technologically dependent on the skills and expertise available in other countries. In the past four decades, an infrastructure and capability largely commensurate with meeting national needs has been created minimising our dependence on other countries. A range of industries from small to the most sophisticated has been established covering a wide range of utilities, services and goods. There is now a reservoir of expertise well acquainted with the most modern advances in basic and applied areas that is equipped to make choices between available technologies, to absorb readily new technologies and provide a framework for future national development.

SCIENCE AND TECHNOLOGY INFRASTRUCTURE

Scientific and technological activities in India are carried out under a wide set-up consisting of Central government, State governments, higher educational sector, public and private sector industry and non-profit institutions / associations. These institutional structures, with their research laboratories, are the main contributors to research and development being carried out in the country. Notable among these are : the Council of Scientific and Industrial Research (CSIR); Indian Council of Agricultural Research (ICAR); Indian Council of Medical Research (ICMR). In addition, there are many departmental laboratories of various departments / ministries, *viz.*, Department of Atomic Energy, Department of Electronics, Department of Space, Department of Ocean Development, Defence Research and Development Organisation, Ministry of Environment and Forests, Ministry of Non-Conventional Energy Sources and the Ministry of Science and Technology. Further, there are over 1,200 in-house research and development units in industrial undertakings supporting research in their respective industries. Many Indian Universities and Deemed Universities such as IITs also undertake substantial research and development work.

TECHNOLOGY POLICY STATEMENT

Technology Policy Statement (TPS) was formulated in 1983 with the basic objective of developing indigenous technology and ensuring efficient absorption

and adaptation of imported technology appropriate to national priorities and availability of resources. It is aimed at attaining technical competence and self-reliance, reducing vulnerability particularly in strategic and critical areas and making maximum use of indigenous resources. The TPS also aims at using traditional skills and capabilities making them commercially competitive. Several other measures through technology-intervention are envisaged to optimise demand on energy and ensure harmony with the environment. With a view to strengthening the economy, structural reforms have been introduced through adoption of a new industrial policy which will have an important bearing on the programmes of development pertaining to science and technology. A Technology Policy is being formulated to provide focus on the development of indigenous technologies and to make India self-reliant and competitive in the technological field.

PROGRAMMES OF THE DEPARTMENT OF SCIENCE AND TECHNOLOGY

The Department of Science and Technology, was set-up in May 1971 with the objective of promoting research in the new areas and to play the role of a nodal department for organising, coordinating and promoting science and technology activities in the country. Over the years, the Department has evolved policy statements and guidelines, provided mechanisms for co-ordination in the areas of science and technology in which a number of institutions have interests and capabilities, supported grants-in-aid to scientific institutions and professional bodies. The Department has to play a catalytic and co-ordinating role and in this process over the past few years, the efforts at promoting science and technology in the States and Union Territories have also gathered considerable momentum.

RESEARCH AND DEVELOPMENT PROGRAMMES

The Department of Science and Technology has been playing a crucial role in identifying and promoting front-line and priority areas on Research and Development (R&D) in various disciplines of science and engineering. This support, is provided through Science and Engineering Research Council (SERC) - an advisory body consisting of eminent scientists and technologists drawn from academic institutions like IITs, universities, national laboratories and industry. The Council through its advisory committees, assists the Department not only in peer reviewing the proposals but also identifies newer and inter-disciplinary areas of R&D for concerted efforts. The Council, with the help of the advisory committees, also monitors progress of individual projects sponsored in various disciplines along with monitoring the progress of co-ordinated and concerted efforts. Every year around 1,000 project proposals are received for consideration in the Department, most of which fall in the category of basic sciences and engineering research. During 1998-99, 233 research programmes were approved for financial support.

Some of the new projects supported relate to Theoretical Studies on Non-Accelerated Particle Physics; Dynamic Physics; Cavity QUED ; Protein Chemistry ; Solid State and Surface Chemistry; Preparation and Densification

of Aluminium Nitride Powder; Plasma based Ion Implantation for Surface Engineering of Titanium Alloys; Ionosphere and Thermosphere Studies; Photochemistry in Jet Cooled Clusters; Indian Solar Terrestrial Energy Programme; all India coordinated programmes on Ionosphere Thermosphere Study (AICPITS-II), etc.

On the occasion of the 50th anniversary of India's Independence, the Government launched *Swarnajayanti Fellowships* for enabling outstanding young scientists to attain world class levels in science. The Fellowships are open to Indian scientists in the age group of 30-40 years, with proven capability for outstanding research work exploring new frontiers in their field of specialisation. During 1998-99, the Fellowships were awarded to 11 young scientists.

INFRASTRUCTURE DEVELOPMENT

The Department through its various programmes has been playing a catalytic role in supporting the setting-up of new R&D facilities alongwith the modernisation of the existing ones. 'Intensification of Research in High Priority Areas'- IRHPA which was initiated during the Sixth Plan period, has helped in strengthening of the infrastructure and research capabilities in selected areas of science and engineering. Under this programme, units/ core groups and National Research Facilities are established around an outstanding scientist to act as a focal point to nucleate research activity in these areas. Some of the areas supported include 300 MHz NMR facility, fabrication of large area multi-junction a-Si Solar modules, augmentation of the facilities at the national centre of experimental mineralogy and petrology, national facility of isotope discrimination studies for water efficiency use, laser scanning confocal microscope facility, X-ray facility for structural biology, unit on social insect biology, etc. In addition, several national facilities have been set up to cater to the needs of scientific community for undertaking research in advanced areas. These include laser processing of materials, geo-technical centrifuge, highfield FTNMR, confocal scanning fluorescence microscope, AMS facility, magneto-telluric facility, etc.

Facilities of sophisticated analytical instruments are provided to the scientists working in universities, R&D laboratories and industries through a programme of setting-up Regional Sophisticated Instrumentation Centres (RSICs) and Sophisticated Instrument Facilities (SIFs). RSICs are being supported at seven institutions namely IIT, Chennai; IIT, Mumbai; Bose Institute, Calcutta; CDRI, Lucknow; Punjab University, Chandigarh; NEHU, Shillong; and Nagpur University, Nagpur. The new Sophisticated Instrumentation Centre for Research and Testing has been set-up at Vallabh Vidyanagar, Gujarat. The SIFs are in operation at IISc., Bangalore ; AIIMS, New Delhi; and Gauhati University, Guwahati. In addition, EPMA facility is being supported under the programme of Roorkee University, Roorkee. Further, in order to attain the objective of strengthening of R&D infrastructure in the academic/research institutions, a new programme 'Fund for the Improvement of S&T Infrastructure in Universities and other Higher Educational Institutions (FIST)' was initiated. The programme

would identify active university/academic departments through a peer review mechanism including on-site visits.

HUMAN RESOURCE DEVELOPMENT

The Department also supports different programmes aimed at identifying new talent and provide them with financial assistance in the from of fellowships for pursuing research in front-line areas of science and technology. Also, for the researchers the Department supports training programmes, summer schools and contact programmes. The programmes supported are : BOYSCAST fellowships, SERC student fellowships, etc. 32 young scientists were chosen for the BOYSCAST fellowships to work in the laboratories abroad. 23 student fellowships were awarded to undergraduate students to get first hand exposure of research in leading research laboratories.

In order to motivate bright young minds at their secondary school/college levels, and to encourage them to stick on to a career in science, a new scheme called *Kishore Vigyanik Protsahan Yojana* has been initiated. Talent would be scouted through a competitive mechanism at school level and scholars would be selected for an attractive fellowship/scholarship until they pass their Masters Degree in Science. Further, in order to generate trained manpower in selected areas of science and technology, training courses, summer/winter schools were organised in theoretical chemistry, earth sciences, astronomy and astrophysics, lasers, optics, atomic and molecular physics. Also, 460 Indian scientists working in educational institutions and national R&D laboratories were given partial financial assistance to enable them to participate in international conferences/workshops, etc.

TECHNOLOGY DEVELOPMENT AND RELATED PROGRAMMES

The Department has been catalytic in identifying, formulating and implementing a number of technology development programmes with the help of industries and socio-economic ministries. Efforts of the Department in this direction have helped in initiation of multi-institutional programmes in the emerging area of technology. As a part of this programme, projects were continued to be supported in the areas such as instrument development, advanced materials, critical technology, sugar technology, flyash utilisation, and advanced composites.

As per the provision of the Technology Policy Statement of 1983 and following the recommendations of the Technology Policy Implementation Committee, the Department has set up an autonomous body - Technology Information, Forecasting and Assessment Council (TIFAC). The main objectives of TIFAC include generation of Technology Forecasting and Technology Assessment and Techno Market Survey (TMS) documents and enabling a Technology Information System. Technology Forecasting/Technology Assessment studies have been carried out in a number of areas such as sugar industry, steel, materials technology, human settlement planning, automated machinery and production systems, foundry modernisation, energy, high volume industrial gases, prospects for biotechnology products

in India by 2000 AD in health and agricultural sector, fertilizers - a relook, and a comprehensive picture of Science and Technology status in India. So far, about 150 specialised reports have been brought out by TIFAC that include a 25 document series on Technology Vision 2020 and a 16 document series on Science and Technology in different sectors.

One of the important activities being pursued by TIFAC is the promotion of specific home grown technologies which is expected to strengthen the linkages between research institutions and industry by commercialisation of technologies developed indigenously. Under this activity, 10 project have been completed so far and out of these four technologies have been transferred successfully. Another fifteen projects are in progress.

The Technology Vision 2020 reports brought out by TIFAC present a long-term technology forecast in the diverse areas such as agro-food processing, civil aviation, electric power, waterways, road transportation, food and agriculture, health care, life sciences and biotechnology, advanced sensors, engineering industries, materials and processing, services, strategic industries, electronics and communication, chemical process industries, telecommunication and driving forces-impedances. The TIFAC Council has constituted 13 action teams. The objectives of the action teams are to generate necessary linkages and specific project proposals to realise vision into missions and to make efforts to bring together project teams and such action packages.

A patent facilitating cell has been set up in TIFAC with the objectives of introducing patent information as a vital input in the process of promotion of R&D programmes, provide patenting facilities for scientists/technologists of the country on a sustained basis, keep a watch on developments in the areas of intellectual property rights, create awareness and understanding relating to patents and undertake studies and analysis of policy related to TRIPS agreement and other agreements under World Trade Organisation, etc. Till November 1998, the cell organised 41 awareness workshops sensitizing about 4,100 scientists/technologists from more than hundred universities, hundred government R&D institutions and 125 industries. Eight patent applications were also filed during the year. Patent facilitating cell has also brought out two CD ROM databases namely EKASWA-A on patent applications filed in India and EKASWA-B on patents accepted and notified for opposition by the patent office. The two disks contain data from 1995. In addition, seven issues of IPR bulletin were also brought out.

TIFAC has joined hands with CMC Limited in view of their experience in information technology areas and the nation—wide network through Internet. TIFACLINE services are now available for online access from major cities like Bangalore, Delhi, Chennai, Hyderabad, Mumbai and Calcutta through CMC's INDONET. TIFAC and CMC have also created a new database on Technology Sourcing Worldwide. The database currently has 4,400 records on technologies ready for transfer/acquisition from various countries across the world. International linkages have been established by TIFAC with ASEAN, WAITRO and IATAFI. In addition, TIFAC regularly

interacts with industry associations such as CII, ASSOCHAM, FICCI on various issues.

To promote innovation among entrepreneurs, a new golden jubilee initiative called "Technopreneur Promotion Programme (TePP)" has been initiated. The main thrust of TePP will be to tap the vast untapped innovative potential of the Indian innovators. The support is supposed to be provided to projects of individual innovators towards scaling-up the idea/invention/know-how/designs to working models/prototypes/pilot plants. Besides the financial support, the endeavour would be to link and couple them to the most appropriate existing R&D facilities and expertise; assist them in patent search/filing of patents; interface for tying-up with financial institutions for commercial exploitation, etc.

The Department of Science and Technology under its scheme on "Drugs and Pharmaceuticals Research" supports collaborative Research and Development projects jointly submitted by drug companies and the academic/national R&D institutes. The programme aims towards the development of new drugs and clearner process technologies for known drugs/key intermediates for drugs. The programme covers all systems of medicine - Allopathic, Ayurvedic, Homeopathic and *Unani.* Four project proposals approved during the year were in the areas of rational design and synthesis of novel anti-bacterial agents, development of recombinant vaccine against rabies, standardisation of certain traditional herbal single plant formulations for commonly encountered diseases.

The Department has guided 24 socio-economic ministries in the setting up of Science and Technology Advisory Committees (STACs) for formulation of long/short-term joint technology development programmes. For co-ordinating the efforts of STACs and to take stock of activities of various ministries, the Department has also set up an Inter-Sectoral S&T Advisory Committee under the Chairmanship of Secretary, DST. A quarterly newsletter *STAC SCAN* is being brought out by IS-STAC to disseminate information.

TECHNOLOGY DEVELOPMENT BOARD

The Technology Development Board was constituted in September 1996. The Board provides financial assistance to industrial concerns and other agencies for attempting development and commercial application of indigenous technology or adapting imported technology for wider domestic application. During the year 1998-99, the Board has signed 11 agreements with a total project cost of Rs 99.85 crore including Board's loan assistance of Rs 40.51 crore. The total number of agreements signed by the Board has aggregated to 31 with total project cost of Rs 243.69 crore including assistance of Rs 91.97 crore from the Board. The areas that got financial assistance from the Board were health and medicine, engineering and electronics, chemicals and lubricants, agriculture and biotechnology, power cable, transport, energy and waste utilistation, and telecommunication. The technology providers include national laboratories, academic institutions and recognised in-house R&D units in the industry. The enterprises supported are from private and

public sector companies, private limited companies and first generation entrepreneurs, etc. Some of the products successfully produced and marketed include first genetically engineered hepatitis B vaccine; bio-fertiliser from maize waist, gluten with the brand name *Suryamin;* DL2 Amino Butanol, an important substitute drug intermediate in the manufacture of anti-tuberculosis drug; Cefixime - an orally active fourth generation Cephalosporin anti-biotic; and recombinant hepatitis B vaccine.

NATIONAL ACCREDITATION BOARD FOR TESTING AND CALIBRATION LABORATORIES

National Accreditation Board for Testing and Calibration Laboratories (NABL) has been registered as a society on 12 August 1998 under Societies Registration Act. NABL continued its activity of according accreditation to testing and calibration laboratories after thorough assessment by the experts. Till date, 150 testing laboratories and 67 calibration laboratories have been accredited by the Board and assessment work has been completed for 145 testing laboratories and 75 calibration laboratories. The Board has been publishing a quarterly newsletter *NABL NEWS.*

S AND T PROGRAMMES FOR SOCIO-ECONOMIC DEVELOPMENT

The Department of Science and Technology is also devoted to evolving and implementing specific programmes to promote applications of S & T to improve the quality of life especially for the disadvantaged sections of the society. The areas in which significant achievements have been made are: setting-up of two Technology Parks for women; low cost housing and sanitation; integrated land water and cover management; eco-restoration and sustainable use of biomass in the hilly region; artisanal pottery; artisanal blacksmithy; artisanal leather tanning; training of agricultural labour (SC youth) in the use of modern agricultural appliances for improved agricultural productivity; farm oriented low-cost technology for utilisation of *Azolla* as biofertilizer; developing livelihood base for tribals in Melghat region through watershed development, etc. Some of the tangible benefits of such programmes have been the generation of appropriate rural technologies, reducing drudgery, generating employment, improving health, and conserving environment. For socio-economic development of the north-eastern states including Sikkim, steps have been initiated to involve State S &T councils, NGOs and S&T personnel. A number of projects are being supported both in farming and non-farming sectors after identifying specific areas.

National Science and Technology Entrepreneurship Development Board (NSTEDB) established in January 1982 has been implementing several schemes and programmes on promotion of entrepreneurship and creation of sustainable employment through the application of S&T. About 18,676 S&T persons have been trained under Enterpreneurship Development Programmes (EDPs) organised by the Board of which 3,678 persons have set-up their own ventures. The Board has also been organising skill development programmes in various trades. So far about 67,000 persons have been trained and provided with sustainable job/self-employment

opportunities.

Science & Technology Entrepreneurship Parks have been set-up in and around 13 different S & Tinstitutions in the country in order to provide facilities to existing as well as start-up entrepreneurs on technology development, testing and calibration, documentation and computation, training, etc. Entrepreneurship Development Cells (EDCs) have been established in academic institutions for creating facilities for the promotion of entrepreneurship and other avenues of self/wage employment among qualified S&T persons. Projects under Science & Technology Entrepreneurship Development Scheme (STEDS) are in operation in eight backward districts. For those unable to join regular Entrepreneurship Development Programmes (EDPs), Open Learning Programme in Entrepreneurship (OLPE) was initiated in 1994-95 in collaboration with Entrepreneurship Development Institute of India (EDII), Ahmadabad.

NATURAL RESOURCES DATA MANAGEMENT SYSTEMS

The Natural Resources Data Management programme is being implemented to upgrade the existing data management methodologies at the district level to facilitate decision making process with regard to local area management and development. Launched in 1982-83, the programme involves several R&D institutes of national repute, universities and non-governmental agencies in a consortium mode. As a part of this programme, spatial and non-spatial databases are being generated and updated at the state and district GIS centres. Different modules of Geo-Refferenced Area Management (GRAM) software package are being developed to assist the information processing needs of the district and sub-district level planning. The programme also envisages to develop and demonstrate the use of GIS technology through specific decision support systems for the identified sectors as per Eighth Plan priorities, *viz.*, water conservation, land use planning, energy management and infrastructure development. Several R&D projects in the areas of land and water management, study of landslides and hydrology of small watersheds were also supported.

STATE S AND T COUNCILS

The Department of Science and Technology has been operating a scheme entitled 'Assistance for Development of State Councils on Science and Technology' since 1980. The main objective of this scheme is to assist the States and Union Territories in setting-up State Councils on Science & Technology which in turn could help the states in formulation, planning, coordination and promotion of S&T activities within their areas. The State Councils on Science and Technology have been set-up in all States and UTs. The State Councils have now reached a phase of programme based S&T cooperation to address location specific and region specific problems. Steps were initiated to formulate studies on health care, traditional artisanship, agricultural practices, etc., to identify and plan S&T intervention. Steps were

also initiated to help the State Councils to encourage replication of successful technologies developed by them.

SCIENCE COMMUNICATION AND POPULARISATION

National Council for Science and Technology Communication (NCSTC), ever since its inception some 15 years ago, has been engaged in science and technology communication / popularisation and inculcation of scientific temper among the people. The emphasis has been on the development, adaptation, promotion and use of different communication technologies and techniques utilising various media - traditional and non-traditional. The activities undertaken centered around few natural phenomena and specific events utilising these for S and T communication.

The National Children's Science Congress is an important activity involving children in the age group of 10-17 years from all over the country. The programme is envisaged to encourage the students to relate the leaning of science to the environment around, to their immediate social and physical environment and provide them a forum to interact with scientists to quench their curiosity and thirst for creativity. In this programme, children in teams of five each on an average, take up scientific projects related to the local issues , work under the guidance of teachers / science activists, and report their findings at school / block, district, state and national level congress. The 1998 National Children Science Congress was organised at Anna University, Chennai from 27-31 December. The theme of the congress was "Nature-Let us Share and Care". The projects related to aspects like air, water, land and soil, minerals, forest and vegetation, eco-system, plants and animals, etc., were taken up. An activity guide meant for the teachers was prepared. Some 500 projects from different states were presented in the National Congress.

In an attempt to make science learning a joyful experience, a hand on activity based module related to middle school science curriculum has been developed. Also, to involve people in science popularisation and inculcate a scientific outlook among them, the organisation of *Vigyan Jathas* continued to be supported. *Kudratnama* — a 27 episode TV serial based on National Science Quiz was telecast on STAR PLUS. Another TV Serial on science for common man titled *Vigyan ki Rahein* produced by NCSTC was telecast by Doordarshan. Efforts are underway to produce a 52-part radio serial on 'Emergence of Modern Science', marking the centenary of the golden decade 1895-1905 during which fundamental scientific discoveries took place that changed the way we live and think.

VIGYAN PRASAR

Vigyan Prasar was established in 1989 to take up large scale science popularisation programmes. It has been striving hard to reach out to masses through the mass media. Besides, efforts are underway to put together a network of Science Clubs for spreading scientific awareness and promoting use of scientific methodology in our lives. A CD-ROM on Eclipses is being

developed to mark the last solar eclipse of the century. *Vigyan Prasar* launched a monthly newsletter *DREAM 2047*, focusing on *Vigyan Prasar* activities and programmes. The first issue of the newsletter came out in August 1998. *Vigyan Prasar* Network (VIPNET) is networking and weaving together science clubs, societies, organisations that are already established, functioning actively or are going to be formed. Further, *Vigyan Prasar* also aims at contributing towards the growth of HAM population as well as to provide technical know-how to the younger generation and form a countrywide network of HAMs.

S AND T RESOURCES INFORMATION

The Department of Science and Technology makes available on a continuous basis information on resources both manpower and financial resources devoted to science and technology activities. The latest directory of R&D institutions in India covers names and addresses of 2,900 R&D institutions under Central government, State governments, in-house R&D units of public sector and private sector industries, universities including deemed universities and institutes of national importance, and scientific and industrial organisations in the private sector.

The database on extramural research and development projects funded by different Central government agencies is being maintained and updated regularly. The data is being utilised to compile the Directory of Extramural Research Projects. The directory of the year 1996-97 contains information on 1,795 new R&D projects approved by 16 Central government departments/agencies. The total cost of the projects approved is Rs 186.48 crore. Based on the database, a report entitled 'Funding Pattern of Sponsored Research by Scientific Agencies during 1990-95' was brought out. The report provides an analysis of 6,791 R&D projects costing Rs 547.64 crore approved by 22 Central government departments and agencies. In all, 1,095 institutions received R&D (extramural) support.

INTERNATIONAL CO-OPERATION

International Science and Technology cooperation is realised at three levels, *viz.*, bilateral cooperation with developed and developing countries, regional cooperation such as with SAARC, ASEAN and BIMST countries; and multilateral cooperation through NAM S&T Centre, COSTED, UNESCO, etc. India has got bilateral science and technology cooperation with 50 countries of the world. In addition to ongoing programmes of science and technology cooperation with developed as well as developing countries, new inter-governmental agreements of cooperation were concluded with Portugal and Malaysia.

Bilateral cooperation with France continued through the active involvement of Indo-French Centre of the Promotion of Advanced Scientific Research and 18 new projects were approved in the areas of Cellular/Molecular Biology/Genetics, Medical Science, Catalysis, Liquid Interface Science, Materials Science and Engineering and Water Resources. Indo-German Committee on Science and Technology agreed that while ongoing

cooperation under special arrangement should continue, priority areas for bilateral cooperation for the next two years would include Information Technology, Advanced Materials, Biotechnology, Genetic Engineering, Medical and Health Sciences, Geosciences, Antarctic Research, Advanced Manufacturing Technology, and Space Science and Technology and its applications. The new programme of cooperation (POC) in S&T for 1998-2001 with Italy consists of joint research projects, exploratory missions, advanced training and expert assistance in the areas of Materials Science and Technology, Medicine and Health, Energy and Environment, Physics, Technology and Applications of Accelerated Particles, Technology for Monument Conservation and Restoration, and Agriculture. Under continued India-Japan Programme of Cooperation, Super Photon Ring Facility (Spring 8) of Japan has extended facilities to Indian Research Groups for conducting fundamental studies in Materials, Protein Crystallography and other Particle Physics experiments.

The Integrated Long Term Programme of cooperation in S&T (ILTP) - a widespread and well-knit S&T cooperation programme between India and Russia, approved 93 projects for implementation and announced several new initiatives, which include the creation of an Indo-Russian Technology Clearing House, aimed at facilitation of transfer of technology to industries. A joint meeting to discuss new India-EU S&T initiatives was held in Brussels. Discussions were held on the S&T areas of common interests and content of the possible India-EU S&T Agreement as well as continued participation of India in Fifth EU Framework Programme 1998-2000 related to EU's participation with developing countries.

METEOROLOGICAL SERVICES

The India Meteorological Department (IMD) was established *in 1875*. It is the National Meteorological Service and the principal government agency in all matters relating to meteorology, seismology and allied subjects. The Department has units all over the country engaged in collecting meteorological and seismological data besides providing various meteorological services. Its main objective is to provide meteorological information for weather sensitive activities like aviation, shipping, agriculture, irrigation, off-shore oil exploration and industries. The Department also issues warnings against severe weather phenomena like cyclones, dust-storms, heavy rains, cold and heat waves that cause destruction of life and property. Besides, it also provides climatological information, records earthquakes and promotes research in meteorology. The Department maintains an extensive network of modern observatories and communication links all over the country. Observations received through high power radars and weather satellites are extensively used these days for analysis and prediction of weather.

INSAT Meteorological Data Processing System is being upgraded to handle reception, processing of data from INSAT 2E Satellite. This satellite is similar to INSAT 2B but has got additional capability of providing imagery in water-vapour band and higher resolution imagery in visible, near IR and short wave IR bands, using charge coupled devices. Current satellites

provide imagery in Visible and IR bands only.

National Seismological Database Centre (NSDC) has been established at IMD, New Delhi for collection, analysis and archival of earthquake data. Under modernisation of seismological observatories in peninsular region, 10 seismological observatories are being upgraded by installing Digital Broad Band Seismograph Systems.

India Meteorological department continues to participate in multi-disciplinary scientific cruises of Ocean Research Vessel in the Arabian Sea, Bay of Bengal and Indian Ocean, etc. during pre-monsoon, monsoon, and post-monsoon periods. These cruises are planned to collect meteorological data over the adjoining sea areas for the study of various aspects of monsoon circulation and other important weather systems affecting the country and also to validate satellite data of meteorological parameters on board the Indian Remote Sensing Satellite (IRS P3) as and when required. A faster humidity sensor for use in Radiosonde, namely Carbon Hygrister was developed indigenously in IMD. It has been field tested and introduced operationally at one upper air station with a plan to use it in the whole network.

The first operational Long Range Forecast of seasonal monsoon rainfall (June-September) of India was issued by IMD in 1986. The operational forecasts are since then issued every year using 16 parameter Power Regression and Parametric Model, Dynamic Stochastic Transfer (DST) and Multiple Regression Model.

The Crop Yield Formulation Unit of the Department has developed statistical models using corelation and regression techniques to forecast crop yield on operational basis for 26 sub-divisional growing *Kharif* rice and for 16 sub-divisions growing wheat. Based on these models, pre-harvest monthly crop yield forecast for *Kharif* rice are bring prepared for every year from August to December and for wheat from January to May.

IMD has also installed 250 Cyclone Warning Dissemination Systems (CWDS). This is unique in the world and helps in direct broadcast of Cyclone warning to the public in general and coastal authorities in particular. IMD publishes its quarterly journal *MAUSAM*, annual publications of Indian Astronomical, Ephemeris, *Rashtiya Panchang* in 13 languages and Sunrise, Sunset, Moonrise and Moonset tables are brought out by the Positional Astronomy Centre, Calcutta.

National Centre for Medium Range Weather Forecasting (NCMRWF) has the primary objective of development and operationalisation of medium range weather forecasts (3-10 days in advance) and provide agrometeorological advisory service to minimise the adverse impact on agriculture. Agromet advisory service network has been strengthened from 73 units to 80 units out of which 27 units are at State Agricultural Universities, one at IARI, New Delhi and 52 at National Agricultural Research Project (NARP) Centres. Location specific weather forecasts are provided by NCMRWF to 67 units once a week and 34 units twice a week for formulation of agromet advisory

bulletins. A satellite based wide area network (WAN) using Very Small Aperture Terminals (VSATs) is being established for speedy dissemination of forecast products to various user agencies, particularly to AAS units. The plan is being implemented by installing VSATs in 127 locations out of which 47 have been installed. NCMRWF is actively associated with the planning and execution of activities pertaining to several national and international scientific campaigns such as GAME-India (Global Energy Water Cycle Asian Monsoon Experiment), I-STEP (Indian Solar Terrestrial Energy Programme), OCEANSAT (IRS P4), Indo-US Agreement on Satellite Data Utilisation, and INDOEX, etc.

Crop Simulation Models, CERES-Wheat was calibrated at eight locations from wheat growing regions of India for different cultivators, CERES-Rice at Hyderabad and Coimbatore and CROGPRO-Soybean for *cv Gaurav* (JS7244) in Madhya Pradesh. The calibrated crop models of CERES-Rice, CERES-Wheat, and CROGPRO-Soybean alongwith database from AAS Units and analysis software were integrated into Decision Support System for Agro-Technology Transfer (DSSAT) and were transferred to the concerned field units for use in preparation of Agro-Meteorological Advisories.

SURVEY OF INDIA

Survey of India (SOI), a national survey and mapping organisation under the Ministry of Science & Technology fulfils the evergrowing demand of vast variety of maps of the country. The primary responsibility of SOI is to maintain topographical coverage on 1:250 K, 1:50K and 1:25 K scales. The topographical surveys on 1:250 K and 1:50 K scales covering the entire country have been completed. Surveys on 1:25 K scale are being taken up as national requirements in the light of priorities indicated by the Central/ State governments and other user agencies. In addition to topographical mapping, SOI is also charged with the responsibilities of other related activities, such as R&D programmes in the field of geodesy, geophysical studies, seismiscity, glaciology, indigenisation of instruments/equipments, etc. SOI has started creation of Digital Cartographic Data Base of topographical maps on 1:25 K, 1:50 K and 1:250 K scales. The digital data is being used by various agencies for planning and GIS applications. It also undertakes large scale surveys for various developmental projects including hydro-electric, irrigation, command area, canal area, cantt. area schemes.

The Department is responsible to fix the external boundary of India, their depiction on maps published in the country and also advise on the demarcation of inter-State boundaries. Coastal mapping has also been undertaken in a phased manner to study the effect of submergence due to rise in sea-level and other natural phenomenon. Surveys on portion Nellore to Bangladesh border has been completed.

Survey of India also provides support to neighbouring countries in the field of survey education, transfer of technology and various other surveying technologies under bilateral programmes. Under Indo-Bhutan

Survey Collaboration project, experts in the field of geodesy, cartography, digital cartography, computer application, printing, etc., have been deputed to Bhutan for acceptability tests of various machines/equipment including training to the officers of Survey of Bhutan.

A Geomatics Centre has been planned at Delhi to meet the requirement of geomatics, *viz.*, regional and urban planning, resource management, infrastructure development, environmental monitoring, agriculture, irrigation, soil conservation, forestry, railways, airways, inland water transport, mineral resources, etc.

In the recent years Survey of India has been involved in various inter-disciplinary scientific projects like Sea-Level, Modelling and Monitoring (SELMAM) project of Department of Ocean Development (DOD), modernisation of cadastral surveys, glaciology programme of DST, etc.

Survey of India has been participating in Indian Scientific expeditions to Antarctica and has strong international linkages especially with International Cartographic Association (ICA), International Society of Photogrammetry and Remote Sensing (ISPRS), South Asian Association for Regional Cooperation (SAARC), International Association of Geodesy (IAG),etc. A map awareness drive has been launched by Survey of India to bring attractive maps in convenient folded size and reasonably priced on various themes, *viz*,. Antique Map Services, Discover India Series, State Map Series, District Planning Map Series, Tourist Map Series, Trekking Map Series, etc. A Survey Training Institute established under UNDP assistance is a premier institution for training in various disciplines of surveying to the trainees sponsored by the department, other State/Central government organisations and neighbouring countries.

NATIONAL ATLAS AND THEMATIC MAPPING ORGANISATION

While Survey of India meets the national needs in cartography, some specialised thematic maps required to meet the needs of the specific users are taken care of by the National Atlas and Thematic Mapping Organisation (NATMO), operating under the Department. It also concentrates its attention in a number of areas to integrate resource maps with other relevant socio-economic data and represent them in spatial froms, useful for developmental planning. NATMO is trying to develop the new technology of reverse printing for NATMO maps on experimental basis. It is also trying to introduce the technique of using metallic colours in map printing. These facilities are also being modernised.

AUTONOMOUS SCIENTIFIC INSTITUTIONS

Department of Science and Technology provides grants-in-aid to the following 13 autonomous scientific research institutions engaged in frontier areas of research in basic and applied sciences: (i) Bose Institute, Calcutta is devoted to fundamental and applied research in physical and life sciences; (ii) Agharkar Research Institute, Pune-research in basic and applied aspects in the fields of biological sciences; (iii) Shri Chitra Tirunal Institute for Medical

Sciences and Technology, Thiruvananthapuram- developing biomedical engineering and technology; providing and demonstrating high standards of patient care in advanced medical specialities and developing post-graduate training programme of the highest quality in these fields; (iv) Indian Association for the Cultivation of Sciences, Calcutta - studies on solid state physics, material sciences, theoretical physics, spectroscopy, energy research, chemistry including biological chemistry, polymer science, etc.; (v) Indian Institute of Tropical Meteorology, Pune-functions as a national centre for basic and applied research in tropical meteorology; (vi) Indian Institute of Astrophysics, Bangalore-research in emerging as well as interdisciplinary areas of astrophysics and heavenly bodies, and development of instruments used in astrophysical studies; (vii) Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore- research in frontier areas of chemistry, physics of materials, computational fluid dynamics, geodynamics, condensed matter theory, animal behaviour, genetics, etc : (viii) Raman Research Institute, Bangalore-research in basic sciences such as astronomy, astrophysics, liquid crystals,etc; (ix) S.N. Bose National Centre for Basic Sciences, Calcutta-promoting advanced studies in selected branches of basic sciences; (x) Birbal Shahni Institute of Palaeobotany, Lucknow-research in the area of palaeobotany, its relevance in modern context, (xi) Indian Institute of Geomagnetism, Mumbai-observing and understanding some of physical processes taking place in the innermost crusts of the earth as well as phenomena occurring on the sun and in near earth and interplanetary space; (xii) Wadia Institute of Himalayan Geology, Dehra Dun-basic research in areas of biostratigraphy, petrology and geochemistry, sedimentology, tectonics and environmental geology to understand the geodynamics of the Himalayan region and (xiii) International Advanced Research Centre for Powder Metallurgy and New Materials, Hyderabad - the development of high perfromance materials, and processes.

DST also extends financial and administrative support to the following academies and professional bodies which are engaged in the promotion of S and T in the country through the involvement of scientists and engineers; (i) Indian Academy of Sciences, Bangalore; (ii) Indian National Science Academy, New Delhi, (iii) Indian National Academy of Engineering, New Delhi; (iv) National Academy of Sciences, Allahabad and (v) Indian Science Congress Association, Calcutta.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

The Departmentt of Scientific and Industrial Research (DSIR), a department under the Ministry of Science and Technology comprises of the activities of the Council of Scientific and Industrial Research (CSIR), four departmental schemes, *viz.*, Research and Development by Industry (RDI), Programme Aimed at Technological Self-Reliance (PATSER), Scheme to Enhance the Efficacy of Transfer of Technology (SEETOT) and National Information System for Science and Technology (NISSAT) and two public enterprises, *viz.*, National Research Development Corporation (NRDC) and Central Electronics Limited (CEL).

Scientific and Technological Developments

RESEARCH AND DEVELOPMENT BY INDUSTRY

A strong S and T infrastructure has been established in the country. This covers a chain of national laboratories, specialised centres, various R&D and academic institutions and training centres. A scheme for granting recognition to in-house R&D units in industry is operated by the Department of Scientific and Industrial Research. The incentives and support measures presently available to recognised in-house R&D units include : Income Tax relief on R&D expenditure; Weighted Tax Deduction for sponsored research; Customs Duty Exemption on goods imported for use in government funded R&D projects; Excise Duty Waiver for three years on goods produced based on indigenously developed technologies and duly patented in any of the countries in European Union, USA or Japan; Accelerated Depreciation Allowance on plant and machinery set up based on indigenous technology; Exemption from Price Control for bulk drugs produced based on indigenous technology; Financial support in-house R&D Centres. There were 1,256 units having valid recognition as on 31 December 1996. During the year, 54 in-house R&D centres were accorded fresh recognition and 308 centres were accorded renewal of recognition. During 1996-97, 11 publications were brought out; Tenth National Conference on In-house R&D in Industry was organised. DSIR National Awards were presented to seven industrial units, besides 13 certificates involving Rs 9,694 lakh as cost of plant and machinery set up based on indigenous technology were issued. The Government has also introduced a provision of weighted tax deducation at 125 per cent for sponsored research programmes.

PROGRAMME AIMED AT TECHNOLOGICAL SELF-RELIANCE

The major activity of the scheme on a selective basis partial financial support to Research, Development, Design and Engineering (RDDE) projects in the areas of : (a) development and demonstration of new or improved product and process technologies including those for specialised capital goods, for both domestic and export markets; and (b) absorption and upgradation of imported technology. Under the PATSER programmes, the Department of Scientific and Industrial Research has provided partial financial support to about 80 industrial units.

SCHEME TO ENHANCE THE EFFICACY OF TRANSFER OF TECHNOLOGY

The Scheme to Enhance the Efficacy of Transfer of Technology (SEETOT) covers National Register of Foreign Collaborations (NRFC); Transfer and Trading in Technology (TATT); and Promotion and Support to Consultancy Services (PSCS).

The objectives of NRFC scheme is to gainfully facilitate acquisition of technology needed in the country. Major activities include: compilation and analysis of data on approved foreign collaborations; undertaking financial, economic and legal analysis of set of data on foreign collaborations; carrying out technology status studies covering state-of-the-art technology in use in the country, international trends and other related issues; providing assistance in the effective transfer of technology process. During 1996-97,

under NRFC, a compilation of primary data on foreign collaborations approved during 1995 was brought out and reports on technology status of various sectors/products were printed.

The TATT scheme aims to promote and support activities towards export of technologies, projects and services. The measures adopted include: support to preparation of technology profiles of developing countries; support to preparation of reports related to technology export capabiliteis and experience in select industrial sectors; publicity and dissemination of Indian capabilities through workshops, trade fairs, delegations and video films; and supporting demonstrations of technologies identified for export.

The scheme relating to Promotion and Support to Consultancy Services (PSCS) essentially aims to strengthen consultancy capabilities for domestic and export markets. The activities have been mainly towards completing the on-going studies towards documenting consultancy needs and capabilities in important industrial sectors and at state levels, and providing institutional and programme support to Consultancy Development Centre (CDC).

CDC was promoted in January 1986 as a non-profit society, with a view to implement some of the programmes of DSIR and also promote and strengthen the consultancy capabilities in the country. It is not to undertake any commercial activity itself but, at the same time, earn revenues to the extent possible, through specialised programmes and activities. The centre is implementing programmes such as Consultancy Development Promotion Assistance (CDPA) scheme, computerised database for consultants, training and human resources development for consultancy and programmes sponsored by other agenices. DSIR is providing recurring and non-recurring support to CDC.

NATIONAL INFORMATION SYSTEM FOR SCIENCE AND TECHNOLOGY

The National Information System for Science and Technology (NISSAT) programme envisages promotion and support to the development of a compatibale set of information systems on science and technology and interlinking these into a network. The approach adopted is to bring the existing centres, systems and services to a higher level of operation so that the interests of the national community of information users could be better served. For the purpose, the programme also contemplates experimentation with and introduction of modern information handling tools and techniques and the development of indigenous capabilities. NISSAT programme continued support to 12 information centres and nine centres to access international database services. Six metropolitan library networks in Calcutta, New Delhi, Mumbai, Pune, Ahmadabad and Mysore continued their services.

NATIONAL RESEARCH DEVELOPMENT CORPORATION

National Research Development Corporation (NRDC) is the principal organisation established for transferring technologies from R&D laboratories to industry. Its operation cover the entire spectrum of industrial technologies

ranging from chemicals to metallurgy, mechanical engineering, electrical engineering, electronics, biotechnology, etc. Some of the major technologies licensed by NRDC during 1995-96 include Invert Sugar, Glycol based Hydraulic Fluid 'PEGCOL 89', Zeolite a Powder Detergent grade, Resorcinol and BOD Biosensor. The ongoing projects include : Glucose Biosensors, Carbon Fibre for Braiding Applications, Single Piece Intra Ocular Lenses and Sand Lime Bricks. The Corporation has successfully completed export projects related to Science and Technology entrepreneurship Parks (STEPS) in Egypt and projects for industrial park in Gabon.

CENTRAL ELECTRONICS LIMITED

Central Electronics Limited (CEL) has been the pioneer in the country in the areas of solar photovoltaics, ferrities and piezo-ceramics. Today, it enjoys the international status among the top producers of single crystalline silicon solar cells in the world. CEL holds a unique position among the family of public sector enterprises in electronics. Its activities are sharply focussed in three thrust areas : (i) solar photovoltaic cells, modules and systems for a variety of applications; (ii) selected electronics systems - equipment for railway signalling and safety, cathodics protection equipment for oil pipelines, switching systems and VSATs, (iii) selected electronic components-professional (soft) ferrites, electronic ceramics, piezo electric elements and microwave components.

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Council of Scientific and Industrial Research (CSIR) was constituted as an autonomous society in 1942. It has an all-encompassing charter which includes promotion, guidance and coordination of scientific and industrial research, funding of laboratories and exploitation of research results for industrial development . It is also charged with rendering assistance to extra mural research. CSIR has over the years established network of 40 laboratories and 80 field / extension centres spread all over the country. The laboratories conduct R&D in a wide range of fields-from micro electronics to metallurgy, medicinal plants to industrial machinery, chemicals to molecular biology, besides commodities like glass, ceramics and leather. Areas of particular strength in CSIR which have won global recognition for excellence are : aerospace engineering, drugs and pharmaceuticals, bio-science and bio-technology, chemicals (catalysts and polymers), petroleum (refining and petrochemicals), materials (composites), leather (processing, chemicals and product design), geophysics and radiophysics. CSIR is today among the largest chains of public funded industrial reseach laboratories in the world.

The CSIR family is 22,000 strong, including 5,300 scientists, 60 per cent of whom hold Ph.D. or M.Tech degrees. The annual budget of CSIR is around Rs 800 crore with the Government providing 75 per cent of it as grant and CSIR generating the rest from contract R&D licensing of its technologies, provision of technical services and consultancy. CSIR has made a commercial beginning in the global knowledge-place and earns around US$ 3 million through contract R&D. The estimated industrial production

based on CSIR knowhow in 1997-98 was Rs 4,000 crore. Over the years, CSIR has developed nearly 4,000 technologies, 80 per cent of which are eminently suitable for adoption by small scale industry. CSIR filed around 260 patent applications in India, the largest number by any single organisation. CSIR spearheads the intellectual property movement in the country and has shown the way with its famous opposition of the US patent on turmeric (*Haldi*). CSIR has awarded about 50,000 research fellowships / associateships and supported about 10,000 bright young highly qualified scientists. About 450 outstanding superannuated scientists have been provided financial assistance to make use of their talent and experience for the advancement of science.

CSIR is a world class source of technology and technology services for the Indian industry. The range of technological services and support includes resource surveys, problem diagnostics, testing, calibration and certification and manpower training. CSIR has contributed significantly to the dissemination of scientific research results and spread of scientific temper and a culture of creativity in the country. Two separate institutes are devoted to science publication and communication - National Institute of cience Communication (NISCOM) and Indian National Scientific Documentation Centre (NSDOC) both at New Delhi.

ACHIEVEMENTS

Some of the outstanding CSIR products, that closely influence the people's life in India, are the first ever all indigenous low horse power (20 hp) *Swaraj* tractor and Amul Baby Food based on buffalo milk laying the foundation for indigenous baby food industry; the *Saheli* contraceptive pills and the recent Memory Plus. In between there is a whole range of technical, industrial products well known to industry and entrepreneurs. Two recent high-tech products worth mentioning are : (a) the all composite, indigenous, two-seater trainer aircraft *Hansa* made history when its flight figured among the trinity of technologial feats on 11 May 1998; and (b) the parallel super computer Flosolver MK3, developed by National Aerospace Laboratories, Bangalore in the league of the very best in the world which can be used for supercomputing needs in such diverse disciplines as monsoon dynamics, structural mechanics, image processing and cryptography.

CSIR has played a crucial role in the transformation of several industrial and other sectors in India like : (1) Chemical industry : CSIR has made globale breakthroughs in some areas while in some other areas it has enabled India to break the MNC monopoly / oligopoly. (a) Agrochemicals: About one-fourth of the technical grade pesticide production in India is based on CSIR technology. CSIR has developed target specific pesticides, controlled release formulations and biological methods of pest control for cotton and sweet potato, as also *neem* based insect antifeedant; (b) Petroleum and petrochemicals : CSIR's wide ranging important contributions include technologies for aromatics (BTX) extraction; food grade hexane; adipic acid (single step process); visbreaking of petroleum residues; zeolite catalysts (xylofining, hydrodewaxing); Pt-Re reforming catalyst); the industrial

production from CSIR technologies in this sector is around Rs 1,500 crore annually; (c) Industrial catalysts: CSIR has provided the industry knowhow for several known and a few new calaysts; (2) Drugs and Pharmaceuticals Industry: CSIR has contributed novel process routes for atleast 30 generic drugs. India has to its credit development of 13 new drugs since Independence, 10 of these have come from CSIR; (3) Leather Industry: CSIR has provided the industry with world class environmental friendly technologies for the entire range of technical activities from curing, dehairing, tanning and finishing to process automation and modernisation of tannery operations and product design including special leathers. With a view to enhancing the quality and quantum of production CSIR has mounted a Technology Mission for the sustainable development of the leather industry; (4) Coal Industry: CSIR's pioneering work on coal enabled preparation of flow-sheets and specifications for all the washeries that have been set up in the country since 1958; (5) Rural Industries: CSIR has promoted and provided technologies suited to local resource endowments for: low cost housing, semi-mechanised brick making; construction of rural roads; sanitation; drinking water; fire resistant thatched roofs; grain and water storage bins; iodine detection kits, cultivation of medicinal and aromatic plants and extraction of essential oils; (6) Advancement of Knowledge: CSIR has made notable contributions to basic science in several areas. For example (a) Precocious flowering of bamboo, developed by National Chemical Laboratory, Pune, drastically cutting down the natural flowering period of 15 years to a few weeks; (b) Pioneering surveys for and grabbing polymetallic sea nodules in the Indian Ocean bed which conferred on India the first Pioneer Investor status country in the world under the UN Law of the Sea; (c) Cholera: Studies at the genetic level, have led to the development of two candidate vaccines undergoing trial. In a different approach, the combined genetic and physical map of the whole V. cholerae genome has been constructed and reported for the first time in the world; (d) *Kala azar*: Understanding basic biology of the parasite, and developing diagnosis and treatment of visceral leishmania; (e) Cataract: Understanding the modifications that occur in the crystalline proteins constituting the human eye lens during ageing; (f) Salt sensitive expression vector to clone and express six divergent genes; (g) Pioneering studies on near space environment ionospheric chemistry, stratosphere-mesosphere coupling and (h) Foundation technology to build on black cotton soil, which opened up hitherto difficult areas of such soil (*e.g.* in Gujarat and Maharashtra) to construction activities. (7) Resource Exploration : CSIR has helped locate new / additional natural resources e.g. coal; delineation of structures for hydrocarbons, gas hydrates, new deposits of gold, diamonds and minerals; polymetalic sea nodules rich in manganese and copper; sources of ground water, etc. (8) Environment and Ecology: Through its NEERI, Nagpur CSIR has been at the forefront for environmental systems design and modelling, environmental monitoring and environmental biotechnology. Two most recent technologies developed by CSIR have made sterling contributions to reducing the level of pollution in the vicinity of the Taj Mahal

viz., (a) cokeless cupola using gaseous fuel to reduce pollution from Agra foundries; and (b) chemo-biochemical desulphurisation of tail gases of Mathura Refinery.

ATOMIC ENERGY

Over fifty years ago, with the enactment of the Atomic Energy Bill in 1948, India had planned to harness the atomic energy for national development. The Atomic Energy Commission was established on 10 August 1948 with Dr Homi J. Bhabha as its first chairman. The commission was entrusted with the formulation and implementation of the policy of the Government in all matters concerning atomic energy. Subsequently in 1956, the Department of Atomic Energy (DAE) was established. Following is the mandate of the Department : i) Generation of safe, economically competitive electricity from nuclear energy by exploiting the natural resources of uranium and thorium available in the country; ii) Building of research reactors and utilisation of radioisotopes produced in them for applications in medicine, agriculture and industry; iii) Development of advanced technology in areas such as accelerators, lasers, biotechnology, information technology and materials including development of non-nuclear and strategic materials like titanium; iv) Encouraging technology transfers and interaction with industry in areas of its strength, contributing to the industrial development; v) Providing support to basic research in nuclear energy and related frontier areas of science, and interaction with universities and academic institutions to improve the quality of education and research, and providing research grants to them; vi) Encouraging international cooperation in advanced areas of research and in mega science projects to realise the benefits of state-of-the-art science and technologies, and vii) Contributing to national security.

Today DAE has under its aegis five Research Centres *viz*., the Bhabha Atomic Research Centre (BARC)- Mumbai, Indira Gandhi Centre for Atomic Research (IGCAR)-Kalpakkam (Tamil Nadu), Centre for Advanced Technology (CAT)- Indore (Madhya Pradesh), Variable Energy Cyclotron Centre (VECC)-Calcutta, and Atomic Minerals Directorate for Exploration and Research (AMD)- Hyderabad; three Industrial Organisations viz. Heavy Water Board (HWB)-Mumbai, Nuclear Fuel Complex (NFC)- Hyderabad and Board of Radiation and Isotope Technology (BRIT)-Mumbai; four Public Sector Undertakings *viz.* Nuclear Power Corporation of India Limited (NPCIL)-Mumbai, Uranium Corporation of India Limited (UCIL)-Jaduguda (Bihar), Indian Rare Earth Limited (IRE)-Mumbai, and Electronics Corporation of India Limited (ECIL)-Hyderabad, and four service organisations, viz, Directorate of Purchase and Stores (DPS)-Mumbai, Construction, Services and Estate Management Group (CS&EMG)-Mumbai, General Services Organisation (GSO)-Kalpakkam (Tamil Nadu) and Atomic Energy Education Society (AEES)-Mumbai.

DAE also financially supports seven autonomous Research Institutes, *viz*, Tata Institute of Fundamental Research (TIFR)- Mumbai, Tata Memorial Centre (TMC)-Mumbai, Saha Institute of Nuclear Physics (SINP)-Calcutta,

Institute of Physics (IOP)- Bhubaneswar, Mehta Research Institute of Mathematics and Mathematical Physics (MRI)-Allahabad, Institute of Mathematical Sciences (IMSc)-Chennai, and the Institute for Plasma Research (IPR)-Ahmedabad. AEES also gets financial support from DAE. DAE, through the Board of Research in Nuclear Sciences (BRNS) and the National Board for Higher Mathematics (NBHM) promotes research in nuclear and allied fields, and mathematics respectively.

NUCLEAR POWER PROGRAMME

The importance of nuclear energy to meet the long term energy needs of the country was recognised quite early in 1954, when Dr Homi J. Bhabha drafted the three-stage Nuclear Power Programme which aimed at using natural resources of uranium and thorium. This programme involves building pressurized heavy water reactors (PHWRs) in the first stage using natural uranium as fuel for producing electricity and plutonium fuel; fast breeder reactors (FBRs) in the second stage, using plutonium as fuel, thorium as blanket, and producing electricity, more plutonium and another nuclear fuel uranium-233; and thorium based reactors in the third stage. Considering the modest resources of natural uranium and the then industrial infrastructure in the country, India had selected pressurised heavy water reactors (PHWRs) for the first stage.

To attain technical capability in managing nuclear power plants indigenously, it was decided to set up at Tarapur (Maharashtra) two boiling water reactors (BWRs) on turnkey basis with foreign technology. In 1969 India figured on the nuclear power map of the world with the Tarapur Atomic Power Station (TAPS) becoming operational. TAPS was a turnkey project set up in India by the General Electric Co. of USA. Subsequently, two PHWRs were built at Rawatbhata (Rajasthan), with the Canadian collaboration. These reactors, which commenced commercial production in 1972 and 1980, were followed by two more PHWRs at Kalpakkam near Chennai (Tamil Nadu). These reactors at Kalpakkam, which started commercial operation in 1984 and 1986, were designed, built and operated with indigenous expertise. This established Indian capability in design, construction, and operation of nuclear power plants.

To accelerate the first stage of nuclear power programme, the erstwhile Nuclear Power Board was incorporated as Nuclear Power Corporation of India Limited. (NPCIL) in the year 1987. Having attained comprehensive capacity in the design, construction and operation of pressurised heavy water reactors, efforts were made to standardise the 220 megawatt(e) PHWR. Based on improved standardised design of PHWR, two reactors of 220 megawatt(e) capacity each, were set up at Narora (Uttar Pradesh) and were successfully commissioned in 1989 and 1991. Two more atomic power reactors, each of 220 megawatt(e) capacity, were built and commissioned at Kakrapar (Gujarat), in 1992 and 1995. With this success, NPCIL's capability in the technology of pressurised heavy water reactors has reached commercial maturity. The country has now an installed power capacity of 1840 megawatt(e).

Scientific and Technological Developments

Average capacity factor of our plants which was 60 per cent in 1995-96, has increased to 75 per cent in 1998-99. Nuclear power plants have so far produced more than 130 billion units. About 150 reactor-years of operational experience have been accumulated free of any incident involving release of radioactivity to the environment.

To achieve high capacity factors, repair technologies were developed, which is a challenging area. Examples of successes achieved are: RAPS-1 south end-shield repair; MAPS-1 & 2 Calandria inlet manifold management; repair of over-pressure relief device of RAPS-1; rehabilitation of an adjuster assembly at RAPS-2; RAPS-1 and MAPS steam generator hair-pin removal: single pressure tube removal in NAPS-2, en-masse removal and replacement of coolant channels at RAPS-2, development of a system called BARCIS to carry out in-service inspection of coolant channels; development of a system to relocate garter springs in coolant channels which have been displaced from their positions and so on. To carry out large scale replacement of pressure tubes in NAPS type PHWRs, a semi-automatic, remotely operated Coolant Channel Replacement Machine (CCRM) consisting of a large number of subsystems, tools and components has been developed. A number of new technologies, such as servo-manipulators, image processing based alignment system; and rolled joint detachment using RF induction heating were developed and have been incorporated in the system.

All the operating PHWRs are of 220 megawatt(e) and construction work on the first two units of 500 megawatt(e) commenced in 1998. In parallel to the indigenous self-reliant three-stage programme, import of light water reactor technology is on the arrival. Such imports have to conform to the latest safety standards and should be economically attractive. The recent deal with the Russian Federation for setting up two 1,000 megawatt(e) units at Kudankulam is a step in this direction. It is planned to have an installed nuclear capacity of 20,000 megawatt by 2020 and it is envisaged that out of this 7,000 megawatt will be based on LWR technology. So far we have tied up only 2,000 megawatt and are looking for appropriate technical and financial proposals for the remaining 5,000 megawatt. As a long-term strategy, we will like to indigenise LWR technology.

The second stage of the Indian Nuclear Power Programme will be using fast breeder reactors (FBRs) for electricity generation. For the development of fast breeders and associated technologies, the Indira Gandhi Centre for Atomic Research was set up in 1971. The Centre has established a comprehensive R&D infrastructure over the entire range of FBR technology spanning reactor engineering, metallurgy and materials, chemistry of fuels and materials, fuel reprocessing and reactor safety studies, control and instrumentation, computer applications, etc., and has developed a strong base in a wide variety of disciplines related to this advanced technology. IGCAR has successfully built a 40 megawatt(th) Fast Breeder Test Reactor (FBTR) which uses indigenously developed mixed uranium-plutonium carbide fuel core. FBTR was synchronised to the southern grid in July 1997.

FBTR has been operated at power levels upto 11.5 megawatt(th) and

generated electricity. Also, a maximum burnup of more than 45,000 MWd/t for indigenously developed fuel has been achieved. The post-irradiation examination of fuel discharged after 25,000 megawatt(th) has indicated satisfactory performance of this fuel. Based on the experience in the design, construction, commissioning and operation of FBTR the Department has undertaken the development of a 500 megawatt(e) Prototype Fast Breeder Reactor (PFBR) at Kalpakkam. The technology development for all major components for this reactor is in an advanced stage and the construction is expected to start in the next few years.

Utilisation of thorium for power generation, forms the third stage of the Indian nuclear power programme. Utilisation of thorium in the research reactors and power reactors for the production of uranium-233, a nuclear fuel, has been established along with the facilities for its separation from irradiated thorium. The neutron source reactor KAMINI which uses uranium-233 obtained from irradiated thorium, has already attained full power level of 30 kilowatt(th). It will be used for a variety of applications including neutron radiography, neutron activation analysis and others. The reactor has been set up by BARC at Kalpakkam. This success is the beginning of the endeavour leading to the third stage of Indian Nuclear Power Programme. Thorium fuel bundles also have been successfully used in the Kakrapar Atomic Power Station for flux flattening. Work is progressing on the design of an Advanced Heavy Water Reactor (AHWR) which will be another step forward.

NUCLEAR FUEL CYCLE

DAE has attained self-reliance over whole of the Nuclear Fuel Cycle and associated technologies which cover activities supporting the nuclear power programme ranging from prospecting, mineral exploration, mining, heavy water production and fuel fabrication, to fuel reprocessing and waste management. The Department has established capability to design, construct, and operate plants for heavy water production, fuel fabrication, fuel reprocessing and nuclear waste immobilisation. These facilities have been operating satisfactorily with good record of safety.

MINERALS EXPLORATION AND MINING

For over 50 years, the Atomic Minerals Division, now renamed as the Atomic Minerals Directorate for Exploration and Research (AMD), has been engaged in carrying out surveys, prospecting and exploration of atomic minerals, for the Indian Nuclear Power Programme.

AMD has established reserves of 92,000 tonnes of uranium oxide. Efforts of AMD have led to the opening of uranium mines at Jaduguda, Bhatin and Narwapahar in Bihar, which are operated by the Uranium Corporation of India Limited (UCIL), a public sector undertaking of DAE. The Directorate has also located sizeable uranium deposits at Damiasiat in Meghalaya; Lambapur-Yellapur, and Tumnalapalle in Andhra Pradesh; Turarmdih, Bagjata, Kanyaluka and Mohuldih in Bihar, and Bodal and Jajawal in Madhya Pradesh. Favourable indications of uranium

mineralization have been obtained by subsurface exploration at Gogi in Karnataka, and Wahkyn in Meghalaya. Reserves of other major minerals identified are : Monazite 6.55 million tonnes (contains 5,90,000 tonnes of ThO_2); zircon 18 million tonnes: Ilmenite 278 million tonnes; beach sand placers along the coastal tracts of India, and in the inland placers in Bihar, West Bengal and Tamil Nadu. Sizeable mineral resources of Niobium and Tantalum, Rare Earth Elements, Yttrium and Beryllium have also been discovered.

UCIL had started operations with only one underground mine and a processing mill at Jaduguda, Bihar. It opened two more mines at Bhatin and Narwapahar. For future uranium requirements, a mine at Domiasiat will also be opened. UCIL also runs two recovery plants at Rakha and Mosaboni to recover uranium from copper tailings, and a By-product Recovery Plant at Jaduguda to recover magnetite. All these units are situated in the Singhbhum (East) district of Bihar.

The Indian Rare Earths Limited (IRE), another public sector undertaking of DAE, has been engaged, since 1950, in mining and processing of mineral sands containing titanium, zirconium, thorium and rare earths. The company has three mineral sands separation plants at Manavalakurichi (Tamil Nadu), Chavara (Kerala) and OSCOM-Chhatrapur (Orissa) which produce six industrial minerals, namely ilmenite, rutile, monazite, zircon, sillimanite and garnet. Activities of IRE units also include value addition to minerals such as ilmenite, zircon, and monazite. At OSCOM, a synthetic rutile plant is operated to convert Orissa ilmenite to synthetic rutile analysing about 92 per cent titanium oxide. At Chavara, the mineral zircon is ground to zirflor (zircon flour) and microzir for its application in the ceramic industry. At Manavalakurichi zircon is chemically treated to zircon frit which is supplied to NFC for further chemical and metallurgical processing to zircaloy components. At Rare Earths Division (RED), Alwaye, monazite is chemically processed for the separation of thorium concentrate and Rare Earths in the form of mixed and individual compounds. Part of the thorium concentrate of RED is subsequently treated at Thorium Plant of OSCOM to yield mantle grade thorium nitrate. RED has recently set up PRYNCE Plant at Alwaye for the production of very pure neodymium oxide.

The company earns foreign exchange of the order of Rs 75 crore per annum. The company's products are exported to advanced markets like USA, Norway, Germany, Japan and S. Korea.

HEAVY WATER PRODUCTION

Eight heavy water plants are installed in the country to meet the heavy water requirements of the Indian nuclear power and research reactors. The Heavy Water Board (HWB) manages the operation and maintenance of seven of these plants namely the Heavy Water Plant (Manuguru)-Andhra Pradesh, Heavy Water Plant (Kota)-Rajasthan, Heavy Water Plants (Hazira and Baroda)-Gujarat, Heavy Water Plant (Thal)-Maharashtra and Heavy Water Plant (Tuticorin)-Tamil Nadu. The first heavy water plant at Nangal (Punjab)

is run and owned by the National Fertilizer Limited, Nangal. Operation of the Heavy Water Plant (Talcher)-Orissa was suspended in August 1994 due to unsatisfactory operation of the fertilizer plant of the Fertilizer Corporation of India Limited, Talcher. The plants at Manuguru and Kota, have shown good safety records. The Board has exported 100 metric tonnes of heavy water to South Korea.

For upgrading the used degraded heavy water from research reactors, a Heavy Water Reconcentration facility was set up at Trombay in 1962. Based on this experience, BARC has developed heavy water upgrading technology and at present 20 reconcentration towers are in operation at various sites.

NUCLEAR FUEL FABRICATION

The technology of conversion of yellow cake into the nuclear grade pure uranium and the fabrication of fuel elements was developed indigenously. On the basis of the development work carried out by BARC, the first fuel element was fabricated by mid-1959. The Fuel Fabrication Plant at Trombay, in addition to producing fuel elements for the Indian research reactors, was also used for research and development on new fuels and materials. Half of the initial core loading consisting of zircaloy clad uranium oxide fuel assemblies for RAPS-1 was fabricated at Trombay. Thus, four decades ago, India had attained the capability of producing nuclear fuel elements for power reactors. Also, all the thorium oxide pellets for FBTR were fabricated here.

With the successful demonstration of the fuel fabrication technology at Trombay, the Nuclear Fuel Complex (NFC) was set up at Hyderabad in 1971 for industrial scale manufacture of nuclear fuel assemblies for PHWRs and boiling water reactors (BWRs), and zircaloy structural materials. NFC has successfully built sophisticated machines for in-house use and components such as instrumentation tubes, to very rigid specifications which have saved substantial foreign exchange. The Complex is also geared towards the development of components needed for advanced reactors such as PFBR. During the year 1998-99, NFC recorded highest production of PHWR fuel bundles and reactor grade zirconium sponge. For the first time, seamless zircaloy square channels for TAPS and prototype blanket, control and safety rod assemblies for the development of 500 MWe PFBR and sub-assemblies for sodium void coefficient measurement for FBTR were fabricated. The new zircaloy fabrication plant was inaugurated and trial production on new uranium oxide fuel project commenced.

For fabrication of indigenous Mixed Oxide (MOX) fuel assemblies for TAPS, an Advanced Fuel Fabrication Facility (AFFF) was set up at Tarapur. Assemblies fabricated here were loaded in the TAPS reactors. Fabrication of MOX fuel on tonnage scale has been achieved. The Sol-gel process for the fabrication of uranium-plutonium mixed oxide microsphere has been developed at BARC. The fuel made of mixed uranium-plutonium carbide for FBTR, developed at Trombay, has performed well. The full carbide fuel core has been used in a fast reactor for the first time in the world. The

fabrication of uranium-233 for KAMINI research reactor at Kalpakkam is also an indigenous effort. This has taken the country to the threshold of the third stage of the Nuclear Power Programmae which will be based on thorium utilisation.

FUEL REPROCESSING AND WASTE MANAGEMENT

Fuel reprocessing and nuclear waste management constitute the back-end of the nuclear power programme. As a result of the research and development carried out at BARC, these technologies are now fully established in the country.

Plutonium, the fuel for the second stage reactors of the Indian nuclear power programme, is obtained from spent uranium fuel of PHWRs. Reprocessing of spent fuel was started with the commissioning of a 30 tonne per annum plant at Trombay in 1964. Based on the experience gained at Trombay, a fuel reprocessing plant PREFRE was set up at Tarapur. Another reprocessing plant KARP, of capacity 100 tonne per annum, with several novel features and concepts, was successfully commissioned at Kalpakkam in 1998. A plant for reprocessing of fast reactor fuel (FRFRP) is under construction at Kalpakkam. A Lead Mini Plant for reprocessing of FBTR fuel has reached an advanced stage of completion. Recovery of uranium-233 from irradiated thorium has been successfully completed at IGCAR. This uranium-233 was used for fabrication of fuel for KAMINI reactor. Also, an engineering scale facility for separation of uranium-233 from irradiated thorium is coming up at Trombay.

The waste treatment, conditioning and disposal systems have been operating at various nuclear installations. Vitrification of radioactive waste in glass matrix is a complex technology for immobilisation of nuclear wastes. This technology has been successfully developed by BARC. A Waste Immobilisation Plant (WIP) is operational at Tarapur and two such plants are under construction at Trombay and Kalpakkam.

R AND D IN NUCLEAR POWER

The programmes relating to Nuclear Power and the Nuclear Fuel Cycle have been built on the multi-disciplinary R and D infrastructure developed by the Department over the years. BARC, working in close collaboration with NPC, has been responsible for creating self-reliance in nuclear reactor technology. Extensive work carried out in the area of reactor technology has accelerated the process of indigenisation of equipment and components and has led to the development of a number of technologies for operation and maintenance of power reactors, which resulted in improved efficiency and safety. The technologies include development of advanced instrumentation and monitoring systems, in-service inspection system for coolant channels, remote inspection and viewing systems, vibration based diagnostic system, chemical decontamination system, technology of detritiation of heavy water for reduction in radiation exposure, and development of special repair equipment, gadgets and devices. A number of state-of-the-art instrumentation and control systems for reactors and heavy water plants have been developed

Scientific and Technological Developments

at BARC and IGCAR.

RESEARCH AND DEVELOPMENT PROGRAMMES

DAE's research centres are engaged in multidisciplinary research in frontier areas of basic sciences as well as the applications of nuclear energy in medicine, agriculture and industry. BARC and IGCAR also give R&D support to the nuclear power programme. Over four decades ago, the Atomic Energy Establishment, later named as the Bhabha Atomic Research Centre, was set up at Trombay. This is a premier nuclear research and development centre in the country. BARC's facilities include research reactors for research and radioisotope production, plants for manufacture of uranium metal and nuclear fuels, fuel reprocessing, waste immobilization and seismic stations. BARC is also engaged in basic research in materials, physical, chemical and biological sciences. The Radiation Medicine Centre - a unit of BARC at Mumbai, is the regional referral centre of the World Health Organisation. The 14 million volt Pelletron Accelerator set up at Mumbai by BARC in collaboration with TIFR, is a national research facility. BARC has also commissioned the national Centre for Compositional Characterisation of Materials (CCCM) at Hyderabad.

The Indira Gandhi Centre for Atomic Research (IGCAR) conducts a broad based multidisciplinary programme of research and advanced engineering, directed towards the development of sodium cooled Fast Breeder Reactor (FBR) technology. In addition, IGCAR also has a strong R&D programme in the areas of materials science and technology, NDT, structural mechanics, chemical sensors, superconductivity, etc.

The Centre for Advanced Technology (CAT) was established in 1987 to take up R&D programme in the areas of lasers, accelerators and related high technologies such as cryogenics, superconductivity, ultra- high vacuum, etc. CAT has made significant advances in all these areas and is internationally recognised for research in science and technology.

The Variable Energy Cyclotron (VEC) Centre at Calcutta is a national research facility. It delivers beams of nuclear particles for research and produces radioisotopes for various applications.

Research Reactors : The country's first research reactor *Apsara*, a 1MW swimming pool type reactor, was set up at BARC. The reactor has completed over four decades of successful operation. *Apsara* was followed by a 40 MW research reactor *CIRUS* in 1960. Since then a number of research reactors have been designed, built and operated by indigenous efforts including setting up a totally indigenous 100 MW, high neutron flux research reactor *Dhruva*. *CIRUS* and *Dhruva* have completed 38 and 13 years respectively, of their service to the national by giving valuable research inputs to the Indian power programme and producing wide range of radioisotopes for use in nuclear medicine, agriculture and industry. Today India is one of the largest producers of radioisotopes and one of the few countries which have developed a comprehensive infrastructure and know-how in radiation technology. Extensive infrastructure has been developed that has given

impetus to radioisotope production and applications. BARC, which has been producing radioisotopes for about four decades, is a major producer of radioisotopes for use in industry, medicine, agricultural and research. Efforts in radioisotope applications have significantly contributed to the societal benefits such as the production of high yielding varieties of several crop seeds, radiation sterilisation of medical products and other socially relevant areas including development of many new procedures and nuclear medicine techniques for diagnosis and treatment.

Nuclear Agriculture : In the field of agriculture, the services offered by the Department cover crop improvement programmes, fertilizer and pesticide related studies, food preservation by irradiation and water management. Efforts in nuclear agriculture have been directed towards the development of new agro products, improved plant growth and protection measures and techniques for the propagation of commercially valuable plants. BARC's mutation breeding programme for crop improvement has resulted in the evolution of high yielding varieties of pulses, oilseeds, rice and jute. The pigeonpea culture TT97-48, developed under the BARC's crop improvement programme, was promoted to advanced yield trial by the All India Coordinated Research Project on Pigeonpea.

Radioisotopes have helped in monitoring the persistence of pesticides in soil and ground water. Based on the irradiation technology developed at BARC, earlier in August 1994, irradiation of onions, potatoes and spices was accepted by the Government of India. The Government has also cleared preservation by irradiation of food items such as rice, wheat products, dried fruits, mango, ginger, garlic, shallots, meat, chicken and its products.

Construction of the demonstration irradiator for spices at Navi Mumbai is reaching completion, and the construction on commercial demonstration irradiator for the treatment of onions at Lasalgaon (Maharashtra) is progressing.

Desalination of Water: BARC has successfully developed technologies of Multi-stage Flash and Reverse Osmosis (MSF-RO) for desalination of water. The MSF and RO pilot plants set up by BARC have been operated to study operational parameters. A 6300 cubic metre/day combined MSF-RO Nuclear Desalination Demonstration Plant is to be set up at Kalpakkam.

Nuclear Medicine: the radioisotopes produced in the research reactors at Trombay and accelerator at VECC are used in the manufacture of various radiopharmaceutical products for diagnosis and treatment. The organisations contributing to the medical segment of the Nuclear Programme are the Radiation Medicine Centre (RMC) of BARC, BRIT and the Regional Radiation Medicine Centre (RRMC), Calcutta. At RMC about 90,000 mCi amounts of technetium based radiopharmaceuticals were dispensed, 8,000 radiodiagnostic investigations were carried out, and 7,000 radioimmunoassays (RIA) were performed. During 1998-99, over 60,000 consignments of radioisotopes and related products valued at about Rs 17 crore were supplied by BRIT to over 1,200 user institutions in the country. Radioisotopes and related equipment

were exported to United Kingdom, Indonesia, Syria, Nepal, Sri Lanka, and Egypt. The radiopharmaceuticals supplied by BRIT enable about eigth lakh patient investigations. The Regional Centres for Radiopharmaceuticals at Bangalore and Delhi regularly provide ready-to-use radiopharmaceuticals to nuclear medicine centres in their regions. Gamma chambers manufactured by BRIT are in good demand within the country and abroad. An indigenously 4 MeV Linear Accelerator installed at the Regional Radiation Medicine Centre of VECC, has been in use for the treatment of patients.

Radioisotopes in Industry : The radioisotopes produced at Trombay are widely used by industry for nondestructive testing, fault diagnosis in chemical plant equipment, thickness measurements and tracer applications. Medical industry is a major beneficiary of BRIT's radiation sterilization facilities. Isomed Plant at Trombay for sterilization of medical products, has been in the service of the health care sector for 25 years. During 1998-99 the plant sterilised 1,50,000 cartons of medical products. A large quantity of Dai kits (midwifery kits) were also sterilized in ISOMED for supply to rural health care programmes funded by the World Health Organisation. Similar plants have been working at Bangalore, New Delhi and Jodhpur.

The R&D activities at Trombay have been focused on the development of processes for the production of radioisotopes, isotopic sources and their applications. These relate to the production of various radioisotopes and development of radiation sources for brachytherapy, radiopharmaceuticals for medical diagnosis, radiation processing for cable polymer industry and use of radioisotopes and radiation sources as a diagnostic tool in industry.

A noteworthy development at BARC is the process for preparation of polyvinyl alcohol-based hydrogel by irradiation for dressing of burns, and blood irradiators for safe blood transfusion.

HIGH TECHNOLOGY DEVELOPMENT

The research organisations of DAE have generated a number of high technologies. These include Accelerators for nuclear research, Lasers for use in surgery and industry, Supercomputer system using parallel processing techniques, Giant Metrewave Radio Telescope (GMRT) at Pune; Advanced remote handling and robotic devices and servo-manipulators for applications in industry; Scintigraphic techniques used in organ imaging in medical diagnosis, and sophisticated facilities for analysis and characterisation of ultra-pure materials.

Accelerators : Accelerators are complex scientific machines which are used in nuclear research, isotope production and as irradiators. DAE has established full capability in particle accelerator technology. Variable Energy Cyclotron (VEC) at Calcutta, 14MV Pelletron accelerator at Mumbai, and Synchrotron Radiation Sources (SRS) under construction at Indore are some of the major accelerator facilities in the country.

The Variable Energy Cyclotron (VEC) set up by BARC in 1977 in Calcutta, is a national research facility. This is designed to give protons,

deuterons and alpha particle beams for research in nuclear fields and production of radioisotope gallium. The Cyclotron has been serving 36 national laboratories and universities. VEC Centre is also constructing a K500 superconducting cyclotron. The Electron Cyclotron Resonance (ECR) ion source at VECC provides a unique facility for nuclear physics research with heavy ions. Also, for the study of exotic nuclei, an Isotope Separator On Line (ISOL) system has been indigenously designed and fabricated by VECC.

CAT is developing Synchrotron Radiation Sources (SRS) which will be a national facility for basic and applied research. The first synchrotron radiation source, the 450 MeV Indus-1 accelerator reached a milestone at Indore on 22 April 1999, when a circulating electron beam current of 113 milli ampere was achieved, superseding its designed value of 100 milli ampere. With seven synchrotron radiation beamlines that are planned on it, the machine will be available to researchers shortly. Fully indigenously designed and built, Indus-1 accelerator complex comprises 20 MeV microtron, a 450/700 MeV booster synchrotron and the 450 MeV storage ring. The booster synchrotron will also be used as injector for 2.5 GeV storage ring of Indus-2 which is under construction.

With synchrotron radiation as a new research tool, the Indus-1&2 will usher the research activities in India to new heights encompassing physical, biological and nuclear sciences.

Last year, at Navi Mumbai, a 500 keV Industrial Electron Accelerator was commissioned by BARC. The Centre is also setting up a Folded Tandem Ion Accelerator (FOTIA) at Trombay.

CAT has supplied some components and precision magnets to CERN for upgrading accelerator LEP-1. This is part of India's participation in the construction of the largest accelerator of the world - the Large Hadron Collider (LHC). Various units of DAE will also develop and supply some subsystems of LHC.

Lasers : The DAE units engaged in the laser research and development programme are CAT and BARC. Under its Laser Programme, CAT has developed laser technologies for applications in medicine, industry and R&D. Carbon dioxide lasers for surgery and power cutting of thick steel plates have been developed successfully. CAT has also successfully developed laser based instruments for medical applications, surgery, endoscopic surgery and treatment of tuberculosis. Ten laser units for surgery have been supplied to various hospitals. CAT has set up a prototype production unit to manufacture the technologies developed by it as marketable product. CAT has successfully developed a semiconductor laser giving 300 mW continuous wave power, and an industrial high power carbon dioxide laser. Under the National Laser Programme, effect of nitrogen laser on burn wounds and non-healing ulcers was studied and about 400 cases were already treated with nitrogen laser. A Nd-YAG laser based marker system, which can trace a designed path on hard surfaces was also developed. CAT supplied a laser marker system for scribing on solar cell. A model RD-YG-300 was also

supplied to the Atomic Energy Commission, Syria.

Information Technology : The processing power of the 6-node *Anupam* Alpha Super Computer developed by BARC has been enhanced to 10 nodes. In its present configuration, *Anupam* gives a sustained performance of 1.5 giga flops for large scientific jobs, with a peak speed of 8 giga flops. A new faster super computer *Anupam* PII has also been developed.

Remote Handling and Robotics : Both at BARC and IGCAR, robotics is a major thrust area of R&D programme of DAE. The Bilateral Master Slave Servo Manipulators, manufactured under collaboration between BARC and HMT, Bangalore, have undergone field trials. A five-degree-of-freedom Robot for deployment in radioactive chemical laboratories, a six-degree-of-freedom Robot and a mobile Robot have been developed at Trombay. The design of mechanical and control systems for the commercial scale Irradiator (POTON) for sprout inhibition of potatoes and onions is in progress. At IGCAR, for automation of nondestructive evaluation, various devices such as a Mobile Scanner (MOBSCAN), and robotic devices, such as a Remotely Operated Power Manipulator (ROPMAN) were developed. For remote operations, a Decapping Robot for capping and decapping bottles, was also built.

Plasma Technology : BARC has been developing plasma technology which has many industrial applications. The Centre has completed a plasma based aerosol generator with integrated 40kW torch and achieved plasma coatings of alumina on carbon steel moulds. Magneto welding canning and end plug collapsing techniques were successfully developed at BARC. A 150 megawatt high power microwaves device VIRCATOR has been developed at Trombay using indigenously developed KALI-1000 system.

Cryogenics : CAT and VECC have successfully developed expertise in cryogenics. Closed cycle cryorefrigerators which can produce temperatures of 10 Kelvin, have been developed at CAT. Also, the two stage and single stage cryocoolers developed here with a mean time between failure of more than 1,000 hours, are ready for trials.

Astronomy Research Facility: In the field of radioastronomy, a giant radio telescope was constructed in the Nilgiri Hills near Ootacamund, Tamil Nadu. The radio telescope facilities were designed and built fully in India. The telescope has been used for studies of very distant extragalactic radio sources and interplanetary objects. Another Giant Metre Wave Radio-Telescope (GMRT) with 30 gigantic parabolic dishes, has been set up by TIFR for at Narayangaon, near Pune frontline research in radioastronomy.

The international class astronomy research facility GRACE set up by BARC at Mt. Abu, Rajasthan, was inaugurated on 13 October 1997 and the Imaging Element of the TACTIC array was successfully commissioned. The imaging gamma-ray telescope of GRACE was in regular use and the mechanical structures of three additional telescopes of the TACTIC array were installed.

Scientific and Technological Developments

Instrumentation and Control : Research centres of DAE have been engaged in the development of sophisticated instruments components and subsystems for varied applications in the nuclear programme. For safe operation of reactors and handling of radioactive materials, reliable instrumentation is very essential. In 1952, studies were initiated at BARC for the design and fabrication of the control systems of reactors and various plants. The know-how and products developed at Trombay in the area of electronics led to the establishment of the Electronics Corporation of India Limited (ECIL) at Hyderabad in 1967. Today, (ECIL) produces a variety of sophisticated electronic systems, instruments and equipment to meet the requirements of Atomic Power Stations, Defence, Railways, Telecommunications, etc. The Company is also a leading producer of computers and consumer electronics. Recent developments at BARC include a microprocessor based traction control system for retrofitting the WAG-5 series locomotives of the Indian Railways, setting up a Femto-Second Spectrometer, and scaling up the Laboratory for Diamond Film Deposition. A number of silicon based detectors were fabricated at Trombay. PC based CAMAC Accelerator Control System, image analysis system for personnel monitoring, and multimedia database to store and retrieve facial image, signature, finger print and voice clip along with personal details for security applications were other salient developments at Trombay. Under the Physical Protection System Development Programme, BARC developed a CCTV System with digital video storage facility, which finds applications in monitoring unattended vaults, strategic materials storage location and high security areas; a micro-controller based distress alarm system, and an Access Control System under real time operating system environment. Also, a computer controlled thermal Ionization Mass Spectrometer for use at KARP was completed, and an Inductively Coupled Plasma Source Mass Spectrometer (ICP-MS) was built indigenously. Under the IAEA programme, BARC exported 81 ANUGAMI-S interface cards for gamma camera.

IGCAR has commissioned a Distributed Data Acquisition and Analysis System, and a Supervisory Control and Data Acquisition System (SCADA). A hydrogen sensor for detecting the leaks in the steam generator of FBTR has been developed and a patent has been filed for the same. IGCAR has also developed Application Specific Integrated Circuits (ASICs). SCADA for Heavy Water Plant at Manuguru was completely developed and commissioned at site by IGCAR. Plant Information System for RAPS-II and Data logging and Display system for Heavy Water Plant at Tuticorin are some of the latest development undertaken by IGCAR. A two dimensional array of 20,000 interconnected Josephson Junctions, meeting international standards was also developed at IGCAR.

At CAT technologies related to the preparation of multilayers, which are used as soft X-ray reflectors, were developed. At VECC computerised control system for the ECRIS and human computer interface are the salient developments.

ECIL led the computer revolution in the country by developing the

first digital computer belonging to the TDC series. ECIL's software expertise enabled the company to provide the much needed automation in the banking sector, control room and dial 100 automation for the police, message switching systems for defence and telecom sectors, management information systems for the ports, municipal corporations and market yards to name a few. ECIL has contributed substantially to the efforts of the Department of Telecom by providing countrywide SPC telex networks, message switching networks and maintenance systems for telephone exchanges .

In the field of Strategic Electronics, ECIL has been providing technology solutions to the Armed Forces, in the areas of command, control, communications, computers and information/intelligence systems over the years. Air Defence Systems for the Indian Air Force were supplied in the 80's covering the entire country. Fully Automated command and control systems and checkout systems for the missile programme of DRDO are provided by ECIL. ECIL developed the Air Traffic Management system, based on Future Air Navigation System employing Global Positioning System and satellite data links. These are installed at Chennai and Calcutta Airports for use in the Civil Aviation Sector. ECIL has been supplying HF, VHF and UHF radio communication equipment for the Defence Services. ECIL has made a name for itself in the development and production of antenna systems for various applications. The Antennae developed by ECIL find wide applications in DoT, Space, Defence and private cellular networks.

Nuclear and Thermal power plants, steel plants and other related process industries are equipped with control systems provided by ECIL. Supervisory control and data acquisition systems, programmable logic controllers, energy management systems, remote telemetry units, Oil and Gas pipe line monitoring systems - all developed through in-house R&D, have contributed towards the nation building activity.

During 70's and 80's EC1L pioneered the television revolution in the country by bringing out the first indigenous black and white, and colour television sets and also rural rebroadcast systems covering the entire nation. ECIL had also provided mobile broadcast stations for Doordarshan and broadcast equipment for All India Radio.

Seismology: For monitoring of seismicity, two Seismic Arrays have been functioning at Gauribidanur (Karnataka) and Delhi. BARC has developed and set up indigenously seismic monitoring systems to acquire high-quality seismic data. The seismic installations successfully recorded the Indian nuclear tests at Pokhran in May 1998.

POKHRAN TESTS

On 18 May 1974, India had conducted a peaceful underground nuclear experiment at Pokhran in Rajasthan desert. India has successfully conducted five nuclear tests on 11 and 13 May 1998 at the Pokhran range. The first three detonations took place simultaneously at 15.45 hrs. IST on 11 May. These included a thermonuclear device, a fission device and a sub-kiloton nuclear device. The two nuclear devices, fired on 13 May at 12.21 hrs. IST,

were also in the sub-kiloton yield range.

TECHNOLOGY SPIN-OFFS

The multidisciplinary research carried out in DAE's research centres, has helped not only in achieving self-reliance in the Nuclear Power Programme and associated Nuclear Fuel Cycle but also generated several products and technologies that have benefited industries. These include material and alloys, radioisotope based tools and techniques, tissue culture technology, lasers for surgery and industrial applications, electronic instruments and devices. The DAE organisations have also transferred technologies, provided consultancy in hitech areas and entered into collaborations. During 1998-99, the transfer of technologies for Video Frame Buffer and Waveform Digitizer with associated softwares, Adaptation of a software on Hospital Information Management System, Manufacture of TLD badges for Personnel Monitoring, for setting up of large sized desalination plants were finalised by BARC. The Centre also signed a Memorandum of Understanding for development of diamond polishing scaives (presently being imported). Three patents were accepted by the Centre and five patents filed with the Patent Office, Mumbai. BARC exported 500 thoria buttons (USA), RIA reagents (Egypt), Liquid injection system and gas apparatus for radiotracer experiments (Bangladesh); TLD Badges (Saudi Arabia); Gamma-Camera-Interface-Cards through IAEA (Latin American, Asian and African countries), and Software for age estimation (Hong Kong University).

The Department has intensified efforts towards strengthening its industrial interface. The Indian Atomic Industrial Forum was created to gain further support of the Indian industry to the nuclear programme. A number of orientation programmes for scientists and engineers engaged in the management and transfer of technology have been conducted. The research organisations of DAE are providing consultancy in hitech areas to both public and private sector companies.

The National Centre for Compositional Characterisation of Materials, Hyderabad, offers compositional analysis of materials of sub-micro levels and other hitech services to industry.

PROMOTION OF RESEARCH IN NUCLEAR SCIENCES

The Tata Institute of Fundamental Research (TIFR) is the national centre engaged in frontline research in astrophysics, astronomy, mathematics, computer science and molecular biology. The Institute's research facilities include a 14 MV Pelletron Accelerator and an NMR Facility at Mumbai, Balloon Research Facility at Hyderabad, and Radiotelescope Array, National Image Processing Facility for Astronomy at Ooty and National Centre for Biological Sciences at Bangalore (Karnataka). In addition, it manages the Homi Bhabha Centre for Science Education.

The Saha Institute of Nuclear Physics (SINP), Calcutta conducts research in nuclear physics, nuclear spectroscopy, nuclear and radiation chemistry, molecular physics, plasma physics, biophysics, molecular biology

and instrumentation.

The Tata Memorial Centre (TMC) at Mumbai comprises the Tata Memorial Hospital (TMH) and the Cancer Research Institute (CRI). It is a major centre for cancer therapy, research and education in the country. The CRI is engaged in cancer research and education. TMC is also setting up an Advanced Centre for Treatment, Research and Education in Cancer (ACTREC) in Navi Mumbai.

The Institute of Physics (IOP) at Bhubaneswar is engaged in advanced research in theoretical and experimental nuclear, high energy and solid state physics. The research facilities at the Institute include a Pelletron Accelerator and a set up for Compton profile and positron annihilation experiment.

The Mehta Research Institute (MRI) at Allabhabad carries out research in operation theory, consumability theory, particle physics and field theory.

The Institute of Mathematical Science (IMSc) at Chennai, is engaged in research in physics, mathematics and computer sciences.

The Institute for Plasma Research (IPR) at Gandhinagar carries out research in plasma physics and has been taken over as an aided institute from the Department of Science and Technology.

With the objective of improving cancer control measures in the country, DAE has also been providing financial assistance to some of the leading cancer centres.

The Board of Research and Nuclear Sciences (BRNS) and the National Board of Higher Mathematics (NBHM) both at Mumbai, under the aegis of the Department promote activities including research in nuclear sciences and mathematics respectively at universities and other academic institutions. NBHM also participates in the International Mathematical Olympiad. During 1998-99, the Board recommended financial assistance for 62 new proposals and renewed 167 ongoing projects involving a total expenditure of around Rs 11 crore. It also financed 84 conferences and offered DAE's Young Scientist Project Awards, Dr K. S. Krishnan Research Fellowships and Homi Bhabha Chairs for distinguished scientists.

BARC and IGCAR have signed MoUs with national institutes, universities and others for research collaborations. Under the Inter-University Consortium-DAE Facilities, research facilities at the DAE research centres are extensively used by various universities.

BARC and IGCAR are recognised as the centres for postgraduate studies by the 30 Indian universities. During 1998-99, about 150 scientists from BARC were accorded the status of university teachers. Under the collaboration scheme between BARC and the University of Mumbai, 32 students of the University of Mumbai are currently carrying out research work leading to Ph.D degree. Similarly, nine students of the University of Madras are currently carrying out research work at IGCAR.

With the objective of improving cancer control measures in the country,

the DAE has also been providing financial assistance to some of the leading cancer centres.

DAE-University Interaction : Through the inter-University Consortium for DAE Facilities (IUC-DAEF), research facilities at various centres of the Department are used by researchers of universities and academic institutions. *Dhruva* reactor at BARC has been in regular use by university scientists. A number of projects have been pursued by the university scientists at Trombay. BARC also entered into MoU with Mangalore University for training and technical guidance.

INTERNATIONAL RESEARCH COLLABORATIONS

DAE has been pursuing collaborative research programmes under Indo-German Bilateral Agreement and other Schemes. Extensive research collaborations are being undertaken with institutions in Russia, Kazakastan, etc., in the development of fast reactor technology. Detector parts for the muon tracking system of the PHENIX detector were fabricated at Trombay. Fabrication work progressed for the arms of the muon detector. For the collaboration experiment at COSY, Julich, a trigger detector (ENSTAR) for N* decays was designed. BARC also remained engaged in the collaboration experiments being done at the Legnaro National Laboratory, Italy and RIKEN, Japan. The experiment at RIKEN involved the study of giant dipole resonance in neutron rich nuclei using the radioactive ion beam facility. A collaboration with RIKEN Laboratory, Japan was also established by the VECC. A highly sophisticated Photon Multiplicity Detector (PMD) was fabricated at VECC and used successfully in WA98 experiments at CERN, Geneva. VECC along with the other Indian institutions will take part in the future collaboration programme ALICE by developing and fabrication future detectors (PMD) capable of handling high multiplicity and high counts rates.

INTERNATIONAL RELATIONS

In the field of peaceful uses of atomic energy, India continues to provide training facilities, fellowships, scientific visits, etc., through IAEA and to the countries with which it has bilateral agreements. Chairman, AEC led the Indian delegation to the IAEA general conference held in Vienna, Austria in September 1998. India has been a member of the Board of Governors of the IAEA since its inception. In September 1994 the country was elected as the Chairman of the Board of Governors of IAEA for one year. Training facilities, fellowships, scientific visits, etc., and providing services of scientists for expert assignments are offered both through the IAEA and to the countries with which India has entered into bilateral agreements for cooperation in the field of peaceful uses of atomic energy. As an active member of the World Association of Nuclear Operators (WANO), Indian experts participated in Peer Reviews in many countries including the USA, Japan and South Korea. IGCAR has played an active role in the International Working Group on Fast Reactors.

Concerted efforts have been continued to publicise Indian expertise

for the purpose of export of technology and equipment for peaceful applications of nuclear ‘energy. A Cooperation Plan for 1999 was signed between the AEC and the Vietnam Atomic Energy Commission for cooperation in the field of nuclear power, exchange of scientists and assistance in setting up a training centre at Vietnam.

HUMAN RESOURCE DEVELOPMENT

The Training School at Trombay and Nuclear Training Centre at Rawatbhatta are the premier training centres of the Department. These provide specialised training to undertake multidisciplinary activities of DAE. Apart from conducting the human resource development programmes for its own requirements, DAE has extended them for other organisations at national and international levels in various areas which cover nuclear agriculture, nuclear medicine, radioisotope technology and many specialised services. A number of training courses, seminars, symposia and workshops are conducted by various units. DAE also offers training facilities, fellowships, visits and services of experts through the IAEA or bilateral agreements for cooperations in peaceful uses of atomic energy.

INDIAN SPACE PROGRAMME

The Indian space programme was formally organised in 1972 with the setting up of Space Commission and the Department of Space (DOS) to promote development and application of space technology, specifically, in the areas of telecommunication, television broadcasting, meteorology, resources survey and management. Development of satellites, launch vehicles and associated ground systems is integral to the space programme objective. The space programme is executed through, mainly, the Indian Space Research Organisation (ISRO), National Remote Sensing Agency and Physical Research Laboratory. Over the last two and a half decades, the Indian space programme has made an impressive progress through a well integrated, self-reliant programme.

INSAT SYSTEM

The Indian National Satellite System (INSAT) is a multi-purpose satellite system for telecommunications, meteorological observations and data relay, television broadcasting and radio and television programme distribution. It is a joint venture of Department of Space (DOS), Department of Telecommunications (DOT), India Meteorological Department (IMD), All India Radio (AIR) and Doordarshan. DOS has direct responsibility for establishment and operation of INSAT space segment.

INSAT system was established in 1983 with the commissioning of INSAT-1B. At present the system is served by the last of the first generatiooon INSAT-1D launched in 1991, three ISRO-built second generation satellites, INSAT-2B, INSAT-2C and INSAT-2E launched in July 1993, December 1995 and April 1999 and INSAT-2DT procured from ARABSAT in October 1997.

The communication payloads on board INSAT-2B, comprise 12 C-

band transponders, six extended C-band transponders and two high-power S-band transponders. The meteorological payload includes a Very High Resolution Radiometer (VHRR) with 2 km resolution in visible band and 8 km resolution in infrared bands, and a transponder for meteorological data relay. The satellites also incorporate a transponder for receiving distress alert signals for search and rescue missions.

INSAT-2C in addition to carrying communication transponders in INSAT-2A and 2B, incorporate Ku-band transponders for business communication, extended coverage C-band transponders to enable TV programme outreach beyond Indian boundaries catering to the population from South East Asia to the Middle East and transponders for mobile satellite services. It does not carry the meteorological payload. INSAT-2C and INSAT-2B are co-located in the geostationary orbit thus enabling efficient use of allocated orbital slots. INSAT-2E incorporates an improved meteorological payload besides the communication payloads as in INSAT-2C. DOS has leased to INTELSAT organisation eleven 36 MHz equivalent units of C-band capacity on board INSAT-2E. Five satellites, INSAT-3A to INSAT-3E are planned to be launched in 1999-2002 time frame. INSAT-3B is scheduled for launch during 1999 followed by INSAT-3A in 2000.

There are more than 300 telecommunication terminals of various types, including 50 terminals for rural telegraphy in the north eastern part of the country, operating in the INSAT network providing about 5,500 two-way speech circuits over 166 routes. More than 800 micro-terminals have been set up under National Informatic Centres to provide nationwide data communication links between district and state capitals. Captive satellite-based networks such as for National Thermal Power Corporation (NTPC), Gas Authority of India Limited (GAIL), Nuclear Power Corporation (NPC), Indian Telephone Industries (ITI), Oil and Natural Gas Commission (ONGC), National Fertilizers Limited (NFL) and Coal India Limited (CIL), are operating through INSAT. The Press Trust of India (PTI) has implemented a system to provide its news and information services at high speed and increased volume by utilising broadcast facilities of INSAT satellite. With the availability of INSAT-2C, business communication in Ku-band and mobile satellite service are being tried out.

The meteorological data gathering with VHRR instrument on board INSAT and its dissemination, along with its collection of remote area meteorological data from unattended platforms, has vastly improved weather forecasting in the country. Satellite based locale-specific disaster warning system has been established with over a hundred disaster warning receivers installed in the cyclone-prone coastal areas.

INSAT has enabled a vast expansion in the television service with over 900 TV transmitters linked through INSAT. The INSAT television network provides access to over 85 per cent of India’s population. INSAT-2C enables Indian television outreach beyond Indian boundaries catering to the population from South East Asia to Middle East. Educational television service through INSAT has been introduced both at university level in the

national network and at primary school level in several states including Andhra Pradesh, Orissa, Maharashtra, Gujarat and Uttar Pradesh. A channel on the INSAT has been dedicated for development of education and training. A pilot project for demonstration of satellite-based developmental communication and training has been taken up in Jhabua district of Madhya Pradesh.

INDIAN REMOTE SENSING SATELLITE SYSTEM

The Indian Remote Sensing (IRS) satellites are the main-stay of National Natural Resources Management System (NNRMS), for which Department of Space (DOS) is the nodal agency, providing operational remote sensing data services. The IRS system was operationalised with the commissioning of IRS-1A in March 1988. An identical satellite, IRS-1B was launched in August 1991 to continue the services from IRS. The IRS system has been further enhanced by IRS-1C, IRS-P3 and IRS-1D, the last two having been launched by India's own launch vehicle, PSLV, IRS-1C, launched on 28 December 1995 by a Russian rocket and IRS-1D launched by PSLV on 29 September 1997, have enhanced capabilities in terms of spatial resolution, additional spectral bands, stereoscopic imaging, wide field coverage and a more frequent revisit capability than its predecessors. They carry tape-recorders on board for recording the data when data is not being transmitted in real time. IRS-P3 was launched by the third developmental flight of PSLV (PSLV-D3) on 21 March 1996. It has a Modular Opto-electronic Scanner (MOS), designed and developed by DLR, Germany and a Wide Field Sensor (WiFS) similar to that of IRS-1C but with an additional Short Wave IR (SWIR) band for the study of vegetation dynamics besides an X-ray Astronomy Payload (XAP) to study the time variability and spectral characteristic of cosmic X-ray sources and detection of transient X-ray sources. Another satellite IRS-P4 (OCEANSAT) series are planned for launch by PSLV during 1998-99, 1999-2000 and 2000-2001. Two more satellites, IRS-P5 and IRS-P6 for cartography and agricultural resources survey respectively are planned for launch in the next three years.

Remote sensing applications in the country, under the umbrella of NNRMS, now cover diverse fields such as crop acreage and yield estimation, drought warning and assessment, flood control and damage assessment, land use/land cover information, agroclimatic planning, wasteland management, water resources management, under-ground water exploration, prediction of snow-melt run-off, management of watersheds and command areas, fisheries development, urban development, mineral prospecting, forest resources survey, etc. Active involvement of the user ministries/departments has ensured an effective harnessing of the potential of space-based remote sensing. An important application of IRS data is in the Integrated Mission for Sustainable Development (IMSD) initiated in 1992. IMSD, under which 175 districts have been identified, aims at generating locale-specific action plans for sustainable development.

Scientific and Technological Developments

LAUNCH VEHICLE TECHNOLOGY

India started launch vehicle development in a modest way through SLV-3 which could put 40 kg class satellite into near earth orbit. The capability was further built up through Augmented Satellite Launch Vehicle, ASLV, which had two successful flights - in May 1992 and May 1994 - when it injected the SROSS (Stretched Rohini Satellite Series) satellites, carrying a gamma ray burst experiment and retarding potential analyser into low earth orbit. The second satellite, SROSS-C2, is still sending valuable scientific data.

Today, India has realised the operational launch vehicle, PSLV, capable of launching 1,200 kg IRS class of remote sensing satellites into polar sunsynchronous orbit. The first successful developmental launch (PSLV-D2) took place on 15 October 1994 when it placed the IRS-P2 remote sensing satellite into the intended polar orbit. The second and final developmental test (PSLV-D3) was conducted on 21 March 1996 when IRS-P3 was placed into the intended polar orbit. The first operational flight, PSLV-C1 placed IRS-1D in orbit. PSLV-C2 placed Indian Remote Sensing Satellite, IRS-P4 (OCEANSAT), a Korean Satellite KITSAT-3 and a German satellite, TUBSAT into 727 km Polar sunsynchronous orbit on 26 May 1999. PSLV-C3 is planned in 2000-2001 to launch IRS-P5 (cartosat) and a Belgium satellite PROBA. The development of Geosynchronous Satellite Launch Vehicle (GSLV), incorporating a cryogenic stage, which will be capable of placing 2,500 kg INSAT class of satellites in geosynchronous transfer orbit, is making rapid progress and its first developmental test is expected by 2000-2001.

SPACE SCIENCE

Space science research is mainly carried out in the areas of astronomy and astrophysics, planetary atmosphere and aeronomy, earth sciences and solar system studies and theoretical physics. The activities are carried out mainly at Physical Research Laboratory, Ahmadabad and, to a lesser extent, at Space Physics Laboratory, Thiruvananthapuram, Space Applications Centre, Ahmadabad and ISRO Satellite Centre, Bangalore. A programme on geosphere-biosphere research using balloon, rocket and satellite-based experiments to study the effect of anthropogenic activities on the earths environment is continuing. A National Mesophere-stratosphere Radar Facility (NMRF) has been established at Gadanki near Thirupati for study of atmospheric dynamics, atmospheric turbulence and diffusion measurement, study of atmospheric pollutant dispersion, detection of wind shear, cloud physics, etc. The gamma ray burst experiment carried on board SROSS satellites and X-ray Payload on IRS-P3 satellite have helped in furthering research in high energy astronomy.

SPACE-INDUSTRY COOPERATION

Under space-industry cooperation, 236 advanced technologies developed by ISRO have been transferred to industry for commercial use. Technology consultancy is also provided to industry. ISRO also utilises the Indian industry capability for the space programme. Certain premier industries in the field of aeronautics, communications and engineering have now set up

to market the variety of hardware and services that are available through ISRO, Antrix Corporation Limited, a government-owned company, has been established. Antrix has already signed an important contract with a leading US company for receiving and marketing data from Indian remote sensing satellites globally. Many ground stations all over the world have already been augmented with Indian supplied hardware to receive data from IRS satellites. Several other contracts have also been executed by Antrix.

INTERFACE WITH ACADEMIC AND R & D INSTITUTIONS

ISRO has an active programme to interact with academic and research institutions all over the country for the benefit of space programme. Under the Sponsored Research (RESPOND) scheme, several research projects relevant to the space programme are being funded by the Department of Space in academic and R and D institutions. Space Technology Cells have been established at reputed institutions.

INTERNATIONAL COOPERATION

International cooperation is an important element of the Indian space programme. The establishment of Equatorial Rocket Launching Station, conduct of SITE and STEP, launches of *Aryabhata*, Bhaskara I and II, IRS-1A and 1B and APPLE, manned space mission, development of Vikas engine, etc., involved cooperation with several countries including USA, the fromer Soviet Union, France, Germany, European Space Agency, etc. India has cooperative agreements with several countries like China, France, Germany, Canada, Hungary, Mauritius, Norway, Russia, Sweden, Syria, The Netherlands and Ukraine and space agencies such as the European Space Agency. India shares its own experience with other developing countries by training their personnel under a programme called SHARES (sharing of experience in space).

India has actively participated in international campaigns related to atmospheric research. India has been actively participating in the UN Committee on Peaceful Uses of Outer Space and has set up two Local User Terminals (LUT) and Mission Control Centre (MCC) as part of the COSPAS-SARSAT network, under the International Satellite aided search and rescue programme. The UN Asia-Pacific Regional Centre for Space Education set up in India in November 1995, is a recognition for India's role in sharing its experience in the development and application of space technology for social benefits.

SPACE CENTRES AND UNITS

The headquarters of the Department of Space (DOS) and Indian Space Research Organisation (ISRO) are located at Bangalore. Research and development activities under the space programme are carried out in the following centres/units of DOS/ISRO: (i) Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram, is the lead centre for launch vehicle development. It pioneers in rocket research planning and execution of launch vehicle development projects; (ii) ISRO Satellite Centre (ISAC), Bangalore,

is responsible for the design, fabrication, testing and management of satellites for scientific, technological and application missions; (iii) Space Applications Centre (SAC), Ahmadabad, is engaged in design and development of payload systems for satellites and carry out application demonstration of space technology; (iv) SHAR Centre, Sriharikota, located on the east coast of Andhra Pradesh, is the main launch centre of ISRO. Propellent processing and ground testing of solid fuelled rocket stages are also carried out in this centre; (v) Liquid Propulsion Systems Centre (LPSC) is the centre for development of liquid propulsion systems both for launch vehicles and satellites. It has facilities located at Thiruvananthapuram, Bangalore and Mahendragiri (Tamil Nadu); (vi) Development and Educational Communication Unit (DECU), Ahmadabad, is involved in conception, definition, planning and socio-economic evaluation of space application programmes; (vii) ISRO Telemetry, Tracking and Command Network (ISTRAC) with its headquarters and Spacecraft Control Centre at Bangalore and a network of ground stations at Sriharikota, Thiruvananthapuram, Bangalore, Lucknow, Port Blair and Mauritius, provides telemetry, tracking and command (TTC) support for the launch vehicle and satellite missions of ISRO and also for other space agencies; (viii) Master Control Facility (MCF) at Hassan in Karnataka is responsible for all post launch operations of INSAT satellite including orbital manoeuvres, station keeping and in-orbit operations on the spacecraft; (ix) ISRO Inertial Systems Unit (IISU), Thiruvananthapuram, carries out development of intertial systems for both satellites and launch vehicles; (x) Physical Research Laboratory (PRL), Ahmadabad, under DOS is the premier national centre for research in space and allied sciences; (xi) National Remote Sensing Agency (NRSA), Hyderabad under DOS is responsible for reception, processing and dissemination of data from remote sensing satellites and also carry out aeraial surveys; and (xii) National Mesophere, Stratospherl Stratosphere, Troposphere Reader Facility (NMRF) at Gadanki, near Thirupati is available to scientists for carrying out atmospheric research.

ELECTRONICS

The Indian electronics industry production is estimated to be Rs 41,140 crore during the year 1998-99, as compared to Rs 32,070 crore during 1997-98, registering a growth of over 28 per cent. Consumer electronics sector has achieved a production level of Rs 9,200 crore during 1998-99. Color TV industry has crossed a production of 42 lakh numbers the calendar year 1998. Electronics production during the last five years is given in table 7.1

The Government is taking all steps to make the country, a global Infromation Technology Superpower. On the recommendations of the National Task Force of Infromation Technology (IT) and Software Development, the Government has announced major fiscal benefits to the Infromation Technology sector and has also recommended that each ministry / department must allocate 2-3 per cent of its budget on IT promotion.

The software industry has emerged as one of the fastest growing

sectors in economy with a CAGR exceeding 50 per cent and with a likely turnover of US$ 4 billion and exports of US$ 2.6 billion during 1998-99. The Government has targeted an export of US$ 50 billion by the year 2008 for the Indian software industry. The Task Force has constituted a panel to prepare an action plan for IT hardware industry along with Policy instruments with an export target of $ 10 billion by the year 2008. The panel has submitted its report. The Department of Electronics has adopted a pro-active role to further enhance competitiveness of India in IT and has initiated a number of programmes for manpower development, quality up-gradation, stimulation of software engineering and research.

IT VENTURE CAPITAL FUND

The Government has approved setting up of the IT Venture Capital Fund of Rs 100 crore for software companies. Out of this, the DOE shall contribute Rs 30 crore. Small Industries Development Bank of India (SIDBI) Rs 40 crore and the remaining funding shall come from financial institutions, private companies and NRIs. The aim is to provide Venture Capital to start up software professionals, and IT units in the small scale sector. The fund will be managed by a professional Asset Management Company.

ELECTRONIC-COMMERCE

To facilitate Electronic Commerce (e-commerce) in the country, the DOE has drafted Information Technology Bill, which provides legal framework for recognition of electronic contracts, prevention of computer crimes, electronic filing / documents, etc. Amendments have been proposed in the Indian Evidence Act, Indian Penal Code and RBI Act. The mechanism of digital signature has been proposed to address the issues of jurisdiction, authentication and origination. The Ministry of Law has vetted the bill to be introduced in the Parliament.

To set up the mechanism and infrastructure for implementation of Cyber laws, Department of Electronics has funded a project at R&D Centre of CMC Limited at Hyderabad to develop technology for issue of digital signature certificate and procedure for certification authorities and other security guidelines.

ELECTRONIC GOVERNANCE

The trends in Information Technology has brought about a new set of services and has transformed the traditional services in terms of fast delivery. The DOE has initiated institutional mechanisms to facilitate initiatives towards greater utilization of IT as an enabling tool for efficiency and effectiveness in the Government. It would, in addition, act as a driving force for the development of both the hardware and software industry in the country.

NATIONAL INFORMATION INFRASTRUCTURE

The Department of Electronics has prepared a document on National Information Infrastructure (NII) for national development with the primary aim to stimulate investment in infrastructure - especially in telecom sector,

network backbone, Internet, set of test-beds and pilot projects as technology providing exercises and demonstration and utility of service or application to one or more set of targeted audience so that the same may be scaled up commercially. The applications such as Internet/Intranet penetration and e-commerce will serve commercial/business/industrial user community while applications like electronic governance, Internet education and telemedicine would stimulate social applications.

Several initiatives have been taken in the area of multimedia promotion, electronic governance and ATM test-bed, tourism infromation network, electronic commerce, distance education, digital library, etc.

In association with the Government of Andhra Pradesh, two test-beds in the area of electronic governance have been initiated. Experience of the test-beds in Andhra Pradesh could be used by other States for replication. DOE has also initiated setting up of a Java Competency Centre at R&D centres of CMC Limited, Hyderabad as a collaborative effort between Sun Microsystems Limited and CMC Limited.

SPECIAL IT PROJECT

Year 2000 or Y2K or millennium bug problem is an important issue for individuals, institutions and governments all over the world. A promotional campaign on Y2K comprising advertisements in national, regional and some local newspapers and advertisements in radio and television has been launched by DOE to sensitize them. IT Enabled Education in Schools (K12) has become and important issue to prepare future generations to learn to use IT effectively in their pursuits apart from entering the IT industry itself. Curriculum preparation, courseware development, teacher training, are some areas in which DOE is working with CBSE, NCERT, COBSE , etc.

R & D EFFORTS

The Department of Electronics has been giving high priority for all round development of technology in the country. A major result of sponsored research has been the enhancement of technological base and capabilities in the county besides generating specific hardware. It has also produced strong pockets of specialized expertise which have been used as a spring board for launching major national projects besides providing the much needed trained manpower to man such national programmes.

India has achieved capability of designing and building supercomputers using massively parallel processing technology to address national requirements in science and engineering applications, mission critical applications and business computing. A supercomputer having 100 GFLOP peak computing power with an architecture scalable to 1 TFLOP has been built by C-DAC and set-up as a national PARAM Supercomputing Facility at Pune.

Education and Research Network (ERNET) has been providing network services to Indian academic and research community. It has ten transit nodes spread throughout the county primarily at leading educational and research

spread throughout the county primarily at leading educational and research institutions. Today, ERNET has over 80,000 users. ERNET was converted into an autonomous society in 1998. A proposal of Rs 196.2 crore has been approved for upgradation of ERNET facilities to provide modern high speed data connectivity and internet facility. This will also be used as a vehicle for distance education.

Jai-Vigyan National Science and Technology Mission Programme : The projects being initiated under *Jai-Vigyan* National Science and Technology Mission programmes are : (i) Development and manufacture of indigenously developed integrated Medical LINAC for Cancer Therapy; (ii) National programme for Braille Literacy to develop system for aiding Braille Literacy incorporating modern computer technique and application of infromation technology; and (iii) Technology development for Indian languages to develop infromation processing tools and techniques for Indian languages to enable wider use of computers.

After successful operation of 100 KV/100 MW HVDC link between Lover Sileru in Andhra Pradesh and Barsoor in Madhya Pradesh under Stage I of the National High Voltage Direct Current Project, Stage II of the NHVDC Project is in progress which upgrades the link to 200 MW/200KV and incorporates state-of-the-art digital controls built indigenously. With this , the total turn key capabilities in HVDC technology from design to commissioning has been established.

POLICY

The electronics industry as a whole, with the exception of aerospace and defence electronics, has been fully delicensed. Fiscal, investment and trade policies for the electronics sector have also been liberalised. To accelerate exports in electronics and Information Technology sector, a number of policy measures were taken and procedures further simplified. These include : Notification of a special advance licensing scheme to provide duty free inputs for export production in electronics sector; a special stock option scheme for Indian Software Companies linked with ADR/GDR offerings by these companies as an instrument to enable them to provide incentives to retain their highly skilled professionals; Guidelines for easy sanction of working capital finance to Infromation Technology and Software Industry; provision for issue of Sweat Equity by companies in the Companies Act, *i.e.,* shares at a discount for consideration other than cash for providing know how or making available rights in the nature of Intellectual Property Rights or value addition; exemption of EOU/EPZ/STP/EHTP units from payment of Corporate Income Tax for 10 years; and measures taken to increase PC penetration like free import of computers, 60 per cent annual depreciation on computers, duty free donation of used computers to educational and charitable institutions, hospitals, etc.

Table 7.1 : ELECTRONICS PRODUCTION

(Rs in crore)

tem	1994-95	1995-96	1996-97	1997-98	1998-99
1 Consumer Electronics	4,665	5,800	6,500	7,600	9,200
2 Industrial Electronics	2,110	2,900	3,100	3,150	3,300
3 Computers	2,450	2,225	2,740	2,800	2,300
4 Communications & Broadcasting Equipment	3,250	2,600	3,000	3,250	4,400
5 Strategic Electronics	600	1,075	1,300	900	1,300
6 Components	3,150	3,500	3,700	4,400	4,750
Sub-Total	16,225	18,100	20,340	22,100	25,250
7 Software for Exports	1,535	2,550	3,700	6,500	10,940
8 Domestic Software	1,070	1,690	2,600	3,470	4,950
Total	18,830	22,340	26,640	32,070	41,140

OCEAN DEVELOPMENT

The Department of Ocean Development was created in July 1981 to serve as a nodal Department for organising, coordinating and promoting ocean development activities in the country, in line with the Ocean Policy Statement. The programmes of the Department are directed towards : (1) Technology Development Programmes for future applications with strategic, industrial and economic significance; (2) Societal Programmes with direct/ indirect benefit for the community by technology applications and pilot project demonstration with the participation of the community for their socio-economic prosperity, and for coastal area development. (3) Marine Resources Programmes for exploration of marine living and non-living resources, techno-economic studies to evolve strategies for sustainable exploration and utilistion, and resource enhancement. (4) Multi-institutional and multi-disciplinary Polar Science Progammes and Antarctic Expeditions with scientific and geo-political significance; (5) Capacity Building Programme towards self-reliance through basic scientific research in ocean sector, human resource development and establishing Centres of Excellence in academic institutions and (6) Creation of public awareness of ocean , its potential and uses.

With the ratification of the UN Convention on Law of the Sea, a new international order has been established for the oceans. India is represented in almost all the important bodies on oceans. The oceanographic programmes have national, regional and global importance. The Department is the nodal agency for several international programmes in the ocean sector and represents the country in Intergovernmental Oceanographic Commission (IOC) of UNESCO, Regional Committee of IOC in Coastal Indian Ocean

(IOCINDIO), International Sea-Bed Authority (ISBA) and the State Parties of the United Nations Convention on the Law of the Seas (UNCLOS), the Antarctic Treaty System (ATS) and its scientific and managerial organs - Commission on Conservation of Antarctic Marine Living Resources (CCAMLR), Council of Managers of National Antarctic Programme (COMNAP), Scientific Committee on Antarctic Research (SCAR), etc. These activities have scientific, economic and geopolitical impact. Further, Marine Research and Capacity Building is one of the key programme areas of the Department to promote basic research in marine science and establish centres of excellence in academic institution and of self reliance.

ANTARCTIC EXPEDITION AND POLAR SCIENCE

The inception of polar science in the country started with the launching of the first Indian Scientific Expedition to Antarctica in 1981. So far 18 annual expeditions have been successfully launched to the icy continent. In addition, an expedition to the Weddell Sea and one for Krill assessment studies in the Antarctic waters have also been undertaken.

The Indian station *Maitri* situated in the Cental Dronning Maudland area of east Antarctica has provided the platfrom to more than 1,250 personnel drawn from about 50 national research laboratories, institutes and universities for conducting experiments in all the major disciplines of polar science. Specialised logistic support for the expedition is being provided by the Indian Army and the DRDO laboratories.

The ability to conduct front ranking science through the maintenance of a permanent base in Antarctica has ensured for India a pre-eminent role as a Consultative Member in the Antarctic Treaty System since 1983. The long term scientific strategy of India in Antarctica has been designed particularly to address the issues of national priority and at the same time focus on common global concerns which are shaped and impacted by the continent. This has prompted the initiation of several international collaborative experiments in various domains of polar science with Germany, Italy, Argentina, Iran , Peru and USA.

Even while using Antarctica as a platform for conducting scientific research, India has always recognised the importance of preserving the pristine nature of this continent which controls intricate global processes of the earth. To uphold this commitment, India-an original votary of the Protocol on Environmental Protection to the Antarctic Treaty has ratified this Protocol and is actively participating in the Committee on Environment Protection (CEP) established during the last Antarctic Treaty Consultative Meeting in June 1998. Our long-term commitments and capabilities in polar science have been further demonstrated by the establishment of the first Polar Research Laboratory of the country, Antarctic Study Centre at Vasco da Gama, Goa which was converted into an autonomous institution of the Department, during September 1998.

The eighteenth expedition to Antarctica consisting of 55 members drawn from 22 organisations sailed from Goa on 14 December 1998. For the first time two helicopters were chartered for providing the logistic support. The expedition also has an Iranian scientist who will conduct studies

on the biology of Antarctic fresh water lakes. In addition to the ongoing programmes several new experiments on biodiversity of anaerobes, eutrophication analysis of lakes, ambient sea noise processes and its effects on Antarctic mammals and utilisation of fuel cells as a source of clean energy have also been inducted. In view of the importance of Antarctica in controlling the global weather phenomenon, a Brewer Spectrophotometer will be installed at *Maitri* station to measure the ozone and trace gas contents. The summer team of this expedition returned on 31 March 1999 leaving behind the winter team of 26 personnel.

The Antarctic Study Centre (ASC) at Goa was converted into an autonomous institute in September 1998. This centre will be responsible for in-house R&D activities in polar sciences and for coordinating expedition activities. The activities of ASC are as under: (i) to serve as a nodal institution for planning, coordination and execution of scientific and logistic activities of the Antarctic expeditions and to conduct a balanced and optimum programme of front-ranking science; (ii) to establish and maintain a research base in Antarctica and provide all operational and logistic support; (iii) to encourage cooperative research both at national and international levels, especially in the frontier areas of science which are emerging and have application potential, such as Global Change; and (iv) to conduct in-house research in the contemporary areas of climate modelling, sea-ice-ocean-atmosphere coupling, Antarctic paleoclimates, Southern Ocean oceanography; address and monitor all issues arising out of the Environmental Protocol; develop a complete database inventory and repository for Antarctic and Arctic science and logistics including a polar museum and a library; provide a fertile platform to generate specialised manpower for polar science and logistics; cruise planning and management of the oceanographic research vessels engaged by the Department and to coordinate oceanographic survey and studies relating to departmental programmes. The expenditure incurred on Antarctic Expedition and Polar Science was Rs 19.611 crore during 1998-99.

MARINE LIVING RESOURCES

A multi-disciplinary and multi-institutional programme aimed at making an assessment of the marine living resources beyond 70 m depth within the Indian Exclusive Economic Zone (EEZ) and corelating the fish abundance/ availability with the oceanographic parameters, was initiated during1997-98. The major objectives of the programme are : to have a realistic and reliable information on the potential of marine living resources in the Indian EEZ for sustainable development and management and to enhance the marine living resource potential of Indian seas.

Six major projects which are pre-requisites for a realistic assessment of the marine living resources were undertaken. *FORV Sagar Sampada* has carried out 10 cruises for these projects on Marine Living Resources during 1998-99. The important observations made during these cruises are summarised hereunder:

Towards "Assessment of environmental parameters and the marine living resources (primary and secondary) in the Indian EEZ and the role of Myctophid fauna in the mesopelagic habitat", altogether 90 stations along

the EEZ were sampled for water quality studies from different depths, up to 1000 m. Phytoplankton sampling was made up to 125 m depth and zooplankton collected by using bongo nets and multiple plankton nets. The benthic environment is also found to be potentially productive as indicated by the presence of chiorophyll-a in the mud samples. The project on "Stock assessment, biology and resource mapping of deep sea shrimps, lobsters, cephalopods and fish in the EEZ of India" envisages assessment of the living resources in the continental slope area with special emphasis on benthic resources. Sampling has already been initiated along the east and west coast of India, for analysis. For "Studies on the Deep Scattering Layers (DSL)", samples collected from within the EEZ of the Arabian sea and bay of Bengal on the basis of acoustic recordings from various depths were sorted and identified up to group level in case of zooplankton (copepods, euphausids, amphipods, siphonophores, ostracods, decapods, jelly fishes, etc.) and up to family level in the case of major micronektonic components (fish-myctophids and photichthids, leptocephalus, crabs, pelagic shrimps and cephalopods). In the "Harvest technology and catch composition of deep-sea fishery resources" project, demersal expo model trawls, mid-water pelagic trawls and Isaac Kid mid-water trawls were tested for gear efficiency. A week's training on harvest technology methodologies, was conducted for the research scholars. Under the "Toxic Alogal Blooms investigations" project to identify and enumerate toxic phytoplankton in the EEZ of India, to study the physico-chemical factors afffecting the distribution, growth and multiplication of toxic phytoplankton, to understand the effect of toxic algae on other organisms and to evolve a mathematical model for the prediction or early detection of occurrence of toxic algal blooms; *Trichodesmium, Goniaulax, Noctiluca* and *Oscillatoria* spp. were isolated from the samples collected in the Indian EEZ. "Investigations on the benthic productivity in the EEZ of India" were studies by collecting samples from 45 stations in the shelf waters on the east coast of India. Duplicate samples were collected using grab for marcrobenthos and meiobenthos from all the stations and these are being processed in the laboratory. The expenditure incurred on assessment of Marine Living Resources was Rs 70,000 during 1998-99.

The National Project on Drugs from Sea taken up by the Department during 1990-91, is a multi-institutional project aiming at developing potential drugs and chemicals from the marine flora and fauna. During the period 15 new marine flora and 53 fauna were collected for general biological screening and repeat collection of 76 flora and 40 fauna was made for confirmation of biological activity and follow-up studies that have yielded valuable clues for developing potent drugs. The project entering Phase IV in 1999-2000, has led to identification of six marine organisms showing potent activity as anti-diabetic/anti-diarrhoeal, anti-hyperlipidaemic, anti-anxiety, anti-cholesterol, anti-bacterial and larvicidal agents. During 1998-99, the extract for anti-diabetic drug was subjected to accelerated stability and shelf life studies. Chronic toxicity studies in rats and monkeys were also completed. The expenditure incurred on Drugs from sea was Rs 2.71 crore in 1998-99.

MARINE NON-LIVING RESOURCES

As a Registered Pioneer Investor since 1987, with Ploymetallic Nodules Mine

site at Central Indian Ocean Basin (CIOB), India has made considerable progress in resource identification and evaluation, technology and manpower development towards exploitation of these resources. The Ploymetallic Nodules Programme consists of four components: Survey and exploration of nodules in the CIOB, Environmental Impact Assessment (EIA) Study, development of technologies for mining of nodules and extraction of metals. The programme is guided and reviewed by the PMN Board of Management.

Survey and Exploration in the CIOB mine site was continued for updating relative concentration and quality characteristics of the ploymetallic nodules in different predetermined blocks. The geo-statistical analysis of all 12.5 km grid sample data is initiated to update the estimate on resource potential. A cruise of *ORV Sagar Kanya* was carried out to CIOB mine site for close grid sampling at 5 km in a selected block.

The comprehensive Environmental Impact Assessment Study initiated in 1996-97 to assess the environmental impact of large scale deep seabed mining activity continued with disturbance of benthic ecosystem, simulating mining operations in identified site in CIOB in 1997-98. The observations of physical, chemical, biological and geological parameters were made at test and reference site. Plans were finalised for monitoring recolonisation effect with deep tow colour video photography, chemical parameters with CTD, and biological and geological parameters with core samples. Documents on 'Baseline study on ocean currents in CIOB', 'Baseline environmental conditions on the physical, biological, chemical and oceanographic parameters in CIOB' and 'Benthic disturbance and impact assessment studies in the Indian Pioneer Area' were prepared on baseline benthic conditions.

Towards development of technology for nodule mining at greater depths, a joint technology development agreement was concluded between National Institute of Ocean Technology (NIOT) of DOD and University of Siegen (IKS) , Germany during January 1998. Under this, it is proposed to test a seabed mining system up to 500 m depth in Indian waters to demonstrate shallow bed mining technology. Pursuant to the joint technology development agreement, an existing crawler at IKS was refurbished and augmented with a cutting system, manipulator, slurry pumping system, control system and necessary underwater systems. This shallow bed mining system module, after completion of evaluation at Germany, was shipped to India for testing in the Indian waters. Preliminary trials for launching, manoeuvering, retrieving, etc., was done at 60 m depth off Malvan Coast, near Goa. Further test to demonstrate sand mining is proposed in Indian waters off Tuticorin coast during October 1999. During the tests, the performance of all the sub-systems will be evaluated besides the sand mining demonstration. Incorporating inputs from this shallow bed mining test, a joint design report of various subsystems like crawler, collector, riser, control system, launching and retrieval system, etc., required for deep sea nodule mining will be prepared. Basic engineering and specifications of a mining complex module capable of operating at 6000 m depth with a mining capacity of 25,000 tonnes of nodules per year is in progress under this joint collaboration.

Demonstration campaigns were carried out at Regional Research

Laboratory (RRL), Bhubaneswar to revalidate the data generated in earlier campaigns for recovery of copper and mixed sulphide of nickel and cobalt. Process for separation of cobalt and nickel metal from sulphate solution produced at RRL (B) and electrowining of nickel and cobalt oxalate were demonstrated at Bhabha Atomic Research Centre, Mumbai.

Basic engineering and designs for a continuous demonstration pilot plant to process 500 kg/day of the polymetallic nodules for Indian mine site were completed. This pilot plant will be established at Hindustan Zinc Limited (HZL), Udaipur who will also partially finance the programme and be responsible for commissioning, maintaining and operating the pilot plant during the trails for evaluation and optimisation of the process to generate parameters for techno-economic studies. R&D efforts were continued to optimise the process routes being pursued at National Metallurgical Laboratory, Jamshedpur; RRL(B) and HZL(U). The expenditure incurred on Polymetallic Nodules Programme was Rs 20.314 crore during 1998-99.

OCEAN OBSERVATION AND INFORMATION SERVICES

With a view to synergise and generate reliable coastal and ocean data and data products for supporting coastal and off-shore developmental activities and oceanographic research, the reorganised and revamped Ocean Observation and Information Services (OOIS) was established in 1997-98. The programme consists of four major elements projects, *viz.,* Ocean Observing Systems, Ocean Information Services, Satellite and Coastal Oceanographic Research, and Ocean Modelling and Dynamics.

OCEAN OBSERVING SYSTEMS

The Ocean Observing Systems (OOS) programme is designed to acquire *in-situ* surface, meteorological and oceanographic data on real-time basis from the seas around India. The parameters measured under the programme are surface winds, waves, atmospheric pressure, temperature, sea surface temperature, salinity, dissolved oxygen, hydrocarbons, nutrients, radio-activity, sea-level, etc. The state-of-the-art instruments like moored data buoys, drifting buoys, XBTs, current meter arrays and tide gauges are deployed for measurements. In addition, validation of the satellite data would also be undertaken using the sea truth data generated under this programme.

Under the National Data Buoy Programme (NDBP) being implemented at National Institute of Ocean Technology, Chennai, 12 data buoys have been deployed in Indian seas. These data buoys have sensors to measure wind speed and direction, air pressure , air temperature, sea surface temperature, current speed and current direction and wave parameters. The buoys are equipped with Global Positioning System, beacon light and satellite transceiver. Few of these buoys are fitted with sensors to measure radioactivity, turbidity, chlorophyll, hydrocarbons and dissolved oxygen.

Daily data at 3 GMT are being sent to India Meteorological Department (IMD) and Coast Guard. Monthly data are being disseminated to Naval Hydrographic Office, ports (wherever the buoys, are deployed). Data is also being supplied to National Institute of Oceanography, Centre for

Atmospheric and Oceanic Science, IISC and other Oceanographic, Research and Academic institutions against their specific project requirements. Buoys' data have played an important role in weather prediction by IMD, particularly during the recent depression and cyclonic storm in Indian seas. During 1998-99 eight re-deployment, eight retrieval and eleven maintenance operations have been carried out.

To augment the ocean observations about 48 drifting buoys will be deployed at periodical intervals over in Ninth Plan period. The buoys so deployed will generate *in-situ* data, as well as validate the satellite data. During 1998-99, 15 drifting buoys with sensors for Sea Surface Temperature and barometric pressure, were deployed in the Indian ocean raising number of drifting buoys to 24 during the last two years.

The Sea Level Monitoring project envisages assessment of variations in the sea level due to climatic and other factors and impact of such variations on the Indian coastal belt. Under this project, eight modern tide gauge stations have been established at Mumbai, Porbander, Goa, Kochi, Chennai, Visakhapatnam, Paradeep and Kavaratti and two more tide gauges will be deployed at Machilipatnam and Tuticorin. The National Tide Data Centre at Survey of India, Dehradun has analysed the data generated and developed a numerical model to simulate ocean circulation in the Northern Indian Ocean.

OCEAN INFORMATION SERVICES

In order to effectively generate ocean data products and disseminate them on operational basis, an Indian National Centre for Ocean Information Services (INCOIS) was set up at Hyderabad in February 1999 as an autonomous society under the Department of Ocean Development. Near real-time data and data products such as Sea Surface Temperature (SST) and Potential Fishing Zone (PFZ) advisories, upwelling zones, maps, eddies, chlorophyll, suspended sediment load, coastal maps, etc., and need based ocean information consultancy services to the corporate sector, Central and State government agencies will be available under one roof. The Marine Data Centres (MDCs) which were set up under DOD's National Ocean Information System (NOIS) Programme have been integrated with OIS. During 1998-99, generation and dissemination of SST and PFZ to 170 fish landing centres were continued. Also validation campaign of Modular Optoelectronic Scanner (MOS) algorithms for retrieval of chlorophyll data from the Indian ocean useful for validation campaign of the to-be launched Oceansat satellite, were continued.

SATELLITE COASTAL AND OCEANOGRAPHIC RESEACH

The programme envisages development of algorithms, models and related capability for an operational retrieval of met-ocean parameters from satellite sensor. Satellilte Coastal and Oceanographic Research (SATORE) programme will be relevant in the development of oceanic parameter retrieval techniques, study of Ocean processes and model forcing functions, studies on bathymetry, marine atmosphere and boundary layer, Antarctic snow/ice sheet, biological oceanography and coastal environment, and data assimilation for numerical models and forecasting.

Scientific and Technological Developments

OCEAN MODELLING AND DYNAMICS

Knowledge of ocean dynamics is a prerequisite for prediction of ocean state based on ocean models. During 1998-99, dynamics of marine ecosystem and air-sea exchange of carbon dioxide were studied using Modular Ocean Model. Air-sea interaction process for monsoon prediction was studied using ocean-atmosphere coupled model. A storm surge prediction model for estimating inland inundation in Andhra coast was developed and a seven component Nitrogen-based Ecosystem Model completed. The expenditure incurred for OOIS programme during 1998-99 was Rs 13.373 crore.

MARINE ENVIRONMENT AND COASTAL ZONE

To monitor the levels of various marine pollutants in the coastal and offshore waters of the country, a multi-institutional programme called Coastal Ocean Monitoring and Prediction Systems (COMAPS) is under implementation. A Centre for Marine Analytical Reference and Standards has been established at Regional Research Laboratory, Thiruvananthapuram. The Department proposed to develop, jointly with CPCB, a coastal action plan for the control of coastal pollution from the land based activities. The expenditure incurred for COMAPS programme during 1998-99 was Rs 1,498 crore.

COASTAL RESEARCH VESSELS

Two Coastal Research Vessels (CRVs) namely *Sagar Purvi* and *Sagar Paschimi* acquired by DOD during 1996-97 for collection of samples from the coastal areas for monitoring the pollution levels in different points, are being managed by a Vessels Management Call set up in the National Institute of Ocean Technology, Chennai. During 1998-99, both these vessels being used by 12 major National Laboratories for their work have successfully completed 28 cruises covering about 160 sampling stations. Another 10 cruises are likely to be carried out by these vessels in March 1999. The critical marine habitat and delicate environment of coral reefs at Lakshadweep were monitored with the help of *Sagar Paschimi*. *Sagar Paschimi* was also charted for 11 days by IPSEM, ONGC for oilrig monitoring work. CRVs were also used to collect data on coastal currents, sea bottom and wave parameters for the Pennar Refinery Project. Construction of a multipurpose building for storage, etc., at the land allotted by Chennai Port Trust is underway. The expenditure incurred for CRVs during 1998-99 was Rs 2.50 crore.

INTEGRATED COSTAL AND MARINE AREA MANAGEMENT

Integrated Coastal and Marine Area Management (ICMAM) plans are designed to provide data and decision support for the management of resources of the coastal zone and islands and their environment. The Department has taken up an infrastructure development and capacity building programme to facilitate adoption of the concept of ICMAM in the coming years. The programme focusses on development of expertise in ICMAM oriented activities and dissemination of knowledge gained to the users like coastal States through organised training programmes. An expenditure of Rs 5.815 crore was incurred for ICMAM programme during 1998-99.

Scientific and Technological Developments

MARINE RESEARCH AND CAPACITY BUILDING

The Department has been implementing the Marine Research and Manpower Development Programmes with active participation of educational institutions, National R&D laboratories, etc. The objective is to encourage research in coastal engineering , marine chemistry , marine biology and microbiology, pharmacology, coastal zone management, exploration and exploitation of marine resources, etc., to create infrastructure facilities in universities/ institutions/organisations and to generate specialist manpower in ocean sector. For promotion of front-ranking research in Ocean Science and Technology and related human resources development three more Ocean Science and Technology Cells (OSTCs), in addition to the five OSTCs set up during 1997-98, were added at Tamil University, Thanjavur (Beach Placers), Annamalai University, Chidambaram (Marine Biology) and Cochin University of S&T, Kochi (Marine Benthos). The expenditure incurred on marine research and capacity building was Rs 3.121 crore during 1998-99.

COASTAL COMMUNITY PROGRAMMES

SHORE TO FISHING VESSEL COMMUNICATION SYSTEM

Phase-II of the Shore to Fishing Vessel Communication System envisages the establishment of shore stations in 10 placs, *viz,*. Shankarpur and Frasergunj in West Bengal; Paradeep and Chandipur in Orissa; Worli and Mirkarwada in Maharashtra; Salegao in North Goa; Marine Hill-Port Blair in A and N Islands; Periya Veerampattinam in Pondicherry and Minicoy in Lakshadweep. The two shore stations in Orissa were handed over to the local authorities and four more will be handed over by the end of 1998-99. In Maharashtra, A&N Islands and Lakshadweep the construction work is under completion. An expenditure of Rs 6.60 lakh was incurred for this programme during 1998-99.

ISLAND DEVELOPMENT PROGRAMME

The Ninth Five Year Plan programme for island development envisages demonstration of technology having a bearing on the socio-economic aspects of the island community. The new programmes proposed to be implemented include development of technologies for augmenting the stock of commercial finfish and shellfish species, marine ornamental fishes, sea weed, etc., introduction of physical oceanographic studies in the island groups as a part of the ongoing programme on pollution monitoring under the Coastal Ocean Monitoring and Prediction System; setting up of tide gauges for measuring the tidal fluctuations and sea level rise, etc. In addition, the ongoing programmes on rejuvenation of coral reefs; monitoring of pollution in different transects already identified in and around Port Blair providing laboratory facilities for research in various disciplines of marine science, etc., were continued. In March 1998, the Department approved a multi-institutional project for Enhancement of Marine Living Resources through lobster rearing and fattening at a total coast of Rs 133.24 lakh, for implementation through NIOT. This programme is aimed at developing viable technologies for enhancement of the lobster resources in the island groups. The project is expected to benefit about 500 island families and produce about 100 tonnes of live lobsters for export. An expenditure of

Rs 1.24 crore was incurred on the programme during 1998-99.

INTERNATIONAL PROGRAMMES

THE LAW OF THE SEA

The Department of Ocean Development is the nodal agency for implementation of the provisions of United Nations Convention on the Law of the Sea (UNCLOS), in India, which establishes the framework and mechanisms for management of oceans.

In accordance with the provisions of UNCLOS, States are entitled to delineate the outer limits of the continental shelf beyond 200 nautical miles of Exclusive Economic Zone (EEZ) and are required to submit data for a claim within ten years from the date of retification. The delineation of the continental margin in case of India is likely to give an additional area of about one million sq km outside the EEZ. This area is rich in non-living resources. It will be possible for India to lay submarine cables and pipelines which are important for the communication purposes in the additional area. For this the existing data were consolidated and the quantum of work identified. The indicative foot of the slope map off West Coast and East Coast was reconciled. The Baseline Survey is being continued by National Hydrographic Office. The department vessel *ORV Sagar Kanya* covered a total of 2,212 nautical miles of cruise lines in Arabian Sea off Goa during April-May 1998 for acquisition of bathymetric data.

ANTARCTIC PROGRAMME

India acquired consultative status in the Antarctic Treaty System in 1983 and is a member of various international bodies affiliated to it. India has been able to decisively influence the outcome of the negotiations leading to the adoption of the Protocol on Environmental Protection to Antarctica.

The Department undertakes a balanced and optimum programme of contemporary science through which it has been possible to maintain an active and influential presence in the Antarctica. The scientific contents, ensure national priorities and also contribute to global issues. Over the years, there has been a distinct impetus on scientific objective resulting in an increase in the scientific component over the logistics. Further, in order to play a perceptible role in Antarctic sciences, a distinct thrust has been provided to bi-multilateral scientific cooperation by way of participation in international scientific campaigns addressing pertinent global issues.

UNDERWATER TECHNOLOGY

A Memorandum of Understanding was signed between DOD and the Russian Academy of Sciences in January 1999 for undertaking joint technology development programmes/projects in the field of deep sea exploration/ exploitation and relevant instrumentation, particularly in the context of mining nodules from a depth of 6,000 m from the Indian mining site at the Central Indian Ocean Basin. Joint technology development, design and manufacture of underwater marine submersibles and the other equipment between institutions in India and Russia and assisted by industries for oceanographic research and exploration has been envisaged in this cooperation.

Scientific and Technological Developments

INTER-GOVERNMENTAL OCEANOGRAPHIC COMMISSION

Established in 1960 under UNESCO, Inter-governmental Oceanographic Commission (IOC) is promoting marine scientific investigations, ocean services and capacity building in developing countries through the concerted efforts of the 124 member states. India is one of the Vice-Chairperson of IOC. India is a contributor to the cause of the international cooperation in oceanographic science and services.

The IOCINDIO is a regional body of IOC for the Central Indian Ocean. IOCINDIO promotes marine scientific investigations and provides co-operation among the Member States relating to ocean research and services. As a part of regional cooperation between IOC nations, an Iranian scientist participated in the 18th Antarctic Expedition. An amount of Rs 49.7 lakh was spent on international cooperation during 1998-99.

NATIONAL INSTITUTE OF OCEAN TECHNOLOGY

The National Institute of Ocean Technology (NIOT) was established in November 1993 as a registered society under the administrative control of the Department of Ocean Development with a view to developing technology relevant to ocean sector. NIOT is also rendering consultancy services to Industry. NIOT is currently implementing major time-bound user oriented technology missions, such as, Ocean Energy, Deep Sea Technology and Ocean Mining, Coastal and Environmental Engineering and Marine Instrumentation. The major achievement of NIOT so far has been development of a new generation power module required for wave energy applications. Through intensive design and modelling an impulse turbine with self-pitching linked guide blades has been designed fabricated and tested for a wide range of parameter. The new power module has been installed in the Wave energy plant. As a result of growth of coastal mega-cities; coastal processes, projects and structures forming part of the essential infrastructure are gaining increasing attentions. Exploration and exploitation of the marine resources, both living and non-living, is unthinkable without acoustic instruments. Acoustic Tide Gauges (ATG) developed and successfully tested in the laboratory are undergoing field trials.

DESIGN AND DEVELOPMENT OF ACOUSTIC TIDE GAUGE

Acoustic Tide Gauge (ATG) electronic hardware components have been built in-house. Dedicated signal processing systems have been developed. The whole system has been designed as a stand-alone system and can hold one month's tidal. Data can be down-loaded to a laptop or desk-top computer through a serial port. A novel calibration technique using quarter wave tubes as side branches has also been developed by NIOT to minimize errors due to temperature effects. This version has a fairly good signal to noise ratio.

Field trials of the first prototype of ATG took place at Chennai Port duirng November 1997. The data collected using the ATG by NIOT has been verified with that collected by using a mechanical tide gauge. The agreement between both the data collected is very good. The prototype II with improved features is under development.

Scientific and Technological Developments

REMOTELY OPERABLE SEA SKIMMER

The objective of the project was to design, develop and fabricate a prototype Remotely Operable Sea Skimmer (ROSS) module with environmental sensor and under radio control from a stationary ship or shore. This will enable rapid acquistion of biological and physical variables that are commonly measured in oceanography. The National Institute of Oceanography (NIO), Goa was entrusted with the task of developing the concept, mission software, etc. The IIT, Chennai, was entrusted with the task of development of a stable, unsinkable hull. The full scale hull module has been tested for its hydrodynamic properties. A joystick controller has also been tested. A GPS card for finding out the position of the platfrom has been acquired and is being integrated into the system. The mission software is also being developed and tested.

TECHNOLOGY DEVELOPMENT FOR MULTILAYER CURRENT MEASUREMENT

A three-component multilayer Perforated Ball Velocity Meter (PBVM) has been developed. This will be useful in collecting information about wave currents and water particle kinematics. Ten strain gauge cantilever arms with perforated balls, which form the main component of PVBM current meter, have been fabricated and tested in laboratory. Software to compute the velocities from the measured forces was also developed and tested. The laboratory model has been demonstrated at the wave basin. The project has been completed in March 1998 with the making of a spare unit and to formulate a proposal for a hand held portable velocity meter for field use.

BIOTECHNOLOGY

With the advent of recombinant DNA technique and understanding at the cellular and molecular level of the structure and function, it is now possible to harness the genetic diversity in the living organisms for the manufacture of useful products and production of novel microbes, plants and animals with improved qualities. The Department of Biotechnology, under the Ministry of Science and Technology in 1986 has promoted and accelerated the pace of development of biotechnology in the country. Through more than 1,000 R&D projects, demonstrations and creation of infrastructural facilities, the impact of the biotechnology related developments in agriculture, health care, environment and industry, has already been visible and the efforts are now cluminating into products and processes. More than 5,000 research publications, 4,000 post-doctoral students, 24 technologies transferred to industries and 41 patents filed including six US patents can be considered as a modest beginning. The Department of Biotechnology (DBT) has been interacting with more than 5,000 scientists per year in order to utilise the existing expertise of the universities and other national laboratories. There has been close interaction with the State governments particularly through State S and T Council for developing biotechnology application projects, demonstration of proven technologies, and training of human resource in States/UTs. Programmes with the states of Gujarat, Rajasthan, Madhya Pradesh, Orissa, West Bengal, Haryana, Punjab, Jammu and Kashmir, Mizoram, Andhra Pradesh and Uttar Pradesh have been evolved. Biotechnology Application Centres in Madhya Pradesh and West Bengal have

been started.

HUMAN RESOURCE DEVELOPMENT

An integrated Human Resource Development Programme has been implemented to generate adequate appropriate trained personnel in the area of biotechnology. The post-graduate, post-doctoral, post-MD/MS programme is being implemented in 26 universities. About 400 students are admitted annually and so far 4,300 students have graduated. Annually 10-15 Overseas associateships and 20 National associateships are awarded for research in modern biology in foreign and Indian laboratories respectively. Other programmes supported every year include seminars, symposia, lectures and short-term training courses. Incentives and awards have been given to eminent scientists/researchers for promotion of biotechnology research. Ten National Bioscience awards for career development have been instituted for young bioscientists below 45 years and three special awards for women scientists have been instituted. The department also participated in exhibitions both in India and abroad highlighting the achievements in biotechnology in India.

INFRASTRUCTURE FACILITIES

In most advanced areas of modern biology and biotechnology, the infrastructure facilities have been a tremendous boost for R and D and Services. The National Facility for Microbial Type Culture Collection (MTCC) at Institute of Microbial Technology, Chandigarh conserves more than 10,000 industrial microbes; National Facility for Blue Green Algae (BGA) Collection at Indian Agricultural Research Institute, New Delhi possesses about 750 blue green algae; National Facility for Marine Cynobacteria at Bharatidasan University, Trichurapalli stores more than 300 strains of marine cyanobacteria collected from Indian sea shores; National Facility for Plant Tissue Culture Repository at NBPGR, Pusa, New Delhi has 850 *in vitri* conserved crop species; laboratory Animal House Facilities at Central Drug Research Institute (CDRI), Lucknow and National Institute of Nutrition (NIN), Hyderabad have supplied 80,000 and 55,000 experimental animals; Centre for Genetic Engineering and strain manipulation at Madurai Kamraj University, Madurai works on streptomycin group of antibiotics; and the Biochemical Engineering Research and Process Development Centre at IMTECH, Chandigarh helps in testing and standardisation of high value metabolites in large bioreactors for commercial feasibility studies. The new Repositories namely Repository on Cryopreservation of blood cells at Indian Institute of Haematology, Mumbai, Repository on Medicinal and Aromatic Plant materials at Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow and Repository on Filaria and reagents, MGIMS, Sevagram have started functioning since last year on similar lines. Thousands of scientists, students, and industries are regularly indenting the services of these facilities.

Under this scheme, support is provided for establishment of progamme based facilities and centres of excellence in various areas of advanced biotechnology and modern biology. Such centres would undertake basic research in modern biology leading to specific products and processes through team work and also serve as National infrastructure facility extending services to the scientific community. At the Indian Institute of

Science, Bangalore, a major programme support in the high priority areas of modern biology was launched for a period of five years involving 55 faculty members to carry out research on three sub-programme : infectious diseases, drug and molecular design as well as genome diversity and genetic disorders. The programmes support is expected to deliver products/ processes such as reagents of permanent value for disease diagnosis, prevention, prophylaxis, drug designing and therapeutics for genetic disorders.

BIOTECHNOLOGY INFORMATION NETWORK

To fulfil the growing need for latest information, a Biotechnology Information Network (BTISNET) has been established. It works as a distributed database and network organisation to provide an integrated information resource on all aspects of Biotechnology. The BTISNET provides bioinformatics and biocomputing services to the researchers and manufacturing activities. The services include analysis of biological data, bibliographic information on published literature, software development for computationally intensive problems in biology such as molecular modelling and simulation, genome mapping, structure-function determination, structure-based drug design, structure alignment and comparison, structure prediction, molecular evolution, gene identification, etc. The BTISNET comprises ten Distributed Information Centres (DICs) and thirty-eight Distributed Information Sub-Centres (DISCs) spread across the country at various institutions and universities. The Apex centre at the department provides facilities for Patent Search in Biotechnology over internet. The DICs are being networked through Ku-Band VSATs of NICNET for the high-speed communication connectivity to internet as well as BTISNET. A mirror-site on European Molecular Biology Network (EMBnet) is being established at the Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad to serve the needs of national users. A new component on bioinformatics R and D activities has been introduced to support product-oriented bioinformatics research. Training courses are organised every year on bioinformatics. To generate manpower on bioinformatics, one-year advanced diploma courses in Bioinformatics are being conducted at Madurai Kamaraj University, Madurai and University of Poona, Pune under this programme.

In the area of molecular and structural biology, six national facilities have been established on Interactive Graphics based molecular modelling at the Indian Institute of Science, Bangalore; Madurai Kamraj University, Madurai; Centre for Cellular and Molecular Biology, Hyderabad; University of Poona, Pune, Bose Institute, Calcutta and Jawahar Lal Nehru University, New Delhi. These facilities provide Silicon Graphics based high-performance computing environment for molecular visualisation to researchers in modern biology/biotechnology. R and D projects leading to development of hardware and software solutions/tools for biologists have also been funded. An indigenous software package for molecular modelling on a PC based desk top computer has been developed by C-DAC to provide an economically priced package for use by students in colleges/homes.

BIOTECH RESEARCH

The Department has launched the following four National *Jai Vigyan* Science and Technology Missions: (i) Development of new generation vaccines for

infectious diseases: this project aims to develop new generation vaccines as a component in the health care system of the country. The different products targets are: recombinant cholera and rabies vaccine, tissue culture based JEV vaccine, peptide based malaria vaccine, recombinant proteins for malaria and intensifying R&D for development of vaccine for HIV infection. These have been identified based on the research leads; (ii) Biotechnological approaches for coffee improvement : A Network Programme on Coffee Biotechnology to manage and improve all aspects related to Coffee improvement using molecular biology tools; (iii) Biotechnological approaches towards herbal product development : the project aims at development of value added herbal drugs from the leads already available from the traditional system of medicine. The end products would be: two immunomodulators, improved strain of *Artemisia* spp, anti-arthritis agent and improved ergot production technology and (iv) setting up of mirror sites for genomic research. The programme provides the tools for genomic research based on the increasing convergence of trends and dependence of genomic research on bioinformatics by setting up of mirror sites of protein (PDB) and genome (GDB) database, plant genome databases, databases of EBI, electronic databases and software on public domain for biological research.

CROP BIOTECHNOLOGY

Seven Centres for Plant Molecular Biology (CPMB) established with a thrust on R and D activities and training on modern areas of plant molecular biology have made significant progress. Two multi-institutional projects; (i) the development of transgenic cotton resistant to insect pests and (ii) quality improvement in wheat, were also launched. The Indian Council of Agricultural Research has been closely associated in prioritising and initiating all these programmes. Significant results in case of transgenic plants which are now being field tested are available, for example tobacco, mustard, chickpea and rice. Cloning and sequencing of at least six genes related to storage proteins, disease and pest resistance has been achieved. Transgenics of mustard, tobacco and chick pea are being evaluated for field demonstrations. A major break-through has been in wheat where high frequency eproducible regeneration of plants from several cultivated varieties was achieved and more than 200 plants have been transferred to field conditions at the University of Rajasthan, Jaipur.

BIOFERTILIZERS

The Mission Mode Project on "Technology Development and Demonstration of Biofertilisers-Blue Green Algae (including Azolla) and Rhizobium" and 30 R and D projects have been supported; large scale production technologies have been developed and standardised for indoor and outdoor production of BGA. Alternate carrier materials like rice/wheat/maize straw, sugarcane waste, coir dust and rice husk have been successfully introduced. Polyalkene bio-reactors have been used for scaling up of genetically pure cultures. For popularising use of biofertilisers, 7,000 experimental demonstrations were conducted and about 6,000 farmers were trained in the use of blue green algae and rhizobium. About 250 training programmes have been conducted. The increase in paddy yield due to application of blue green algae ranged from 13-16.67 per cent whereas in pluses and oil seeds, application of rhizobium resulted in yield increase in the range of 5-13.5 per cent. Mass

production technology of Mycorrhiza, a biofertiliser developed by Tata Energy Research Institute, New Delhi has been transferred to M/s. Cadila Pharmaceuticals Limited.

BIOCONTROL AGENTS

Eight new bio-pesticides have been developed and two pilot plants are producing bio-control agents for use by the farmers, catering to the needs of about 0.224 million hectares. An area of 55,000 hectares has been covered in various field crops for demonstrating the use of bio-control agents. About 20,000 farmers benefitted by attending the on-sight training programmes and extension activities. The technologies for mass production of candidate biocontrol agents-baculovirus, parasites, predators, antagonistics, fungi and bacteria for economically important crops have been transferred to industries.

TREE AND WOODY SPECIES-TISSUE CULTURE

Through the establishment of two tissue culture pilot plants at National Chemical Laboratory (NCL), Pune and Tata Energy Research Institute, (TERI), New Delhi, nearly 4.0 million plant-lets of eucalyptus, popular, teak, bamboos and anogysia (desert teak) have been field demonstrated in 3,500 hectares covering 17 states. Micro-propagation technology parks established at these pilot plants are serving as platform for effective transfer of technology to the entrepreneurs; training of manpower and demonstration of technology for mass multiplication of horticulture and forestry species. Tissue culture production protocols for regeneration have been perfected for coffee, tea, pepper, cocoa and with very good leads in mango. In citrus varieties, disease free planting material has been produced. Tissue culture raised elite vanilla and large cardamom are being demonstrated for their improved perfromance in 38 hectares and 70 hectares respectively. Two Micropropagation Technology Parks at National Chemical Laboratory, Pune and Tata Energy Research Institute, New Delhi have been established.

BIOPROSPECTING

India is a mega diversity centre and has enormous biological wealth with two hot spots in the north-east Himalayas and south-western *Ghats*. In view of the immense biological wealth marked by the eco-system, species and genetic diversity which constitute potential resource base for bioprospecting and sustainable development, an initiative has been taken to launch a major programme on bioprospecting Accordingly, a multi-institutional collaborative programme has been evolved for characterisation, inventorisation and conservation of the bio-diversity of different eco-geographical regions and prospecting of genes and bio-molecules. The programme initiated in October 1997 involves nine major and four collaborating institutions. The Department of Space has been very closely associated to help in the remote sensing and satellite imaging of the identified areas.

MEDICINAL AND AROMATIC SPECIES

The efforts have been devoted in two directions : conservation of the genetic wealth and improvement of medicinal plants/products through the intervention of biotechnology. Three National Gene Banks (NGBs) have been established at Tropical Botanical Garden and Research Institute,

Thiruvananthapuram, National Bureau of Plant Genetic Resources, New Delhi, and CIMAP, Lucknow for the conservation of our rich germplasm wealth in respect of medicinal and aromatic species. These are equipped with field banks, seed banks and *in vitro/cryo-preservation* facilities. The Department of Biotechnology (DBT) is the nodal agency for the establishment of a network of gene banks among G-15 countries; it is also co-ordinating the work of Asian Region and is the over all co-ordinator for the programme. The DBT published the first four numbers of the network newsletter. Besides, inventories of medicinal and aromatic plants of India and Indonesia have also been brought out. A study of the immunomodulatory agents from certain plants reputed in Ayurveda has resulted in the isolation and purification of biologically active compounds from *Piper longum* and *Curcuma longa* with distinct anti-bacterial activity. Chemical structure of these has been worked out. Using chemicals and irradiation, distinct mutant of *Catharanthus* with greater content of total alkaloids have been isolated. Hairy root induction on rhizome with *Agro-bacterium rhizo-genes* has shown promising leads.

SERIBIOTECHNOLOGY

The Department in association with the Central Silk Board (CSB) has identified thrust areas in sericulture (both mulberry and non-mulberry) in which biotechnology can play a vital role in increasing productivity, enhancing quality of silk and bringing about improvement of host plants. Towards the integrated management to control uzifly, a serious pest of silkworm, it was demonstrated that two components *viz.*, spraying benzoic acid and release of an insect parasitoid which parasites on uzifly can be successfully integrated for the effective suppression of uzi menace at farmer's level. Immunodiagnostic tests have been developed for early detection of pebrine and nuclear polyhedrosis disease of silkworm. Large scale field evaluation of these tests are being carried out to make them more specific and sensitive. Several artificial diet fromulations for rearing of silkworm larvae have been developed and are being tested at laboratory level. A transgenic silk worm has been produced. For construction of the molecular genetic map, a silkworm genome project has been initiated.

ANIMAL BIOTECHNOLOGY

Programme on embryo transfer, nutrition, health, diagnosis, vaccines, leather biotechnology, etc., have given promising results. Projects in upstream areas of embryo transfer towards improvement of the various techniques resulted in development and field testing. DNA markers for sex determination of embryos during embryo transfer. This technology is now a customised service. Embryo transfer work has been taken up in goats and camels. Embryo sexing was done using bovine specific primers.

The development of Immunodiagnostics for Rinderpest, Johne's disease, blue tongue virus, duck-plague virus, and *Bacillus* anthracites, etc., Collagen sheets developed for wound healing application taken up for clinical trials have been successful. Projects were implemented on management of wastes in leather industry. Parentage determination and genetic characterisation of indigenous breeds, and allele frequencies of breeds have been studied. The regional centres at Bidaj, Nasik, Salon and Nekkarikallu continued embryo production and supply to the 14 State Centres located

in different parts of the country. Cows generated through embryo transfer <+> came into production (3,000-6,000) liters per lactation. Embryo of two indigenous breeds, Kankrej and Ongole were collected. Under the Open Nucleus Breeding Scheme, male calves were being genetically evaluated. These bulls would be supplying quality semen for the National artificial insemination programmes. Production units were established at Nagpur and Chennai at the level of enterpreneurs. Towards alleviation of diseases in animals and aquaculture, major projects for development of vaccines and diagnostics have been undertaken. All validation trials have been completed accordingly for tissue culture based vaccine for new castle (Raniket) disease in poultry and infectious bovine rhinotrachietis (IBR) disease of cattle. The technology transfer is being effected by NRDC, New Delhi.

AQUACULTURE AND MARINE BIOTECHNOLOGY

For detection of bacteria associated with food, dairy products and infected fish diagnostic kits have been developed. Immunostimulants useful in shrimp management are being evaluated. Mantle tissue culture technology has been developed to produce *in vitro* marine pearls. Genomic library for Catla has been generated and screening of the library for useful genes is underway. Under the mission mode Prawn aquaculture project, a grow out operation carried out at a farm in Eastern M.P. achieved one to 1.5 tonnes per hectare production in 6-7 months. Hatchery technology developed at National Institute of Oceanography, Goa is ready for technology transfer to industries.

BIODIVERSITY CONSERVATION AND ENVIRONMENT

Specific application of biotechnology for the protection of environment and conservation of biodiversity have given significant results. Four technologies for environmental monitoring based on DNA probes and ELISA technique have been developed each in the area of detection of Entamoeba, pathogenic viruses, and organo-phosphate pesticide residues in drinking water. The technology for precombustion biobenefication of coal containing high pyritic sulphur and ash and precombustion desulphurisation of gaseous fuels and emissions containing hydrogen sulphide with concomitant recovery of elemental sulphur has been transferred to industry. Restoration of manganese and coal-mine spoil dumps using biotechnological approaches in holistic manner is in progress at Gumgaon mines of Manganese Ore India Limited and Dongribuzreg Mines near Nagpur. A spectacular regeneration of forest cover has been achieved. An integrated biotechnological approach has been adopted for bio-remediation of mine spoil dump on large scale.

Efforts have been made to apply biotechnological tools successfully for the conservation of endangered plant species which are of economic and medicinal importance. To start with, the Red Data Book of BSI has been the reference point to develop research projects. The techniques for extraction of nuclear DNA have been standardised. Tissue culture techniques have been developed for 11 endangered mangrove species available in southern coastal eco-system. Complete molecular characterisation of endangered mangroves of eastern and western *ghats* was accomplished. Tissue culture protocol for Jojoda has been perfected and the tissue culture raised plants are being field planted for the sand dune stabilisation. An important work was to establish nursery to raise the plants of Indian Desert. Germ plasm of rare desert plants

has been collected from Barmer, Jaisalmer, Jodhpur, Pali and Nagpur for conservation.

MEDICAL BIOTECHNOLOGY

The main emphasis in the health care system has been on early diagnosis, prophylaxis and therapeutics in relation to communicable and non-communicable diseases covering tuberculosis, malaria, filariasis, diarrhoeal diseases, viral hepatitis, cancer, genetic disorders neurosciences. A mission like approach to develop cholera vaccine by employing molecular biology and recombinant technologies has been a major breakthrough in development of candidate vaccine strain and validation of this vaccine in Phase-I trials in three different hospitals is undergoing. The "LEPROVAC", a chemotherapeutic immuno-modulator, *i.e.,* leprosy vaccine developed at National Institute of Immunology (NII) is now being produced commercially. Amphotercin B encapsulated liposomes for the treatment of systematic fungal infection has been trasferred to industry.

Indigenous AIDS diagnostics have been successfully developed, validated and transferred to indsutry. An ELISA system using synthetic peptides for HIV I and II, Chimeric monoclonal reagents to detect HIV I and II in a drop of blood and western immuno blot assay have been developed and are ready for commercialisation. In addition, immunoassays and molecular probes have been developed for typhoid, filaria, leishmaniasis, TB, hepatitis A,B, and C, rabies, toxoplasmosis, amoebiasis, cerebral malaria and aspergellosis. A diagnostic kit for leishmaniasis developed at the Central Drug Research Centre (CDRI), Lucknow is being marketed by M/s Span Diagnostics. A genetically modified candidate cholera organism has been used for development of cholera vaccine. The phase-1 human volunteer trails completed recording no side effects and reactogenecity. An anti IGm ELISA kit for a hepatitis A has been developed at National Institute of Virology, Pune and anti body detection kit for aspergelosis developed at Centre for Biochemical Technology, New Delhi. AIIMS, New Delhi; Tuberculosis Centre, New Delhi; CDRI, Lucknow and JALMA, Agra have jointly developed a PCR, based diagnosis systems for tuberculosis.

Bharat Immunologicals and Biologicals Corporation Limited (BIBCOL), a public sector company to manufacture 100 million doses of Oral Polio Vaccine (OPV) and other immunobiologicals has implemented Phase-I activity and bottled many batches of OPV from imported bulk after the quality of the vaccine was tested at National Quality Control Laboratory at CRI, Kasauli. The 33 million doses have been supplied to the National Immunisation Programme. Phase-II activities *i.e.,* indigenous production of OPV from primary cell culture have been initiated. Under Indo-US Vaccine Action Programme progress has been made under some of the projects implemented in the area of viral Hepatitis C and B, cholera, typhoid, polio, rotaviral diarrhoea, *E. coli* diarrhoea, and tuberculosis. Candidate vaccine strain against rotaviral diarrhoea has been patented and has received approval from FDA for development of prototype vaccine for field trials.

HUMAN GENETICS AND GENOME ANALYSIS

Fourteen genetic clinics, established for molecular diagnosis and counselling for the common genetic disorders like beta-thalassemia, Duchenne Muscular

Dystrophy (DMD) and other haemoglobinopathies prevalent in the country are providing prenatal diagnosis and counselling to the affected families. A major project on genome diversity to study for the first time the genetic variations among different population groups was initiated in the country. A programme on "Functional genomics" with an objective to develop technological capability and provide assistance to clinical scientists has been launched at Centre for Biochemical Technology, New Delhi. It aims at identifying novel mutations in Indian population in known genetic desorders like beta-thalassemia, Down syndrome and other mental retardations, DMD, myotonic dystrophy, spinocerebellar ataxia, etc., and develop novel diagnostics.

FOOD BIOTECHNOLOGY

Several research projects oriented toward product/process development are being implemented. In an inter-institutional R and D programme low cost nutrient supplement for malnourished children has been launched. Protocols have been standardised for detection of food toxicants, pesticide residues, contaminants and for colour leaching from plastic containers. Protocols for production of Biodegradable eco-friendly packaging films for preservation of fresh fruits and vegetables and processed foods were developed and tested for their perfromance. These films extend the shelf-life of fruits and vegetables by 21 days at ambient temperature and over 40 days at cold storage temperature. A national food safety facility at Central Food Technology Research Institute (CFTRI), Mysore has been established. A low cost nutrient supplement for malnourished children using biotechnological approaches, developed jointly by these institutes was releases on 14 November 1998. This can provide 4000 k. cal. to school children.

MICROBIAL BIOTECHNOLOGY

Technology development for microbial enzymes active in extreme temperatures, novel antibiotics, bioactive proteins and other bio-molecules have been undertaken for industrial use. Emphasis has been on development of separation and purification technologies, automation, bio-process optimization, downstream processing and bioreactor design in food and allied industries. The demonstration projects on mine dumps and recovery of gold from refractory ore have been initiated.

INTELLECTUAL PROPERTY RIGHTS BIOSAFETY AND BIOPRODUCTS

The Department has been instrumental in encouraging and supporting scientists to file patents for protecting inventions in biotechnology. Biosafety guidelines in r-DNA research are strictly followed through Institutional Biosafety Committee , RCGM and GEAC mechanisms. So far 102 Institutional Biosafety Committees have been constituted in different universities, national institutions and industries. During the year, nine patent applications were filed in India and two applications were filed for patent protection in foreign counties, and two US patents and one Indian Patent were granted on the inventions made by Indian investigators. Besides, the National Institute of Immunology has been granted two foreign patents and has applied for five foreign and four Indian patents. A separate " Patent Facilitating Cell" has been established. On National Technology Day - 11 May 1999 - the technologies were formally announced for LEPROVAC and HIV kits.

Biotechnology-Based Programmes for Society : The department is also implementing several programmes to provide benefits of biotechnological processes and techniques to SC/ST populations, women and rural society. Projects on training, field demonstration and extension - oriented activities on proven technologies/processes are implemented so that technology transfer could be done effectively among the target population of the society. The programme aims to increase the skills and income in addition to their present occupation. Universities, other institutions, *Krishi Vigyan Kendras*, NGOs, voluntary organisations and national laboratories are the implementing agencies.

For the benefit of SC/ST population and weaker sections, 30 demonstration-cum-extension type projects were implemented in the area of mushroom cultivation, vermicomposting, poultry, biofertilizer, sericulture, acquaculture and medicinal and aromatic plants. About 15,000 persons benefited in terms of training, employment, improved nutrition and health status. The foundation stone for Golden Jubilee Women's Biotechnology Park was inaugurated on 29 July 1998 at Chennai. The concept behind this is that the park would act as a joint venture enterprise with the State government where individual entrepreneurs would be shareholders. The financial institutions are expected to contribute in this venture.

INTERNATIONAL COLLABORATION

The ongoing bilateral programmes with Germany, Israel, Switzerland, Sweden, UK and USA have progressed well. New programmes are being developed with these countries and other countries including Egypt, France, Japan, Khazakistan, Poland, Russia, Sri Lanka and Tunisia. Interactions have been made with Australia, Brazil, Hungary, Mexico, Norway, Romania and Slovenia.

Under multilateral collaboration, for cooperation amongst SAARC countries a proposal from the government of India on SAARC Biotechnology Council is under consideration. Specific programmes of cooperation with ASEAN countries in the area of plant Biotechnology and ETT have been developed. The UNDP-FAO funded project on Farmer Central Agriculture Resources Management (FARM) continued successfully. The Department of Biotechnology has been assigned the main responsibility of providing technical support for biotechnology and bioinfromatics activities in all eight member countries. Successful demonstration of proven technologies has been conducted. All the member countries have been linked through the Internet. A data base of technology packages is being prepared. A separate Home Page for FARM has been released on the Internet. A UNDP-GOI funded project on Jute Biotechnology is being implemented at five institutes. DBT is the main coordinating agency. The programme aims at the characterisation of the jute germplasm and hybridisation breeding of transgenic jute resistant to disease.

INSTITUTIONS DEVOTED TO BIOTECHNOLOGY

The Department of Biotechnology has established three autonomous institutions, *i.e.,* National Institute of Immunology (NII), New Delhi, National Centre for Cell Science (NCCS) and Centre for DNA Fingerprinting Diagnostics (CDFD) at Hyderabad. Two new centres namely National Brain Research

Centre (NBRC) and National Centre for Plant Genome Research (NCPGR) have been approved to be set up in Delhi.

The National Institute of Immunology, New Delhi (NII), a premier institution has a mandate to conduct research in immunological defence mechanisms of the body in order to facilitate development of innovative prophylactic, diagnostic and theraputic measures for the health care delivery. The Institute has focused its research activities on immunology and molecular biology, reproductive biology, communicable diseases and disagnostics. From an initial collection of about 20 immunoconjugates, the reagent bank today has expanded its inventory to 110 reagents.

The National Centre for Cell Science (NCCS) has been involved in cell repository and supply of cell lines. The objectives have been to maintain, identify, store, propagate and supply human and animal cell lines, establishment of technology for collection, maintenance and supply of various human organs like cornea, skin, bone-marrow. It also imparts specialized training and laboratory facilities to the scientists and researchers. About 189 research teams from 65 laboratories and institutions are benefited by the cell culture supply service. So far, more the 4,000 cultures have been sent to different laboratories across the country. A total of 58 vectors, plasmids, DNA probes and genomic libraries are stocked in the cell repository. More than 26 different synthetic media, balanced salt solutions and tissue cultures reagents were prepared.

The Centre has developed a method to grow large sheets of skin from small pieces removed from the unaffected areas. In collaboration with health institutes such as K.E.M Hospital, Pune and Mumbai and I.T.T.M.M.C & Hospital, Mumbai, such cultured epithelia sheets have been grafted to more than 85 patients successfully. The technology has been transferred to more hospitals. The NCCS has also perfected a technology to preserve the bone marrow cells and stem cells over longer period of time by freezing in liquid nitrogen. The Centre has transferred the cryopreservation technology for bone marrow and stem cells and for healing the burn cases by skin culture to various hospitals.

Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad has mandate to do DNA Profiling and related analysis with application in crime investigation, research and development in the area of DNA fingerprinting and DNA diagnostics. So far more than 270 cases of DNA fingerprinting were dealt with and 175 cases received for molecular diagnosis.

The National Brain Research Centre, New Delhi has started functioning. It will coordinate the research activities and also initiate newer areas including learning, memory, ageing, artificial intelligence and develop diagnostics and therapeutics for mental diseases and disorders. The objective is to do both fundamental and applied research on identified aspects of plant genome, in order is isolate important genes and manipulate these for generating transgenic plants with improved agronomic characters and pathogens/stress resistance.

Scientific and Technological Developments

The objective of establishing National Centre for Plant Genome Research at Jawahar Lal Nehru University, New Delhi is to do both fundamental and applied research on identified aspects of plant genome, in order to isolate important genes and manipulate these for generating transgenic plants with improved agronomic characters and pathogens/stress resistance.

The Government has approved the establishment of National Bioresource Development Board (NBDB) New Delhi. The objective of NBDB is sustainable utilisation of biodiversity of the country employing biotechnology tools and techniques.

CHRONOLOGICAL HIGHLIGHTS

1942 Council of Scientifc and Industrial Research constituted as an autonomous society

1971 The Department of Science & Technology set up (May)

1982 National Science & Technology Entrepreneurship Development Board established (January)

1996 Technology Development Board constituted (September)

1998 National Accreditation Board for Testing and Calibration Laboratories registered as a society (12 August)

ATOMIC ENERGY

1948 Atomic Energy Commission established (10 August)

1956 Department of Atomic Energy established

1956 India's first reactor *Apsara* built indigenously

1957 Bhabha Atomic Research Centre set up at Mumbai

1962 First Heavy Water Plant set up at Nangal, Punjab

1969 Tarapur Atomic Power Station becomes operational

1971 Indira Gandhi Centre for Atomic Research set up at Kalpakkam

1972 1st unit of Atomic Power Station at Rawatbhatta commissioned

1974 First peaceful underground explosion conducted at Pokhran (18 May)

1984 Centre for Advanced Technology set up at Indore

1986 1st indigenously built & designed reactor commissioned at Kalpakkam (March)

1998 Five underground nuclear tests conducted at Pokharan (11 & 13 May)

SPACE PROGRAMME

1962 Indian National Committee for Space Research (INCOSPAR) formed and work on establishing Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram began

1963 First sounding rocket launched from TERLS (21 November)

1965 Space Science & Technology Centre established in Thumba

1967 Satellite Telecommunication Earth Station set up at Ahmadabad

1972 Space Commission and Department of Space set up

1975 First Indian Satellite *Aryabhat* launched (19 April)

Scientific and Technological Developments

1976	Satellite Instructional Television Experiment (SITE) conducted
1979	Bhaskara-1, an experimental satellite launched
—	First Experimental launch of SLV-3 with *Rohini* satellite on board failed
1980	Second Experimental launch of SLV-3 with *Rohini* satellite successfully placed in orbit.
1981	APPLE, an experimental geo-stationary communication satellite successfully launched
—	*Bhaskara-II* launched (November)
1982	INSAT-1A launched (April), deactivated in September
1983	Second launch of SLV-3. RS-D2 placed in orbit
—	INSAT-1B launched
1984	Indo-Soviet manned space mission (April)
1987	ASLV with SROSS-1 satellite on board launched
1988	First Indian Remote Sensing Satellite, IRS-1A launched
—	INSAT-1C launched (July). Abandoned in November
1990	INSAT-1D launched successfully
1991	Launch of second operational Remote Sensing Satellite, IRS-1B (August)
1992	Third Developmental launch of ASLV with SROCC-C on board (May). Satellite placed in orbit
—	First indigenously built satellite INSAT-2A launched successfully
1993	INSAT-2B launched successfully (July)
	First developmental launch of PSLV with IRS-1E on board fails
1994	Fourth developmental launch of ASLV successful (May)
—	Second developmental launched of PSLV with IRS-P2 successfully (October)
1995	INSAT-2C launched in December
—	Third operational Indian Remote Sensing Satellite launched
1996	Third developmental launch of PSLV with IRS-P3 successful (March)
1997	INSAT-2D launched in June, becomes inoperational in October
—	ARABSAT-1C, since renamed INSAT-2DT, acquired in November
—	First operational launch of PSLV with IRS-1D successful (September)
1999	INSAT-2E launched successfully (May)
—	IRS-P4 launched by indigenously built PSLV-C2 vehicles

OCEAN DEVELOPMENT

1966	National Institute of Oceanography established in New Delhi under CSIR
1981	Department of Ocean Development created
—	First expedition to Antarctica
1984-85	First supply station, *Dakshin Gangotri* established in Antarctica
1987	India becomes the first country in world to register as the pioneer investors in polymetallic nodules
1988	*Matrai*, the first permanent station established in Antarctica
1991	National project on drugs from sea taken up by the Department of Ocean Development
1993	National Institute of Ocean Technology established in Chennai
1995	UN convention on laws of the seas ratified by India
1996	Two coastal research vessels *Sagar Purvi* and Sagar Paschimi inducted to facilitate seismic research in Ocean Development