19

Science and Technology

19.1 The Eleventh Plan accorded high priority for investments in science and technology (S&T) to derive maximum benefits for society and for knowledge generation for capacity building. The major priorities of the Eleventh Plan for the science and technology sector are as follows:

- Setting up a national-level mechanism for evolving policies and providing direction to basic research
- Enlarging the pool of scientific manpower, strengthening the S&T infrastructure, and attracting and retaining young people in careers in science
- Implementing selected national flagship programmes, which have a direct bearing on the technological competitiveness of the country in a mission mode
- Establishing globally competitive research facilities and Centres of Excellence (CoEs)
- Developing new models of PPP in higher education, particularly for research in universities and high technology areas
- New ways and means of catalysing industry-academy collaborations
- Promoting strong collaborations with advanced countries, including participating in mega international science

19.2 Significant initiatives/contributions have been made for each of these priority areas. A detailed account of these is provided in Appendix 19.1.

19.3 The pattern of utilization of funds in the six S&T departments at the mid-term stage of the Eleventh Plan indicates a healthy trend. Total Plan allocation during the first four years was Rs 41,477 crore and anticipated expenditure by all the six S&T departments put together is Rs 37,562 crore. Thus, the overall utilization capacity of the S&T sector was about 91 per cent. The financial performance of the six S&T departments during the first four years of the Eleventh Plan is given in Annexure 19.2.

19.4 Performance highlights, achievements, new initiatives proposed, and important issues in various areas of scientific research and technology development are given in the following section.

NUCLEAR RESEARCH

19.5 The objective of nuclear research is to meet the technological requirements of the country and to build self-reliance in all aspects of the nuclear fuel cycle. Indigenous technologies for Pressurized Heavy Water Reactors (PHWRs) are now in the commercial domain and the current approach is of developing fast breeder reactor and thorium technologies. Emphasis is on peer review of projects on a continuous basis, human resource development, and encouraging students to carry out research on the interface of science and engineering. All efforts are being made to develop new techniques for exploration and deploying known techniques extensively for uranium exploration. The

focus is also on developing metallic fuels with short doubling time for use in fast breeder reactors.

19.6 The Indira Gandhi Centre for Atomic Research (IGCAR) and the Bhabha Atomic Research Centre (BARC) have developed indigenous the Time Domain Electromagnetic (TDEM) system for airborne surveys to locate deep-seated uranium deposits. Uranium investigation in the Proteozoic basins has been completed. Other major achievements include the development of: (i) BARC Containment Model (BARCOM) of 540 MWe PHWR at Tarapur, the largest nuclear containment model in the world for ultimate load capacity assessment; (ii) special material for Light Water Reactor (LWR); (iii) 50 L/hr fluidized de-nitration plant; (iv) process for the recovery of radio-isotopes for application in radio-pharmaceuticals; (v) prototype magnetic crawler robot for in-service inspection of boiler tubes at thermal power plants; and establishing Indian Environmental Radiation Monitoring Network (IERMON) stations at 84 locations.

19.7 In the area of Fast Breeder Reactors (FBRs), alloy characterization facility for fast reactor fuels, CNC plasma cutting machines, adiabatic calorimeter, fuel cell and argon glove box for sodium chemistry studies, and ultra filtration units for separation of strontium, cesium, lanthanides, and actinides from simulated wastes have been commissioned. Robotic device for in-service inspection and indigenous SPIDER ROBOT for steam generator tube inspection have also been developed.

19.8 In the area of thorium fuel cycle development various activities, such as assessment of critical power of Advanced Heavy Water Reactor (AHWR); installation of a test facility to check the performance of the passive containment isolation system; accelerated ageing and corrosion studies for base and weld material of the Primary Heat Transport (PHT) system of AHWR; development of copper vapour laser for U^{233} cleanup; and development of Lead-Bismuth Eutectic (LBE) loop for Accelerator Driven Systems (ADSs) have been taken up.

19.9 Several other advanced technologies like critical facility for the validation of physics design of AHWR and PHWR; low-power Diode-Pumped Solid-State Laser (DPSSL); and Pumped Dye Laser for isotope selective material processing, trace analysis, and other spectroscopic applications have been developed. Cobalt Tele-Therapy Machines Bhabhatrons have been established in various hospitals in India; 29 hospitals, including seven from the North-East and two in foreign countries have been connected with the Tata Memorial Hospital through the telemedicine network.

19.10 In the area of basic research a software for LHC Computing Grid (LCG) of the European Organization for Nuclear Research (CERN) has been developed and a high performance cluster computer system has been commissioned. The other major achievements include: (i) installation of a system for producing hard coatings; (ii) plasma ion immersion implantation system for plasma surface modification; (iii) commissioning of all the Muon Chambers of 2nd tracking station of Muon Spectrometer as part of ALICE (A Large Ion Collider Experiment) operations; (iv) mounting of all the Multiple Analog Signal (MANAS) processor chips (a total of 68,750); (v) commissioning of the Dimuon high level trigger; and (vi) establishing four new laboratories for structural biology work. Under the Research and Education Linkages Programme, activities relating to the establishing of an advanced digital library at IGCAR; setting up the National Institute for Science Education and Research (NISER) at Bhubaneswar; and University of Mumbai-Department of Atomic Energy CoE in Basic Sciences (UM-DAE CBS) at Mumbai have been taken up. A new training school complex at Anushakti Nagar, Mumbai has been established; while a common facilities building, which will house Low Energy High Intensity Proton Accelerator (LEHIPA) and fuel cell facility is under construction at Trombay.

Mid-Course Corrections

19.11 The department has proposed taking up 18 new projects during the remaining two years of the Eleventh Plan in order to strengthen the nuclear programme with an outlay of Rs 643 crore. Some of the major new projects include: (i) External Engineering Utility Services at BARC-Vizag and the International Centre for Theoretical Sciences (ICTS) at Tata Institute of Fundamental Research (TIFR), (ii) establishing infrastructural facilities at Chennai by IGCAR;

(iii) developing LEHIPA for front end of ADS driver at BARC, (iv) renovation/upgradation of 20-year-old buildings under Directorate of Construction, Services & Estate Management (DCS&EM); (v) augmentation of infrastructure facilities—Phase II of Institute of Mathematical Sciences (IMSc) campus; (vi) new campus of TIFR at Hyderabad; (vii) imaging services and additional facilities at TMC; and (viii) setting up of a cancer hospital at Vizag. In addition, three other new projects with an outlay of Rs 160 crore were introduced during the first year of the Eleventh Plan. These are: (i) Indian participation and utilization of Jules Horowitz Reactor, Cadarache, France, (ii) DAE University Institute of Chemical Technology (UICT) Centre for Chemical Engineering Education and Research; and (iii) management development.

19.12 In order to ensure a steady supply of radio-isotopes for medical and industrial applications and also for developing custom-built radio-isotopes for specific applications, the department may consider setting up dedicated reactors, which can provide radio-isotopes, both for domestic needs as well as for exports.

19.13 There is a need to encourage nuclear research in universities and other academic institutions. Therefore, establishing small research reactors in universities may also be supported.

19.14 CoEs in the field of nuclear science may also be established to enable the international scientific community to work jointly with Indian scientists in the field of nuclear science and engineering.

19.15 The department needs to give greater thrust to the dissemination of various spin-off technologies developed by it, which have direct social relevance, especially the tele-cobalt therapy Bhabhatron machine for treatment of cancer, the sewage sludge hygenization technology and NISARGRUNA, a biogas plant based on bio-degradable waste.

SPACE SCIENCE & TECHNOLOGY

19.16 The thrust of the space programme during the Eleventh Plan period has been on developing critical technologies for the human space flight programme and next generation launch vehicle; augmentation of state-of-the-art space segment; ensuring continuity of data through constellation of earth observation satellites; undertaking space science and planetary exploration; strengthening space-based disaster management support; and societal applications of space technology.

19.17 The most significant achievement was the successful launch of India's first unmanned moon mission Chandrayaan-1, on 22 October 2008, thereby achieving the historic feat of placing the Indian tri-colour on 14 November 2008 on the moon's surface. The deep space network with two large antennae (18 metre and 32 metre diameter) with associated ground segment was established in Bylalu, near Bangalore to provide Tele-Tracking Control (TTC) support for the mission. Excellent quality high resolution data from Chandrayaan-1 has led to the identification of new lunar features and characteristics and environmental factors around the moon. An analysis of the scientific data has led to the detection of water molecules and rocks on the lunar surface.

19.18 Twelve major space missions were successfully accomplished, which included six launch vehicle missions with the Polar Satellite Launch Vehicle (PSLV) and the Geosynchronous Satellite Launch Vehicle (GSLV) and six satellite missions. The important missions include the launch of (i) ten satellites, including Cartosat-2A and IMS-1 in a single launch of PSLV C9; (ii) Microwave Radar Satellite RISAT-2 (procured from Israel) and Mini Satellite ANUSAT onboard PSLV-C12; (iii) high power satellite INSAT-4CR onboard GSLV F04; (iv) launch and operation of Oceansat-2 satellite along with six nano satellites (commercial) onboard India's PSLV C14; (v) conducting a qualification test of indigenously developed cryogenic stage; (vi) building a state-of-the-art communication satellite (W2M) for an European customer; (vii) establishing GEO and GPS Augmented Navigation System (GAGAN); and (viii) commercial launches for international customers (AGILE and TECSAR). Setting up of an Indian Institute of Space Science and Technology for developing critical human resources for space S&T has been yet another major milestone. Significant progress has been made towards developing GSLV Mk III, the next generation advanced launch vehicle. A world-class solid propellant plant

has been successfully commissioned at the Satish Dhawan Space Centre, Sriharikota (SDSC-SHAR), for manufacturing large solid stage booster segments (S-200) for GSLV Mk III vehicles.

19.19 Significant developments have taken place in the area of societal applications of space technology. Some of the important ones are: (i) expansion of tele-education over 35,000 classrooms; (ii) telemedicine facility in 375 hospitals; (iii) setting up of 470 Village Resource Centres (VRCs); (iv) location of drinking water sources using Indian Remote Sensing (IRS) satellite images covering more than 2 lakh habitations in ten states; (v) wasteland mapping of the whole country using IRS data; and (vi) biodiversity characterization of bio-rich areas of the country

19.20 Several missions have been targeted for the remaining period of the Eleventh Plan. The significant ones among them include: (a) third development flight of GSLV D3 (fitted with indigenous Cryo stage) and launching the GSAT-4 satellite; (b) launch and operation of Resourcesat-2 and Youthsat onboard PSLV C16; (c) launch and operationalization of Cartosat-2B and the commercial launch of ALSAT-2 onboard PSLV C15; (d) development flight and operationlization of the GSLV Mk III; (e) launch and operationalization of the microwave remote sensing radar satellite RISAT-1 with day and night all-weather imaging capability onboard PSLV; (f) augmentation of the INSAT/GSAT system with the launch of six satellites together adding about 100 transponders to the INSAT system; and (g) realization of advanced meteorological satellite INSAT-3D with six channels imager and 19 channels sounder for launch onboard GSLV. It has also been planned to upgrade the Very Large Scale Integration (VLSI) fabrication facility at the Semi Conductor Laboratory (SCL), Chandigarh, from 0.8 micron capability to better than 0.25 micron capability, to meet the VLSI device requirements of strategic sectors.

19.21 The broad directions for the space programme for the next decade would include: (i) operational services in communications and navigation; (ii) developing enhanced imaging capability for natural resource management, weather, and climate change studies; (iii) space science missions for better understanding of the solar system and the universe; (iv) planetary exploratory missions; (v) development of heavy lift launcher, reusable launch vehicles; and (vi) the human space flight programme. Innovations in space-based communications and earth observations will be pursued to achieve faster delivery of information to remote areas and finer observations of the earth.

Mid-Course Corrections

19.22 The Human Spaceflight Programme (HSP) involves developing several new technologies, such as life support systems, aerospace medicine, space suits, and crew training. This is the first of its kind programme. The overall development, system realization, and complexity of efforts required for HSP are several orders of magnitude higher than the missions realized so far by the Department of Space. There is a need to address issues relating to networking of institutions from various fields within the country, decisions on buy or make options, international cooperation, human resource requirements, including training needs, and harnessing industry and academia support for effective realization of HSP. It is, therefore, planned to realize the HSP in phases with focus on developing critical technologies in the first phase.

19.23 The Department of Space is unable to provide high resolution data in time to concerned users due to restrictive processes. Since RSDP, 2001, significant advances have taken place in the remote sensing technology and associated geo-spatial tools like Google Earth. Therefore, suitable mechanisms need to be created and the policy needs to be revisited to consider whether high resolution data (at least up to 2.5 metre resolution) can be made available to users in a timely manner.

19.24 Further, ISRO has successfully demonstrated several applications of space technology for societal benefits, specifically tele-education, telemedicine, and VRCs. The pilot phase of these applications has been completed. In the context of large-scale expansion of these applications on an operational basis, ISRO would essentially be a 'technology and bandwidth provider' and the responsibility for implementing

will rest with the respective state governments and central ministries. An institutional mechanism would, therefore, be required for the implementation of these applications by networking state governments, central ministries, NGOs/VOs, and planning authorities supported with an appropriate policy framework.

19.25 A major challenge in the coming years will be meeting the enhanced throughput requirement of satellites and launch vehicles. From 20 missions (launch vehicle and satellite missions) in the Tenth Plan, the demand in the Eleventh Plan is to realize 60 missions. For ISRO to retain an R&D character at the organization level, it is important to farm out production jobs to industries. Good progress has been made in this direction, especially in the launch vehicle area. Today 40 per cent of the space budget flows to Indian industries. However, to meet the demands for space services projected for the Eleventh Plan and beyond, a three-pronged strategy may be necessary: (a) enhancing the throughput capacity of the industries already involved in space technology and also identifying and developing new industries to take up production jobs for ISRO, (b) farming-out higher level of production aggregates/systems to Indian industries, and (c) encouraging industries to take up specific development initiatives of relevance to ISRO. Strategies to achieve a quantum jump in Industry participation may, therefore, be worked out in the coming years.

19.26 Space science research/planetary exploration has been an important component of the Indian Space Programme and several missions including Chandrayaan-2 and ASTROSAT have been planned in the coming years. Akin to this, a major challenge lies in creating a human resource base in the country for analysing the enormous amount of scientific data that would be available from these missions. There is a need to adopt aggressive measures in this direction to ensure availability of scientists in the area of space science and planetary exploration.

BIOTECHNOLOGY

19.27 Several new activities have been initiated during the Eleventh Plan to promote biotechnology research. New institutions in basic and applied research are being established to address areas which are vital to India's progress. Six new institutions in the areas of stem cell, agri-food biotechnology, animal biotechnology, health science, genomics and biotechnology, training and education are at various stages of establishment. In addition, two more institutions in the areas of seri-biotechnology and marine biotechnology and three molecular medicine centres are proposed to be established. It is also proposed to establish the Biotechnology Regulatory Authority of India. These institutions have been designed with a strong bias for integrating science and translational research and are aimed at producing skilled personnel driven towards entrepreneurship. Cluster development is a key strategy for promoting innovation and hastening technology and product development. Three clusters, one each at Faridabad, Mohali, and Bangalore are being actively pursued.

19.28 Besides the seven existing autonomous institutions under the Department of Biotechnology, the Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram was recently taken over from the government of Kerala. These institutes have generated 429 publications in SCI journals, 24 patents were granted/filed, while nine patents are in the pipeline; and 13 technologies were developed/transferred to the industry.

19.29 Establishing biotechnology parks has also been supported to facilitate small and medium enterprises in translational research, product advancement and innovation, and to produce biotech entrepreneurs. The state governments are also making earnest efforts to promote biotechnology activities by setting up biotechnology parks and incubators, as well as pilot projects through PPP. A biotechnology park in Hyderabad has become operational and the contract has been awarded to M/s Allexendria. A promoter for a food biotech park at Mohali has also been identified. The Himachal Pradesh Biotechnology Park is negotiating with a nano-science company for finalizing the design. The IIT Guwahati biotech incubator is progressing well and seed money has been provided for the Orissa Biotechnology Park. In addition, a technology platform for idea generation (in collaboration with FICCI) has been established with three platforms in

the field of agriculture biotechnology, implants and devices, and biopharmaceuticals.

19.30 In order to ensure a steady flow of young scientists and technologists in the life science sector, ongoing postgraduate teaching programmes in different areas of biotechnology were continued at 62 universities, besides starting these programmes in eight new universities. Thirty-five star undergraduate colleges were identified and funded for imparting quality education at the graduate level. The number of fellowships for PhD have also been increased from 100 per year to 250 per year, besides the 100 post-doctoral and 50 biotechnology overseas associateships that are given. This has resulted in a 20 per cent increase in the number of PhDs in the life science area. Twenty-one candidates were selected for overseas specialized training in niche areas of biotechnology. In addition, training was provided to 665 postgraduate students in 185 companies out of which 27 per cent have been absorbed by the industry. A major initiative has also been taken up in North-East (NE) to promote life science education with biotech emphasis at higher and secondary levels. A Stanford-India bio-design programme has been launched for leadership training in biomedical technology innovation to develop next generation innovators and entrepreneurs. A re-entry R&D fellowship grant has also been started in collaboration with Wellcome Trust, UK and nine fellows have already been selected. In addition, 35 fellows have been selected for Ramalingaswami Fellowships.

19.31 Twelve CoEs have been established in the areas of Hepatitis 'C'; cancer biology; silkworm genomics; microbial biology; stem cell research; basic and translational R&D; genome science and predictive medicine; genome mapping; and molecular breeding of brassicas. Programme-based R&D support was also provided in 28 different areas including, translational research on eye diseases, chronic diseases, genetic medicine, tissue engineering, and therapeutic proteins. Some of the important breakthroughs achieved include development of small anti-viral peptides against the Hepatitis C virus; design of inhibitors to work as anti-microbial and anti-malarial agents; identification of protein and peptide vaccine candidates for filariasis; and development of transgenic silkworm lines resistant to baculovirus.

19.32 A legal framework in the form of 'The Protection and Utilization of Public Funded Intellectual Property Bill, 2008', is in the process of approval. The Bill aims at promoting innovation and patenting on a benefit sharing pattern between innovators and institutions.

19.33 Establishing research resources and facilities has also been undertaken to promote research and education. The Department of Biotechnology-International Crops Research Institute for the Semi-Arid Tropics (DBT-ICRISAT) platform for translational research on transgenic crops started operations for facilitating contract R&D on validation, regulatory tests, and commercialization of agri-biotechnology products. A national certification system for tissue culture raised plants has also been evolved. Synchrotron X-ray beam line (BM14) was acquired at the European Synchrotron Research Facility, France, for macromolecular crystallography and was made available to 130 Indian scientists. In addition, establishing of several other biotech facilities has been initiated, which include stem cell research facility at AIIMS and CMC Vellore, primate animal research facility at National Institute of Immunology (NII), national plant gene repository at NIPGR, aerosol containment facility at NII, and core immunology laboratory to evaluate vaccine elicited immune responses in HIV/AIDS at ICGEB.

19.34 As a participant in the international rice genome sequencing programme, Indian laboratories sequenced 16 Mb of chromosome 11 (against a target of 14 Mb) containing 1,443 genes out of a total of 3,754 genes present in rice genome. India became a partner in the International Cancer Genome Consortium (ICGC) with commitments of eight countries and 11 funding organizations.

19.35 In the field of vaccines and diagnostics, Phase-II clinical trials of the rotaviral vaccine have been completed and preparation for Phase-III trials are progressing well. The cell bank and technology

for production of recombinant malaria vaccine were transferred to BBIL, Hyderabad, for developing a master cell bank. A novel candidate for the dengue vaccine was developed and expressed in the yeast and purified to near homogeneity in high yields. This 'know-how' is being transferred to an industry partner in India for further development. Several other vaccines relating to Japanese encephalitis, rabies, typhoid, leprosy, anthrax, cholera, infectious bovine rhinotracheitis, and DNA vaccine against the brucella disease of livestock are at different stages of trials. At least four vaccines are likely to be commercialized by 2012 and India is fast developing into a vaccine manufacturing hub.

19.36 Systematic basic and translational research in stem cell biology started in the Eleventh Plan. Noteworthy leads in R&D include: (i) four human embryonic stem cell lines; (ii) immortalized breast stem cell lines with the potential to continuously initiate mammospheres; and (iii) a simple and rapid method for the isolation of cardiomyocytes from neonatal mice heart and their maintenance in primary cultures. A Phase-I clinical study on acute myocardial infarction using autologous bone marrow mononuclear cells, was carried out at five hospitals in the country involving the Clinical Research Organization (CRO). India along with seven other countries is now a part of the Stem Cell Network on Asia Pacific (SNAP).

19.37 Seven grand challenge programmes were launched in the areas of microbial prospecting of genes and molecules, vaccines, food science and nutrition, accelerated molecular breeding, biodesign, genomics and bioenergy, and biofuels.

19.38 Some of the early leads from the Small Business Innovation Research Initiative (SBIRI) include a silk protein blend film-for burn wound management (patent filed); a homologous natural bio-material for treating cancer lesions, and burn wounds (patent filed); and technology for nitrifying bioreactor for organic re-circulation in the prawn seed production system (in fish farms). A new scheme, the Biotechnology Industry Partnership Programme (BIPP) was launched in 2008 as a viability gap funding scheme on a cost sharing basis. The objective of this scheme is to achieve competitiveness in frontier biotechnologies and to fill the viability gap in the development of high risk futuristic technologies.

Mid-Course Corrections

19.39 Basic R&D support was centred on genomics, RNA biology, proteomics, systems biology, stem cell biology, and nanosciences. Although initiatives were taken, greater emphasis is needed for emerging research in metabolomics, computational biology, synthetic biology, and novel animal models.

19.40 There is a need to vigorously pursue programmes for creating an innovation eco-system through focused investments in biodesign programme; the programme on molecular diagnostics through biodesign; new institutions and operationalization of incubators, clusters, and other centres; support to inter-disciplinary life science research with mission mode R&D in universities, IITs, IISERs, and NIPERs; developing the HIV vaccine; setting up of drug discovery and genomics centres; DBT: Welcome Trust Joint Programme for R&D on Affordable Healthcare; and expanding existing research institutions. Mega R&D projects involving an inter-institutional network around big challenges and modern technological opportunities in tuberculosis, malaria, influenza, HIV, animal/zoonatic diseases, molecular breeding in specific crops for drought and salinity, biofuels and bioenergy, implants and devices and environmental technologies also need to be supported. In addition, a novel molecular imaging programme and development of platforms for personalized medicine may be taken up.

19.41 Department of Biotechnology and ICAR need to intensify collaboration to ensure synergy in their activities and to accelerate transfer of technology to the field. A major collaborative initiative at the national level is needed for improving agriculture productivity, particularly under unfavourable climatic situations like drought and climate change, predominantly for rainfed areas. An agri-biotech entrepreneurship programme similar to the Stanford Biodesign programme needs to be started and an agri-biotech policy and communication centre may be set up.

BASIC RESEARCH AND TECHNOLOGY DEVELOPMENT

19.42 The Science and Engineering Research Council (SERC) is the single largest scheme for promoting basic research in the country and through its support, on an average, about 1,200 research papers are published annually with an average impact factor of about 2.2 per paper. With a view to increase the speed and flexibility of funding research projects, the government has approved the establishment of the Science and Engineering Research Board (SERB) as an autonomous funding body. As many as 71 institutes including universities/colleges were supported during 2007–08 and another 145 in 2008–09 under the Fund for improvement of S&T Infrastructure in Universities and Higher Educational Institutes (FIST) programme for improving their S&T infrastructure. Special packages have been developed for strengthening S&T infrastructure in colleges in the North-Eastern region and in Jammu and Kashmir. This programme has enabled departments in academic institutions to install some of the state-of-the-art R&D facilities. A third party review of FIST has revealed that there was a substantial increase in the number of research publications and enrolment in MTech and PhD programmes and a three-fold increase in the generation of funds through consultancy in engineering departments. The pace of financial deliveries for EMR projects has also doubled since the Tenth Plan period.

19.43 With a view to widen the base of R&D in the country and to attract the best available talent to pursue research as a career, 72 JC Bose National Fellowships, 14 Ramanujan Fellowships, 19 Ramanna Fellowships, and 144 BOYSCAST Fellowships were awarded during 2007–09. A research incentive grant system has been mounted for the university sector based on evidence of scientific publications—Promotion of University Research and Scientific Excellence (PURSE). In addition, a special initiative, Consolidation of University Research, Innovation, and Excellence (CURIE) has been launched to improve the R&D infrastructure of women universities. The Women Scientist Scheme has facilitated a number of women scientists in returning to mainstream science and technology. Under the National Science and Technology Management Information System (NSTMIS), publications on R&D statistics at a glance; R&D statistics 2007–08; funding pattern of sponsored research by scientific agencies; and analysis of outcomes of extramural R&D projects have been brought out.

19.44 The Technology Development Programme (TDP) has been reoriented to build convergent solutions rather than technology demonstration. Demonstration of technologies to the ultimate users under real life conditions enables migration and flow of technologies from sources to the places of need. Several technologies aimed at specific end use have been developed, which include atmospheric plasma processing system for angora wool, arsenic removal technology using the microbial–cum-adsorbent route, and ceramic membrane-reverse osmosis based iron removal plant for removal of iron and salinity in drinking water. Under the Science and Technology Advisory Committee/Inter-Sectoral Science and Technology Advisory Committee (STAC/IS-STAC) Joint Technology Programme, a pilot plant for CO_2 capture has been commissioned and several other projects on carbon sequestration have been supported.

19.45 The Survey of India has developed a database in 3D GIS for a 20 sq. km area in Chandni Chowk, Delhi and handed it over to the Municipal Corporation for using it for applications like property tax collections, traffic management, disaster management, and change detections in buildings. Seeing its success, the government of the National Capital Territory has approved a major project to replicate the methodology to cover the entire capital in the next 18 months. Further, the National Spatial Data Infrastructure has been established.

19.46 A community of 600 researchers has been nurtured in the country under the Nano Mission and approximately 1,000 students are doing their PhDs in nano sciences with access to state-of-the-art facilities in the country and abroad. Over 1,500 publications in leading journals have so far been published. A total of 65 R&D projects in different areas of nano science and technology and six joint Industry-academia/national lab R&D projects focusing on applications of nano technology were supported during 2007–09.

Establishing the Institute of Nano Science and Technology at Mohali; clean room facilities at IISc, Bangalore; Ultra High Resolution Aberration Corrected Transmission Electron Microscope (TEM) at Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bangalore; Centre for Knowledge Management of Nano Science and Technology (CKMNT) at ARCI, Hyderabad; and strengthening of computational facilities at IUAC, New Delhi have also been taken up. In addition, an India-Japan beam line was established for nano materials research at the Photon Factory at KEK, Tsukuba, Japan. One more beam line equivalent is being sanctioned for assured access by Indian scientists at the PETRA-III synchrotron radiation facility at DESY-nano-sized x-ray source. Steps have also been taken to establish two new institutes for nano science and technology in Bangalore and Kolkata. However, loans to industries for product-specific projects have not been sanctioned so far. New ways to disburse such soft loans are being discussed and finalized.

19.47 There has been a paradigm shift in the Drugs and Pharmaceutical Research Programme during the Eleventh Plan and a new dimension of giving grants-in-aid to industry for R&D on neglected diseases like malaria and kala-azar has been added to this programme. Thirteen collaborative R&D projects with leading industries are being implemented. Several new facilities like the National Biosafety Level 4 (BSL4) facility for infectious diseases at the Council of Scientific and Industrial Research-Centre for Cellular and Molecular Biology (CSIR-CCMB) and clinical research facility to develop stem cell technologies and regenerative medicine have been sanctioned. The programme has resulted in filing of ten product patents. Some of the important products that have been developed include: (i) BONISTA for osteoporosis; (ii) RECEPTOL for the management of HIV/AIDS; and (iii) RHOCLONE for Hemolytic Disease of the New Born (HDN). Several industrial leads on psoriasis, migraine, malaria, and anti-glaucoma are being taken up for different phases (Phase I, II, and III) of clinical trials.

19.48 A major programme was initiated for attracting talent in science and for nurturing students right from the school level. The programme comprises of three components: (i) Scheme for Early Attraction of Talent (SEAT), (ii) Scholarships for Higher Education in Science (SHE), and (iii) Assured Opportunity for Research Careers (AORC). Selection of 1,500 SHE fellows has been completed for 2007–08 and 2008–09. Full scale expansion of SHE is expected in 2010–11. Innovation in Scientific Pursuit for Inspired Research (INSPIRE) Internship and INSPIRE fellowship schemes have been announced and the implementation of the INSPIRE faculty scheme is planned for 2010–11.

19.49 State Science and Technology Councils provide important links to the Department of Science and Technology (DST) for state bound actions. DST provides core funding support to the state S&T Councils. Additional support was also provided to the councils for undertaking projects for field trials/demonstration of technologies developed by national laboratories like plastic and hospital waste disposal demonstration plants based on indigenously developed plasma incineration technologies, ceramic membranes based plant for removal of iron from water, and 1 tonne seeds per day, 250 lpd capacity biodiesel plant.

Mid-Course Corrections

19.50 The DST has been entrusted with the responsibility of coordinating two out of the eight National Missions on Climate Change under the National Action Plan on Climate Change (NAPCC): (i) National Mission for Sustaining the Himalayan Eco-system; and (ii) National Mission on Strategic Knowledge for Climate Change. Both these missions are proposed to be taken up under the ongoing TDP for which an additional fund requirement of Rs 225 crore will be accommodated within the overall Eleventh Plan allocation for the department.

19.51 Recognizing that the government has established the Department of Pharmaceuticals for the promotion and coordination of basic and applied research in areas related to the pharmaceutical sector, the Pharmaceutical Research and Development Programme, presently being pursued by DST would be transferred to Department of Pharmaceuticals at the end of Eleventh Plan.

19.52 State S&T Councils in most states need to be strengthened in terms of human and financial resources to meet state-specific technological needs and to integrate S&T with the state development process. DST linkages with the states also need to be strengthened several fold.

19.53 Keeping in view that significant technology development has already taken place, the National Mission on Bamboo Applications (NMBA) may be wound up by the end of the Eleventh Plan and may be integrated with the overall National Bamboo Mission being implemented by the Department of Agriculture Cooperation.

19.54 Establishment of SERB was approved by the government in May 2008. This will subsume the activities hitherto being carried out by SERC. However, SERB is yet to be formally constituted. DST needs to take necessary action to operationalize SERB in a definite time frame.

19.55 As a directional change in the Mid-Term Appraisal, there is a need to segregate the funding and developmental roles of DST. While SERB would primarily focus on funding and implementation of R&D projects, the focus of DST would be on developmental and policy interventions like expansion of FIST for inclusive development of special regions, PURSE, and CURIE type programmes.

19.56 Focus of the Technology Development and Demonstration programme would have to move from demonstration to convergent solutions in priority areas like energy, water, environment, security technologies, and biomedical devices and instrumentation.

19.57 Aided institutions would focus on synergy and consolidation in their domain areas of strength; and leadership building in astronomy and astrophysics, materials science and technology; and other areas of national need like biomedical devices and instrumentation, and the climate change agenda of the country in assessing the changes on account of natural and emission related causes. There is a need to relate their investments to SCI publication outputs and other eminence indicators.

19.58 As the S&T sector is cutting across all other socio-economic sectors, there is a need to create a mechanism for promoting R&D and for providing technological inputs in the implementation of various projects/programmes by various socio-economic ministries/departments.

19.59 The DST being the nodal department for promoting high end basic research, it is important that it reduces the time lag between the receipt of research proposal and release of first instalment to about five months. For this purpose, DST may adopt online monitoring of all the research proposals. It would also be useful to take a comprehensive review of all the projects funded by DST during the last five years in terms of their rate of success in achieving the desired objectives.

SCIENTIFIC AND INDUSTRIAL RESEARCH

19.60 Under the Technology Promotion Development and Utilization (TPDU) programme, recognition was granted to 200 in-house R&D units of industry along with certification of an investment of Rs 940 crore by in-house R&D units as eligible for weighted tax deduction at 150 per cent. Support was also extended to 125 innovator's projects (TePP projects), 28 TePP outreach centres, and 11 new technology development and demonstration projects. Some of the other achievements include establishing a technology management chair, developing a database on exportable projects, support to consultancy clinics, and developing a S&T portal.

19.61 The Consultancy Development Centre has taken up studies on the potential of consultancy export and consultancy development and promotion. Besides, a database on 15,000 professionals/experts has been developed, and five issues of the journal 'Consulting Ahead' were brought out. In addition, 370 professionals were trained through educational programmes and 205 professionals were trained through capacity building programmes.

19.62 Central Electronics Limited (CEL) has developed the prototype of a point zone digital axle counter, which shall be put on field trial. The plant upgradation of the factory and upgradation of the manufacturing facility for digital axle counter is in

the completion stages. The company has also signed a MoA with the Russian company, M/s Podolsky Chemical & Metallurgical Plant for supply of silicon wafers and subsequently establishing a joint venture to manufacture silicon wafers. The company plans to expand PV manufacturing capacity to 100 MW in two phases—25 MW by 2012 and then up to 100 MW.

19.63 The National Research and Development Corporation (NRDC) provided financial assistance to 151 inventions for patenting in India and organized 32 Intellectual Property Rights (IPR) awareness programmes. Techno-commercial support was also provided to 58 inventions, besides strengthening of 17 Regional Technology Demonstration and Transfer (RTDT) centres and opening four new RTDT centres.

Mid-Course Corrections

19.64 With the change in emphasis for industrial research, particularly to support start-ups and SMEs, it would be desirable that a candid assessment and review of the TPDU programme is undertaken within six months by a third party. This would help identify the opportunities available and for restructuring activities, particularly for the Twelfth Five Year Plan.

19.65 The Technology Promotion Development and Utilization scheme is being modified to take up programmes under new initiatives aggressively. It is envisaged to encompass grants to technology-based start-ups, small businesses, and innovative business models. The modified scheme proposes that re-payment norms by established companies receiving Department of Scientific and Industrial Research (DSIR) support would be made softer. DSIR would also support technology up-scaling projects emanating from CSIR-800 and from rural and overseas showcasing of technologies from various R&D establishments.

19.66 The NRDC will aggressively promote a women entrepreneurship programme, entrepreneurship development in the North-East, IP awareness programme, upgradation of technology for rural clusters (sericulture, coir, and milk dairy clusters), developing basic engineering design packages for exportable technologies, angel funding, development of economic activities for anganwadi centres, setting up knowledge parks, and collaborating with the World Food Programme for use of non-conventional energy.

Council of Scientific and Industrial Research

19.67 The CSIR has a pan-India presence through its network of national laboratories, which undertake well-focused basic and applied research in diverse fields of science and technology. CSIR has emerged as a model organization, leading in cutting-edge science on the one hand and providing end-to-end technological solutions for economical and societal goods on the other.

19.68 CSIR has refocused and reprioritized its R&D activities in the Eleventh Plan and seven areas have been identified for focus and for deriving synergy therefrom. These are affordable healthcare, sustainable energy, chemistry and environment, smart and functional materials, engineering structures/design and electronics, earth system science, information technology, and CSIR-800-S&T interventions for the masses. CSIR has put in place a new R&D management strategy for planning and performance monitoring of R&D projects. The effort is aimed at developing end-to-end technological solutions.

19.69 In the Eleventh Plan, CSIR has made significant contributions. It had the distinction of having the highest scientific impact in the country with the publication of 7,972 research papers in SCI journals of national and international repute during 2007–09 and contributing on an average 12 per cent of the national SCI publications with an average impact factor per paper of more than two. CSIR also published 12 papers in top reviewed journals ('Cell', 'Nature, Science', and 'Nature Biotechnology'). Its scientists have also received prestigious fellowships and awards for scientific excellence.

19.70 At the national level, CSIR has been contributing significantly for the development of highly qualified S&T manpower in diverse areas and has supported over 8,000 research scholars; 3,300 students are pursuing PhD in various CSIR laboratories. Currently, CSIR produces 500 PhDs and 2,000 postgraduate

degree holders and research trainees every year. CSIR is at the forefront of generating intellectual property. It was granted 658 foreign patents and 1,094 Indian ones during 2007–09 and it has 2,562 patents in force and 222 patents licensed as on date. The percentage utilization of patents is 8.67 per cent, which is much above the world average of 3–5 per cent. CSIR's per patent cost is the lowest in the world amongst state funded R&D organizations.

19.71 A number of technology transfers have taken place for catalysing industrial growth. Design and development of a new generation clot specific protein that displays plasminogen activation property was transferred to M/s Nostrum Pharmaceuticals, USA at Rs 19.60 crore plus 5 per cent royalty. Technology for Caerulomycin A, and its proprietary derivatives and analogues ('Caerulomycin') for their novel indication of immuno-suppression—a discovery of immense importance in tissue transplantation like in kidney and heart, was licensed to M/s Nostrum Pharmaceuticals, USA at Rs 14.70 crore plus 2 per cent royalty. Recombinant streptokinase produced from E.coli was launched by M/s Shasun Drugs & Chemicals through M/s Lupin Pharmaceuticals and M/s Alembic Chemicals, which would bring down the prices of clot busters significantly. The technology was transferred at a cost of Rs 1 crore plus 3.5 per cent royalty. A new anti-ulcer drug—CSIR's patented know-how on a natural agent for treatment of gastro-intestinal toxicity associated symptom and ulcer was licensed to M/s IPCA Laboratories Ltd., Mumbai at Rs 2.5 crore plus royalty. A facile process for Heptafluropropane (FM 200), a halon substitute used in fire fighting systems was transferred to M/s Mechvac Fabricators Ltd., Mumbai for commercial production. A 3,000 TPa plant of Aditya Birla Group for the manufacture of epichlorohydrin from allyl chloride based on an improved and patented catalytic process went onstream at Ryong, Thailand, for which technology was transferred at a cost of Rs 1.64 crore. Process technology for fractionation of sugarcane bagasse for the recovery of cellulose, hemi-cellulose, and lignin was licensed to M/s Godavari Sugars at Rs 6.5 crore plus 3 per cent royalty. The carbon fibre technology was licensed to M/s. Kemrock, at a cost of Rs 3.5 crore plus 3 per cent royalty. Technology for Head Up Display (HUD) for LCA was transferred to BEL, Panchkula, at Rs 1.6 crore. With this achievement, India became one of the world's top five nations producing HUD. During 2007–09, CSIR received a total external cash flow of Rs 754 crore of which around 32 per cent, that is, Rs 247 crore was from the industry.

19.72 In the area of affordable healthcare, the first ever large-scale comprehensive study of the genetic structure of the Indian population has been completed, thereby creating an Indian Genome Variation database (IGVdb). This has opened up new vistas for developing predictive medicine using repeats and single nucleotide polymorphisms. India's foot print in the genomic world, a CSIR initiative along with others, led to reconstructing Indian population history. Prostalyn, an anti cancer drug, a herbal molecule obtained from *M.koenigii* and *Tribulus terrestis* for treatment of prostate cancer was released in the market. It has also developed and commercialized Risorine, an advanced tuberculosis therapy, which will reduce the cost of the rifampicin, isoniazid combination by 23 per cent. CSIR has also launched a novel Open Source Drug Discovery project, which seeks to develop low cost new molecules for the treatment of tuberculosis. CSIR's Traditional Knowledge Digital Library (TKDL) in collaboration with AYUSH has emerged as a unique resource for protecting Indian traditional knowledge from exploitation through IP filings and has been adopted for prior art search by European Patent Office (EPO) and United States Patent and Trademark Office (USPTO).

Mid-Course Corrections

19.73 During the Eleventh Plan CSIR would initiate new programmes, such as zero cost diagnostics, low cost therapeutics, and affordable biomedical instrumentation. In the area of sustainable energy, CSIR would launch programmes for solar energy, technologies for energy efficiency, CO_2 capture through synthetic biology, clean coal technologies, and the open source energy initiative. These would be linked to the NAPCC. It would also initiate some futuristic programmes, such as zerone, the India chip, novel materials, and nano devices, micro-machines and robotics. CSIR has proposed to set up a few CoEs in niche R&D domains, in collaboration with

well-known national/international institutions. Two major initiatives in this regard are the CSIR-IISc Centre for Neurosciences and the CSIR-ILS CoE for affordable Healthcare.

19.74 For strengthening the S&T human resource base, CSIR has proposed establishing the Academy of Scientific & Innovative Research, which would aim at innovative curricula, pedagogy, and evaluation for creating the highest quality personnel with cross-disciplinary knowledge.

19.75 CSIR has proposed to set up an entity company named CSIR-Tech with the objective of innovation-led inclusive growth through entrepreneurship. CSIR-Tech will be based on CSIR's exploitable knowledge base and spinning off scientific enterprises based on IPs secured by CSIR scientists.

19.76 The project on SARAS development is at a critical stage and CSIR is contemplating bridging technology gaps in collaboration with aerospace experts like Myasishchev Design Bureau (MDB), Russia and Piaggo, Italy.

19.77 The project on Acquisition of Oceanographic Research Vessels sanctioned on 14 October 2005 could not be completed in the 4-year time frame due to variation in prices in the international market. The contract for vessel construction was signed in December 2007 after going through the global tendering process. The project on setting up of a world-class research institute at Lucknow, approved in July 2005 has progressed well and nearly 70–80 per cent of the work has been completed. Meanwhile, due to increase in cost of civil works, iron and steel, furniture, and electrical air conditioning, the cost of the project has increased. These major projects would be completed during the Eleventh Plan at an enhanced cost.

19.78 CSIR had proposed the setting up of an Institute of Translational Research at Hyderabad. With the establishment of Translational Research Institute by the Department of Biotechnology (DBT), which is focused on health, CSIR has now proposed the setting up of research centres spread across various areas like affordable healthcare and sustainable energy as innovation complexes and part of translational centres.

19.79 In order to have national visibility, CSIR should have two to three flagship/mega projects, which are critical to the present problems of the country to provide end-to-end expertise for these flagship projects and demonstrate its technological competitiveness. There is a need to identify a major player for developing technology/product. The specification/deliverables of the final product should be based on user requirements and the expertise across S&T departments should be used by networking with the best institutions and tapping the rest from within or outside the country. Delivery in a definite time frame is critical and the focus should be on leadership in chosen areas.

19.80 Concerted efforts may be made to set up an autonomous business unit of CSIR on the lines of Antrix Corporation of DOS to market products and services.

EARTH SCIENCES

19.81 The activities in the field of earth sciences cover a wide range of areas that contribute to various societal benefits in the fields of weather, weather advisories specific to agriculture, aviation, shipping, and sports; monsoon, disasters (cyclone, earthquake, tsunami, the sea level rise); living and non-living resources (fishery advisory, poly-metallic nodules, and gas hydrates), coastal and marine eco-systems, and climate change.

19.82 Under Atmospheric Science and Information Services, a major step on the modernization of the India Meteorological Department (IMD) was accorded highest priority for providing accurate observations and advance warnings against natural hazards and for developing appropriate dissemination systems. Some of the major accomplishments towards this were: (i) commissioning of ten GPS stations; (ii) installation of 37 Digital Meteorological. Data Dissemination (MDD) systems, including one each in Nepal and Male; (iii) installation of integrated AMIs at Mumbai, Hyderabad, Bangalore, Jaipur, and Delhi airports; (iv) installation of 124 Automatic Weather Stations (AWSs) apart from the existing 125 AWSs, and one

earth station; (v) setting up of a 17-station Real Time Seismic Monitoring Network (RTSMN) as part of the Tsunami Warning System; and (vi) acquisition of a set of four High Performance Computing Systems (HPCSs) for global data processing and Numerical Weather Prediction (NWP) for weather forecasting services in IMD. A district-level agro-meteorological advisory service along with a five days in advance district-level weather forecast system, covering all the 300 districts was launched for farmers on 1 June 2008 in partnership with a number of Central Government ministries and organizations, state-level institutions, private agencies, NGOs, progressive farmers, and the media. Microzonation, a multi-disciplinary and multi-institutional effort was also launched during the period. It has direct application in disaster mitigation and management, urban development, planning, design, and construction, and risk assessment to existing life and property, defence installations, heavy industry, and public utilities and services. While the microzonation of Guwahati and Sikkim has already been completed on a scale of 1:25,000, work related to Delhi on a 1:50,000 scale has also been completed and the maps are being further refined on a 1:10,000 scale. The microzonation for Bangalore is under process.

19.83 Under Ocean Science and Services, an integrated unique system of fisheries advisories based on identification of Potential Fishing Zones (PFZs), using remote sensing technology has been made operational. This will help in disseminating location-specific advisories in regional languages to over 225 nodes, three times a week. Besides, information on Ocean State Forecast, basin-wide ocean wave and wind forecast (resolution, interval, and extent) for 10 days at 0.5 x 0.5 degree resolution and at 3-hour intervals has been made operational for the Arabian Sea, Bay of Bengal, and Northern and Southern Indian Ocean, South China Sea, Red Sea, and the Persian Gulf. The work on coral reef zonation mapping for Andaman and Nicobar Islands has been completed. Towards strengthening ocean observation systems, a ground station for Ocean Sat-2 Ocean Colour Monitor (OCM) data has been established. Over 59 argo floats (ten floats with oxygen sensors), and 47 drifting buoys have been deployed in the Indian Ocean. A wide range of user-oriented data products being generated from the argo data, are made available through the INCOIS Ocean portal for effective utilization.

19.84 A scientific expedition using the international research facility at Ny-Alesund in the Spitsbergen island of Norway has been undertaken for Arctic research. In the first phase, it has initiated three projects on atmospheric studies, arctic microbes, and earth sciences. Four more projects have been initiated in the second phase and an Indian Arctic station Himadri has been set up at the base camp in Norway. A third research base station in Antarctica at Larsemann Hills is also being established after securing approval from the 30th Antarctic Treaty Consultative Meeting (ATCM).

19.85 For activities under ocean resources, an instrument, along with complete hardware and software has been developed in collaboration with Russia to measure sea bed soil properties in-situ, at a depth of 5,200 metres. A prototype for a remotely operated vehicle has also been developed and tested successfully at a depth of over 3,000 metres. India has become one among a handful of nations which have the capacity for deep sea mining. As a part of technology development for harnessing gas hydrates, developing a 6,000 m rated deep water world-class remotely operable vehicle is nearing completion in association with the Experimental Design Bureau of Oceanological Engineering, Russian Academy of Sciences, Moscow. Further, survey and exploration of polymetallic nodules has been carried out at a closer grid of 6.25 km for selected blocks, along with developing and testing the artificial nodule laying system. The entire work relating to data/analysis of sea-bed sedimentation has been completed to stake India's claim to the continental shelf by the prescribed deadline of 12 May 2009.

19.86 Low Temperature Thermal Desalination (LTTD) technology-based desalination plants of 1 lakh litre capacity are being set up in the Minicoy, Agatti, and Androth islands of Lakshadweep and a 1 million litre per day LTTD plant has been successfully demonstrated at Chennai (Tamil Nadu). Using waste heat from power plants, a 1 lakh litre per day LTTD plant was demonstrated which produced

fresh water at the first trial run at the North Chennai Power Plant.

19.87 The construction of a multi-purpose vessel, Sagar Nidhi, equipped with state-of-the art facilities was completed and commissioned. The vessel is capable of conducting multi-disciplinary studies in the coastal and deep sea areas continuously for 45 days with 30 scientists onboard the vessel. Indigenous development and testing of a bottom pressure recorder for the Tsunami Early Warning System was completed at the acoustic test facility. A set of mining equipment, such as crawler, crusher, in-situ soil tester, and remotely operable vehicles have been developed and tested in the field for harnessing the ocean's mineral resources.

19.88 An atlas on marine mammals of the Indian Exclusive Economic Zone (EEZ), and a climatological atlas on the seasonal patterns of the environment and productivity of Indian EEZ were prepared and released. A field research station in the Agatti island of Lakshadweep was set up to develop hatchery technology for the captive breeding of marine ornamental fishes and technologies transferred to the islanders. Two molecules extracted from marine organisms are in the advanced stage of development and one compound with anti-diabetic properties is undergoing multi-dose clinical trials.

19.89 With climate change science getting special attention and focus, a dedicated Centre for Climate Change Research at Pune has been set up to address scientific issues relating to climate change, including impact on sectors like health, agriculture, and water. A programme on Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) was launched for cloud seeding to understand cloud microphysics and rainfall processes.

19.90 Under disaster support activities, the state-of-the-art Tsunami Warning System with the world's best infrastructure and communication system was made fully operational in October 2007 at INCOIS, Hyderabad. A set of 17 broadband seismic observational networks in peninsular India were also upgraded. Towards this, an Earthquake Risk Evaluation Centre was created in New Delhi to evaluate seismic hazards at a very high resolution.

19.91 A dedicated programme for strengthening extramural research in the field of ocean, atmosphere, and seismology, in a number of research organizations/ universities has also been initiated towards capacity building in the field of earth and atmospheric sciences. MTech and PhD programmes with IIT-Delhi, CSIR, and IISc have been initiated for advanced ocean atmospheric modelling. A major collaboration agreement with the National Oceanic and Atmospheric Administration (NOAA) in the field of meteorological science and services has been signed.

Mid-Course Corrections

19.92 Out of the 34 schemes being operated by the ministry, some of the major ones which are not performing well, include modernization of IMD; Multi-channel Seismic System onboard the Ocean Research Vessel (ORV) Sagar Kanya; development of a manned submersible; demonstration of shore protection measures through a pilot project; and seafront facility.

19.93 Four major schemes: (i) Desalination Project; (ii) Coastal Research Vessels (CRVs) and other research vessels; (iii) National Institute of Ocean Technology (NIOT) Extension Centre, West Bengal; and (iv) National Oceanarium have not yet been approved. The Ministry of Earth Sciences needs to expedite the processes to get approvals for the pending Eleventh Plan projects as well as for the new proposals put forward at the mid-term stage and take appropriate measures for implementing various schemes on a fast track.

19.94 It is proposed to take up a few new activities under various areas. These include: an integrated project over the Himalayan region; a seismology centre; an Aircraft Probing Cyclone facility; a high altitude station in Maharashtra; and development of a coupled assimilation forecast system. It is proposed to initiate a multi-disciplinary, multi-institutional study on the ocean bio-geochemistry of the Indian Ocean and establish a Centre for developing drugs from the sea. It is also proposed to launch an integrated

programme for island development through S&T intervention. Towards development of human resources for providing a wide range of services in the field of ocean, atmospheric, climate, and seismological services, an advanced training school is proposed to be set up in Pune.

19.95 The ministry has two major research vessels—the ORV Sagar Kanya vessel, and Fishery and Oceanographic Research Vessel (FORV), Sagar Sampada, which are more than 25-years-old and need to be replaced to undertake major activities envisaged during the Eleventh Plan, such as a myctophid survey of the central and western Arabian Sea and deep sea fishery surveys of the Indian continental slope.

19.96 The pace of implementation of the IMD modernization scheme has been very slow and a cause for concern. There is a high level of urgency to complete the modernization, which is already delayed. Considering this, appropriate time targets should be adhered to strictly. IMD is making long, medium, and short-term forecasts across the country. Efforts should be focused more on regional and locale-specific forecasts and over a greater time horizon so that farmers can benefit. Regarding meteorological research, there is need to lay more emphasis on the modelling aspect and the issues of long, medium, and short-term weather forecasting could be taken up in a focused manner. There is also need to evaluate the instrumentation component with respect to global standards. A few eminent scientists with modelling and forecasting expertise may be involved in the entire method of prediction.

19.97 Ocean science and technology as a discipline needs to be expanded to take care of emerging requirements. Specific courses and departments need to be created at IITs and IISERs. In addition, the North-Eastern Hill University (NEHU), Shillong may be developed as a CoE in this field.

WAY FORWARD

19.98 It is becoming increasingly evident that gross investments in R&D form an important indicator of global competitiveness of science, technology, and innovation systems of countries. Global competitiveness of India in the knowledge economy does call for larger investments in research and development than what have been possible until the Eleventh Plan period. Eleventh Plan programmes have laid the foundations for further strengthening the R&D base of the country, which needs to be consolidated in the coming years.

19.99 Public investment in R&D has thus far centred around public-funded institutions with finite challenges in migrating research outputs into economic development processes. Public investment in PPPs in the R&D sector may require a different paradigm of planning. The tools required for making decisions on public investment in PPPs require management innovations.

19.100 R&D cannot be left to government efforts alone. Much greater investment in R&D is needed from the corporate sector. Currently, the industrial sector in India spends around 0.54 per cent of the sales turnover on R&D. In particular, PSUs should do R&D not only in-house R&D but also by research contracting with scientific institutes and national laboratories. Appropriate fiscal incentives need to be put in place for this purpose.

19.101 Most planning processes so far adopted a supply side approach for sizing investment into R&D. In case of some select sectors, demand side assessments followed by a strategic investment-based approach will be necessary. Most Asian countries like China, Korea, and Singapore have adopted such paths during the recent past with success.

19.102 It is necessary to look at the innovative component of several technologies that have been developed by the three strategic departments of atomic energy, space, and Defence Research and Development Organisation (DRDO) for their own respective needs, but which also represents a fund of ideas which could have broader relevance in the context of unique initiatives on innovation. If mapped properly, this could trigger unique mechanisms for encouraging innovation and ensuring the right impact on social, industrial, and strategic sectors in the Twelfth Plan. A preparatory step in this connection needs to be encouraged by various departments, as well as those

of public and private sectors, which could enable developing strategies for undertaking these dimensions of S&T activities in the Twelfth Plan.

19.103 Over the years, several emerging areas of science and technology have been identified and appropriate institutional frameworks created to enhance India's R&D base and capability. However, the question of continuing relevance and a critical review of some of the existing institutions, structures, and mechanisms have not been simultaneously addressed. It is time to conduct such reviews to ensure that the much-needed resources, both financial and human, are deployed in an optimal fashion. To derive maximum benefits of the investment, greater emphasis also needs to be put on the use of industrial infrastructure and the creation of an appropriate institutional framework cutting across departments and other kinds of organizational mechanisms.

19.104 Technological capacity in the area of agriculture, water management, medicine, clean energy, and transport needs to be accelerated based on our own efforts as well as through global partnerships. Greater thrust is also needed for dissemination of various spin-off technologies from strategic sectors which have direct social relevance.

19.105 S&T development in the country presents several possibilities of intervention for socio-economic development, particularly for finding innovative technological solutions for sectors like health, education, energy, water, food, and nutritional security. The Science and Technology Councils established in the states to serve this objective have not been able to play their rightful role. Similarly, the linkage between the scientific agencies and the state S&T Councils/ state S&T departments has been sub-optimal. In the remaining period of the Eleventh Plan it is necessary to embark upon some initiatives that would focus on these aspects and to develop certain proof of concept models for achieving these. This could provide the necessary lead for major initiatives in the Twelfth Plan.

19.106 The Department of Space has demonstrated the power of multiple institutions working together towards achieving important mission objectives like developing launch vehicles and satellites. Its impact at the national level in the socio-economic sectors as well as in the strategic sectors has also been demonstrated. However, there is a need to further strengthen the linkages that have been established, particularly with various user agencies by creating appropriate institutional mechanisms to sustain the flow of the benefits accruing to society.

19.107 The Department of Atomic Energy has made impressive strides towards achieving self-reliance in an area which is complex and at the same time governed by strong international controls that inhibit transfer of various technologies. Against these challenges, the country has demonstrated its capability to go at it alone, which is both timely and appropriate. However, the nuclear power scenario projected for the coming decades depends critically on the operationalization of the Fast Breeder Reactor system followed by developing the third stage of the nuclear fuel cycle involving the use of thorium that is abundantly available in the country. The Fast Breeder Reactor system needs accelerated efforts and several technological challenges have to be addressed on an urgent basis. It is difficult to place an exact time frame for the operationalization of the Fast Breeder Reactor system before having a clear understanding of different technological approaches and options as well as creating the necessary industrial capabilities for large-scale replication of such systems. The third stage of the nuclear fuel cycle, considering the technological complexities and need for intensification of research and development, would call for stepping up infrastructural capabilities, creation of appropriate human resources, as well as putting in place the required financial investment. A critical assessment of these issues may be carried out by the department during the remaining period of the Eleventh Plan so that realistic strategies can be worked out and realized during the subsequent Plans.

19.108 Biotechnology research and development has made impressive strides with a modest investment, particularly in the pharmaceuticals, health, and agriculture sectors through building up limited and appropriate human resources, creating PPP models, as well as bringing in international collaboration to

accelerate the pace. The department has also been developing a relevant legislative framework and is putting in place the necessary regulatory mechanism in the context of the overall safety of biotech products and processes. The future expansion of this sector will critically depend on enhancing the human resource base and the requisite infrastructure as well as the ability to forge stronger linkages with the industry.

19.109 The challenge for S&T institutions, therefore, is to play a stronger role in accelerating inclusive development in the country and breaking out of the traditional silos. It must find solutions that will enable people to obtain basic needs for a good life at affordable costs. These include good quality healthcare, low cost energy sources, adequate quantities of clean water, environmentally sustainable transportation, affordable housing, and universally accessible high quality education. In addition, of course, Indian S&T capabilities must enable the country to become strategically secure in its defence, communications, and energy requirements. New PPP models must be developed for research, industry-academy collaborations must multiply, and more effective collaboration with organizations in advanced countries needs to be made. Indian talent, perhaps even grassroots talent, outside formal science and technology establishments can also contribute to the inclusion agenda, as described later in the chapter on Innovation (Chapter 20). Indeed, the more inclusive and open the process of innovation, the more likely it will be to find the required solutions at low costs that the country needs for its agenda of inclusive growth. New organizational architectures will enable innovations in the R&D processes. An example is the Open Source Drug Discovery programme, led by CSIR, for finding a cure for tuberculosis.

19.110 Sustained action and timely implementation of the carefully developed S&T plan may yield desired results for the country. The S&T sector must get fully integrated with the development needs of the country through appropriate programmes and technological interventions as well as solutions.

ANNNEXURE 19.1
Eleventh Five Year Plan Emphasis—Significant Initiatives/Contributions (Illustrative)

Stated Emphasis of the Eleventh Plan Programmes	Actions/Initiatives Taken	Agency/ Department	Status
Setting up a national-level mechanism for providing directions to basic research	Formation of Science and Engineering Research Board	DST	Bill passed by Parliament. Will be in position soon
	Promotion of University Research and Scientific Excellence (PURSE)	DST	Operationalized
	Redesigning University Life Science Departments for Interdisciplinary Research and Education	DBT	Operationalized
	Science Advisory Council to the Prime Minister	DST	Constituted
	Science Advisory Council to the Cabinet	DST	
Enlarging pool of scientific manpower	Established 12 new research institutions and 7 different types of fellowships	DBT, DST	Approvals obtained and some of them are already functional
	Wellcome Trust—DBT alliance, Ramalingaswamy fellowships	DBT	Initiated
	Ramanujan fellowships, scientists, and technologists of Indian origin	DST	Initiated
	50% increase in the value of PhD fellowships in the country	All S&T Departments	Initiated
	Doubling the number of fellowships of doctoral research and providing post-doctoral fellowship schemes	CSIR, DST, DBT	Initiated
	Special re-entry programmes for scientists of Indian origin	DBT, CSIR	Initiated
	Fellowships for special areas like glaciology, computer sciences, and climate change science	DST, MoES	Initiated
	Chair professorships and student fellowships in CoEs	DBT, MoES, DST,	Established
	Exemption from deemed abolition of S&T posts	MST	COS decision obtained. Cabinet note ready
	ADCOS (Advisory Committee on Space Science) Research Fellowship Scheme	DOS	Initiated
	Setting up of BARC training school at IGCAR for Fast Reactor programme	DAE	Established
	Niche overseas long-term and short-term fellowships in the areas of stem cell biology, nano-biotechnology, bio-design, molecular breeding, etc.	DBT	Initiated
Attracting and retaining young people in careers in science	Innovation in Scientific Pursuit for Inspired Research (INSPIRE)	DST	Launched
	Indian Institute of Space Science and Technology	DOS	Established
	CSIR-Academy of Scientific & Innovative Research (AcSIR)	Proposal of CSIR	Proposal made
	Establishment of new academic institutions like NISER	DAE	Established
	Postgraduate research training programme in engineering	CSIR	Implemented
	Establishment of DAE-Mumbai University CoE	DAE	Established
	Industrial placement for training postgraduates in life sciences and biotechnology on a large scale	DBT	Initiated
National flagship programmes for technological competitiveness on a mission mode	Nano mission	DST	Mounted
	Water Technology Mission	DST	Mounted
	Vaccine grand challenge	DBT	Mounted
	Small Business Innovation Research Initiative	DBT	Mounted
	Synthetic biology initiative	CSIR	Proposal made

(*contd...*)

(*Annexure 19.1 contd...*)

Stated Emphasis of the Eleventh Plan Programmes	Actions/Initiatives Taken	Agency/ Department	Status
	Open Source Drug Discovery	CSIR	Initiated
	Modernization of met observation system, including advanced weather modelling and super computer system	MoES	Initiated
	Regional Tsunami Watch Provider Operations	MoES	Established
	Earth Observation System	MoES, DOS	Under establishment
	Ocean Observation System	MoES	Under establishment
	Chandrayaan-1 Mission	DOS	Successfully completed
	Oceansat-2 Mission	DOS	Successfully completed
	National Mission for Sustaining the Himalayan Eco-system	DST, MoES, MoEF, DOS, DSIR	Proposal made to PM's Council
	National Mission on Strategic Knowledge for Climate Change	Ministry of S&T and MoEF and MoES	In-principle approval obtained from PM's Council
	Geospatial technology applications mission	DST	Mounted
	Demonstration unit of a Compact High Temperature Reactor at BARC, Mumbai	DAE	Design getting completed
	Demonstration of fabrication technology of sodium bonded metallic fuel elements for fast reactors	DAE	Initiated
	Pre-service, in-service, and post-irradiation examination technology to be developed for FBR fuels	DAE	Initiated
	Development of high power lasers for engineering applications in nuclear and industrial fields	DAE	Initiated
	Bioenergy grand challenge	DBT	Mounted
	Microbial prospecting for genes and molecules	DBT	Mounted
Establishing globally competitive research facilities	Translation research in agriculture biotechnology	DBT	Established
	Macromolecular structure and function	DBT	Established
	Microbial repositories	DBT	Established
	Advanced seismic testing facilities	SERC/CSIR	Established
	Low temperature thermal desalination plant	MoES	Established
	Modernization of met observation system	MoES	Under establishment
	High altitude cloud physics laboratory	MoES	Under establishment
	Aberration corrected transmission electron microscope	JNCASR/DST	Established
	Devasthal 3.6 m telescope and HAGAR facilities	ARIES/IIA/DST	Under establishment
	Bio safety level 4 facility	DST/CSIR	Under establishment
	Climate observatory, low altitude wind profiler, LIDAR system for boundary layer aerosol, and cloud studies	DOS	Initiated and nearing completion
	Indian space science data centre	DOS	Initiated and nearing completion
	A multi-institutional, multi-organizational India-based Neutrino observatory	DAE, DST	Awaiting site clearance
	A high flux multipurpose research reactor at Visakhapatnam	DAE	Initiated
	Upgradation of APSARA reactor by enhancing reactor power up to 2 MW	DAE	Initiated
	A first of its kind in the country 250 MeV superconducting cyclotron for proton beam to be constructed at VECC, Kolkata	DAE	Initiated
	National radioactive ion beam facility at Kolkata	DAE	Under implementation
	Upgradation of INDUS-2 for better utilization by scientific community	DAE	Under implementation

(*contd...*)

(*Annexure 19.1 contd...*)

Stated Emphasis of the Eleventh Plan Programmes	Actions/Initiatives Taken	Agency/ Department	Status
Innovative spirit to translate R&D leads in scalable technologies	Biotechnology Industry Partnership Programme	DBT	Mounted
	National Development Services Agency	DBT	Mounted
	Biotechnology Industry Research Council	DBT	Mounted
	Protection of Intellectual Property Bill	DBT	Under discussion
	New Millennium Indian Technology Leadership Initiative (Revised)	CSIR	Under implementation
	Innovation law	DST	Under discussion
	National innovation fund	DST	Launched
	National effort on development and commercialization of inventions and innovations along with relevant guidelines for CSIR	DSIR/CSIR	Mounted
Developing new models of PPP in higher education, particularly in universities and high technology areas	Small Business Innovation Research Initiative, Biotechnology Industry Partnership Programme	DBT	Launched
	Technology/IP management capacity	DBT, DSIR	Launched
	Consolidation of university research, innovation, and excellence	DST	Launched
New means of catalysing industry-academy collaborations	Global Innovation and Technology Alliance	DST	Initiated
	Biotechnology incubator parks	DBT	Initiated
	Biodesign programmes	DBT	Initiated
	Innovation clusters	DBT, DST	Initiated
	Thematic centres in CoEs in academic institutions	DST, DBT	Initiated
	Novel units for training, innovation, capacity augmentation, and learning	DSIR	Initiated
	CSIR-TECH	CSIR	Under discussion
	New joint fellowship programmes and joint extra mural research proposals	DST, DBT	Launched
Promoting strong linkages with advanced countries, including participation in mega science	Indo-UK Science and Innovation Council, science bridge, UKIERI,EPSRC-DST initiative on solar PV and next generation telecom network	DST	Launched
	Facility for Antiproton Ion Research(FAIR)	DST	Under finalization
	Indian beam line in Synchrotron at KEK, Japan	DST	Initiated
	Beam line facilities in Synchrotron at Petra III, Germany	DST	Under discussion
	Beam line facilities in Synchrotron at Grenoble, France	DBT	Initiated
	Indo-US Research Endowment Board	DST	Formation finalized
	Science express, partnership institutes with Max Planck	DST	Initiated
	Indo Australian Strategic Research Fund	DST, DBT	Launched
	ITER, CERN, ALICE	DAE, DST	Under discussion
	Solar Energy Research Initiative with Russia	CSIR	MoU signed
	Indo -EU framework programme	DST, DBT	Under implementation
	Indo Canada	DST, DBT	Under implementation
	Indo-Finland, Indo-Denmark	DBT	Under implementation
	CSIR-RISE (Research Institute for Sustainable Energy)	CSIR	MoU signed
	Synthetic biology programme	CSIR	MoU signed with University of Berkeley Programmes initiated
	Stanford-India biodesign programme	DBT	Under implementation

ANNEXURE 19.2

Financial Performance of Science and Technology Sector at the Mid-Term Stage of Eleventh Five Year Plan

(Rs crore)
(at current prices)

S. No.	Name of the Department	Eleventh Plan (approved outlay)	2007–08		2008–09		2009–10		2010–11	2007–11		% Utilization of Allocation (2007–10) (12/11)* 100
			BE	Actuals	BE	Actuals	BE	AE	BE	Allocation (4+6+ 8+10)	Anti. exp. (5+7+ 9+10)	
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Department of Atomic Energy (R&D)	11,000.00	1,215.00	978.46	1,228.00	1,313.81	1,638.00	1,638.00	2,084.86	6,165.86	6,015.13	97.56
2	Department of Space	30,883.00	3,420.00	2,821.75	3,600.00	2,810.02	4,100.00	3,164.03	5,000.00	16,120.00	13,795.80	85.58
3	Department of Biotechnology	6,389.00	675.00	616.68	900.00	871.77	1,000.00	878.45	1,200.00	3,775.00	3,566.90	94.49
4	Department of Science and Technology	11,028.00	1,526.00	1,266.89	1,530.00	1,517.12	1,775.00	1,668.69	2,025.00	6,856.00	6,477.70	94.48
5	Department of Scientific and Industrial Research	9,000.00	1,070.00	1,054.98	1,200.00	1,189.00	1,350.00	1,278.10	1,600.00	5,220.00	5,122.08	98.12
6	Ministry of Earth Sciences	7,004.00	690.00	359.06	750.00	469.56	900.00	756.06	1,000.00	3,340.00	2,584.68	77.39
	Grand Total	75,304.00	8,596.00	7,097.82	9,208.00	8,171.28	10,763.00	9,383.33	12,909.86	41,476.86	37,562.29	90.56