

Innovation and Technology

INTRODUCTION

8.1. Since Independence, India has endeavoured to bring economic and social change through science and technology. The effort has been both on upgrading the traditional skills to make them relevant and competitive and developing advanced capabilities in frontier areas of science and technology. The visionaries who led the growth of science and technology (S&T) in India were convinced that S&T could play an important role in transforming India into a modern, industrialized society. Experience and results show that this confidence was well placed. Science, technology, and innovation are even more relevant today. Scientific knowledge and expertise, innovation, high technology, industrial infrastructure and skilled workforce are the currencies of this new era.

8.2. The investments made in Research and Development (R&D) by the developed countries reveals that the comparative strength of India in knowledge sectors would be seriously disadvantaged in competition to other nations with similar or even smaller sizes of economy relative to India if adequate investments are not made in this domain. As per R&D statistics for 2004–05, India invests around 0.8% of GNP in R&D compared to more than 2% by the developed countries. India currently ranks 13th among the top 38 countries in terms of number of publications in SCI journals; China ranks ninth. On the other hand, India ranks second after China, among the top 23 developing countries. However, the productivity of Indian science as a measure of dollars spent per publication in Science Citation Index (SCI) journals is comparable with other countries.

ELEVENTH PLAN POLICY AND APPROACH

8.3. While India's economic growth in the recent years has been impressive, many challenges remain to be met to create a strong and vibrant innovation eco-system, which is the need of the day. This requires (i) an education system which nurtures creativity; (ii) an R&D culture and value system which supports both basic and applied research and technology development; (iii) an industry culture which is keen to interact with the academia; (iv) a bureaucracy which is supportive; (v) a policy framework which encourages young people to enter into scientific careers and (vi) an ability to scan scientific developments in the world and use technology foresight to select critical technologies in a national perspective. It is with this conviction that the Eleventh Five Year Plan approach to S&T has emphasized the following:

- Setting up a national-level mechanism for evolving policies and providing direction to basic research;
- Enlarging the pool of scientific manpower and strengthening the S&T infrastructure and attracting and retaining young people to careers in science;
- Implementing selected National Flagship Programmes which have direct bearing on the technological competitiveness of the country in a mission mode;
- Establishing globally competitive research facilities and centres of excellence;
- Kindling an innovative spirit among scientists to translate R&D leads into scalable technologies;
- Developing new models of PPPs in higher education, particularly for research in universities and high technology areas;

- Identifying ways and means of catalysing industry–academia collaborations; and,
- Promoting strong linkages with advanced countries, including participation in mega international science initiatives.

8.4. The Eleventh Five Year Plan will provide policy support for incentivizing greater accountability, administrative efficiency and flexibility and in some cases, systemic changes. The most important among these is the need for organizational and administrative changes in S&T departments/agencies/institutions to create a conducive environment for R&D and ensuring optimal/efficient use of public sector R&D resources. Manpower being critical for the successful implementation of research projects, approval of the scheme/project needs to be accompanied by approval of the scientific and technical manpower.

8.5. In addition there is a need to focus on policy issues relating to experiments on animals, women in science, cyber infrastructure for S&T, encouragement of S&T based entrepreneurs, mobility of scientists between organizations, multi-ministerial funding and implementation mechanisms for projects. The role of socio-economic ministries towards mainstreaming S&T in their programmes is also an important policy issue because many programmes/activities relating to S&T fall within the purview of these ministries. A substantial part of the activities that affect large sections of society are carried out at the State level using local infrastructure and resources. To derive maximum benefits from the application of science and technology, it is necessary that the State S&T departments and councils play a crucial role involving and using the facilities and expertise created within the State as well as by the Central agencies.

DOMAINS FOR FOCUSED ATTENTION FOR THE ELEVENTH PLAN

INNOVATION FOR FASTER AND MORE INCLUSIVE GROWTH

Innovation for Increasing Returns from Raw Materials

8.6. Innovation is linked to first application of concepts and the creation of value from an idea or concept. In the global market economy, the ability of nations to create, absorb and commercialize innovations determines their competitiveness. Innovation is closely linked to the creation

of wealth in a modern knowledge economy. Value addition to raw materials in India through applications of technology has remained low compared to other nations such as Israel, Finland, Japan, and South Korea. Typically, innovation-led manufacturing provides 20–25% increase in value to raw material inputs. Increasing labour productivity through technology change and innovation is the main route for the creation of additional wealth to enterprises and better wages to employees.

Innovation as the Means for Sustained and Sustainable GDP Growth

8.7. There is a vast untapped potential in India for wealth creation by increasing the levels of innovation content in the entire economic development activities of the country. It is a tall call but an essential one, if the current levels of growth of GDP were to be maintained over the next two decades. There are several case histories of nations benefiting substantially from a flow of innovations. Innovation will also be a key for sustainability—the ability to meet developmental objectives while ensuring sustainable use of natural resources.

Institutional Elements of an Innovation Eco-system

8.8. The elements of an innovation ecology identified earlier fall into a number of institutional domains. An institutional representation of the innovation system is a useful tool for exploring the role of various actors in the innovation process and the way in which they may interact. Five categories of institutional participants can be identified:

- (i) Governments, which play a key role in setting broad policy directions and a primary role in funding basic scientific research;
- (ii) Private enterprises and their research institutes, which contribute to development and other activities that are closer to the market than governments are;
- (iii) Universities and related institutions that provide key knowledge and skills;
- (iv) Bridging institutions acting as intermediaries under such names as ‘technology centre’, ‘technology brokers’, or ‘business innovation centres’, which play an important role in closing the gaps among the other actors and have been important to the success of all types of research centres; and
- (v) Other organizations, public and private, such as venture capital firms, federal laboratories, and training organizations.

8.9. The interaction and role of these stakeholders and institutions is defined and determined by four contextual factors sufficiently important to the operation of innovation systems to be able to make or break them: market conditions, physical infrastructure, education and training and regulatory conditions.

Role of Governments in the Innovation System—Global Experience

8.10. There is a wide spectrum with regard to the extent to which governments can influence the innovation system. To a large extent, the approaches adopted by various nations in the direction of innovation systems have varied depending on the overall national economic orientation. These approaches have ranged from a ‘directed or coordinated’ model such as the one selected by Japan, to a much more laissez faire model employed in the USA. Countries such as Canada and others in the European Union (EU) region have adopted models that fall in between those of Japan and the US, at least in terms of strategy and sector identification for leveraging innovations. Thus, from the standpoint of a national planning process, there are several approaches to directing and shaping the innovation-led development processes. Although there may be varying levels of the directed or coordinated functions of the governments in shaping the innovation infrastructure, most nations have recognized the similarity of needs for creating an innovation infrastructure.

Examples of Global Experiences

8.11. The economic rationale for government support and intervention in the innovation process described earlier provides the basis for most of the major innovation support programmes and mechanisms in different countries. Examples include the Small Business Innovation Research and the Advanced Technology Programme (ATP) in the US. An important part of the innovation system is courage on the part of the scientist to take risks and the support of risk-taking by the S&T system. The greater the innovation, the greater is the risk in converting it into a commercial product or process. Thus, the US Government provides between 20 to 25% of all funds for early stage technology development. This contribution is rendered more significant in segments of the innovation cycle that private investors often find too risky.

Intellectual Property Regime

8.12. As a result of global competition, it is becoming difficult for the Indian industry to compete on the basis

of low cost alone without value creation through new technology. With the Indian Intellectual Property Regime (IPR) getting Trade Related Intellectual Property Rights (TRIPS) complaints since January 2005, many Indian companies have stepped up their R&D spending to keep generating new technology, particularly in the pharmaceutical and automobile sectors. Besides amendment of the Indian Patents Act, 1970, the country has also enacted intellectual property (IP) laws covering geographical indicators, biodiversity, plant varieties and farmers’ rights and layout design of integrated circuits. The IP Acts covering designs, trademarks and copyrights have also been updated to be TRIPS compliant.

8.13. Due to increased patent awareness and changed circumstances, patent filing by Indians in the country has increased threefold from a stagnant figure of about 1000 in the pre-World Trade Organization (WTO) regime. Patent filing by foreigners in India has also increased substantially, which reflects increasing interest of foreigners in the Indian economy. Thus, the current patent filing by Indians and foreigners in India has reached a level of more than 17000. The Council of Scientific and Industrial Research (CSIR) alone is filing approximately 500 foreign patents and 400 Indian patent applications every year.

Creating an Innovation Infrastructure in India and the Need for a National Innovation Policy

8.14. Often missing within discussions of innovation in the developed countries is the role of innovation for directly improving the livelihood or quality of life of the poor. The general assumption is that the market mechanism will take care of this. However, innovation may also be important for the delivery of, and access to, services that are essential for a quality of life; whether it is clean water, modern energy or affordable health care. In terms of an innovation policy for India, this may be an important and distinguishing feature.

8.15. The forward plan of India is towards faster and more inclusive growth. Faster growth in a globally competitive market environment demands a national innovation infrastructure that connects knowledge systems to wealth creation efficiently and effectively. In the Indian social context, there is a need to ensure that innovative growth-linked processes do not bypass the poor and leave them out of developmental choices emanating from the benefits of globally competitive innovations. Therefore, the Indian model for innovation should be unique. The innovation

infrastructure of India should aim to bridge the internal asymmetries and serve the dual purpose associated with global competitiveness and inclusive growth.

8.16. Both pro-poor and global competitiveness objectives should be embedded in the search for innovations. The number of grass-root innovators in the informal sector in India is large. However, grass-root innovations are not able to reap sufficient economic benefits for want of backing with adequate resources. The innovation infrastructure in the formal sector is thin. It requires deepening by referencing to global best practices and market demands. Such an innovation infrastructure would depend strongly upon a vibrant and gainful PPP in research and development as well as commercialization of innovations.

8.17. The prevailing asymmetry between inventors and investors is required to be bridged. Financing systems for backing up early-stage innovations with risk capital are required. Provisions for exiting from non-profitable innovations also need to be made. Innovations created at the expense of considerable investment of resources would demand a matching Intellectual Property Rights (IPR) regime. While the legal framework for protecting IPR is in place, infrastructure for capturing and protecting IPR is still evolving in India. Use of technology tools and capacity building in the area of IPR management require scaling up. New approaches and programmes are essential for unleashing India's innovation potential. Competitiveness innovation cluster has emerged as a successful global concept. Such innovation clusters in which academia, research and industry partner under viable and equitable PPP are the way forward.

8.18. The design and development of a sustainable innovation infrastructure should take into account global best practices, attraction, attachment, retention and renovation of talent within the research and development streams, PPPs, venture and angel financing and capacity building. The realization of Indian Vision 2025 to emerge as a major economic power in the global knowledge economy would call for a sustainable innovation infrastructure.

8.19. At the root of innovation is invention, which is an essential creative step that cannot really be directed or forced. However, there is much that can be done to facilitate this initial step and the many subsequent steps that will ultimately yield the value to society from the

invention. These steps are not isolated or distinct from one another; therefore it is more appropriate to think of a comprehensive innovation policy, rather than a policy that is aimed at only one of the steps in the process or elements of the innovation system. Innovation policy needs to be placed within the broader social and economic context, informed by goals and aspirations of development and should reflect a fair and effective balance between public and private interests, social and economic goals and inclusiveness versus rapidity.

8.20. In order to unleash our full innovative potential, we need to put in place a National Innovation policy, which encourages competition among enterprises, greater diffusion of knowledge and increased support to early-stage technology development initiatives and grassroots-level innovators. We need to foster increased collaboration among R&D institutes, universities and private sector enterprises and leverage upon their cumulative strengths in designing and implementing various innovation programmes. There is also a need for an appropriate legislative framework for incentivizing the innovators and commercialization of public funded R&D, where the government, the recipient(s) of funds, the inventor, as well as the public benefit from the protection and commercialization of IP.

SCIENCE AND TECHNOLOGY AS A CAREER OPTION/ CHOICE FOR THE YOUNG

8.21. Attracting and retaining young meritorious students in science and technology is a major concern. The general perception among students and their parents about science as a career is that it is not an attractive enough option as it requires a long time to enter the job market, and that good employment opportunities do not exist for science degree holders, including those with doctorate degrees. The absence of colleges/universities with a brand value equivalent to that of the IITs for pursuing courses after Class XII also acts as negative factor.

8.22. In order to make science an attractive career option for the talented, scientists need encouragement. Peer-reviewed good performance should be given recognition through a suitable scheme of incentives. Assured career support for 15 years may induce meritorious students to opt for the science stream after the senior secondary ('Plus Two') stage. There is a need to multiply institutions like the Indian Institutes of Science Education and Research (IISER) at Pune, Kolkata, and Chandigarh, and discipline-specific institutions like the National Institute of Science

Education and Research (NISER) at Bhubaneswar and Indian Institute of Space Science and Technology (IISST) at Thiruvananthapuram, with a view to capture talent at senior secondary level for developing quality human resources in the country. There is also need to strengthen universities/colleges which already have accomplishments to their credit and who show promise for future growth. Such institutions should be identified and provided with the required infrastructure facilities. The focus should be on creating new integrated programmes to which bright students are attracted, rather than multiplying the existing conventional undergraduate (UG) and postgraduate (PG) programmes.

8.23. Unfortunately, mobility is conspicuously absent among college teachers. A strong and vibrant Visiting Teacher scheme should be launched through which teachers are able to go for six months, every five years, to reputed research institutions/university departments. Similar mobility is needed for PhD/PG/UG students working on their projects.

PROMOTION OF BASIC SCIENCES

8.24. Basic research in science, engineering, and medicine is essential for the overall growth of science and technology and it is a critical input for development. To promote basic science research in academic and research institutions, there is need of a well-defined and focused approach for building infrastructure of equipment, facilities in colleges/universities/institutions.

8.25. Apart from supply-side interventions through higher allocation of funds for S&T, there is also a need to increase efficiency of the delivery system so that the resources are made available to R&D groups in a much faster manner. The promotion of basic research in the different disciplines of science needs a mechanism which can be charged with the responsibility of formulating and implementing programmes, and playing a catalytic role for upgrading research infrastructure and attracting a new generation of students and faculty into the research system. This is essential since much of modern research in science and engineering requires development, acquisition and up-gradation of sophisticated equipment facilities. The mechanism should act both as a creator of facilities and as a watchdog to ensure efficient operation. Most institutions have aged collectively with a consequent decline of their research profile. Vigorous and attractive recruitment policies for S&T personnel need to be introduced by the government and the corporate sector. Flexibility in salary

support and start-up grants would facilitate to attract class scientists to work in India. There is also a need for improving inter-institutional linkages to quickly enhance scientific activities within the university system. Focus is also required on initiating programmes to promote establishment of technology business incubators in universities which support scientists to start commercial activities based on indigenous technologies developed at their institutions. This type of technology transfer can be very effective for implementation, particularly for low initial capital start-ups. Industries with active R&D divisions should be encouraged to recruit research students working in basic science areas related to new technology demands.

MEGA SCIENCE PROJECTS

8.26. The implementation of mega science projects in high technology areas will lead to direct technological gains for the country in terms of advanced technologies and equipment building, as well as development of expertise to take on similar projects in future. Mega science projects would involve multi-institutional teams, including possible international collaboration and linking projects to a broader academic framework would help in sustaining the research activities around these large facilities. Mega science projects would also create exciting opportunities for young students to actively involve them in cutting-edge research and attract them to science. India's successful participation in European Organization for Nuclear Research (CERN) has enabled it to participate in the International Thermonuclear Experimental Reactor (ITER) project as an equal partner. Some of the other mega science projects include: Nano-technologies, International Linear Collider and related programmes, India based Neutrino Observatory (INO), National Radioactive Ion Beam Facility, Facility for Antiproton and Ion Research (FAIR), astronomy based research, creation of National Hetero-structure Facility and the Square Kilometre Array (SKA). These programmes have a major component of international collaboration, and participation in them will allow the Indian scientific community to take its rightful place in the world scene.

CROSS-DISCIPLINARY TECHNOLOGY AREAS

8.27. Modern technology development is increasingly becoming dependent on research inputs from a large number of disciplines. A seamless and multi-sectoral flow of technologies and inputs from scientists and engineers from various disciplines is essential for making a visible societal impact and create economic prosperity. Under

the umbrella of cross-disciplinary technologies, efforts are needed to identify programmes cutting across the traditional divides of sciences, engineering, and medicine, where investments can pay rich dividends. Strong interfaces amongst academia, R&D laboratories and industries and special mechanisms need to be created for financing innovation in the early stage of technology development. Cross-disciplinary technology areas include: desalination and water purification technologies, nutrition, health care (medical diagnostics, medical devices, vaccines), advanced computing, advanced manufacturing, robotics and automation, combustion research, sensors and integrated systems, distributed sensors and networks, security technologies, and advanced functional materials. The list is not comprehensive and it represents a common denominator of cross-disciplinary areas where building core expertise and competence will have far-reaching consequences in the development of science-based technologies for societal benefits, economic competitiveness and national security.

STRENGTHENING ACADEMIA–INDUSTRY INTERFACE (INCLUDING PUBLIC–PRIVATE PARTNERSHIPS)

8.28. The relationship between the academia and industry should be of interactive, collaborative and participative nature, realizing and respecting each other's role and contribution. Efforts are needed to focus on PPP and creation of enabling environments. Effective academia–industry interaction will lead to: strengthening competitiveness, promoting innovation and new technology development on the one hand and ensuring development and supply of qualified S&T manpower. In order to strengthen the interface and tap the PPP potential effectively, the thrust should be on creation of new interface structures such as consortia, partnership research institutions for basic and applied R&D; enhancing mobility of S&T professionals; and promotion of technology transfer and new venture creation. Industrial houses may be encouraged to create corpus funds in academic institutions for promoting applied R&D relevant to their needs. Centres of Relevance and Excellence may also be set up in academic and R&D institutions in select areas of S&T, which are of direct relevance to industries. The student internship programme should also be made more meaningful, so that it benefits both the students and the industry.

8.29. The focus of consortia approach should be on pre-competitive partnerships involving academia to help the

industries develop advanced technologies and upgrade their manufacturing competitiveness. While government participation could be in the form grant-in-aid to academia and/or conditional grant to innovative small companies, industry partners will bring with them inputs like domain knowledge, market research and facilities for testing and validation of prototypes. PPP can also comprise co-locating an industrial R&D Centre within the premises of a national laboratory or academic institution and co-sharing some of the laboratory's select facilities with industry. For enhancing the mobility of S&T professionals, the young faculty could be given an internship programme at an advanced level so that they can spend some time in industry. This would enable them to impart more practical knowledge to students, relevant to industry. Active programmes may be established for regular visits of experts from industry to address students, academic and scientific staff. Efforts are also needed to strengthen venture funding for an effective proliferation of knowledge-based entrepreneurship.

SCIENCE AND TECHNOLOGY FOR SMALL AND MEDIUM ENTERPRISES

8.30. Small and medium scale enterprises (SMEs) occupy an important and strategic place in economic growth and equitable development of the country and are the driving force behind a large number of innovations. The post-liberalization era has enhanced opportunities and challenges for this sector. For enabling the SMEs to tide over the problems of technological backwardness and to enhance their access to new technologies, it is essential to understand and assess the real needs of the SMEs and devise approaches accordingly. There is also a need to leverage on modern technologies through increased communication, cooperation and linkages both within the enterprise as well as across enterprises and across knowledge-producing organizations.

EFFECTIVE DELIVERY AND PROPAGATION OF APPROPRIATE TECHNOLOGIES FOR RURAL DEVELOPMENT (INCLUDING PARTNERSHIP WITH VOLUNTARY ORGANIZATIONS)

8.31. The effective delivery of rural technologies is an important issue for the development and growth in the country. Technology transfer for rural areas is weak due to a lack of field-tested and validated models and inadequate institutional support both for technology development and transfer. The Council for Advancement of People's Action and Rural Technology (CAPART) is

the nodal government agency for creation and delivery of rural development related technologies. The role of the Support Voluntary Organization (SVO) programme is to search out and link up the thousands of disparate, small but sincere, groups working in far-flung corners of the country and provide them the necessary wherewithal to implement watershed programmes in their areas and mobilize rural communities for this purpose. The SVOs should be linked to S&T institutions so that they can absorb and deliver the technology packages to grass-root NGOs/Community-based Organizations (CBOs). CAPART should become an effective link between the technology generation centres and the line Departments such as the Ministries of Rural Development (MoRD), Agro and Rural Industries, Welfare, Tribal Affairs and Human Resource Development, for dissemination and propagation of technology packages through schemes for income/employment generation and capacity building. The S&T interventions in all spheres of rural life, such as agriculture, sanitation, health, physical and social infrastructure, need to be strengthened. Efforts are also needed to develop cost-effective rural technologies for non-farm rural enterprises, since non-farm rural employment assumes increasing importance due to low employment elasticity in the farm sector.

8.32. The role of NGOs in rural technology delivery should relate to: field surveys for assessing feasibility; preparation of Detailed Project Report with inputs from potential users; networking, motivating and organizing rural poor producers, artisans, small farmers and other partners/beneficiaries. NGOs need to develop linkages with technology providers, development agencies, and financial institutions and provide support for location-specific technology adaptation and upgradation and assistance in marketing. The NGOs will also need to play an entrepreneurial role on behalf of pro-poor enterprises, especially in dealing with financial institutions, traders, and the like. The NGO efforts of disseminating technologies relating to rural development, however, need to be enhanced by establishing synergy with the efforts of other government agencies so as to strengthen the existing and nucleate new initiatives.

LEVERAGING INTERNATIONAL COLLABORATION INPUTS

8.33. International S&T collaborations are essentially mechanisms of providing opportunities and platforms to various countries to work together, taking mutual advantage of complementary scientific & technological

capabilities of each other. They provide first-hand acquaintance with scientific and technological developments and work cultures in other countries and access to sophisticated research facilities abroad. Interaction between scientific researchers helps in updating and refining their knowledge base for accelerating the pace of investigation as also to fill up information gaps. Science being location neutral, international collaboration affords the way forward for development of advanced technologies, high tech equipment/facilities and new-generation materials.

8.34. Technology-led growth of the economy is a proven global model of growth, more so of developed nations. This has brought technology-led diplomacy to the centre-stage in international cooperation, and India also needs to leverage such technology-led diplomacy. Several developed nations have been targeting the young population of India for catalysing the growth of their own science and technology systems. India cannot remain a supply system of talents alone. Our strategy for international cooperation needs to be based on mutual gain and complementary strength. There are nations from which India may stand to gain by teaming up in certain sectors of development. Overall growth in important sectors of the economy cannot be based on total self-reliance as that may prove too expensive and time consuming. Re-inventing and reverse engineering models of growth are also not sustainable for modern India. In such domains, India would need to develop strategic partnerships with other nations after appropriate cost benefit analysis. Energy-, water-, ecological and nutrition-security of India would call for large global models of S&T cooperation. Areas of research such as high energy physics, nuclear physics, accelerator physics and technology, are distinctly international in character. Suitable collaborative projects by mobilizing the national strengths in these areas would need to be evolved and funded in coordination with other agencies.

8.35. A mechanism will also need to be evolved for attracting the best talent from other parts of the world, particularly people of Indian origin settled abroad and excelling in their respective areas of S&T. There is need to attract them for building active research centres/schools in frontier areas of science, engineering and technology. Scientists and technologists of Indian origin, abroad, could contribute in developing capabilities of Indian institutions and S&T groups. International S&T collaboration inputs may also be leveraged effectively by undertaking joint

R&D projects of industrial interest/commercial value at the pre-commercial stage involving academic and R&D groups as well as industrial groups at both ends.

NUCLEAR RESEARCH

ELEVENTH PLAN OBJECTIVES/THRUST/FOCUS

8.36. The Department of Atomic Energy (DAE) has been pursuing research in high-tech areas and developing technologies to meet the technological requirements of the country and building self-reliant capabilities in all aspects of the nuclear fuel cycle. Even in the present era, when globalization and liberalization have become buzzwords, we have to retain and strengthen our capability in the nuclear field so that the country remains unaffected by technology denial regimes. That apart, India's nuclear power programme has to be in tune with our nuclear resource profile. Therefore, the R&D programmes have been designed keeping in view the modest uranium and vast thorium resources that we have. While the technologies for Pressurized Heavy Water Reactors (PHWR) developed indigenously are now in the commercial domain, the approach now is to push the fast breeder reactor and thorium technologies. The thrust would also be on expansion of human resource development activities and encouraging students to carry out research on the interface of science and engineering. To augment the installed nuclear power capacity, maximum possible thrust would be given to development of new techniques for exploration of uranium and deployment of known techniques extensively for quick results. For uranium resource sustainability, credible waste management, and eventual thorium utilization, focus would be on development of advanced fuels having short doubling time for use in fast breeder reactors. Major achievements of the DAE (R&D) sector during the Tenth Plan period are given in Box 8.1

ELEVENTH FIVE YEAR PLAN PROGRAMMES

8.37. During the Eleventh Plan, R&D support will continue to improve capacity utilization, environment and safety and economic competitiveness of PHWRs. Technology will be upgraded based on latest developments in the entire PHWR fuel cycle. R&D work on the development of 700 Megawatt electrical (MW_e) PHWR will also be taken up. Focus would also be on the development of new techniques for uranium exploration to increase installed capacity based on PHWRs. Since the nuclear power programme in the next few decades will have a large component of Fast Breeder Reactors

(FBRs), major R&D programmes would be taken up for development of materials, equipment and processes for FBRs on a comprehensive basis.

8.38. R&D on advanced fuels for FBR, fuel reprocessing, study of fuel chemistry and other safety studies would also be carried out to be on a firm footing during the operation of Prototype FBR (PFBR) and planning of subsequent FBRs.

8.39. While the current generation nuclear energy systems have been very successful in terms of safety and economy, it is necessary to continue R&D for the development of advanced nuclear reactor systems. R&D towards the development of the thorium-fuelled Advanced Heavy Water Reactor (AHWR) would be continued. A demonstration unit of the Compact High Temperature Reactor would be built during the Eleventh Plan, which will serve as a platform for development and demonstration of very high temperature heat removal capabilities and other challenges associated with the operation of high temperature reactors. Work on the development of materials for high temperature reactors, including fusion reactor would also be taken up.

8.40. The International Thermonuclear Experimental Reactor (ITER) is a prestigious international project which will nearly complete the scientific and technological investigations required to build a prototype demonstration reactor, based on the magnetic confinement scheme of controlled thermonuclear fusion. India's contributions to ITER, worth nearly Rs 2500 crore in terms of equipment to the experiment, are largely based on the indigenous experience and the expertise available in Indian industry. India will also participate in the subsequent operation of ITER and the experiments thereon. R&D efforts on fusion and plasma science will continue to strengthen domestic technologies.

8.41. The research reactors, Assessment of Passive System Reliability (APSARA), CIRUS, DHRUVA, and KAMINI, which provide reactor based facilities for research in basic sciences, and other services like: production of radioisotopes, neutron radiography, neutron activation analyses, material irradiation testing, fuel testing, shielding studies, and so on, would be refurbished. It is also planned to set up a Multi-Purpose Research Reactor with high flux especially for basic research in frontier areas of science and for applied research related to development and testing of nuclear fuels and other

Box 8.1**Major Achievements of DAE (R&D Sector) during the Tenth Five Year Plan Period**

- The DAE contributed significantly to international mega-science projects, particularly the CERN. This contribution has been recognized and lauded by the international scientific community.
- Some of the important deliverables under the Advanced Reactor Design and Technology Development Project include: polyurethane booting for rugged duty manipulators, special purpose water hydraulic valves, in-core flux mapping system, DNA micro arrayer, and so on. The technology for on-line vibration diagnostics of the steam turbine has now been offered to NTPC for their 500 MW_e thermal power plants. Using the tools developed by BARC, pre-service inspection was carried out on 20 coolant channels prior to criticality. BARC also developed a methodology, called Assessment of Passive System Reliability (APSARA), for evaluation of passive systems which would be useful in new reactors under development.
- A process for recovery of uranium from low grade Tummallapalle ore using the pressure alkali process has been successfully developed and a technology demonstration pilot plant was set up at Jaduguda. Processes have also been developed for bulk separation of trivalent actinides from high level waste (HLW). Removal of uranium from simulated HLW was also demonstrated on full scale. BARC has also established the 'Indian Environmental Radiation Monitoring Network' with 37 monitoring stations across the country.
- The emphasis of the nuclear power programme stage-II has been on development of materials, equipment and processes as well as development of advanced fuels for fast breeder reactors. The Mark-I fuel (uranium-plutonium mixed carbide fuel with 70% plutonium) for Fast Breeder Test Reactor (FBTR) has reached a burn-up of 154.3 GWd/t without any fuel pin failure in the core. Compact Reprocessing Facility for Advanced Fuels in Lead Cells, was commissioned successfully for reprocessing high Plutonium content mixed carbide fuel. Sodium resistant concrete has also been developed to protect the structural concrete of FBRs.
- As part of Reactor Engineering studies, towards developing robust steam generator for FBRs, a Steam Generator Test Facility has been commissioned. Scale model of reactor assembly was commissioned and several experiments were completed successfully for qualifying the PFBR design. Realization of a robust, safe and economic fuel cycle for fast reactors is the ultimate goal for achieving rapid growth of fast reactors in the country.
- Under the nuclear power programme stage-III, DAE has initiated work towards development of the thorium fuelled Advanced Heavy Water Reactor. One major deliverable under the project is the AHWR Fuelling Machine (prototype). Installation of passive valve test facility, development and demonstration of conductivity probe, procurement of high speed CCD camera, development of indirectly heated fuel rod simulator, and installation of the liquid metal loop have been completed. Under the Thorium Fuel Cycle Technology Development and U²³³ Clean up project, a new process based on coated agglomerate particles (CAP) for (Th-U²³³) MOX fuels has been developed.
- Refurbishing the CIRUS Research Reactor and integration of a seawater desalination unit for demonstration of Low Temperature Vacuum Evaporation Process utilizing low-grade reactor waste heat from the CIRUS reactor has been completed. In the area of lasers, a facility for in-situ cutting operation using Nd:YAG lasers has been developed and deployed for en-mass coolant channel replacement at the Narora power plant. A facility for laser welding of automobile transmission gear assemblies using indigenously developed high power CO₂ laser was also set up. Substantial progress has also been made in the development of processes for ceramic materials synthesis and thin film processes for the solid oxide fuel cell components.
- Several new technologies have been developed for societal applications, which include: Sea water Reverse Osmosis plants for coastal areas, brackish water RO plant in villages for producing safe drinking water, Multistage Flash evaporator plant for seawater desalination using low grade steam, Low Temperature Evaporation plant using waste heat for seawater desalination, and waste water recycle and reuse plants for the effluent. In the field of nuclear agriculture, 26 elite Trombay varieties have been developed. In addition, a laser-based land levelling system was built at the behest of the Ministry of Agriculture, and this technology has been transferred to M/s OSAW Udyog of Ambala Cantonment for mass production.

materials. A radioisotope processing facility is also planned to be set up at Visakhapatnam.

8.42. Some of the other major programmes proposed to taken up include: setting up of the second campus of BARC at Visakhapatnam and R&D for Accelerator and

Accelerator Driven Systems development; development of beam lines for Indus-2 and their utilization; and development of superconducting cavities and associated technologies for high energy accelerators. A proton therapy unit would be assembled and installed the Advanced Centre for Treatment, Research and Education

in Cancer, Navi Mumbai, for clinical application in treatment of cancer. Medical cyclotron, which is under construction, would also be available during the Eleventh Five Year Plan period.

8.43. A programme on enhancement of the DAE Grid and Anunet facility will be taken up to improve the communication and computing power of the DAE units. It is also planned to have an INO in collaboration with the scientific community of the country. This would be open for international participation also. In addition, the project on energy conversion technologies for study of alternate energy conversion technologies will be strengthened.

8.44. Research–education linkages are the backbone for developing of scientific manpower for the country at large and within the DAE in particular. It is planned to have a separate training school for an Atomic Minerals Directorate for Exploration and Research in line with other training schools in the Department. The DAE has also initiated the process for establishment of the NISER at Bhubaneswar, at par with the IISER to undertake integrated five-year Masters' courses and integrated M.Sc–Ph.D. programme in core and emerging branches of science to provide world-class education to students.

8.45. The Eleventh Five Year Plan outlay of the DAE (R&D Sector) has been tentatively fixed at Rs 9726 crore at 2006–07 constant price and Rs 11000 crore at current price.

SPACE SCIENCE & TECHNOLOGY

ELEVENTH PLAN OBJECTIVES/THRUST/FOCUS

8.46. The major objectives of the Space Programme are to establish self-reliant operational space services in the areas of satellite communications, satellite-based information for management of natural resources and satellite meteorological applications. Over the years, India has established two operational space systems—the Indian National Satellite (INSAT) System providing services for telecommunications, TV broadcasting and meteorology including disaster warning support, and the Indian Remote Sensing Satellite (IRS) System for natural resource monitoring and management.

8.47. The focus of the INSAT programme will continue to provide a variety of services in telecommunications

and television broadcasting, including meteorological observations, disaster communications, tele-education, tele-health services and village resource centres (VRCs). Under the IRS programme, the focus will be on vital applications of IRS data for identifying locations for ground water recharging, monitoring command areas, estimating crop areas and yields, assessing deforestation, mapping urban areas for planning purposes, delineating ocean areas with higher fish catch potential and monitoring of the environment. The emphasis of the space programmes will be on large-scale applications of space technology in the priority areas of national development. The already established space-based services for socio-economic development of the country will be sustained and strengthened. The future directions for the space programme will take into account the needs of the country in the context of emerging international environment and the potential that India holds for human development.

8.48. Technology advancement, which is essential to maintain competitive relevance, will be an important thrust area for space endeavours. Emphasis will be given to strengthening the ground segment to ensure and enhance effective utilization of the remote sensing data for programmes relating to the creation of a natural resource inventory and databases, food security, water security, disaster management support, infrastructure development, weather forecasting, ocean state forecasting, environment protection and climate variability and change. The emphasis in the area of satellite communications will be towards meeting the growing demand for transponders, ensuring continuity of quality services, protection of space systems, efficient spectrum management and continuous improvement in technology.

8.49. In the area of launch vehicle development, emphasis will be on the development of Geosynchronous Launch Vehicle (GSLV) Mk III capable of launching 4T class INSAT satellites. Polar Satellite Launch Vehicle (PSLV) and GSLV will continue to be workhorse vehicles for launching IRS and INSAT (2T class) satellites and their capabilities will be further improved. The objective of the Manned Mission programme would be to develop a fully autonomous manned space vehicle to carry two crew to 400 km Low Earth Orbit and safe return to earth. Major achievements of the Department of Space (DoS) during the Tenth Plan period are given in Box 8.2.

Box 8.2 Major Achievements of DoS during the Tenth Five Year Plan Period

- The Tenth plan witnessed significant progress in Indian space capabilities. Operationalization of GSLV, development and qualification of indigenous cryogenic engines, establishment of a state-of-the-art, second launch pad facility at Sriharikota, launch and operationalization of Kalpana (Metsat-1), Resourcesat-1, Cartosat-1/HAMSAT and Cartosat-2/SRE-1 by PSLV, augmentation of the INSAT system with INSAT-3A, 3E, GSAT-2, EDUSAT, INSAT-4A and 4B satellites are some of the important achievements of the period.
- GSLV Mk III has made good progress towards the establishment of S-200 facilities. With the successful initiation of stage hot tests, the GSLV flight with indigenous cryo stage will take place in 2008.
- The design, development, characterization and realization of the supersonic combustor module, required for future Reusable Launch Vehicles, were completed and the technology was successfully demonstrated through ground tests for 2.5 kg/s and 5 kg/s air flow rates.
- Yet another important technological achievement was the development and testing of an Electric Stationary Plasma Thruster (18 millinewton) for future inter-planetary missions. This will be flight tested onboard GSAT-4 spacecraft planned for launch during 2008. Planetary mission Chandrayaan-1, multi-wavelength astronomy mission ASTROSAT, Indo-French joint climatic mission Megha-Tropiques, microwave remote sensing mission RISAT and oceanography mission OCEANSAT-2 were other important initiatives during the Tenth Plan period. Work on the Indian Regional Navigational Satellite System (IRNSS) was initiated.
- Development of indigenous strategic capability in certain critical areas like ring rolling mill, alloy, Titanium sponge, hi-reliability electronic components and space materials were other important achievements. ANTRIX Corporation won contracts for two dedicated launches of PSLV and also supply of a sophisticated communication satellite in consortium with a leading European manufacturer M/s EADS ASTRIUM.
- India is now one among the six countries in the world to develop Geosynchronous Transfer Orbit (GTO) (36000 km high) launch capability. The technological capability to recover a satellite from orbit through a space capsule recovery experiment was demonstrated, thus laying the foundation for future reusable launch vehicle systems.
- India's first lunar mission, Chandrayaan-1 (scheduled for launch in 2008), and the multi-wavelength observatory satellite ASTROSAT are two important initiatives of the recent past in space science research. The end-to-end capability in space for vital applications in communications, broadcasting, meteorology and natural resource information, which are of direct relevance for national development, has secured India a unique place in the international community.

ELEVENTH FIVE YEAR PLAN PROGRAMMES

8.50. The major plans/programmes during the Eleventh Plan would be related to:

- Building capabilities in Space Communications and Navigation; development of high power Ka band satellites and ground systems for point-to-point connectivity; building navigational satellite systems and related services; R&D in satellite communications; institutionalization of tele-medicine, tele-education and VRCs; communications systems/support for disaster management; self sustenance of INSAT/GSAT system;
- Developing Leadership in Earth Observations: improved imaging capability and continuity of data/services; development of advanced microwave imaging capability; strengthening ground systems and State Natural Resources Management System; establishment of a national natural resource database; Data Management System (DMS) infrastructure and urban/rural development;
- Providing thrust in Space Transportation System: operationalization of GSLV Mk III; development of perfect payload recovery and re-entry technologies; reusable launch vehicle; and development of critical technologies for manned missions;
- Strengthening Space Science Enterprise: advanced space science endeavours, namely Chandrayaan, multi-wavelength X-ray astronomy, mission to Mars; establishing space science instrumentation facilities and an Indian Space Science Data Centre;
- Promoting spinoffs in the discipline of human resource development, space science and technology education, industry-academia interface and international

cooperation. The thirst for expanding knowledge about the universe, solar system and planet Earth would be the driving force of the programmes.

- Based on demand, the INSAT system capacity will be progressively augmented to about 500 transponders (currently 175). Development of a cost-effective 4T-12KW bus with capacity of more than 50 transponders and flexibility to accommodate a wide range of payloads, will also be undertaken.

8.51. Earth Observation (EO) Systems would be taken up primarily to ensure continuity and quality of EO data with a view to maintain global leadership in this area. The EO series of satellites, both in the IRS and INSAT/METSAT series, will address broadly the thematic applications in three streams—Resourcesat series, Cartosat series and Atmosphere series. The Radar Imaging Satellite (RISAT) would be launched to provide all-weather remote sensing capability critical for applications in agriculture and disaster management. The other thrust areas would include expansion of tele-education and tele-medicine networks and VRCs with the involvement of Central Government ministries/departments, State Governments and NGOs. Satellite navigation would be a vital component not only for civil aviation but in many other areas such as mobile telephony, surface transport, intelligent highway system, maritime transport, rail, oil and gas, precision agriculture, fisheries, survey and marine engineering, electricity networks, and so on. Besides the completion of GAGAN (Global Positioning System and Geo Augmented Navigation), focus will also be on the establishment of the IRNSS with a constellation of seven satellites. The realization of a national database for emergency management, impact mapping and monitoring support for disasters, satellite-based communication support for disaster management, strengthening of early warning systems and development of tools and techniques for decision support systems would be the major activities under the DMS programme.

8.52. Considering the need to provide an impetus to studies and research in the critical area of atmospheric research, an Atmospheric Science Programme has been planned with special emphasis on the use of satellites and advanced observation tools and techniques of modelling. A mechanism would be worked out for interactions with scientific departments and academia for initiating suitable projects, leading to operational end-user products in different domains. Human resource development, international cooperation, industry and academia interface,

indigenous development of space materials and components and space commerce will continue to be priority areas. An important target during the Eleventh Plan period would be to set up an Indian Institute of Space Science and Technology with a view to capture the talent at the 'Plus Two' (senior secondary) level for creating quality human resources in the country for Indian Space Research Organization (ISRO). While efforts would be made to partner with Indian industries or outsource a majority of the production, fabrication, testing and software development activities, some of the routine production jobs, which requires capital intense infrastructure and involves strategic and security considerations, will be taken up in-house by creating a few production islands.

8.53. The Eleventh Five Year Plan outlay of the DoS has been tentatively fixed at Rs 27305 crore at 2006–07 constant price and Rs 30883 crore at current price.

BIOTECHNOLOGY RESEARCH

ELEVENTH PLAN OBJECTIVES/THRUST/FOCUS

8.54. The approach of the Department of Biotechnology (DBT) has been to create tools and technologies that address the problems of the largest section of the society and provide them with biotech products and services at affordable prices. The ultimate objective is to make India globally competitive in the emerging bio-economy by converting the country's diverse biological resources to useful products and processes. Developing a strong biotechnology industry and technology diffusion capacity is critical for fulfilling this objective. The advancement of biotechnology as a successful industry confronts many challenges related to research and development, creation of investment capital, technology transfer and technology absorption, patentability and intellectual property, affordability in pricing, regulatory issues and public confidence and tailor-made human resources related to all these aspects. The department has been working on cross-cutting issues such as human resource development, smarter re-entry for our scientists abroad, new and varied models of creating an innovation-friendly environment, R&D in small and medium size companies, newer ways of collaborating with large companies, establishing centres of excellence and translational research centres, remodeling life science departments in universities/institutions, establishment of technology management centres, promoting dynamic biotech regional clusters, establishment of biotechnology parks and incubators, and setting up of

Box 8.3

Major Achievements of DBT during the Tenth Five Year Plan Period

- In the area of Human Resource Development, the Department is implementing an Integrated Programme of Human Resource Development in Biotechnology to generate adequate and appropriately trained manpower required for overall development of Biotechnology in the country. The MSc/MTech teaching programme which was started in 1985–86 in five universities, has been gradually increased to 63 courses with a total intake of around 1000 students per annum. Of these, 22 courses were started during the Tenth Five Year Plan. The Junior Research Fellow (JRF) programme has also been started from 2004 to fill the gap between the PG teaching courses and the Post Doctoral Fellowship programme.
- 35 biotech facilities were established in the public sector for production and supply of biologicals, reagents, culture collection and experimental animals to scientists, industries and students at nominal costs and to conduct regular training programmes for capacity building. An International Depository Authority was established at Institute of Microbial Technology, Chandigarh, which is the first such facility in India, 7th in Asia and 34th in the World. The Department also initiated the Centres of Excellence programme during 2005–06 and supported five centres in the areas of cancer biology, industrially important non-conventional yeasts, drought tolerant crop varieties, genetics and genomics of silk moth, and tuberculosis.
- An extensive bioinformatics network, covering 65 institutions, spread geographically across the country, has been established. Scientists associated with this network have published more than 1200 bioinformatics research papers in peer reviewed journals and helped in publishing more than 3500 research papers in biology/biotechnology. Courses such as MSc/MTech/PhD in Bioinformatics have also been introduced.
- Technology for recombinant anthrax vaccine has been developed and transferred to M/s Panacea Biotech Ltd., New Delhi. Ovum pick up technology for production of a large number of embryos in cattle and buffalo has been standardized and ELISA/PCR based diagnostic kits for *Peste des petits ruminants* (PPR) virus and Buffalopox virus (BPV) have been developed.
- India has successfully decoded the genome information of the rice chromosome number 11. Some of the important achievements in the field of crop biotechnology include: transformation technologies for rice for salinity and drought tolerance; molecular marker for wheat quality traits; novel Bt-cotton technology; transgenic virus resistant tomato; Genetically Modified (GM) mustard with higher yields; and technology for double haploids in cereals. Four mass production technologies for bio-control agents/biopesticides have been developed and standardized and six patents have been filed.
- Development of newer technologies for affordable vaccines for malaria, tuberculosis, cholera, HIV, rabies and Japanese encephalitis, helicobacter, and filariasis has been undertaken. Efforts to develop a tetravalent dengue vaccine candidate are in progress. Two candidate vaccines on rotavirus developed under INDO-US Vaccine Action Programme, have been found to be safe in clinical settings. Limbal stem cells have been successfully used to repair cornea surface disorders and more than 220 patients have been treated. In the area of medicinal and aromatic plants, four technology transfer agreements have been made for further screening of compounds as potential anti-diabetic and immunomodulatory agents.
- In the area of environmental biotechnology, technologies for bioremediation of mine spoil dumps; ecological restoration of degraded ecosystems and wastelands; mangrove afforestation; biosensors for detection of organophosphorus pesticides; bioscrubber for removal of obnoxious odours from industrial emissions; and oilzapper technology for bioremediation of crude oil spills and treatment of oily sludge ready for commercialization.
- Technologies have also been developed for the manufacture of nutrient supplements, health foods, fruit juice processing, production of natural food additives, oil and fat modification, ensuring food quality/safety, biodegradable food packaging and production of chitosan based packaging films. Out of 19 technologies developed, eight technologies were transferred to the industry. Diagnostic kits were developed for rapid detection of food-borne pathogens like *E. coli*, *Listeria monocytogenes*, *Bacillus cereus*, and so on.
- Four international patents and ten Indian patents were granted to the National Institute of Immunology (NII). A technology relating to novel molecules which inhibit tuberculosis bacteria with the potential to be developed as anti-mycobacterial drugs, is being explored under a memorandum of understanding with Astra Zeneca India, Bangalore, and Cadila, Ahmedabad. A technology developed for the high density culture of Vero cells of an Indian strain of Japanese encephalitis virus (JEV) has been transferred under a memorandum of agreement to International Panacea, New Delhi.
- The repository at the National Centre for Cell Science (NCCS) procured 34 new cell lines, raising the total culture collection to 1161. The Centre made a total of 155 publications and obtained six US and three Indian patents. Methodologies for cryo-preservation and revival of bone marrow and cord blood cells have been transferred to Armed Forces Medical College, Pune. A technology on use of selected amino acid–zinc complexes as anti-malarials has been transferred to Shreya Life Sciences, Mumbai.
- The Department supported the setting up of a biotechnology park at Lucknow, and five biotechnology incubation centres, one each at Hyderabad, Bangalore, Kochi, Chandigarh, and Solan. The Department has also launched the Small Business Innovation Research Initiative (SBIRI) to boost PPP efforts in the country. An agreement has been executed by the Department with Biotech Consortia India Ltd., New Delhi, which is acting as the Special Purpose Vehicle (SPV)/Fund Manager for smooth running of the scheme. So far, ten proposals have been recommended for support.

biotechnology regulatory mechanisms. For this purpose, the DBT will be formulating the 'National Biotechnology Development Strategy' during the Eleventh Five Year Plan in consultation with all the stakeholders. Major achievements of DBT during the Tenth Plan period are given in Box 8.3.

ELEVENTH FIVE YEAR PLAN PROGRAMMES

8.55. The priority areas for the Eleventh Five Year Plan include the development of improved crops, functional foods, nutraceuticals, nutritional rich food for combating malnutrition, bioprocessing and scale up for production and manufacture of biologicals, R&D on bio-drugs, vaccines, biological reagents and adjuvants, diagnostics, implants, devices, medical bioinformatics, clinical research, stem cell research and regenerated medicine. Nano-biotechnology applications for drug, delivery, biosensors, microbial prospecting for novel compounds, genes, bio-energy and bio-fuels, bioremediation, and so on, are other important thrust areas. International cooperation activities matching national needs and the above priorities, will also be accelerated.

8.56. A technology management network that is locally linked to stronger Central resources is an essential link. It is therefore proposed to create ten national/regional technology transfer cells (TTC) to provide high-calibre, specialized and comprehensive technology transfer services; evaluate technology and identify potential commercial uses; develop and execute commercialization and intellectual property protection strategies identifying appropriate potential licensees; negotiate a wide variety of licenses and monitor the licensing arrangements. Each TTC would service a cluster of institutions in a region. New Centres of Excellence (CoEs) would be established within existing universities and medical, agriculture and allied colleges, around innovative leaders.

8.57. Cutting-edge research in biotechnology requires creation of state-of-the-art infrastructure. Therefore, large animal house facilities with Good Manufacturing Practices (GMP) for testing candidate vaccines and biotherapeutics; DNA and stem cell banking facilities; depositories of biological materials; testing facilities for Genetically Modified Organism (GMO)/Living Modified Organism; and validated laboratory facilities to support major clinical trials would be set up. Upgradation/reengineering of existing life science departments of

selected university departments and medical colleges by way of providing infrastructure support and faculty, and creating new research agenda would also be undertaken to develop world-class life science departments doing both education and research. Strengthening bioinformatics R&D and infrastructure in terms of higher super computing capabilities, expansion of biogrid, human resource development, linkages with industry, institutional mechanisms for software development and validation, development of an Indian portal site and bioinformatics parks and clusters through PPPs, would also be taken up.

8.58. In the areas of industrial biotechnology, priority would be on biotransformation to make bioproducts cost effective; advanced manufacturing technologies for production of vaccines and other medical products; bio-separation technologies for recombinant DNA products; reactor engineering; and development of bioprocesses for high quality textiles, silk and paper industry. Some of the other important R&D areas would be genomics, proteomics, pharmaco-genomics, and in-silico drug design.

8.59. Interdisciplinary 'grand challenge' projects would be taken up in areas of national importance, where biotechnology interventions can bring about significant value addition, cost effectiveness and competitiveness in product and process development. These would be implemented through special management, administrative and organizational structures for time-bound results. Some of the areas identified for this purpose include: (i) food and nutrition security; (ii) molecular breeding of agricultural crops and silk worm; (iii) microbial prospecting for industrial, agricultural, environmental, medical and therapeutic purposes; (iv) new generation human and animal vaccines and delivery systems; (v) diagnostics for health care; (vi) integrated tuberculosis research; (vii) stem cell biology and regenerative medicine; and (viii) bioengineering for implants and medical devices.

8.60. With a view to focus on translational and innovation activities, the existing autonomous institutions would be remodelled. This would require expansion of the scope of the institutions by building centres of translation, innovations and services along with focused networking. The National Institute of Immunology, New Delhi, will establish translational research programmes for the development of anti-HIV microbicides, anti-viral vaccines and Cancer diagnostics and therapeutics. The NCCS,

Pune, will be initiating focused programmes on diabetes and an inter-institutional network programme on HIV and Tuberculosis, apart from establishing centres for cell and tissue engineering and immuno-therapeutics. The Centre for DNA Fingerprinting and Diagnostics, Hyderabad, will undertake new activities such as a national facility for training in DNA profiling; a Disaster Victim Identification Cell (DVIC); and creation of a national DNA database. The National Brain Research Centre, Manesar, will take up Neural Stem Cell research and set up a Clinical Research Centre for brain disorders and Brain Machine Interface. The Institute of Life Sciences, Bhubaneswar, will undertake translational activities for the development of DNA chip-based diagnostics and nano-medicine.

8.61. It is also proposed to establish new institutional structures, especially in the areas which have marginal strength and a critical mass of expertise. These include institutes for translational research in health science and technology; stem cell research and regenerative medicine; UNESCO regional centre for science, education and innovation; agri-food biotechnology and bioprocessing unit; animal biotechnology; marine biotechnology; seric and textile biotechnology and molecular medicine and medical genetics. Besides, three autonomous Translational Molecular Medicine Centres and one centre for plant sciences in existing institutions and taking over of the Rajiv Gandhi Institute of Biotechnology, Thiruvananthapuram, from the Government of Kerala, are also proposed.

8.62. The establishment of biotechnology parks and incubators as part of biotech clusters, essentially through PPPs would be supported. It is also proposed to promote the biotech cluster concept, and based on an analysis of opportunities and feasibility, creation of new clusters at Punjab, Delhi, Haryana, West Bengal, Gujarat, and Orissa would be considered. Major expansion of the SBIRI scheme has also been envisaged. A Special Purpose Vehicle (SPV) will be created for managing this scheme professionally. New models of partnership namely, the Biotechnology Industry Partnership Programme, would be worked out to pursue path-breaking technology initiatives and building greater flexibility in public institutes to enable them to work with industry. A Biotechnology Industry Research Assistance Council (BIRAC) would also be put in place for monitoring,

supporting and nurturing R&D in small and medium biotechnology companies.

8.63. A scientific, rigorous, efficient, predictable and consistent regulatory regime for biosafety evaluation and release of protocols is essential. It is therefore proposed to create a 'National Biotechnology Regulatory Authority' to provide an effective, single window clearance mechanism for all biotechnology products.

8.64. The Eleventh Five Year Plan outlay of the DBT has been tentatively fixed at Rs 5649 crore at 2006–07 constant price and Rs 6389 crore at current price.

DEPARTMENT OF SCIENCE AND TECHNOLOGY (DST)

ELEVENTH PLAN OBJECTIVES/THRUST/FOCUS

8.65. It is envisaged that the S&T output indicators of India would register more than double growth rates during the Eleventh Plan period as a result of planned investments based on output directed development strategy. The thrust would be on developing processes and strategic alliances with other departments and State agencies for ensuring efficient delivery of the programmes.

8.66. The focus would be on strengthening R&D systems in order to shorten the waiting time for funds from the current 12–16 months on an average, to 4–6 months. The development of a measurement and assessment system suited to the S&T landscape of the country and an enhanced accountability of research and technology institutions are critical requirements. There is also a need for expanding and strengthening of the institutional framework of higher learning and research, which is showing signs of saturation and maturity. The accelerated growth processes desired by the country calls for development of new aggressive models and establishment of institutions without jeopardizing the existing S&T systems. Major achievements of the DST (R&D) sector during the Tenth Plan period are given in Box 8.4.

ELEVENTH FIVE YEAR PLAN PROGRAMMES

8.67. The low entry of talent into the S&T streams is one of the most serious challenges facing S&T systems in the country. Therefore, during the Eleventh Plan period and beyond, a new scheme under the title 'Innovation in

Box 8.4**Major Achievements of DST during the Tenth Five Year Plan Period**

- The Science and Engineering Research Council (SERC) is the flagship programme of DST for Extra Mural Research (EMR) support to individual researchers in the country with a 40–44% share. The support provided by SERC has resulted in more than 500 research publications per year in Science Citation Index (SCI) journals with an average impact factor consistently in the range of 2.2 +/- 0.1.
- SERC has contributed significantly towards augmentation of R&D capabilities at academic institutions and national laboratories in terms of advanced research facilities, which include: National Facility for High Field Nuclear Magnetic Resonance (NMR) at Tata Institute of Fundamental Research; Non-Destructive Evaluation (NDE) facility at National Metallurgical Laboratory and IIT, Chennai; Low temperature High Magnetic field facility at University of Hyderabad; Centre for study of ultra fast processes at University of Madras; National Facility for protein sequencing at IIT, Mumbai; Superconducting Quantum Interference Device (SQUID) based Magneto Encephalography (MEG) system for non-invasive studies of human brain at Indira Gandhi Centre for Atomic Research (IGCAR); NMR facility for biological research at Indian Institute of Science (IISc), Bangalore; and Linear accelerator with conformal radiotherapy and intensity modulation radiotherapy facility at Sanjay Gandhi Post-Graduate Institute of Medical Sciences (SGPGIMS), Lucknow. Ten centres on nano science were also established for quality nano science research aimed at anchoring technology development programmes. SERC has also played a crucial role in strengthening S&T infrastructure in the Universities under the Fund for Improvement of S&T infrastructure (FIST) programme and has helped in rejuvenating to a great extent, R&D activities in the university system.
- The average output indicators per scientist per year of the autonomous institutions during the Tenth Plan period has been in the range of 2–6 publications with an aggregated average impact factor in the range of 2.3 per paper.
- Indian scientists were also assisted and supported in accessing/utilizing some of the major international research facilities like CERN (Geneva), ELETTRA (Italy), Sp Ring-8 (Japan), KEK Accelerator (Japan), National Laboratory for High Energy Physics (Japan), Synchrotron Radiation Sources Beam line facility (Novosibirsk, Russia), FAIR (Germany), Fermi Lab (United States), and Synchrotron Light Source (Singapore), for advanced training and conducting experiments in the fields of crystallography, condensed matter physics, high energy scattering, solid x-ray spectroscopy, nuclear resonance scattering, magnetic Compton studies, and so on.
- Under the Drug and Pharmaceutical Research programme, national facilities in the field of Regulatory toxicology, Proteomics, Pharmacokinetic Evaluation and Biosafety Facility at level 3 have been created. Collaborative R&D projects on diseases like AIDS, TB, diabetes, and leucoderma were supported in R&D and academic institutions with the participation of leading industries. R&D efforts have led to six product patents filed both in India and abroad, 13 process patents, and synthesis of over 250 New Chemical Entities (NCEs) resulting in around 25 lead molecules. Around 7000 molecules already existing in various national laboratories were screened for their efficacy. The programme has been able to bring in private contribution to the tune of Rs 150.00 crore for drugs and pharmaceutical research and has emerged as a good example of the PPP model in research and development.
- Inter-governmental agreements for cooperation in S&T were signed with 16 countries, which include Canada, China, Colombia, the EU, Islamic Republic of Iran, Iceland, Italy, Laos, Mozambique, South Korea, Serbia and Montenegro, Sudan, Sweden, Switzerland, Thailand and USA. Detailed protocols on IPR were also signed with Canada, Israel, USA and Switzerland. Eight joint centres were also set up with active cooperation of some of the bilateral partner countries, namely, Indo-French Centre on Organic Synthesis, IISc, Bangalore; Indo-French Laboratory for Solid State chemistry, IISc, Bangalore; Indo-Russian Centre for Ayurvedic Research, Moscow; Indo-Russian Centre for Gas Hydrate Studies, NIOT, Chennai; Indo-Russian Centre for Earthquake Research, Indian Meteorological Department (IMD), New Delhi; Indo-French Institute of Mathematics, Mumbai, and Indo-Russian Centre for Biotechnology, Allahabad. Several new programmes have also been launched during the Tenth Plan period, which include: Indo-Israel Industrial R&D Cooperation, Indo-Russian Technology Centre, Indo-UK Science and Innovation Council, Indo-Russian S&T Cooperation in cutting-edge areas, Indo-Canadian S&T Cooperation in cutting-edge areas, and establishment of Joint Bilateral Centres of Excellence in the areas of Non-ferrous Metallurgy, Biomedical Technology and Lasers and Accelerators.

Science Pursuit for Inspired Research' (INSPIRE) would be initiated to attract and foster talent in scientific research. The main features of the proposed scheme would be innovation funding in schools (one million young innovators); summer camp with Science Icons (for high performers); assured opportunity schemes for proven

talent; and retention of talent in publicly-funded research through PPP. The Oversight Committee's recommendation regarding SHE providing 10000 scholarships of one lakh rupees each per year, for attracting talented science students to BSc and MSc courses, would also be subsumed in this scheme.

8.68. Research and development support mechanisms will be strengthened by launching a two-pronged strategy. While continuing its endeavour to widen and strengthen the base of basic research through appropriate HRD measures and building up of research capabilities of the academic sector, support would also be provided for undertaking major, internationally competitive and front-ranking projects through a Science and Engineering Research Board. For this purpose, the existing SERC mechanism would be restructured in to the National Science and Engineering Research Board. Necessary in-house infrastructure and suitable changes in procedural mechanisms will be undertaken to ensure both quality and speed in the delivery of resources. A special programme for rejuvenation of research in universities would be initiated.

8.69. The national mission on nano science and technology would be a major new programme, designed to enable India to become a significant player in the global race by tapping the potential applications of nano science and technology. The proposed Nano Science and Technology Mission would focus on basic research, infrastructure development for quality nano science and technology research, human resource development, forging international collaborations and most importantly, promoting PPP in the area of nano science and technology. The Drugs and Pharmaceutical Research Programme, which has emerged as a true PPP in the area of pharmaceutical research and development, will be another major programme to be pursued during the Eleventh Plan period.

8.70. Investment in autonomous institutions would be on the basis of performance and assistance will be provided to them to attain global best standards in science and engineering. A study of impact assessment of the Technology Information, Forecasting and Assessment Council (TIFAC) and National Accreditation Board for Testing and Calibration Laboratories (NABL) has also been planned. The proposed study will form a decision tool to shape the future structure and programmes of these two organizations. TIFAC will be developed into a policy body for developing technology foresight and strengthening the innovation infrastructure of the country. The Survey of India (SoI) enjoys brand equity in the area of geo-spatial products. In the wake of a new map policy of India, geo-spatial products have gained market value in the consumer market. Keeping this in view, SoI requires an urgent package for modernization of its physical, human,

market and intellectual capitals. The modernization package of SoI will also bring about organic linkages in the programmes of the National Atlas and Thematic Mapping Organization. A few new autonomous S&T institutions would also be established in critical areas like glaciology, molecular materials, pre-competitive research institutes for computer sciences, and so on.

8.71. Several new initiatives like the Water Technology Initiative, setting up of innovation clusters, security technology initiative, and programmes for setting up mega facilities for basic research will also be taken up. The Water Technology Initiative would focus on the design and development of low-cost solutions for safe drinking water for domestic use. Innovation clusters are emerging on the global platform and numerous success stories of such innovation clusters benefitting both academic and industrial sectors have been reported. It is necessary for India to mount such an initiative under an effective PPP model in areas where the trade and advantages have already been established and the clustering processes are evident. A proposal for taking up a National Innovation Project has also been contemplated, which would be taken up after a dialogue with key stakeholders to identify the needs regarding the innovation system and possible interventions, with World Bank involvement. The Security Technology Initiative would address issues relating to internal security. DST, along with DAE, has also identified areas where an effective partnership of the two departments can bring about effective capacity building in the university and academic sector for building mega facilities for basic research both within and outside the country.

8.72. The Eleventh Five Year Plan outlay of DST has been tentatively fixed at Rs 9750 crore at 2006–07 constant price and Rs 11028 crore at current price. The existing allocation for schemes like INSPIRE, Security Technology Initiative and support to autonomous institutions may need to be enhanced during the course of the Plan, depending upon the actual progress.

SCIENTIFIC AND INDUSTRIAL RESEARCH

ELEVENTH PLAN OBJECTIVES/THRUST/FOCUS

8.73. The avowed objectives of the Department of Scientific and Industrial Research (DSIR) are to promote industrial research, technology development and transfer, and its utilization, with a view to making Indian industry

globally competitive. During the Eleventh Plan, the focus would be on promoting creativity and innovation among individuals; promoting and supporting industry for development of new products, processes and technologies; attracting venture capital funding; developing the consultancy profession; promoting commercialization of technologies in India and abroad; and creating awareness about the latest IPR regime.

8.74. The focus of CSIR would be on finding holistic and optimal solutions to the pressing problems of the country by deploying technologies ranging from the simplest to the most sophisticated ones. Innovation in all spheres of activities, ranging from science, technology, management and financing, would be supported. The thrust would

be on adoption of three-pronged approach to: (i) conceptualize, plan and work, in network mode, on R&D of relevance both nationally and globally and to align it with public, private, strategic or social needs as the case may be; (ii) forge viable, defined and scientifically challenging R&D projects in supra institutional mode to make each laboratory a cohesive and close-knit unit. This would help in aligning and reinforcing the core competency of the laboratory; and (iii) build within each laboratory, Centres of Sustainable Growth, a kind of magnet to attract scientists/technologists of Indian origin, industry (both national and foreign) and a large number of trainees. Such centres would aim to be creative think-tanks to look at the future with a clear vision. Major achievements of DSIR/CSIR during the Tenth Plan period are given in Box 8.5.

Box 8.5

Major Achievements of DSIR/CSIR during the Tenth Five Year Plan Period

- Major achievements under the Technology Promotion, Development and Utilization Programme (TPDU) programme include: Composite insulators for high power transmission; technologies for manufacture of digested organic supplement enriched with micronutrients, Tetrabromobisphenol-A; Liposomal Amphotericin-B, Pyrazinamide using the catalytic route; and processes for Hydrogen Sulphide removal and recovery of sulphur from sour gases; isolation of natural dyes from forest plants of Uttaranchal. A cotton seed delinting plant and an integrated pilot demonstration plant for spice processing have also been developed in collaboration with various industries.
- The two-seater, all composite trainer aircraft Hansa designed and built by National Aerospace Laboratories has been certified by Director General Civil Aviation (DGCA) for day and night flying. It is now being manufactured along with a private partner and a dozen of them are now flying successfully across the country. Saras, India's first indigenously developed, multi-role civilian aircraft, took its inaugural test flight on 22 August 2004, and till March 2007, the prototype-1 has made more than 110 test flights. Taxi trials for the second prototype have begun and it is expected that the prototype-2 test flight would commence soon. After successful completion of the test flights and DGCA license, the aircraft will go in for commercialization by Hindustan Aeronautics Limited.
- For the first time in India, an optical fibre amplifier for light wave telecommunication network has been developed using erbium-doped optical fibre (EDF) and power semiconductor pump laser source which has the potential for use in the propagation of 'Fibre-to-Home' technology. An alternative novel route for synthesis of 1, 1', 1''-Tris 4'-hydroxyphenyl ethane (THPE) was developed and transferred.
- CSIR operated a New Millennium Indian Technology Leadership Initiative (NMITLI) scheme in PPP mode through which 42 projects were developed involving 65 industrial partners and 222 research groups for capturing global technology leadership position. Some of the significant achievements were: development of a new pharmacophore for the treatment of tuberculosis where the molecule works through combination therapy (compatible with the present drugs), is less toxic, clears the total infection within two months and no recurrence has been observed; development of a novel drug delivery system based on dry powder inhalation of micro particles containing rifampicin/rifabutin and isoniazid; development of 'Bio Suite' and 'Geno Cluster' software, and also of two new varieties of *Mentha piperita* namely, 'CIM-Indus' (with the characteristic of high menthofuran and pulegone) and 'CIM-Madhuras' (with the characteristic of sweet smell).
- In the areas of drugs and pharmaceuticals, significant achievements were related to: isolation of a compound from the leaf of the betel plant (*piper betel*) that is able to induce death of cancer cells in chronic myeloid leukemia; crude extract prepared from a marine organism (mussel) by the enzyme-acid hydrolyzing process shows a potent anti-malarial activity when examined for *in-vitro* cultures of *Plasmodium falciparum* in human erythrocytes; isolation of a natural compound

from *Boswellia* species, and alternatively prepared its semi-synthetic compounds for cancer of colon, prostate, liver, breast, central nervous system, leukemia and malignancy of other tissues, including ascites and solid tumors; herbal formulation from the plant extract of *Cedrus deodar* for the treatment of cancer, a process for high-level production of recombinant Staphylokinase which is produced intracellularly using a genetically engineered strain of *Escherichia coli*; developed a single plant base standardized hepatoprotective agent useful for the treatment of liver disorders such as alcoholic and viral cirrhosis; developed a herbal medicament which has shown promising anti-stroke activity along with antioxidant and anti-inflammatory properties on pre-treatment in rats; developed a process for the oral delivery of insulin and also of hepatitis B vaccine, this new invention is a boon to the diabetic population showing the reduction of blood glucose levels comparable to that of the injectable insulin; isolated the first biologically derived molecule ATB 1 that inhibits HIV-1 protease; developed gelatin micro spheres wherein SSD-loaded collagen membranes have been evaluated for wound healing; developed and commercialized two important formulations one as a brand name Regen-D™ –60 for skin graft and burn injuries, while the other, Regen-D™ –150, meant for diabetic foot ulcer.

- Some other important achievements include: development of synthetic peptide-based nanotubes; Thin Film Composite reverse osmosis high flux membrane suitable for treatment of tertiary treated sewage water; technology for arsenic and iron removal based on ceramic membrane technology for the production of safe drinking water from contaminated ground water; developed, demonstrated and transferred an Ultra Filtration (UF) membrane-based water purification technology which removes germs, cysts, spores, parasites, bacteria, cryptosporidium, endotoxin, Pseudomonas viruses of hepatitis A and E (the filtration unit requires no electricity and chemicals to filter water); and design and development of a 10HP small tractor. A Fog Forecast and Visibility model, which is a combination of high performance computing and new generation dynamical meso-scale models, advanced data analysis and informatics, was also developed and calibrated during this period.
- During the Tenth Plan, the research outputs of CSIR had been of a very high order. It has emerged among the top three entities from the developing world in terms of PCT filing. US patents granted are considered as one of the indices in measuring the technological achievement of a country. CSIR was granted 667 US patents during the Tenth Plan. 62% of the total US patents granted to Indians excluding, NRIs and foreign assignees, belonged to CSIR. As a result of researches carried out in the national laboratories, over 13000 basic research papers were published in internationally peer reviewed journals. The average impact factor per paper of nearly 2.01 has been achieved during 2005–06. The external cash flow from contract research was nearly Rs 1500 crore.
- HRD initiatives: During the Tenth Plan period, 5946 JRFs (NET qualified), 2228 Senior Research Fellows, 484 Research Associates, 375 Senior Research Associates (Under Scientist's Pool Scheme), and 35 Shyama Prasad Mukherjee Fellows were supported in different disciplines till 31 March 2007. 59 meritorious scientists were recognized with the prestigious Shanti Swarup Bhatnagar prizes for their outstanding research contributions done primarily in India, and 25 CSIR Scientists were given Young Scientist Awards to promote in-house excellence, during the same period.

ELEVENTH FIVE YEAR PLAN PROGRAMMES

8.75. During the Eleventh Five Year Plan, DSIR would continue the TPDU programme with increased emphasis on technopreneur promotion, technology development and demonstration, information facilitation, PPP with SMEs in SBIRI mode, and Funding for Accelerating Start-ups in Technology (FAST). These programmes will be supplemented by technology transfer and management assistance as well as incentives for research and development. Focus will be to create opportunities for starting new technology- and knowledge-based businesses by science entrepreneurs, encouraging small businesses to increase their R&D capabilities and capacities and stimulating technological innovation. The major objective of the FAST

programme will be to prepare start-up companies to become eligible for venture capital funding. The IPR programme will aim at providing support for patent filing, creating information systems and facilities for patent searches by using modern software tools and commercialization of patented innovations. Efforts would also be made to operationalize an Indo-Australian Bi-national Industrial Research and Development Programme; undertake technology benchmarking and audit exercise; establish technology management national resource centres; and set up an S&T portal in a PPP mode. Central Electronics Limited has set a target to achieve solar photovoltaic production of 25 MW per annum and a production of 30000 to 40000 of phased control

modules per year during the Eleventh Plan period. The focus of the National Research Development Corporation will be on incubation and venture capital funding, development of basic design engineering packages, development of rural clusters in dairy and sericulture industries and programmes for development of women entrepreneurship and the NER. The CDC will emphasize on consultancy services exports and implementation of the Technical Consultancy Development Programme for Asia and the Pacific.

8.76. CSIR laboratories will seek to leverage their unique scientific and technological capabilities through a series of:

- Supra-institutional project wherein the laboratory will have at least one flagship project in which a majority of the groups within the laboratory participate and synergize the in-house capabilities to optimize outputs;
- Inter-laboratory network mode projects started during the Tenth Plan which will be further strengthened with a sharp focus to develop products/processes and knowledge;
- Network mode with institutions/agencies outside CSIR to develop advanced technologies/products/prototypes/knowledge base that require multi-disciplinary inputs and synergies; and
- Major national facilities which will be created in frontier areas to help in the generation of competitive knowledge capabilities at par with international standards of future relevance.

8.77. The Plan would be operationalized by undertaking projects which would create high value and large impact on socio-economic delivery. A few major projects are:

- Supra-institutional projects: technology development and R&D initiatives in aerospace; niche food processing technologies for cost effective, safe, hygienic, nutritious food for the targeted population; evolution of the Indian lithosphere—focus on major earth processes, natural resources and the geo-environment since the break-up of gondwana super continent; science for the development of a forecasting system for the waters around India; development of know-how and technology for environmental friendly conversion and

utilization of biomass to fuels, lubricants and additives; competencies in clean coal initiative and energy conservation technologies leading to development of Integrated Gasification Combined Cycle (IGCC) and Under Ground Coal Gasification (UGCG) in India; development of new drugs programmes for parasitic diseases and microbial infections.

- Networked projects: designing and developing a regional aircraft specially suited for developing economies; plasma proteomics health, environment and disease; exploitation of India's rich microbial diversity; pathway engineering and system biology approach towards homologous and heterologous expression of high-value phytochemicals; multi-scale modelling platform including state-of-the-art multi tera flop high performance computing facility; uncertainty reduction, vulnerability impact assessment, mitigation policy intervention and capacity building for global change; programme on climate change; hydrogen energy initiative—overcoming materials challenges for the generation, storage and conversion of hydrogen using fuel cells; design and fabrication capabilities for very high power, high efficiency and very high frequency microwave tubes; fabrication of Light Emitting Diode devices and systems for solid state lighting applications; technology for assessment and refurbishment of engineering materials and components; development of advanced lightweight metallic materials for engineering applications; diabetes mellitus—new drug discovery R&D, molecular mechanisms and genetic factors; nano material and nano devices in health and disease; comparative genomics and biology of non-coding RNA in the human genome.
- Inter-agency projects: new insights in cancer biology—identification of novel targets and development of target based molecular medicine; development of cost effective mine water reclamation technology for providing safe drinking water; utilization of indigenous know-how to address drinking water needs in coastal/rural areas.
- National facilities: Advanced Centre for Flight Mechanics and Control; facilities for functional genomic research (i) celloomics facility, (ii) zebrafish facility, (iii) Liquid Chromatograph-Nuclear Magnetic Resonance Spectrometer facility; Advanced Centre for Protein Informatics, Science, Engineering and Technology; setting up a compact high energy light

source for the structural analysis of biomacromolecules; Centre of Excellence for lipid research; Bio-Safety Level-4 facility for infectious diseases research.

8.78. Recognizing the changing context of scientific enterprise and the present national needs, HRD programmes would be strengthened with a focus on fostering scientific research in universities and other academic, scientific and engineering institutions, and attract the brightest young persons to careers in science and technology. Under the Intellectual Property and Technology Management scheme, the major activities would be relating to: filing, capturing, prosecution and maintenance of IPR for CSIR R&D outputs; valuation and valorization of patent and IP portfolios; surveillance for infringement and enforcement of IPR; human resources in IP cells of CSIR laboratories; modernization of computing, communication and related facilities and infrastructure. Activities pertaining to Early-Stage Venture Fund; National Innovation Foundation; Human Resource Development Centre; R&D management and business development; international scientific collaboration; and science dissemination would be strengthened under the R&D Management Support scheme.

8.79. The New Millennium Indian Technology Leadership Initiative (NMITLI) scheme will be expanded with new approaches of innovation development and focus on funding with industry (50:50 Initiative); co-financing with venture capital funds; and acquisition of early stage relevant knowledge/IP for portfolio building. An Institute of Translational Research would be set up as a part of the new scheme for application of knowledge of modern biology into clinical care; systematic collection and analysis of large amounts of clinical data; development of specific stem cell populations to treat a variety of illnesses such as Parkinson's disease, Type I diabetes, retinal degeneration, spinal cord damage, multiple sclerosis; development of nano materials, and so on. Training programmes broadly in the areas of induction, orientation, refresher and skill upgradation, would be continued for different categories of CSIR staff in addition to the number of other programmes in specialized areas such as technology management, research methodology, development of management information system, e-procurement, and so on. The scope of the Human Resource Development Centre would be expanded to give

impetus to produce specialized scientific human resource in selected frontier areas, to take up scientific industrial research as a career

8.80. The Eleventh Five Year Plan outlay of the DSIR, including CSIR, has been tentatively fixed at Rs 7957 crore at 2006–07 constant price and Rs 9000 crore at current price.

EARTH SCIENCES

ELEVENTH PLAN OBJECTIVES/THRUST/FOCUS

8.81. The Ministry of Earth Sciences (MoES) was created in July 2006, with the objective to reorganize national effort in atmospheric and ocean sciences and related services by integrating activities of related departments such as the Department of Ocean Development, India Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM) and National Centre for Medium Range Weather Forecasting (NCMRWF). The focus will be on the study of interdisciplinary links of phenomena relating to global climate change and to create a framework for understanding the complex interactions among key elements of the Earth system, namely ocean, atmosphere and the Earth, encompassing national programmes in ocean science, meteorology, climate, environment and seismology. The emphasis of activities in the area of ocean science would be towards the development of technology to harness ocean resources with the active participation and support of national R&D laboratories, educational institutions and industries. There will be a special thrust on the development of several cutting-edge technologies, including deep-sea mining technology; ocean information services; marine geophysical surveys; development of potential drugs from the sea; setting up of metallurgical plant for extraction of metals from polymetallic nodules; and to undertake front-ranking research in polar science and southern ocean studies. Major achievements of the MoES during the Tenth Plan period are given in Box 8.6.

ELEVENTH FIVE YEAR PLAN PROGRAMMES

8.82. India has made great strides both in polar sciences and related logistics, through a judicious and harmonious blend of multi-institutional expertise brought together under the umbrella of the MoES. This has paved the way

Box 8.6**Major Achievements of MoES during the Tenth Five Year Plan Period**

- The major achievements in ocean science were related to:
 - Development and demonstration of desalination technology to cater to the requirement of fresh water in coastal States and island territories of India
 - Setting up an interim early tsunami and storm surge warning system
 - Strengthening of ocean observing network by deployment of state-of-the-art technology data buoys and Argo floats for operational weather forecast and climate variability studies
 - Indigenous development of data buoys and tide gauges to meet the requirement of ocean observations
 - Completion of geophysical surveys for delineation of the continental shelf
 - Close grid surveys for polymetallic nodules in the allotted area in the central Indian Ocean Basin
 - Establishment of an extractive metallurgical pilot plant to extract copper, nickel and cobalt from the nodules
 - Design, development and testing of soil sampler at 5000 m depth in the central Indian Ocean
 - Establishment of a Ferro-Silico pilot plant at NML
 - Design and development of Remotely Operable Vehicle capable of working up to 6000m depth
 - Development and testing of deep sea crawler at 500m depth
 - Completion of clinical trials of two potential drug molecules from marine organisms having anti-diabetic and anti-hyper lipedemic properties
 - Multi-disciplinary studies to assess the marine living resources of the Indian seas, and to understand the large-scale variation of fishery resources
 - Monitoring of coastal pollution to assess the health of the coastal seas of India;
 - Strengthening of basic research by setting up of a network of nine Ocean Science and Technology Cells in universities/institutes and a chain of Marine Data Centres at National Institutions
- NIOT has developed and demonstrated commercial-scale Low Temperature Thermal Desalination Technology (LTTD) and a land based 0.1 million litre per day (MLD) plant was commissioned at Kavaratti, in May 2005. The technology was upgraded and a 1 MLD barge-mounted demonstration plant was commissioned in April 2006.
- Forecasting services for monsoons and other weather/climate parameters, ocean state, earthquakes, tsunamis and other phenomena related to earth systems were provided through well-integrated programmes. IMD acted as a national weather service provider by focusing its efforts on weather forecasting services for the government, public and weather-sensitive activities like agriculture, aviation, shipping, engineering industry, environment and hydrometeorology.
- IITM is an institution dedicated to atmospheric science, mesoscale processes, climate and paleo climate research. NCMRWF continued to develop expertise on numerical modelling and data assimilation. Capability to analyse the storm/cyclone structure using data received from Doppler Weather Radars installed at Chennai, Kolkata, Machhilipatnam, Vishakhapatnam and Sriharikota, helped in providing accurate cyclone and weather warning. About 100 Digital Cyclone Warning Dissemination centres were setup along the Andhra coast and the warnings were disseminated directly to the concerned agencies.
- The other major achievements in the areas of atmospheric sciences include: upgradation of meteorological capability at airports; establishment of a Mountain Meteorology Centre at Delhi to provide meteorological inputs to enable prediction of landslides, avalanches and flash floods; setting up of an Earthquake Risk Evaluation Centre at Delhi for seismic micro-zonation at a scale of 1: 50000; validation of crop-weather models for a variety of crops; preparation of atlases depicting the spatial and temporal variations in rainfall during 1813–2003 over India; and development of a state-of-the-art atmospheric chemistry model to study long-term trends in the atmosphere from the surface to 100 km

for the country to sustain its scientific endeavour in the icy continent on a year-round basis, from the Indian Permanent station, Maitri.

8.83. The major endeavours under polar science would include: launch of research expeditions to the Arctic, preferably through international cooperation; construction of a new Antarctic Research Station to enhance research activities; establishment of a dedicated

satellite based communication and data transmission system between the Antarctic and India; undertake southern Indian oceanographic studies for assessment of living and non-living resources and acquisition of ice class vessels.

8.84. In the area of desalination technology, setting up of a 10 MLD capacity barge-mounted plant has been envisaged. In the next phase, this programme would be

expanded with industry partnership, for taking up large-scale plants of 25–50 MLD capacity. The thrust of NIOT would be on the development of world-class ocean technology by strengthening its activities related to: design, development and demonstration of underwater technologies for deep sea mining; development of underwater materials and sensors; creation of seafront facility and other research infrastructure for testing of various oceanographic equipment; and coastal engineering related activities. The emphasis of NIOT would be on societal applications of various ocean sciences related technologies, and development of necessary infrastructure and skill base to support and maintain the deep ocean systems. Indian National Centre for Ocean Information Services, Hyderabad, would be strengthened for providing reliable coastal ocean services and to meet the requirement of a wide range of user communities in India. User-oriented data/data products such as species specific Potential Fishing Zone advisories and Coastal Ocean State forecast would be generated and disseminated using existing and upcoming satellites and in-situ data, on an operational basis. Electronic display boards and information kiosks would be established in every coastal village covering the entire coast of India for providing various ocean information services including storms, cyclones, weather, sea state, and so on. Special focus would be on the development of an effective early warnings system for oceanogenic disasters such as storm surges and tsunamis. Under the Integrated Coastal Marine Area Management and Coastal Ocean Monitoring Area and Prediction Systems programmes, focus would be on the demonstration of ideal coastal protection measures, coastal circulation, ecosystem modelling, marine ecotoxicology, carbon cycling in coastal waters and preparation of a coastal risk atlas; and modelling of movement of oil spills along the western and eastern Exclusive Economic Zone of India.

8.85. Under atmospheric science and technology, emphasis would be on modernization of the observation networks in a phased manner. This will facilitate rendering of various services relating to weather and climate to the public (by setting up a dedicated weather channel) and

to other specific sectors like agriculture, aviation and hydrology. Focus would be on the development of expertise both for numerical models and assimilated models. This is essential for making an accurate forecast of local-scale weather which is highly diverse in India due to its climatic and topographic condition. In addition, strengthening of infrastructure facilities for numerical weather modelling; undertaking state-of-the-art climate and atmospheric research by setting up a Centre of Climate Studies to act as a dynamic feedback to improve weather forecast and services; and climate research and monitoring with focus on the computing and data requirements to build a credible climate service facility in India, have also been envisaged. Focus will also be on Numerical Weather Prediction based on a global Atmospheric General Circulation Model of horizontal resolution of 25 km in order to generate a district/taluk level Agromet Advisory Service. Seismic monitoring for earthquake detection and support to a tsunami warning system and other related hazards would be initiated, and a state-of-the-art network to augment real time connectivity with major analysis and decision support centres will be established at Delhi. Micro-zonation activity would be strengthened to study hazard potential in a few cities and hot spots with respect to seismogenic areas would be identified. Micro-zonation of specific geo-hazards like land slides, inundation and damage potential by cyclones and floods, would be taken up in a project mode. IMD will cover all the 127 agro climatic zones and provide forecast to these units on a bi-weekly basis.

8.86. The Eleventh Five Year Plan outlay of the MoES has been tentatively fixed at Rs 6193 crore at 2006–07 constant price and Rs 7004 crore at current price.

8.87. The Progress of Plan Outlays/Expenditure during the Tenth Five Year Plan and Eleventh Plan Outlays of the central scientific departments is given in Annexure 8.1. In absolute terms, the Eleventh Five Year Plan proposed allocation for scientific departments is almost 3–4 times that of the Tenth Plan. The major deliverables of the scientific departments are given in Annexure 8.2.

ANNEXURE 8.1
Progress of Plan Expenditure of Central Scientific Departments

(Rs in crore)

S. No.	S&T Department/ Agencies	Tenth Plan (2002-07) Outlay	Annual Plan 2002-03		Annual Plan 2003-04		Annual Plan 2004-05		Annual Plan 2005-06		Annual Plan 2006-7		Tenth Plan (2002-07)		Eleventh Plan (2007-12) Projected Outlay (at current price)
			BE	Actuals	BE	Actual	BE	Actual	BE	Actual	BE	RE	Total BE	Anti Expdr.	
1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17
1	Dept. of Atomic Energy (R&D Sector)	3501.35	535.00	405.56	464.00	409.94	703.58	609.52	872.74	770.80	1003.00	1032.72	3578.32	3228.54	11000.00
2	Ministry of Earth Sciences	1125.00	175.00	138.69	175.00	147.38	200.00	198.88	340.00	225.04	438.00	417.49*	1328.00	1127.48	7004.00
3	Dept. of Science & Tech.	3400.00	625.00	537.10	800.00	602.37	900.00	896.26	1250.00	1024.24	1367.00	964.16 #	4942.00	4024.13	11028.00
4	Dept. of Biotechnology	1450.00	225.00	203.25	260.00	248.76	310.00	319.27	445.00	386.36	521.00	496.00	1761.00	1653.64	6389.00
5	Dept. of Scientific & Industrial Research, incl. CSIR	2575.00	440.00	366.96	520.00	380.15	650.00	596.25	846.00	730.33	975.00	775.00	3431.00	2848.69	9000.00
6	Dept. of Space	13250.00	1950.00	1846.71	2050.00	1941.00	2400.00	2194.70	2800.00	2294.30	3220.00	2600.00	12420.00	10876.71	30883.00
	Grand Total	25301.35	3950.00	3498.27	4269.00	3729.60	5163.58	4814.88	6553.74	5431.07	7524.00	6285.37	27460.32	23759.19	75304.00

Note: * including outlays for IMD, NCMRWF & IITM; # excluding outlays for IMD, MCMRWF & IITM.

ANNEXURE 8.2

Major Deliverables of Scientific Departments during the Eleventh Five Year Plan

- **Department of Space (DoS)**
 - Development of satellite launch capabilities to GSLV Mk-III
 - Indigenous development and initiation of cryogenic engine and stages
 - Enhancing INSAT systems capacity for communications and broadcasting to 500 transponders
 - Development of critical technologies for manned missions in space
 - Exploration of the lunar environment through Chandrayaan
 - Establishing Diurnal All Weather Microwave Imaging Capability, crucial for Natural Resource Management (NRM) applications in agriculture and disaster management
 - Establishing Regional Satellite Navigational System and providing Global Positioning Services
 - Setting up a constellation of state-of-the-art high-resolution remote sensing satellites for NRM, weather forecasting and disaster management
 - Enlarging societal applications of space technology in areas of education, health care, rural development, agriculture and disaster management
 - Capacity building for advanced space missions and infrastructure, creation of ground facilities and technology upgradation

- **Department of Atomic Energy (DAE)**
 - Development of a new campus for Bhaba Atomic Research Centre (BARC) at Vishakhapatnam
 - Infrastructure upgradation at—
 - (i) Tata Institute of Fundamental Research (TIFR), Mumbai
 - (ii) Institute of Plasma Research (IPR), Gandhinagar
 - (iii) Variable Energy Cyclotron Centre (VECC), Kolkata
 - (iv) Saha Institute of Nuclear Physics (SINP), Kolkata
 - Participation in the International Thermo-nuclear Experimental Reactor
 - Setting up of a National Institute of Science Education and Research (NISER)
 - Intensification of Uranium exploration and development of aerial electromagnetic survey capability
 - Thorium fuel cycle development
 - Life extension of existing nuclear/heavy water power plants
 - Fuel cycle and safety related R&D
 - Development of new energy systems such as Advance Heavy Water Reactor (AHWR), Indian High Temperature Reactor (IHTR) and a multi-purpose research reactor with facility to accommodate a Proton beam-driven neutron source
 - Setting up Scientific Frontier Research Facilities such as or Radioactive Ion Beam (RIB) or Indian Neutrino Observatory (INO)
 - Participation in international mega-science projects like:
 - (i) Facility for Anti Proton and Ion Research (FAIR)
 - (ii) International Linear Collider (ILC)
 - (iii) X-Ray Free Electronic Laser (XFEL)

- **Department of Earth Sciences**
 - Comprehensive modernization of India Meteorological Department (IMD) with a network of state-of-the-art weather observation systems—Automatic Weather Stations, Rain Gauges and Data Buoys connected with Doppler Weather Radars. This network will be serviced by an IT-based decision support system using 10 Teraflop Supercomputing facilities at IMD, NCMRWF and IITM
 - Provision of comprehensive atmospheric, hydrological, land surface and oceanic data services to client communities
 - Dissemination of weather forecasts/warnings, flood and cyclone warnings, tsunami early warnings for coastal communities, and so on, and providing agro-met services to all farmers
 - R&D on climate change and cloud seeding
 - Seismic research on earthquake precursors and micro-zonation of major earthquake prone cities
 - Polar science R&D; a third Indian station in Antarctica and a dedicated Arctic Expedition; acquisition of an ice-class vessel

- Development and exploitation of Exclusive Economic Zone or EEZ and the continental shelf; acquisition of state-of-the-art technologies for deep-sea mining and manned missions, particularly for gas hydrates and polymetallic nodules
- Upscale sea water desalination technology up to 25 million litres/day to meet the potable water supply requirements of coastal cities and areas affected by coastal salinity
- **Department of Science and Technology (DST)**
 - National Mission on development of nanotechnology
 - Creation of new R&D institutes on Molecular Materials, and Glaciology
 - Modernize existing R&D institutions
 - Modernization of SoI and Creation of a seamless GIS in digital format
 - Promote innovation and creation of Intellectual Property and National Innovation clusters
 - Attracting bright young students to take up science as career by launching a new scheme INSPIRE to cover 100000 scholarships of Rs 1 lakh per year each for students joining Universities and dedicating themselves for scientific research. INSPIRE will also fund innovation in schools (one million young innovators) and provide assured opportunity schemes for proven talent and for retention of talent in public funded research through PPP.
 - Building research capabilities in the academic sector
- **Department of Scientific and Industrial Research**
 - Creation of Centres of Excellence in CSIR laboratories
 - Expanding the New Millennium Technology Leadership Initiative (NMTLI)
 - Providing fellowships for research in basic sciences and interdisciplinary areas
 - Setting up Translational Research Centres
 - R&D on Photovoltaics and solar energy
 - Technology development in the strategic aerospace sector
 - Development of alternative energy source for a cleaner and green environment
 - Expanding scientific frontiers in areas such as Plasma Proteomics, bioactive molecules, bio-energy technology, cancer biotechnology and gene environment
- **Department of Biotechnology (DBT)**
 - Creation of new institutes for

(i) Stem Cell Research	(iv) Seri Biotechnology
(ii) Marine Biotechnology	(v) Animal Biotechnology
(iii) Centre for Translational Research in Public Health	(vi) National Institute for Agri-food Biotechnology at Punjab Knowledge City
 - Human Resource Development—Biotechnologists with expertise in Genomics, Proteomics and Metabolomics, Development of 'Info-bio' and 'Info-bio-nano' manpower
 - Creation of a SPV for Small Business Innovation Research Initiative (SIBRI) to pursue technological innovation
 - Creation of: Large animal house facilities for testing candidate vaccines; DNA and stem cell banks and depositories of biological materials.