# Twelfth Five Year Plan
# (2012–2017)

## Faster, More Inclusive and Sustainable Growth

Volume I

# 8

# Science and Technology

## INTRODUCTION

8.1. India's development plans have consistently emphasised the need for sustained investment in research and related activities leading to creation of substantial capacity and capabilities in science and technology (S&T). The fruits of this effort are evident in India's nuclear and space programmes, information and communication technology services, automotive and pharmaceuticals industries and other areas. As the Indian economy continues on the path of rapid, more inclusive and sustainable growth, it will be necessary to ensure that India's capabilities in S&T grow in strength. This is especially important if India is to become one of the major economies of the world over the next 20 years.

8.2. Many positive steps have been taken in recent years to give a boost to S&T efforts and these are having a steady, incremental effect. The Indian science sector has gained growth momentum during the last three years. Relative position of India with respect to scientific publications has improved from 15th in 2003 to 9th in 2010. Our science output has reached 3 per cent of the global output in 2010. While this is heartening, the current rate of improvement is slow and falls short of global standards in many areas. This is indicated by the fact that India's share of top 1 per cent publications is only 0.5 per cent, as of 2006, less than those of other Asian countries like China and South Korea.[1] Inventiveness in our basic science, as indicated by creation of intellectual property, is low and India's innovation system ranking varies between 50 and 60 among the nations. The country has major challenges to address in health, food, energy and environment and these can be met by doing quality science, showing greater inventiveness and achieving quality in product innovation. The challenges of a robust economy can be met by investing adequately in knowledge systems and achieving global leadership positions in some areas in the next two decades.

8.3. For a country of the size of India, with a robust scientific infrastructure and a vast pool of trained scientific manpower, productivity gains from a hike in research and development (R&D) spending could be huge. The country needs to move up from investing 1 per cent of gross domestic product (GDP) in the R&D sector to 2 per cent of GDP and more, as has been the case with several developed and emerging economies for quite some time now. This must be achieved through an additional government effort, but also a much increased private sector effort.

## APPROACH TO THE TWELFTH PLAN

8.4. India made substantial investments in the R&D sector during the Eleventh Plan period laying a strong foundation for building a vibrant and dynamic S&T sector in the country. Average growth rate of publications from India in scientific journals is about 14 per cent during the last three years of the Eleventh Plan period. This is against the global average of 4.1 per cent during the same period. The share of scientific publications emanating from universities increased from 15 per cent in 2003 to 31 per cent in 2012. These are welcome changes as far as expanding

the R&D base of the country is concerned. However, these remain incremental changes. What the country really needs at this point of time is a quantum jump, to position itself at par with the developed economies in the next two decades.

8.5. To face up to the increasing challenges in the new world order, the Indian S&T landscape needs to undergo a paradigm shift. It needs to evolve new delivery mechanisms for innovative deployment of technologies and business models for financing deployment of innovations. This calls for a well-enunciated Science, Technology and Innovation policy. The Twelfth Plan should therefore work to develop an ecosystem that addresses the national priority for sustainable, inclusive and accelerated growth taking along the education, research and corporate sectors. The corporate sector, in particular, must play a much larger role in building research capability as happens in other countries.

8.6. A competitive knowledge economy must be built on the pillars of: (*i*) an educational system that produces human resources which are employable and globally benchmarked; (*ii*) S&T pursued on an enormous scale to generate knowledge for long-term use and (*iii*) strategic translational research inspired by national needs and global opportunities. In pursuit of these objectives the Twelfth Plan should be geared to achieve the following:

- Evolve a new Science, Technology and Innovation policy to bring in more resources from both public and private sector for R&D for socially and strategically relevant projects and mainstream innovation-related activities with a focus on affordable and sustainable innovations;
- Catalyse a radical but participative transformation of the Indian S&T system by refocusing the efforts of the designated Departments/Agencies at:
  - National Focus—build partnership with identified players of the National Innovation System to build the scientific, technological and human resource niches for the country;
  - Organisational Focus—address the needs of each Department/Agency for achieving the goals in national focus and rigorously review the ongoing projects/programmes to phase out those which have by and large fulfilled their goals; and
  - Leadership Focus—stimulate the Department/Agency's leadership in identified domains of science, technology and human resource development.
- Ensure that S&T becomes an integral component of the national developmental processes by interconnecting competencies and research resources and strengthening interconnections with the weakly connected stakeholders to the R&D outputs;
- Increase the number of full-time researchers/scientists from the current level of 1.54 lakh to 2.50 lakh; the volume of publication outputs in basic research from a global share of 3 per cent to, say, 5 per cent; improve the global ranking from 9th to 6th by the end of the Twelfth Plan; focus on doubling the number of patents and increase the commercialisation of patent portfolio to 5–6 per cent from a level of less than 2 per cent;
- Increase R&D expenditure to 2 per cent of GDP and significantly enhance corporate sector R&D expenditure to at least 1 per cent of GDP by attracting investments and engaging the corporate sector in R&D through policy and reforms processes; earmark 10–15 per cent of public investment exclusively for public–private partnership (PPP) R&D to private sector through the competitive grant process with a stipulation that comparable provisions would be made by the private sector under PPP model;
- Provide more flexibility to the younger generation of scientists to pursue their ideas and greater mobility between industry, academia and R&D institutions; strengthen gender parity in R&D by way of mobility and women re-entry programmes; consolidate on the gains achieved during the Eleventh Plan in nurturing students to pursue science as a career;
- Build technology partnerships with States through new models of technological solutions, design, development and delivery;
- Initiate Grand Challenge Programmes and launch PAN-India missions to address national priorities

in various developmental sectors through bottom-up approach, particularly in the areas of Health, Water, Energy and Food through consortia of institutions and agencies cutting across public and private sectors; two major areas which require immediate focus during Twelfth Five Year Plan are Energy and Water;

- Encourage large Indian industries to establish globally benchmarked R&D centres on the lines of R&D centres set up by multinational companies (MNCs);
- Leverage the large-scale innovative component of strategic research spin-offs from defence, space and atomic energy for civilian benefits in a much larger segment.
- Create new Inter-University Centres (IUCs) and Inter-Institutional Centres (IICs) in chosen areas of Science and Engineering, which will provide access to state-of-the-art facilities and academic ambience for researchers in universities and academic institutions;
- Create new R&D institutions in trans-disciplinary science and engineering to achieve leadership positions;
- Create Peta-scale supercomputing facilities and provide high-performance computing for various applications such as climate modelling, weather prediction, aerospace engineering, computational biology, nuclear applications, earthquake simulations, animation in movies, national security and finance;
- Create an independent institutional arrangement for Technology Assessment capability.
- Bring in structural reforms in the S&T sector by creating new financial appraisal and audit mechanisms and a new personnel policy based on best global practices coupled with seamless mobility of S&T personnel;
- Partner with high-value global mega projects in the areas of contemporary scientific interest and technological relevance and enhance India's role in global mega projects such as India-based Neutrino Observatory, Thirty Meter Telescope, Square Kilometer Array, Next Generation Synchrotron and so on; and
- Enhance collaboration with reputed foreign universities/agencies towards addressing the scientific aspects of common interest and global in nature.

## SPECIFIC FOCUS AREAS FOR THE TWELFTH PLAN

### Enrichment of Knowledge Base

8.7. In 1985, the number of PhDs produced in India was in the range of 4,500 and the country figured among the top in the league of developing nations in the science sector. Since 1985, however, other emerging Asian economies invested heavily in R&D, blunting India's competitiveness in the S&T sector. None of the Indian institutions figure among the top 100 in the world. The full-time equivalent (FTE) R&D professionals in India have stagnated for long; India ranks 9th as far as FTE of R&D professionals are concerned. In scientific publications as well, India ranks 9th. The global share of Indian publications in most cited papers has also remained low.

8.8. The last few years show an improvement as far as some of these parameters are concerned, but if the country has to aim at positioning its R&D institutions among the top 50, or gaining the top three slots with respect to scientific publications or target a ranking of even 6th with respect to FTE, it will have to aim at quadrupling its R&D base, stimulate research where R&D productivity is relatively lower, provide challenges to institutions for global positioning including in intellectual property (IP) generation, establish new academies and institutions, build up large publicly funded and privately managed facilities to help researchers and adopt aggressive mechanisms to attract the Indian diaspora for R&D positions. Emphasis should also be given on strengthening linkages between universities, R&D institutions, science academies and industry.

8.9. India's established research centres from which R&D outputs are generated need to expand their personnel strength to give a boost to R&D outputs. Expanding the strength of R&D personnel in the established centres of R&D by about 10,000 within the Twelfth Plan period should be considered feasible. It is also imperative that the large latent potential in colleges, universities and some academic centres is tapped. Adequate measures for ensuring quality of research output should also be looked at.

8.10. Basic research in India should aim at cutting-edge science leading to impact-making discoveries. Investments in basic research may be sized to meet the aspirational goals of the research community during the Twelfth Plan period. Basic research supporting group and interdisciplinary efforts on grand challenges would require a new paradigm of R&D funding. Approaches for spotting, nurturing and encouraging sparks and talent in scientific research have to form one of the established strategies for promotion of basic research. In addition to support for emerging areas in various disciplines of science, there should also be a parallel effort to identify areas of national interest and gaps and promote basic research in such areas. Some orientation to basic research to combine relevance with excellence may be in order. Focus on the research areas of national relevance such as energy and food security, affordable health care and water-related areas needs to be accorded high priority.

## S&T Human Resource Development and University Interaction

8.11. There is a close relationship between human resources in S&T and economic growth. Although the country has a vast network of schools, colleges and universities apart from national institutes and Indian Institutes of Technology (IITs), which have produced one of the largest pools of scientific manpower in the world, the global competitiveness of the S&T sector can only be achieved through much better quality. For this, the science education system, as it stands today, needs radical transformation.

8.12. Science teaching as a profession needs to be incentivised, accorded the respect it deserves and once again placed on a high pedestal. Equally important would be exposing these teachers at all levels in the country to the best global practices and pedagogy innovations to enable them to practise and spread superior methods of teaching and research. A scheme needs to be designed and developed jointly by the Ministry of Human Resource Development and the Ministry of S&T.

8.13. The quality of S&T education and research at the college and university levels needs to be improved to give an edge to the scientific task force coming out of these places of learning. There is now adequate evidence for significant gain in scientific outputs and citation frequencies when the university sector engages in S&T cooperation within the country and abroad. As one of the strategies, international cooperation for deployment needs to be scaled up manifold, for enriching quality of research in the university sector. IUCs have shown a positive impact on the university system. Several new IUCs in carefully chosen areas should be set up during the Twelfth Plan in newer areas such as Biodiversity and Genetic Epidemiology; Mathematical Modelling; Computer Science and Cyber Security; Cognitive Sciences; Advanced Materials, Manufacturing and Fabrication; Technology Management; and Interdisciplinary Approaches in Humanities, Social Science and Natural Sciences.

## Aligning S&T to Developmental Needs

8.14. In addition to R&D in high science and strategic technology areas that would enable the country to position itself at the world level, there are several areas that require significant S&T inputs to generate solutions for issues that are significant for the country's development goals, in the context of both industrial development and rural development. These include energy, water and sanitation, farm production, health care, waste disposal, computing and communications, e-infrastructure, cyber security and so on.

8.15. A strategy needs to be evolved for implementation of R&D programmes focused on social and public goods for: (*i*) connecting competencies and research resources for scaling and impact; (*ii*) mounting Grand Challenge programmes on topics of national interest; (*iii*) adopting different funding strategies for basic and translational research under Extra Mural Research models; (*iv*) strengthening Intra Mural Research mechanisms for public and social goods in agencies like Council of Scientific and Industrial Research (CSIR); (*v*) forging State–Centre technology partnerships and technology coalitions among R&D agencies and (*vi*) promoting PPPs for public and social good by developing new models.

8.16. The Twelfth Plan must find ways of connecting States and socio-economic Ministries with R&D outputs leading to public and social goods as a priority. For deployment of readily available technologies in States, the following need to be evolved: (*i*) a synergy among the S&T and socio-economic sector, (*ii*) a policy decision by socio-economic Ministries to allocate a certain minimum percentage (say 1–2 per cent) of their overall budget for supporting R&D, (*iii*) setting up of joint centres by the socio-economic Ministries in R&D institutions and universities, (*iv*) participation of socio-economic Ministries in PPP projects supported by the science sector and (*v*) involving enterprises for effective implementation of R&D solutions arising out of synergies among science sector and socio-economic Ministries. Focus should also be on creating start-ups and utilising the cutting-edge knowledge base.

8.17. The involvement of States in R&D in the country is at present relatively low. Most States have not established suitable mechanisms for full utilisation of technologies emanating from public-funded research in the country. State Councils for S&T in many States remain as weak links between the national science sector and the State Governments. Allocation of States in their own budgets for S&T remains relatively insignificant. Special mechanisms need to be developed to promote the technology relationships between the Centre and the States. Establishment of special competitive fund for States for absorption of indigenous technologies could form one of the strategies for creating demand pull for technologies in the States. Emphasis should be given for connecting the State Councils for S&T to R&D organisations like CSIR, Indian Council of Medical Research (ICMR) and Defence Research and Development Organisation (DRDO) and so on.

8.18. The Indian R&D system is predominantly government funded. It is important that the corporate sector (both public and the private) come forward to fund R&D programmes directed towards national developmental goals. The target of total expenditure in R&D increasing to 2 per cent of GDP by the end of the Twelfth Plan could be achieved by about 1 per cent in the public sector and 1 per cent in the corporate sector, including public sector undertakings (PSUs). At present, the resources devoted to R&D by large public sector organisations are pitiably small. They need to be incentivised to make larger provisions for both in-house R&D as well as R&D in research institutions and universities, both public and private. The step taken during the Eleventh Plan by Bureau of Public Enterprises to include R&D in the memorandum of understanding (MoU) of a PSU with the government is a move in the right direction. These sectors should spend 2–3 per cent of their sales turnover on R&D contracting out research to institutions and universities. The current levels of coupling between the R&D and manufacturing sectors are weak. High priority to PPPs that would ensure flow of innovation into industrial manufacturing leading to wealth creation, thus, has to be accorded. Industry needs to identify critical technology areas where through the partnership with publicly funded R&D system they can become global leaders.

8.19. The corporate sector both from public and private sectors too needs to be encouraged and incentivised to set up R&D centres just as the R&D centres set up in India by some of the world's leading research institutions, as R&D activities by MNCs have created enclaves for world-class technological development and have helped the creation of a pool of highly skilled scientists and technologists through setting up of their R&D centres in India. Thus, it is crucial to evolve new strategies and mechanisms to propel investment by industry if 1 per cent of GDP investment on R&D is to be targeted by this sector.

8.20. The strategic research sector could play an effective role in meeting the national developmental goals in non-strategic areas, whether it is space technology, nuclear technology or defence research. Several technologies developed by the strategic sector could trigger successful spin-offs for social and industrial sectors. A suitable mechanism to provide thrust to utilising outputs of strategic research for the social and industrial sectors needs to be worked out and created.

## Implementation of National Missions

8.21. Realising that national challenges cannot be tackled without nationally coordinated mission mode programmes involving interdepartmental and inter-ministerial collaborations, PAN-India S&T missions in select areas such as (*i*) Agriculture, (*ii*) Water, (*iii*) Energy, (*iv*) Environment and (*v*) Health need to be given priority.

**Agriculture Sector**

8.22. The Department of Biotechnology (DBT) proposes to support 10 agricultural universities through long-term R&D grants for promoting R&D on agriculture for public and social good. Synergy and connecting competencies of institutions under Indian Council of Agricultural Research (ICAR) with the research programmes supported by the six science departments form the selected approach for R&D on agriculture. As an example, synthesising R&D outputs from agro-metrological services of Ministry of Earth Sciences (MoES), advisory services of State remote sensing centres and State-based Spatial Data Infrastructure initiatives of Department of Space (DOS), National Spatial Data Infrastructure and National Geographic Information Systems (NGIS), fertiliser and other agrochemical technology solutions from CSIR, food processing technologies from both CSIR and Department of Atomic Energy (DAE), translation research in molecular breeding emanating from the efforts of DBT and technology deployment support to States for implementation of technologies and services by Department of Science & Technology (DST) would form a strong impact. Secondary agriculture, climate-resilient agriculture, water-saving agriculture, technologies for reducing food wastages as well as indigenous manufacture of fertilisers, precision agriculture for water-starved agro-climatic zones and international S&T cooperation for enhancing water and land productivity would form the priority areas of the six departments. The regulatory aspects for genetically modified (GM)-related crops will also be given due emphasis. Biotechnology Regulatory Authority of India (BRAI) Bill is considered as essential for streamlining regulation of all modern biotechnology products.

**Water Sector**

8.23. R&D for development of technologies for managing water-related challenges is being undertaken by almost all the six science departments in association with the line departments of Central and State Governments. While the DoS is engaged in resource mapping of water, MoES has developed and demonstrated technologies for Low Temperature Thermal Desalination (LTTD) and DAE has been developing and demonstrating a range of technologies including reverse osmosis (RO) and multi-stage flash for sea water desalination. CSIR has developed significant knowledge base on water, ranging from source finding to mapping of water resources, from quality assessment to enhancing potability of water and from recycling to waste water treatment. The technologies on flocculation and chlorination currently in vogue do not remove trace organics, metals and pathogens in treated drinking water and, therefore, R&D in ion exchange technique and nano-filteration processes need to be taken up. The DST is implementing a technology mission on Winning, Augmentation and Renovation of water where solutions to water-related challenges are being implemented and demonstrated in several locations. Therefore, in the design, development and delivery of the Twelfth Plan programmes, end-to-end solutions of water-related challenges by integrating R&D efforts of the six science departments with the line departments of both centre and State are to be given thrust.

**Energy Sector**

8.24. For achieving the full objectives of the National Solar Energy Mission, technology breakthroughs are required to increase the conversion efficiencies and to lower the costs of delivered power, for which it would be necessary to engage mainstream scientists drawn from the entire S&T sector of the country with expertise in relevant areas. R&D for clean energy systems is of paramount importance. On energy R&D, almost all six science departments are engaged in either performing research or supporting R&D or both. Similarly, clean coal technology, fuel cells, hydrogen energy, materials for harvesting both light and heat, new inorganic chemistry for converting coal into liquid fuels, bio-inspired

inorganic materials for artificial photosynthesis and bio-refinery for agro-wastes as energy sources also need focus. Since energy sector works in regulated environments, it is necessary for the R&D sector to develop adequate synergies with Bureau of Energy Efficiency and the concerned departments. The MoES is engaged in the assessment of wind, wave and tidal energy potential as a part of tapping renewal energy, including gas hydrate exploration. Thus, collaboration and cooperation in areas of technology leads where synergies could benefit the R&D systems need to be promoted, including that from the defence research system during the Twelfth Plan period.

**Environment Sector**

8.25. R&D for controlling pollution of the local environments and emission of green house gases for mitigating global climate change demands different approaches. Whereas the R&D for mitigating pollution is promoted best through intramural research in domain area organisations, national capacity on climate change science needs to be developed over wider cross section of scientists and R&D professionals. Accordingly, under the National Action Plan for Climate Change, DST shall coordinate two missions under which formation of knowledge networks and thematic centres has been proposed by DST. These actions are focused on stimulating the latent and inherent capacities of the universities and research institutions. PPP for R&D for adaptation and mitigation of climate change will be another tool to be used. R&D sector may need to develop technology plans for solving the environment-related challenges of such sectors in association with the relevant line Ministry, and accordingly efforts of all the players need to be significantly synergised in the area of R&D on environment during the Twelfth Plan period. The MoES has been monitoring the health of coastal waters of India which would be of immense importance to UN endeavour on global assessment of marine environment.

**Health Sector**

8.26. Affordable human health care is an area of high priority to the country. There are several parallel efforts of high significance. Indian Council of Medical Research is the important national agency for R&D on human health care. The focus of the agency is generally on delivery of human health-care tools and public health–related R&D at this time. The agency is also well poised for delivery of R&D outputs. DBT is aggressively promoting research in human health care sector through both intra- and extramural mechanisms, as well as PPP models. CSIR has launched a major initiative on Open Source Drug Discovery (OSDD) and large number of programmes relating to R&D on human health care. In view of the high relevance of the R&D efforts for the country, some of these initiatives of the six science departments might have to be fostered as strategy for the Twelfth Plan. Human health care is an area where regulatory processes require advanced scientific knowledge and technical expertise. Speed in regulatory processes without sacrifice to the correctness of decisions demands applications of many modern technologies and R&D outputs and tools. Current mechanisms of regulation require a revisit. Biomedical Regulatory Authority Bill is considered essential if the indigenous manufacture of biomedical devices were to gain momentum and access to affordable health care system were to be enlarged. There is a strong case for promotion of PPPs for R&D on Drug and pharmaceuticals. Particularly, investment requirements for drug discovery are large. Special schemes for promotion of drug discovery and support for phase III clinical trials may be required in diseases of national interest. India could engage in basic research on disease biology for gaining new insights for discovering drugs including from marine organisms.

8.27. For building programme synergies and implementation on the above socially relevant missions, a special task force needs to be created. A separate PAN-India Mission Fund needs to be built-in in every department so that this fund could be deployed for building synergies among the programmes proposed by various departments and address gap areas. The Twelfth Plan emphasises that PAN-India mission mode projects addressing national needs and priorities may be launched through extensive participation of stakeholders to achieve the goals and targets in a defined time frame.

## Mega Science Projects

8.28. While PAN-India missions could bring about synergies in R&D programmes at the national level, the efforts need to be made to position Indian researchers at the global level. This involves participation at the international level in exciting experiments like in European Organization for Nuclear Research (CERN) and International Thermonuclear Experimental Reactor (ITER). During the Twelfth Plan period, India needs to invest into developing following major Mega facilities: (*i*) Laser Interferometer Gravitational Wave Observatory (LIGO) Experiments; (*ii*) India-based Neutrino Observatory (INO); (*iii*) Thirty Meter Telescope (TMT); (*iv*) Square Kilometre Array (SKA); (*v*) National Large Solar Telescope and (*vi*) Next Generation Synchrotron.

8.29. These mega science projects would be coordinated by DAE and DST through appropriate funding sharing mechanism. Besides, the above mega science projects, each department will also have mega projects already built in their budget.

8.30. Besides providing a quantum leap for scientific research, many of the above international collaborations will open up possibilities of creating technological capabilities for India. It is also time to embark upon indigenous efforts to build Peta-scale supercomputer capacities and capabilities for the country's requirements that will place India among the top five supercomputing power in the world.

8.31. While Box 8.1 gives a glimpse of collaborative research through which India's competency to deliver good on global research agenda has been demonstrated, Box 8.3 provides a novel path to launch National Biodesign alliance through collaborative technology innovation for leveraging international collaboration, thereby strengthening national programmes.

## Strategies for Transformational Changes

8.32. In order to promote transformational changes within the S&T sector and gain global competiveness with respect to S&T output indicators, it is necessary

**Box 8.1**
**Discovery of Higgs Boson—Indian Contribution**

During the Tenth and Eleventh Five Year Plan, India has taken major initiatives relating to mega science programmes by collaborating with international partners. These include themes related to High Energy Physics, Astronomy, Thermonuclear Fusion and Synchrotron supported material science research. This model is turning out to be very beneficial in the context of India's involvement in frontier science research, development of capabilities in high technology and facilitating the creation of new generation of scientists working for PhD as well as postdoctoral scientific research. The most recent example of this strategy of science collaboration relates to the Indian participation in the Large Hadron Collider (LHC). Indian Institutions joined the large LHC experiments at a pretty early stage, starting from 1994.

India contributed high technology items for Compact Muon Solenoid (CMS) experiment, which was a key detector facilitating the discovery of possibly the most important particle in High Energy Physics, the Higgs Boson. Further, India also contributed to the design and development of A Large Ion Collider Experiment (ALICE) looking for quark-gluon plasma which is important to answer some key questions in fundamental Physics beyond standard model. Both these experiments produced large amounts of data which need to be processed quickly. This called for creating a distributed computer environment and opened up a new computing regime called Grid computing. Indians not only contributed in the development of this field by developing the software but also set up a CMS computing centre resulting in the overall computing infrastructure for the experiments. The scientific team that participated in the CMS experiment included 33 PhD physicists from India. Further, the ALICE experiment has participation from several Indian universities and other institutions with 36 faculty, 22 engineers and 30 students. Together, the two experiments, CMS and ALICE, involved a total expenditure of about ₹150 crore besides kind contribution of about ₹300 crore involving many high-technology items from India.

This example of a collaborative research has demonstrated India's competency to deliver on global research agenda and provides an opportunity to work on similar model in the Twelfth Five Year Plan. Some of the mega science projects being considered in the Twelfth Plan are Laser Interferometer Gravitational Wave Observatory, National Large Solar Telescope and India-based Neutrino Observatory, besides the ongoing International Thermonuclear Experimental Reactor (ITER). These envisage adopting similar models to keep India in the forefront of scientific research, development of high technology capability, innovative computing techniques and creation of specialised human resource base.

to make strategic interventions during the Twelfth Plan period. These include: (*i*) increasing density of scientists by about 60 per cent, (*ii*) interconnecting competencies, (*iii*) synergy development of research resources, (*iv*) establishment of performance–reward relationships, (*v*) engaging in rewarding and mutual international partnerships, (*vi*) investing larger resources into performing individuals through grant model of funding, (*vii*) deploying more effectively the tool of PPP for R&D and (*viii*) creating an enabling policy environment for sustainable innovation ecosystem.

8.33. To this end, SAC to PM under National Vision for Science has suggested the development of a new, expansive personnel policy for R&D sector, based on global best practices. The National Vision also recommends re-engineering and rationalisation of processes for the science sector to increase the speed of decision-making, without compromising rules and processes, for accelerated and transformational changes and enabling youthful leadership opportunities. The SAC-PM has also suggested that the audit discipline needs to be modified from procedure- or process-based to performance- and objective-based system. In the Twelfth Plan, the suggested structural reforms for S&T sector need to be pursued so as to derive the best out of it. More recently, SAC to PM has also prepared outlines of an agenda for action on the S&T inputs to pressing national problems which will be pursued for implementation.

## Performance Measurement Systems

8.34. For Indian science to gain global competitiveness in all its dimensions, it is essential to develop suitable measurement systems for the science, technology and innovation output indicators for India. Appropriate measurement systems and comparative analysis of India vis-à-vis other emerging economies needs to form a basis for outcome-based performance. It may accordingly be desirable to adopt strategic planning for positioning India in niche positions in areas of comparative strength rather than to invest through a broad spectrum approach.

## Review of the Eleventh Plan Programmes

8.35. High priority was accorded by the government during the Eleventh Plan period for investments into S&T for deriving maximum benefits for the society and knowledge generation for capacity building. Major priorities of the Eleventh Plan for S&T sector have been:

- Setting up 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 that have direct bearing on the technological competitiveness of the country in a mission mode
- Establishing globally competitive research facilities and centres of excellence
- Developing new models of PPPs in higher education, particularly for research in universities and high technology areas
- New ways and means of catalysing industry–academy collaborations
- Promoting strong collaborations with advanced countries including participation in mega international science.

8.36. Significant initiatives/contributions have been made for each of these priority areas. Detailed account of these is provided in the respective section of the S&T departments.

## STRATEGY FOR THE TWELFTH PLAN

8.37. In spite of some positive signs, India's performance in science is yet to match her potential. The emphasis during the Twelfth Plan by the six science departments and agencies is to consolidate the gains of the Eleventh Plan period and propose new initiatives with the objective of enhancing global competitiveness of the Indian R&D system. All departments and agencies have developed programmes based on their own niche and position in the mind-to-market chain.

8.38. All the six departments of science sector must make elaborate efforts to meet the aspirations of their stakeholders. This section below presents the summaries of the proposals of each department for Twelfth Plan programmes. The deliverables and targets from the S&T sector as a whole and those from the departments are provided in Annexure 8.1 given at the end of the chapter.

## Department of Science & Technology

### *Twelfth Plan Objectives/Thrust*

8.39. The DST, engaged in the formulation of S&T related policies and promotion of R&D through Extra Mural Research Schemes has mounted a large number of proactive schemes and measures during the Eleventh Plan period. There are some incremental improvements in the S&T outputs of the Indian science sector. The department is committed to align its Twelfth Plan programmes and initiatives to support the overall plan of the Indian Science, Technology and Innovation sector towards global leadership. One of the strategies evolved for implementation of Twelfth Plan proposals of the Indian science sector is connecting competencies and research resources. Several new initiatives of DST for the Twelfth Plan period have been prepared taking into account national needs and likely impact. However, such initiatives should be preceded by a careful and critical review of all ongoing programmes and consolidation of successful schemes as well as the new Eleventh Plan initiatives. While formulating the Twelfth Plan programmes, the department has adopted an output-directed development path and related inputs to expected and targeted goals as well as likely impacts.

8.40. The significant achievements of Department of Science &Technology during Eleventh Plan are given in Box 8.2.

**Box 8.2**
**Significant Achievements/Development of DST during Eleventh Plan Period**

### ORGANISATIONAL

- National Science and Engineering Research Board (SERB) has been established as an autonomous funding body and has assumed the major role from the erstwhile Science and Engineering Research Council (SERC).
- DST has also established new institutions, namely, National Innovation Foundation (NIF), Ahmedabad; Institute for Advanced Studies in Science and Technology, Guwahati; National Center of Molecular Materials, Thiruvananthapuram; and Institute of Nano Science and Technology, Mohali.

### PROMOTIONAL

- The SERC, one of the largest schemes for promoting basic research in the country supported about 1800–2000 new projects annually, which has resulted in more than 7500 scientific publications. Five hundred departments were supported under the fund for improvement of S&T infrastructure in the form of the state-of-the-art R&D facilities in universities and higher educational institutes.
- Promotion of University Research and Scientific Excellence (PURSE) and Consolidation of University Research, Innovation and Excellence (CURIE) have been launched to improve and support the R&D in the universities.
- Two hundred and seven JC Bose National Fellowships, 155 Ramanujan Fellowships and 323 Boyscast Fellowships were awarded to support excellence in research. A major scheme known as INSPIRE for attracting talent in science and for nurturing students right from the school level has been initiated and around 14000 students have been awarded SHE Scholarships; more than 6 lakh awards for students in classes ranging from Class VI to X and 1200 INSPIRE Fellowships for pursuing doctoral degrees have been granted, and INSPIRE faculty awards have been made to 74 postdoctoral scholars.

## S&T HIGHLIGHTS

- Several technologies aimed at specific end use have been developed, which include: atmospheric plasma processing system for angora wool, arsenic removal technology using microbial-cum-adsorbent route and ceramic membrane–reverse osmosis based iron removal plant for removal of iron and salinity in drinking water; development of large chemical vapour deposition (CVD)-coated silicon carbide substrates for space optics applications.
- Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram, has successfully commercialised indigenous technologies like Chitra Heart Valve, Bioceramic Bone Graft, Opthalmic Sponge and so on. International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad, has developed and supplies IR transparent ZnS domes to DRDO for the missile programme, light-weighted SiC substrates for satellite mirrors for Indian Space Research Organisation (ISRO) and oxide dispersion strengthened (ODS) steel for Fast Breeder Reactor (FBR) clad tubes. Raman Research Institute (RRI), Bangalore, studied re-ionisation era of early universe and also published papers on generation of Nano Scale heat conductors which has practical application in minimising heat dissipation in computer connectors.
- Under Drugs and Pharmaceutical Research Programme, 25 collaborative R&D projects and 15 new facilities like the clinical research facility to develop stem cell technologies and regenerative medicine have been implemented with leading industries. The programme has resulted in filing of 10 product patents. Some of the important products that have been developed include: (*i*) BONISTA for osteoporosis; (*ii*) RECEPTOL for the management of HIV/AIDS and (*iii*) RHOCLONE for Hemolytic disease of the new born (HDN). Several industrial leads on psoriasis, migraine, malaria and anti-glaucoma are being taken up for different phases (Phase I, II and III) of clinical trial. A drug for fighting malaria developed through PPP.

## MAJOR FACILITIES

- Several high-end R&D facilities have been established. Some of the notable ones are Clean room facilities at IISc, Bangalore; Ultra High Resolution Aberration Corrected Transmission Electron Microscope (TEM) at Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bangalore; and Centre for Knowledge Management of Nano Science and Technology (CKMNT) at ARCI, Hyderabad. Three accelerator-based research facilities have also been established at IIT, Kharagpur, Kurukhestra University and University of Allahabad. In addition, an India–Japan beam line was established for nano materials research at the photon at KEK, Tsukuba, Japan. India has also leased 13 beam lines equivalent times at the PETRA-III synchrotron radiation facility at DESY-Nano sized X-ray source for access by Indian scientists.
- The following major atmospheric observatory facilities have been established/being created: (*i*)1.3 m Optical Telescope; (*ii*)3.6 m Devasthal Optical Telescope; (*iii*) high-energy pulse LIDA system; (*iv*) fabrication and development of an Ultraviolet Imaging Telescope (UVIT) as a payload for the dedicated Indian astronomy mission ASTROSTAT; (*v*) design, development and execution of experiments for studying the solar corona through total solar eclipses; (*vi*) High Altitude Gamma Ray (HAGAR) telescope system at the Indian Astronomical Observatory, Hanle.

### *Twelfth Five Year Plan Programmes*

8.41. Basic research in frontier areas of S&T will remain a priority of the R&D sector. Since basic research is expected to give rise to applications in the long-term horizon, investments into basic research are generally made on the basis of competitive grant model employing concepts of Extra Mural Research funding. Among the various departments and arms of the government, the DST has emerged as the major source of Extra Mural

Research funding in the country. In recent times, the department has also established Science and Engineering Research Board as an autonomous agency and alternative mechanism for supporting basic research in India.

### *Scenario in Basic Research—Strategies for Global Positioning of India*

8.42. The DST has adapted, to the extent possible, evidence-based approaches to make its proposals for investments during the Twelfth Plan for supporting basic research. DST has made an attempt to compare the per capita outputs of Indian scientists in basic research in terms of scientific publications and developed national strategies for improving the relative position of India in global ranking. The current rate of growth of scientific publications is more than 14 per cent during the last three years. If Indian rank were to improve from the current 9th to 6th during the Twelfth Plan period in basic research-based on volume, the total number of scientific publications should increase from the current levels to at least 62,500 per year.

8.43. The SERB scheme would be strengthened during the Twelfth Plan. In addition to current models of project funding, SERB proposes to invest into researchers of proven record and establish about 200–250 centres based on Grant Model with fixed budgets and reward–performance relationships. 'Centres of Excellence' around a group of individuals would also be established. Advanced centres in scientific research around performing scientists in the cutting-edge areas of science of relevance within the country are proposed.

8.44. *Rejuvenation of Research in the University Sector*: During the last three years, DST has been investing into university sector through PURSE based on volume of scientific publications and h-indices of these universities. The success of the PURSE scheme is evident from the growth of number of universities eligible for support increasing from 14 in 2008 to 44 in 2010. The collective share of publications of the universities receiving support through PURSE has improved from less than 15 per cent to 25 per cent as of 2010. Analysis of data has shown that among the top 50 Indian institutions engaged in scientific publications, 23 are from the university sector. Further analysis of citations per paper for publications emanating from the university sector indicates that as many as seven universities register citations per paper for the data corresponding to the period 2004–09 above the national average of 3.47 per paper. All the 23 universities seem to gain in citations per paper when they collaborate with other international R&D centres. New schemes to promote the international S&T cooperation for the performing universities are proposed during the Twelfth Plan.

8.45. *Performance Observation in Science Sector*: Overall, the percentage share of scientific publications emanating from individuals and various institutions receiving support from DST (without discounting contributions from funding by other sources to the same researchers and institutions) could be assessed as high as 40–42 per cent of India's publications in Science Citation Index (SCI)-indexed journals currently. However, the R&D outputs of the individuals and institutions could not be entirely attributed to the support extended by DST for basic research. DST proposes to establish Science Observatory as well as Technology Observatory for monitoring the S&T output indicators of the Indian R&D system without cause attributions. Such measures are considered necessary as planning tools and decision support systems.

8.46. *National SERB—New Vehicle of Funding Basic Research*: SERB is emerging as a new body and mechanism for promoting basic research in the country. SERC is a national flagship for Extra Mural Research support. Ongoing programmes of SERC for investigator-based research grant models and investments into individual scientists based on track records will be dealt by SERB. The new body is expected to offer the benefits of (*i*) re-engineering and rationalisation of governance processes to suit the nature and efficiency of funding agencies, (*ii*) enrolling other arms of the government and private sector into R&D funding and (*iii*) flexibility and speed in research funding. Some of the new initiatives proposed by DST for investing into individuals would be delivered through SERB. DST proposes to invest up to 35 per cent of

its budgetary resources through SERB during the Twelfth Plan period for supporting the ongoing and some new initiatives of DST.

8.47. *Strategic Interventions for India Emerging as One of the Top Six Global Powers in S&T Sector*: Indian aspiration to emerge as one of the top six scientific powers in basic research would call for twin strategies. For increasing the volume share of scientific publications from India to reach the top six nations in the world, the FTE of R&D personnel may need to be increased to about 2,50,000. This could be partially accomplished by (*i*) increasing the density of scientists in performing institutions and (*ii*) unleashing the latent potentials available in the academic sector in colleges and universities. DST has proposed schemes for increasing the volume and density of R&D professionals by enlisting researchers from the university sector.

### Approaches for Strengthening and Expanding R&D Base

8.48. *Programmatic Approaches*: During the Twelfth Plan period, DST has proposed a number of new initiatives. They are: (*i*) 1,000 overseas doctoral scholarships, (*ii*) 250 overseas postdoctoral fellowships, (*iii*) women mobility scheme for employed scientists, (*iv*) Enlarging the PI base to include about 500 teachers from colleges and universities, (*v*) Start-up research grant for Indian diaspora undertaking faculty assignments in Indian academia, (*vi*) 'Disha' for women in science programme, (*vii*) building educators for science teaching, (*viii*) challenge awards for institutions for global positioning and (*ix*) National Centres for Advanced Research.

8.49. Technology Development and Deployment: The DST has responded to the changing stakeholder aspirations with respect to Technology Development and Deployment programmes. Whereas the programmes of the DST under Technology Development and Deployment in the previous plans were generally focused on demonstrating the viabilities of technologies developed by public-funded institutions, proposals for the Twelfth Plan under this objective have been developed under a different paradigm. User needs for technologies have been accorded high priority in selection of technology goals. Technology platform for solving real-life challenges is a novel approach proposed. Technology platforms are expected to enlarge the scope of work of DST in the technology arena. The department has proposed a total of eight platforms. Climate change programmes, modernisation of Survey of India (SoI) and National Atlas and Thematic Organization (NATMO), and district-level technology interventions for increases in per capita incomes are new objectives of the Twelfth Plan programmes. Promoting technology deployment will receive as much focus as technology development. Technology solutions for agricultural, chemicals, water, energy requirement, environmental sustainability and affordable human health care would form areas of thrust. Technology Mission for biomedical devices engineering and technology is proposed for implementation during the Twelfth Plan period.

8.50. *Partnerships and Alliances Involving DST and Programmes for Serving the Social Contract of S&T*: Partnerships and alliances for technology development and deployment form essential linkage capitals. Objectives of the programmes under partnerships and alliances are generally based on reciprocity and parity principle for international cooperation and for value generation of R&D outputs from public-funded research under national linkages. New mechanisms have been proposed for PPPs and Centre–State Technology partnerships. Established mechanisms are proposed to be employed for bilateral and multi-lateral S&T cooperation. Contributions to PAN-India missions, like Joint (Virtual) centres and North East Centre for Technology Applications and Reach form new schemes. Social contract of S&T has remained an important programme of the department. DST has recently constituted a Council for Science and Technology for Rural India (CSTRI) providing new mechanisms for delivering technologies to the rural India. Special schemes for vulnerable sections of the society will be taken through CSTRI.

8.51. *Building Capability and Capacity in Supercomputing*: A national programme on creating

supercomputing capabilities and scaling capacities to Peta scale is being envisaged for which DST has been assigned the coordinating responsibility. Alliance and partnership programmes with Ministry of Human Resource Development for enhancement of quality to science teaching and with DAE for the creation of large R&D office structure for Mega Science would be further developed during the Twelfth Plan Period.

8.52. *Strengthening Existing Autonomous Grant-in-Aid Research Institutions*: DST extends Grant-in-Aid to a total of 13 research institutions across the country. These institutions have been established by eminent scientists and citizens. Some of these institutions, although small in size with respect to the number of scientific personnel employed there, have emerged as major sources of scientific outputs with contributions to the national share of high-impact-making publications. Some of these institutions lend themselves to playing important roles in increasing the share of India in high-impact-making publications. During the Twelfth Plan, a strategic funding support to these institutions based on their contributions to national share of high-impact-making scientific publications and citation frequencies is proposed to be implemented. It is proposed to commission performance review of these existing Grant-in-Aid institutions by international or national experts during the Twelfth Plan Period. The Terms of Reference to the proposed Review teams would include as suggestions for directional changes and recommendations for governance model, if required.

8.53. *Strengthening of R&D Support and Knowledge Service Organisations under DST*: DST would continue to support the governance of Technology Development Board (TDB), Technology Information, Forecasting and Assessment Council (TIFAC), Vigyan Prasar (VP), National Accreditation Board for Testing Laboratories (NABL), Good Laboratory Practice (GLP), SoI and NATMO and National Spatial Data Infrastructure. These organisations serve special and niche needs in their own domain. The role of TDB in promoting PPP for R&D is proposed to be expanded significantly during the Twelfth Plan. TIFAC proposes to refocus its programmes and meet the mandated goals better and participate in developing a technology vision 2035 for India. Vigyan Prasar is working in unique space in science communication, particularly with respect to development of content and new communication tools and techniques. Alliances and partnerships for larger outreach of R&D outputs of VP are proposed. NABL has emerged as a major national accreditation body in the world platform. The body does not receive government grants and is engaged in a special space. This organisation proposed to expand its reach by establishing regional centres and expanding its scope of business. It is proposed to modernise SoI and new administrative governance systems for SoI and NATMO is proposed to be introduced.

8.54. *National Geographical Information System (NGIS)*: To meet the rapid growth of the country and developmental activities, it is proposed to establish a robust information and decision support system as envisaged through setting up an Indian Geographical Organisation (INGO) under the programme NGIS. The endeavour will be implemented through a network of agencies such as ISRO, DIT, NIC, DST, SOI and MoES, so on. The process would give a boost to various developmental activities for government, industry, academia and citizens including sectors like education and research.

8.55. An indicative plan outlay of ₹*21,596 crore* at current prices for the Twelfth Five Year has been made for the DST.

## Department of Biotechnology

### *Twelfth Plan Objectives/Thrust*

8.56. The overall strategy for DBT for the sector during the Twelfth Plan is to 'accelerate the pace of research, innovation and development to advance biotechnology as strategic area by taking India's strengths in foundational sciences to globally competitive levels and expanding the application of

**Box 8.3**
**Leveraging International Collaboration for Strengthening National Programmes**
**Journey From Stanford–India Biodesign Programme—A Novel Collaborative Technology Innovation to Launching National Biodesign Alliance**

Bioengineering and biodesign integrates physical, chemical or mathematical sciences and engineering principles for the study of biology, medicine, behaviour or health. It advances fundamental concepts, creates knowledge for the molecular to the organ systems levels and develops innovative biologics, materials, processes, implants, devices and informatics approaches for the prevention, diagnosis and treatment of disease, for patient rehabilitation and for improving health.

Recognizing the need for capacity building in terms of human resources as well as biodesign and medical technology development, Department of Biotechnology sponsored the program "Stanford India Biodesign Internship" in the year 2008–09 as a collaborative venture with Stanford University, USA, for a period of five years. In India, this programme is centred at All India Institute for Medical Sciences (AIIMS) and Indian Institute of Technology (IIT), Delhi, with a focus to develop implants, medical devices and bioinstrumentation matching national priorities.

Achievements so far include (*i*) training of a total 20 fellows and 28 interns; (*ii*) formation of a start-up company 'Consure' by the fellows of the first batch (2008) of this programme; (*iii*) development of several other technologies/prototypes such as: Intraosseous device—useful for intraosseous infusion in any emergency that overcomes the limitation of resource constrained environment; patient transfer device—to transfer patient from one surface to another surface; limb immobilisation device—to immobilise and support an injured body part; and (*iv*) technology transfer of a low-cost disposable device to manage fecal incontinence in non-ambulatory patients across all care facilities.

Phase II of this programme has been initiated for refinement, validation, testing developing business model for commercialisation of developed prototypes/technologies.

Scale up at national level: During the Twelfth Plan, a programme "National Biodesign Alliance" has been established with various partners such as Regional Centre for Biotechnology, Gurgaon; Translational Health Science and Technology Institute, Gurgaon; International Centre for Genetic Engineering & Biotechnology, Delhi; IIT, Delhi; AIIMS, Delhi; and Christian Medical College, Vellore. A Centre for Biodesign and In vitro Diagnostics has been established at Translational Health Science and Technology Institute, NCR region. Efforts are being made to expand the concept of biodesign at other IITs, medical schools and other related institutions.

biotechnologies for overall growth of bio-economy within the framework of inclusive development'.

8.57. The significant achievements of DBT during Eleventh Plan are given in Box 8.4.

### *Twelfth Five Year Plan Programmes*

8.58. The strategy of the Twelfth Plan complementing the foundations laid during the Eleventh Plan shall be achieved through focused investments, policy support, reforms in governance and management of projects around the following strategic goals:

1. *Expand available pool of research scholars and scientists at all levels (PhD, PDFs, young faculty) in biological and interdisciplinary space by three to five folds*: A major programme-based support will be provided for expanding biological/life science departments and clusters in universities, IITs, medical, veterinary and agriculture and pharmaceutical universities/departments, centres of excellence. This would involve important interdisciplinary bio-based science linking to quantitative sciences (chemistry, engineering, and physics) and expanding biological and interdisciplinary sciences in human, animal and plant science systems to achieve greater translatability of knowledge with feasible model system.
2. *Connecting and augmenting existing competences across institutions and universities for bio-economy and social impact*: Interdepartmental and institutional centres and extramural centres of DBT institutions supported with a novel contractual career path for faculty and scalability to connect existing competencies will improve interdisciplinary science, using inspired and

**Box 8.4**
**Significant Achievements/Development of DBT during the Eleventh Plan Period**

- Under Human Resource Development efforts, a total of 5,887 research personnel were supported in R&D projects which include 1,768 Junior Research Fellows, 1,844 Senior Research Fellows, 1,060 Research Associate and 70 professorships. In addition, about 2,142 postgraduate students in life sciences and biotechnology were given biotechnology industry training fellowships involving 200 industries. About 2,410 projects have been implemented under various R&D schemes costing about ₹1,600 crore, of which 26 per cent (535) of the projects in the area of medical biotechnology and allied areas, 22 per cent in agriculture and allied areas of biotechnology, 21 per cent in basic research and emerging areas, 19 per cent bio resources and bioprospecting and 12 per cent in capacity building.
- Through DBT support, a total 1,104 publications of impact factor 5 and above published; 312 patents (national/international) were filed and 110 patents have been granted; and 105 technologies developed, 21 transferred to industry and 5 commercialised. A large number of technology transfers are in process. Health care technologies dominated in technology development compared to agriculture.
- Under Centres of Excellence activities around innovative leaders and institutions, 35 programme supports and 11 individual projects resulted in 200 publications with impact factor >5 published; 33 national patents filed and 24 granted; 37 international patents filed and 26 granted; 10 research leads obtained and 1 technology transferred.
- Ten translational research centres and platforms established for clinical development service, GM crops translational research, energy biosciences, bio-design for implants and medical devices, stem cell research, drug discovery, Primate Research and veterinary biologicals. Major translational research initiatives through Grand Challenge schemes and network programmes in the areas of agriculture and health care resulted in several technological developments. Vaccines for malaria, dengue, cholera, and rotavirus are at various phases of clinical trials. Rota viral vaccine is in phase III trials and may be commercialised soon.
- Seven new autonomous R&D institutions, namely (*i*) Translational Health Science and Technology Institute, Faridabad; (*ii*) Regional Centre for Biotechnology, Faridabad; (*iii*) National Agrifood Biotechnology Institute, Mohali; (*iv*) National Institute of Biomedical Genomics, Kalyani; (*v*) Institute of Stem Cell Biology and Regenerative Medicine, Bangalore; and (*vi*) National Institute of Animal Biotechnology, Hyderabad were set up.
- Under Small Business Innovative Research Initiative (SBIRI) and Biotechnology Industry Partnership Programme (BIPP), 100 PPP projects have been launched so far which has resulted in 6 Indian patents and development of 16 technologies in agriculture, health care and instrumentation. Sixty projects supported under BIPP scheme benefitted 51companies (27 small, 12 medium and 12 large companies).
- Public sector–developed GM crops such as insect-resistant chickpea, rice, brinjal; drought-tolerant groundnut, sunflower and mustard with hybrid vigour are in regulatory pipeline. Accelerated molecular breeding programmes in rice, wheat, corn and mustard have been launched, and protein-rich maize is already commercialised.

translational research. Some such connectivities proposed are: Biosciences with chemical sciences and synthetic biology for next-generation biofuels; Nano science; chemical sciences and pharmaceutical sciences with clinical research for novel drug delivery, novel diagnostic and medical imaging; engineering–medicine–biology and medical science for implants and devices, chemical biology and physical biology.

3. *Expanding, diversifying career paths with a linkage to high-end interdisciplinary sciences, innovation, translation and entrepreneurship*: Involving

support to centres of excellence, incubators, programmes for expanding existing research and human resource capacity by threefolds through increase in current areas of relative strength such as molecular and cell biology, structural biology, immunology, neurobiology, bioengineering and promoting career paths in clinical and translational research, regulatory sciences, Intellectual Property (IP) technology transfer and knowledge management, entrepreneurship and education, and so on, are proposed. It is also proposed to expand, redesign and create extramural and inter-institutional centres as a cost-efficient process of scale up, utilising the existing best people with some additional younger people. The IIT system offers a unique opportunity over a substantially large interconnected and effective bioscience, interdisciplinary science, bio and other engineering science linked to technology innovation in almost all areas of biotechnology relevant to the country. This would receive high priority and use the instruments defined above for connectivity and for conversion of early leads to meaningful solutions and products.

4. *Strengthening regulatory science and infrastructure*: Involves establishment of BRAI; central agency for regulatory testing and certification laboratories with some core activities and network of testing facilities in public sector laboratories; promotion of regulatory science research units; and human resource development.
5. *Expanding existing autonomous R&D institutions*: The expansion aims at expanding current strengths of researchers and scientists by threefolds at all levels through on-site expansion or establishment of second research campus; setting up of Extra Mural Research centres on or off site to promote translational science, launch mission programmes or to advance interdisciplinary science area and expanding physical infrastructure including technology platforms. It is proposed to adopt a system of intramural institutes and extramural centres for each of the 13 autonomous institutes of DBT. These extramural centres would be located in medical schools, State agricultural universities, engineering schools with about 10–12 Principal Investigators at each extramural centre. About 500 scientists additionally can be supported with existing leadership and anchor role by the autonomous institutes.
6. *Expansion and commissioning of bio clusters at Faridabad, Mohali, Kalyani and Hyderabad*: This would involve adding new programme-based centres at each cluster: academic centres, medical centres, bioengineering centre, contract labs, Genetically Modified Products (GMP) units, animal model resources, novel platforms for therapeutics for sharing by SMEs, technology incubators and parks of entrepreneurship training centres and offices for technology transfer and management and to provide connectivity for innovation.
7. *Establish DBT Grant-in-Aid or partnership research and translational centres through long-term support* in 10 best universities/institutions in at least 10 areas of interest, for example: Agriculture sciences and innovation for pre-breeding, genetic modification (GM) technology and molecular breeding; veterinary S&T for animal productivity and health; biopharmaceutical sciences and health technology; chemical biology and synthetic biology.
8. *Reorient 'Grand Challenge Programme' scheme of the Eleventh Plan to address national priorities* in various developmental sectors through bottom-up approach and also encourage discovery-led innovative ideas: These are eight mission mode programmes with separate governance, management, milestones with inter-departmental participation and global partnerships and bottom-up idea-based competitive grants for R&D and innovation or network projects with several partners along the biotechnology value chain.
9. *Rejuvenate existing and establish new research resources, facilities and services*: A National Life Sciences Resource Centre (NLSRC) with specialised research staff, informatics support and databases to network all research resources, training for skill development activities and organise a systematic information access management facilitating biology research community proposed to set up. New facilities and resources proposed include: low-end virtual supplies for

small organisations such as micro array, knock-out mice; validation and prototyping, safety testing technology platforms/centre for implants, devices, cell therapies; large animal resource centre; viral testing facilities; genomic and proteomic facilities; new generation sequencing service units and so on.

10. *Leverage international collaboration for partnerships in cutting-edge areas of research, education and technology development, access and acquisition*: The experience with existing global partnerships with countries and international agencies will be leveraged to bring about directional change in partnership strategies. Towards this objective, focus shall be on establishing joint centres of excellence; graduate schools across universities; forging 2×2 international partnership involving industry and academia on either side, 1×1 partnership among SMEs; projects linking DBT autonomous institutions with international institutions and universities; joint development of industrial biotechnologies with global organisations. Global consortia of industries and public institutions will be promoted on the lines of the Indo-US Bioenergy initiative in other areas, such as molecular breeding, cell therapy and regenerative medicine and so on.
11. *Continued and sustained support to PPPs with new innovative funding schemes*: Besides continuing with some reforms in SBIRI and BIPP schemes operations innovative funding schemes such as: Ignition Grant Scheme available to individuals or a team of individuals–in partnership with private investment agencies; schemes for creating and nurturing start-up for early-stage technologies; provision of 'bridge funding' firms to function between successive private equity funding or planning for IPOs; funding for technology access and acquisition and licensing and special investment incentives to industry for building more biotechnology/pharma special economic zones (SEZs). Biotechnology Industry Research Assistance Council (BIRAC) would be made fully operational in Twelfth Plan to assess and facilitate bio industry as per its mandate and manage funding through PPP schemes. The affordable health technology initiative with Welcome Trust will be launched. It will have a pro-poor bias, focus on mass health impact and enhance our abilities to access technology from overseas in addition to from within the country.
12. *Promoting discovery-led innovation and strategic investments in priority sectors*: The department has been funding investigator-driven R&D projects across areas of basic agriculture, health care, environment, animal health and reproduction, bio resource utilisation and food S&T and so on. During the Twelfth Plan, it is proposed to redesign sectoral strategy in such a way that every sector utilises more than one mechanism or modality, linkages, partnerships and alliances and platforms that are required for successful development of both S&T.
13. *Promoting new-generation biotech industries*: Innovative funding schemes and incentives within the framework of existing mechanisms shall be extended to develop capacity for setting up of new bio industries such as bulk/specialty chemicals/biochemicals; food and nutrition technologies; biotech-led/biotech-enabled services engineering, components and equipment manufacture; nano–bio industries and so on. Efforts would also be made for reengineering the economic model for biotechnology product/industry development.
14. *Technology acquisition, transfer and licensing for product development*: Major initiatives will be taken in Twelfth Plan such as establishment of Intelligence Innovation and Idea units to serve as 'think tanks' in life sciences and biotechnology to imagine the future and prepare for the future to analyse needs and opportunities and create product profile for products that will be usable and marketable; technology acquisition fund with legal process and mechanism technology and IP management centres, particularly DBT partner universities and institutions.
15. *Communication platform/system for creating awareness and public understanding of biotechnology*: To address this issue, it is proposed to set up Centre for Biotechnology Communication for content creation and coordination; communication units in universities and institutions; commissioning regular programmes

and publications in electronic and print media and constitution of authorised communication expert groups for crisis management and response.

16. *Expedite legal framework and legislations*: BRAI Bill has been tabled in parliament for introduction. It is proposed to bring other bills dealing with public sector–funded IP management; DNA profiling and Regional Centre for Biotechnology.
17. *Strengthening and consolidation of the major Eleventh Plan initiatives*: Keeping in view zero-based budgeting (ZBB) exercise, certain projects and programmes that have outlived their relevance will be phased out. At the same time, successful schemes shall be strengthened through stringent project management and scale up. Schemes in this category belong to promotion of innovation and excellence; PPPs; research resources specialised centres, translation platforms and service facilities; innovative human resources development programmes and major R&D programmes and networks for technology development.
18. *Promote policy research and analysis in biotechnology*: Policy research and analysis has become an essential ingredient of biotechnology development due to IPR, regulations, public concerns and technology options/alternatives, affordability, access and trade issues. Besides general capacity building through workshops, training and research, centres/units for health and agriculture biotechnology policy research will be supported along regular policy dialogue among stakeholders through special meetings and seminars.
19. *Establishment of new autonomous national research centres/institutions in emerging areas*: It is proposed to establish few institutes/research centres in emerging areas of translational research such as Bioinformatics and Computational Biology; Marine and Microbial Biotechnology; Biodesign, Bioscience and Bioengineering; Chronic Disease Science and Biotechnology and Infectious Science and Biotechnology Institute in North East (linking to Translational Health Science and Technology Institute [THSTI] as partner for Training and Education).

8.59. An indicative plan outlay of ₹*11,804 crore* at current prices for the Twelfth Five Year has been made for the DBT.

## Ministry of Earth Sciences

### *Twelfth Plan Objectives/Thrust*

8.60. The MoES/Earth System Science Organisation (ESSO) was established by the Government of India in 2006 to address holistically various aspects relating to earth processes for understanding the variability of earth system and for improving forecast of the weather, climate and hazards. The programs of the Ministry has been reinforced and restructured with a view to provide best possible services relating to earth system science towards socio-economic benefit of the Indian sub-continent and in the Indian Ocean region. The various services being rendered by the Ministry caters to over 25 sectors and the estimated economic benefits appear to be contributing significantly to GDP of the country. The major focus of the Twelfth Plan proposals has been to carry out research on discovering new phenomena; exploring unchartered areas, especially sea-bed and Antarctica; understanding earth processes and developing new services as well as improving existing services for societal, environmental and economic benefits. The programmes of MoES/ESSO have been grouped into major schemes which are as follows: (*i*) Observation System, (*ii*) Atmospheric Processes, Modelling and Services, (*iii*) Climate Change Research, (*iv*) Airborne Platforms for Atmospheric Research, (*v*) Ocean Observations, (*vi*) Ocean Science and Services, (*vii*) Ocean Survey and Mineral Resources, (*viii*) Ocean Technology, (*ix*) Ocean Research Vessels, (*x*) Polar Science and Cryosphere, (*xi*) Marine Geoscientific studies, (*xii*) Seismological Research, (*xiii*) High Performance Computing (HPC) for Earth System Science Research, (*xiv*) Research, Education, Training & Outreach, and (*xv*) Earth Enterprises.

8.61. The significant achievements of ESSO during the Eleventh Plan are given in Box 8.5.

### *Twelfth Five Year Plan Programmes*

8.62. *Atmospheric Observation Systems Network*: The modernisation plan aims at commissioning of

**Box 8.5**
**Significant Achievements/Development of MoES/ESSO during the Eleventh Plan Period**

- Under the first phase of modernisation of the India Meteorological Department (IMD), accomplishments include: (*i*) commissioning of 10 global positioning system (GPS) stations; (*ii*) installation of nine Doppler Weather Radars (DWRs) one each in Delhi, Nagpur, Patna, Patiala, Agartala, Lucknow, Hyderabad besides the existing five DWRs which have improved now casting services; (*iii*) installation of integrated Airport Meteorological Instruments (AMIs) at Mumbai, Hyderabad, Bangalore, Jaipur and Delhi airports; (*iv*) installation of 550 Automatic Weather Stations (AWSs) apart from the existing 125 AWSs, in addition to installation of 689 Automatic Rain Gauges (ARGs); (*v*) commissioning of a set of four HPCs with a total installed capacity of 124 Teraflops for global data processing and Numerical Weather Prediction (NWP) for weather forecasting services. A district-level agro-meteorological advisory service along with a five days in advance district-level weather forecast system, covering all the 555 districts, was launched for farmers in partnership with a number of Central Government ministries and organisations, state-level institutions, private agencies, non-governmental organizations (NGOs), progressive farmers and the media. Over 3 million farmers have subscribed for receiving this information through mobile phones.
- A programme on 'National Monsoon Mission' was launched which will be equipped with the state-of-the-art infrastructure, namely, high-end computers, radars and scientific manpower to generate more detailed and accurate forecasts.
- In atmospheric modelling, there has been remarkable improvement in capability by running a wide range of high-resolution global circulation models. By introduction of these models like T574, the spatial resolution of the models has been increased sustainably from 50 km to around 22 sq km.
- Under Ocean Science and Services, an integrated unique system of fisheries advisories based on identification of Potential Fishing Zones (PFZs), using remote sensing technology, has been made operational. A tuna fishery forecast specifically for deep sea fish industry has also been made operational.
- A high resolution Indian Ocean forecast for the Indian Ocean on various parameters, namely, currents, sea surface temperature and mixed layer depth was also launched using a suite of ocean models. Towards strengthening ocean observation systems, a ground station for Ocean Sat-2, Ocean Colour Monitor (OCM) data has been established. Over 160 Argo floats (10 floats with oxygen sensors), and 66 drifting buoys were deployed in the Indian Ocean. Besides, a 16-moored buoy network has been made operational for continuous acquisition of data from the seas around India for operational weather forecast. In addition, over 25 tide gauge stations and 10 Coastal Radars were also installed to improve ocean information services.
- The first Indian scientific expedition to the South Pole was conducted in December 2010 which significantly improved India's scientific capability in the Antarctic. A scientific expedition using the international research facility at Ny-Alesund in the Spitsbergen island of Norway has been undertaken for Arctic research. India has successfully commissioned 3rd Permanent Antarctic Station 'Bharati' in the Larsemann Hills with state-of-the-art facilities for conducting Antarctic Research.
- Two Low Temperature Thermal Desalination (LTTD) technology-based desalination Plants with 1 lakh litre capacity have been established, one each at Minicoy, Agatti islands of Lakshadweep . Using waste heat from power Plants, a 1 lakh litre per day LTTD Plant was demonstrated which has been operational at the North Chennai Power Plant.
- With climate change science getting special attention and focus, a dedicated Centre for Climate Change Research at Pune has been set up to address scientific issues relating to climate change, including impact on sectors like health, agriculture and water.

- For activities under ocean resources, an instrument, along with complete hardware and software has been developed in collaboration with Russia to measure seabed soil properties in situ, at a depth of 5,200 metres. A prototype for a remotely operated vehicle has also been developed and tested successfully at a depth of over 5,284 metres. India has become one among a handful of nations that have the capacity for deep sea mining. Further, survey and exploration of polymetallic nodules has been carried out at a closer grid of 6.25 km for selected blocks, along with developing and testing the artificial nodule laying system.
- Under disaster support activities, the state-of-the-art Tsunami Warning System with the world's best infrastructure and communication system was made fully operational on 24×7 basis at INCOIS, Hyderabad. A set of 17 broadband seismic observational networks in peninsular India and six bottom pressure recorders in the Arabian Sea and Bay of Bengal were also upgraded. Towards this, an Earthquake Risk Evaluation Centre was created in New Delhi to evaluate seismic hazards at a very high resolution. The Indian Tsunami warning centre, which has been recognised the best centres in the Indian Ocean, is capable of issuing bulletins within 10 minutes of occurrence of earthquakes in the Indian Ocean.

state-of-the-art observing systems throughout the country. It is proposed to undertake phase II of the modernisation, focusing on the augmentation of the existing infrastructure established during the phase I of the modernisation in terms of observing systems and integrating the same with the rest of the network, namely, ground-based radiometers providing temperature and humidity profiles and complementing the sonde observations to be developed with priority. A Centre for Atmospheric Technology (CAT) is also planned to coordinate development of instruments, calibrate instruments including satellite-based and provide overall technology support to atmospheric sciences, besides validation of satellite data. It is proposed to set up a dedicated forecasting system for the entire Himalayan region with a much focused objective of integrating and improving the weather related services.

8.63. *Atmospheric Processes and Modelling and Service*: The sole purpose of the programme is to develop a wide range of atmospheric models for providing weather and climate forecasting services to various sectors by integrating all the process studies and models. The major sectors would be agriculture, aviation, metro cities, mountain regions, defence, sports and disasters. The existing district-level Agromet Advisory Services (AAS) to deliver crop and location-specific AAS to farmers will be graduated to the block level with village-level advisory. The upgradation of facilities of about 100 airports in the country will be taken up. Metropolitan air quality and weather service providing real-time weather, as well as now casting of weather and air quality in all metro cities as well, are proposed. It is essential to work out a modelling framework and put it in use to predict monsoon weather and climate in India on different time scales ranging from short and medium range to seasonal mean. National Monsoon Mission will be set up with the state-of-the-art weather infrastructures, namely, high-end computers, radars and scientific manpower to generate more detailed and accurate forecasts. Other deliverables are Cloud Physics and severe weather warning system.

8.64. *Climate Change Research*: It is proposed to develop long-term (multi-decadal) simulations of monsoon using coupled ocean–atmospheric models upon the commissioning of the HPC system upgrade for climate change research. The development of seasonal and intra-seasonal prediction of monsoon through coupled model is to be taken up. The utility of geo-engineering schemes to mitigate global warming has to be explored. There is need to develop expertise in India to evaluate the benefits and risks of these schemes. The research projects would be taken up to enhance our understanding of the changing water cycle. Besides, paleoclimatic studies will be conducted to understand the past variations of climate for possible projections of climate scenarios.

8.65. *Airborne Platforms*: A wealth of atmospheric, aerosol and cloud microphysics data will be generated using airborne platforms which will be useful to validate the convection and cloud schemes, and for improving the model physics. The proposed programme will be useful in air pollution assessment and associated impacts over India (health, visibility, climate), hydrological and water resources studies, and enhancement of research infrastructure.

8.66. *Ocean Observation System (OOS)*: The objective is to acquire time-series data from the seas around India and to develop a wide range of ocean atmospheric models towards augmentation of services. The data acquired through Argo floats, Drifters, Current Meter Arrays are being used for various operational and research purposes including forecasting of cyclones and understanding the climate variability.

8.67. *Ocean Science and Services (OSS)*: The OSS have been reoriented into a major programme during the Twelfth plan by integrating all the service-oriented ocean-related projects under one umbrella. These are providing a suite of Ocean Information services, assessment of marine Living Resources, periodical monitoring of health of the coastal waters of India, Management of Coastal Marine Area and operation of Tsunami Warning system on 24×7 basis for issue of bulletins for India and to the countries of the Indian Ocean region. In the Twelfth Plan, an International Centre for Operational Oceanography has been planned. The major deliverables under the scheme are high-resolution ocean modelling and microbial oceanography.

8.68. *Ocean Survey and Mineral Resources*: This programme is primarily aimed at conducting surveys for harnessing the marine nonliving resources in a sustainable way, available in exclusive economic zone (EEZ) and deep sea region of the Indian Ocean. These include gas hydrates, polymetallic nodules, hydrothermal sulphide minerals and cobalt crust. Apart from continuing some of the activities of ongoing schemes like gas hydrate and polymetallic manganese nodule (PMN), the major emphasis would be on research activities relating to Hydrothermal.

8.69. *Ocean Technology*: The Ocean Technology programme of India encompasses four core missions as Ocean Energy, Deep Sea Mining, Coastal end Environmental Engineering and Marine Instrumentation. National Institute of Ocean Technology plays a key role in undertaking ocean-related activities, Ocean Science & Technology and enhancement of marine living resources, development for breeding, rearing and fattening of lobsters, to begin with, for Andaman and Nicobar Islands. Consolidation of deep sea mining technology such as integrated deep sea mining system, soil tester, Remotely Operated Vehicle (ROV) and manned submersible would be carried out, besides developing Marine Sensors and underwater equipment. Under ocean technology, a set of eight in-house R&D programmes like Energy, Ocean Acoustics, Marine Sensor, offshore structures, Inter-institutional R&D of National Institute of Ocean Technology (NIOT) would be carried out. Desalination plants would be established in all major islands of Lakshadweep.

8.70. *Ocean Research Vessels*: Two new vessels are proposed which will be greater than 100m, Ice class, with speed of 20 knots and fitted with winches and systems for exploration of deep sea living resources. *Sagar Sampada* had the limitation of undertaking these studies only up to 1,000m to 1,500m depths. These vessels will give a considerable boost to mineral surveys and ocean research in the Indian Ocean Region.

8.71. *Polar Sciences and Cryosphere*: The Polar Science and Cryosphere programme entails the study of the Antarctic, Arctic and Glaciers of Himalayas that are important to understand the climate change and climate variability in the Indian region. The deliverable under the scheme would be replacement of Maitri station.

8.72. *Seismological Research*: It is proposed to provide thrust to the earthquake-related studies and to generate inputs for earthquake disaster mitigation. The primary activities would include: (*i*) Deep crustal studies across the Indian continental margin and the interior, (*ii*) Paleo seismological studies and kinematics of the Himalayan region,

(*iii*) Andaman subduction zone and (*iv*) Active faults of India. Besides, this programme also envisages reconciling the constraints from available geophysical and geological data along a series of transects across the Indian peninsula into a consistent model of the Indian lithosphere to conduct studies on deep bore holes investigations in Koyna, Warna region and Marine Geoscientific Studies. To address these issues relating to earthquake in a holistic manner, a National Centre for Seismology (NCS) is being set up.

8.73. *Geoscience*: Deep sea drilling in the Arabian Sea basin through the Integrated Ocean Drilling Programme is proposed to be undertaken. The scientific proposal of deep sea drilling in the Arabian Sea for discovering the tectonic climatic unknowns will be taken up. An institute for Geo Technologies, integrating all the scientific and operational bodies and taking new initiatives on merit like finding geo technology solutions to serious problems like global warming is proposed to be established. The deliverables under the scheme would be exploring the origin of the largest Geoid low on the earth and origin of monsoon and evolution of Himalayas. For advanced research in isotope geochemistry and geochronology pertaining to earth, atmospheric and oceanic sciences, high-resolution Secondary Ionization Mass Spectrometry studies would be carried out.

8.74. *High Performance Computing System*: Towards catering to the demand of computing facility for Centre for Climate Change Research (CCCR), Seasonal Prediction of Monsoon, Extended Range Prediction of Active Break Spells, National Monsoon Mission, Programme for Advanced Training in Earth System Science and Climate, and activities of CCCR, it is proposed to augment computing power from existing 124 Terra-flops to 2.5 Peta-flop during the Twelfth Five Year Plan.

8.75. *Research Education, Training and Outreach*: Facilities will be created to provide necessary infrastructure. The other main activities would be setting up a Centre for Operational Meteorology and an International Training Centre for Operational Oceanography as part of UNESCO's endeavour for training and capacity building and Indo-African Centre for Medium Range Weather Forecast for extending weather forecasting services in the African region. It is proposed to support Human Resource Development through establishment of MoES Chair Professorship in IITs and IISERs and initiation of academic programmes at IITs and IISERs.

8.76. *Earth Enterprise*: There has been a phenomenal increase in the sectoral applications of weather and climate products as well as ocean technologies and related products, resulting in an unprecedented demand for reliable and timely supply of products and information. A PSU, the Earth Systems Enterprise, would be set up under the Companies Act under the administrative control of the Ministry for providing data/technologies on commercial basis developed by the autonomous bodies/attached and subordinate offices.

8.77. An indicative plan outlay of ₹*9,506 crore* at current prices for the Twelfth Five Year has been made for the MoES.

## Department of Scientific & Industrial Research (Including CSIR)

### *Twelfth Plan Objectives/Thrust*

8.78. The thrust of the Department of Scientific & Industrial Research (DSIR) is to promote industrial research, technology development and transfer to enable India to emerge as a global industrial research and innovation hub. Emphasis is on attracting industrial research in the country through industry and institution-centric motivational measures and incentives, creating an enabling environment for development of new innovations to channelise benefits to the people.

8.79. CSIR has conceptualised and developed a document entitled 'CSIR@80: Vision and Strategy 2022', which is a road map for 2022. The document is based on the motivation that the year 2022 would bring us to India@75—the platinum jubilee of Indian independence. The India@75 will coincide with CSIR@80, a unique stage in the life of any R&D

organisation. By that time, as per the various projections, India would have changed its image as a third world country to the third most powerful country in the world. CSIR, as India's largest and most diverse S&T organisation is aspiring to help India in achieving this goal. In view of the building scenario by 2022, CSIR's vision would be to build a new CSIR for new India and CSIR's mission would be: 'Pursue science which strives for global impact, technology that enables innovation-driven industry and nurture trans-disciplinary leadership thereby catalysing inclusive economic development for the people of India.' The people and nation-centric thrust to science, technology and societal pursuits would remain the cornerstone of CSIR's mission.

8.80. The Twelfth Five Year Plan of CSIR focuses on achieving science and engineering leadership; developing innovative technological solutions; practising open innovation initiatives; developing and nurturing human resource in trans-disciplinary areas; facilitating science-based entrepreneurship; and enabling socio-economic transformation through appropriate S&T intervention. In view of attaining the above focus, CSIR proposes many new initiatives and envisages adopting strategies that are goal focused—attaining the identified goals; process focused—building and streamlining organisational processes; growth focused—achieving organisational growth; and competitive advantage focused—achieving competitive advantage over peers.

8.81. The significant achievements of DSIR including CSIR during the Eleventh Plan are given in Box 8.6.

### *Twelfth Five Year Plan Programmes*

8.82. *Programmes of DSIR*: The major Plans and Programmes of DSIR for the Twelfth Five Year Plan include: (*i*) *Promoting Innovations in Individuals, Start-ups and MSMEs (PRISM)*—wherein innovative proposals of MSMEs shall be supported; CSIR—Cluster Innovation Centres (CICs) promoted by National Innovation Council shall be supported for providing innovative solutions; existing network of TePP Outreach Centres shall be expanded; proposals from individual innovators/incubates shall be supported and support shall be extended to approved Technopreneur Promotion Programme (TePP) projects, spilling over from the Eleventh Five Year Plan; (*ii*) *Scheme on Patent Acquisition and Collaborative Research and Technology Development (PACE)*—wherein support shall be provided to Indian industries to acquire Intellectual Property at early stage from overseas or within the country and add value to the acquired IP; and focus shall be on PPPs to create enabling environment for collaborative research between Industry and Universities/Public Funded Research Institutions; (*iii*) *Building Industrial R&D and Common Research Facilities* (*BIRD*)—wherein R&D in Industry shall be encouraged and supported; and support shall be provided for creation of Common Research Facilities for Small and Micro Industries; (*iv*) *Access to Knowledge for Technology Development and Dissemination (A2K+)*—wherein science-, technology- and innovation-related international journals from major publishers shall be made accessible to 1,500 in-house R&D units of industry and 600 Scientific & Industrial Research Organisations (SIROs) and techno-entrepreneurs, besides conducting studies/conferences on industrial status in the country; support shall be provided for Technological Empowerment of Women projects, including projects spilling over from the Eleventh Five Year Plan; and support shall be extended to Technology Development and Demonstration Programme (TDDP) projects, spilling over from the Eleventh Five Year Plan.

### *Consultancy Development Centre*

8.83. The important activities envisaged during the Twelfth Five Year Plan period would include Consultancy Promotion, Services, Research and Analysis, National Programme for Competency Development in strategic focus areas, Technology Delivery Transfer and Commercialisation, National Knowledge Depository, Training and Development, Export promotion and International Collaborations.

### *Central Electronics Ltd. (CEL)*

8.84. During the Twelfth Five Year Plan period, leveraging on its technology prowess, CEL plans to develop capabilities for the manufacture of Dye Sensitized Solar Cells (DSSCs or Grätzel cells), which

**Box 8.6**
**Significant Achievements of DSIR/CSIR during the Eleventh Plan Period**

- CSIR has enabled India excel in high science and has been the pioneer of the country's intellectual property movement. It has been contributing on an average 12 per cent of the national SCI publications with an average impact factor per paper of more than two. It has published 16,664 research papers in SCI journals of national and international repute during 2007–10. It has also contributed towards the development of highly qualified S&T manpower in diverse areas and has supported over 8,396 research scholars; 4,000 students are pursuing PhD in various CSIR laboratories. It produces 500 PhDs and 2,000 postgraduate degree holders and research trainees every year. Being in the forefront of generating intellectual property, it was granted 1,282 foreign and 1,507 Indian patents, and it has 3,250 foreign and 2,350 Indian patents in force and 222 patents licensed as on date. The percentage utilisation of patents is 8.67 per cent, which is much above the world average of 3–5 per cent. CSIR's per patent cost is the lowest in the world amongst state-funded R&D organisations.
- CSIR designed and developed, through a PPP, the CNM5, a five-seater all-metal civil aircraft that had been successfully test flown. The carbon fibre technology was licensed to M/s Kemrock. The technology for recovery of Sulphate of Potash (SOP), developed by CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI) from bittern has been transferred to M/s Arcana Chemical Industries. Technology for Head Up Display (HUD) for Light Combat Aircraft (LCA) was transferred to Bharat Electronics Limited (BEL), Panchkula. The ATBS process developed by CSIR-NCL has been commercialised by M/s Vinati Organics Limited (VOL) at MIDC, Lote Parsuram, Chiplun.
- CSIR has licensed to Nostrum Pharmaceuticals for worldwide commercialisation of new generation thrombolytic molecules and will receive over 150 million US$. A new-generation clot-specific protein that displays plasminogen activation property was transferred to M/s Nostrum Pharmaceuticals, USA at ₹19.60 crore plus 5 per cent royalty. Technology for Caerulomycin A, and its proprietary derivatives and analogues for their novel indication of immuno-suppression—a discovery of immense importance in tissue transplantation like in kidney and heart—was licensed to M/s Nostrum Pharmaceuticals, USA at ₹14.70 crore plus 2 per cent royalty. Recombinant streptokinase produced from *Escherichia coli* was launched by M/s Shasun Drugs & Chemicals through M/s Lupin Pharmaceuticals and M/s Alembic Chemicals, at a cost of ₹1 crore plus 3.5 per cent royalty. This would bring down the prices of clot busters significantly. A new anti-ulcer drug—CSIR's patented know-how on a natural agent for treatment of symptoms associated with gastrointestinal toxicity and ulcer—was licensed to M/s IPCA Laboratories Ltd., Mumbai, at ₹2.5 crore plus royalty.
- CSIR developed a 10hp tractor named 'Krishi Shakti' which is low in cost (₹1 Lakh) and is suitable for small and marginal farmers. A facile process for Heptafluropropane (FM 200), a halon substitute used in fire-fighting systems was transferred to M/s Mechvac Fabricators Ltd., Mumbai, for commercial production. A 3,000 TPA Plant from Aditya Birla Group for the manufacture of epichlorohydrin from allyl chloride, based on an improved and patented catalytic process, went on stream at Ryong, Thailand. Process technology for sugarcane bagasse for the recovery of cellulose, hemi-cellulose and lignin was licensed to M/s Godavari Sugars at ₹6.5 crore plus 3 per cent royalty.
- CSIR laboratories have developed significant knowledge base on water and water-related technologies. CSIR has developed a high-flux hollow-fibre membrane based technology for disinfection and purification of water. Refined and portable device called the Terafil water filter has been developed which provides drinking water without the use of chemicals. This coupled with a technology for RO desalination has been used extensively to provide fresh drinking water in disaster-affected areas. RO plants are further being exported to Afghanistan and Kenya.

- A novel variety of Ashwagandha with a high root yield developed and released to farmers. The plant has useful anti-inflammatory, anti-stroke and anti-arthritic applications.
- In the area of affordable health care, the first-ever large-scale comprehensive study of the genetic structure of the Indian population has been completed, thereby creating an Indian Genome Variation database (IGVdb). This has opened up new vistas for developing predictive medicine using repeats and single nucleotide polymorphisms. India's footprint in the genomic world, a CSIR initiative along with others, led to reconstructing Indian population history. CSIR with Cadila Pharmaceuticals has developed for the first time a novel therapy named as 'RISORINE' for the treatment of tuberculosis. Lead for this novel therapy is obtained from Ayurveda. Commercialisation of Risorine has reduced the cost of formulation containing Rifampicin–Isoniazide by 23 per cent. Prostalyn, an anti-cancer drug, a herbal molecule obtained from *Murraya koenigii* and *Tribulus terrestis* for treatment of prostate cancer was released in the market. CSIR has also developed bacosides-enriched standardised extract of *Bacopa*—Bacosides Enriched Standardized Extract of Bacopa (BESEB)—a single plant–based unique natural memory enhancer formulation, and patented the development. The BESEB is successfully commercialised.
- A high-yielding cultivar of Lavender developed by CSIR has proved to be an excellent alternate crop for cultivation by farmers in the state of Jammu & Kashmir. CSIR has set up post-harvest centres in Mizoram (Aizawl) and Arunachal Pradesh (Pashighat). More than 10,000 farmers of the North-East would be able to sell their produce at 20–25 per cent higher price to these processing centres.
- CSIR has launched an ambitious, socially relevant programme named CSIR 800. This programme aims at developing and providing innovative R&D-based products and processes which would be affordable by the common masses. These would come in handy not only for removing drudgery but also for adding to economic upliftment of the Indian populace by successfully launching small scale enterprises. CSIR has designed and developed an eco-friendly dual-powered rickshaw named 'Soleckshaw'. The soleckshaw is in commercial production.
- CSIR launched Open Source Drug Discovery (OSDD) programme has emerged as a new platform for innovation in the domain of health care. This CSIR-led 'Team India' consortium with global partnership has more than 4,500 researchers from over 100 countries as registered participants.
- CSIR's Traditional Knowledge Digital Library (TKDL) in collaboration with Department of Ayurveda, Yoga & Naturopathy, Unani, Siddha and Homoeopathy (AYUSH) has emerged as a unique resource for protecting Indian traditional knowledge from exploitation through IP filings. TKDL has signed access agreements with European Patent Office (EPO), United States Patent and Trademark Office (USPTO), German Patent Office, Japan Patent Office and so on.
- CSIR has established an Academy of Scientific and Innovative Research (AcSIR) through a gazette notification by the government which would aim at innovative curricula, pedagogy and evaluation for creating high-quality personnel in trans-disciplinary areas.
- CSIR has set up the CSIR Tech Private Limited, registered at Pune, to catalyse the valorisation of its technologies. The main purpose of CSIR Tech is to hold equity and give feedback loop of technology creation and transfer.
- DSIR has granted or renewed recognition to over 1,600 in-house R&D units of industry. Over ₹10,000 crore of R&D investment by in-house R&D units were reported to Directorate General of Income Tax (Exemptions) for weighted tax deduction under Section 35(2AB) of Income Tax (IT) Act. Support was also extended to 400 innovator's projects (TePP projects), 34 TePP outreach centres and 70 new technology development and demonstration projects.

are emerging as one of the highly creditable alternatives to silicon photovoltaic and to the more recently developed thin film technologies. CEL has proposed to develop the design of systems for a relatively new approach for optimising solar system efficiency and improving reliability with the design and manufacture of micro-inverters that connect to individual solar panels. CEL will establish an R&D Division to cater to the needs for design, development, testing and validation of a range of improved strategic electronic, special purpose vehicle (SPV), surveillance, safety/security products. Harnessing technology advancements and improvement of manufacturing techniques as also the need to enhance manufacturing capacity commensurate with active marketing efforts and business expansion, steps are being taken up by CEL to ensure that the present plan capacity of 10 MW for SPV products is increased to 80 MW. CEL has also proposed through a joint venture to set up a National Silicon Wafer production facility for producing silicon wafers of 1,000 MW/year capacity to reduce the nations' reliance on availability of this critical resource of silicon materials through import from other countries.

### *National Research Development Corporation (NRDC)*

8.85. NRDC was assigned more than 270 technologies by various R&D institutions in the country, and it signed more than 175 license agreements with industry for commercialisation during the Eleventh Five Year Plan period. The focus of NRDC during the Twelfth Five Year Plan period will be on launching (*i*) Programme for Inspiring Inventors and Innovators (PIII) and (*ii*) Programme for Development of Technologies for Commercialisation.

### *Council of Scientific and Industrial Research*

8.86. CSIR proposes to pursue 10 schemes during the Twelfth Plan. The initiatives are summarised below:

8.87. *Setting Up of New Institutions*: CSIR envisages setting up five new institutes during the Twelfth Five Year Plan, in both physical and virtual mode. These institutes include: CSIR-Institute of Synthetic and Systems Biology (CSIR-ISSB); CSIR-Fourth Paradigm Institute (CSIR-4PI); CSIR-Institute of Bio-Mimetic Materials (CSIR-IBMM); CSIR-Network Institute of Solar Energy (CSIR-NISE) and CSIR-Network Institute of Manufacturing Technology (CSIR-NIMT).

8.88. *R&D in Clusters through National Laboratories*: During the Eleventh Plan, CSIR has categorised its R&D programmes across seven clusters. The Twelfth Plan envisages strengthening and streamlining the cluster approach substantially. Programmes of the National Laboratories in the Twelfth Five Year Plan would be undertaken across five clusters which are as follows: Biological Science, Chemical Science, Engineering Science, Information Science and Physical Science. There is a specific focus on Human Resource Development in cluster mode. The projects have been formulated to encompass intra-cluster, inter-cluster and trans-cluster entities covering the domains of mega projects, large mission projects, supra-institutional network projects, cross-cluster projects, facility creation/augmentation projects and other small projects.

8.89. *CSIR Outreach Centres*: CSIR during the Twelfth Five Year Plan envisages setting up CSIR Outreach Centres that would essentially function in partnership with stakeholders. The focus is on new States and other such States where CSIR has no presence. CSIR Outreach Centres are envisaged to be operated and managed through CSIR–people partnership mode (CPP), and implemented either through mobile kiosks or pre-fabricated self-inclusive containers placed at identified locations. The centres would also have close coordination and networking with the CICs of the NInC-CSIR initiative.

8.90. *Initiative for Scale-up and Validation of Leads*: In order to ensure that the various leads developed as a result of R&D in CSIR labs attain fruition, CSIR has proposed to upgrade an activity for scale-up and validation of leads towards product/process development into an independent initiative.

8.91. *CSIR Special Centres for North-Eastern States, Lakshadweep and Andaman and Nicobar Islands*: In its endeavour to align with the national approach to achieve faster, sustainable and more inclusive growth

of the country, CSIR during the Twelfth Plan would focus on special eco-regions of the country and facilitate their sustainable development through S&T intervention. The North-East region and the islands of Lakshadweep, Andaman and Nicobar have been chosen in this regard. CSIR's efforts would include promoting innovation and CSIR technologies for the north-eastern States and undertake S&T intervention towards disaster mitigation and sustainable development of the coral reefs in the Lakshadweep, Andaman and Nicobar Islands.

8.92. *R&D Infrastructure Creation and Refurbishment*: Increase in the number of research programmes and the number of scientist calls for a corresponding increase in R&D infrastructure. This includes building new facilities; advanced workplace design; building ancillary facilities such as animal house, test range, fab-labs and so on.

8.93. *Energy Efficient Green Campus Development*: During the Twelfth Plan, it is proposed to continue with this initiative so as to spruce up CSIR laboratories to substantially high standards such as green building. The building of civil infrastructure would also cover increasing the number of staff quarters, student hostels, guest houses and other fringe facilities. Initiatives would be undertaken to renovate and improve the existing staff quarters, hostels, guest houses and so on.

8.94. *Building Excellence*: CSIR during the Twelfth Plan envisages building excellence. Well-focused initiative to pursue innovative ideas and embark upon high-risk, high-impact projects, thus, would be pursued to travel traversed paths and open up newer vistas. Programmes under this category include EMPOWER (Encouraging and Motivating Pursuit of World Class Exploratory Research), RISK (Research Initiative to Scale New Knowledgebase) and U-Excel (Unit for Excellence), targeted at early career scientists, mid-career scientists and late-career scientists, respectively.

8.95. *Innovation Complexes*: CSIR during the Mid Term Appraisal of the Eleventh Five Year Plan had resolved to bolster its translational research capability through establishment of Innovation Complexes at identified locations across the country. The Innovation Complexes are envisaged to consolidate and sustain the value chain of R&D within the CSIR; consolidate the CSIR brand and make CSIR R&D accessible to society at large; catalyse regionally balanced economic development and promote entrepreneurial culture among the scientific community. During the Twelfth Plan period, CSIR would endeavour to operationalise twelve such complexes all over the country including the three complexes that are initiated during the Eleventh Plan.

8.96. *CSIR 800*: The programme on CSIR 800 that was launched during the Eleventh Five Year Plan for improving the quality of life and augmenting livelihood for the people at the base of the economic pyramid is being expanded during the Twelfth Five Year Plan. As a part of the programme, CSIR would address the needs of rural communities also through implementation of 24 identified CSIR Technology Enabled Villages (TECHVILS) across the country. The programme would be implemented in the following three stages: the REACH-TECH (to be transferred immediately), DEMO-TECH (to be transferred mid-way into the Plan) and INNO-TECH (to be transferred by the end of the Plan period).

8.97. *Open Innovation*: CSIR is building up open innovation as a key vehicle for delivering S&T output to the public at large. CSIR during the Eleventh Plan has achieved significant success through its OSDD initiative. Open Innovation has been identified as a major platform during the Twelfth Plan. It shall cover an expanded version of the OSDD programme (encompassing OSDD, Open Source Drug Delivery, Open Source Drug Development and Open Source Disease Diagnostics), and the Distributed Organic Chemical Synthesis (DOCS) programme that envisages building a national repository of 4,00,000 small molecules by the end of the Plan through open source. Apart from these, Science 3.0, an initiative for open innovation and knowledge-ware development through crowd sourcing would endeavour to engage a large number of engineering institutions to identify

the most vexing problems, and attempt to provide solutions on issues like attaining energy efficiency, reduction in materials use, minimising waste generation and developing business and financial models to increase productivity and profitability of the units.

8.98. *CSIR Initiative on Inclusive, Participative and Collaborative R&D*: This new initiative for CSIR during the Twelfth Plan would comprise the following four sub-components: Grand Challenge Initiative, Inverted Innovation, Participative Science and Participatory Technology Development, and Centres for Collaborative Research.

- *The Grand Challenge Initiative*—would focus on solving unsolved problems or providing a comprehensive solution to an enduring national problem. It will help in creating new core competence in the CSIR system; or create leadership in a new domain in trans-disciplinary/interdisciplinary science that would position CSIR globally;
- *The CSIR Initiative for Inverted Innovation*—a unique paradigm where children/young engineers invent, CSIR laboratories mentor and industries commercialise;
- *CSIR Initiative on Participative Science and Participatory Technology Development*—an initiative to pursue R&D that would provide mutual benefits to all the stakeholders participating in the scheme; inclusive innovation can be achieved, translational research can be carried out, a fluid team with like-minded people can be involved and the scientific outcome can be effectively leveraged.
- *Centres for Collaborative Research—CSIR-Academia, CSIR-R&D Institutes and CSIR-Industry*: The centres would focus on collaborative R&D in the identified domains through desired networking. They would be state-of-the-art set-ups and work in a fluid networked organisation mode. The R&D in such centres would be in domains such as health care, secondary agriculture, civil aviation and green transportation, sustainable energy and infrastructure engineering. It is envisaged that these centres would help develop seamless linkages between CSIR and Academic institutions, CSIR and R&D institutions, and CSIR and industry.

8.99. *National S&T Human Resource Development*: CSIR envisages continuing its endeavour of strengthening S&T human resources in the country through fellowships at various levels. In addition, during the Twelfth Plan, it is envisaged to introduce novel fellowship programmes such as hand-holding support to dyslexic children; provision of analytical ability–based fellowships; and also introduce the PC Ray Innovation Postdoctoral Fellowship.

8.100. *Intellectual Property and Technology Management*: CSIR continues to remain at the fountainhead of innovation through ownership of a large number of patents. During the Twelfth Plan period, the efforts to consolidate this IP portfolio further would be continued.

8.101. *R&D Management Support*: The programme on R&D Management Support comprises the following four components: International Collaboration, Planning and R&D Management, collaborative activities with the National Innovation Foundation, and Science Dissemination. The entire programme is proposed to be strengthened considerably during the Twelfth Plan period and taken to new heights.

8.102. *New Millennium Indian Technology Leadership Initiative (NMITLI)*: The NMITLI has been among one of the successful programmes of CSIR during the Eleventh Plan. The programme is envisaged to be strengthened and broadened further during the Twelfth Plan by the following approach:

- Post-NMITLI projects
- Funding with industry (50:50 initiative)
- Co-financing with Venture Capital funds
- NMITLI innovation centres
- Acquisition of early-stage relevant knowledge/IP for portfolio building.

8.103. *National Civil Aircraft Development Programme*: CSIR also envisages being a part of the National Civil Aircraft Development (NCAD) programme to develop the first civil aircraft in the country.

8.104. An indicative plan outlay of ₹*17,896 crore* at current prices for the Twelfth Five Year has been made for the DSIR including CSIR.

## Department of Space

### *Twelfth Plan Objectives/Thrust*

8.105. The space programmes are driven through a decade profile and directions for 2025. The broad directions for the space programme for the next decade would include: (*i*) Strengthening/Expanding of operational services in communications and navigation; (*ii*) developing enhanced imaging capability for natural resource management, weather and climate change studies; (*iii*) space science missions for better understanding of the solar system and the universe; (*iv*) planetary exploratory missions; (*v*) development of heavy lift launcher, reusable launch vehicles and (*vi*) the human space flight programme. Innovations in space-based communications and earth observations (EOs) will be pursued to achieve faster delivery of information to remote areas and finer observations of the earth. Overall, 58 missions are planned for realisation during the Twelfth Plan period which includes 33 Satellite missions and 25 Launch Vehicle missions.

8.106. The significant achievements of DOS during the Eleventh Plan are given in Box 8.7.

### *Twelfth Five Year Plan Programmes*

8.107. *Satellite Communications Programme*: In the area of Satellite Communications, it is proposed to augment the Indian National Satellite System (INSAT) capacity to bridge the gap between the demand and supply of the transponders for meeting all the requirements of the country and also to maintain sufficient spares capacity to meet contingencies. Development of state-of-the-art technologies and latest applications areas shall also be

**Box 8.7**
**Significant Achievements/Development of DOS during the Eleventh Plan Period**

- During the Eleventh Plan period, 29 major space missions were successfully accomplished, which included 13 launch vehicle missions with the Polar Satellite Launch Vehicle (PSLV) and the Geosynchronous Satellite Launch Vehicle (GSLV) and 16 satellite missions. The most significant achievement of the Eleventh Plan period was the successful launch of India's first unmanned moon mission Chandrayaan-1 on 22 October 2008, thereby achieving the historic feat of placing the Indian tricolour on 14 November 2008 on the moon's surface. The deep space network with two large antennae (18-metre and 32-metre diameter) with associated ground segment was established in Byalalu, near Bangalore to provide Telemetry, Tracking and Command (TTC) support for the mission. High-resolution data of excellent quality from Indian scientific instruments on board Chandrayaan-1 has led to the identification of new lunar features and characteristics around the moon. Analysis of scientific data jointly with international agencies has led to the detection of water molecules on the lunar surface.
- The other important achievements include the launch of (*i*) 10 satellites including Cartosat-2A and IMS-1 in a single launch of PSLV-C9; (*ii*) Microwave Radar Satellite RISAT-2 and Mini Satellite Anna University Satellite (ANUSAT) on board PSLV-C12; (*iii*) high-power satellite INSAT-4CR on board GSLV-F04; (*iv*) Oceansat-2 satellite along with six Nano satellites (commercial) on board India's PSLV-C14; (*v*) Cartosat-2B along with three Nano satellites and Student Satellite (STUDSAT) on board PSLV-C15; (*vi*) Resourcesat-2, Youthsat and Singaporean Satellite, X-Sat, on board PSLV-C16; (*vii*) GSAT-12 on board PSLV-C17; (*viii*) Indo-French joint mission Megha-Tropiques on board PSLV-C18; (*ix*) GSAT-8 through procured launch services; (*x*) conducting a qualification test of indigenously developed cryogenic stage; (*xi*) building two state-of-the-art communication satellites (W2M and Hylas) for international customers; (*xii*) providing launch services for two satellites for international customers (AGILE and TECSAR) on commercial basis by PSLV-C8 and PSLV-C10 and (*xiii*) establishing GEO and GPS Augmented Navigation System (GAGAN).

- Significant progress has been made towards developing GSLV Mk III, the next-generation advanced launch vehicle. A world-class solid propellant plant has been successfully commissioned at the Satish Dhawan Space Centre SHAR (SDSC-SHAR), Sriharikota, for manufacturing large solid stage booster segments (S-200) for GSLV Mk III vehicles. Two static tests of Solid propellant Rocket Booster stage (S-200), the third largest booster in the world, was successfully conducted to demonstrate the repeatability of S200 motor performance within the specified limits and has reconfirmed its design adequacy. As a part of C25 cryogenic stage development, realisation of thrust chamber test article and its trial suiting at the thrust chamber test facility has been successfully completed. The second static test of L110 stage of the GSLV Mk III vehicle was successfully conducted for its flight duration of 200 seconds.
- During the Eleventh Plan, there were failures of 2 GSLV flights, namely, GSLV-D3 with Indigenous Cryogenic Stage during April, 2010, and GSLV-F06 with Russian Cryogenic Stage during December 2010. The GSLV-D3 mission failed as the Indigenous Cryogenic engine after its ignition couldn't sustain the combustion beyond 1 second. The corrective steps based on Failure Analysis Committee are being effected for future launches.
- A new Remote Sensing Data Policy (RSDP 2011) containing modalities for managing and/or permitting acquisition/dissemination of remote sensing data in support of developmental activities has been approved which will enable the department to provide high-resolution data in time to concerned users.
- An Indian Institute of Space Science and Technology (IIST) was established for developing critical human resources for space S&T and the first batch of fresh graduates from the institute to the ISRO system have been inducted.
- Significant developments have taken place in the area of societal applications of space technology. Some of the important ones are: (*i*) expansion of tele-education network to over 55,000 classrooms; (*ii*) telemedicine facility in 382 hospitals; (*iii*) setting up of 473 Village Resource Centres (VRCs); (*iv*) location of drinking water sources using Indian Remote Sensing (IRS) satellite images covering more than 2 lakh habitations in 10 states; (*v*) wasteland mapping and monitoring of the whole country using IRS data; (*vi*) space-based Potential Fish Zone mapping benefitting the fishermen community of coastal areas (*vii*) biodiversity characterisation of bio-rich areas of the country; (*viii*) wetland mapping of entire country and (*ix*) operationalisation of Earth Observation Data Visualisation portal BHUVAN.

pursued. The operational transponder capacity from INSAT/GSAT satellites at the end of Eleventh Five Year Plan is satisfying a demand of around 198 transponders.

8.108. Based on the demand, about 400 transponders are planned to be realised by end of the Twelfth Plan period. Towards this, 14 communication satellites are planned to (*i*) increase the transponder capacity, (*ii*) introduce new-generation broadband very small aperture terminal (VSAT) systems, (*iii*) introduce Ka-band systems, (*iv*) build high-power S-band satellite mobile communications and (*v*) introduce new-generation geo-imaging satellite.

8.109. In terms of spacecraft platforms, it is planned to adopt I-2K, I-3K and I-4K buses for the communication satellites. I-3K and I-4K buses are planned to be launched using procured foreign launcher. It is also planned to initiate development of High throughput I-6K–12KW bus in higher frequency bands like Ka/Ku and the technologies associated with it.

8.110. Maintaining and securing sufficient orbit-spectrum resources for country's Satcom activities will be a thrust area of the Twelfth Plan. It has been planned to pursue rigorously to secure spectrum for 100 additional Ku-band transponders and around 50 C-band/Ext C-band transponders in newer orbital locations.

8.111. *Satellite Based Navigation*: Satellite-based Navigation service is an emerging satellite based

system with commercial applications. To meet the Civil Aviation requirements, ISRO is working jointly with Airport Authority of India (AAI) in establishing the GAGAN system. To meet the user requirements of the positioning, navigation and timing, ISRO is establishing a regional satellite navigation system called Indian Regional Navigational Satellite System (IRNSS).

8.112. The Satellite Navigation Programme (SNP) has the primary objective of establishing a space-based infrastructure, Ground Segment for satellite-based position, navigation and timing services. The SNP also has an objective for the user segment, the task of developing the receivers for IRNSS including Global Navigation Satellite System (GNSS) indigenously through participation of Indian industry.

8.113. The Major Programmatic Targets of the Twelfth Plan are:

1. Implement the final operational phase for satellite-based augmentation system (SBAS) GAGAN over the Indian Airspace jointly with AAI and providing position, navigation and timing services through an integrated receiver.
2. Implement an independent IRNSS over Indian region and encourage the growth of user segment in Indian Market.
3. Develop indigenous expertise in applications of GNSS for critical National applications, identify specific application software development areas and work towards development of receivers for IRNSS including GNSS through participation of Indian industry.
4. Secure sufficient orbit-spectrum resources for country's Sat-Nav Programme activities.
5. There is a need to formulate the Indian Satellite Navigation Policy as ISRO is implementing and going to provide satellite-based navigation services in India.

8.114. *IRNSS* is an independent and indigenously developed Indian satellite-based positioning system for critical national applications. The main objective is to provide reliable Position, Navigation and Timing services over India and its neighbourhood; to provide fairly good accuracy to the user and to provide Integrity and Ionosphere correction messages to the user. The IRNSS will basically provide the following two types of services: (*i*) Standard Positioning Service (SPS); (*ii*) Restricted Service (RS). Space Segment consists of seven satellites, three satellites in geosynchronous earth orbit (GEO) and four satellites in geostationary earth orbit (GSO). The three GEOs will be located at suitable orbit slots, and the four GSOs have their longitude crossings at two suitable orbit slots (two in each plane). All the satellites will be visible at all times in the Indian region. Ground Segment is responsible for the maintenance and operation of the IRNSS constellation. It provides the monitoring of the constellation status, computation of the orbital and clock parameters and navigation data uploading. The Ground Segment comprises TTC and Up-linking Stations, Spacecraft Control Centre, IRNSS Timing Centre, Code Division Multiple Access (CDMA) Ranging Stations, Navigation Control Centre and Data Communication Links. User segment mainly consists of a single frequency receiver for SPS, dual-frequency IRNSS receiver for both SPS and RS service and a multi-mode receiver compatible with other GNSS providers. The first IRNSS satellite is planned for launch in 2012–13. Thereafter, it is planned to launch two satellites each year and complete the constellation by 2015–16.

8.115. *EO Systems and Atmospheric Science Programme*: The thrust areas of EO for the Twelfth Five Year Plan have been identified based on extensive interactions with users under the aegis of National Natural Resources Management System (NNRMS) as well as after detailed deliberations in the inter-centre committee of ISRO. In terms of spacecraft missions, there are eight EO missions planned for Twelfth Five Year Plan (including special projects) that cover observation in the area of natural resources, ocean and atmosphere, climate and environment, all weather and high resolution imaging. With the realisation of these missions, there would be significant improvements in the areas of short-term weather and ocean state forecasting, natural resources management, high-resolution cartography, large-scale mapping, space-based Essential Climate Variables (ECVs) with enhanced spatial,

spectral, radiometric and temporal resolution. In the area of applications, the focus will be to ensure continuity of services in the areas of Natural Resources Census (1:50000 and 1:250000 scale), groundwater potential mapping, snow and glacier studies, coastal zone management, PFZ, Ocean State forecasting, weather forecast, Space-based Information Support for Decentralized Planning (SIS-DP), Accelerated Irrigation Benefit Programme (AIBP), India-Water Resource Information System (India-WRIS), National Urban Information System (NUIS), including the initiative to help user Ministries in the institutionalisation process for remote sensing–based services (with MoEF, MoES, Ministry of Agriculture [MoA], Ministry of Water Resources [MoWR], already in the forefront).

8.116. *Disaster Management Support (DMS)*: The DMS Programme of ISRO is intended to provide near-real-time support and services from imaging and communication satellites towards efficient management of disasters in the country. The major programmatic targets of DMS programme in Twelfth Five Year Plan are:

1. Operationalisation of National Database for Emergency Management (NDEM)
2. Continue impact mapping and monitoring of natural disasters with improved turnaround time and with newer capabilities
3. Risk evaluation and reduction
4. Acquisition of close contour data through Airborne Laser Terrain Mapper (ALTM)
5. Extension of the communication network to the District Emergency Operation centres
6. Geolocation-based services such as Search and Rescue and distress alerts
7. Operational dissemination of the information and products directly to the affected areas
8. Operational utilisation of early warning systems
9. Extension of the Hydro-meteorological network
10. Key areas of R&D
11. Continued participation in international initiatives

8.117. *Space Transportation System*: The main focus of the Space Transportation Systems during the Twelfth Plan period will be towards achieving self-sufficiency in launching our satellites, developing launch vehicles for enhanced payload capability, adopting appropriate outsourcing strategies for assuring productionisation of launch vehicles, enhancement of infrastructure for launch vehicles and developing technologies for the future programmes of ISRO. The major thrust areas of Space Transportation System during the Twelfth Plan period would include:

1. Enhanced level of production of PSLV systems with vigorous industry participation to meet the projected launch requirements.
2. Complete the development flights and operationalise GSLV MKII with indigenous Cryogenic Upper Stage
3. Complete development and qualification of C25 Engine and Stage
4. Complete the development flights of GSLV MkIII with 4.0 T geostationary transfer orbit (GTO) capability
5. Progress in the development of Semi-cryogenic engine with the establishment of test facilities.
6. Enhancement of infrastructure to meet the launch vehicle requirements and advanced mission requirements.
7. Demonstrate critical technology related to reusable launch vehicle (RLV) and dual-mode ramjet (DMRJ) through technology demonstration
8. Develop the critical technology and subsystems related to Human Space flight programme
9. Develop and demonstrate the critical technologies that will make ISRO's launch vehicle more cost-effective and more capable.
10. Continue the technology development efforts to improve the present capabilities and to contribute for long-term Space Research.
11. The mission profile for meeting the satellite launch demand includes 17 PSLV missions, 6 GSLV MK-II missions and 2 GSLV MK-III missions (this also includes one experimental mission). This demands increased stage and system production rates, expanding human infrastructure and test facilities and substantial technological achievements in cryogenic stage elements.

8.118. *Space Sciences and Planetary Exploration*: Space Sciences and Planetary Exploratory missions contribute significantly towards understanding the mysteries of the universe, our existence, and provide an opportunity towards development of cutting-edge technologies. Through space science investigations, we seek to understand the processes governing solar radiation, evolution of planetary systems, formation of galaxies, evolution of stellar systems and the universe. Successful launch and realisation of Chandrayaan-1, India's first Mission to Moon in 2008, has been a landmark achievement in Indian Space Programme. The major contributions of Chandrayaan-1 were the discovery of water on the lunar surface and exosphere, clear evidence for the production of energetic neutral atoms and the development of detailed Digital Elevation Model of regions mapped by its stereographic camera. The work on Chandrayaan-2, Astrosat-1 and Aditya-1, initiated during the Eleventh Plan, is in progress and all these missions will be realised in the Twelfth Plan. Besides the spillover missions of Chandrayaan-2, Astrosat-1 and Aditya-1, the newer mission that is planned during the Twelfth Plan is Mars mission. In addition, POLIX (to study the X-ray polarisation from bright X-ray–emitting objects) shall also be persued.

8.119. *Mission to Mars (during November 2013 launch opportunity)*: Mars with its many similarities to earth is an important planet to understand the origin and evolution of the solar system. India certainly cannot afford to be behind in its independent exploration of the red planet. India's first Mission to Mars during 2013 would be important more from the technological perspective, namely, entire mission design, planning, management and operations, and communication from a distance of nearly 400 million km. This mission will demonstrate ISRO's capability to undertake deep-space planetary mission where the travel time from earth to Mars is nearly 300 days. The Indian Mission to Mars would also provide an opportunity to the scientific community, to further understand the Martian Science. The present plan is to launch a Mars-orbiter using PSLV-XL during the November 2013 launch opportunity. Mars-orbiter will be placed in an orbit of 500×80,000 km around Mars and will have a provision for carrying nearly 25 kg of scientific payloads on board.

8.120. An indicative plan outlay of ₹*39,750 crore* at current prices for the Twelfth Five Year has been made for the DOS.

## Department of Atomic Energy

8.121. The DAE has been pursuing R&D in nuclear science and engineering and also in advanced mathematics. The Department comprises several multidisciplinary R&D centres, aided institutions and closely linked industrial units that contribute towards basic R&D of technologies so as to harness nuclear science for the growth of the country. R&D by the R&D units of DAE provide valuable support to expand the indigenous Indian nuclear power programme and also to develop non-power applications of nuclear technology for use in industry, agriculture, health care and research. The DAE programmes also support collaborative research, establishment of centres of excellence as a part of efforts to establish linkages with academia.

8.122. *Programmatic Activities of DAE*: The mandate of the Department is to develop and deploy technologies for the production of nuclear power and to harness applications of radiation and isotope technologies for societal benefits. To fulfil this mandate, several technologies need to be developed and it is necessary to carry out basic research to provide a strong foundation to ongoing developments and to spur new developments. To meet all these objectives, human resource development is the most important requirement. Categorisation of the DAE's R&D activities into seven major programmes MP1 to MP7 followed during the previous two Plan periods will be maintained in the Twelfth Plan. Major programmes MP1–MP3 address R&D support to the three-stage Indian nuclear power programmes; MP4 addresses the development of advanced technologies such as accelerators, lasers and so on, and radiation technologies and their applications; MP5 incorporates the basic research in all the relevant branches of science; MP6 facilitates strengthening the research-education linkages and MP7 aims to development of the infrastructure for all the R&D activities.

### *Twelfth Plan Objectives/Thrust*

8.123. Right from its inception, the Indian nuclear power deployment is based on a three-stage programme. The first stage is well established and is already in the commercial domain. The second stage is also geared to take off in a big way with the Prototype Fast Breeder Reactor (PFBR) going operational soon. The third stage of nuclear programme is in the R&D phase. The main emphasis of the DAE in the Twelfth plan includes ageing management and safety upgrades of all nuclear plants in operation, and incorporating enhanced safety features in the upcoming plants. Another thrust area, metallic fuel deployment with its associated fuel cycle in the fast reactor, is the key to reducing doubling time, thus accelerating the pace of nuclear power deployment. In short, the thrust areas address pursuit of multiple reactor technologies, safety upgrades to address beyond-design-basis external events, increased emphasis on development of applications of nuclear technology for societal benefits, outreach programmes to enhance public awareness and acceptance, and strengthening of linkages with universities and national laboratories.

8.124. The significant achievements of DAE under R&D sector during the Eleventh Plan are given in Box 8.8.

### *Twelfth Five Year Plan Programmes*

8.125. The details of the projects and programmes planned to be pursued are given below. Programme under MP1–MP3 include experimental verification of safety-related issues, ageing and degradation studies, life-extension assessment and investigation of new safety concepts for incorporation in nuclear power plants to address extreme external events. Thrust would be given to the development of new techniques for further exploration of uranium with a view to augmenting installed nuclear power capacity.

**Box 8.8**
**Significant Achievements/Development of DAE during the Eleventh Plan Period**

- Bhabha Atomic Research Centre (BARC) and Indira Gandhi Centre for Atomic Research (IGCAR) have developed indigenous Time Domain Electromagnetic (TDEM) systems for airborne survey to locate deep-seated uranium deposits. Other achievements include: development of BARC Containment Model (BARCOM) of 540 MWe Pressurised Heavy Water Reactor (PHWR) at Tarapur, the largest nuclear containment model in the world for ultimate load capacity assessment; installation and commissioning of thermal denitration pilot plant; development of prototype magnetic crawler robot for in-service inspection of boiler tubes at thermal power plants; and establishment of country-wide Indian Environmental Radiation Monitoring Network (IERMON) Stations at 115 new locations to provide online information about the radiation levels.
- Construction of Prototype Fast Breeder Reactor of 500 MWe capacity at Kalpakkam is nearing completion. Other activities for the fast reactor programme include production of mixed oxide fuel pins for PFBR at Advanced Fuel Fabrication facility; alloy characterisation facility for fast reactor fuels, pyrochemical reprocessing and sodium fire facilities, fuel cell and argon glove box for sodium chemistry studies and ultra filtration units for separation of strontium, cesium, lanthanides and actinides from simulated wastes. Robotic device for in-service inspection and indigenous spider-robot for steam generator tube inspection have also been developed.
- Under R&D for future reactors that use thorium-based fuel, ($ThO_2$-1%$PuO_2$) and ($ThO_2$-1%$^{235}UO_2$) Mixed oxide (MOX) fuel pins have been fabricated to be used for experiments in the AHWR Critical Facility. The AHWR fuelling machine has been manufactured, assembled and tested. An AHWR calandria test facility has been commissioned. A scaled semi-transparent experimental set-up of the calandria has been designed, fabricated and installed in house. For U-233 clean-up project, copper vapour laser systems and the tuneable lasers have been fabricated indigenously.

- Starting from raw materials, technologies and processes leading to the fabrication of long lengths of niobium-titanium–based superconducting cable-in-conduit-conductor (CICC) have been realised. These cables are capable of carrying 30 kA current at 5 tesla. These indigenously manufactured cables have applications in accelerator program and also in Steady-state Superconducting Tokamak.
- The Indian synchrotron Indus-2 became operational and the beam life time in Indus-2 has reached 22 hours at 2 GeV and 100 mA. Six beam lines were made operational, and are being used by researchers from the Department as well as other universities in the country. On 6 December 2011, Indus-2 reached a major milestone of 100mA current at the design energy of 2.5 GeV. Raja Ramanna Centre for Advanced Technology (RRCAT) has developed a new technique of laser welding of niobium superconducting radio frequency (RF) cavities, which offers advantages of low-energy deposition and, therefore, less shrinkage and distortion, and is of a much lower capital cost.
- Research in nuclear agriculture has resulted in development of 10 new mutant crop varieties. One hundred and twenty Nisargruna biogas Plants have been installed in various parts of the country. Cancer research in Tata Memorial Hospital has resulted in cost-effective screening method (costing less than ₹100) in breast cancer.
- High-power Nd:YAG lasers along with fibre optic delivery systems and remote control operation developed by RRCAT were commissioned in different units of PHWRs for cutting and welding operations and for cutting of 612 bellow lip weld joints during the En-masse Coolant Channel Replacement (EMCCR). Besides the large savings in time, this technique also reduces the occupational radiation exposure to the workers by a factor of about 40 as compared to the conventional technique.
- The Board of Research in Nuclear Sciences (BRNS) and University Grants Commission–Department of Atomic Energy (UGC–DAE) Consortium for Scientific Research stand out as important initiatives of DAE in the direction of linking research with education. The Homi Bhabha National Institute (HBNI) is fully functional and plays an important role in conducting academic programmes under its own umbrella as well as in linking DAE with other academic institutes in the country and abroad.
- Large experimental facilities that were set up by DAE during the Eleventh Plan period to facilitate basic research include commissioning of High Altitude GAmma-Ray (HAGAR) array, which consists of seven telescopes, at the high-altitude (4,300 m) station Hanle (in Ladakh) for ground-based gamma ray astronomy, and a high-resolution spectrometer Indian Gamma Ray Array consisting of Germanium clover detectors at the Pelletron Linac Facility at the Tata Institute of Fundamental Research (TIFR). The first phase of parallel supercomputer (Anupam Adhya), delivering 47 terraflop of sustained linpack computational performance, has been developed and released to the users. New campus of TIFR at Hyderabad and two major new centres for basic research—International Centre for Theoretical Sciences at Bengaluru and the TIFR Centre for Interdisciplinary Sciences at Hyderabad are being established. Under ITER-India, design activities of in-kind contribution to ITER, namely, neutron-shielding plates, cryostat, RF and neutral beam systems, and so on, have been completed. Other areas of basic research leading to important findings include radiation biology towards understanding of mechanism of processes involved in response to radiation and other abiotic stresses, utilisation of microbes for bioremediation of radioactive waste, development of stress-resistant crop plants, diagnosis, treatment and research in cancer, establishing the lack of deleterious health and biological effects in people living in high-level natural background radiation areas (HLNRA).
- A total of 11,206 journal papers were published by 13 major DAE institutions during 2007–10. These publications received a total of 49,578 citations during the period. The average number of publications published per year was 2,801.50 and the number of citations per publication during the period was 4.42.
- The first batch of Integrated MSc students joined the National Institute of Science Education Research (NISER) in September 2007. NISER also initiated PhD programmes from 2009 onwards.

For Light Water Reactor (LWR) programme, R&D to develop, design and verify indigenous LWR concepts and development of equipment is planned. The civil construction of the PFBR is in an advanced stage and is expected to be completed by 2012–13. Two 500 MWe MOX-fuelled fast reactors are planned to be set up. For validating the design of the fuel subassembly and to gain large-scale experience in the fabrication and irradiation testing of metallic fuels, a 120 MWe metal-fuelled fast reactor will be designed at IGCAR in the Twelfth Plan, with construction proposed in the Thirteenth Plan.

8.126. *R&D related to Thorium-based Reactors*: The development and demonstration of thorium-fuelled Advanced Heavy Water Reactor (AHWR) is an important initiative for thorium utilisation and for the third stage of nuclear power programme. This reactor also already embodies several innovative passive safety features that have now assumed added significance internationally following the Fukushima-Daiichi events. A major programme to experimentally demonstrate the available margins to extreme internal and external events will be carried forward in the Twelfth Plan period to further add to validation of these advanced safety features, many of which are generic in nature.

8.127. *Compact High Temperature Reactor (CHTR) Technologies*: In addition to AHWR, planning for a CHTR is an important step towards the development of advanced reactor technologies required for hydrogen generation. For designing CHTR, consideration of material behaviour as well as technologies for utilisation of high temperature heat warrant investigations for assessing the performance of structural material in corrosive environment of liquid metal and molten salt coolants. Molten salt is a promising coolant for high-temperature application as it also offers the possibility of a thorium-based thermal breeder reactor design suitable in the Indian context with a high level of passive safety. The advanced reactor systems including fusion reactor systems require appropriate materials to be specially developed, characterised, and compatibility issues resolved. Furthermore, special instruments and sensors also need to be developed for measurement of process parameters in such harsh environment. All necessary studies will be taken up in the Twelfth Plan.

8.128. *Research Reactors*: Cirus reactor was permanently shut down in December 2010 and presently only Dhruva reactor, which is in operation for more than 25 years, is available for providing the research reactor–based facilities. Further, the requirement of medical isotopes is expected to increase. To meet the increasing requirement of various radioisotopes for use in the field of medicine, industry and agriculture, needs of special materials, and various facilities for basic and applied research, a 125 MW(th) Research Reactor and a 30 MW High Flux Research Reactor (HFRR) are proposed in the Twelfth plan at BARC Campus Vizag. These new reactors will also provide advanced facilities for basic research in frontier areas of science and for applied research related to development and testing of nuclear fuels and reactor materials. An associated isotope processing laboratory is also proposed.

8.129. *Development of Applications of Radiation Technology*: Radioisotopes and their formulations (radio chemicals, labelled compounds and radiopharmaceuticals) and radiation sources (isotope sources, gamma plants and electron accelerators) are required for nuclear applications in health care, industry, food security, agriculture, water resources management and research. A national hadron therapy facility for cancer treatment at Advanced Centre for Treatment, Research and Education in Cancer at Tata Memorial Centre (ACTREC-TMC) will be set up. Accelerators and lasers are very powerful tools for basic as well as applied research. Several new beam lines will be installed at INDUS 2 and the existing ones will be upgraded with modern equipment for supporting high-quality research.

8.130. *International Cooperation in Accelerator Physics and Astronomy*: DAE continues to increasingly participate in international collaborative ventures. Participation in activities at LHC, CERN, Geneva, has led India to get the status of an 'observer state'. Indian participation in the seven-member ITER project will continue during the Twelfth Plan. The test blanket module (TBM) development

for testing in ITER will be another major activity. India's participation in ITER has demonstrated our scientific and technological strength to be a partner in mega science projects. India has joined the multinational, multi-organisational project Facility for Anti-proton and Ion Research (FAIR) being set up in Germany.

8.131. *Participation in Mega Science Projects*: DAE is participating in several Mega Science Projects. The S&T expertise in the Department will be leveraged in order to contribute to these projects. The FAIR and India-based Neutrino Observatory (INO) are the other ongoing projects. Several new projects are proposed, such as LIGO, Thirty Metre Telescope and Square Kilometre Array. Apart from these, setting up of an Indian Synchrotron for Materials and Energy Research is also proposed. These projects will involve several DAE Institutions including BARC, IGCAR, RRCAT, Variable Energy Cyclotron Centre (VECC), TIFR, IPR as well as universities, and the research facilities built will be available for utilisation by the research community of the nation.

8.132. *DAE in Human Resource and Expertise Building*: The research centres and aided institutions lay strong emphasis on frontline research and human resource development for their personnel and also contribute towards human resource development requirement of the country. Units of the Department also maintain strong linkage with the academic and research community in the country. The initiative of the Department to set up HBNI as a deemed-to-be university is another step towards strengthening the linkage between the institutions of the DAE and also with the academic and research community in the country. It will also help DAE in utilising its vast research infrastructure and faculty towards human research development for the country. Similarly, TIFR has increased intake of research students after having been declared a deemed-to-be university. The present methods of collaboration through BRNS and MOUs with select academic institutes will continue to be supported and further strengthened. The Department of Atomic Energy–Science Research Council (DAE–SRC) award scheme, providing incentive to competent professionals within and outside DAE, will be continued. Increasing linkages with the national higher education institutions (universities, IITs and NITs and so on.) will be continued so as to ensure availability of quality manpower for DAE programmes and projects.

8.133. The Global Centre for Nuclear Energy Partnership (GCNEP), the sixth R&D centre of DAE, is being set up in Haryana near Delhi. The main objective of setting up GCNEP is to enable India in establishing the leadership in the field of nuclear energy through research and training and organise workshops, schools and seminars by Indian and international scientists/experts on topical issues. Under GCNEP, the following schools are being set up:

- School for Studies on Applications of Radioisotopes and Radiation Technologies
- School of Advanced Nuclear Energy System Studies
- School of Nuclear Security Studies
- School of Radiological Safety Studies
- School of Nuclear Material Characterisation Studies

8.134. *Strengthening R&D infrastructure*: In order to meet the growing number of programmes and projects, including in greenfield locations, it is necessary to strengthen and expand the investments in infrastructure. The ongoing projects towards strengthening and upgrading existing security systems need to be also continued. New campuses coming up, for example of BARC in Vizag and of TIFR in Hyderabad, would involve considerable efforts and resources. The TIFR Centre for Interdisciplinary Sciences (TCIS), Hyderabad, has started functioning at the transit premises from mid-June 2011. Laboratories for research in chemistry, biology, lasers and optics, magnetic resonance and condensed matter will be set up in this transit campus during the twelfth plan. Development of the new TIFR Hyderabad campus will be given priority. The newly formed International Centre for Theoretical Sciences (ICTS, TIFR) in Bengaluru is a multi- and interdisciplinary effort with a strong component of

human resource development. Emphasis will be on research areas such as biophysics, computational science, complex systems, fluids, the interface between cosmology, particle physics and string theory, new emergent areas of mathematics with applications to biology, and so on.

8.135. An indicative plan outlay of ₹*19,878 crore* at current prices for the Twelfth Five Year has been made for the DAE under R&D sector.

## PLAN OUTLAY

8.136. A total Plan outlay of ₹*1,20,430 Crore* has been approved for Six Scientific Departments/Agencies for the Twelfth Five Year Plan. Table 8.1 provides Department-wise allocation and expenditure for the Eleventh Five Year Plan and the break-up of Outlay for Twelfth Five Year Plan.

**TABLE 8.1**
**Plan Outlays and Expenditure of Central Scientific Ministries/Departments/Agencies During Eleventh Five Year Plan and Indicative Outlay for Twelfth Five Year Plan**

(₹ in Crore)

| Sl. No. | S&T Department/Agencies | Eleventh Plan (2007–12) | | Twelfth Plan (2012–17) |
|---|---|---|---|---|
| | | Outlay | Anti. Expdr | Outlay |
| 1 | DAE (R&D sector) | 11,000.00 | 8,068.26 | 19,878 |
| 2 | MoES | 7,004.00 | 3,202.30 | 9,506 |
| 3 | DST | 11,028.00 | 8,636.61 | 21,596 |
| 4 | DBT | 6,389.00 | 4,832.24 | 11,804 |
| 5 | DSIR including CSIR | 9,000.00 | 6,940.61 | 17,896 |
| 6 | DOS | 30,883.00 | 15,834.79 | 39,750 |
| | Grand Total | 75,304.00 | 47,514.81 | 1,20,430 |

# ANNEXURE 8.1
## National Targets for S&T Sector for the Twelfth Plan

**National Targets for S&T Sector for the Twelfth Plan**

| | | |
|---|---|---|
| Global Share of Publications | : | >5 per cent |
| Global Ranking in SCI publications | : | better than sixth |
| Global Ranking in Number Patent Cooperation Treaties (PCTs) | : | better than tenth |
| FTEs in R&D Personnel | : | 2,50,000 |
| PhDs Outputs in Whole Science Sector | : | 12,500 per year |
| Public–Private Sharing of Investments | | 50:50 |
| Gender Parity in EMR Funding (PI Ratios) | : | better than 60:40 |
| The Relative Global Rank in Patent Portfolio | : | better than ninth |
| Commercialisation of Patents | : | better than 5 per cent levels |
| Share of High Technology Content in Exports | : | better than 20 per cent |
| Global Ranking in Innovation Index | : | better than 25th |
| Establishment of Section 25 Companies | : | in select sectors |

## DEPARTMENT-BASED DELIVERABLES AND TARGETS FOR THE TWELFTH PLAN

### DST

- To strengthen Human Capacities, 30,000 new scholars for Scholarship for Higher Education targeted, Award of Overseas Doctoral scholarships—3,000 man years, Overseas postdoctoral fellowships—500 man years, Women mobility scheme for employed scientists—1,000 positions, Start-up research grant for Indian diaspora undertaking faculty assignments in Indian academia—1,000 man years, enlarging the Principal Investigator base—1,500 man years, INSPIRE Award scheme—2 million awards.
- Support under Fund for improvement of S&T Infrastructure (FIST)-1200-1500 departments and 500 colleges, PURSE—50 Universities, CURIE—6 Universities and 50 Women colleges, IRHPA—15 research areas, SAIF—25 new centres and 10 select centres. Autonomous Institutions focused on Institutional Capacities, Water Technology Solutions—20 implementable solutions to be demonstrated in at least 15 clusters, 20 centres to be created for Nano S&T Mission, 5 National Centres in Advanced Research.
- Centre–State Technology partnerships—At least five viable partnerships through programme support, PPP for R&D. One mega PPP for national challenge area, five PPPs for large-scale challenge, 25 PPPs for proof of concepts for technology solutions.
- Technology Development and Transfer, IDP, IS-STAC through the ongoing programmes, 200 technologies demonstrations, 150 proof of concepts, and 25 cooperative investments with other socio-economic Ministries have been targetted.
- Five product designs and prototypes under security technology R&D.
- Solar Energy Research Initiative—Support 250 doctoral-level researchers from 10 institutions.
- Under Natural Resources Data Management System (NRDMS) and National Spatial Data Infrastructure (NSDI), State Spatial Data Infrastructure has been targeted.
- Technology Platforms for four Identified Areas.
- Under Modernisation of SoI and NATMO, 1:10000 scale map has been targeted.

- Under Nano S&T Mission—25 start-up companies under PPP models would be created.
- PPP for R&D—One mega PPP for national challenge areas and five PPPs for large-scale challenge and also 25 PPPs for proof of concepts for technology solutions.
- Hundred projects for Science for Equity, Employment and Development and 50 Model Demonstration Projects.
- To commission 15 Study Reports, 10 Policy Research Studies, 3 Development of STI indicators for India, 5 Inter-country policy comparison studies, 12 External consultations and inter-country and 10 Technology and Innovation (STI) indicator reports have been planned.

### DBT

- Under Human Resource Development, it is proposed to establish 100 Star Undergraduate Colleges, 100 Ramalingaswami fellowships for returning scientists from abroad, 10 finishing schools for industry-ready graduates, award 200 Welcome trust-DBT biomedical fellowships, junior research fellows and 250 postdoctoral fellowships in life sciences.
- Under Promotion of Excellence and Innovation, the targets are to create 25 Centres of excellence in plant sciences, animal sciences, human biology systems and industrial research;10 new centres for translational science education and innovative research in Medical Schools, 20 IICs connecting basic sciences with translational R&D and 2 centres for policy research in agriculture and health care biotechnology.
- For Biotech Facilities and Research Resources the targets are to establish five research resources and service facilities, upgrade and redesign life science research and education in 38 universities.
- Launching of eight Grand Challenge programmes in health care and agriculture on a mission mode around national priorities in development sectors through bottom-up approach and discovery-led innovation, interdepartmental participation and separate government and management structure.
- Establishment and commissioning of three ongoing bio-clusters at Faridabad, Mohali and Bengaluru and two new bio-clusters with clusters boards to govern, and establish incubators, common technology platforms, contract labs for SMEs, genetically modified products (GMP) facilities, research hospital and so on.
- Establish five national research centres/institutions in the areas of Bioinformatics and Computational Biology; Marine and Microbial Biotechnology; Bio-design; Bioscience and Bioengineering; Chronic Disease Science and Biotechnology; and Infectious Science and Biotechnology Institute in the North-East.
- Strengthening of regulatory system for biotechnology through establishment of BRAI, under the act of Parliament and establishment/strengthening of 10 regulatory testing laboratories with good laboratory practice (GLP) standard.
- Expanding existing AIs threefold in terms of human resource, setting up of Extra Mural Research centres on or off site to promote translational science; starting of number of disease-specific network programmes; and physical infrastructure.
- Establishment and operationalisation of BIRAC and launching of two to three new PPP schemes such as ignition grants, start-up grants, shared technology incubators and bio-parks.
- For translational and strategic research in agriculture, health care and environment, about 50 projects/networks shall be launched in system biology, synthetic biology, computational sciences, nano-biology, pre-breeding of crops, photonics, molecular imaging and tissue engineering, biopharmaceuticals and drug development and other emerging areas.

### MoES

- Augmentation of Agrometeorological Advisory Services (AAS) from the existing district level to the block level. Plan to reach 30–40 per cent (10 million) farmers for providing the agro-met services from the current level of 10 per cent (2.5 million).
- Strengthen HPC facility from the existing 124 T flops to 2.5 P flops.

- Upgradation of facilities of about 100 airports in the country.
- Setting up of an International Training Centre for Operational Oceanography.
- Development of high resolution model of 13 km to provide a credible, integrated ocean information services.
- Development and demonstration of higher-scale offshore desalination of 10 MLD
- Acquisition of three state-of-the art ocean research vessels.
- Commissioning of third station at Antarctic to strengthen research activities in the Polar Regions.
- Drilling a deep bore hole in Koyna–Warna region for better understanding of stable continental region earthquakes and Reservoir Triggered Seismicity.

### DSIR

- Establishment of 40 CICs; support to 1,200 plus innovative proposals from MSME Clusters; acquisition of around 20 Globally Patented Technologies by Indian Industries and value addition.
- Establishment of R&D Facilities for Solar Photovoltaic (SPV) and Solar Thermal (ST) at CEL.

### CSIR

- Development of five game-changing technologies that impact lives of millions.
- Thirty exceptional publications of global impact.
- Development and transfer of 50 advanced products/technologies.
- Setting up 15 spin-off companies.
- Training of 3,000 PhDs in trans-disciplinary areas of science and engineering through AcSIR.
- Establishment of the following five new institutes: CSIR Institute of Synthetic and Systems Biology; CSIR Fourth Paradigm Institute; CSIR Institute of Bio-mimetic Materials; CSIR Network Institute for Solar Energy and CSIR Network Institute for Manufacturing Technology.
- Setting up of 10 CSIR Outreach Centres.
- 1,000 patent applications to be filed in India, 1,000 patent applications to be filed abroad and 75–150 non-patent IPRs to be secured and prosecuted.
- To award 15,000 fellowships under the JRF-NET, 1,000 Syamaprasad Mookherjee Fellowships to be awarded, 100 awards under Trans-Disciplinary Fellowship Scheme yearly, 100 awards under CSIR Nehru Science Post-Doctoral Fellowship Scheme yearly, 250 scholarships for dyslexic students.
- Establish 24 CSIR TECHVILS across the country. Showcase TECHVIL to enroll 1 million citizens in adjoining communities to the benefits of technology.
- Setting up CSIR offshore Joint Centres of Excellence in Malaysia, Sweden and USA. Setting up of 12 world-class Innovation Complexes in identified locations across India.
- Under NMITLI, the target is to launch five to seven new projects per year; launch some unique products such as Micro PCR (a platform technology for diagnostic applications), dental implants benefiting Indian masses, next generation clutch plates and so on.
- Expand OSDD to OS drug discovery, OS drug development, OS drug delivery and OS disease diagnostics for MTb.
- Extending OSDD programme to malaria.
- Launching of three Grand Challenge–driven projects with global participation. Develop at least five technologies in participatory mode and transfer the same to stakeholders. Set up at least five CSIR Centres for Collaborative Research with academia, R&D institutions and industry.

### DOS

- Realisation of total 25 launch vehicle flights—17 PSLVs + 6 GSLVs + 2 GSLV Mk III including one Experimental Mission (as against 14 flights of the Eleventh plan). First Developmental Flights of GSLV Mk III—the next generation launch vehicle.

- Establishment of Indian Regional Navigational Satellite System (IRNSS) with a constellation of seven satellites.
- Implementation of fully operational base of GAGAN.
- Augment the INSAT/GSAT capacity to ~500 Transponders in C, Ku, Ka, MSS and BSS bands.
- Realisation of GSAT-11—Advanced Communication Satellite.
- Realisation of Advanced Remote Sensing Technology for 0.25m resolution.
- Realisation of Geo Imaging Satellite (GISAT) for Disaster Management Support.
- Implementation of Space based Information Support for Decentralised Planning.
- Multi-wavelength Astronomy Observational Satellite—ASTROSAT.
- Undertaking challenging Mars Orbiter Mission.
- Realisation of Chandrayaan-2 with Rover and Lander. Operationalisation of NDEM with multi-thematic, multi-scale database and relevant Decision Support systems.

## DAE

- Apsara Reactor upgradation with indigenously developed fuel.
- Construction and commissioning of AHWR Thermal Hydraulics Test Facility (ATTF) and AHWR Fuelling Machine Test Facility (FMTF).
- Technology development and commissioning of a low energy (20 MeV) linear proton accelerator (LEHIPA) as a part of front end of ADS driver.
- Setting up additional 500 IERMONs (Radiation monitoring stations).
- Setting up an experimental Solar Test Facility (SOTEF).
- Technology development for Electron and Ion Accelerators.
- Augmentation of facilities for Fast Reactor Fuel Reprocessing.
- Establishment of 30 MeV Medical Cyclotron.
- Commissioning of the MACE at Hanle.
- 3m scale optical interferometer as prototype gravitational wave detector.
- Enhancement of INDUS synchrotron user facility.

## NOTE

1. SAC-PM (Scientific Advisory Council to the Prime Minister), *India as a Global leader in Science*, 2010.

# 9

# Innovation

9.1. India is the second fastest growing economy in the world, but as the pace of development increases rapidly, the country faces an increasing challenge to ensure that future growth is sustainable and inclusive. Innovation can play a key role in not only driving growth and competitive advantage, but also ensuring that this development includes a larger cross section of people and is socially, economically and environmentally sustainable. Realising that innovation is the engine for national and global growth, employment, competitiveness and sharing of opportunities in the 21st century, the Government of India has declared 2010—20 as the 'Decade of Innovation'.

9.2. India has unique challenges and large unmet needs across diverse areas such as health, education, skills, agriculture, urban and rural development, energy and so on. We also have significant challenges of exclusion and inequitable access due to multiple deprivations of class, caste and gender—all of which require innovative approaches and solutions, and looking beyond the conventional way of doing things. Innovation is going to be central to providing answers to the most pressing challenges and for creating opportunity structures for sharing the benefits of the emerging knowledge economy. Affordable solutions, innovative business models or processes which ease delivery of services to citizens can enable more people to join the development process.

9.3. In this context, there is a need for an Indian Model of Innovation that focuses on affordability and inclusive growth which can be a model for emulation for countries across the globe facing similar challenges of sustainable development. Indian entrepreneurs and policymakers are already moving towards this inclusive model of innovation, and three distinctions of this emerging Indian approach to innovation are worth noting. First, it focuses on finding affordable solutions for the needs of people—for health, water, transport, so on—without compromising quality. For instance, extremely low-cost eye surgeries which do not compromise on surgical standards at US$50 compared to US$1,650 in the US. Second, in this Indian approach to innovation, desired outcomes are produced by innovations in organisational and process models that deliver to people the benefits of technologies that may be developed in scientific laboratories. An example is the delivery models of mobile telephony services that have expanded the reach of telephony with the cheapest call services in the world. Third, there are innovations in the process of innovation itself to reduce the cost of developing the innovations. An example is the Open Source Drug Discovery (OSDD) process being applied by the Council of Scientific and Industrial Research (CSIR) to develop drugs for treatment of tuberculosis, based on a semantic-search, web-based platform for collaboration developed by Infosys, an innovative approach that has cut down the costs and reduced the time for drug development.

9.4. This new paradigm of innovation, focused on producing 'frugal' cost solutions with 'frugal' costs of innovation, in which India may be emerging as a global leader, contrasts sharply with the conventional approach, mostly focused on increasing inputs of Science and Technology (S&T) and R&D and

measurement of the numbers of papers and patents produced. Frugal innovation is focused on the efficiency of innovation and on outcomes that benefit people, especially the poor. Industrially advanced countries too are examining their innovation policies to incorporate this broader concept of innovation that moves beyond the R&D paradigm.

9.5. India is also uniquely poised to reap the advantages provided by a nation of a billion connected people, with over 800 million mobile phones, and global leadership in Information and Communication Technology (ICT) and software. This connectivity as well as ICT talent is changing the nature of processes, business, industry, governance, education and delivery systems: and our innovation thinking also has to leverage the unprecedented advantages provided by this changing landscape of connectivity and collaboration.

## Towards an Innovation Ecosystem: The Role of NInC

9.6. Conversion of R&D to results for people requires an ecosystem of enterprises working in conjunction: entrepreneurs, researchers, finance providers, business enterprises, and policymakers. Therefore, the national strategies for innovation need to focus on various types of institutions in the ecosystem and aim for more effective collaboration amongst them. This must be India's agenda too if India is to accelerate inclusive growth through innovation.

9.7. Government has a critical role to play in strengthening the innovation ecosystem. It must provide the enabling policy interventions, strengthen knowledge infrastructure, improve inter-institutional collaborations, provide a mechanism for funding business innovations at all levels especially small and medium scale enterprises (SMEs) and provide vision through a national-level road map for innovations. Recognising this need, the Prime Minister has set up a NInC with the mandate to formulate a Road Map for Innovations for 2010–20 with a focus on inclusive growth.

9.8. NInC is focused on encouraging and facilitating the creation of an *Indian Model of Innovation* by looking at five key parameters: Platform, Inclusion, Ecosystem, Drivers and Discourse. The aim is to redefine innovations to go beyond formal R&D parameters and look at innovation as a broader concept that breaks sectoral silos and moves beyond a high-tech, product-based approach to include organisational, process and service innovation where many players can plug into this platform. The core idea is to innovate to produce affordable and qualitative solutions that address the needs of people at the Bottom of the Pyramid, eliminate disparity and focus on an inclusive growth model. NInC's initiatives are also aimed at fostering an innovation ecosystem across domains and sectors to strengthen entrepreneurship and growth, and to facilitate the birth of new ideas. While conceptualising these initiatives, the key drivers are going to be parameters of sustainability, affordability, durability, quality, global competitiveness and local needs. Finally, through its various initiatives, NInC will aim to expand the space for disruptive thinking, dialogue and discourse on innovation.

9.9. Principal initiatives already undertaken by the Council to drive innovation and create an innovation ecosystem in the country are mentioned below.

## Supporting Financial System and Mentoring: India Inclusive Innovation Fund (IIIF)

9.10. Innovators need financial support at an early stage to develop and test their ideas in the marketplace. Venture funds are recognised globally as the most suitable form of providing risk capital for the growth of innovative technology and breakthrough ideas. While India is amongst the top recipients in Asia for venture funds and Private Equity Funds, these investments are so far focused on relatively large and 'safer' investments. Thus, despite the growth in the venture capital industry in India and some government schemes for supporting entrepreneurs, the seed funding stage in the innovation pipeline, where amounts required may be small but risks high, is severely constricted.

9.11. To plug this gap and to promote inclusive innovation and entrepreneurship focusing on the needs

of people in the lower echelons of society, NInC is creating an India Inclusive Innovation Fund (IIIF). The Fund seeks to promote enterprises engaged in developing solutions in key areas such as health, education, agriculture, handloom, handicrafts and other small business enterprises. The Fund will combine commercial and social returns. The Fund will be capitalised to an eventual target size of ₹5,000 crores to be achieved in phases. It will be kick-started with seed investment from the government and bilateral/multilateral institutions and go to scale with private capital. The Fund will be an autonomous, professionally managed entity with a social investment focus. Government of India has committed seed capital of ₹100 crore to kick-start the Fund and NInC will aim to operationalise this Fund by the year 2013 with an initial close of ₹500 crore.

## Increasing Skills, Productivity and Competitiveness of Micro, Small and Medium Enterprises (MSMEs) through Innovation

9.12. MSMEs are among the largest job creators in the country. They contribute to 40 per cent of export and are recognised as engines of economic growth. However, to keep up the pace of strong economic growth and to stay globally competitive, MSMEs need to innovate in all aspects of business. Recognising this need, NInC has envisioned the Industry Innovation Cluster initiative.

9.13. The focal point of this initiative would be the creation of a Cluster Innovation Centre (CIC). The CIC will actively seek relationships to address the needs of the cluster and establish frameworks for knowledge and best practice sharing. By connecting and creating local ecosystem encompassing actors and stakeholders who can bring in technology, financing, skills and mentors, the CIC will help enhance productivity, growth and employability. The Pilot Phase of the Innovation Cluster Initiative has been launched and nine clusters (seven industry and two university) have been chosen to be part of this phase. Pilot activities have commenced at the Ayurveda cluster in Thrissur, Kerala; Food Processing cluster in Krishnagiri, Tamil Nadu; Bamboo cluster at Agartala, Tripura; Auto Components cluster at Faridabad, Haryana; Brassware cluster at Moradabad; Furniture cluster at Ernakulam, Kerala; Life Sciences cluster at Ahmedabad, Gujarat; Delhi University, Delhi; and Maharaja Sayajirao University, Baroda, Gujarat. NInC has been collaborating with State Governments, Ministry of MSME and the Department of Scientific and Industrial Research in this effort.

## Nurturing Innovation through Education

9.14. Schools are the best places to inculcate a spirit of innovation. To promote creativity and nurture innovations in the education system, NInC has made the following proposals to the Ministry of Human Resource Development (MHRD), including:

1. Creation of a separate scholarship stream of National Innovation Scholarships analogous to the National Talent Search Scheme. This will help identify talented children at the school level who think creatively, laterally and innovatively on issues that they perceive as important in their local environment. It is expected to have a multiplier effect of valuing creativity and innovation by parents, teachers and the learning system.
2. Setting up an Innovation Centre in each DIET (District Institute of Education and Training) to enhance teacher training and enable them to become facilitators of creativity and innovative thinking.
3. Mapping of local history, ecology and cultural heritage by each high School in the country to create critical thinking on their local environment by students.
4. Creation of a National Innovation Promotion Service to replace/add to National Service Scheme in colleges to use college students to identify local innovations. This is a scheme of the Ministry of Youth Affairs and Sports which along with Ministry of Human Resource Development (HRD) has been requested to examine its feasibility.
5. Setting up a Meta University, as a redefinition of the university model in the 21st century by leveraging India's National Knowledge Network to enable multidisciplinary learning and collaborative knowledge creation.

6. Setting up 20 Design Innovation Centres co-located in Institutes of National Importance. Co-location in campuses of national repute like Indian Institutes of Technology (IITs)/National Institutes of Technology (NITs) will help leveraging of academic and industry resources and give a boost to design capacity in the country. Also, setting up an Open Design School; creating an institute for facilitating training of trainers in design and introducing design thinking at the school level.
7. Identifying and facilitating the development of 20 University Innovation Clusters across the country where innovation would be seeded through CICs, as mentioned earlier. The CIC will provide a platform for the university and its partners to forge linkages between various stakeholders from industry and academia, initiate and assist innovation activities, encourage innovations in curricula and act as a catalyst and facilitator. It will also work closely with other industry clusters in its region. As mentioned earlier, initial pilot with University of Delhi and Maharaja Sayajirao University in Baroda have commenced and have received overwhelming response from the student community.

9.15. The Ministry of Human Resource Development has green-lighted the proposals relating to the award of 1,000 Innovation Fellowships at the school level (Classes 9–12); introducing the Mapping of Local History, Local Ecology and Local Culture and Heritage by all high schools and setting up the first Meta University of the world for multi-disciplinary learning and collaborative learning. MHRD has also incorporated steps on re-positioning DIETS in the country in the new Guidelines for the Centrally Sponsored Scheme on Teacher's Training. MHRD is also working on a concept note on design education in consultation with the Council and Planning Commission.

## Connecting India for Innovation: Rural Broadband and Applications

9.16. Government approved the proposal to connect all panchayats through optic fibre and the rural broadband plan on 25 October 2011. NInC is currently working on applications for rural broadband in collaboration with Ministries of Rural Development, Panchayati Raj, HRD, Health and the Prime Minister's National Council on Skill Development so that even as hardware connectivity is under progress, applications also get addressed. The vision is to transform governance, service delivery in areas such as health, education and agriculture, and unleash local innovation capacity through rural broadband.

## Platform for Best Practices and Innovations

9.17. Currently, there are many enterprises across the country which are delivering benefits to citizens and meeting challenges of inclusion in areas such as health, education energy, low-cost housing and sanitation, through innovative solutions. It is often said that India is a country with many successful experiments that do not achieve scale. Scaling up the impact of such innovations requires that such ideas be spread around rapidly so that others could emulate them. And it also requires that larger business organisations and venture funds become aware of them and support them. We have instances of documentation of these practices in the form of the Honey Bee Network, but no virtual platform exists for the same. Therefore, the strengthening of the innovation ecosystem requires a platform for information sharing and dissemination. While some knowledge portals for innovations in specific areas already exist, the NInC has developed the India Innovation Portal to enable easy access to these as well as to become a wider information repository on innovation and a platform for collaboration as well. (www.innovation.gov.in)

## Developing Institutional Framework for Innovation

9.18. An extensive innovation ecosystem requires many lateral connections, often at local levels, between producers, sellers and financiers, and the facilitating government machinery. Sweden has a region-wise process of participation of citizens and enterprises in formulating the innovation agenda. In a much larger and more diverse country, as India is, development of the innovation ecosystem must be even more widely devolved.

9.19. To create a cross-cutting system to boost innovation performance in the country, NInC is facilitating the setting up of State Innovation Councils in each State. These Councils would enlist non-government expertise and are expected to drive the innovation agenda in the States. Using the broad templates suggested by NIC, they will develop interventions to suit their State's specific needs. In this way, the national innovation agenda will combine with other thrusts for improvement of governance and service delivery described elsewhere in the Plan to introduce more flexibility and innovation in centrally sponsored schemes and, thus, improve the efficiency and inclusiveness of the growth process. Currently, 22 States have constituted State Innovation Councils.

9.20. NInC is also encouraging the setting up of Sectoral Innovation Councils aligned to Union Government Ministries to promote innovation ecosystems across sectors and domains. Currently, 24 Ministries have set up Sectoral Innovation Councils.

## Challenge Funds for Innovation

9.21. To induce a culture of innovation in the country, there is a need to offer encouragement through awards and challenges which mobilise people to engage and respond creatively and bring focus on neglected societal challenges. Internationally, examples range from the X Prize to the DARPA Grand Challenges and the World Bank's Development Marketplace. The NInC is also seeking to set challenges for the Indian imagination to incentivise the citizens to come up with solutions, especially those that relate to inclusive innovation. NInC has already announced awards for its challenge to improve work tools, innovate on products and processes that reduce drudgery of the working-class population.

## Partnering for Innovation: Collaboration and Networks

9.22. In an increasingly global world, partnerships and knowledge sharing are critical and can lead to mutual growth and development. NInC is also focused on facilitating and leveraging platforms for international collaboration for driving innovation and multidisciplinary research. To exchange ideas on fostering international collaborations for innovation, NInC hosted a Global Roundtable on Innovation on 14th–15th November 2011 in New Delhi where heads of innovation policy from 15 governments across the world came together to share cross-country experiences and best practices. This was followed by a Second Global Roundtable on Innovation in 2012 where several collaborative initiatives were outlined.

## Bringing Innovation into Science Museums

9.23. Science Museums and Centres in the country can be an important resource for nurturing creativity and encouraging a spirit of innovation in the country, but their potential remains underutilised. The NInC is partnering with the National Council of Science Museums (NCSM), National Museum of Natural History (NMNH) and others to enhance the impact of existing Science Centres in the country and use them as channels for innovation outreach. NInC will aim to invigorate the existing Science Centres in the country through more interactive exhibits, while leveraging locally available resources to showcase science in a hands-on manner. It will also use the Science Centres for showcasing innovations on a regular basis and improving outreach.

9.24. NIC is currently working on seven pilots of Innovation Spaces at Science Centres/Museums in Ahmedabad, Bangalore, Delhi, Kolkata, Mumbai, Sawai Madhopur and one in the North-East.

9.25. Apart from these initiatives, NInC is also working on several other ideas such as announcing 10 Grand Challenge Awards to leverage public imagination for innovative solutions in critical areas. It is also looking at promotion of projects that create an innovation dividend like the setting up a Knowledge City in Kerala. NInC is also working on the 'Courts of Tomorrow' initiative to give effect to the extensive computerisation plan as laid down by the e-courts Mission Mode Project. This initiative will put the best ICT tools in the hands of judges and the registrars, to aid them in the speedy dispensation of justice. Further, NInC is also working towards creating draft policies on innovation and entrepreneurship

to institutionalise innovation thinking into policy-making for providing the requisite stimulus from the Central Government.

9.26. The efforts of NInC are just a starting point for creating an innovation ecosystem in the country. Apart from the earlier mentioned efforts on stimulating finance for innovation, driving innovation at industry clusters or institutionalising innovation by liaising with States and Central Ministries, focus also has to be on stimulating new models of enterprise where producers are also the owners so that they can not only earn incomes but also share in the wealth created by the enterprise. Organisations like Self Employed Women's Association (SEWA), and companies formed by the Chanderi weavers in Madhya Pradesh, are such examples. Such enterprises require innovations in organisational and legal forms. The Planning Commission is examining changes that would facilitate the multiplication of more such enterprises. Through such innovations, businesses that are of the people (owned by them), and businesses by the people (in which people are a principal resource in production and distribution) can cost-effectively produce products and services for people at the bottom of the pyramid.

9.27. Creating a robust innovation ecosystem will also require focus on Intellectual Property Rights (IPR) issues. Management of IPR has become extremely important in the new knowledge economy with global competition. Adequate rights on the intellectual property produced by an innovator enable innovators to recoup their investments and make profits: thus IPR spurs innovation. Good national IPR systems also enable knowledge of technological advances to be accessible through the patent system to others who can build on them. To obtain both these benefits, India must improve its management of IPR. The administrative machinery for IPR management must be considerably strengthened and professionalised and Department of Industrial Policy and Promotion (DIPP) has taken up this task.

9.28. Holders of IPR have incentives to strengthen and extend their monopolies. However, monopolies can restrain competition and further innovation, and thus tend to increase costs for customers. This is the fear even in the West, with respect to pharmaceuticals, for example. The concept of monopolising knowledge, albeit for a limited period, that underlies prevalent models of IPR can have perverse effects when it is extended to areas of traditional knowledge, preventing poorer people from continuing to use their own knowledge without payments to those who have 'patented' it under IPR. Also new models of collaborative innovation are emerging, such as OSDD, mentioned before. Concepts of IPR will have to be developed to suit such new models of innovation in which, incidentally, India has great stakes because of their potential to produce 'frugal' innovations for inclusive growth. Therefore, as India aims to become amongst the global leaders in innovation, it will also have to be amongst the leaders in efficient management of IPR and innovations in IPR concepts and policies.

## Technology Innovations in the Government

9.29. Apart from the effort of the NInC to strengthen innovation and provide a policy direction for fostering innovation within the system, there are also several innovative efforts underway within the government structures that aim to improve processes and service delivery, enhance collaboration and generate greater transparency and accountability.

9.30. The *Aadhaar* or Unique Identity Programme is the first 'online' identity system anywhere in the world wherein resident's identity can be authenticated 'in real-time', even on a mobile network, anywhere in India. This programme will create a foundation for more transparent and efficient public service delivery and is internationally considered as a game-changing approach to inclusion. By providing a clear proof of identity, *Aadhaar* will empower India's poorer citizens in accessing services such as the formal banking system and give them the opportunity to easily avail various other services provided by the government and the private sector. It seeks to cover 60 crore residents in India by 2014 and eventually cover the entire country. Twenty crore residents have been enrolled into the system as on March 2012.

9.31. Going forward, the *Aadhaar*-enabled bank account and payment infrastructure will enable e-payments to the beneficiaries' bank accounts for government's social welfare schemes such as Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and mitigate delays and losses. For trying out the *Aadhaar*-enabled payments for various government schemes, a list of 50 districts in the country for initiation of the programme has been proposed to the Ministry of Finance. The government is also looking at using the *Aadhaar* platform for PDS and achieving substantial economies in subsidy outgo in areas such as Fertiliser, Liquefied Petroleum Gas (LPG) and Kerosene by enabling direct transfer of subsidies. Pilot projects on the above are currently ongoing. Collectively, this will have a transformational impact on the delivery of public services in the country.

9.32. Government is also leveraging ICT to reduce pendency in the legal system, encourage a move towards e-governance, e-procurement, e-tendering and e-office. It is also undertaking an ambitious initiative to connect 2,50,000 panchayats with fiber-based broadband to improve governance and service delivery at the last mile. A national geographic information system (NGIS) organisation is also being thought of to map information, assets and data accurately, which will assist in policy and works planning and improve delivery of services in urban and rural areas.

9.33. The National Knowledge Network (NKN) of the Government of India which is a high-speed multi-gigagibit network is not only connecting educational and research institutes in the country, but is getting connected to global research networks to enable real-time collaboration and research. The NKN is allowing students and researchers to move towards a new paradigm of education and research based on a virtual platform that breaks silos of geography and boundaries.

9.34. Other innovations are in the management of performance of government Ministries. The government has initiated a performance management system which requires every ministry and department to undertake a stakeholder consultation to assess the gaps between its stakeholders' expectations and its actual delivery. Ministries must develop innovative strategies to bridge these gaps, and must accordingly specify the measures of its performance by which it should be judged. After initial trial runs and adjustments in its design, this system, generally called the Results Framework Document (RFD), is now adopted by almost all Ministries at the Centre. Some State Governments such as Kerala and Himachal Pradesh have also begun to adopt this approach.

9.35. There are also other complementary actions by multiple agencies of the government to facilitate innovation in the public systems. For instance, on the initiative of the Office of the Prime Minister, the Cabinet Secretariat issued orders to have the agenda of innovation embedded in all proposals to the Cabinet where action on innovation is reported specifically in each proposal to the Cabinet. The 13th Finance Commission which predated NInC provided for ₹1 crore (₹10 million) for each of the over 600 districts as a District Innovation Fund in the country to promote innovation. Further, on the suggestion of the 13th Finance Commission, a new institution to create a 'climate and nurture a culture of accelerating and diffusing innovation in public systems' has been set up in the Administrative Staff College of India (ASCI) in Hyderabad called the Centre for Innovations in Public Services. Also, as mentioned above, an initiative of the CSIR, the portal for OSDD, has been created as a platform for global partnership to provide affordable health care to poorer people afflicted by diseases.

9.36. Apart from the above, the Department of Science & Technology has launched an INSPIRE programme to identify and reward young talent in science, and it covers students from high schools, Bachelor of Science and Master of Science levels. Finally, to encourage local responses to local problems and encourage local problem solving, flexi-funds have become an integral part of major flagship programmes like Sarva Shiksha Abhiyan (Elementary Education) and the National Rural Health Mission (Basic Health). The National Rural Employment Guarantee Act (NREGA), the largest flagship programme, promotes local innovation by

providing for comprehensive planning with funds directly given to panchayats.

9.37. *To summarise*, innovation can play a very important role in the development discourse, because it can offer a new approach to a system that is currently over-burdened by the multiple demands and has limited resources at its disposal. Enhanced focus on innovation can have an impact much beyond the realm of S&T in diverse areas such as health and education delivery, governance, enterprise development and much more. Collectively, this can herald a generational change in the country and can lay out a chart for a more sustainable and inclusive growth paradigm.