SCIENCE AND TECHNOLOGY

Introduction

17.1 India has had a long and distinguished tradition in science and technology. In the half-century prior to Independence, India produced many scientists who achieved world renown; generally, they were teacher—researchers in educational institutions. At the time of Independence, the industrial and technological base of the country was very small. Since then a scientific and technological infrastructure, covering a very broad spectrum of disciplines has been created. Scientific and technological accomplishments of significant magnitude have been seen in areas of high-technology like atomic energy, space and electronics, while closer to the lives of the masses, the success in attaining self-sufficiency in foodgrain production, based on genetic engineering, has been equally spectacular. Indian scientists and technologists have been able to fulfil national expectations when clear-cut objectives and tasks are indicated and necessary support provided. The true contribution of science is to endow a nation with competence and confidence, in terms of both these criteria, the self-reliance developed in many areas, and in terms of economic returns, India has reaped ample rewards from the investments made in science and technology.

17.2 For sustaining the thrust towards emergence of an industrialising economy with rising levels of scientific and technological maturity and self-reliance, a major effort in science and technology is clearly called for. The per capita income and quality of life that a nation enjoys is, in the final analysis, dependent largely on the technology it adopts, and which in turn has to be appropriate to its endowments, resources and skills. Any over dependence on imports from abroad could in the case of a country of India's size and complexity, involve a heavy price too large to pay:hence self-reliance—which really implies scientific and technological self-reliance.

17.3 During the Sixth Plan there has been significant expansion and consolidation of the scientific infrastructure, resulting in a sound base for major application of science and technology for national development in the Seventh Plan. The resulting capabilities have been taken note of in preparing the plan for the Science and Technology sector.

REVIEW OF THE SIXTH PLAN

Institutional Arrangements

17.4 In the Sixth Plan, to give the necessary thrust to areas such as environment, ocean development and non-conventional sources of energy, new Departments were established—the Department of Environment in November 1980, the Commission for Additional Sources of Energy in March, 1981 and subsequently the Department of Ocean Development in July 1981 and the Department of Non-Conventional Energy Sources, in September, 1982.

17.5 A Cabinet Committee on Science and Technology (CCST) was constituted on 3rd March, 1981 under the chairmanship of the Prime Minister to provide policy guidance in all matters relating to S and T. A Science Advisory Committee to the Cabinet (SACC) was set up in March, 1981; Member (Science) in the Planning Commission is Chairman of SACC, to ensure appropriate linkages with the Planning Commission. As recommended by the SACC, a National Biotechnology Board (NBTB), was established in 1982 as an inter-ministerial coordinating agency, to accelerate the pace of development in the frontier and emerging areas of biotechnology. This area has great relevance for agriculture, medicine and industry.

17.6 To deal with the problems of unemployment and manpower planning among science and technology personnel, a National Science and Technology Entre, reneurship Development Board (NSTEDB), was set up in 1982 to prepare a basket of employment opportunities, including self-employment, to arrange for training of S and T personnel in entrepreneurial matters and to channel institutional finance for promoting self-employment among scientific and technological personnel. For popularising science and to develop a scientific temper in the country, a National Council for Science and Technology Communication (NCSTC) was set up in May, 1982. These new organisational structures were created to initiate, promote, develop and strengthen S and T activities in the country.

17.7 There has been growing awareness of the need to promote a proper environment for scientific work, so that scientists and technologists can make the most effective use of existing facilities, and so that they can perform the tasks assigned to them without experiencing any frustration. Government has approved several measures in this

connection to provide more incentives and facilities to scientists and technologists.

17.8 The Technology Policy Statement (TPS), was announced in January, 1983. This is a major policy statement of Government covering a whole range of issues relating to technology: indigenous development, assessment, forecasting, import and subsequent absorption, adaptationandfurtherdevelopment, fiscal aspects, etc. To evolve mechanisms for implementing the TPS, a Technology Policy Implementation Committee (TPIC) has been constituted by Government.

17.9 A special scheme to provide funds to some institutions of higher education on a selective basis is now being implemented by the University Grants Commission. The aim is to enable the institutions to strengthen and modernise their infrastructure for undertaking work in frontline areas in S and T.

Progress and Perspective for the Future

17.10 There have been major accomplishments in many areas of S and T during the Sixth Plan; these have had significant impact on the socio-economic progress of the country and promoting self-reliance. Some of these are briefly outlined below:

17.11 Agriculture: With the existing strong base of agricultural research and education, agricultural scientists moved into the new areas of repatterning of genetic architecture to increase productivity of crops: the development of hybrid maize, dwarf rice, hybrid sorghum, hybrid pearl millet, dwarf wheat, etc., are some of the important milestones. A subsistence agriculture was thus transformed into a commercial agricultural system through massive application of science and technology. The effort now called for is an enlargement of the agricultural base to bring about increased production in low-productivity areas of the country, and to improve yields in specific crops of great importance such as rice, pulses and oilseeds.

17.12 Basic research in agriculture has related to: work on photosynthesis and photo-respiration; the development of new rhizobium strains for nitrogen fixation; use of tissue culture techniques in important crops; induction of haploids through anther and pollen culture; and genetic engineering related to animal sciences, especially viral genetics including gene splicing for vaccine production. A significant research accomplishment has been the cloning and expression of histone gene in rice. There will be a continuing major thrust in basic work, particularly related to the new biotechnologies. There is at present a major gap in the transfer of available knowledge to the field, along with provision of all the inputs necessary to make effective use of the recommended package of practices; closing this gap alone will make possible large increases in agricultural output, particularly in rice, pulses, oilseeds and many cash crops. A major area of weakness at present relates to agro-meteorology, and relating a package of seeds, inputs and practices that will ensure that the best yields are obtained under given weather situations. Efficiency in the use of water and fertilisers is another area of major research concern.

17.13 Nuclear energy: In the field of nuclear energy, capabilities have now been established covering the entire nuclear cycle: exploration, mining, extraction, purification and conversion of nuclear materials; production of fuel elements for reactors; the design and construction of power reactors and their control systems, for units of 235-MWe capacity; production of heavy water; health and safety instrumentation; reprocessing of spent fuel; and waste management. In this area of high technology, it is the creation and substantial growth of the research base which has led to this degree of self-reliance. A major achievement in the Sixth Plan period was the commissioning of the Madras Atomic Power Plant, which was wholly designed, fabricated and set up indigenously, using locally produced fuel, heavy water, instrumentation and control systems, as also all items of heavy engineering. A 100-MW heavy water reactor, DHRUVA, which is a major facility for engineering research in support of the nuclear power programme and for production of isotopes, has been built at the Bhabha Atomic Research Centre (BARC). There has been a significant fall-out from the associated technological developments related to the nuclear programme. These are in the fields of: high vacuum, very low temperature, electronics and control systems, precision engineering, heavy engineering (with production of items such as calandria, fuelling machines, end-shields etc.), welding of all types, use of radio isotopes in agriculture and health, and so on. In the area of nuclear and related sciences, fundamental research of a high order has been carried out.

17.14 Space science and technology: Another area of high technology where there has been continuing and significant progress is that relating to the space programme. This activity was taken up because of the clear realisation that space-based systems have an inherent edge over conventional, purely ground-based systems for a country of India's sub-continental dimensions. In particular, an optimal mix of ground and space capabilities has been sought to be built up.

17.15 India's first indigenously designed and fabricated experimental communication spacecraft, APPLE, was launched in June, 1981 on the European Ariane launcher, and it successfully completed its mission in October, 1983. Bhaskara-ll, a remote sensing satellite launched in November, 1981 by a USSR launcher successfully completed its 2-year earth observation mission. As against five flights projected for Satellite Launch Vehicle (SLV)-3/Rohini Satellite

system during the Sixth Plan period, the programme was reviewed and closed after the successful completion of only two additional flights, viz., SLV-3-D-1 and SLV-3-D-2, since all the technological objectives were realised by then. The SLV-3-D-2 launched in April, 1983 from Sriharikota put a 42-kg. indigenous ROHINI satellite, carrying a smart-sensor payload, into the desired near-earth orbit.

17.16 Three major projects, the Indian Remote Sensing Satellite (IRS), Augmented Satellite Launch Vehicle (ASLV) and Polar Satellite Launch Vehicle (PSLV) were approved in June, 1982. ASLV is a follow-up of the SLV development programme, whose main objective is to upgrade SLV performance to be able to carry heavier payloads, e.g., launch satellite of approximately 150 kilogram mass in near-earth orbit. Some of the major components of the PSLV mission would get proven with this vehicle; these include strap-on technology, on-board computer and the execution of yaw manoeuvres after launch. ASLV is scheduled for a first launch in 1986. The PSLV is designed to place satellites in the 1000 kilo-gramme class in a sun-synchronous polar orbit.

17.17 The Indian National Satellite (INSAT)-IB is a multipurpose satellite with activities covering telecommunications, radio and TV broadcasting, and meteorology (using a very high resolution radiometer). The basic concepts of this unique and complex satellite system were worked out by the Indian Space Research Organisation (ISRO); the satellite was built in the USA and launched by the United States on a space shuttle mission on 30th August, 1983. Another significant event related to space activities was the successful trip on the SOYUZ-SALYUT Mission of an Indian Cosmonaut, Wing Commander Rakesh Sharma, who performed several experiments in space.

17.18 Now that the space programme is increasingly an operational one, there are arising new developments which relate to the fullest utilisation of these operational capabilities. The overall management and coordination of the INSAT system rests with the INSAT Coordination Committee. Of the Departments represented in this Committee, the Department of Space has the responsibility for establishment and operation of the space segment, the Department of Tele-communications for the telecommunications ground segment, the Indian Meteorological Departments for the meteorological ground segment and applications, and AIR and Doordarshan for radio and TV utilisation. One is, therefore, seeing not only a technical innovation in the practical applications, of space hardware specific to India for cost-effective enhancement of national services, but also a major organisational innovation which cuts across the traditional boundaries of government departments and agencies. In a similar sense when the 800 kilogramme Indian Remote Sensing Satellite becomes operational in 1986 after a launch from the USSR, it will be a major element in a space-based remote-sensing system for national natural resources survey and management in agriculture, forestry, geology, hydrology and meteorology. To prepare for this, a National Natural Resources Management System (NNRMS) is under evolution.

17.19 In addition to the above, various new and innovative approaches are being worked out concerning software relating to the field of telecommunications and to the radio and TV broadcasting segment, on an interdepartmental and multidisciplinary basis.

17.20 Ocean development: There is increasing recognition of the importance of the oceans: from the viewpoint of national security; for ensuring ecological equilibrium; and as an important source of food and many mineral, chemical and biological resources. A coordinated national programme initiated under the Department of Science and Technology (DST) on oceanographic research and development became the nucleus for the setting up of the Department of Ocean Development (DOD) during the Sixth Plan. An important development in this area was the signing of the United Nations Convention on the Law of the Seas, which provided a framework for a new international order for the oceans. The Ocean Policy Statement of 1983 outlines the policies of Government with regard to developing, harnessing and preserving ocean resources and stresses the importance of scientific programme for developing capabilities in this area.

17.21 Four scientific expeditions to Antarctica were organised in 1981, 1982, 1983 and 1984, and a permanent research station has been established there at Dakshin Gangotri. Scientists from the National Institute of Oceanography (NIO) brought up polymetallic nodules on a cruise in early 1981. DOD has further pursued this area and has completed the first phase of a project for identification of a mining site, through extensive regional surveys covering an area of 3.8 million square kilometres and over ten thousand locations. The oceanographic research vessel (ORV), "Sagar Kanya" and the fisheries and oceanographic research vessel (FORV) "Sagar Sam-pada" are both operational.

17.22 Science and Technology: The programmes of the DST for supporting research of a multidisciplinary nature, and those in emerging frontline areas of science, made significant progress during the Sixth Plan. The funding provided has made a major impact on University research. A special programme of Intensification of Research in High Priority Areas (IRHPA) has played an important role in initiating and supporting major national activities in the areas of immunology, visceral mechanisms, plasma physics, setting up of a major facility for high frequency FTNMR, Indian Middle Atmosphere Programme (IMAP), etc. A National Institute of Immunology was set up under this scheme. Three Regional Sophisticated Instrumentation Centres (RSICs) were set up at Nagpur, Chandigarh and Shillong for providing expensive and sophisticated research equipment/instruments to the scientific community as

centralised facilities. Three major science and society related schemes, viz., S and T for women, technology development for Scheduled Castes and Scheduled Tribes and promotion of scientific interest in youth have been effectively pursued so that the benefit of S and T percolate more effectively to various target sections of the community. At the initiative of the DST, S and T councils have been set up in 18 States and 4 Union Territories. In addition, 13 States have set up separate Departments for Science and Technology. A sustained effort has been made to accelerate the pace of a large number of science and technology programmes which are relevant from the viewpoint of basic research, generation of knowledge and expertise, and which have societal application. The Department has been providing secretarial support to the Science Advisory Committee to the Cabinet (SACC) for processing its recommendations.

17.23 In areas such as earth and atmospheric sciences, calibration facilities, instruments development, composites and fibres, information systems, a good beginning has been made. These efforts, through consolidation and growth in the Seventh Plan, will lead to fruitful results.

17.24 Research and development activities in the field of biotechnology are of enormous significance and relevance to the future development of agriculture, medicine. and industry. To ensure the growth of this area on a high priority basis in the country, under the auspices of NBTB, a long term plan of action in the areas of agriculture, energy, environment and health has been prepared. Mechanisms have been evolved to ensure the supply of radio-labelled chemicals, and for indigenous produc-tion(and, where needed, bulk import) of restricted enzymes, etc. Publications on the status of biotechnology in India, and re-combinant DNA research, safety regulations for India, etc., have been brought out. Work has been initiated on programmes relating to manpower development and creation of infrastructural facilities (animal houses, culture lines, etc.).

17.25 Scientific and industrial research: In the area of scientific and industrial research, carried out under the Council of Scientific and Industrial Research (CSIR), a wide spectrum of problems have been tackled. These include: R and D work related to exploration of oil in the off-shore areas; and detailed studies on the alignment of pipelines, location of terminal points of pipelines onshore, discharge of effluents from the terminal pumping stations and from possible spills along the pipelines. Based on processes developed at National Chemical Laboratory (NCL), Pune, Indian Petro-Chemicals Corporation Ltd., (IPCL) have put up a 10,000 tonne/annum plant at Vadodra for production of acrylates. A solvent extraction process for the production of benzene has been released to Bharat Petroleum Corporation for processing 1,70,000 tonnes of feed per annum; the process is also under consideration of the Cochin Refinery and the Salimpur Aromatics Complex. A totally indigenous 900-TPD plant for low-temperature carbonisation of coal, based on technology developed at Regional Research Laboratory, (RRL), Hyderabad, has gone into production in Andhra Pradesh. The Central Electronics Engineering Research Institute (CEERI), Pilani, has developed 500-KW and 1-MW fixed-frequency S-band Magnetrons and the design and development of 6-GHz, 20-W travelling wave tubes has also been completed. The RRL, Jorhat, has developed a flow improver, SWAT-106, for the transportation of Bombay High crude. The average power saving by using titanium substrate insoluble anodes in place of graphite anodes in the chloro-alkali industry is about 700 KWH per tonne of caustic soda; it is estimated that over 200 million KWH of power could be saved annually as a result of the use of anodes of the design developed by the Central Electro-Chemical Research Institute. The National Aeronautical Laboratory (NAL) has generated critical aerodynamic data for the Light Combat Aircraft programme. Under a major CSIR-Steel Authority of India collaboration programme, important R and D work is being carried out on coal beneficiation, development of steel for cryogenic application, combustions systems using oil-water emulsion etc.

17.26 Three new laboratories were set up during the Sixth Plan: an Institute for Microbial Technology (IMT) at Chandigarh, a Regional Research Laboratory at Bhopal, and CSIR Complex at Palampur in Himachal Pradesh. In many disciplines, facilities have been created for advanced R and D work.

17.27 The two public sector undertakings, namely, the National Research Development Corporation (NRDC) and Central Electronics Limited (CEL), recently transferred from the DST to the Department of Scientific and Industrial Research (DSIR), have made significant progress in carrying the benefits of S and T to the country's rural population and are emerging as a potential source of appropriate technology to other developing countries. CEL has perfected indigenous know-how for the production of professional ferrites, automatic slide projectors and audio-visual systems.

17.28 Medical research: A major thrust relating to medical research was made in the Sixth Plan through the very significant enhancement in support for the Indian Council of Medical Research (ICMR), which is the apex body for the formulation, coordination, and promotion of biomedical research. A net-work of Regional Medical Research Centres has been set up to undertake R and D programmes on regional health problems. A network of 26 human reproduction research centres was established in different parts of the country, in close association with the medical colleges, to carry out clinical studies on new and emerging contraceptive technologies.

17.29 Short course therapeutic regimens have been developed through controlled clinical trials, and are being introduced under field conditions in several districts in India for the control of tuberculosis.

17.30 Integrated methods for control of malaria and vectorborne diseases, including biological control methods, environmental improvement and community participation have shown promising results; these are particularly applicable to areas where the vector has developed resistance to chemical insecticides. A major outcome of these studies was the isolation and development of a bacterial larvicide, which appears to be highly effective against several species of mosquitoes.

17.31 Prompt and early treatment of acute diarrhoeal diseases with oral fluid therapy, irrespective of etiolgy, has been shown to reduce mortality in all ages to a low level. Pulse immunisation with oral polio vaccine has proved to be highly effective, and is believed to constitute an appropriate strategy for the successful control of polio in India. Isaptent indigenously produced through work at the Central Drug Research Institute (CDRI), Lucknow, has been shown to be effective in producing cervical dilatation similar to that obtained with the much more expensive imported lamnaria tent. Immunological approaches to contraception are now being pursued intensively as a multi-institutional technology mission. In the area of nutrition, fortification of common salt with iron as a measure to prevent anaemia in the community has been successful.

17.32 Other achievements include the demonstration of the successful use of multi-purpose workers and primary health care workers in the recognition and management of common psychiatric problems in the community, launching of the National Cancer Registry, and the setting up of a demonstration module for testing the feasibility of utilising the primary health care approach for the prevention, detection and management of rheumatic fever and rheumatic heart disease.

17.33 Health is included as one of the important points in the new 20-Point Programme. The solution to a large number of the health problems in the country lies in development of appropriate manpower on a sufficient scale to provide adequate coverage; integration of the indigenous and modern systems of medicine; close coordination with sectors such as food and nutrition, water supply, sanitation and hygiene; implementation of the expanded programme of immunisation; and in particular, closing the gap between available knowledge and its application. In addition, there is need for research in the bio-medical area at the frontiers of modern science as also to couple the medical research system much more effectively with the health care delivery systems in the country.

17.34 S and T in socio-economic sectors/The S and T aspects relating to the major socio-economic sectors are given in the respective chapters; some illustrative highlights from sectors where significant S and T work has been carried out are summarised in the following paragraphs.

17.35 A major development in the field of energy relates to the increasing and significant degree of self-reliance in the manufacture of equipment for generation, transmission and distribution. The work initiated in the area of High Voltage Direct Current (HVDC) transmission has great promise for the power sector.

17.36 Electronics and associated areas of informatics and telematics is one of the key areas of development in the world today. It permeates every sector of human activity. The S and T base in electronics is principally spread over a large number of national laboratories and ministries/departments. A number of systems engineering units have successfully executed or are executing major electronics systems for users in the defence, oil and power sectors. The operationalisation of the Semiconductor Complex Ltd., (SCL) at Chandigarh, and other major developments in the area of professional electronics equipment and system have established major capabilities covering both research and development and production.

17.37 A well-planned programme of upgradation of technology has been carried out in the areas of machine tools, automotive and electrical equipment, earth-moving and construction equipment, oil exploration equipment and chemical equipment industry. In all these areas, new products have been introduced and manufacturing technology upgraded. The large industrial establishments, such as SAIL, BHEL, HMT, IPCL, etc. have set up sizeable in-horse R and D establishments. Three industry-associated organisations, viz., Central Machine Tools In-stute (CMTI), Automotive Research Association of India (ARAI) and Electrical Research and Developmental Association (ERDA) have done very useful development work. It has been possible to develop new processes or products like fluidised bed boilers for utilising very low grade coals, valves for oil field applications, new ranges of machine tools, photovoltaic systems for off-shore platforms, etc.

17.38 The Magneto Hydro-Dynamics (MHD) programme at the Tiruchirapalli unit of BHEL, development of larger capacity fluidised bed combustion unit, equipment for co-generation plants, cryobiological containers, super-insulated containers for transportation of liquid gases etc., have also made significant progress.

17.39 In the oil and natural gas sector, remarkable technological and manufacturing achievements have been made across the entire spectrum of: exploration and extraction; prognostic surveys; studies and investigations in deep drill investigations, both off-shore and onshore; oil production techniques and pipeline facilities; design and manufacture of offshore rigs and platforms; underwater technologies; offshore communications, etc. Refinery capacity has expanded steadily and substantial progress has been made in energy conservation as regards energy consumption

in existing refineries. New facilities for lubricant evaluation have greatly helped in successful formulation of new lubricants.

Some General Issues

17.40 In the preceding paragraphs a brief account has been given of some of the major accomplishments in S and T only to highlight the fact that there has been significant progress in a large number of areas. While there are weaknesses and gaps, and the capabilities that exist are somewhat uneven, a sound overall base has now come into existence. There is a climate of confidence which needs to be made use of fully.

17.41 An account like this would be incomplete if some of the weaknesses and imbalances that exist are not highlighted. Some of these are briefly indicated below.

17.42 It has to be recognised that S and T has been one of the most dynamic aspects of the modern world. As a result of the symbiotic relationship between various sectors of science and of technology, advances in any one sector have triggered major developments in many others. Thus advances in micro-electronics have transformed the fields of computers, communications, and digital electronics, and these in turn have transformed informatics, industrial electronics, consumer electronics, space sciences, etc. This is also true of the future of biotechnologies over the next few decades in agriculture, biomedical areas and industry. Thus, while significant advances have taken place on the science and technology front in India over the past few decades, the gap has significantly widened between what obtains in the country and that in other advanced countries, in terms of capabilities, due to the much faster rate of progress in those countries. There is, therefore, no room for complacency on the basis of our past accomplishments. It is for this reason that for the Seventh Plan, emphasis is being laid on the new developing areas, such as micro-electronics and informatics, biotechnologies, materials technologies, the new frontiers in chemistry, oceanography and so on. In these areas the major advances taking place are likely to create completely new approaches and techniques, and introduce new concepts and opportunities which are not only highly relevant to national development, but very important from the viewpoint of national security as well as international competitiveness.

17.43 Within the country there are enormous differences between infrastructural facilities and capabilities that are available in specialised scientific agencies anc national laboratories, in the industrial undertakings, and ir the educational system. The latter, in particular, has beer allowed to run down to an unbelievable extent. This situation needs to be remedied rapidly.

17.44 The coupling between the science and technology infrastructure and capabilities and the production system in the country is weak. This has led to an insufficieni use of the science generated and a lack, of appreciation by decision makers in government and industry of the capabilities in the universities, national laboratories, and scientific agencies. There is often a feeling that the fruits of science and technology are not reaching the bulk of the population, and not contributing in sufficient measure to economic and social growth. For science and technology to be effectively applied, there is need to complete the total innovation chain consisting of basic research, applied research, design and development, prototype fabrication, upscaling, extension, awareness building, production engineering, design and consultancy, and production and services. It may not be possible to accomplish this immediately in all sectors; what is necessary is to start on a significant basis in a few major socio-economic sectors of importance during the Seventh Plan.

17.45 The total resource of S and T personnel in the country, compared to the population and the magnitude of the tasks before us, is small in contrast to what obtains elsewhere in the world. The quality of these personnel varies very widely: furthermore, large numbers of these are not actually engaged in activities that can be construed as scientific or technical. A clear manpower development, planning and placement policy is called for to match the numbers and actual training of personnel with the needs of the country.

17.46 There has been an increasing allocation for S and T activities over the past three decades. From Rs. 20 crores in the First Plan, the total allocation (Plan and Non-Plan) for the S and T Sector rose to Rs. 3460 crores in the Sixth Plan. This increase is significant. However, as in the case of other sectors, some part of what has been allocated to S and T as Plan resources has had to be used to cover the gap in resources for non-Plan activities arising out of inflation and inadequate increase on the non-Plan side. It is important to ask onself: what is the cost of not doing research? This will be immediately reflected in a lack of self-reliance, increased vulnerability and dependence on the outside world, inability to take advantage of recent advances in S and T to increase productivity and efficiency and failure in accomplishing end objectives in better and newer ways and loss of international competitiveness, leading to further dependence on aid etc.

17.47 One of the major reasons why it has not been possible to successfully exploit the scientific research carried out, has been the lack of emphasis on engineering in product development. This will call for a new strategy, like creation of task forces, linkages with operating companies aPan early stage, more effective deployment of consultants, etc., so that scientific advance is transformed into technological advances and innovation.

17.48 There is concern at senior levels of the scientific community that the very best talent in the country, who would be leaders of the scientific effort if they came into the sector, are being lost either to opportunities available abroad or to other areas of endeavours in the country. This is resulting in gaps in the ranks of leadership and excellence. If there emerges in course of time, relatively mediocre leadership in science, it will become difficult to retrieve the situation, since mediocrity tends to breed mediocrity. There has to be a determined effort to attract some of the best and well-trained among our students to science and technology and to induce them to take to research, as a career. For this, not only it is necessary to provide them new and major challenges that will stretch them to the full, but also the facilities for such work and amenities and incentives relating to pay scales and emoluments, promotions and career advancement, mobility and particularly housing.

Approach to the Seventh Plan

17.49 In the Approach to the Seventh Five Year Plan, it is stated: "The guiding principles of the Seventh Five Year Plan should continue to be growth, equity and social justice, self-reliance, improved efficiency and productivity." In addition, it has also been stated that, in the Seventh Plan, there will be an emphasis on policies and programmes which will accelerate growth in food production, increase employment opportunities, and raise productivity. It is against this broad conceptual framework that the strategies for the S and T sector have been formulated.

17.50 The large infrastructure and capability in the field of science and technology have yet to be coupled meaningfully to activities that relate to the accomplishment of defined national socio-economic goals. For this, science and technology should be an integral part of all sectors of national activity, and particularly the major sectors, such as chemicals, coal, various areas of engineering, fertilizers, industry, irrigation, etc. The efforts in these sectors have, thus far, concentrated on immediate short-term implementation aspects and corresponding investments, production, etc. The realisation is largely missing that if S and T aspects are adequately covered, we can make up for deficiencies in natural resources, reduce demand on capital and increase efficiency, productivity and quality. Thus an important element in the approach would be to make science and technology an essential and integral part of all major socio-economic sectors, to develop capabilities essential for fulfilment of S and T tasks in the these areas, and to undertake Science and Technology missions that are well-defined.

17.51 As a first step, it would be necessary to consolidate and modernise the infrastructure in all the areas of relevance for the future, in terms of both physical facilities and human resources. It would be necessary to establish linkages between the different sectors of education, scientific research, technology development, productive activities in agriculture, industry etc. and government decision-making structures. The S and T component of the State Plans will have to be worked out in detail by the States. The area of rural development is one which has not received adequate S and T back-up so far; the plans for the application of S and T for rural development should mesh closely with the State Plans. There will be need for a major effort to develop a scientific temper and for popularisation of science. Special efforts will have to be made to involve voluntary agencies in these programmes.

17.52 There are major new areas in S and T emerging on the world scene, such as micro-electronics, informatics and telematics, robotics, biotechnologies, material sciences, oceanography, instrumentation, several areas in chemistry, modern biology and earth sciences and space technologies. These should be reorganised as thrust areas and should receive significant support.

17.53 Priority will be given to programmes in the field of education, particularly those relating to science and technology. It is essential to evolve mechanisms to attract some of the best brains of the country to science. There is need to grow centres of excellence in the educational systems, and in the national research system including the socio-economic sectors. Excellence and generation of leadership are vital for the sustained viable growth of science.

17.54 The Technology Policy Statement (TPS) has been a major enunciation of Government policy during the Sixth Plan period. It is important that measures are taken to ensure implementation of this policy. This will involve: technology assessment and forecasting; support for development of indigenous technology, and demonstration to prove its viability, through upscaling, use of design and consultancy. engineering and establishing linkages between different sectors; ensuring meaningful absorption, adaptation and improvement of important technology; ensuring that technology inducted will be in harmony with environmental considerations and needs of employment, etc. There has to be commitment of industries to R and D, and an appropriate percentage of sales turnover should be earmarked for R and D expenditure. Special emphasis is called for concerning S and T efforts to enhance productivity in the various major socio-economic sectors.

Aspects of policy formulation and implementation

17.55 The success of the efforts outlined in the above approach will depend on the institutional framework for policu formulation, decision making, funding and implementation including project management, monitoring and review. Structures have already been created in the Sixth Plan at the highest level, viz., a Cabinet Committee on Science and Technology under the chairmanship of the Prime Minister and a Science Advisory Committee to the Cabinet

(SACC) under the chairmanship of Member (Science), Planning Commission. There will be need to implement the recommendations made by SACC expedi-tiously. This institutional framework will continue to play an important role, and will need further strengthening. Similarly, the S and T Division of the Planning Commission will need to be appropriately structured and strengthened because. The Planning Commission and Department of Science and Technology will have to work closely on many issues involving long-range perspectives, inter-ministerial coordination etc.

17.56 As recommended in the Technology Policy Statement, strong central groups will have to be constituted in each of the major Ministeries to work on a continuing basis on the S and T component in that sector. These will bne responsible for collection, collation and disseminatio of information for planning, analysis and coordination. They will also be involved in technology forecasting and assessment and systems analysis. The recommendations of the Technology Policy Implementation Committee will need to be implemented expeditious-ly. Linkages between industry and research are best built when goals have been properly defined and specified and tasks formulated. These will have to be laid out in carefully drafted Memoranda of Understanding. Linkages between S and T activities, financial institutions and development banks will need to be strengthened. The appointment of scientists and technologists to the boards of directora of financial institutions can assist the institutions to play their role effectively; and this can be further supported by these institutions nominating scientists and technologists to the boards of directors of enterprises to which they have extended substantial financial assistance.

17.57 Appropriate management structures will be created for various large national facilities to ensure their effective and optimal utilisation.

Monitoring Aspects

17.58 The present internal monitoring mechanisms in each of the scientific agencies will have to be adequately strengthened, where necessary through the involvement of experts. External monitoring of overall progress (fiscal, time-scheduling, major holdups, problems in coordination, etc.) for all major S and T projects/missions will have to be done at the national level through the constitution of appropriate task forces, steering committee, etc., by the Planning Commission. Experts from various discipline; and organisations will be associated with these.

Implementation Aspects

17.59 Implementation of the various recommendation;in the plan document will have to be given highest priority Innovative approaches to ensure implementation ar< called for. The present administrative and managemen system clearly need substantial change; in particular, th(practices normally adopted in Government are used fo the S and T sector also, where these are wholly inappropri ate; the S and T sector calls for a more flexible approact which can cater to innovation and rapid change. Withou urgent and deliberate actions, the investment in S and 1 cannot yield returns commensurate with its true potential

Science and Technology Missions and Linkages

17.60 The basic effort in the Seventh Plan will be tc ensure that science and technology has a significan positive impact on the functioning of the country, through improvement and enlargement of its agriculture, industry and various infrastructure sectors. For this, S and T has tc relate closely to the objectives in these sectors, to the investments and economics involved and to the available materials and skills. This calls for goal-directed S and 1 efforts. A mission-oriented apporach to technologica development can foster relevance and provide motivation automatically establish organic linkages, which are live and working, between sectors which otherwise tend tc remain compartmentalised, and would also indroduce the sense of urgency required to meet time-targets.

17.61 In the Seventh Plan, it is planned to take up some missions which will have a large S and T component, which relate to major socio-economic sectors and which will have high visibility when accomplished. In the Report of the Steering Group on S and T and Environment there is an illustrative list of missions. This has been furthet shortened (Annexure 17.1) and is under consideration for implementation. For each mission there will be a lead agency and other associated agencies/institutions. All o1 these will have clearly defined responsibilities, resources and commitments as agreed to at the start. Empowered task forces and working groups will be set up on an interagency basis to work out detailed implementation strategies for missions. A programme office would be set up for this purpose in the Department of Science and Technology. Appropriate management structures will have to be designed according to the mission to be performed, and an Inter-Ministerial Mission Approval Board will be constituted.

Linkages

17.62 Most natural linkages arise between two or more organisations when they are jointly engaged in accomplishing a task. However, there will be other measures needed for this purpose, such as representation of senior persons from R and D establishments on the boards of industrial enterprises and vice versa. Agreements would have to be

concluded between universities, research laboratories and industry for exchange of personnel. The need for mobility of S and T personnel is essential. Consultancy organisations should be encouraged because they can act as agents for collecting and using the experience, techniques and people available in different organisations.

Thrust areas in science and technology

17.63 India is a large country faced with a broad and complex range of problems. With the present constraints of fiscal and human resources, it would not be possible to deal with all the problems or all areas of S and T at the same time. Therefore, there has to be a degree of selectivity and allocation of priorities. There is need to not only define areas of strength for consolidation and development, but also areas of weakness that require corrective action, together with identification of gaps, particularly in newly emerging areas of great promise. These will constitute carefully selected thrust areas for concentration during the Seventh Plan period. There would be need to specify the level of capability that would be attained.

17.64 In some areas, the thrust could be to utilise efficiently the existing knowledge and capabilities, in the country to deal with short-term objectives. In others, it could involve the generation of know-how and technology which would be relevant for the Eighth Plan and beyond. These would be thrust areas where, without undue handicaps, it would be possible to work at international levels in the country. In the case of thrust areas that have end application potential, it will be necessary to define the total process and indicate where scientific endeavour ends and operationalisation begins. In these cases, manifested most clearly in sectors like health field-level tasks that are essential and necessary for any meaningful application will also have to be given high priority and encouraged. A large number of replicable demonstration projects, on an integrated basis, at the micro level, will have to be taken up. Only thus will the gap between available knowledge, and its application be closed. Thrust areas need not be only in the high technology areas.

17.65 The information and communications sectors, and instrumentation, are all essential infrastructural elements for the total S and T plan; these will need to be included in the thrust areas.

17.66 There is widespread concern regarding the quality and extent of the technology base in the country. Engineering education and research need significant support. It would be necessary to establish a mechanism which will enable funds from research stations regionally distributed, or created for sectors of industry in cooperation with industry. The mechanical and electronic engineering areas require immediate attention. There is need to establish a mechanism which will enable funds from Government as well as from industry, including the public and private sectors, to be received and used for engineering research.

17.67 It is necessary to provide at least a minimum critical support in chosen specific areas so that viable groups and capabilities could emerge. An indicative list of thrust areas is given in the Report of the Steering Group. It is hoped that once all the thrust areas are identified and notified, it will lead to increasing numbers of those starting on research making their careers in these, as also as redevelopment of the existing infrastructure and capabilities towards these. A major effort in the identified areas is called for in the Seventh Plan itself.

Development of S and T in the States

17.68 Upto now, allocations in the State sector for science and technology have been very small; these need to be significantly stepped up. A large part of the development activities in sectors affecting the major part of Indian society and particulary the poor, is carried out by the State Governments. It is, therefore, essential to ensure that the S and T component in the State sector is fully developed to support these activities. There is need to make an analysis of the S and T component of the State Plans; this will be the responsibility of the State S and T Councils and departments and the Planning departments. It will then be ensured that the ncessary S and T work is carried out making fullest use of the existing infrastructure. The main functions of the State S and T Councils will be to provide linkages between operational departments of the Government, research and educational institutions, and productive sectors in agriculture/industry, etc; prepare an inventory of voluntary agencies, and educational and R and D institutions; ensure application of S and T to solve real problems encountered in plan implementation; promote location-specific research;demonstrate through model experiments, utilisation of local capabilities and local resources on an integrated basis; and ensure utilisation of the existing capabilities in the States set up by various Central Government Organisations.

Science and Technology and Rural Development and for reducing regional imbalances

17.69 The real impact of S and T on rural development is yet to be made. There is considerable scope for mobilising the large S and T potential, expertise and facilities in the country for accelerating the pace of rural development and widening its horizons. The needs in the countryside will have to be carefully analysed from the viewpoint of the contribution that S and T can make. To assess the real needs, inputs from those who have lived and worked in rural areas and who understand the interplay of economic,social and cultural factors in that environment would be

essential. Positive policy directives will have to be given at the highest level, as it is necessary to bring about a change in the value system and ethos of the scientific community, so that work relating to rural development will be considered as important as basic scientific or industrial research.

17.70 Some of the measures recommended for more meaningful application of S and T to rural development include:

i. all S and T laboratories, agencies, universities, IITs and other academic and research institutions analysing the contribution that they can make to rural development and allocating an appropriate part of their resources and efforts towards realising it;
ii. the development of the right value system in these institutions, to ensure that those scientists involved in research on rural problems are given appropriate credit and recognition;
iii. scientists participating fully in the field of application and technology development in rural areas;
iv. support being given to rural development groups on a long term and selective basis;
v. a specific Plan allocation being for this activity in the allocations of all concerned sectors, and
vi. a concerted effort being made to effectively involve artisans not only for transfer of technology but for the expression of their creativity.

17.71 A national network covering all those in the field of S and T for rural development should be developed. Highly innovative efforts in this context in different parts of the country are already underway. These need to be sustained and replicated with necessary modifications. The importance of deploying S and T personnel who could spend extended periods in rural areas and could establish rapport with the people and their problems needs to be stressed.

17.72 Regarding the application of S and T for reducing regional imbalances, the State S and T Councils and the Regional Research Laboratories of CSIR will have to play an important role, particularly in the use of S and T to promote locale-specific developmental activities and research problems. The scientific agencies will also have to initiate major projects on regional development for which they should set aside specific allocations. It will be necessary to have district level organisations in the form of district councils which could arrange for the involvement of large numbers of S and T personnel from the agricultural, medical science and engineering systems in the region. Specific regional development missions could be identified; S and T inputs will have to be provided, in a)l the sectors, and agriculture with its related areas made into a base for developing a science culture in the rural areas.

17.73 Voluntary agencies have an important role in the application of S and T for the social and economic development of rural people. A list of voluntary agencies needs to be prepared and updated. S and T activities will have to be based on these vast reservoirs of social activists, with extensive field experience. Processing by Government funding agencies of the proposals by voluntary agencies and those relating to rural development need to be streamlined and expedited. Home science colleges and other such institutions could be more effectively involved, for acting as catalysts in some of the forward looking areas in rural development.

S and T and Specific Groups

17.74 One of the principle Plan objectives is to ensure equity and social justice. Poverty amelioration and employment programmes are some of the specific mechanisms relating to these objectives. It is clear that S and T must be brought to bear on these programmes. There is need for a range of S and T activities specifically oriented towards weaker sections of society.

S and T for Weaker Sections

17.75 The programmes will be directed towards reduction of drudgery, increase in efficiency and productivity, reduction of hazards, etc. Specific efforts are called for the survey and identify areas of need and required technologies, and to carry out programmes for field applications, and prototype development through demonstration and field trials. Support will need to be provided for a large number of training programmes in technologies which are of day-to-day use among the weaker sections.

S and T for Women

17.76 Programmes to improve the quality of life for women through application of S and T, including enhancement of employment opportunities as also those aimed at ensuring greater contribution by women to science and technology, would require more emphasis. Trained women S and T personnel could be utilised in a major way in a large number of areas like family planning, health and nutrition, post-harvest technologies and major national programmes such as ICDS, MNP, IRDP, etc. The efforts of the scheme of S and T for women will have to be continued by involvement of voluntary agencies, Home Science colleges and women workers at all levels.

Involvement of Young Scientists in S and T Task

17.77 It is important that the best use is made of young scientists, including those just out of universities in terms of their basic training and areas of interests. The formation of interdisciplinary teams or groups of young scientists in universities and research institutions should be encouraged and they should be induced to undertake creative S and T research of relevance. Young scientists should be given opportunities to work on research projects of interest to them, and present them for inclusion in R and D programmes in their respective institutions. To encourage young artisans and those endowed with creativity in rural areas or remote parts of the country encouragement needs to be provided so as to support them for developing particular skills with the help of S and T. Young scientists employed in academic or research institutions should be allowed to do field work in rural areas for periods ranging to about two years.

Role of Retired Scientists in S and T Activities

17.78 The need to disseminate scientific information who continue to be active and are deeply motivated and who would wish to participate in the national development activities. To make effective use of this large potential specific schemes will have to be worked out. Retired scientists need not only be encouraged to work in the institutions from where they have retired but also in rural areas and other institutions.

Popularisation of Science, Dissemination of Scientific and Technological Information and Growth of Scientific Temper.

17.79 The need to disseminate scientific information among various segments of society, to popularise science and to create a scientific temper has been well recognised. In fact, in a world geared to science and technology, some degree of understanding of science and technology is necessary for all citizens. The promotion of this aspect, therefore, has to be an important goal of science popularisation activity. Scientific temper is more an attribute of the human mind and of the social decision-making process than mere knowledge about things which are scientific. It is more related to the method of science than to the content of science. The creation of a scientific temper relating to scientific developments and knowledge and their implications are basic to the large-scale growth and utilisation of science by society.

17.80 In the Sixth Plan, as an institutional mechanism, a National Council for Science and Technology Communication (NCSTC), was set up. The role of this Council would be to encourage and facilitate all activities aimed at dissemination of science and creation of a scientific temper; more particularly, to orchestrate the various on-going activities in this area so as to render them more effective and mutually supportive. The National Council of Science Museums (NCSM) has made significant progress in setting up District Science Centres. This activity should be expanded. An important role of these centres should be to provide support to the large number of voluntary science movements and science clubs which have emerged, and would continue to emerge all over the country.

17.81 Professional academies of science should engage in popularisation of science discussion of social issues with science content, and in monitoring and eliminating the occasional incursions of pseudoscience.

17.82 Universities and colleges, with their large population of students, can also play a similar important role. All scientific agencies, departments and laboratories should have an unwritten mandate to popularise science through various means. The full potential of science has to be utilised for eradication of irrational attitudes which tend to hold back the nation from the path of progress.

17.83 Many locations in rural areas are provided with Krishi Vigyan Kendras, District Industries Centres, various Health Centres, Paryavaran Kendras, etc. These should all become places for dispensing not only know-how and information, but also know-why and understanding. "T ere are a number of scientifically-oriented voluntary agencies working in rural India. These need to be promoted and assisted.

17.84 A number of popular science journals have come up during the last few years. This activity should be encouraged and support provided for their growth. There is a lack of good science communicators. Training programmes will be organised during the Seventh Plan to rectify this lacuna. There is need to establish a National Science and Technology Information Bureau through which information will be readily accessible.

17.85 The role of the media, including the press, radio, television and films is of crucial importance. A programme that does not enlarge understanding is not an educational science programme. We need to, and can do, with our media what nobody else has done, aimed as it is to a large multilingual audience, and with a present illiteracy figure of 64 per cent. There is, thus, a need for speical programmes to develop the art and science of using electronics media in our context. This may be done by building around some of the nuclei which have already developed; an Academy of Audio-visual Science Communication can be thought of to catalyse such movement. It may be useful to institute a number of prestigious awards for science popularisation through press, field activity, radio and television.

Science and Technology and Education

17.86 From the viewpoint of science and technology, it must be recognised that it is the educational system which produces the manpower necessary for the growth and application of science and technology. The health of the science and technology sector is intimately connected with the health and well-being of the educational system. In the present age, science and technology has to be an essential part of the educational system. The scientific method based on a questioning approach, the absence of a rigid hierarchy, the ability to make accurate observations and to do experiments is more important than mere knowledge. Education must ensure that it equips the individual to emerge into a world that is today largely fashioned by science and technology and is in a process of continual change.

17.87 Education would, thus, need significant restructuring during the Seventh Plan period; it must contribute to the development of quality, of excellence and of leadership. It is essential to work out ways and means whereby highly capable individuals are identified and provided with opportunities for true development of their innate gifts.

17.88 The higher educational institutions with their research facilities are a unique base for the training of competent scientists and technologists. There is deep concern about the extent to which the university science system has been allowed to run down through lack of support in the past. Allocations under the scheme recommended by SACC for the selective strengthening of infrastructural facilities in the university system need to be enhanced. There has to be a major effort to improve the quality of science teaching at school levels. There is need to make increased use of audio-visual aids and science teaching kits. In addition to the prevalent National Science Talent Search Scheme, other special schemes need to be initiated for identification of gifted students.

17.89 In the undergraduate colleges, at least 25 per cent seats should be available for admission on the basis of the results of a talent search examination. Colleges with highly advanced facilities for training of especially meritorious students need to be set up in all the States. Multi-purpose employment—oriented training courses should be introduced at the graduate level. This would lead to self-reliance on the one hand and augmentation of employment opportunities on the other. College Science Improvement Programme (COSIP) should be further strengthened and diversified. Training and retraining of those who are teaching science must be started. There is need for continuing research on low-cost, appropriate instruments needed in the schools, colleges and in the universities on a large scale.

17.90 Environmental education should be introduced at school level and integrated life science and biotechnology at graduate levels. Engineering education and research are key elements for technology generation and industrial productivity. Mechanical engineering, fabrication technologies, modern electronics and information technologies are critical for new industrial development.

17.91 For advanced level research and education, centres in specialised, newly emerging areas of S and T need to be set up. In the Sixth Plan, the need to have complementary funding by industry and concerned departments was emphasised. This has to be ensured in the Seventh Plan. The programmes for Centres of Excellence and schemes on Regional Sophisticated Instrumentation Centres (RSIC) and University Science Instrumentation Centres (USIC), need further augmentation. The scheme of National Professor and Professors of Eminence should be augmented and strengthened. There is need to weld the new field of informatics to the educational system. There is a large amoumt of obsolete equipment which needs to be discarded. For import of sophisticated equipment, chemicals and enzymes, the present procedures are complicated and time-consuming and need to be changed. The present recruitment procedures also require change. There is a significant amount of inbreeding at present. Industry must be made to spend an appropriate amount on research in universities. While setting up new S and T institutions for research and development in the Seventh Plan, there is need to ensure that these have appropriate formal linkages with the educational system.

17.92 In enterprises operating in areas of high technology, there is increasing need for continuing education, particularly in the form of refresher and retraining programmes. Industry in India, specially the public sector, would have to devote considerable attention to this aspect of continuing technical education for its scientific and technical personnel. The existing industrial training institutes, which are the major source of skilled artisans, require considerable upgradation.

17.93 Universities and colleges should be encouraged to take up applied research of value to the regions in which they function. Basic research is importnt not only for its own sake but also because of the solid foundation it provides for applied research and development. Adequate funds must be provided for basic research, particularly in the education system.

17.94 Agricultural education carried out through 23 agricultural universities and ICAR institutions needs to be strengthened, especially in terms of institutional framework. Short courses in agricultural management and educational technology should be included in training programmes at the summer institutes. Special emphasis must

be laid on human resources development.

17.95 In medical research and education, there are several problems. Undergraduate medical education has to undergo a thorough overhaul, not only to imbue medical students with the excitement of modern biology, which will have a major impact on the practice of medicine in the years to come, but also to orient them to the health needs of society; in particular, there is need to give emphasis to health promotion and disease prevention rather than the curative aspects alone. The Rural Orientation of Medical Education (ROME) scheme needs to be activised and implemented vigorously. It is necessary to provide suitable measures to attract talented medical and non-medical scientists to a career in medical research.

Nurturing and Developing Excellence in Science and Technology

17.96 Apart from the cultural aspect, work at the most advanced level in S and T is essential for self-reliant development since it has the inherent possibility of opening up new approaches to accelerated development through innovative research and implementation. Such challening scientific work encourages originality and develops leadership; it can only be carried out in an environment characterised by excellence. The search for excellence calls for uncompromising standards, integrity, dedication and a spirit of self-confidence.

17.97 The increase in the number of scientists engaged in R and D work during the last few decades has not been matched by an equal improvement in quality, even though there have been peaks of high accomplishment. There is need, therefore, for emphasis during the Seventh Plan on quality, and in the direction of creating and nurturing a sufficiently large number of centres of excellence.

17.98 Unless a true enthusiasm for science is generated during school and college stages, even the very intelligent and scientifically minded, who would achieve much in science, would turn to safer and more lucrative professions, as is already happening. We have to be particularly sensitive in spotting talent and creativity, wherever it exists and providing opportunities for its emergence. In the Seventh Plan, at attempt should be made to ensure that only dedicated students are admitted to Ph.D. programmes in science.

17.99 Excellence is a vulnerable entity, even after it is established. Institutions of excellence have to strive for and maintain excellence in all aspects of their functioning. Attention to these aspects in the physical and managerial environment of science would be increased during the Seventh Plan. To nurture and develop excellence, it is essential to exercise great caution in inducting people into R and D institutions. The standardised procedures adopted by Public Service Commissions are not entirely suitable for scientific recruitment and aspects of advancement of scientists. There is need to be particular in selecting those who are to perform leadership roles. Leaders of science would, in addition to competence also exhibit a 'taste' in the selection of problems and approaches. Mediocrity at these levels will only result in support for larger masses of mediocrity, would be fatal for the pursuit of excellence. All scientists and technologists must learn to be evaluated by others, even if these others are administratively their juniors. Excellence, wherever it exists, should be made visible. Among other things, this calls for a system of awards and recognition.

17.100 Knowing when to terminate some activities is as important as starting new areas of work, in seeking to maintain a climate of excellence. Cross-fertilization between different persons, groups and techniques in research institutions, university departments and in production and industrial organisations, is more than just desirable; it is essential for excellence to flourish. New developments significantly depend on inputs from outside a given field. Modern research need several large facilities which cannot be owned and operated by a single institution. These would have to be set up nationally.

17.101 It is desirable to develop industry-oriented institutions as centres of excellence in selected areas. During the Seventh Plan, such centres should be set up in selected fields around industry, in close association with the academic institutions and national laboratories. It has long been recognised that creative work cannot be administered or controlled in the same manner as general administration. Existing recommendations in this regard should be implemented.

17.102 It is essential that appropriate cadre-age planning be done to ensure that maturing organisations are not peopled only by the older generation, no matter how bright or experienced.

Basic Research

17.103 Since Independence, as has been mentioned earlier, there has been significant development of the S and T sector as a whole. A large part of this development has resulted in quantitative expansion in many institutions. A number of institutions, specially designated for basic research, have been supported and have grown in the past. Areas where basic research carried out in India has had significant international recognition are: several fields in pure mathematics and statistics; cosmic ray physics;solid state chemistry and surface sciences; cosmo-geophysics;

molecular and cellular biology, immunology, genetics, structure and conformational aspects of biopo-lymers; liquid crystals; order-disorder phenomena; particle and high energy physics and astrophysics; ionospheric studies; natural product chemistry; physical metallurgy;optical and radio astronomy, etc.

17.104 A sector of great importance for basic research, namely institutions of higher learning and universities, needs to be supported in a bigger way by much greater financial inputs, better management structures and a more conducive environment for research.

17.105 Basic research is concerned with the discovery of new knowledge and with increasing our understandingof natural phenomena. Basic research is not directed towards solutions, but is at the frontiers of knowledge and the quality of such work and achievements have to be judged by the entire international scientific community. Quite clearly those who would accomplish such research have to possess capabilities necessry for work at the frontiers of science on a competetive international basis. Another important aspect of fundamental research is its essential place in the system of education. Higher education is primarily the responsibility of the universities, and quite clearly there must be basic research in the universities if education has to have any quality. All basic research will, of course, not be done within the universities. There will be need for basic research in the national laboratories because working at the frontiers of knowledge will sharpen the researchers' capability to perform the many other tasks on which they are engaged.

17.106 The new frontiers are largely in interdisciplinary areas. A related point which needs emphasis is that just as working at the frontiers of our present knowledge, on a competitive basis, and dealing with the challenges that this implies, sharpens abilities to deal with the many other problems of applied science and technology, so is a sound base relating to applied sciences, technology and industrial capabilities important for carrying out good basic research today. For this reason, basic research would benefit significantly from linkages with applied research and technological developments in industry.

Certain Infrastructural Elements for S and T (a) National Facilities

17.107 There are many areas of research and development which require extensive, sophisticated, costly and modern facilities. These should be set up as national facilities, available to all scientists and technologists in the country who can make effective use of these. It is proposed to set up during the Seventh Plan period a few such common national facilities in priority areas. It would also be of great advantage for India to join international collaboration to derive the benefit of using similar unique international facilities.

17.108 With regard to national facilities, it is clear that only a limited number can be put up during the Plan period in view of the large outlays involved. The priorties vis-a-vis the most important facilities would have to be arrived at through discussions among the scientific community. There would have to be a project management structure to identify optimal locations and ensure completion of the facility in a stipulated time and cost frame. Appropriate managment structures would also have to be evolved to ensure that the facility is freely and easily available to all genuine users and, further, that the latter are supported adequately by funds for travel, for building equipment in their own institutions, which they can use in conjuncti< with the national facility, for developing that particul application in their institution, etc. The Giant Met Wavelength Radio Telescope, the Phytotron and ti Synchrotron Radiation Source are some examples of sue national facilities to be set up during the Seventh Plan.

(b) Instrumentation

17.109 Over the past few decades there has been spectacular revolution in the field of instrumentatici particularly as a result of development in modern electrc nics and optics. A very large number of instruments ai today defined as "smart" instruments; instead of bein purely passive devices to observe, measure or displa' they can now perform active and highly precise role;Obsolescence in instrumentation is taking place at a rapi pace, with significant new fecilities being added cor tinuously.

17.110 There are many categories of instruments the are required. These are of various levels of sophisticatior the demand profile in terms of numbers and total financic outlays varying very significantly.

17.111 There is clearly need for a sweeping change ii our instrumentation sector, both in terms of productiol and utilisation of instruments, and for a new culture o self-reliance and self-confidence. A national policy in th< field of instrumentation covering all aspects of the problerr is essential and urgent.

17.112 A proposed national policy calls for perspective planning, covering both short-term and long-terrr strategies on the needs of different sectors, developmen of the industry, development of endogenous capabilities import of necessary technology, import of high technology instrumentation, pricing policies, role of consultancy organisations with regard to instrumentation industry, etc. National facilities for the production of instrumentation required in large quantities for schools, colleges, industries, etc., as also for the production of selected sophisticated instruments will

have to be created. A major effort will be required concerning research and development, which will have to be carried out in a variety of institutions, on a planned, and coordinated basis, with interdisciplinary projects, mechanisms of transfer of technology, etc. There is need to promote an instrumentation culture, both in terms of design and use of instruments and innovative ideas in this field, as well as maintenance of instruments in the large-user sectors, such as agriculture, medicine and industry. To cover all these aspects, it is proposed to set up a National Instrumentation Board, as recommended by SACC.

17.113 Instrumentation must be given a high priority as a key transectoral and underpinning element, for the development of science, technology, industry, education and the many user sectors that further derive from it.

(c) Information Systems

17.114 The rapid advancement of science and technology has resulted in a vast body of knowledge, which hitherto has been stored in printed form, as published papers/reports, patent information and so on. For this reason, libraries, documentation centres, patent offices, etc., have been an essential element in the infrastructure for science and technology. With the increasing tempo of research and development, the stock of our knowledge is enlarging so rapidly that it is clear that the classical approaches adopted hitherto, relating to storage, retrieval and utilistion of information, will no longer do. The solution lies in making fullest use of the new developments relating to computers, informatics, telematics, micro-recording, etc., rapid advance in these is another major characteristic of our times. It is clearly necessary to have a viable science and technology information system based on these new capabilities.

17.115 For meaningful scientific development, the quality of manpower, and of the information base, is even more important than the other physical aspects. It is, therefore, proposed that during the Seventh Plan, emphasis will be placed on the setting up of an appropriate National Science and Technology Information System. This should cover both bibliographic and technical information required for scientific work, as well as an integrated data-base for decision-making and policy formulation in the field of S and T.

17.116 A comprehensive and appropriate S and T National Information System would need to be evolved through the joint efforts of the Department of Electronics, DST, CSIR, Department of Environment, Defence Research and Development Organisation, ICAR, ICMR, Controller General of Patents, DGTD and various other organisations concerned with specific data-base areas.

17.117 The present library community also needs to be exposed to the concept of computers and their usage, and the library training courses have to be enlarged to include computer application aspects. The Seventh Plan proposes to initiate the computerisation of most major libraries.

S and T and Productivity

17.118 Productivity depends on several factors besides available technology: management; availability, quality and reliability of inputs; incentives; labour efficiency; training and skills, etc. Efforts to increase productivity must be based on an integrated consideration of all these factors. Productivity is important not only in agriculture, industry and infrastructural areas of energy, transportation; etc., but in all aspects of national endeavour,including (and particularly in) administration and decision-making. Apart from productivity, it is necessary to ensure product quality. At present the capital-output ratio in Indian industry is very high and needs to be brought down. There is also inadequate attention to quality. Imports of technology and/or machinery that can be clearly identified with enhanced productivity or improved quality would be considered favourably. It would be incumbent on public financing institutions to support changes in equipment and technology for enhanced productivity, and also for companies to report productivity and energy use figures in their Annual Reports. Criteria will be evolved for measurement of productivity, and industry-wise productivity norms established. A major effort in the Seventh Plan would be to identify performance creteria for all the important sectors of the economy and lay these down explicitly, so that systematic and regular monitoring (concerning improvements in productivity) can be carried out.

S and T and Employment

17.119 Regarding S and T and Employment opportunities, two aspects need consideration: (a) the manner in which employment opportunities could be increased for qualified S and T personnel; and (b) the manner in which S and T could be utilised to increase employment opportunities in the country in general.

17.120 India today has a large stock of scientific and technical manpower, of just under three million. This would appear to be a large figure at first sight, but as a proportion of the total population it does not compare favourably with that in advanced countries or even in some other developing countries. Therefore, for a meaningful development of S and T and its application, there is need to increase the numbers of S and T personnel, ensuring at the same time that their quality and training is appropriate for the S and T tasks on which they would have to be deployed. At present, there is wide variation in the quality of S and T personnel emerging from the educational system, and a

serious lack of coordination between manpower requirements (in terms of areas, numbers and levels of training) and the actual training of personnel. This has led, on the one hand, to serious shortages of qualified and trained manpower in many areas and, on the other, to the diversion of a large part of the S and T manpower to activities that can not be construed as Scientific and/or technical. This position clearly needs to be remedied, and a start will be made in the Seventh Plan.

Enhancement of Employment Opportunities for existing S and T Personnel

17.121 With regard to already existing S and T personnel, and those that will emerge from the educational system until the measures now planned begin to take effect, several measures initiated during the Sixth Plan period will have to be intensified. A National Science and Technology Entrepreneurship Development Board (NSTEDB) has been set up with the specific aim of inproving the entrepreneurial capabilities of S and T personnel and generating schemes for self-employment in the S and T sector.

Increase in Employment Opportunities through S and T

17.122 With regard to the creation of significant employment opportunities in the country, clearly these will have to be related to agriculture and rural development. In agriculture, there are significant opportunities for enhancing employment through the extension of new agricultural technologies to low productivity regions and to small farmers. With S and T inputs major developments are possible in horticulture, fisheries, piggeries, poultry and animal husbandry, sericulture and post-harvest technologies. Again, S and T inputs leading to enhancement of rural energy supply through renewable sources of energy will create opportunities for cottage and village industries and home technologies and expansion of off-farm employment in agro-based rural industries and services. The Technology Policy adopted by the Government in 1983 states: "In all sectors, the potential impact on employment will be an important criterion in the choice of technology." This will be kept in mind to ensure that only technology and automation appropriate in the Indian context is introudced. The related objectives may be spelled out as follows: the effective use of what would otherwise have been regarded as wastelands and waste materials; the development of products and processes which increase the productivity of farm workers, artisans and industrial workers, thereby increasing their incomes and purchasing power; and the creation of productive and durable assets through S and T activities oriented towards beneficiaries, such as IRDP, NREP, etc. S and T can play an important role in enhancing employment, in making better use of available human resources, and creating national assets. This would call for a detailed analysis of the S and T component in each of these areas involved.

S and T: Defence and Civilian Sectors' Interface

17.123 Outlays on defence are included in the non-Plan sector. A large volume of items needed for defence are produced in Departmental and Public Sector undertaking (PSUs) under the Ministry of Defence as well as through civilian industry; there is a very considerable amount of science and technology associated with this production. Many sophisticated items are imported and significant S and T is involved in their use, maintenance and licensed production. A large chain of laboratories under the Defence Research and Development Organisation (DRDO), has now grown to maturity in the 25 years of its existence. There is great strength and competence in these laboratories over a wide range of disciplines in science and technology. This S and T infrastructure and capabilities, built up in relation to the defence needs, must be regarded as an integral component of the S and T capabilities of the country.

17.124 Defence PSUs present us with a challenge and an opportunity. The challenge is to make them flexible both technologically and managerially so that they can meet some of the demands of the civilian sector; the opportunity is in curbing excessive dependence on manufacturing units outside the country.

17.125 In defence, considerations of quality and reliability are paramount. But there is another compelling reason for a link-up between the civilian and defence needs. This arises out of the quick obsolescence inherent in military equipment. Numbers are not helpful either, as force-multiplier effects of new weapons will be telling. There is thus a continuing necessity to develop new weapon systems and update the available ones to stretch them a little further. Such capabilities, arising through the imperatives in the defence sector, can be of great importance for the development of new technologies and capabilities in the very large civilian sector.

17.126 The Defence Research and Development Organisation (DRDO) has grown into a group of efficient laboratories already engaged in the design and development of aircraft, missiles, tanks, armaments and a variety of electronic equipment systems. To develop these designs further, and to engineer and to execute these designs, the expertise and infrastructure of other engineering units in the country is needed, apart from that of the defence production units.

17.127 There are more than forty defence laboratories, and some of these are only national repositories in some specific areas of technology. Their competence and experience must be available to other areas of national endeavour so that the available skilled manpower and high-cost infrastructure is profitably used. Signs of these are

already visible, but more needs to be done in an organised way.

Management and Administration of Scientific Institutions

17.128 Success is scientific endeavour depends significantly on imaginative and flexible systems of management and administration, which will help in realisation of the full potential of the gifted, trained and highly valuable manpower resources, and ensure conditions for the highest level of performance in achieving the objectives that are laid down. It is imperative to have a dynamic and sensitive management, and appropriate working conditions and incentives which will attract, retain and deploy in a patently efficient manner these precious human resources.

17.129 Scientists and technologists in scientific institutions perform their best under good leadership, when the challenges posed are clear and exciting, and achievements are regularly recognised and rewarded.

17.130 There is every need now to make careers in Science and Technology highly attractive, exciting and rewarding. Excellence can be fostered only when there is competition and selection. Mobility therefore must be positively encouraged.

Science as a Rewarding Career

17.131 Recruitment: To attract the bright and the motivated to research, care should be taken to ensure a career for them so that they are not at a disadvantage vis-a-vis other career opportunities likely to be available to them. At present, except for autonomous agencies like CSIR, ICAR, ICMR, Universities and autonomous institutes, and specialised Government Departments like Atomic Energy, Space, Electronics, DRDO and CASE, all other recruitment to scientific departments/institutions is carried out through UPSC/State Public Service Commissions. There is no rationale behind keeping some of the recruitment within this system, while a large part of it lies outside. Recruitment and promotions in the case of scientific and technical posts call for speed, flexibility and a close appreciation of the needs and objectives. New recruitment procedures outside to the UPSU/State PSC will need to be adopted for recruitment in scientific institutions.

17.132 Advancement: In situ promotion by work assessment should be introduced wherever it is lacking. Flexible complementing has been or is being introduced in scientific departments and agencies. This should be implemented uniformly, and made applicable in appropriate form in the case of associated administrative staff, since ultimately the whole institution has to function as a team.

17.133 The highest grades available in Government should be available to scientists working on scientific tasks. Special attention should be paid to the university system to see that proper career opportunities exist right from the point of entry, and outstanding scientists are on par in respect of opportunities, remuneration and prospects with corresponding personnel in national laboratories. Better salary structures are called for than are available at present.

17.134 In fact what is important is not the scale and gross pay received, but the net or take-home pay. It should at least be ensured that the quality of life at corresponding levels is comparable to what obtained at the time of Independence.

17.135 Retirement: The age of retirement for scientists should be made uniformly 60 years.

17.136 Nurturing young scientists: Scientists should be provided with challenges and given necessary resources at an early age so that they have an opportunity to satisfy their scientific creativity ad ambitions, such incentives would raise considerably their performance levels and would ensure their advancement as well as groom them for leadership. The task of identifying promising young scientists and nurturing them should receive high priority. This would include provision of research facilities, administrative back-up as well as support for travel and participation in scientific meetings and symposia in the country and abroad. These should be available on a direct basis rather than through a hierarchical reporting system.

17.137 Incentives and awards: Performance should be constantly reviewed against announced objectives. This should be done on a peer-review basis. There is very special need for recognition of contributions to the development and improvement of technology, and for success in transfer of technology.

17.138 Mobility: More than ever before, a rewarding career in science requires easy transfer between institutions. Technology development and application can be truly realised only when S and T personnel move, with minimum discomfort and disadvantage, to new positions, locations and institutions, carrying with them know-how and know-why, knowledge and skills. Conditions today discourage and indeed preclude mobility. There is urgent need to facilitate mobility by removing related disincentives. Rules should be such that terminal benefits, leave etc. can be moved alongwith the individual. Systems for scientists and technologists to hold concurrent positions in research institutions/universities/governments/ industry should be introduced.

17.139 Facilities for scientists: The most pressing need is housing. Without assured housing, recruitment of fresh talent and also mobility is becoming increasingly difficult. Institutions should be allowed to deploy the total resources allocated in such a manner that housing needs are met, as fulfilment of assigned tasks will demand not only operational buildings, equipment, salaries of staff and revenue budgets, but also assured housing.

17.140 Provisions for sabbatical leave, liberal study leave and other measures are very necessary to enable scientists to improve their professional competence.

Mechanisms for Utilisation of Scientist of Indian Origin Working Abroad

17.141 In recent years the number of Indian scientists, technologists, engineers, doctors, etc. working outside the country has increased. However, it has been found that they have continuing commitments to India's development. They have shown interest in working on several vital research and development areas in India. In order to bring them back, on short or long tenures, appropriate mechanisms would need to be evolved. These can include lecture assignments, consultancy in industry and assistance in setting up pilot projects in India. The areas of bio-technology, micro-electronics, informatics etc. offer significant potential. For this, there will be need for new approaches and more flexible administrative procedures.

Management System

17.142 In view of the large number of S and T institutions, laboratories, etc. in the country and their charter, objectives and constitutions, it is recognised that one uniform management structure will not be suitable for all these institutions. It is necessary to ensure that all S and T institutions have real and meaningful autonomy, and should be characterised by pursuit of excellence and functioning of a scientific culture. These should be involvement of scientists at all levels in decision making processes as a scientific culture is characterised by a non-hierarchical approach.

17.143 Planning and implementation of research: Each institution should have clearly defined objectives and goals, having regard to its charter, and such missions as may be assigned to it. It should be acknowledged that all research may not lead to generation of new know-how;even access to new knowledge should be considered adequate pay-of. All institutions should adapt advanced planning strategies, keeping in mind these features.

17.144 Alongwith projectisation of as much of the total activity of the institution as possible, project funding should be substantially enlarged, and an appropriate strategy for project management should be developed.

17.145 Management information system: All S and T institutions should have a Management Information System (MIS) so that the total scientific effort in the institution is suitably reflected; standard UNESCO classifications may be used for this. The MIS should reflect the periodic progress in achieving objectives and should also provide for closure of a project on review, if necessary, development of strategy and direction, and redeployment of total resources, both human and physical. A nationally integrated MIS on projects, resources available, expertise etc. should be developed so as to achieve optimal utilisation of human and other resources.

17.146 Training: Training and re-training of personnel, as well as mobility, should be built into the management culture of all institutes and ogranisations.

17.147 Office Management: Office managemen should be modernised by the replacement of conventiona methods with modern equipment. The capabilities that arc available through recent developments in informatics should be fully assimilated.

National Science Press

17.148 In order to have scientific journals, publications, pamphlets, etc. printed expeditiously, on the most modern lines, there is a need to establish a central processing unit linked with a high-power computer in the country. Such a facility would help in standardisation of the format of scientific periodicals and provide total control on printed information in machine readable form.

Culture

17.149 Investment in S and T can become truly effective only if adequate attention is paid to the development of human resources and to systems for their effective functioning. Major changes can be brought about rapidly by careful planning, and training for such changes and monitoring these.

International Collaboration in Science and Technology

17.150 The growth of science and technology in the recent past has been truly phenomenal. These new developments are not only of fundamental scientific significance but have great potential for application. Some of these should enable developing countries like India to accelerate the pace of their progress. It is important therefore to keep abreast, and to develop awareness and understanding about these developments, as also to inititate work in selected areas that hold great promise for scientific development and for applications. International collaboration constitutes an important means for accomplishing this at lower costs and in shorter time-frames.

17.151 India has thus strongly supported international collaboration for meeting its own needs. There is, however, another equally important aspect. We have considered it our responsibility to share our knowledge and experience, and some of our infrastructure and training facilities, with other nations that would benefit from it.

17.152 Whether in collaboration with scientifically advanced or other developing countries, we have regarded international collaboration as something which should be based on trust and mutuality, involving meaningful participation of all those working together, with sharing of benefits and generation of understanding and friendship. Additionally, it must be ensured that our activities do in the field of international collaboration conform to the objectives we have set for ourselves, and do not distort our national priorities, values and approaches.

17.153 Future international collaboration in S and T should take note of the levels of excellence and capabilities reached in India in different sectors. Such a strategy would demand fuller coordination between different S and T agencies as well as users of S and T. A comprehensive information system on international collaboration has to be created. Adequate investments should be made nationally for physical facilities and for training programmes to enable us to make meaningful use of scientists from abroad to work jointly in desired directions. Programmes to make optimal use of foreign technical assistance available through bilateral or multilateral cooperation arrangements, should mesh with national priorities as outlined in the Plan document. The mechanisms to implement international collaboration in S and T would be through bilateral and multilateral cooperation and Technical Cooperation among Developing Counties (TCDC).

17.154 The objectives, priorities and thrust areas as identified through the planning process in the country should be fully recognised, e.g., in the formulation of the UNDP Country Programme and meaningful utilisation of foreign technical assistance.

National Data Base

17.155 An integrated information system has to be instituted to cover data of all types relating to bilateral as well as multilateral cooperation in S and T.

National Effort

17.156 The international cooperation programme should make a definite contribution to S and T development in India, and should be increasingly evaluated for their relevance to the planned development processes.

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